Control IC for 3-Channel Switching DC-DC Converters

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1. Introduction

With the proliferation of portable electronic devices typified by notebook-sized personal computers, importance has been attached to device portability and to longer service life of the batteries installed in these devices.

Consequently, DC-DC converters used as power supplies for these devices require smaller size, lighter weight and higher efficiency.

In addition, these portable electronic devices increasingly require lower operating voltage. Accordingly, control ICs for DC-DC converters must operate at lower voltages.

To meet these market needs Fuji Electric has developed the FA3629AV, a small, light and thin control IC for 3-channel DC-DC converters, mainly aimed at power supplies for liquid crystal displays used in notebook-sized personal computers and other electronic devices. This paper presents an overview of the FA3629AV.

2. Product Overview

The newly developed FA3629AV IC for 3-channel DC-DC converters drives and controls PWM (pulse width modulation) type switching power supplies. This IC has the following features.

(1) TSSOP 16-pin package
(2) Can drive three channels simultaneously, two boost converters and an inverting converter
(3) Built-in n-channel MOSFET (metal-oxide-semiconductor field-effect transistor) as a switching element
(4) Operating voltage: 2.5 to 6.5V
(5) Oscillation frequency: 100kHz to 1MHz
(6) Built-in maximum duty limiting for each channel
(7) Built-in timer and latch type short circuit protection
(8) Built-in soft start circuit, overcurrent limiting circuit, thermal shutdown circuit and undervoltage lockout circuit

The FA3629AV incorporates a MOSFET as well as 3 channels and various protective functions on 16 pins, allowing smaller and thinner DC-DC converters.

Table 1 shows the ratings of the FA3629AV.

3. Internal Circuitry

Figure 1 shows a photograph of the FA3629AV chip and Fig. 2 shows its circuit diagram. Basic circuit blocks use CMOS (complementary MOS) technology and high-voltage sections such as the MOSFET use DMOS (double diffused MOS) technology.

Main circuit blocks are described below.

3.1 Built-in MOSFET

This IC incorporates an n-channel MOSFET, a switching element, in the No. 1 channel, constituting a boost converter. The MOSFET has on-state resistance

Table 1 Ratings of FA3629AV

Item	Condition	Min.	Std.	Max.
Supply voltage (V)		2.5		6.5
Output voltage at OUT1 pin (V)				40
Reference voltage (V)		0.98	1.00	1.02
Oscillation frequency (kHz)		480	550	620
Source current at CS pin (μA)		– 1.2	– 1.0	– 0.8
Sink current at CS3 pin (μA)		0.8	1.0	1.2
Overcurrent sensing current (A)		1.6	2.0	2.2
Thermal shutdown operating temperature (°C)		125	135	145
Undervoltage lockout operating voltage (V)		1.95	2.05	2.15
OUT1 on-state resistance (Ω)	I_{OUT1} = 200mA		0.275	0.3
OUT2, 3 H level on-state resistance (Ω)	I_{OUT} = 150mA	2.6	4.0	5.5
OUT2, 3 L level on-state resistance (Ω)	I_{OUT} = – 150mA	2.0	3.5	5.0
Average current consumption (mA)	f_{OSC} = 500kHz		3.0	3.8

<Note> Unless otherwise indicated, rated values are specified under the condition of a 3.0V supply voltage and 25°C ambient temperature.

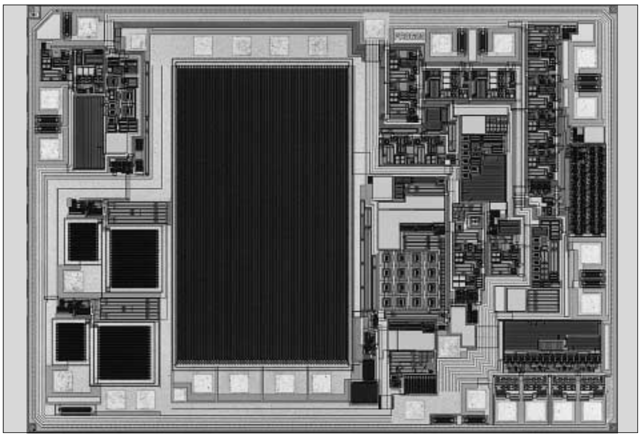
of 0.3Ω (max.) and can provide a current of up to 1.8A. This leads to a reduction in the number of switching elements and to greater output. The OUT1 pin is the drain and the PGND pin the source. Withstand voltage of the OUT1 pin is 40V.

