Power Management IC for a Cellular Phone with a Li-Ion Battery Charger

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1. Introduction

Portable electronic equipment has recently been improved with respect to reduced size and weight and to advanced functionality. Cellular phones, as typical products of such equipment, have been favored by many consumers and have attained high market penetration due to their enhanced portability and convenience which allows phone calls to be made whenever and wherever desired, enabled by the reduction of size and extension of standby/talk time with low power consumption.

Fuji Electric developed the FA3694R power supply IC for cellular phones, which provides low power consumption (reduction of IC power consumption) and downsizing (integration of each function) and is housed in a 48-pin small package.

This paper presents an overview of the FA3694R power management IC for cellular phones.

2. Features

The FA3694R is a system power supply IC developed for cellular phones, containing a high-precision battery charger (stand alone), six 2.85 V voltage output terminals, an LDO (low drop out) regulator for maximum output current of 150 mA, a speaker amplifier, various drivers [LED (light emitting diode), buzzer, backlight], various detectors, reference voltage circuits, etc.

Moreover, each LDO regulator, speaker amplifier and various drivers can be individually turned on or off via a serial interface. The ability to switch each power supply on or off as needed makes it possible to save battery power and to achieve low power consumption in a cellular phone.

The features of the FA3694R are summarized as follows:

(1) Built-in integrated battery charger.
- ○ Pre-charge.
- ○ Fast charge.
  - Constant current mode.
  - Constant voltage mode.

This IC, targeting the full charging of the battery (to extend the available period of use) and safety during the charging process (to prevent battery damage caused by overvoltage), regulates the voltage of the constant voltage charge during the fast-charge mode, i.e. in the last stage of the charge, and has realized the voltage with high precision of 4.2 V ± 30 mV.

(2) Built-in six LDO regulators.

Fig.1 Photograph of the FA3694R package

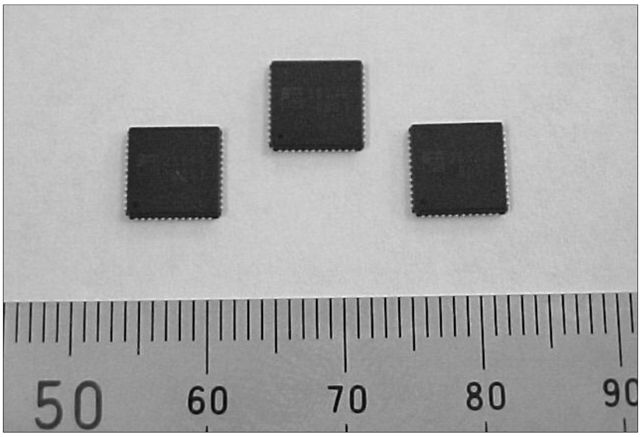
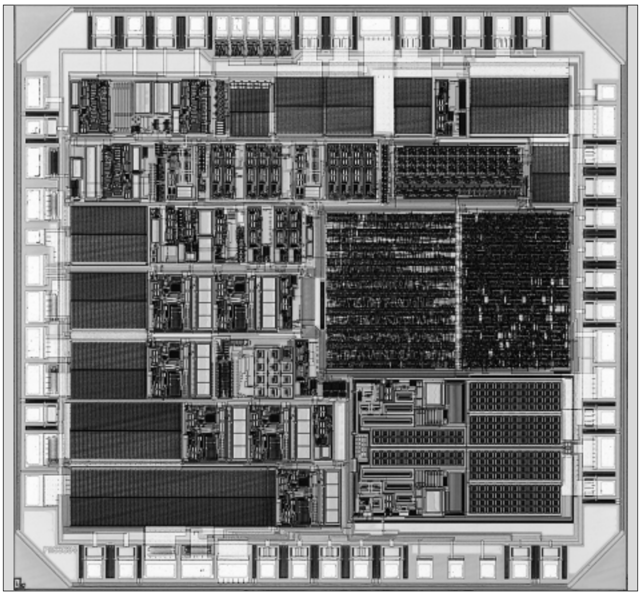


Fig.2 Photograph of the FA3694R chip



(3) Built-in speaker amplifier (to drive speaker of 32 Ω load)
(4) Built-in various driver circuits
LED, buzzer, backlight.
(5) Built-in various detector circuits
Regulator, main power and battery detection.
(6) Built-in reference voltage circuit
(7) CMOS (complementary metal oxide semiconductor) silicon gate 1 µm process
(8) Low consumption current : 100 µA (in standby)

Table 1 Absolute maximum ratings

Item		Ratings	Unit
Supply voltage range	VCHG	6.5	V
	MPWR	6.5	
Input voltage of control terminal		–0.3 to 3.15	V
Input voltage of speaker amplifier		–0.3 to 3.0	V
Power dissipation (T_a = 25°C)		600	mW
Operating temperature		–30 to 85	°C
Storage temperature		–40 to 125	°C

