PMMCD Series ICs with Motor Control and Power Management Functions

Motor control driver (MCD) integrated circuits (ICs) are used for controlling various systems that utilize motors, such as office equipment, home appliances, and in-vehicle systems. Particularly in the case of MCD ICs for office equipment, including inkjet printers, there is a need for a power management function that can supply several different voltages to other devices in the equipment and manage their power consumption, in addition to the basic motor control function.

In response to these market needs, Toshiba Electronic Devices & Storage Corporation has been developing and supplying a lineup of multifunctional ICs called the PMMCD (Power Management Motor Control Driver) series incorporating motor control and power management functions in a single chip. We have recently been focusing on further enhancing the functions of the PMMCD series while paying close attention to customers' requirements for reductions in the size and power consumption of their equipment. The latest-generation PMMCD series ICs are expected to contribute to solutions realizing a more compact footprint and cost savings by reducing the size and number of peripheral parts.

1. Introduction

Toshiba Electronic Devices & Storage Corporation has been in the MCD market for over thirty years, where the devices have been used in various applications including office automation equipment, household appliances and in-vehicle equipment.

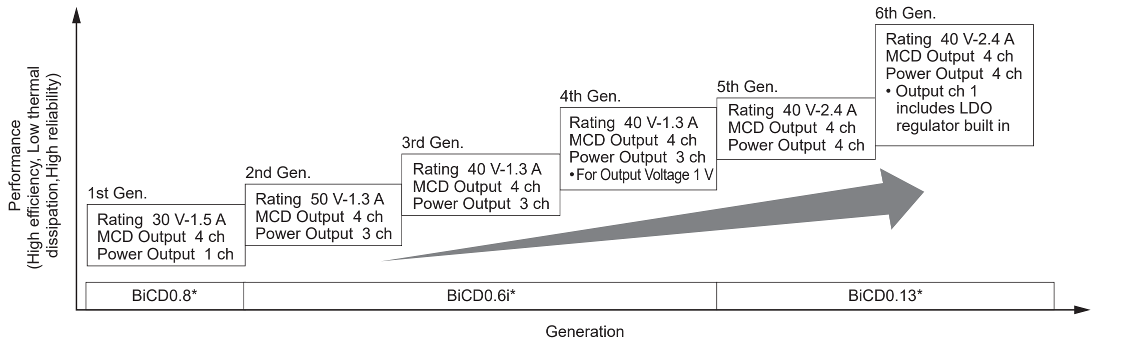
Inkjet printers, one the most widely employed types of office automation equipment, typically use an application-specific IC (ASIC) that handles image processing and system control, memory, and an MCD for controlling the motors that feed the paper. These functions require different power supply voltages in order to operate. To simplify the total control and reduce the number of parts needed, taking into account the power system configuration, power is first applied to the MCD, which requires the highest voltage. It is then fed from the MCD to the ASICs and memory, which require lower voltages. In addition to motor control, the MCD also supplies power with several different voltages for the entire device. Inkjet printers must also comply with the international Energy Star program, which certifies energy-saving systems for information equipment. To address all this, we developed a PMMCD that has both motor control functions and power management functions, including power supply by DC (Direct Current) - DC converter. In 1998 it was introduced for the first time in the world for OA equipment.

Here, we describe the characteristics of our PMMCD and the technologies developed for the latest sixth-generation products.

2. Features of PMMCD and technology up to the fifth generation

Figure 1 shows the PMMCDs from the first generation to the sixth generation.

With inkjet printers equipped with PMMCDs, the number of motors (for printer head control, paper feed control, scanner



*: LDMOS (Lateral Double-Diffused MOS), bipolar transistor and various analog devices are built together based on the 0.8, 0.6, and 0.13 μm CMOS processes

LDO: Low Drop Out

(Figure 1) : Trends in performance of PMMCD series

light source control, etc.) and power supply interfaces (ASIC, memory, USB (Universal Serial Bus), I/O (Input/Output) etc.) increases year by year. In order to keep up with this, the PMMCD has been increasing the voltage and current ratings with each generation, as well as the number of channels (ch) for controlling the motor and the power supply.

