

# Charge Pump Booster IC

Yutaka Yoshida  
Hirohisa Arai

## 1. Introduction

Portable electronic equipment such as PDAs (personal digital assistants) and cellular phones that have rapidly spread into the market requires reduction in size, weight and power consumption because portability and extended battery operation are essential features.

For electronic components used in portable electronic equipment, the power supply voltage of digital ICs has been lowered as device dimensions have been miniaturized. On the other hand, the operating voltage of analog ICs and RF communication components remains around 3 to 5 V as their electrical characteristics are susceptible to change depending on the power supply voltage. Lithium-ion rechargeable batteries used in portable electronic equipment typically provide an output of 3.6 V, therefore use of booster converters is necessary.

Moreover, analog ICs and RF communication parts are susceptible to possible malfunction if the noise of the power source is large; thus a stable power supply is necessary.

This paper introduces the FA3705NM charge pump booster IC, developed in response to market needs for a small-size boost power supply with the features of low ripple voltage and low power consumption.

## 2. Features

The FA3705NM was developed for components in portable electronic equipment requiring a stable 5 V power supply, and its merits are low ripple voltage, low power consumption and a compact circuit size.

As a boost converter, DC/DC switching converters with inductors or charge pump converters with capacitors are often used, but ripple voltage on the output due to the switching operation is so large that they cannot be utilized in analog ICs or RF communication components.

On the other hand, the FA3705NM integrates a charge pump boost converter operating with capacitors and a series regulator suppressing ripple voltage into a

Fig.1 Magnified view of chip (FA3705NM)

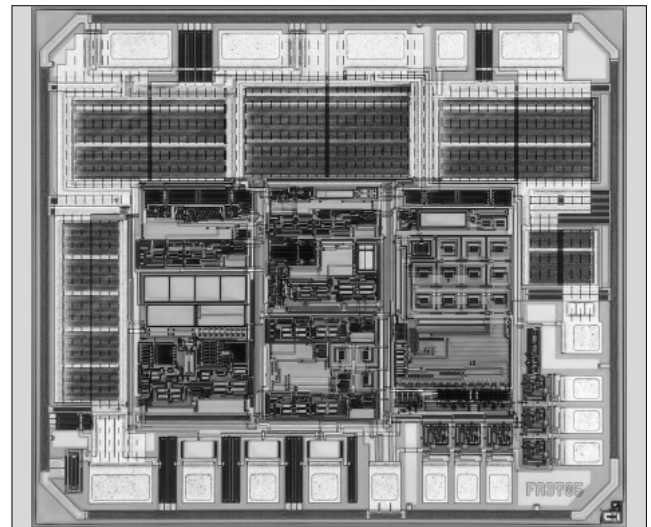
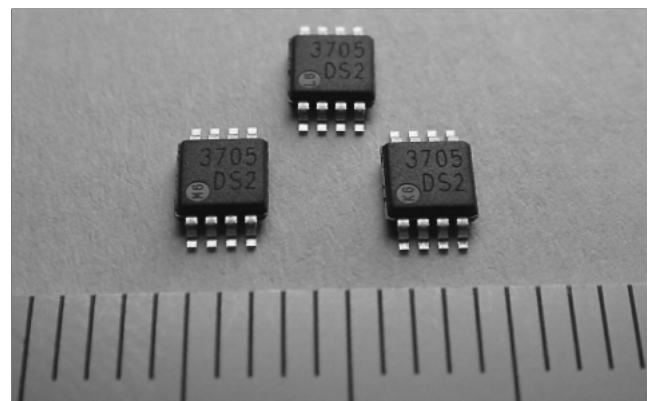


Fig.2 External view (FA3705NM)



single chip, thereby realizing a boost converter with low ripple voltage.

Low power operation is accomplished by using CMOS (complementary MOS) process technology and setting up the shutdown mode. A small size is accomplished by adopting an ultra-small MSOP (micro small out-line package)-8 package and attaching only a small number of external parts (as few as five capacitors).

The features are summarized briefly below.

- (1) Low ripple voltage: typ.1 mV<sub>p-p</sub>
- (2) Input voltage range compatible with a Lithium-ion battery: 2.7 to 4.4 V
- (3) Shutdown mode available
- (4) Built-in protection circuits for overheating, overloading and low input voltage
- (5) Built-in reference voltage circuit
- (6) Ultra-small MSOP-8 package: 3.0 mm by 4.9 mm (including the tip of the leads)

Figures 1 and 2 show views of the magnified chip and the exterior of the FA3705NM respectively.