Table 2 Main electrical characteristics

Item	Condition	Typical	Unit
Battery charger			
Pre-charge	R_s = 0.4 Ω	100	mA
Fast-charge (CC Mode)	R_s = 0.4 Ω	1,000	mA
Fast-charge (CV Mode)	R_s = 0.4 Ω	4.20	V
Over voltage threshold for VCHG		6.0	V
Under voltage threshold for VCHG		3.65	V
Over voltage threshold for VBAT		4.55	V
Under voltage threshold for VBAT		2.90	V
Low temperature threshold		0	°C
High temperature threshold to cut off pre-charge		43	°C
High temperature threshold to cut off fast-charge		50	°C
Maximum pre-charge time		140	min
Maximum fast-charge time		140	min
Regulator			
Output voltage	I_{load} = 150 mA	2.85	V
Ripple rejection rate	f = 21 kHz	–60	dB
Load regulation	I_{load} = 1 to 150 mA	0.2	mV/mA
Buzzer			
Turn on voltage for NMOS	I_{load} = 120 mA	0.20	V
LED			
Output current	V_{in} = 1.0 V	40	mA
Output current	V_{in} = 2.85 V	114	mA
Current dissipation			
Standby current	During standby	100	µA

(9) 48-pin QFN (quad flat non-lead) package.

The external appearance of the FA3694R is shown in Fig. 1 and a photograph of the chip interior is shown in Fig. 2.

3. Specifications

The absolute maximum ratings are indicated in Table 1 and the main electrical characteristics are indicated in Table 2.

4. Brief Description of the IC

4.1 Charge control

The charge control circuit has been developed for a Li-ion battery. The block diagram of the charge block is shown in Fig. 3.

The charge block consists of a charge current monitor block, a monitor for supply voltage, a charge voltage/current control block (for CC/CV mode), a charge voltage monitor block, a battery temperature monitor block (including monitoring for the presence of a battery), a monitor for clock operation and a sequential logic circuit.

The sequential logic circuit (Fig. 4) monitors and controls the adaptor voltage, the battery voltage, the battery temperature, the charge current and the charge time.

The timing diagram of charging is shown in Fig. 5.

The normal charge process is described as follows.

(1) When the battery voltage is greater than 3 V and the adaptor voltage is normal (3.75 V < V_{CHG} < 6.0 V), a fast-charge is performed.
(2) During a fast-charge, either a constant current

