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)

Table 1 FA3676F ratings

(a) Absolute maximum ratings

Item	Ratings
Supply voltage	20 V
Output peak current	±0.2A
Total power dissipation	550mW
Ambient temperature	–20 to +85°C
Storage temperature	–40 to +125°C

(b) Electrical characteristics

Item	Ratings
Supply voltage	2.5 to 18V
Oscillation frequency	50kHz to 1MHz
Oscillator timing capacitor	22 to 1,000pF
Oscillator timing resistor	6.8 to 100kΩ
Dead time setting resistor	0 to 100kΩ
Reference voltage	1.0V
Supply current	4mA/12μA (during operation/ standby)

(5) Standby function

(6) Built-in timer latch short-circuit protection

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-

Fig.1 Internal circuit diagram of FA3676F

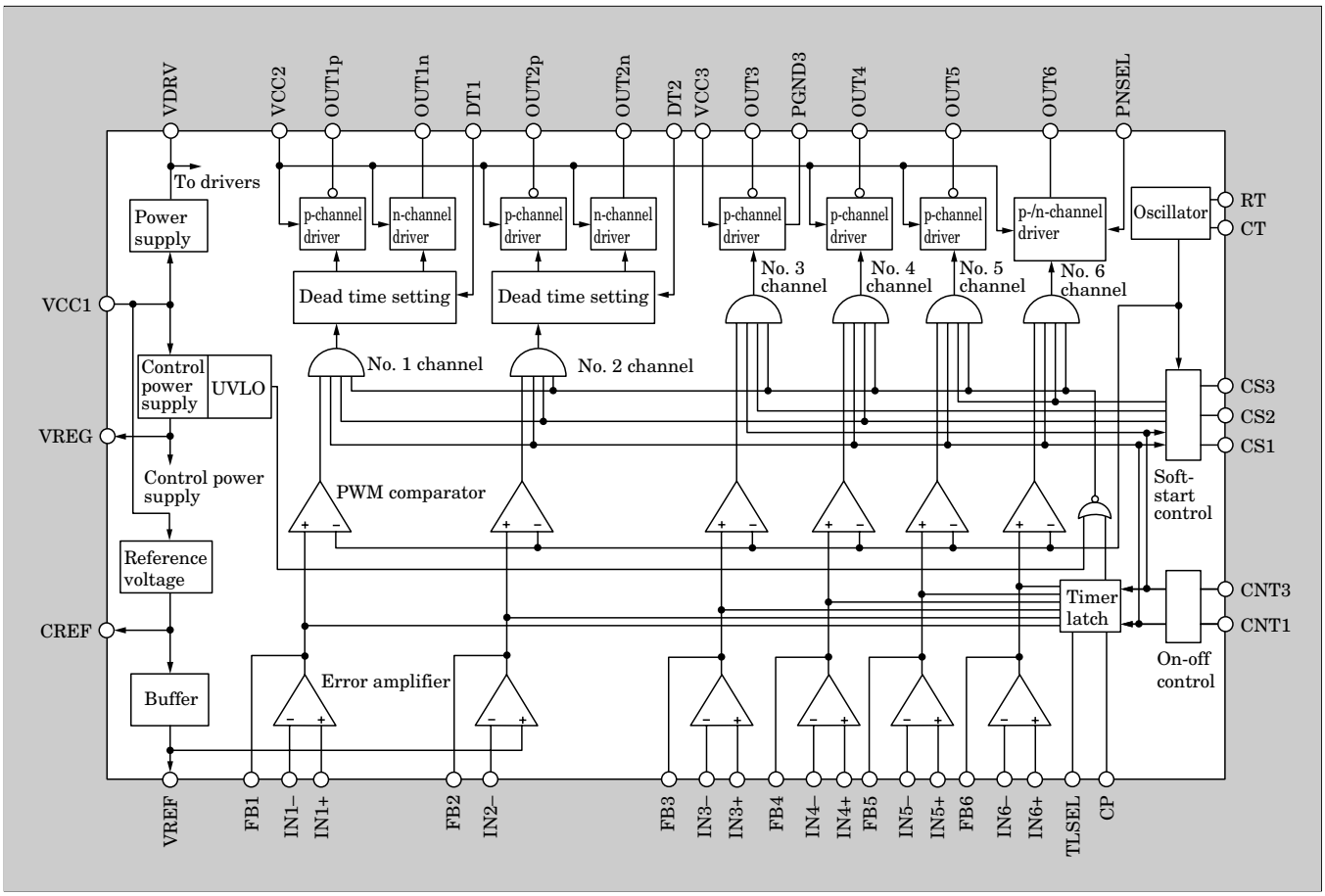


Table 2 Channel control specifications

Item / Channel	Output specifications				Application circuit	ON/OFF control pin	Soft-start setting pin
	Output pin	Drive MOSFET	On-state resistance	Synchronous rectifier			
No. 1	OUT1p/n	p-channel	10Ω	Compatible with	Buck converter	CNT1	CS1
No. 2	OUT2p/n	p-channel	10Ω	Compatible with	Buck converter		
No. 3	OUT3	p-channel	6Ω	——	Buck converter	CNT3	CS3
No. 4	OUT4	p-channel	10Ω	——	Buck converter	CNT1	CS1
No. 5	OUT5	p-channel	10Ω	——	Buck/inverting		CS2 (On-duty limit setting)
No. 6	OUT6	p-/n-channel selectable	10Ω	——	Buck/boost		

chronous rectifier system can be constructed in the No. 1 and No. 2 channels.

Figure 2 (a) shows a synchronous rectifier circuit. In the circuit, a reactor current passes through a diode (D) while the p-channel MOSFET (Q11) is in the off state. Power is dissipated as a result of the on-voltage of the diode and the current passing through the diode produce. When the converter output voltage is low and output current large, power dissipation may reduce the power supply efficiency. Therefore, a synchronous rectifier system is adopted as an effective means to improve power supply efficiency. In the system, an n-channel MOSFET (Q12) having lower on-state resistance than the diode is connected in parallel with the diode; while current is flowing to the diode, the MOSFET is made to turn on and current flows through the MOSFET, reducing power dissipation.

In the synchronous rectifier system, p- and n-channel MOSFETs are connected in series between a

