EPSON

S1F77500 Series

Lithium-ion Battery Charger

Preliminary

■ DESCRIPTION

SIF77500 is a charge control IC for 1-cell lithium-ion battery.

In addition to charging function, including constant current (full charge)/constant voltage charging, 0 V battery charging, and preliminary charging, this product incorporates protection function such as full charging detection, overvoltage detection, protection against overcurrent, battery temperature detection, adapter anomaly detection, and timer function. All these functions ensure safe charging of lithium-ion battery.

SIF77500 contains the function necessary for charging lithium-ion battery in a small package (SSOP3-24, WCSP), can realize high cost performance and a large space saving and is optimum for cellular phone, PDA, digital camera, etc.

■ FEATURES

- High precision constant voltage charging 4.1 V/4.2 V±1%
- Constant current charging (0 V battery charging, preliminary charging, and full charging)
- Full charging detection
- Recharging detection
- Overvoltage battery charging detection
- Overcurrent protection function
- Selectable ON/OFF of 0 V battery charging function
- Charging current output to monitor
- Capability of control of preliminary charging/full charging/prohibition from external pin
- Adapter anomaly detection
- Battery temperature detection (external thermista)
- Timer function (internal CR oscillation)
- Power on reset function
- Forced termination function
- LFDR and LEDG output
- Charging anomaly output
- CMOS process
- 24-pin plastic SOP (SSOP3-24pin) WCSP (4.6 mm × 3.2 mm)
- Not designed for radiation-proof.

