Linear Li-Ion Battery Charger IC

General Description

The ET9513C is a cost-effective, fully integrated single-cell Li-Ion battery charger. The charger uses a CC/CV charge profile required by Li-Ion battery. The charger accepts an input voltage up to 28 V but is disabled when the input voltage exceeds the OVP threshold, typically 6.9 V, to prevent excessive power dissipation. The 28 V rating eliminates the over-voltage protection circuit required in a low input voltage charger.

The charge current and the end-of-charge (EOC) current are programmable with external resistors. When the charge current reduces to the programmable EOC current level during the CV charge phase, an EOC indication is provided by the CHGSB pin, which is an open-drain output. An internal thermal foldback function protects the charger from any thermal failure.

Two indication pins (PGB and CHGSB) allow simple interface to a microprocessor or LEDs. An internal top off timer will make ET9513C enter into standby mode after 38 minutes of full charged.

When no adapter is attached or when disabled, the charger draws less than 10uA leakage current from the battery.

Features

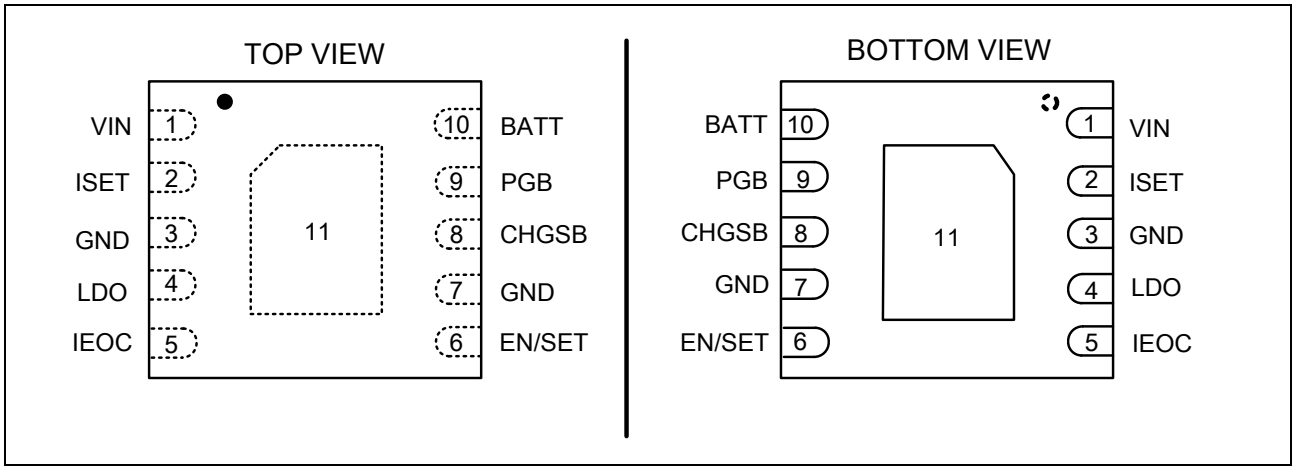
- 28 V Maximum Voltage for the Power Input
- Internal Integrated Power MOSFETs
- An internal top off timer
- Support 4.2 V or 4.35 V/2.3 A Factory Mode
- 50 mA Low Dropout Voltage Regulator
- Status Pin Indicator
- Programmed Charging Current
- Programmed End-of-Charge Current
- Under Voltage Lockout
- Over Voltage Protection
- Over Temperature Protection
- Reverse Current Blocking
- Part No and Package Information

Part No.	Package	MSL
ET59513C	DFN10 (3 mm × 2 mm × 0.75 mm)	Level 1
ET59513CY	DFN10 (3 mm × 2 mm × 0.5 mm)	Level 1