Fig.2 Synchronous rectifier circuit and driver output waveform

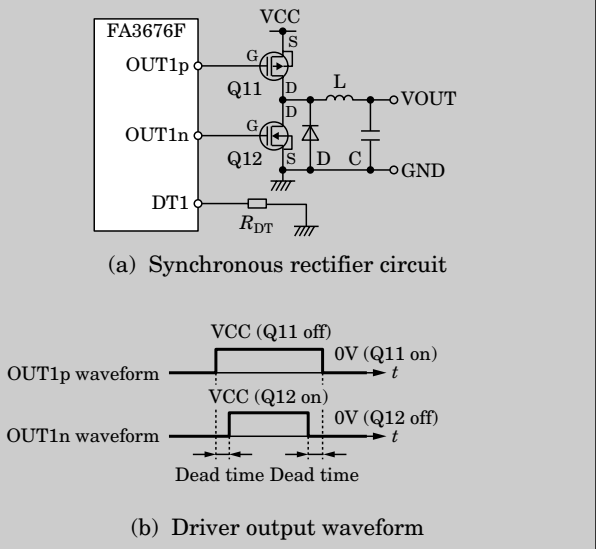


Fig.3 Relationship of dead time to external resistance

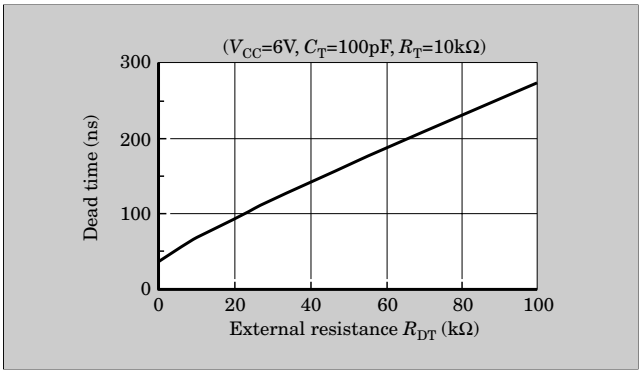
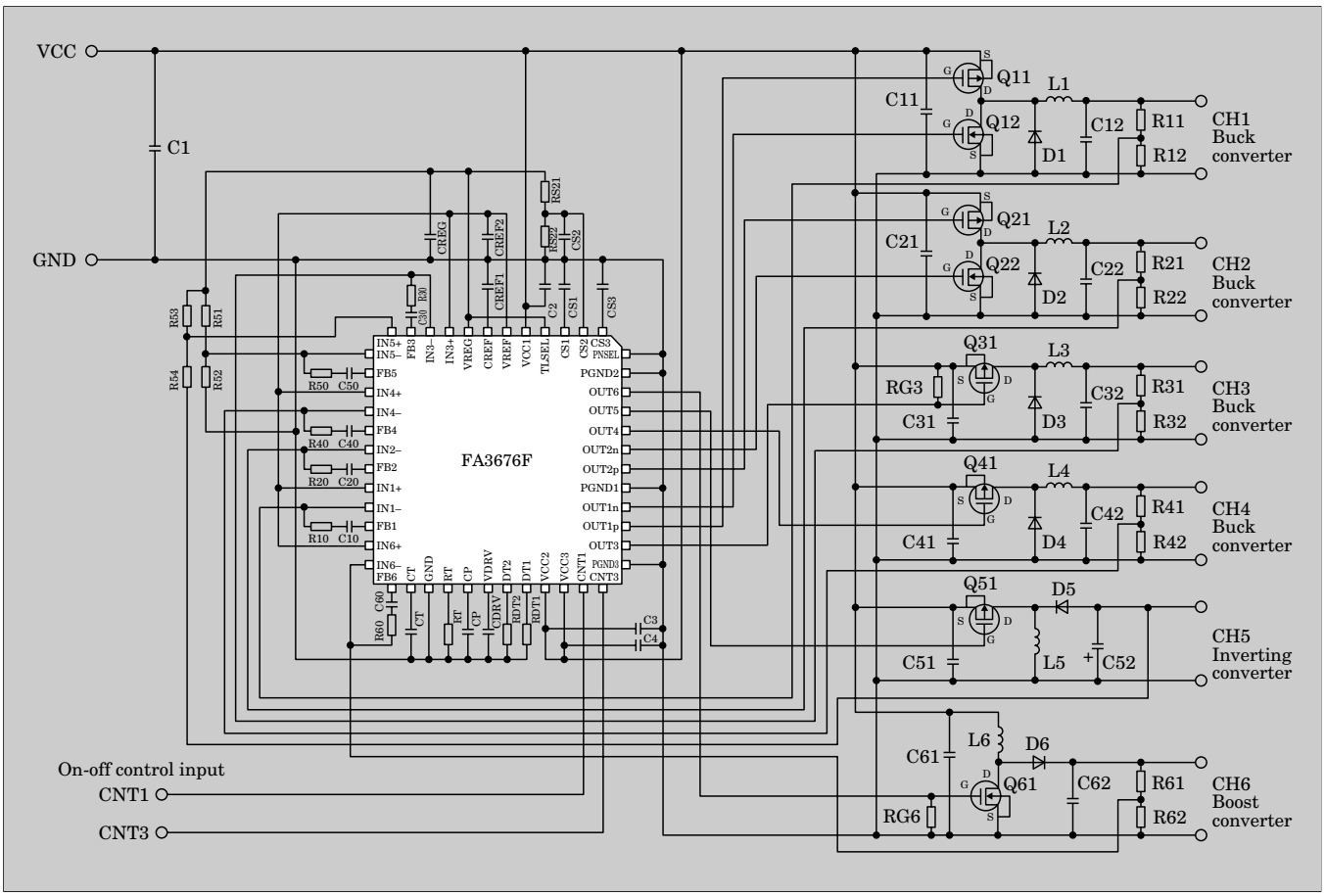


Fig.4 FA3676F Application circuit example



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.