■ BLOCK DIAGRAM

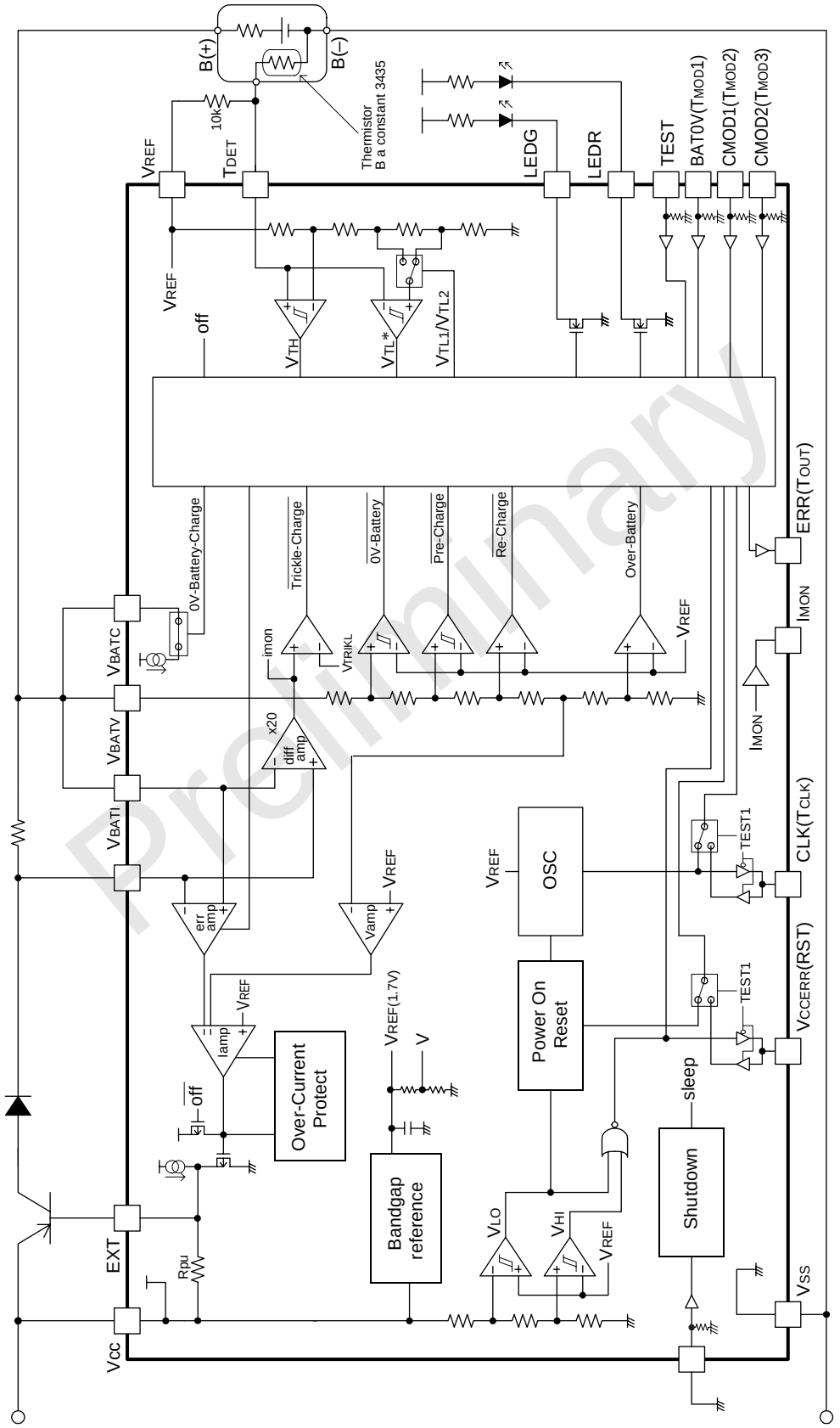


Fig.1 Block Diagram

■ PIN ASSIGNMENTS

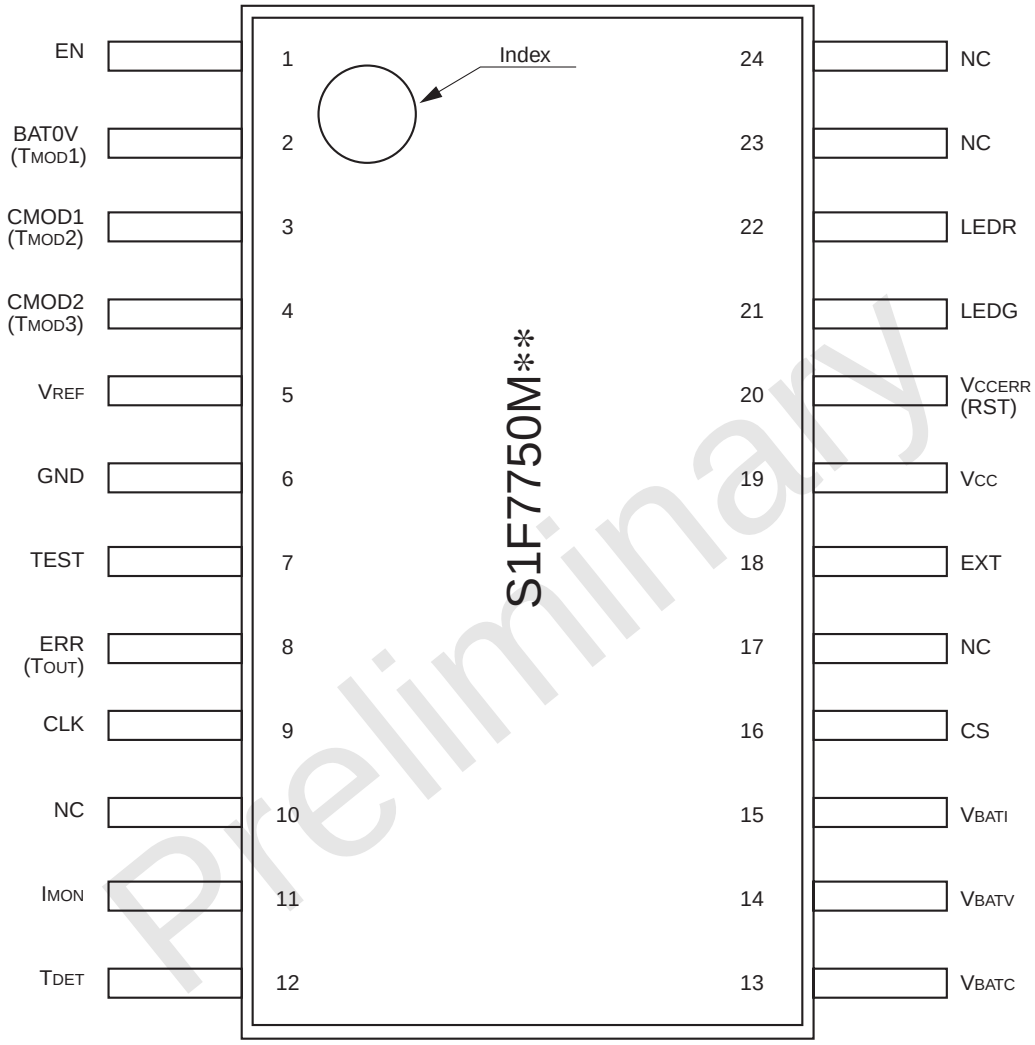


Fig. 2 Pin Assignments

■ PIN FUNCTION

Table 1 Functional Description of Pin

Number	Designation	Type	Function
1	EN	Input (pulldown)	Power off pin: Power off at HIGH
2	BAT0V (T_{MOD}1)	Input (pulldown)	0 V battery charging function ON/OFF control pin Turns OFF 0 V battery charging function at HIGH. (Test setting pin 1 in the test mode)
3	CMOD1 (T_{MOD}2)	Input (pulldown)	Charging current control pin 1 (See Table 3 on page 8.) (Test setting pin 2 in the test mode)
4	CMOD2 (T_{MOD}3)	Input (pulldown)	Charging current control pin 2 (See Table 3 on page 8.) (Test setting pin 3 in the test mode)
5	V_{REF}	Output	Reference power supply output pin (1.7 V)
6	GND	—	Power supply pin (0 V)
7	TEST	Input (pulldown)	Test pin Enters the test mode at HIGH.
8	ERR (T_{OUT})	Output (pulldown)	Charging anomaly output: Pulldown on detection of anomaly. (Test output pin in the test mode.)
9	CLK	Input/Output	CR oscillation clock output pin (Test clock input pin in the test mode)
10	NC	—	—
11	I_{MON}	Output	Charging current detection output pin
12	T_{DET}	Input	Temperature detection input pin
13	V_{BATC}	Output	0 V battery charging pin Charging of 0 V battery from internal IC
14	V_{BATV}	Input	Battery voltage input pin (for voltage detection)
15	V_{BATI}	Input	Battery voltage input pin (for voltage detection)
16	CS	Input	Current detection pin Detects voltage drop of sense resistance connected between CS and V_{BATI}.
17	NC	—	—
18	EXT	Output	Charging control output pin Controls base current of the external PNP transistor and puts on constant current, constant voltage charge.
19	V_{CC}	—	Power supply pin (+)
20	V_{CCERR} (RST)	Output (pulldown)	Adapter's abnormal output: Pulldown on detection of anomaly (Test reset input pin in the test mode)
21	LEDG	Output	LEDG output pin (Nch open drain)
22	LEDR	Output	LEDR output pin (Nch open drain)
23	NC	—	—
24	NC	—	—