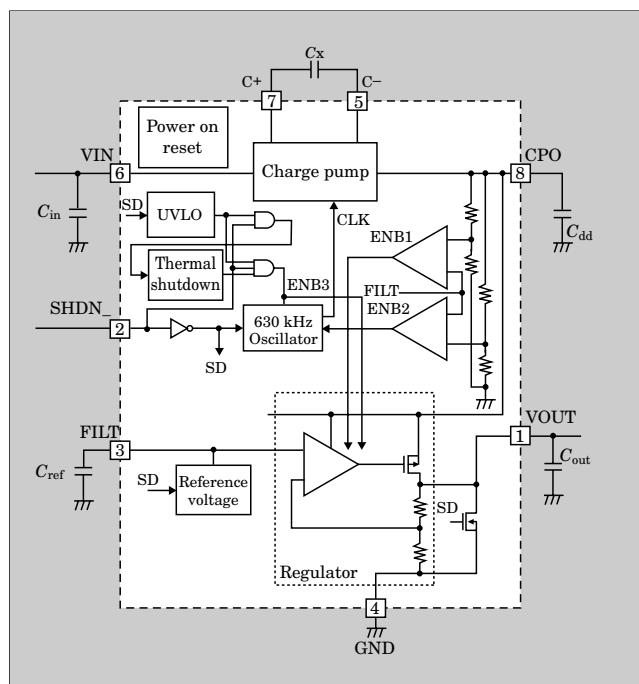
### 3. Product Summary

Operation of the FA3705NM is described below, and the electrical characteristics are listed in Table 1 and the internal block diagram is shown in Fig. 3.

Table 1 Electrical characteristics

Item	Characteristic
Input voltage range	2.7 to 4.4 V
Startup input voltage	2.5 V (Typical)
Output voltage	5.00 V $\pm$ 0.10 V (Input voltage = 3.2 V, Output current = 1 mA)
Output current	50 mA (Maximum)
Oscillation frequency	630 kHz (Typical)
Supply current	250 $\mu$ A (Typical) (Input voltage = 4.4 V, Output current = 0 mA) 4.1 mA (Typical) (Input voltage = 3.2 V, Output current = 1 mA)
Supply current in shutdown	0.1 $\mu$ A (Typical)

Fig.3 Block diagram



### 3.1 Basic operation

The built-in charge pump generates about 5.8 V from the voltage input at the VIN terminal, and outputs that generated voltage to the CPO terminal. In contrast to a conventional charge pump that outputs twice the value of the input voltage, the FA3705NM outputs a constant value by disabling temporarily while the output voltage exceeds 5.8 V. It accomplishes this by monitoring the output voltage with a built-in voltage reference circuit and comparator.

The output of the charge pump contains ripples due to the switching operation, but the built-in series regulator attenuates the ripples and outputs a stable voltage of 5.0 V at the VOUT terminal. In order to prevent malfunction of the series regulator, it stays inactive until the voltage at the CPO terminal reaches 5.1 V.

The oscillating rate of the charge pump is 630 kHz. This frequency has to be selected so as not to cause interference with the intermediate frequency of 450 kHz or 455 kHz used for converting from a high radio frequency to the data transmitting frequency adopted in portable electronic equipment.

The startup operation of the power supply is described below.

- (1) First, the built-in voltage reference circuit starts, and then the voltage at the FILT terminal rises from the initial value of 0 V to about 1.22 V.
- (2) After a while, the built-in charge pump starts, and charges the external capacitor  $C_{dd}$  connected at the CPO terminal from an initial value of 0 V to about 5.8 V through the flying capacitor  $C_x$ .
- (3) While the voltage at the CPO terminal is less than 5.1 V, the built-in series regulator does not operate and the voltage at the VOUT terminal remains at 0 V. After the voltage at the CPO terminal exceeds 5.1 V, the built-in series regulator starts operation and the voltage at the VOUT terminal increases gradually up to 5.0 V.

