Power Management IC for cSSDs Realizing Space Saving and Low Power Consumption

With the reductions in unit price per storage capacity of solid-state drives (SSDs) equipped with NAND flash memory in recent years, the replacement of hard disk drives (HDDs) by SSDs as storage devices for client systems, including notebook PCs and tablets, has been progressing. However, the higher speed interfaces and larger storage capacities of such client SSDs (cSSDs) may result in a trend toward increasing power consumption in the future. It has therefore become necessary to improve the energy conservation performance of cSSDs in accordance with international standards such as the Energy Star program.
In response to this situation, Toshiba Electronic Devices & Storage Corporation developed the TC7738WBG power management integrated circuit (IC) for cSSDs with the aim of realizing both space saving and low power consumption in December 2016. The TC7738WBG achieves a reduction in power consumption of approximately 55% during sleep mode, when power consumption is at its lowest, and a reduction in package area of up to 30% through the use of a wafer-level chip scale package (WCSP) and an onboard protection switch instead of the conventional fuse, respectively, compared with our conventional products.

1. Introduction

An SSD is a storage device that employs a NAND flash memory as the storage medium. Unlike in the case of HDDs, no motors are needed, which results in faster access, quiet operation, higher shock resistance, lower power consumption, less weight and smaller size.

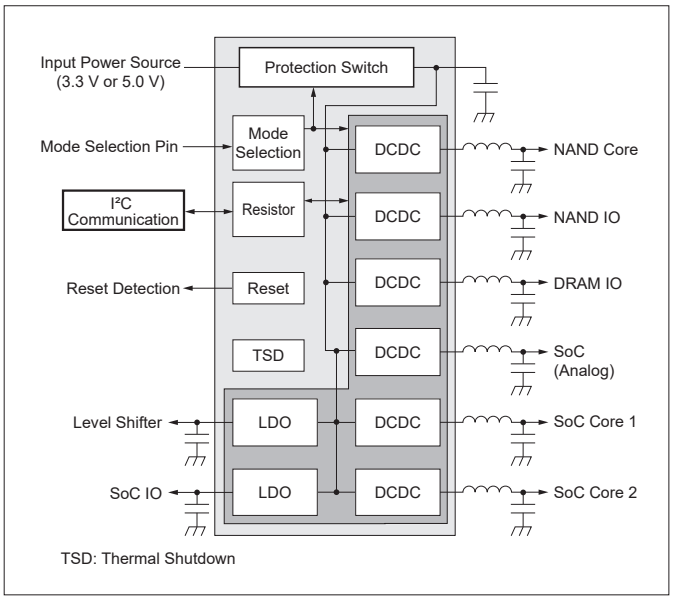
Therefore, in line with the Energy Star program and other international efforts for energy conservation, HDD storage media for clients such as notebook PCs and tablets are being replaced by cSSDs. In addition, the per-unit cost of storage for SSDs is decreasing. It is expected that the application field will continue to expand, mainly for client devices, by catering to different form factors[(1)].

With these circumstances in mind, Toshiba Electronic Devices & Storage Corporation developed a power management IC for cSSD. This IC has a high-speed load response characteristic by the adoption of hysteretic control employing fixed-frequency modulation, which is a unique DC (direct current) - DC conversion (hereinafter abbreviated as DCDC) control method. In addition, instead of a fuse, a built-in protection switch with enhanced input protection was developed and enclosed in a small WCSP, helping reduce space. Here we describe the characteristics and functions of this newly developed product.

2. Overview of power management IC for cSSD

The developed cSSD power management IC TC7738WBG has multiple DCDC and LDO (Low Drop Out) regulators (hereinafter abbreviated as LDO) built-in to supply power to all the ICs on the cSSD board (Figure 1). Specifically, it

contains six DCDC units and two LDO regulators. The DCDC supplies power to the core - IO (Input Output) of the NAND flash memory, the DRAM's core - IO, and the multiple blocks of the SoC (System on a Chip). The two LDOs supply power to the temperature sensor IC and the level shifters of the cSSD interfaces, as well as to other sections. In addition, the input protection switch, which was traditionally located on the power supply's input line on the cSSD board, is integrated as a protection switch IC. By adopting this configuration, the supply line from the input connector to each block is simplified, power losses due to wiring are reduced, and power consumption is reduced by combining the separately generated reference voltages into one common reference.