■ COMPOSITION OF PIN CIRCUIT

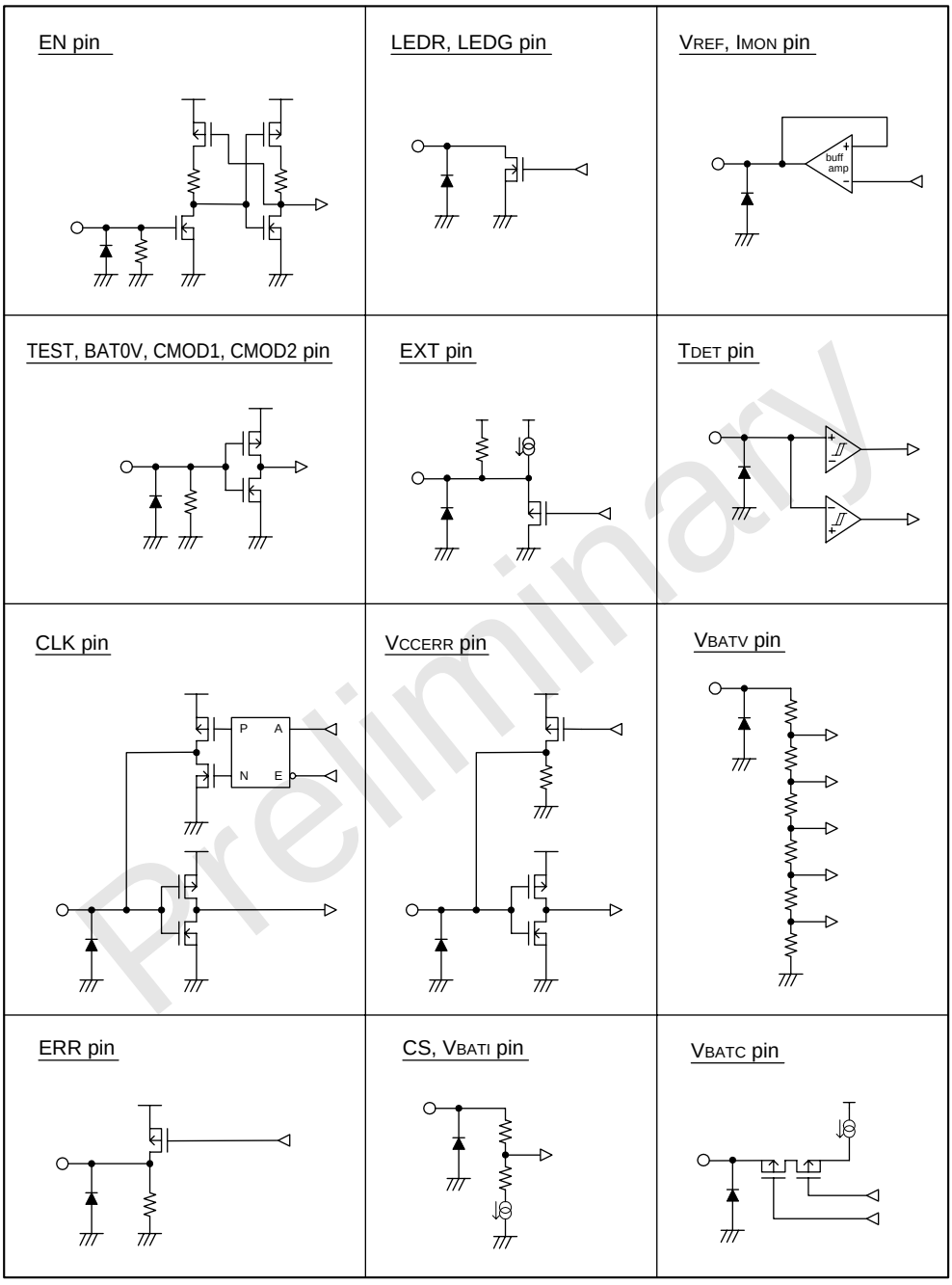


Fig. 3 Composition of Pin Circuit

■ FUNCTIONAL DESCRIPTION

SIF77500 is a charging control IC for 1-cell lithium-ion battery. Fig. 1 (P2) is a block diagram of this IC. Fig. 4 (P10) is a flow chart in the charging sequence. Fig. 5 (P11) is a timing chart in the charging sequence. Functions of this IC will be explained, using these figures.

(1) Adapter Anomaly Detection Function

If V_{CC} is below V_{CC} detection voltage L (V_{LO}) or above V_{CC} detection voltage H (V_{HI}), when the voltage V_{CC} supplied from AC adapter is monitored, it is determined as adapter anomalies and charging is prohibited. During prohibition against charging, EXT pin is pulled up to V_{CC} by internal resistance (Rpu) and turns OFF external PNP transistor.

ERR pin becomes LOW output and this IC stops operation. Under abnormal adapter conditions, V_{CCERR} pin becomes LOW output.

(2) Battery Temperature Detection Function

The voltage V_{TDET} into which the reference voltage V_{REF} has been split by external resistor and thermistor is monitored. The reference voltage is connected to T_{DET} pin. During prohibition against charging or standby after completion of charging, the battery temperature is determined abnormal, if V_{TDET} is above the battery temperature detection voltage H (V_{TH}) or below the battery temperature detection voltage L1 (V_{TL1}) and charging is prohibited. During charging, the battery temperature is determined abnormal, if V_{TDET} is above the battery temperature detection voltage H (V_{TH}) or below the battery temperature detection voltage L2 (V_{TL2}). When the battery is not connected, charging is prohibited as V_{TDET} becomes V_{REF} voltage (above the battery temperature detection voltage H (V_{TH}).

(3) Charging Sequence

If no abnormal conditions are encountered in (1) and (2), this IC starts charging. First, all timers are reset and then the battery voltage is detected. Depending on the results of the detection, the following charging mode will be selected.

① 0 V battery charging

0 V battery charging function turns ON when BAT0V pin is open or LOW input is made. When 0 V battery charging function is turned ON, battery charging starts in the internal charging circuit from V_{BATC} pin. If the battery voltage exceeds 0 V battery voltage H (V_{0VH}), the mode changes to preliminary charging. While 0 V battery charging is in progress, 0 V charging timer goes into operation. When the timer reaches 0 V charging time (T_{0V}), it is determined as battery anomalies and charging is prohibited. If the V_{BATC} pin is opened, 0 V charging can be prohibited. Charging of internal charging circuit will not be carried out. After reaching 0 V charging time (T_{0V}), charging will be prohibited.

When 0V charging function is turned OFF, preliminary charging will be carried out totally, if the battery voltage is below preliminary charging voltage H (V_{PREH}).