Application

- Cell Phones
- PDA, TWS
- Digital Cameras
- Other Hand-held Devices

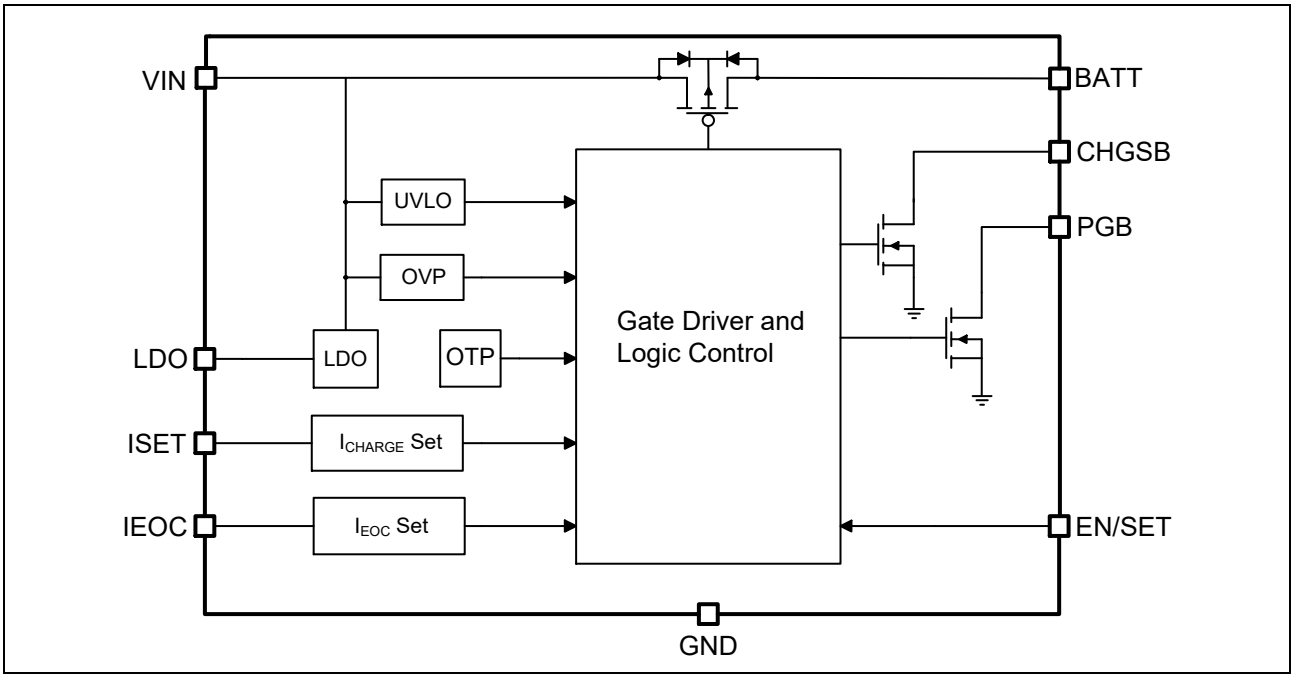
Pin Configuration



Pin Function

Pin No.	Name	Function
1	VIN	Power Supply Input.
2	ISET	Charging Current Setting
3,7	GND	Ground
4	LDO	LDO Output (4.9 V). This pin provides 50 mA output current
5	IEOC	End-of-Charge Current Setting.
6	EN/SET	Enable and Operation Mode Setting.
8	CHGSB	Indicator Output for Charging Status.
9	PGB	Indicator Output for Power Status.
10	BATT	Battery Charge Current Output.
11	GND	Exposed Thermal Pad. Must be electrically connected to the GND.

