Micro DC-DC Converter Chip Size Module

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1. Introduction

Smaller and thinner size, lighter weight and longer hours of operation are ongoing requirements for the internal power supplies installed in portable electronic devices such as mobile phones and personal digital assistants.

As the design rules for LSI circuits have become finer, the required power supply voltage to operate those LSIs has been decreasing year after year. Most LSI circuits are now operating at 1.5 V or 1.2 V.

On the other hand, the type of battery most commonly used to power portable electronic devices is a rechargeable lithium-ion battery, which has a typical output voltage of 3.6 V. Due to the increase in the conversion ratio between this battery voltage and the LSI operating voltage, and the increase in current consumption, the issue of conversion efficiency has come to attract widespread attention. As a result, replacement of the series regulator in a mobile phone with a switching DC-DC converter is being considered since the DC-DC converter is more efficient at higher conversion ratios. But conventional DC-DC converters are bulkier than series regulators. Therefore it is required to reduce their size and thickness.

In order to meet this demand from the portable electronic equipment market, an ultra-small, thin DC-DC converter module has been developed. This paper presents Fuji Electric's newly developed DC-DC converter chip size module (CSM).

2. Product Overview

This DC-DC converter module is a single-output, buck converter with an integrated control IC and inductor. The switching devices and inductor structure are optimized to achieve optimum conversion efficiency with minimum size. Features are as follows:

(1) Module size: 3.5 mm by 3.5 mm by 1.0 mm
(2) Output power: 1 W (maximum)
(3) Efficiency: 93.4 % (maximum)

3. Internal Configuration

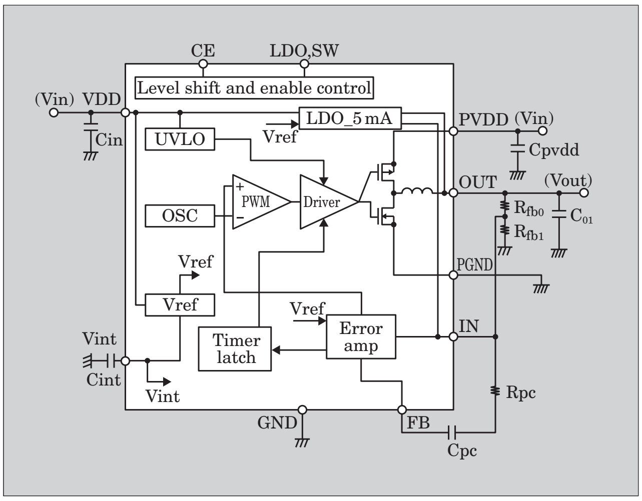
Module components, their features and the process for integrating the components into a module are summarized below.

3.1 Control IC

Figure 1 shows the block diagram of a control IC. The output unit consists of two MOSFETs optimized for high frequency switching and synchronous rectification. An additional LDO (low drop out) regulator is connected in parallel with the DC-DC converter output. Output voltage is controlled with PWM (pulse width modulation) and the control circuit is designed for a CMOS implementation. Table 1 shows the electrical characteristics of the IC. High-frequency switching of 1 to 2.5 MHz enables a reduction in size of passive components and high-speed response of the output voltage. Built-in switching devices and synchronous rectification eliminate discrete external semiconductor devices. As a result, we were able to reduce the size and thickness of the DC-DC converter circuit as a whole. Features of this IC are as follows:

(1) PWM buck converter with synchronous rectification (500 mA)
(2) Built-in LDO regulator for small output current

Fig.1 Block diagram of control IC



(3) Adjustable output voltage by external resistor
(4) Accurate output voltage (±4 %)
(5) Protection circuits; short-circuit protection, UVLO (under voltage lock-out)
(6) Built-in oscillator (1 to 2.5 MHz)
(7) Sleep mode / shutdown mode

3.2 Micro inductor

The inductor is usually the largest component in a DC-DC converter. To reduce the inductor size, Fuji Electric developed a technology for fabricating micro inductors on a ferrite wafer using thin film technology.