Fig.3 Block diagram of the charge block

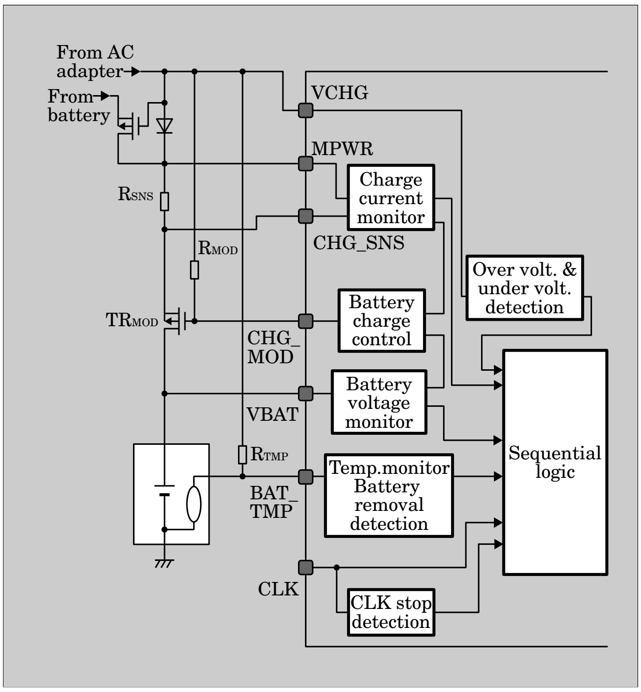


Fig.4 Flowchart of charging sequence

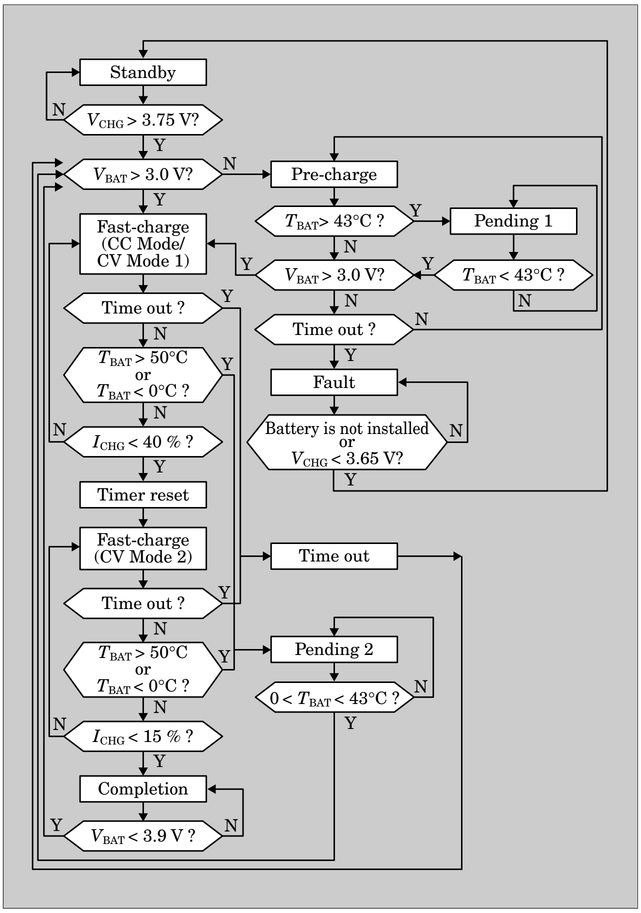
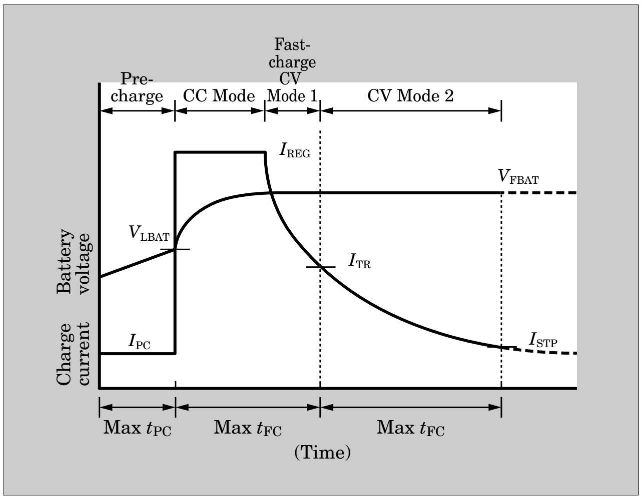


Fig.5 Timing diagram of charging



charge or constant voltage charge is performed, according to the charge current and the battery voltage. Normally, a constant current charge with 1 A is performed, and then a constant voltage charge at 4.2 V is done.

(3) The charge is completed at the point in time when the charge current decreases to less than 150 mA during a constant voltage charge.

(4) When the battery voltage drops less than 3.9 V, a recharge is initiated.

(5) When charging is initiated, if the battery voltage is less than 3.0 V, pre-charging is performed. Pre-charging in the constant current mode at 100 mA is continued until the battery voltage exceeds 3.0 V. If pre-charging has continued for more than 140 minutes, it will be stopped and the battery judged to be defective.

(6) During charging, if the battery temperature rises over 50°C or drops under 0°C, the charging will be stopped. Charging will resume when the battery temperature again falls into the range between 43°C and 0°C.

(7) Charging will be stopped in the following cases.
- ○ If the adaptor voltage becomes less than 3.65 V or greater than 6.0 V
- ○ If the battery voltage exceeds 4.55 V
- ○ If the battery is not physically present
- ○ If the clock is stopped

4.2 LDO regulator

The FA3694R incorporates an LDO regulator based on CMOS technology. Compared to bipolar products, CMOS products operate with smaller current consumption and smaller voltage drops, and therefore the FA3694R IC enables the use of smaller battery capacity and also lower battery voltage. The LDO regulator built into this IC has a high ripple rejection rate of – 60 dB, up to 21 kHz range, and achieves a low current consumption of 40 µA per circuit.

4.3 Speaker amplifier

In order to drive the speaker with a BTL (balanced transformer less) configuration, two push-pull amplifiers are built into this IC. By setting the EN terminal to a low-level, the shutdown mode is enabled, therefore the current consumption can be suppressed to less than 1 µA.

4.4 Various drivers

In order to drive the buzzer and backlight, n-channel MOSFETs (metal oxide semiconductor field effect transmitter) in the open drain configuration are built into this IC.

