

IC Technology for High-Frequency Switching DC-DC Converters

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1. Introduction

For internal power supply devices installed in portable electric equipment such as cellular phones and PDAs, there have been continuous requests for smaller size, lighter weight and higher efficiency.

The output voltage of the lithium-ion secondary battery, the major battery for portable electric equipment, is 3.6V. However, LSI power supply voltages have been trending lower with advances in fine pattern processing and at present, voltages of 2V or lower are widespread. Due to increasing voltage conversion ratios, attention has focussed on the conversion efficiency of power supply circuits. The view that switching regulators will play an advantageous role is spreading. However, since the external dimensions of switching regulators are large compared with conventional linear regulators, further miniaturizing and thinner shape are required.

Fuji Electric has been promoting the development of thin type micro-size DC-DC converters with switching systems that are compatible with lithium-ion secondary batteries. Since the IC for driving the converter has been developed, summary of that IC is introduced here.

2. Summary of Developed Products

This IC for DC-DC converters was developed to drive the switching regulators of portable electric equipment, and has a single output. A PWM (pulse width modulation) system is utilized for voltage control and this IC has the following features.

- (1) Switching frequency: 1 MHz to 6 MHz
- (2) Each of an n-channel and a p-channel DMOS (double diffused MOS) are integrated as switches
- (3) Compatible with synchronous rectifying system operation (No external diode required)
- (4) Operation input voltage range: 2.5 V to 6.5 V
- (5) Compatible with various conversion modes (buck type, boost type)
- (6) Various internal protection circuits

Since this IC executes high-frequency switching on the order of MHz, passive components required for

configuration of the DC-DC converter circuits can be miniaturized. In addition, since the switching elements are built-in and operation with a synchronous rectifying system is possible, the external mounting of discrete semiconductor components is unnecessary, enabling the whole DC-DC converter circuit to be made smaller and thinner. Rated specifications of this IC are shown in Table 1.

3. Internal Circuits

The circuit configuration is shown in Fig. 1. CMOS (complementary MOS) devices are used in the basic circuits of the control unit, and DMOS devices are used in the switches of the output unit.

The principal circuit blocks are described here.

3.1 Internal MOSFET

One n-channel DMOSFET (hereafter abbreviated as NDMOS) and one p-channel DMOSFET (hereafter abbreviated as PDMOS) are integrated as switches in the output unit. The maximum voltage is 30V and the maximum driving current is 1A. On-resistance of the NDMOS and PDMOS is 0.4Ω and 0.45Ω, respectively.

In general, MOSFETs have a tendency for switching loss to increase with increasing switching frequen-

Table 1 Rated specifications of IC

Item		Rating (standard value)
Absolute maximum rating	Supply voltage range	2.5V to 6.5V
	Output current	1.0A
	Operating temperature range	-20 to +85°C
	Storage temperature range	-40 to +125°C
Electrical characteristics	Oscillation frequency	1.0 to 6.0MHz
	Over-current detection current	1.25A
	Overheat protection temperature	125°C
	Low voltage detection voltage	2.5V
	Reference voltage	1.0V, 1.2V
	Supply current (at 3MHz operation)*	3.0mA
	Supply current (at shutdown)	20μA

* including driving current of MOSFET driver

cy. Accordingly, in order to reduce the switching loss, Fuji Electric has improved the structure of the NDMOS and PDMOS gate electrode wiring to lower gate resistance. Through this measure, the rise and fall speeds of the drain-to-source voltage and drain current during switching becomes very fast. Consequently, switches could be realized that have low loss and are compatible with switching on the order of MHz. (Fig. 2 shows waveforms at PDMOS turn-off before and after the improvement.)

Fig.1 Circuit configuration of IC (circuit block diagram)