3.2 Output drivers (OUT2 and OUT3 pins)

The No. 2 channel pin is for driving an n-channel MOSFET and the No. 3 channel pin is for driving a p-channel MOSFET. These channels constitute a push-pull construction and form a boost converter and an inverting converter respectively.

In addition, these channels can drive bipolar transistors as switching elements.

Fig.1 Photograph of the FA3629AV



3.3 Basic operating sections (error amplifier and PWM comparator)

Since PWM-type switching power supplies are to be controlled, the basic configuration of the main operating sections is to feed back the output voltage provided from each channel to the error amplifier of each channel and to convert the output of the amplifier into a pulse signal with a comparator to create a driving signal for switching elements.

Each channel has an inverting input pin (IN1-, IN2- or IN3-) and an output pin (FB1, FB2 or FB3) connected to the error amplifier.

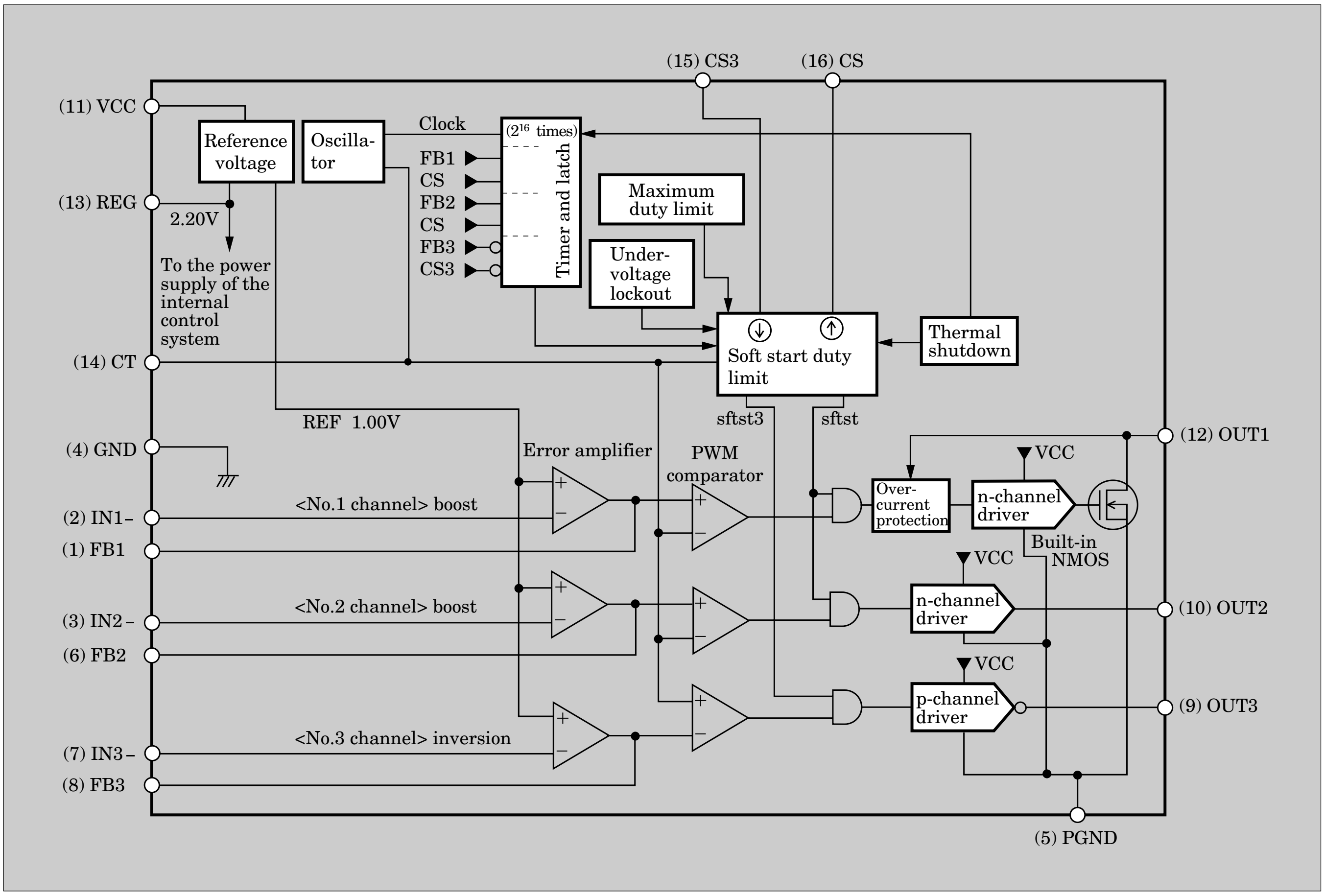
The No. 1 and No. 2 channels constitute boost converters and the No. 3 an inversion booster. This combination is most suitable for the power supply of liquid crystal displays.

