Integrated Circuits for a Switching Power Supply

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1. Introduction

Switching power supplies are used widely in all types of electronic equipment due to their small size, light weight, and high efficiency. Power supply techniques have advanced steadily to meet system trends. Control methods will be improved and new functions will be added to these power supplies in the near future.

Fuji Electric has developed the FA76 series of ICs for DC-DC converter controllers and the FA53 series for AC-DC converter controllers.

This paper describes trends of the latter series and introduces the recently developed current mode IC FA5321P.

2. Control IC Requirements

With the increased use of switching power supplies in electronic equipment, IC chip techniques and the integration of protection functions are advancing.

Table 1 summarizes technique trends and required functions for control ICs.

Table 1 Trend of electric power supply techniques and required functions for control ICs

Trends of power supply technique	Required function for control ICs
⇨Higher switching frequency ↓ use MOSFET for switching transistor	High speed switching Direct control of MOSFET ↓ Internal output stage of 1 to 2 Amp.
⇨Control at primary coil side	Low power consumption before startup Hysteresis characteristics at startup
⇨Complete protection functions	Overload protection Over voltage protection Over current limit Under voltage lock out Thermal shut down
Other	Frequency synchronized to external signal Low power consumption during standby

2.1 Higher switching frequencies

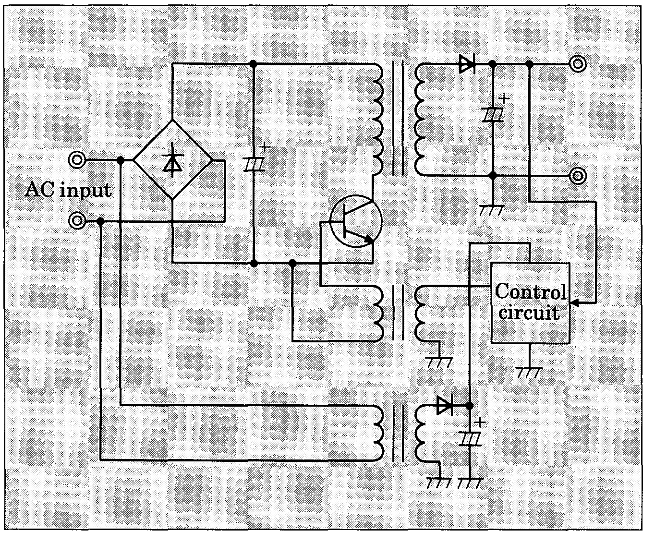
The size of an inductor, transformer, and electric field capacitor take up a high proportion of the overall size of the switching power supply. Higher switching frequencies are always demanded since the size of the above devices can be reduced as switching frequencies. In recent times, switching frequency values have generally been above 100kHz, with control circuit requirements being in the range of 50kHz to 1MHz. These requirements have resulted in a change of switching devices from bipolar transistors to MOSFETs (Metal Oxide Semiconductor Field Effect Transistor), which are more suitable for high speed switching. This trend has made it necessary for a special driving circuit having push-pull transistors and a high peak current in the control IC.

There is a trade-off between higher switching frequency and higher efficiency. However, by developing a faster turn-on and turn-off MOSFET, switching loss has been reduced.

2.2 Control at a primary coil side

The method of setting a control circuit at the primary coil side has been mainly used. Figure 1 shows a method of setting a control circuit at the secondary

