Control IC for 6-Channel Switching DC-DC Converters Compatible with Synchronous Rectifiers

Kazuya Endo

1. Introduction

In recent years, portable electronic devices have been made smaller, lighter and with higher level functions. With these trends, DC-DC converters, devices which convert battery power supply DC voltages to other types of DC voltages, are increasingly required to operate at higher efficiency and lower power consumption for longer operation from the battery source.

Multi-channel output of different voltages is particularly required for digital cameras and camcorders with their enhanced functions.

Fuji Electric has developed the FA3676F, a control IC for PWM (pulse-width modulation) switching power supplies that is highly efficient and suitable for multi-channel power supplies. This paper presents an overview of that IC, which integrates six channel control circuits into a single chip. Two of the six channels are compatible with a synchronous rectifier system to achieve high-efficiency power supply, and the IC uses a CMOS (complementary MOS) process to realize low supply current.

2. Product Overview

Table 1 (a) and (b) show the absolute maximum ratings and electrical characteristics of the FA3676F respectively.

Main features of the IC are as follows.
1. 48-pin LQFP (low profile quad flat package)
2. Six-channel output and compatibility with a synchronous rectifier
   - p-channel MOS driving: five channels (two of the channels are compatible with a synchronous rectifier system)
   - p-channel/n-channel selectable MOS driving: one channel
3. Operable over a wide range of power supply voltages: 2.5 to 18V
4. Low supply current due to CMOS analog technology
   - during operation: 4mA (typical value)
   - during standby: 12µA (typical value)

3. Internal Circuitry

Figure 1 shows a block diagram of FA3676F’s internal circuitry. The circuitry is comprised of components common among the channels such as a control circuit, 1.0V reference voltage circuit, triangular voltage oscillator and UVLO (under voltage lock-out) circuit, and of components specific to each channel such as an error amplifier, PWM comparator, soft-start circuit and output driver circuit.

Table 2 shows channel control specifications. Based on the specifications, an overview of the control is described below.

3.1 Control specifications

All of the six channels are push-pull drive circuits, which permit direct driving of the switching of external MOSFETs (metal-oxide-semiconductor field-effect transistor). On-state resistance is 6Ω for the No. 3
channel and 10Ω for the other channels, permitting a current flow of up to ±0.2A. A bipolar transistor can be used as an external switching device by connecting a current limiting resistor to the output pin of its channel.

The No. 6 channel can be selected for driving on external p-/n-channel MOSFET by Hi/Low connection of the PNSEL pin, allowing buck converter or boost converter circuits to be selected depending on the product system.

Each channel is controlled as shown in Table 2 with two ON/OFF control pins and three soft-start control pins. When both two ON/OFF control pins are set at OFF, the IC goes into standby mode, extremely reducing supply current by turning off the internal control power supply.

CS1 and CS3 of the soft-start control pins are for constant current output. CS2 is not for current output, but the charge completion voltage can be set by an external resistor at CS2 to limit the maximum on-duty of an externally driven MOSFET.

### 3.2 Synchronous rectifier system

A buck converter circuit compatible with a syn-

---

**Table 2** Channel control specifications

<table>
<thead>
<tr>
<th>Channel</th>
<th>Output pin</th>
<th>Drive MOSFET</th>
<th>On-state resistance</th>
<th>Synchronous rectifier</th>
<th>Application circuit</th>
<th>ON/OFF control pin</th>
<th>Soft-start setting pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>OUT1p/n</td>
<td>p-channel</td>
<td>10Ω</td>
<td>Compatible with</td>
<td>Buck converter</td>
<td>CNT1</td>
<td>CS1</td>
</tr>
<tr>
<td>No. 2</td>
<td>OUT2p/n</td>
<td>p-channel</td>
<td>10Ω</td>
<td>Compatible with</td>
<td>Buck converter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 3</td>
<td>OUT3</td>
<td>p-channel</td>
<td>6Ω</td>
<td></td>
<td>Buck converter</td>
<td>CNT3</td>
<td>CS3</td>
</tr>
<tr>
<td>No. 4</td>
<td>OUT4</td>
<td>p-channel</td>
<td>10Ω</td>
<td></td>
<td>Buck converter</td>
<td></td>
<td>CS1</td>
</tr>
<tr>
<td>No. 5</td>
<td>OUT5</td>
<td>p-channel</td>
<td>10Ω</td>
<td></td>
<td>Buck/inverting</td>
<td>CNT1</td>
<td>CS2 (On-duty limit setting)</td>
</tr>
<tr>
<td>No. 6</td>
<td>OUT6</td>
<td>p-/n-channel</td>
<td>10Ω</td>
<td></td>
<td>Buck/boost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig. 2 Synchronous rectifier circuit and driver output waveform

(a) Synchronous rectifier circuit

(b) Driver output waveform

Fig. 3 Relationship of dead time to external resistance

Fig. 4 FA3676F Application circuit example
power supply and ground (GND). Turning on both MOSFETs at the same time causes a short circuit in the power supply. To avoid this, dead time (where both MOSFETs are off) is provided as shown in Fig. 2 (b). The dead time depends on the switching characteristic of the external MOSFET and the optimal setting value varies according to the application. In the FA3676F, resistors are connected between DT1/DT2 and GND, allowing dead time to be independently set in each channel according to the resistance values.

Figure 3 shows the relationship between set values of dead time and external resistance.

4. Application Circuit Example

Figure 4 shows an example circuit of an FA3676F application. The circuit consists of buck converters in the No. 1 to No. 4 channels, an inverting converter in the No. 5 channel and a boost converter in the No. 6 channel. A synchronous rectifier system is utilized in the No. 1 and No. 2 channels to improve power supply efficiency.

Switching power supplies in six channels are thus integrated into a single IC chip. In addition, the use of a multi-winding transformer instead of reactors in the channels allows the construction of power supplies having more than six channels.

5. Conclusion

This paper has presented an overview of the FA3676F, a control IC compatible with a synchronous rectifier system for a six-channel DC-DC converter. Based on the FA3676F, Fuji Electric is determined to respond to future market needs and to develop lower-voltage ICs that can be driven from a single cell lithium battery, power ICs with a built-in battery-charge control function and multiple output control ICs compatible with a synchronous rectifier system for more than six channels.
* All brand names and product names in this journal might be trademarks or registered trademarks of their respective companies.