In addition, there has been growing demand in recent years to reduce the size of the devices and lower the power consumption. This demand extends down to the components that comprise these devices..

Under these conditions, PMMCD product development has been addressing the following three issues:

(1) Heat countermeasures – Avoid concentrating heat caused by the integration of heat source functions. Improve the heat radiation efficiency, utilizing the motor control and power supply voltage management systems

(2) Miniaturization of packaging – Adopt small packages while suppressing increases in output resistance arising from downsizing

(3) Reduction of standby power - Comply with the international Energy Star requirements for inkjet printer products

The solutions for problems up to the fifth generation are described below.

2.1 Heat countermeasures

As the PMMCD integrates multiple functional blocks in one chip, there is a problem of heat concentrating when several functions are operated at the same time. Reducing the heat generation and improving the heat radiation efficiency are important issues.

2.1.1 Reduction in heat generation

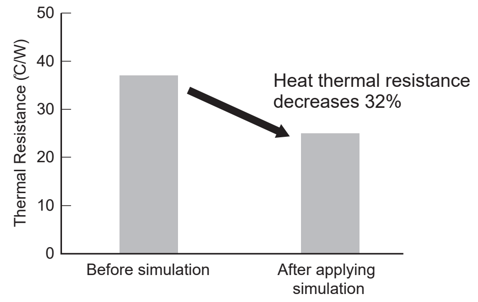
The heat generation is mainly caused by the steady-state loss that occurs when the output DMOS (double-diffused metal oxide semiconductor) of the motor control unit or the DC-DC converter is in the ON state as well as when the output DMOS is switched from ON to OFF (or OFF to ON). It is attributable to the switching loss generated during switching.

To reduce heat generation due to steady-state loss, it is effective to lower the ON resistance of the DMOS. In the fifth generation, by adopting a 0.13 μm process and adjusting the DMOS size, the ON resistance of the motor control part and the DC-DC converter were made small.

To reduce heat generation due to switching losses, it is effective to shorten the turn-on time and turn-off time of the output DMOS of the DC-DC converter. Like the on-resistance, speedup was attained by means of process evolution and DMOS size adjustment.

2.1.2 Improvement of heat dissipation efficiency

From the fifth generation, QFN (Quad Flat Non-Lead Package) has been adopted for the PMMCD. In this package, a metal pad (E-PAD) extends from the center of the back side. When this E-PAD is soldered to the printed circuit board, the E-PAD is thermally connected to the copper planes on the inner layers and the back surface of the printed circuit board through thermal via structures (metal holes penetrating the boards) that provide paths for heat to escape. In addition, the E-PAD also dissipates heat from the four corners of the package backside for soldering, helping radiate heat from the front surface of the board as well.



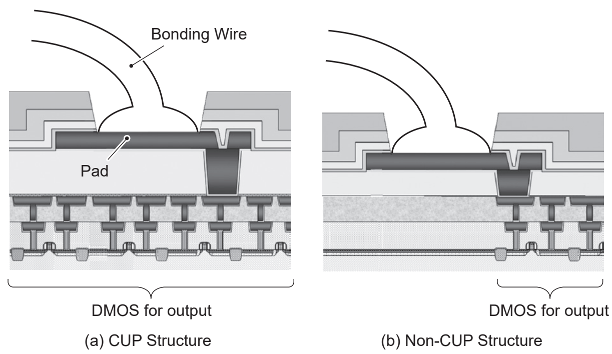
(Figure 2) : Example of reduction of thermal resistance with improvement in layout of printed circuit board based on thermal simulation

Also, from the fifth generation, we have devised thermal simulation tools to study and verify the effects of solder wettability of the E-PAD, the number and arrangement of thermal vias on the board, and the effect of via diameter on heat radiation performance. By providing these results to customers, we support the optimization of printed circuit boards to improve heat dissipation performance. The thermal simulations improve heat removal from the package to the printed circuit board. An example where the thermal resistance was reduced by 32% is shown in Figure 2.