② Preliminary charging

Constant current charging in the preliminary charging current is carried out. The limit value of the preliminary charging current is determined by the preliminary charging limit($V_{LI\text{-}PRE}$)/sense resistance (recommended 0.2 Ω). When the battery voltage exceeds the preliminary charging voltage H (V_{PRREH}), the mode changes to full charging. During preliminary charging, the preliminary charging timer operates. When the timer reaches the preliminary charging time (T_{PRE}), the battery is determined abnormal and then charging is prohibited. If the

battery voltage decreases below 0 V battery voltage L (V_{0VL}) when 0 V battery charging function is in the state of ON , the mode changes to 0 V battery charging.

③④ Full charging/constant voltage charging

When the battery voltage is below the charging voltage (V_{BAT}), constant current charging in full charging current is carried out. The limit value of full charging current is determined by the full charging limit voltage(V_{LI-FU})/ sense resistance (recommended 0.2 Ω). In proximity to the charging voltage, the constant voltage charging works, so that the battery voltage will not exceed the charging voltage (V_{BAT}). In the constant voltage charging, the charging current gradually decreases with increasing battery voltage. If the state of charging current x sense resistance (recommended 0.2 Ω) below full charging detection voltage (V_{TPR}) persists beyond full charging detection time (T_{TPR}), the mode becomes full charging detection. Following full charging detection, constant current charging will be added during trickle charging time (T_{TRK}) and charging will be brought to an end (standby). During the period from full charging to completion of charging, the charging timer operates. If the timer reaches the charging time (T_{FU}), the battery is determined abnormal and charging is prohibited. If the state of the battery voltage exceeding overvoltage (V_{OVER}) continues beyond the overvoltage detection time (T_{OVER}), it is determined as overvoltage and charging is prohibited. If the battery voltage decreases below preliminary charging detection voltage L (V_{PREL}), the mode changes to preliminary charging.

⑤ Standby

During standby, EXT pin is turned OFF and charging is stopped. Upon completion of charging, all timers are reset. If the state of the battery voltage below recharge voltage (V_{RE}) persists beyond recharging detection time (T_{RE}), this puts in recharging detection mode and then changes to full charging/constant voltage charging.

⑥ Overvoltage

If the state of the battery voltage exceeding overvoltage (V_{OVER}) persists beyond overvoltage detection time (T_{OVER}), it is determined as overvoltage and charging is prohibited.

Notes: 0 V charging timer, preliminary charging timer, and charging timer are not reset except at the initial time and when charging is terminated. Even if the battery voltage fluctuates due to battery anomalies and each mode is repeated, it is controlled in the accumulated time. So excessive charging of abnormal battery can be prohibited.

(4) Charge Status Output Function

As the charge status output function, LED control function (LEDR and LEDG pins), output function of prohibition against charging (ERR and V_{CCERR} pins), internal CR oscillation monitor function (CLK pin), and charging current monitor function (I_{MON} pin) are available.

· LED control function/output function of status of prohibition against charging

LEDR and LEDG pins are Nch open drain output. The charge status can be checked by externally connecting red LED and green LED.

The status of prohibition against charging can be checked by monitoring ERR and V_{CCERR} pins. Table 2 shows each function.

Table 2 LED Control Function/Output Function of Status of Prohibition against Charging

Charge status	Red LED	Green LED	ERR	VCCERR
Adapter anomalies	No	No	LOW output	LOW output
Battery temperature anomalies	No	No	LOW output	HIGH output
0 V battery charging	1.8 s flashing	No	HIGH output	HIGH output
Preliminary charging	Yes	No	HIGH output	HIGH output
Full charging/constant voltage charging	Yes	No	HIGH output	HIGH output
Normal termination/standby	No	Yes	HIGH output	HIGH output
Battery anomalies (Note)	1.8 s flashing	No	LOW output	HIGH output
Overvoltage	No	No	LOW output	HIGH output

Note : Prohibition against charging due to a lapse of time of 0 V charging timer, preliminary charging timer, and charging timer.

· Internal CR oscillation monitor function

When the CLK pin is monitored, using a watchdog timer or others, if it is found out that the timer function does not normally operate because of a stop of oscillation, etc., charging can be forcefully terminated by CMOD1, CMOD2, and EN pins. When the adapter is abnormal, the internal CR oscillation stops. Therefore, set the watchdog timer so that it would operate when VCCERR pin outputs HIGH.

· Charging current monitor function

The voltage with amplified charging current x sense resistance (recommended 0.2 Ω) by 20 times can be monitored on the IMON pin. The output voltage range extends from 0 to VCC x 0.9. At VCC 5 V, the charging current of 4.5 (V)/20/0.2 (Ω) = 1.125 (A) can be monitored.

(5) External Control Function

EN, CMOD1, and CMOD2 pins make it possible to externally switch among forced termination, preliminary charging, and full charging/constant voltage charging. Table 3 shows a function table of CMOD1 and CMOD2 pins. Here, the timer refers to a preliminary charging timer and a charging timer. Other timers are under normal operation. Advanced and flexible charging control can be effected by detecting and controlling the charging current (IMON pin), battery voltage, temperature, time, and cycle time by microprocessor.

Table 3 CMOD1 and CMOD2 Pins Function Table

CMOD1 pin	CMOD2 pin	Charging current mode
LOW input	LOW input	Controlled by this IC.
LOW input	HIGH input	Prohibition against charging (Timer OFF)
HIGH input	LOW input	Preliminary charging (Timer OFF)
HIGH input	HIGH input	Full charging/constant voltage charging (Timer OFF)

(6) Overcurrent Protection Function

Overcurrent protection function is included, which protects external PNP transistor and EXT pin from overcurrent flow in the event of failure of feedback of charging current caused by short-circuit of sense resistance.

Note : Considering the possibility that this function would not operate due to failure of IC, protect them against overcurrent using those other than this IC.

(7) Return from State of Prohibition against Charging

Return from the state of prohibition against charging takes place in the event of any of the following:

- Prohibition against overvoltage due to overvolatage: When the battery voltage drops to normal value due to electrical discharge;
- Prohibition against charging due to battery temperature anomalies: When the battery temperature becomes normal value;
- Other prohibition against charging: Returns to charging by reconnecting battery and adapter;
- Returns to charging by clearing forced termination through C_{MOD1}, C_{MOD2}, and EN pins.