Table 1 Major electrical characteristics

Item		Characteristic values
Power supply voltage		2.7 to 5.0 V
Output voltage <accuracy>		Variable with an external resistance <±4 %>
Output current		Up to 500 mA
Oscillating frequency		1.0 to 2.5 MHz
Current consumption	Shutdown mode	1 μA max.
	Sleep mode	20 μA max.
	LDO mode	100 μA max.
	Switching mode (1.8 MHz)	500 μA max.

Fig.2 Load characteristics of micro inductor

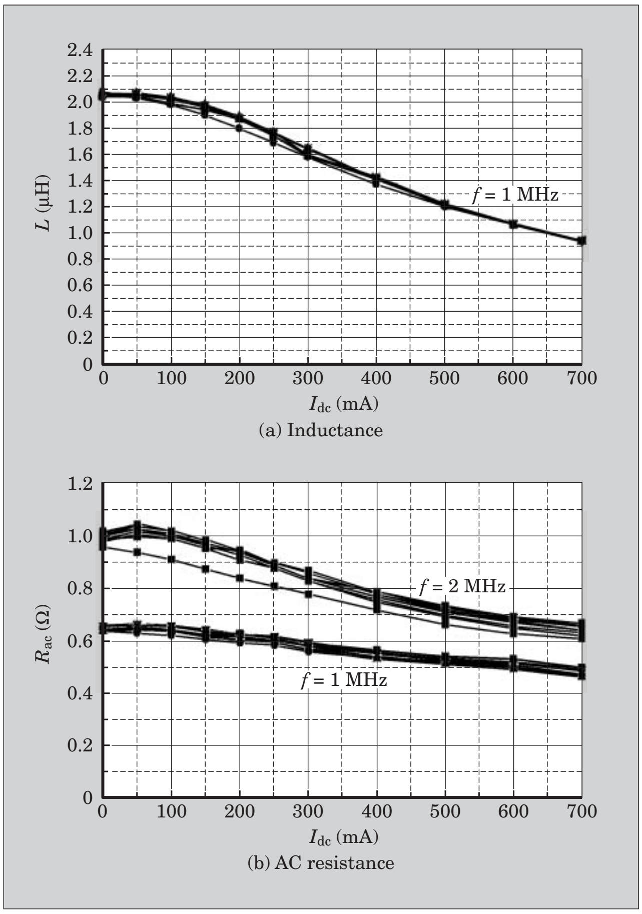


Figure 2 shows the load characteristics and Fig. 3 shows an external view of the new micro inductor. A solenoidal-winding micro inductor is formed by performing electroplating on a 525 μm-thick ferrite wafer which provides a matrix of through-holes. The number of coil turns is 11. Several peripheral terminal electrodes are formed around the inductor simultaneously. The electrodes on the top side are used to connect the control IC, and those on the bottom side are used as terminals that are to be mounted onto printed circuit boards. This structure enables size reduction when forming the modules.

3.3 Assembly process of the CSM

Fuji Electric has developed CSM (chip size module) technology for integrating an IC chip and an inductor into a structure that is almost same size as the IC chip. This simple structure, in which the magnetic core of the inductor is a ferrite substrate that also functions as a support substrate onto which an IC can be directly mounted, enables substantial reductions in size and thickness. Figure 4 shows a schematic diagram of the CSM structure.

First, IC chips are bonded onto an inductor substrate using an ultrasonic flip chip bonding method with an Au stud bump connection. Next, all gaps between the inductors and IC chips are filled with an under-fill material to enhance peeling resistance.