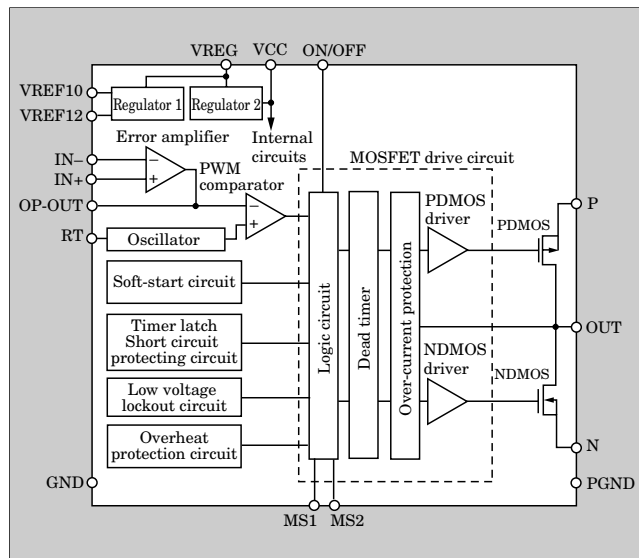
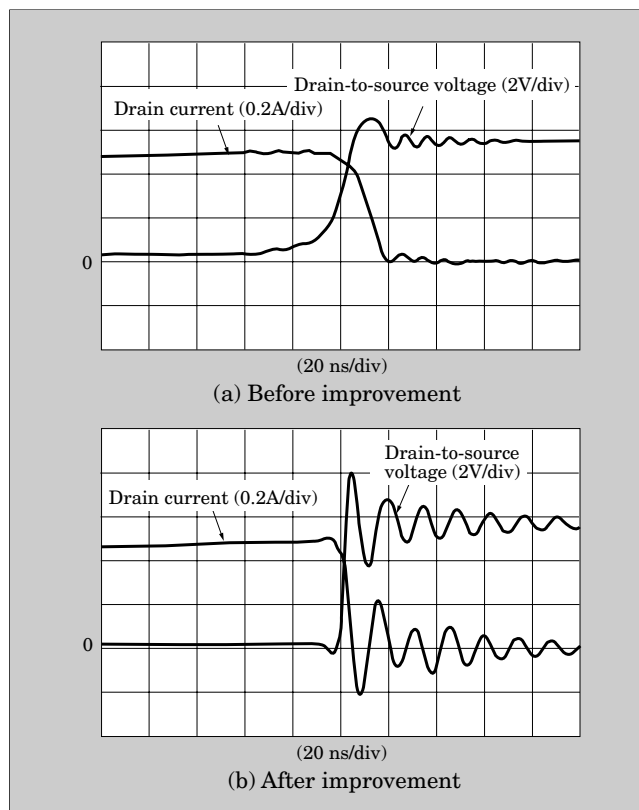


Fig.2 Waveform at turn-off of PDMOS



3.2 MOSFET drive circuits

The MOSFET drive circuit is mainly composed of a MOSFET driver, dead timer and logic circuit. The MOSFET driver has improved the circuit system and optimized the driving capability to enable high-frequency driving of the internal DMOSFET and to suppress the supply current. It is capable of charging and discharging a capacitance of 200pF within 5ns.

The dead timer is a circuit to prevent penetrating current generated by turn-off delay at the alternating on-off change over of PDMOS and NDMOS, when a buck type converter is operated with a synchronous rectifying system. In this IC, the dead time (forced delay time setting of synchronous rectifying switch-on signal relative to main switch-off signal) is optimized to 10ns in order to optimize conversion efficiency.

3.3 Basic control circuits (error amplifier, PWM comparator)

PWM control suited to higher switching frequency is applied in which output voltage is fed back to an error amplifier, that output is converted into a pulse signal by a PWM comparator, and this signal is used as the driving signal for the switches. Bandwidth of the error amplifier is 10MHz or more and output delay time of the PWM comparator is small at 30ns. As a result, both are compatible with control up to 10MHz.

3.4 Triangular wave oscillator

The triangular oscillator is operated by charging and discharging a timing capacitor from an internal current source with the oscillation frequency of the triangular oscillator as the basic frequency.

The oscillation frequency can be set from 1MHz to 6MHz by means of a resistor connected to the RT terminals.