In addition, the No. 3 channel utilizes inverted-phase switching (as compared to the other channels). This avoids load concentration during simultaneous operation of the three channels.

3.4 Oscillator

The fundamental frequency of this IC is the

Fig.2 FA3629AV circuit diagram



frequency of the oscillator. Repeated charging and discharging of a timing capacitor by a temperature-compensated built-in power source generates the oscillation ranging from 100 kHz to 1 MHz depending upon capacitance. The oscillation frequency is 550kHz at 150pF.

3.5 Soft start circuit

The IC incorporates a soft start circuit to prevent current flow when the DC-DC converter starts.

Gradual expansion of the pulse signal width in proportion to the charged voltage of a soft start capacitor (connected to CS and CS3 pins) limits the current flow at start-up.

The CS pin is used for the No. 1 and No. 2 channels, and the CS3 pin for the No. 3 channel. These pins can be controlled independently.

3.6 Maximum duty limit

If a boost converter and an inverting converter remain switched on, the heavy current flow may damage the converters. To prevent this, an off-period is forcibly provided for each switching period, in other words, the maximum on-period duty is limited.

For each channel, a maximum duty limit of 86 to 87% of is imposed for an oscillation frequency of 500kHz. Since this is a built-in function, external parts are unnecessary.

3.7 Undervoltage lockout circuit

From the time when the IC is turned on until the internal control power supply is established, switching is halted in order to prevent malfunction.

During operation of this circuit, the soft start capacitor is discharged. The soft start function can be used to return to normal IC operation.

3.8 Overcurrent limiting circuit

This function shortens the switching period to prevent elements and circuits from being damaged when, for some reason, the current of the built-in MOSFET increases.

From the on-state voltage of the built-in MOSFET, this function detects the overcurrent state for each switching operation. If an overcurrent state is detected, the IC is turned off. The detection point is 2.0A for a supply voltage of 3.0V.

Switching is not halted by this function but if the overcurrent state continues for a long time, switching will be halted by a timer and latch circuit to be described later.

3.9 Thermal shutdown circuit

This IC incorporates a MOSFET and has a driving circuit for external switching elements. These elements generate heat when there is a large current flow. The thermal shutdown circuit detects the heat and turns off the IC.

Heat is detected by changes in temperature of an on-state diode. If the chip temperature reaches 135°C, switching is halted.