(Figure 1) : Block diagram of TC7738WBG IC for cSSDs

3. Main features of the power management IC for cSSDs

The power management IC used for cSSD needs to save space and reduce power consumption. Also, cSSDs powered from host devices by different manufacturers, such as notebook PCs, must operate safely regardless of the type of power supply. In order to satisfy these market demands, the following techniques are used for the TC7738WBG.

3.1 Built-in protection switch to reduce power consumption and improve safety functions

Electronic devices have fuses inserted in the input power section in order to prevent fires due to overcurrent from shorts etc. The cSSD is modularized, thus requiring fuses in its power input sections. On the other hand, multiple DCDCs are used in a cSSD, with bypass capacitors placed at the input of each DCDC in order to operate them stably. The total capacitances exceed several tens of μF, and there is the risk that a fuse may blow because of the inrush current generated at the time of power ON. Traditionally, an input protection switch IC that performs both the fuse function and the inrush current suppression function is used instead of a fuse.

We have integrated the power management IC with this input protection switch IC and DCDC and built the input protection function as a protection switch. As a result, in sleep mode where the lowest power consumption is required by the cSSD, by unifying the reference voltage generation circuit and the power supply circuits of the internal sections that previously existed separately, the power consumption has been reduced by about 55% compared to traditional implementations. In addition, since the operating states of the protection switch and the power management IC can be managed together, it is possible to stop the protection switch when entering an abnormal state and to reduce the power consumption while safely maintaining the stopped state.

3.2 Space saving by DCDC control using fixed-frequency-modulation hysteretic control

Various control methods such as current control, voltage control and hysteretic control exist for the DCDC control, but in order to realize space saving, we developed a unique method of hysteretic control using fixed-frequency modulation (Figure 2).

For the power management IC, since the wiring layout in the chip directly leads to power loss, an optimized arrangement

of the elements in the chip is required, but using this method, the circuit can be constructed with a smaller number of elements than with other methods. Since the degree of freedom of the layout inside the chip increases, the losses due to unnecessary wiring are reduced.

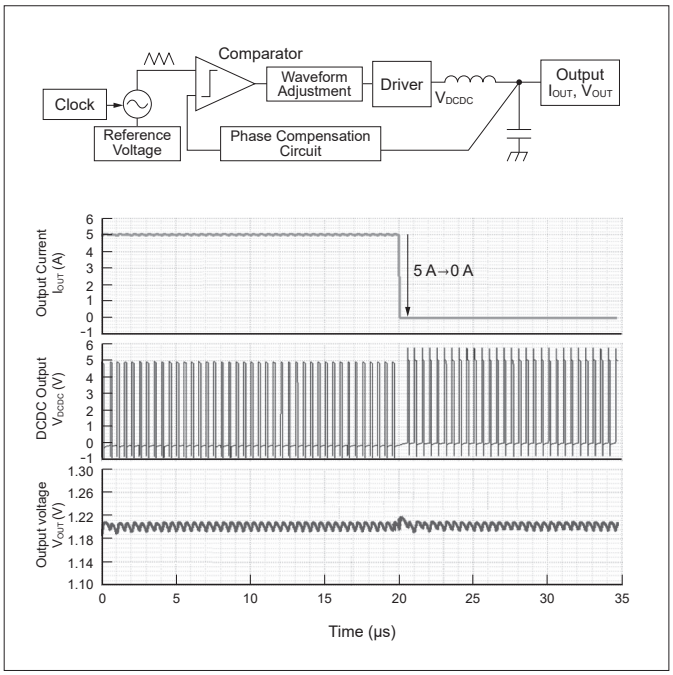
Also, because the output ripple voltage is small, it is possible to select a capacitor with low capacitance for the output capacitor. For example, when compared with the conventional current control, equivalent load response characteristics can be obtained with the capacitance reduced to about 50%. This leads to miniaturization of external parts.