Fig. 1 Control at secondary coil side



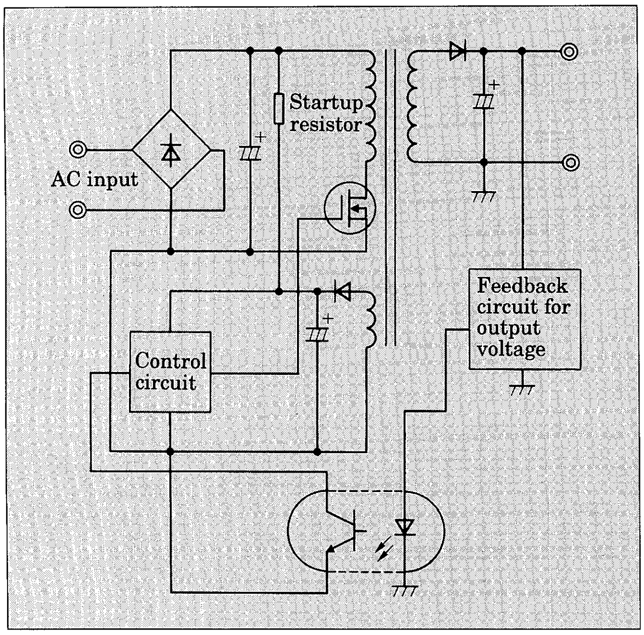


Fig. 2 Control at primary coil side

side, and Fig. 2 shows a method of setting a control circuit at the primary side. The latter method has the following advantages.

(1) The power supply for the control circuit can be simplified because the supply current can be generated from a transformer used for switching.
(2) A pulse transformer to drive the switching transistor is unnecessary. By using a photo-coupler, the DC output voltage feedback loop can be isolated between the primary coil side and secondary coil side.

In addition, for primary side control, the following characteristics are required of the control IC.

(1) To simplify the start up circuit and to achieve low power consumption, it is necessary that the supply current to the IC before start up is small. The value of supply current before startup is generally about 100 μA, and will be reduced in the future.
(2) To ensure the startup operation, a hysteresis voltage (greater than a few volts) is provided for the threshold voltage of the under-voltage lock out circuit.

2.3 Synchronizing operation

For a power supply used in a CRT (Cathode-Ray Tube) display, synchronization between the video frequency and the switching frequency of power supply is sometimes necessary to reduce screen disturbances caused by switching noise.

This function is required for control IC optionally.

3. Control IC Series for AC-DC Converters

Figure 3 shows a series of control ICs.

The types from FA5304A to FA5315 are unique

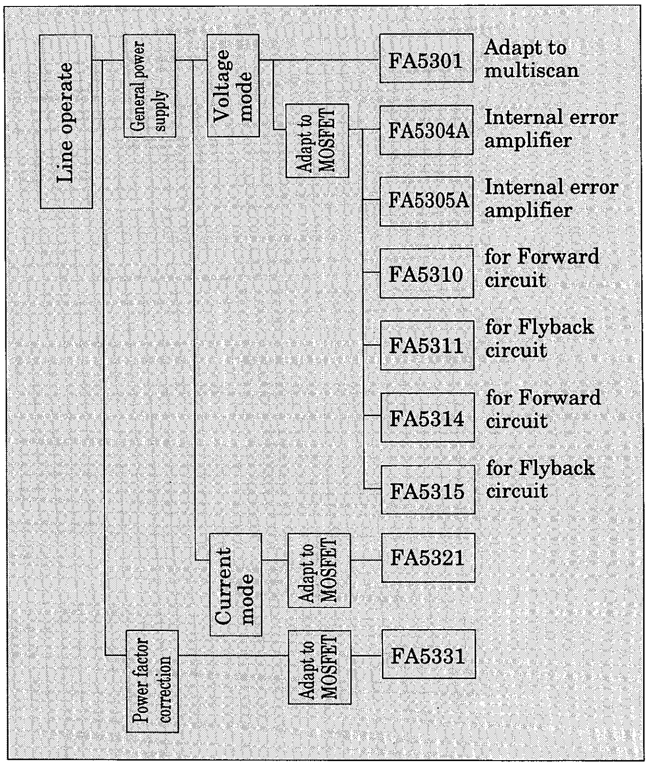


Fig. 3 Control IC series for AC-DC converter

Table 2 Summary of FA5321 characteristics

Item	Symbol	Characteristics	Unit	Condition
Working input voltage	V_{COP}	8 to 27	V	
Maximum output current	I_{OUT}	1.5	A	
Startup voltage	V_{CST}	16	V	
Stop voltage	V_{COF}	8	V	
Current consumption at startup	I_{CST}	90	μA	
Current consumption at restart	I_{CRST}	320	μA	Restart after overload protection
Stop VCC voltage	V_{CC1}	16	V	Overvoltage, overheat
	V_{CC2}	8	V	Load shortcircuit