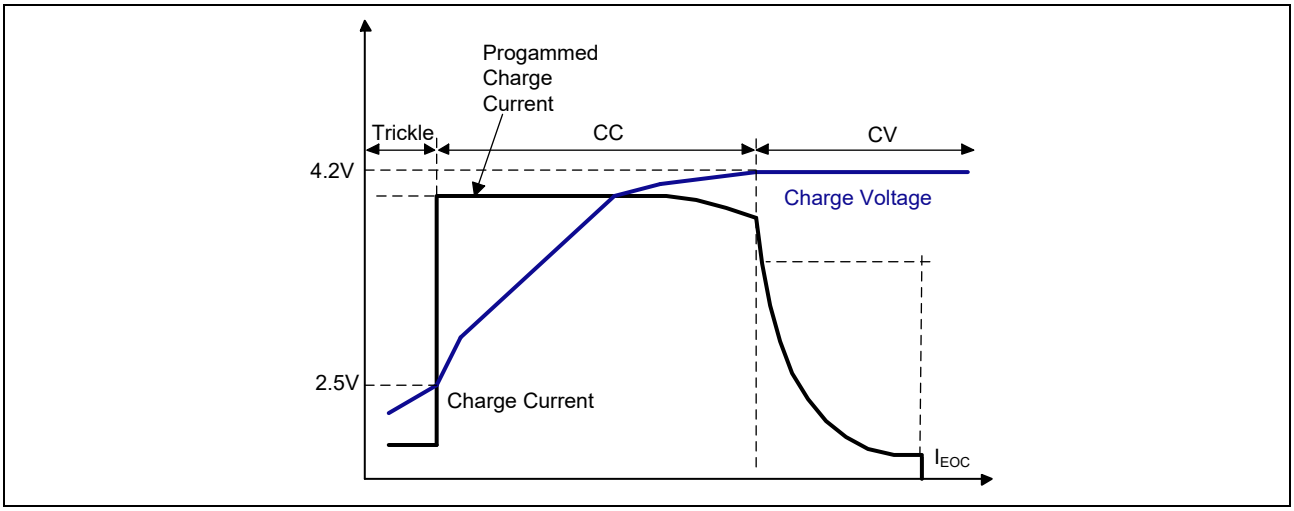
Block Diagram



Functional Description

The ET9513C charges a Li-ion battery with a constant current (CC) or a constant voltage (CV). The charge current is programmable to USB100, USB500 or ISET mode. The constant current is set with the external resistor R_{ISET} and the constant voltage is fixed at 4.175 V/4.314 V. If the battery voltage is below the pre-charge threshold, the ET9513C charges the battery with a trickle current until the battery voltage rises above the pre-charge threshold. The pre-charge threshold is fixed at 2.6 V. When the battery voltage reaches 4.175 V/4.314 V, the charger enters CV mode and regulates the battery voltage at 4.175 V/4.314 V to fully charge the battery without the risk of over charging.

The ET9513C is capable of being powered up from AC adapter and USB (Universal Serial Bus) port inputs. Moreover, the ET9513C include a linear regulator (LDO 4.9 V, 50 mA) for supplying low power external circuitry.



Charger Enable and mode Setting

EN/SET is used to enable or disable the charger as well as to select the charge current limit. Drive the EN pin to low or leave it floating to enable the charger.

The EN/SET pin has a 300 kΩ internal pull down resistor. So, when left floating, the input is equivalent to logic low. Drive this pin to high to disable the charger.

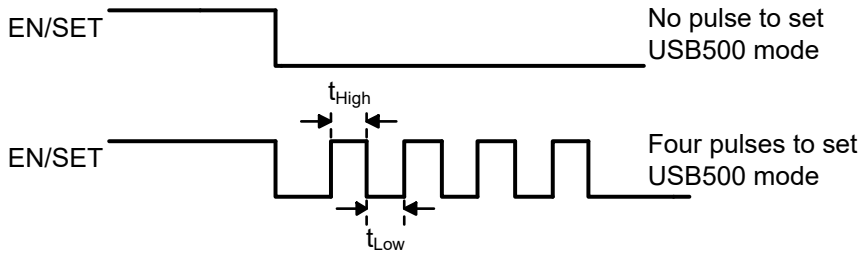
After the EN/SET pin pulls low for 50 μs, the ET9513C enters the USB500 mode and wait for the setting current signal. EN/SET can be used to program the charge current during this cycle. The ET9513C will change its charge current by sending different pulse to EN/SET pin. If no signal is sent to EN/SET, the ET9513C will remain in USB500 mode.

A correct period of time for high pulse is between 100 μs and 700 μs and the period of pulse to pulse must be between 100 μs and 700 μs to be properly read.

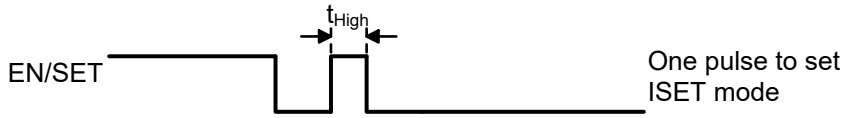
Once EN/SET is held low for 1.5 ms, the number of pulses is locked and sent to the control logic and then the mode changes. The ET9513C needs to be restarted to reset the charge current. Once the EN/SET input is held high for more than 2 ms, the ET9513C is disabled.