3.3 Miniaturization by adopting WCSP

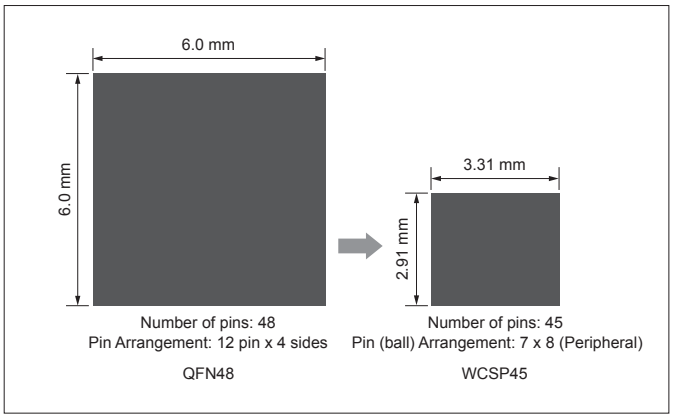
M.2 is the most common compact form factor for cSSDs, for which the type 2280 (substrate size: 22 × 80 mm) is often used. In order to realize high-speed and large capacity while maintaining this size, it is necessary to reduce the total number of parts while also miniaturizing these parts. We adopted WCSP to satisfy this requirement.

For the power management IC, QFN (Quad Flat Non-Lead Package) is generally used in view of its excellent heat dissipation properties and availability in small sizes and weights, but by adopting WCSP, the effective area is reduced by 30% (Figure 3).

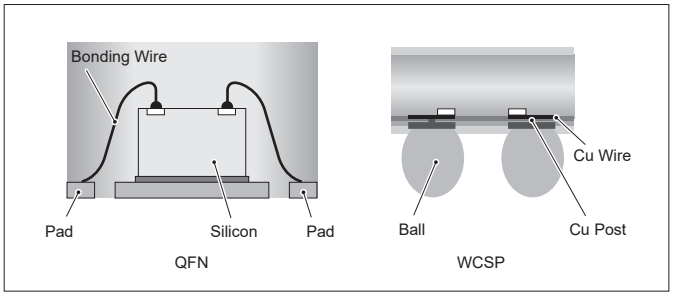
In addition, although the chip and the pads are connected by bonding wires for QFN, in the case of WCSP the Cu (copper) wiring is connected with the Cu post, thereby decreasing the effective ON resistance of the driver element and the dissipation loss (Figure 4). By reducing this loss, the amount of heat generated decreases and makes up for the increase in heat dissipation due to the package shape of WCSP.



(Figure 2) : Basic configuration and load transient characteristics of hysteretic control by fixed-frequency modulation



(Figure 3) : Comparison of size of quad flat non-leaded (QFN) and WCSP packages



(Figure 4) : Cross-sectional outline of QFN and WCSP packages

4. Future Developments

Since the cSSD will continue to improve with higher-speed interfaces and larger storage capacities, the power management IC will need to further save space and lower power consumption. Along with the miniaturization of the IC itself, it is necessary to reduce power consumption, improve response speed, and miniaturize external parts by improving the DCDC control methods.

Also, along with the space saving, the risk of destruction such as by shorting will increase, and so it will be necessary to put in place appropriate safety functions, including short protections.

5. Conclusion

cSSDs are still expensive compared with HDDs, and the storage medium for notebook PCs is still predominantly HDDs. However, cSSDs capable of high-speed access match the needs of notebook PCs and their prices will come down, accelerating their adoption as replacements for HDDs.

For power management ICs for cSSDs, we will promote low loss by improving the DCDC control methods and internal circuitry while developing products with enhanced safety functions, such as short protection for modules with high integration.

References

(1) Yanagi, S. et al. “Trends in Storage Product Technologies and Toshiba’s Approach” . Toshiba Review 70(8): 2-8.