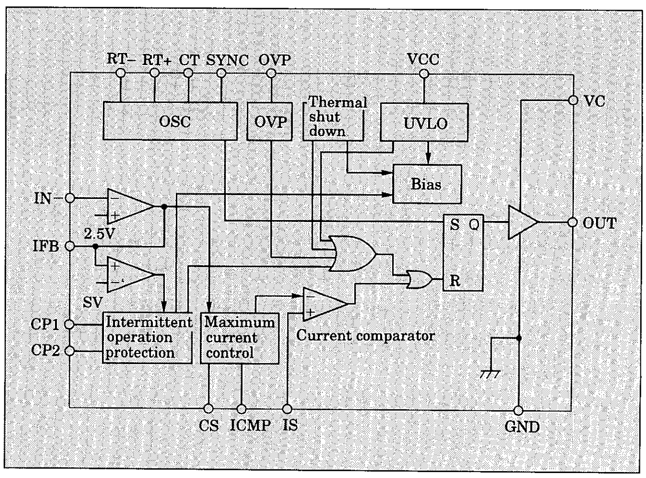


Fig. 4 FA5321 block diagram

Fig. 5 FA5321 application circuit

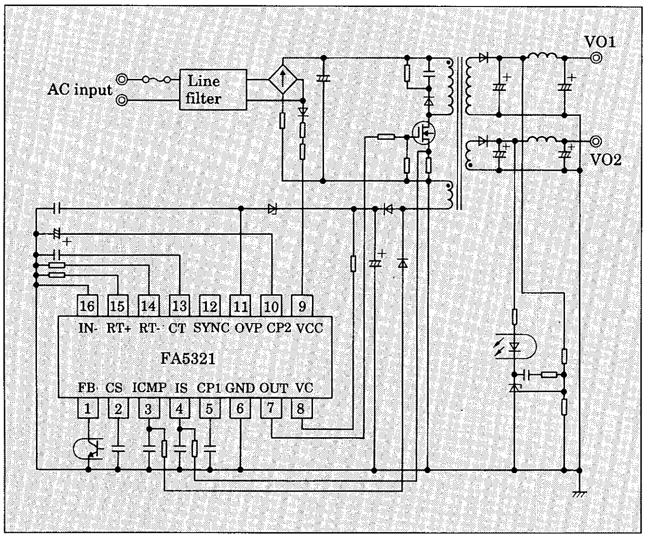


Fig. 6 PWM control timing chart

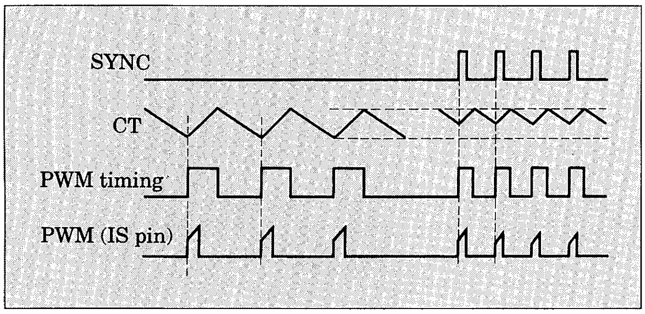


Fig. 7 Under voltage lock out

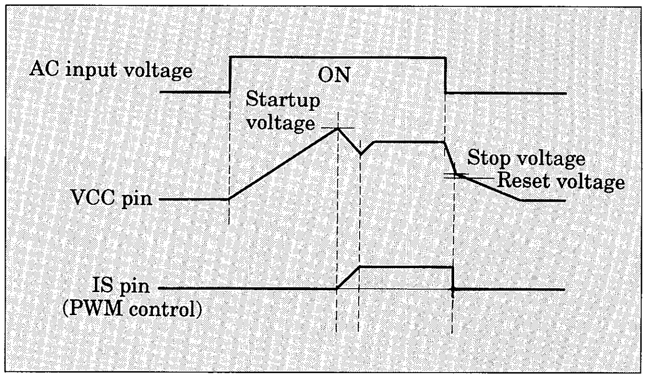


Fig. 8 Intermittent operation for overload protection

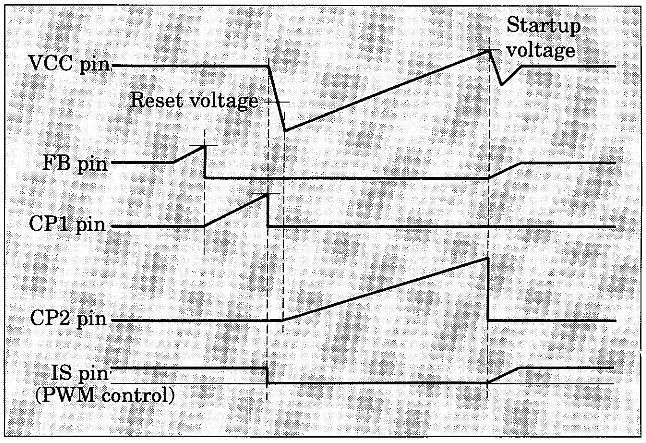
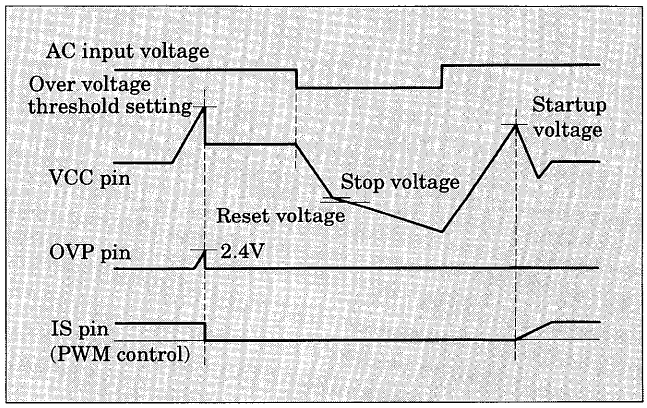


Fig. 9 Overvoltage protection



ICs, having 8 pins with many protection functions. For new requirements a control IC for power factor correction, FA5331, has been developed.

4. Current Mode Control IC "FA5321"

This section will introduce the FA5321, a recently developed current mode control IC, and the functions required for control ICs. Table 2 shows the outline of characteristics, Figure 4 shows the block diagram, and Fig. 5 shows a typical application circuit for the FA5321.

A current mode control IC will control the switching device current, while a voltage mode control IC will control pulse width according to the DC output voltage. Current mode control has the following merits.

(1) Stable control is easily achieved by a first degree transmission function for the feedback loop.
(2) For the reason described above, stable control can be achieved by applying a capacitor with relating small equivalent series resistance to the secondary coil side.
(3) A simple control circuit makes it possible for an external synchronous frequency to have a wide range of settings for a specified free run frequency.

4.1 PWM (Pulse Width Modulation) control

Figure 6 shows a timing chart of PWM control. The PWM timing signal is the output of an internal oscillator, in which its periods of high or low voltage are synchronous with the positive or negative slope of the CT pin voltage.

A synchronizing frequency must be set higher than a free run frequency. The PWM waveform is similar to that of IS pin voltage, which detects switching current at the primary coil side. The switching current is controlled by the following conditions.