Fig.3 Schematic diagram of switching operation

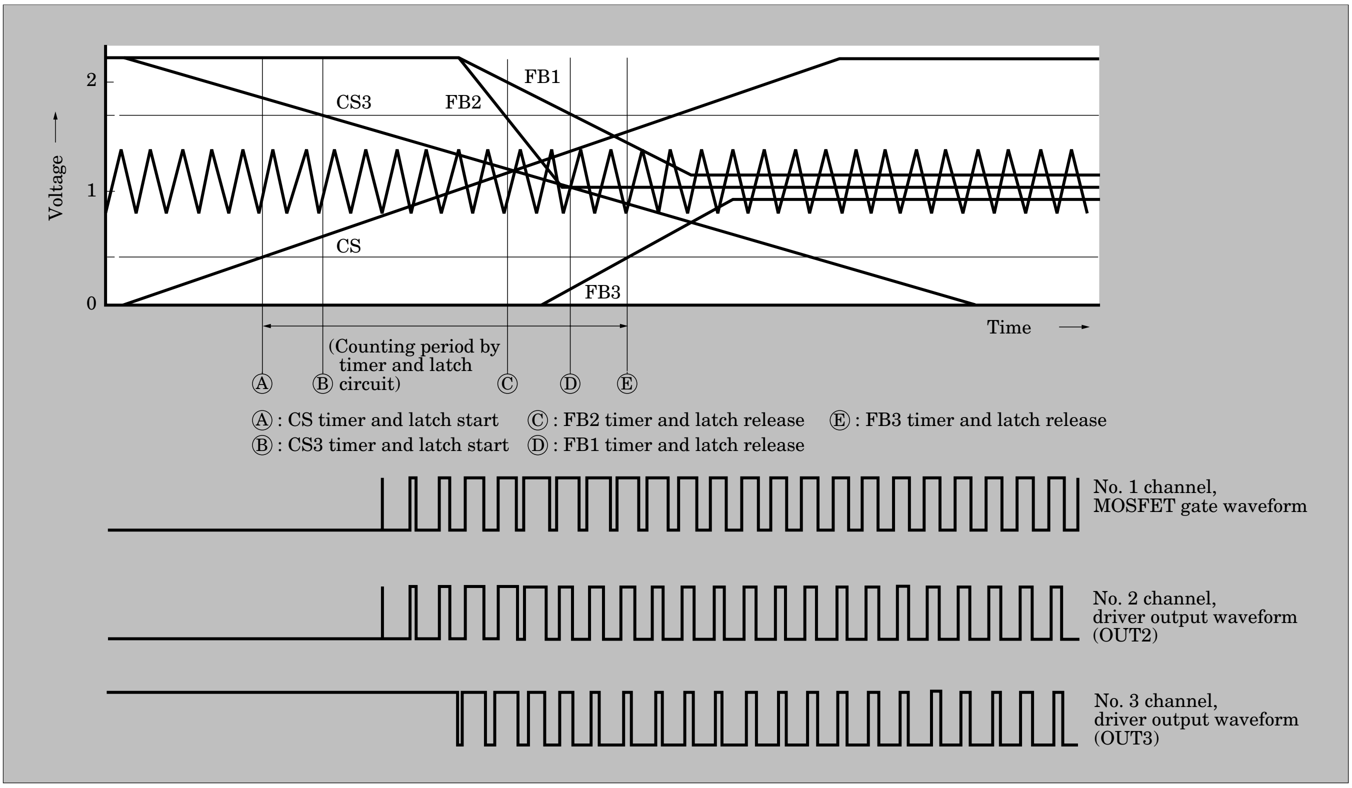
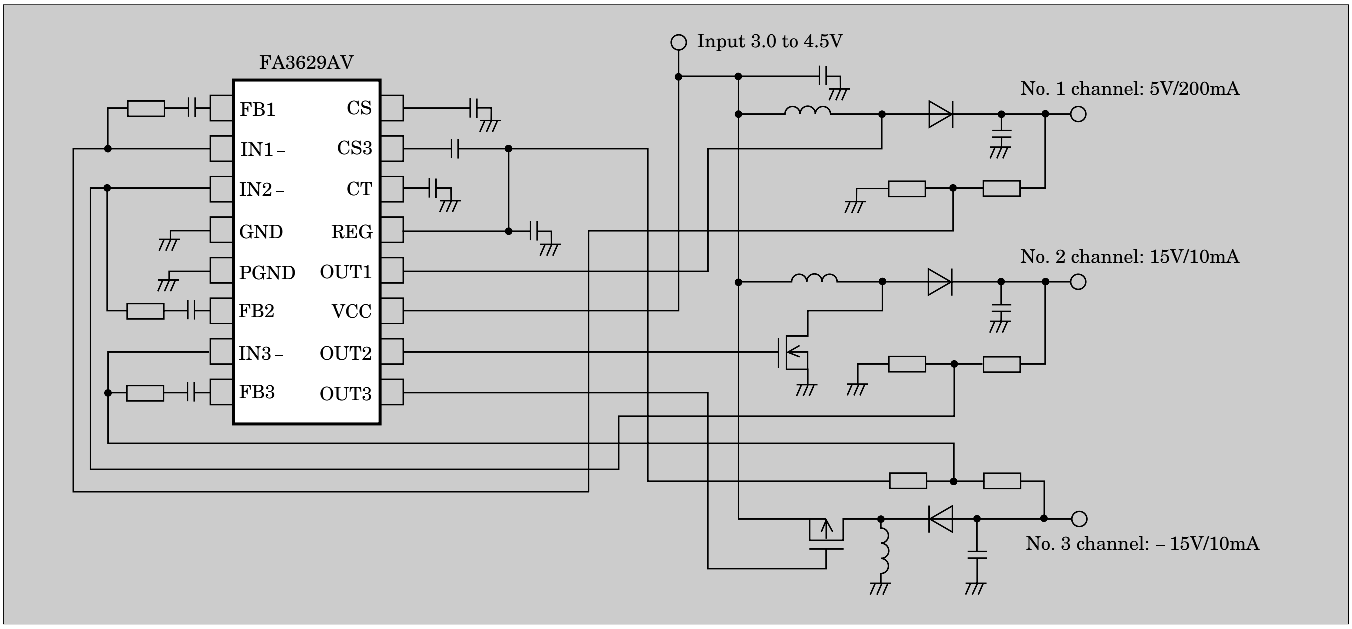