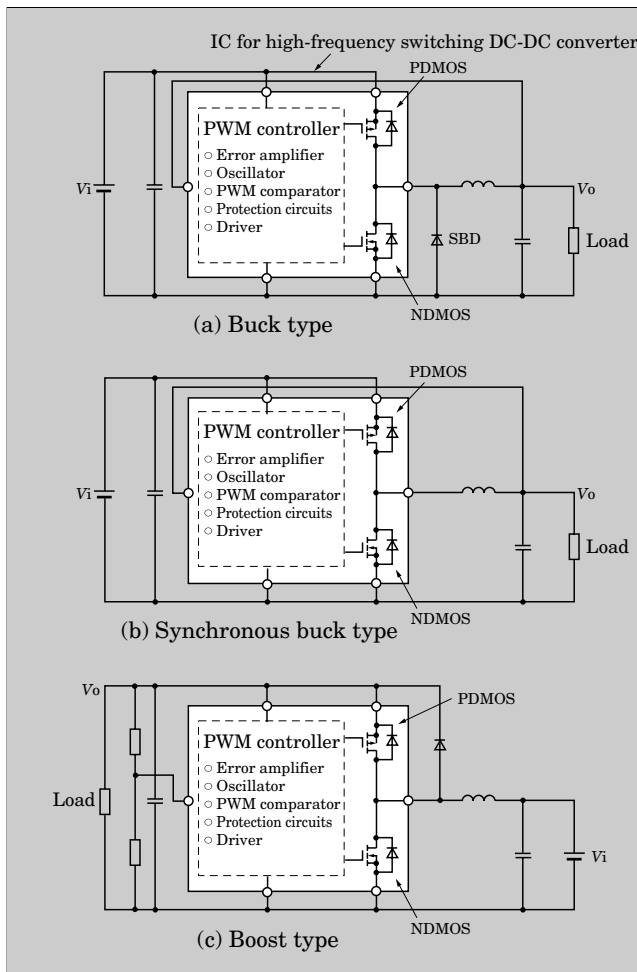
3.5 Protection circuits

In addition to the soft-start circuit that prevents inrush current at startup, the maximum duty cycle limitation that prevents the continuous ON operation of switches during boost mode circuit operation and the low voltage detecting circuit that prevents malfunctions by detecting lowering of the supply voltage, there is a short current protection circuit, an over-current protection circuit and an overheat protection circuit that are integrated as protection functions.

4. Examples of Application Circuits

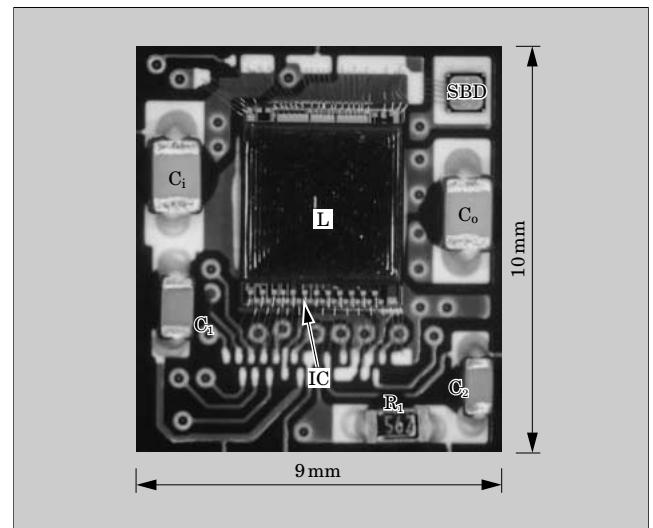
As shown in Fig. 3, configuration of buck type, synchronous buck type and boost type DC-DC converters are possible depending upon the connecting method. Figure 4 shows a picture of an example mounting of a buck type DC-DC converter circuit module. The constituent components are IC, input and output smoothing capacitors (C_i , C_o), SBD (Schottkey barrier

Fig.3 Examples of DC-DC converter configuration



diode), resistor (R_1) and capacitors (C_1 , C_2) for IC adjusting, and inductor (L). A reduction in the number of adjustment components required to configure the circuits is planned. In addition, Fuji Electric has developed technology by which the inductor, the largest among the constituent components of the conventional DC-DC converter, can be integrated onto an IC chip with a thin film deposition process. Through these technologies, a 1W output class micro-size DC-DC converter module with external dimensions of 9 by

Fig.4 Mounting example of DC-DC converter



10 by 1.8mm and output power density of $6.2\text{W}/\text{cm}^3$ (external parts are not required) is realized.

5. Conclusion

A summary has been presented of the IC developments for high-frequency switching DC-DC converters aiming at super miniaturization, lighter weight and thinner shapes.

Fuji Electric is endeavoring to contribute to the growth of electric equipment and the information transmission field by responding to the expanding market needs for portable equipment and by assisting in technical innovation based on PWM control technology of high-frequency switching.

References

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