(1) Feedback control for the output of power supply: The switching current is proportional to FB pin

Fig. 10 Power factor correction using the FA5321

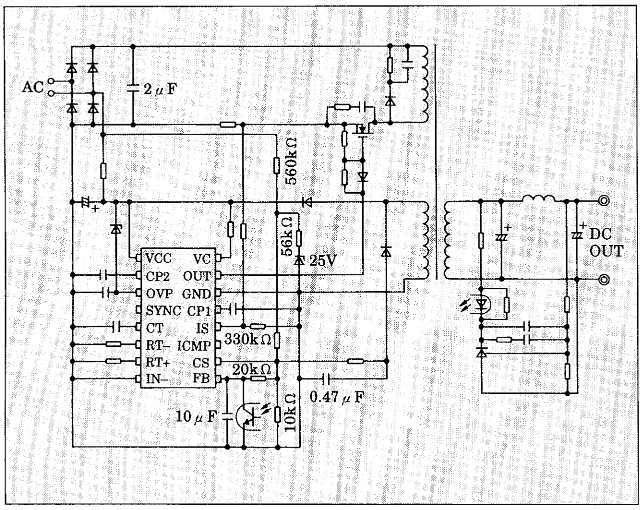
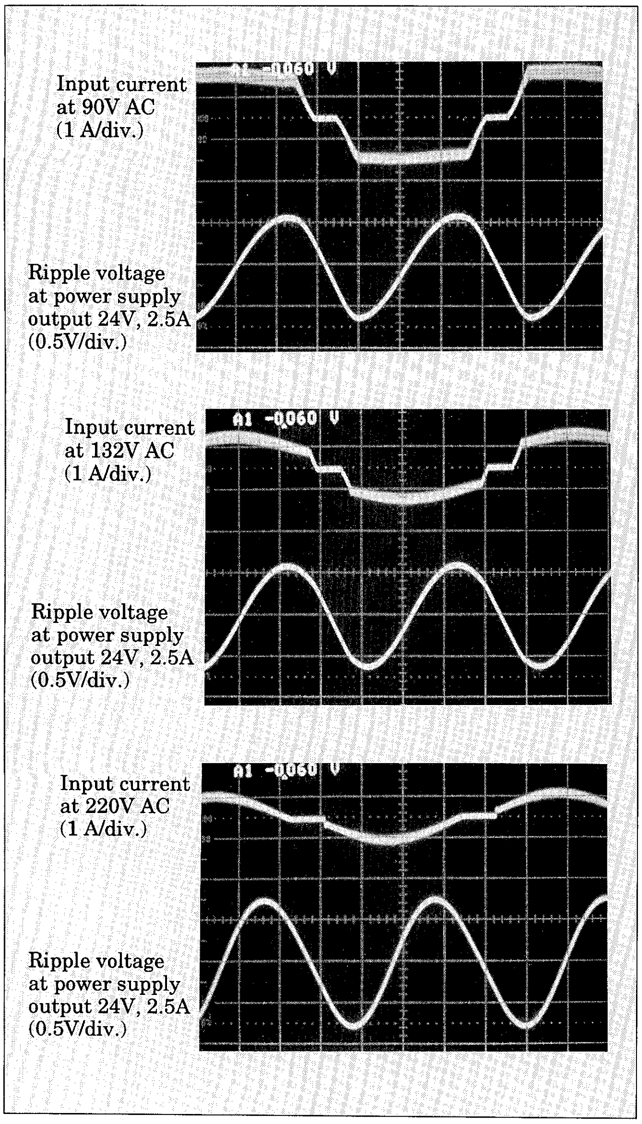