Pulse	Charge Condition	Mode Control
0	USB500 Mode	Charge Current Limit
1	ISET Mode	Charge Current Limit
2	USB100 Mode	Charge Current Limit
3	Factory Mode	Enabled
≥4	USB500 Mode	Charge Current Limit

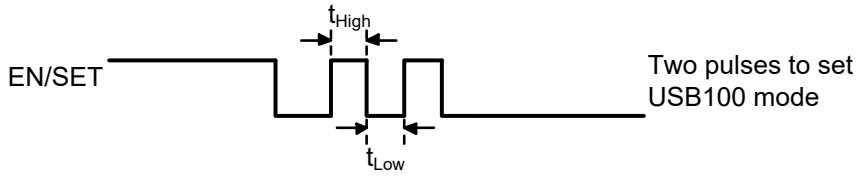
A. USB500 Mode with CV=4.175 V



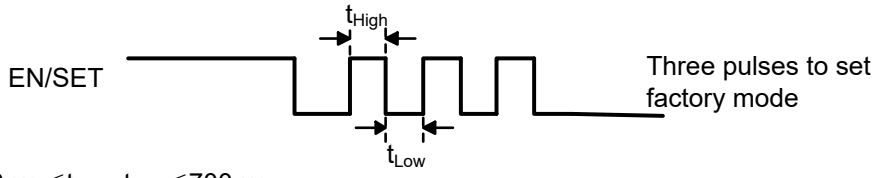
B. ISET Mode with CV=4.175 V



C. USB100 Mode with CV=4.175 V



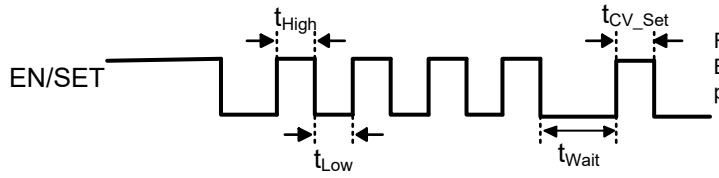
D. Factory Mode with CV=4.175 V



100 μs＜t_{High}, t_{Low}＜700 μs

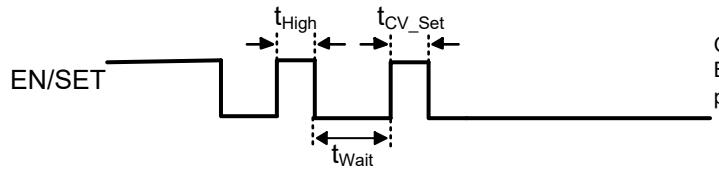
Figure 1(a). CV is 4.175 V

E. USB500 Mode with CV=4.314 V



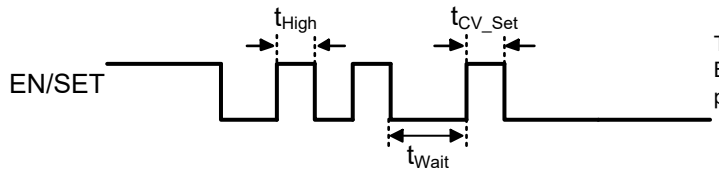
Four pulses to set USB500 mode
Besides, wait the time , t_{Wait} and send a pulse of t_{CV_Set} width for CV=4.314 V

F. ISET Mode with CV=4.314 V



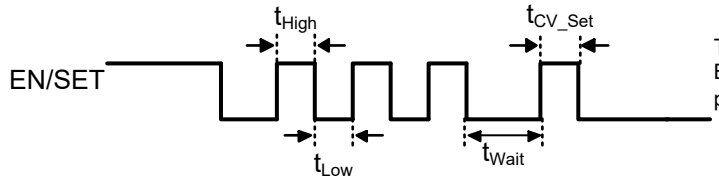
One pulse to set ISET mode
Besides, wait the time, t_{Wait} and send a pulse of t_{CV_Set} width for CV=4.314 V

G. USB100 Mode with CV=4.314 V



Two pulses to setUSB100 mode
Besides, wait the time, t_{Wait} and send a pulse of t_{CV_Set} width for CV=4.314 V

H. Factory Mode with CV=4.314 V



Three pulses to set factory mode
Besides, wait the time, t_{Wait} and send a pulse of t_{CV_Set} width for CV=4.314 V