Figure 4 shows the startup waveform of the power

Fig.4 Startup waveform

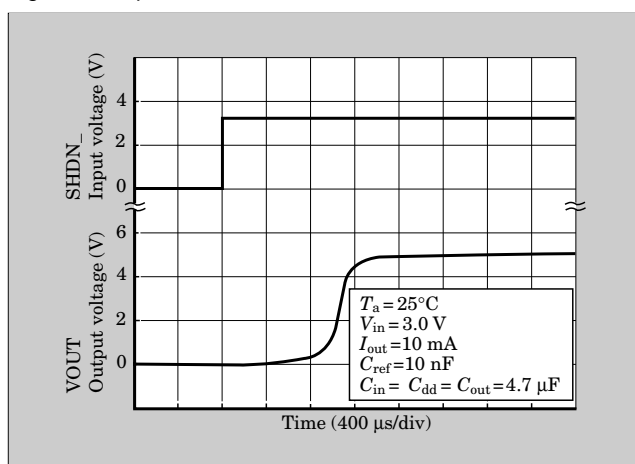


Fig.5 Relationship between  $C_{ref}$  and rise time

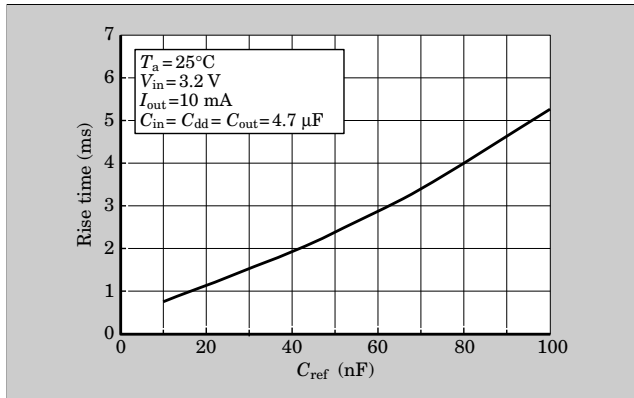


Fig.6 Shutdown waveform

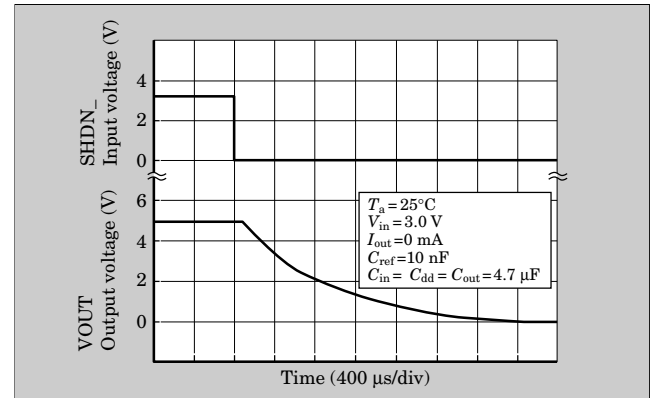
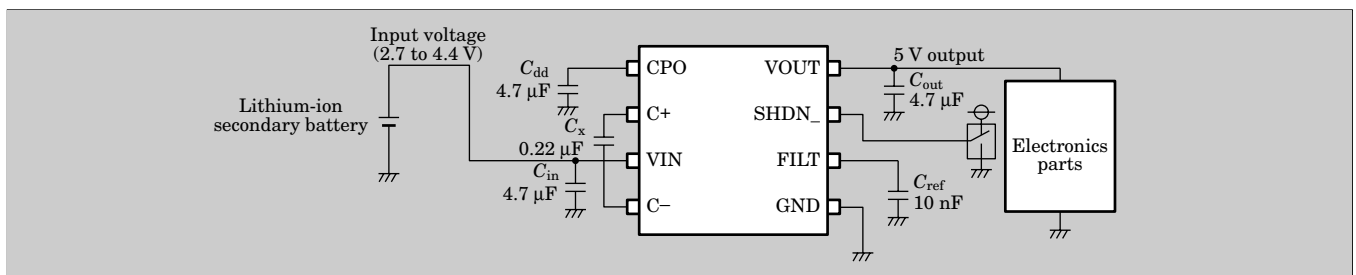


Fig.7 FA3705NM application circuit example



supply. The output voltage settles at the desired value 1.2 ms after startup.

The rise time depends on the value of  $C_{ref}$ , which is a 10 nF capacitor in the case of the measurement shown in Fig. 4. Figure 5 shows the relationship between  $C_{ref}$  and rise time. There is a tendency for the rise time to become longer but ripples on the output to become smaller with larger values of  $C_{ref}$ .

### 3.2 Shutdown

Setting the SHDN\_ terminal to a low level causes all internal circuits to suspend operation, and consequently the consumption current drops below 1 μA. While the FA3705NM is in shutdown mode, the VOUT terminal is shorted to GND internally and the power supply is cut off. This prevents malfunction of the electronics components that are supplied power by the FA3705NM.

Figure 6 shows the shutdown waveform of the power supply. The voltage settles down to 0 V approximately 2.5 ms after shutdown.

### 3.3 Protection circuit

To avoid damage caused by accidental external conditions, the following protection circuits are built-in.

- (1) Overheat protection: When the temperature of the IC rises to about 150°C, the charge pump stops its operation and cuts off power to the load. After cooling down to about 140°C, the charge pump resumes operation.

- (2) Overload protection: If the output of the series regulator falls below about 1.22 V, that event is regarded as an overload condition, and the series regulator stops its operation.
- (3) UVLO (undervoltage lockout): While the input voltage is below approximately 2.5 V, all internal circuits except the reference voltage circuit stop their operation to avoid malfunction.

## 4. Application Circuit

Figure 7 shows an example application circuit that utilizes the FA3705NM. This example is a power supply circuit providing stable 5 V to radio frequency components such as a VCO (voltage controlled oscillator) with a Lithium-ion battery power source.

The only external components necessary are five low-priced ceramic capacitors.

Connecting the SHDN\_ port to one of the external ports of the microcontroller makes shutdown mode available.

## 5. Conclusion

This paper has presented an overview of the FA3705NM, developed as a power supply for portable electronic equipment.

In keeping with the trend toward increasingly higher integration of LSI devices, Fuji Electric is determined to provide technological innovation for more versatile systemized circuits.



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