Note: Since a return from the state of prohibition against charging takes place from (1), all timers will be reset.

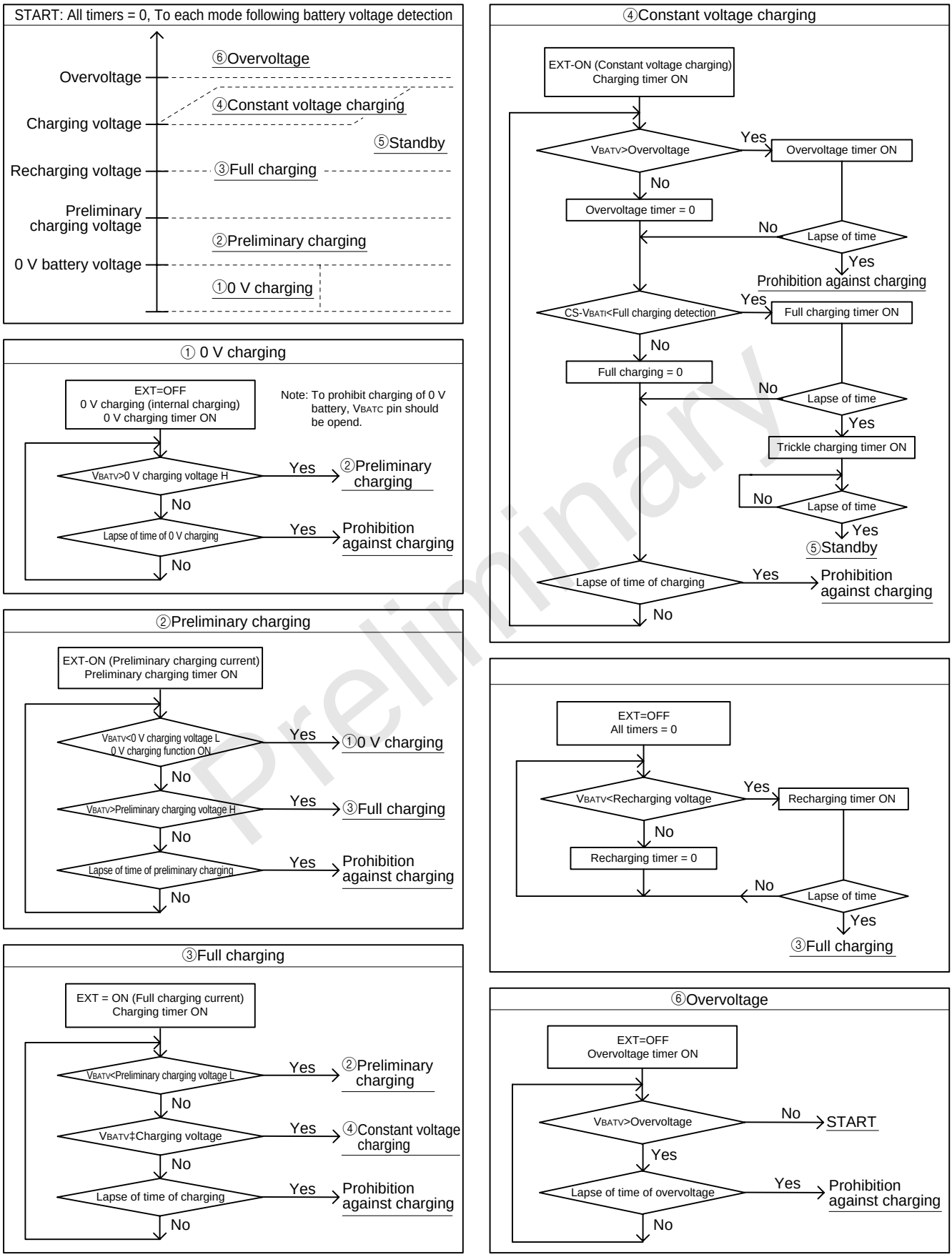


Fig.4 Charging Sequence Flow Chart

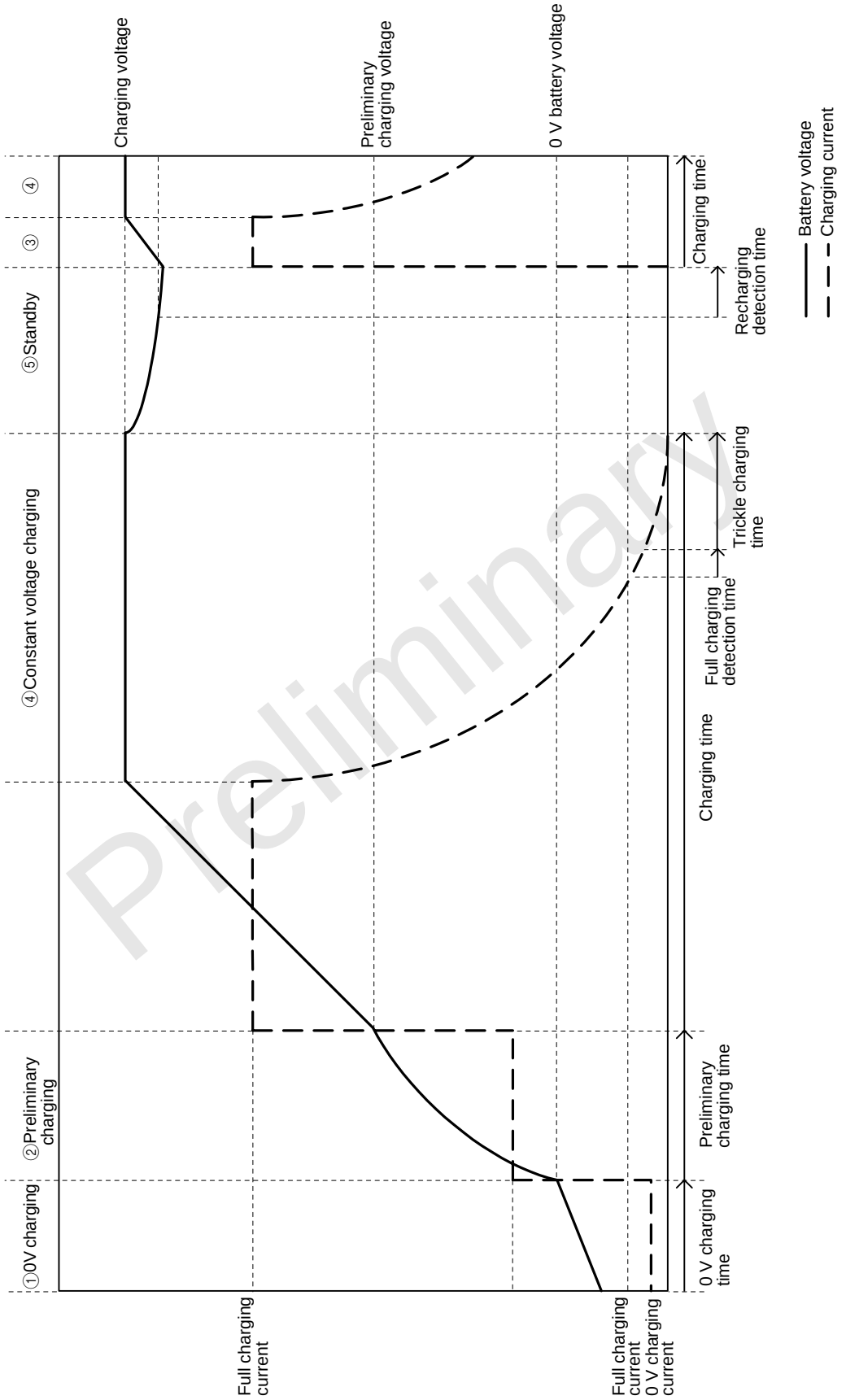


Fig. 5 Charging Sequence Timing Chart

■ ABSOLUTE MAXIMUM RATINGS

Item	Symbol	Applicable pin	Rating		Unit
			Min.	Max.	
Supply voltage	V_{CC}	V_{CC}	–0.3	7.0	V
Battery voltage	V_{BAT}	V_{BATV} V_{BATI} V_{BATC} CS	–0.3	7.0	V
Input voltage	V_{IN}	EN C_{MOD1} C_{MOD2} CLK V_{CCERR} T_{DET} BAT0V TEST	–0.3	V_{CC}+0.3	V
Output pin voltage	V_{OUT}	ERR V_{REF} CLK V_{CCERR} I_{MON} LEDR LEDG EXT	–0.3	V_{CC}+0.3	V
Output current 1	I_{OUT1}	ERR CLK V_{CCERR}		10	mA
Output current 2	I_{OUT2}	LEDR LEDG		20	mA
Output current 3	I_{OUT3}	EXT		50	mA