Fig.4 Example application circuit using the FA3629AV



3.10 Timer and latch circuit

The timer and latch circuit detects an abnormal condition when the output voltage of the power supply circuit is less than the specified value for a period of time, and then halts the switching operation.

The charging time of an external capacitor is commonly used to set the time between detecting an abnormal condition and halting the switching operation (hereafter referred to as the “timer-latch time”). To reduce the number of pins and external parts in this IC, however, an internal counter is utilized to set this time.

The counter clock uses the oscillator frequency. When the counterís value reaches 2^{16}, the latch mode is entered and a halt signal is transmitted.

The output voltage of the error amplifier of each channel is used to detect an abnormal condition. When the power supply voltage is below the specified value, the output voltages at FB1 and FB2 reach the voltage level of the FA3629AV’s reference voltage (2.20V), and the voltage at FB3 reaches the ground or zero voltage level to maximize the on-state pulse width of each channel.

Figure 3 shows a schematic diagram of the switching operation.

During start-up operation or when there is an unused channel, the output voltage of the error amplifiers is the same as when there is an abnormal condition. Therefore the pin voltage at the soft start pins (CS, CS3) is detected and input to the timer and latch circuit.

4. Example Application Circuit

Figure 4 shows an example application circuit using the FA3629AV. The No. 1 and No. 2 channels constitute booster converters and the No. 3 channel an inverting converter. This conforms to the general power supply specifications of liquid crystal displays.

The application circuit incorporates an n-channel MOSFET and utilizes a counter type timer and latch circuit. This results in a reduction in the number of parts and mounting surface area.

5. Conclusion

This paper has presented an overview of the FA3629AV, a small size, lightweight and thin shaped control IC for 3-channel DC-DC converters.

Fuji Electric is now developing ICs for power supplies based on CMOS analog technology. Fuji Electric will continue to closely monitor market needs and develop control ICs, in particular, ICs that meet the various requirements of DC-DC converter applications.

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