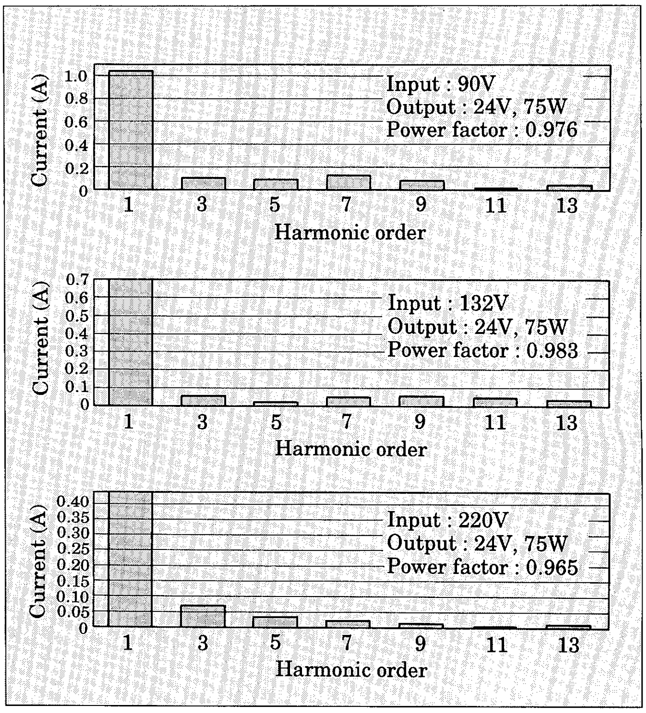
Fig. 11 Input current and output voltage for power factor correction



voltage.

(2) Soft start: The duty cycle is controlled to be proportional to the CS pin voltage, which rises linearly at startup.

Fig. 12 Power factor and input harmonic current for an application using the FA5321



(3) ICMP pin control: The over current limit threshold value is corrected for the AC input voltage of the power supply.

(4) Over current limit: The maximum value of over current limit is determined by an internal circuit, which detects the value as an IS pin voltage.

4.2 Under voltage lock out

Figure 7 shows a timing chart from startup to stop. A startup current of greater than 90 μA flows through the startup resistor and is supplied to the VCC pin. The IC will start when VCC, which is the pin voltage of the power supply, reaches 16V. After IC startup, the switching operation begins to supply current to the IC from a third coil. The VCC voltage difference of approximately 8V between startup and stop is determined to maintain the switching operation from IC startup until the rectified third coil voltage is greater than the VCC pin voltage.

4.3 Intermittent operation for overload protection

If the power supply output voltage falls below the set value, intermittent operation will start by raising the FB pin voltage. Figure 8 shows the timing chart. The switching period is determined by a capacitor connected to CP1 pin and the stop period is determined by a capacitor connected to CP2 pin.

4.4 Overvoltage protection

VCC pin voltage is detected at the OVP pin through a zener diode. Switching is stopped when the

OVP pin voltage reaches 2.4V. During overvoltage protection, VCC is constant at 16V. To reset the protection, it is necessary that the power supply input is turned off. Figure 9 shows the timing chart.

4.5 Thermal shut down

When the IC chip temperature reaches 125℃, the switching operation is stopped.

Operation after being stopped is the same as for overvoltage protection.

4.6 Short protection

If due to rapid load changes or overload at startup, current from the third coil to the IC becomes less than the IC consumption current, the switching operation is stopped. During this condition, VCC is constant at 8V.

5. Power Factor Correction with FA5321

Figure 10 shows a power supply with power factor correction in which an FA5321 is used and is composed of a single converter. This method has the advantage of low cost.

The peak value of drain current is controlled to form an approximate rectified waveform for AC input.

Figure 11 shows an AC input current waveform and the power supply output ripple voltage for the conditions of 24V/2.5A output. Since the AC input current waveform is "quasi-trapezoid", the peak value is much lower than when a sine wave is used for power factor correction.

Figure 12 shows data of power factors, fundamental currents, and harmonic currents.

The power factor is greater than 95% for AC input voltages from 90V to 220V.

6. Conclusion

A summary of switching power supply technique trends, the FA53 series of control ICs, and power factor correction using the FA5321 has been presented above. Fuji Electric will continue to develop unique ICs in the future.