Output current 4	I_{OUT4}	V_{REF} I_{MON} V_{BATC}		5	mA
Operating temperature	T_{OP}	—	–20	+70	˚C
Storage temperature	T_{ST}	—	–40	+125	˚C

■ ELECTRICAL CHARACTERISTICS

(1) Recommended Operating Conditions

Item	Symbol	Applicable pin	Specification			Unit
			Min.	Typ.	Max.	
Supply voltage	V_{CC}	V_{CC}	4.5	5.0	5.5	V
Battery voltage	V_{BAT}	V_{BATV} V_{BATI} V_{BATC} CS	2.0	3.6	4.2	V
Input voltage	V_{IN}	EN C_{MOD1} C_{MOD2} CLK V_{CCERR} T_{DET} BAT_{0V} TEST	0	—	V_{CC}	V
Output pin voltage	V_{OUT}	ERR V_{REF} CLK V_{CCERR} I_{MON} LEDR LEDG EXT	0	—	V_{CC}	V
Output current 1	I_{OUT1}	ERR CLK V_{CCERR}	—	—	2.0	mA
Output current 2	I_{OUT2}	LEDR LEDG	—	—	10.0	mA
Output current 3	I_{OUT3}	EXT	—	10.0	—	mA
Output current 4	I_{OUT4}	V_{REF} I_{MON} V_{BATC}	—	—	2.0	mA
Operating temperature	T_{OP}	—	0	—	43	˚C