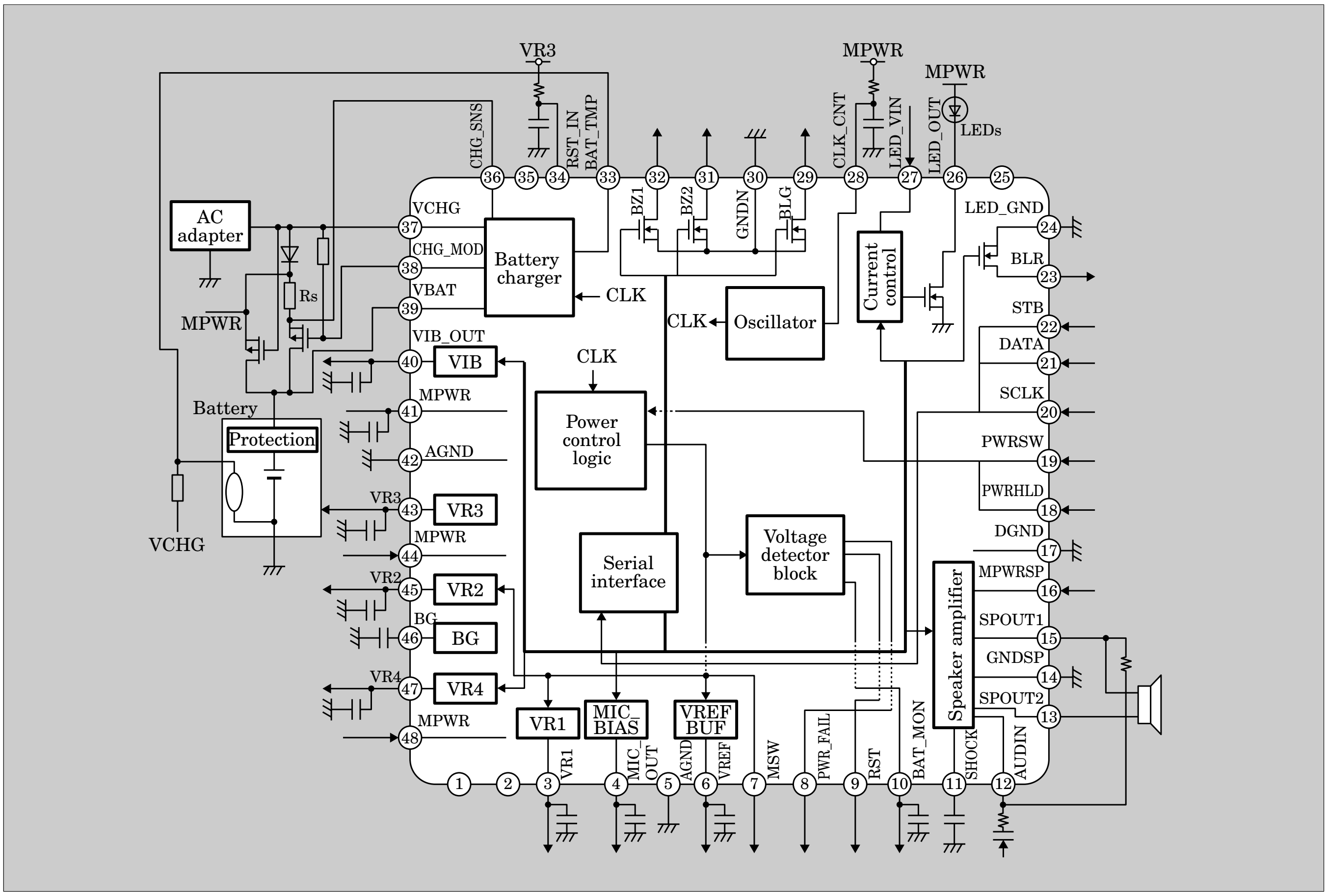
In the LED driver, the driving current is controlled with the input voltage level at the IN terminal, and in order to drive two or more LEDs, the driver is configured so as to be capable of supplying current up to 120 mA.

4.5 Various detectors

The internal regulator (VR1) and the main power (MPWR) are constantly monitored for low voltage, and their signals are output from the IC terminals in order to shutdown the system itself.

Also, in order to confirm the remaining power of the battery, the battery monitor converts the detected signal to an analog voltage and outputs it.

Fig.6 Block diagram of the FA3694R circuit



4.6 Serial interface

On/off switching of each block is controlled via the three-line serial interface.

4.7 Overall circuit

The block diagram of the FA3694R circuit is shown in Fig. 6.

5. Conclusion

This paper has presented an overview of the FA3694R developed as a power management IC for cellular phones having a built-in Li-ion battery charger.

It is forecast that the trend of integration in the field of LSI devices for cellular phones will increase further. Fuji Electric will continue efforts to develop ICs for high-performance systems through pursuing low power consumption and downsizing technology, and also will respond to market needs in the promising field of portable electronic equipment and will contribute to the development of electronic equipment.

Reference:

(1) Sano, I. et al. Power Management System IC for Cellular Phones. Fuji Electric Review. vol.46, no.4, 2000, p.124-126.