Fig.3 External view of the micro inductor

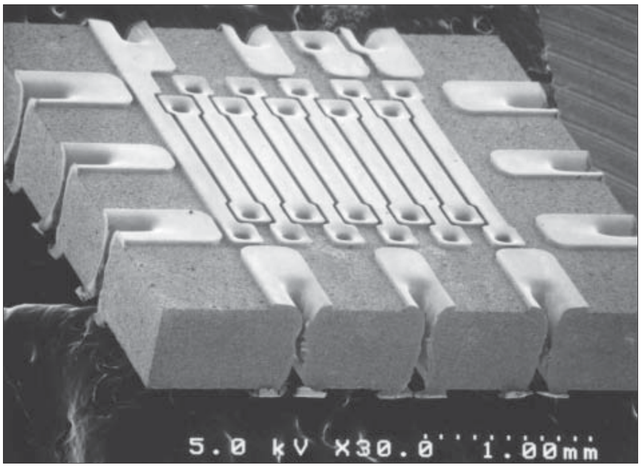


Fig.4 Schematic diagram of CSM structure

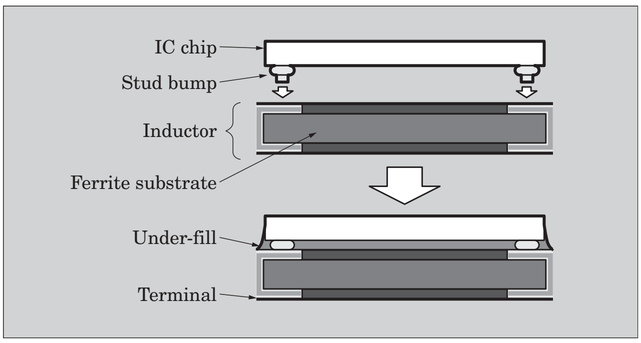


Fig.5 Micro DC-DC converter chip size module (CSM)

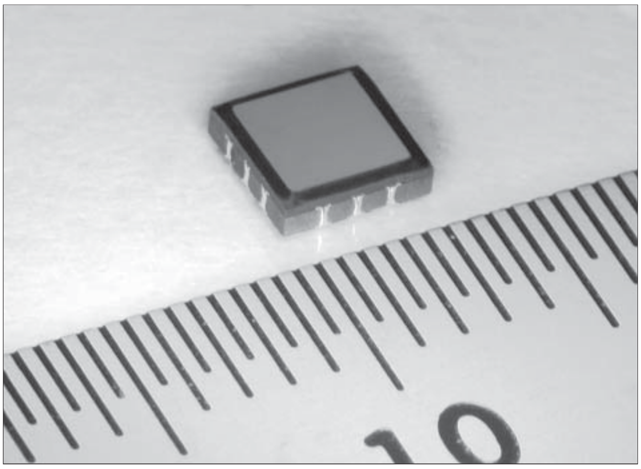
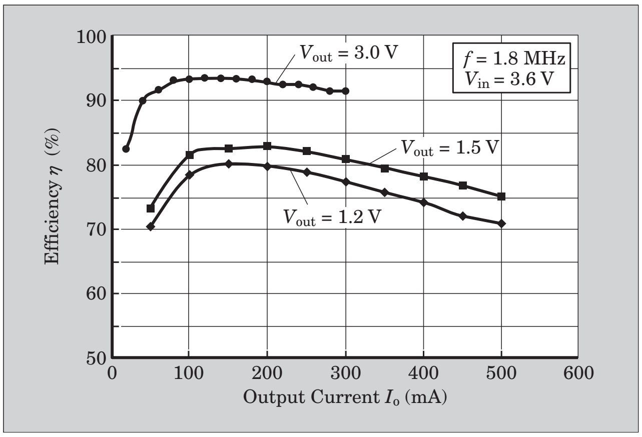


Fig.6 Efficiency characteristics of micro DC-DC converter



Finally, the module is diced into separate modules with the through-holes divided into equal halves.

Figure 5 shows an external view of the DC-DC converter CSM. The module dimensions of 3.5 mm by 3.5 mm by 1.0 mm were realized with a mounted IC chip of size 2.9 mm by 2.9 mm by 0.27 mm. Compared to conventional module assembly methods, the CSM method is very effective in reducing the DC-DC converter module size and mounting area on a printed circuit board.

4. DC-DC Converter Characteristics

Figure 6 shows the relationship between output current and efficiency at the input voltage of 3.6 V and output voltages of 1.2 V, 1.5 V and 3.0 V. The maximum efficiency of 93.4 % is realized.

5. Conclusion

This paper presented an overview of the ultra-small, light and thin micro DC-DC converter CSM.

Fuji Electric is endeavoring to contribute to the advancement of society by responding to the needs of the growing market for mobile devices and by furthering technical innovation based on ultra-small power supply system technology using high-frequency switching.

References

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