(2) DC Characteristics 1

Unless otherwise specified, V_{CC} = 5V, V_{TDET} = 1V, Ta = –20 to +70˚C

Item	Symbol	Applicable pin	Specification			Unit
			Min.	Typ.	Max.	
Operating supply voltage	V_{OPR}	Applicable pin: V_{CC}	4.5	—	5.5	V
Current consumption in a state of rest	I_{SBY}	EN=5V	—	—	1.0	µA
Current consumption in a state of operation (V_{CC})	I_{OPR}	V_{BAT}=4.2V	—	5	7	mA
V_{CC} detection voltage H	V_{HI}	At a rise of potential	6.1	6.3	6.5	V
Width of hysteresis	V_{HIH}	—	50	100	150	mV
V_{CC} detection voltage L	V_{LO}	At a rise of potential	4.1	4.3	4.5	V
Width of hysteresis	V_{LOH}	—	50	100	150	mV
V_{REF} output voltage	V_{REF}	I_{REF}=–100µA	1.64	1.7	1.76	V
Battery temperature detection voltage H	V_{TH}	Low temperature 3˚C±3˚C	V_{REF} ×0.70	V_{REF} ×0.72	V_{REF} ×0.74	V
Battery temperature detection voltage L1	V_{TL1}	High temperature 43˚C±3˚C Starting of charging, standby	V_{REF} ×0.32	V_{REF} ×0.34	V_{REF} ×0.36	V
Battery temperature detection voltage L2	V_{TL2}	High temperature 50˚C±3˚C Charging in progress	V_{REF} ×0.27	V_{REF} ×0.29	V_{REF} ×0.31	V
0V Battery temperature H*	V_{0VH}*	At a rise of V_{BATV} potential	1.9	2	2.1	V
0V Battery temperature L*	V_{0VL}*	At a fall of V_{BATV} potential	1.8	1.95	2.08	V
Preliminary charging voltage H*	V_{PREH}*	At a rise of V_{BATV} potential	2.8	2.9	3.0	V
Preliminary charging voltage L*	V_{PREL}*	At a fall of V_{BATV} potential	2.7	2.85	2.98	V
V_{BATV} charging voltage*	V_{BAT}*	Ta=0 to 50˚C	4.16	4.2	4.24	V
Overvoltage*	V_{OVER}*	At a rise of V_{BATV} potential	4.30	4.35	4.40	V
Refilling voltage*	V_{RE}*	At a fall of V_{BATV} potential	3.85	3.90	3.95	V
0 V battery charging current	I_{0V}	V_{BATV},V_{BATC}=1V	0.5	1	2	mA
Preliminary charging current limit*	V_{LI-PRE}*	V_{BATV},V_{BATI}=2.5V	12	17	22	mV
Full charging current limit*	V_{LI-FU}*	V_{BATV},V_{BATI}=3.6V	0.13	0.15	0.17	V
Full charging detection voltage*	V_{TPR}*	V_{BATV},V_{BATI}=4.2V	7	12	17	mV
EXT output sink current	Isink	V_{BATV},V_{BATI}=4V	—	—	10	mA
EXT overcurrent detection value	Imax	V_{BATV},V_{BATI}=4V	12	16	20	mA
EXT off leak current	Ioff	EN=5V	—	—	0.1	µA
EXT output pull-up resistance	Rpu	—	250	500	1000	kΩ
CS,V_{BATI},V_{BATV}, and V_{BATC} leak current	Ioff2	V_{CC}=0V	—	—	1	µA
I_{MON} amplification	G_{IMON}	—	19.2	20	20.8	—

The set values marked with an asterisk can be changed by customization.

(3) DC Characteristics 2

Unless otherwise specified, V_{CC} = 5V, V_{TDET} = 1V, Ta = –20 to +70˚C

Item	Symbol	Conditions	Specification			Unit
			Min.	Typ.	Max.	
LOW level output voltage 1 (CLK)	V_{OL1}	I_{OL}=2.0mA	—	—	0.4	V
LOW level output voltage 2 (LEDR,LEDG)	V_{OL2}	I_{OL}=10.0mA	—	—	0.4	V
Pulldown current 1 (V_{CCERR},ERR)	I_{PD1}	V_{OL}=0.5V	5	10	20	µA
HIGH level output voltage 1 (CLK)	V_{OH1}	I_{OH}=–1.0mA	V_{CC} – 0.4	—	—	V
HIGH level output voltage 2 (V_{CCERR},ERR)	V_{OH2}	I_{OH}=–1.0mA	V_{CC} – 0.4	—	—	V
LOW level input voltage 1 (TEST,BAT0V,C_{MOD1}, C_{MOD2},CLK,V_{CCERR})	V_{IL1}	—	—	—	0.2× V_{CC}	V
LOW level input voltage 2 (EN)	V_{IL2}	—	—	—	0.3	V
HIGH level input voltage 1 (TEST,BAT0V,C_{MOD1}, C_{MOD2},CLK,V_{CCERR})	V_{IH1}	—	0.7× V_{CC}	—	—	V
HIGH level input voltage 2 (EN)	V_{IH2}	—	2.4	—	—	V
Input leak current (Full input)	I_{LEAK}	—	–1	—	1	µA

(2) DC Characteristics 2

Unless otherwise specified, V_{CC} = 5V, V_{TDET} = 1V, Ta = 0 to +50˚C

Item	Symbol	Conditions	Specification			Unit
			Min.	Typ.	Max.	
Oscillation cycle	T	T	1.59	1.77	1.95	ms
0 V charging time*	T_{0V}	$T \times 2^{13}$	13	14.5	16	s
Preliminary charging time*	T_{PRE}	$T \times 2^{19}$	14	15.5	17	min
Full charging detection time	T_{TPR}	$T \times 2^{6}$	0.1	0.11	0.12	s
Trickle charging time*	T_{TRK}	$T \times 2^{19}$	14	15.5	17	min
Charging time*	T_{FU}	$T \times 2^{23}$	3.6	4	4.4	hour
Overvoltage detection time	T_{OVER}	$T \times 2^{8}$	0.4	0.45	0.5	s
Recharging detection time	T_{RE}	$T \times 2^{5}$	51	57	63	ms
LEDR flashing cycle	T_{LEDR}	$T \times 2^{10}$	1.6	1.8	2.0	s

The set values marked with an asterisk can be changed by customization.