2.2 Miniaturization of packaging

Up to the fourth-generation PMMCD package, QFP (Quad Flat Package) was used, where leads emerged from the four sides of the package and implementation was relatively easy. However, in recent years, due to advances in mounting technology, QFN has become mainstream in which only the pins are arranged on the four-sided surfaces and the bottom surface of the package.

When comparing QFP64 and QFN64, the mounting area of QFN64 is about 56% smaller, and the mounting height of QFN64 is also about 0.3 mm lower compared to QFP64, thereby contributing to higher-density packaging.



(Figure 3) : Cross-sectional outline of circuit-under-pad (CUP) structure

To miniaturize the package, it is important to reduce the chip size. We have adopted a Circuit Under Pad (CUP) technology (Figure 3) that can form pads directly above the DMOS area for output. As a result, a pad of sufficient size becomes possible, and miniaturization of the chip is realized without compromising the output resistance.

2.3 Reduction of standby power

The standby power consumption of an international Energy Star program inkjet printer was required not to exceed 1 W in 2009 and 0.5 W in 2014. The standards are getting stricter year by year, and power management during standby periods is a critical issue. During standby, the motor is not operating, and the PMMCD is only supplying power. Since the motor control unit that is not in operation shuts down the circuit completely, it is important to reduce the current consumption in the DC-DC converter in order to further reduce the standby power consumption.

During normal operation, the DC-DC converter is switching at 400 to 420 kHz in order to operate at high loads of 1.5 to 2.0 A. However, during standby, since the ICs other than the PMMCD are in the standby state, the load current drops to several mA, such that high-speed switching is unnecessary. The fifth-generation PMMCD includes the function of lowering the switching frequency of the DC-DC converter and reduces power consumption when the device goes into the standby state.

During the standby period of the equipment, by reducing the switching frequency to about half the normal operating rate, the current consumption of the DC-DC converter, which normally consumes about 20 mA, was reduced to about 15 mA (about 25%).

3. Sixth-generation PMMCD

Cost competitiveness is a primary requirement for office automation equipment such as inkjet printers. In order to reduce the total cost for the equipment makers, we developed the sixth-generation product that allows reduction in the size of the peripheral parts necessary for mounting the PMMCD on the board as well as reducing the total number of parts.

First, by increasing the switching frequency of the DC-DC converter, the inductance of the coil needed for the output is reduced. In addition, an LDO (Low Drop Out) regulator was adopted on one of the four power supply channels, making the coil itself unnecessary. These techniques contribute to the reduction of the board area and the lowering of the parts cost.

However, heat generation increases when the LDO regulator is installed, and we have dealt with this by further steps to reduce the two heat dissipation values explained in 2.1.1.

By adopting a 0.13 μm process and adjusting the size of the DMOS, the ON resistance of the motor control part of the fourth-generation conventional product was 1.2 Ω and the on-resistance of the DC-DC converter was 0.7 Ω . In the sixth generation, these values were reduced to 0.5 Ω and 0.1 Ω respectively. As a result, heat generation due to steady-state loss was reduced by about 65%. The switching time was also shortened from 100 ns in the fourth generation to 12 ns in the sixth generation, making up for the switching loss and adjustment to the higher frequency.

It should be noted that when the switching time is shortened, the EMI (electromagnetic interference) noise increases. As a countermeasure against this, a sequential switching function was installed. This function turns ON/OFF while gradually changing the gate voltage of the output DMOS and has the effect of suppressing output overshoot and undershoot, reducing EMI noise.

4. Conclusion

The PMMCD has evolved in response to the demand for energy saving and design needs such as compactness and low weight. In the future, it is expected that differentiating factors such as higher speed and quiet operation will become ever more important requirements, depending on the market trends. In order to satisfy these needs, we will continue to advance the core technologies for the PMMCD and pursue product development by applying these latest technologies.