■ EXAMPLE OF EXTERNAL CONNECTION REFERENCE CIRCUIT

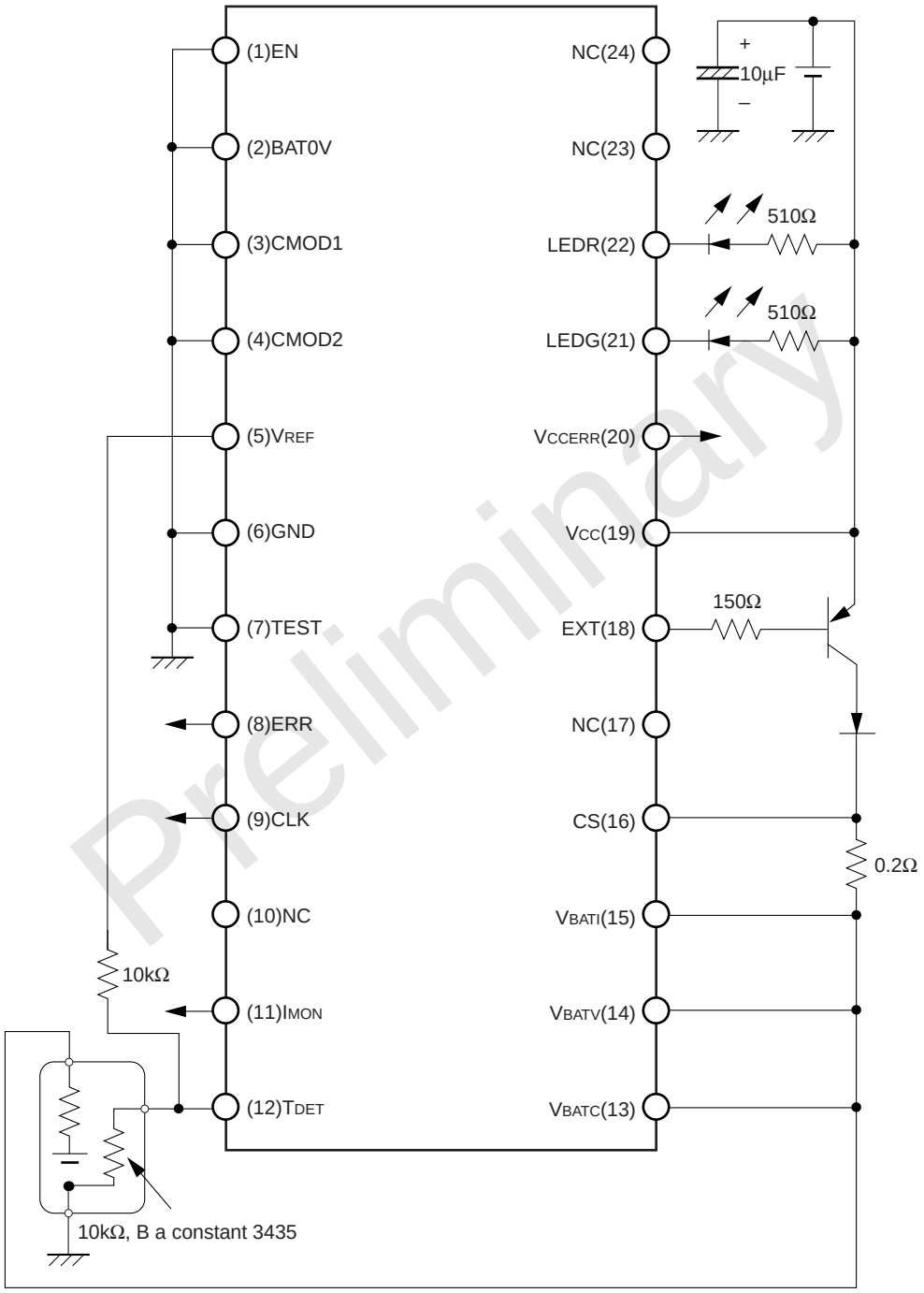
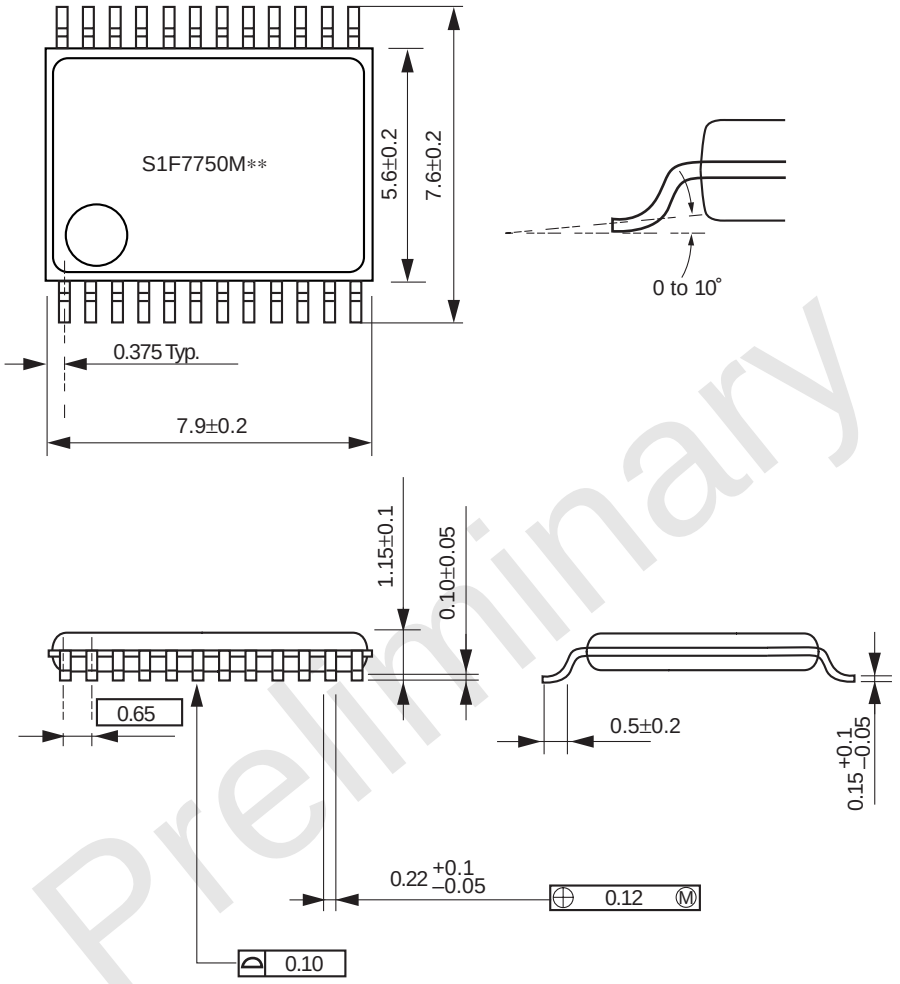


Fig. 6 Example of External Connection Reference Circuit

■ EXTERNAL VIEW (SSOP3-24pin)



Unit : mm

Fig. 7 External View

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