100 μs＜t_{High}, t_{Low}＜700 μs, 1.5 ms＜t_{Wait}, 750 μs＜t_{CV_Set}＜1 ms

Figure 1(b). CV is 4.314V

VIN Over-Voltage Protection (OVP)

The input voltage is monitored by the internal comparator and the input over voltage protection threshold is set to 6.9 V. However, input voltage over 28 V will still cause damage to the ET9513C. When the input voltage exceeds the threshold, the comparator outputs a logic signal to turn off the power P-MOSFET to prevent the high input voltage from damaging the electronics in the handheld system. When the input over voltage condition is removed, the comparator re-enables by running through the soft-start.

Battery Pre-Charge Current

During a charge cycle, if the battery voltage is below the pre-charge threshold, the ET9513C enters the pre-charge mode. This feature revives deeply discharged cells and protects battery. Under USB100 Mode, the pro-charge current is internally set to 95 mA. When the ET9513C is under USB500 and ISET Mode, the pre-charge current is 20% of fast-charge current set by external resistor R_{ISET}.

Battery Fast-Charge Current

ISET Mode

The ET9513C offers ISET pin to program the charge current. The resistor R_{ISET} is connected to ISET and GND. The parameter K_{ISET} is specified in the specification table.

$I_{CHARGE} = K_{ISET}/R_{ISET}$; $K_{ISET} = 530$

USB500 and USB100 Mode

The fast-charge current is 95 mA in USB100 mode and 395 mA in USB500 mode. Note that if the fast-charge current set by external resistor is smaller than that inUSB500 mode (395 mA), the ET9513C charges the battery in ISET mode.

Battery Voltage Regulation (CV Mode)

The battery voltage regulation feedback is through the BATT pin. The ET9513C monitors the battery voltage between BATT and GND pins. When the battery voltage closes in on the battery regulation voltage threshold, the voltage regulation phase begins and the charging current begins to taper down. When the charging current falls below the programmed end-of-charge current threshold, the CHGSB pin goes high to indicate the termination of charge cycle.

The end-of-charge current threshold is set by the IEOC pin. The resistor R_{EOC} is connected to IEOC and GND. The parameters K_{EOC} and I_{EOC} are specified in the specification table.

$I_{EOC(\%)} = R_{EOC}/K_{EOC}$; $K_{EOC} = 200$

The current threshold of I_{EOC} (%) is defined as the percentage of fast-charge current set by R_{ISET}. After the CHGSB pin is pulled high, the ET9513C still monitors the battery voltage. Charge current is resumed when the battery voltage goes to lower than the battery regulation voltage threshold.

Factory Mode

The ET9513C provides factory mode for supplies up to 2.3 A for powering external loads with no battery installed and BATT is regulated to 4.2 V/4.35 V. The factory mode allows the user to supply system power with no battery connected. In factory mode, thermal regulation is disabled but thermal protection (150 ℃) is still active. When using currents greater than 1.5 A in factory mode, the user must limit the duty cycle at the maximum current to 20% with a maximum period of 10 ms.

LDO

The ET9513C integrates one low dropout linear regulator (LDO) that supplies up to 50 mA. The LDO is active whenever the input voltage is between POR threshold and OVP threshold. It is not affected by the EN/SET input. Note that the LDO current is independence and not monitored by the charge current limit.

Top off Timer

An internal top off timer meeting the full charged condition (CHGSB_High and PGB_Low) to start top off timer and checking the EN/SET pin. The battery is full charged when the charge current reduce to the end-of-charge current which set by the IEOC pin, the top off timer start to count. If EN/SET input is not held high for more than 2 ms it will make ET9513C enter into standby mode after 38 minutes from full charged condition. When ET9513C enter into standby mode, the charging FET is closed and the OVP, UVP, thermal protection are still working.

When ET9513C enter into temperature regulation mode, it limits the charge current, if the charge current is limited to the end-of-charge current, the top off timer start to count, if the charge current lower than the end-of-charge for 38 minutes, ET9513C enter into standby mode.

If top off timer checking the EN/SET input pin is held high for more 2 ms or the remove and reapply the input voltage or momentarily shut the charger down it will make to reset the top off timer.

Top off function on factory mode is disabled.

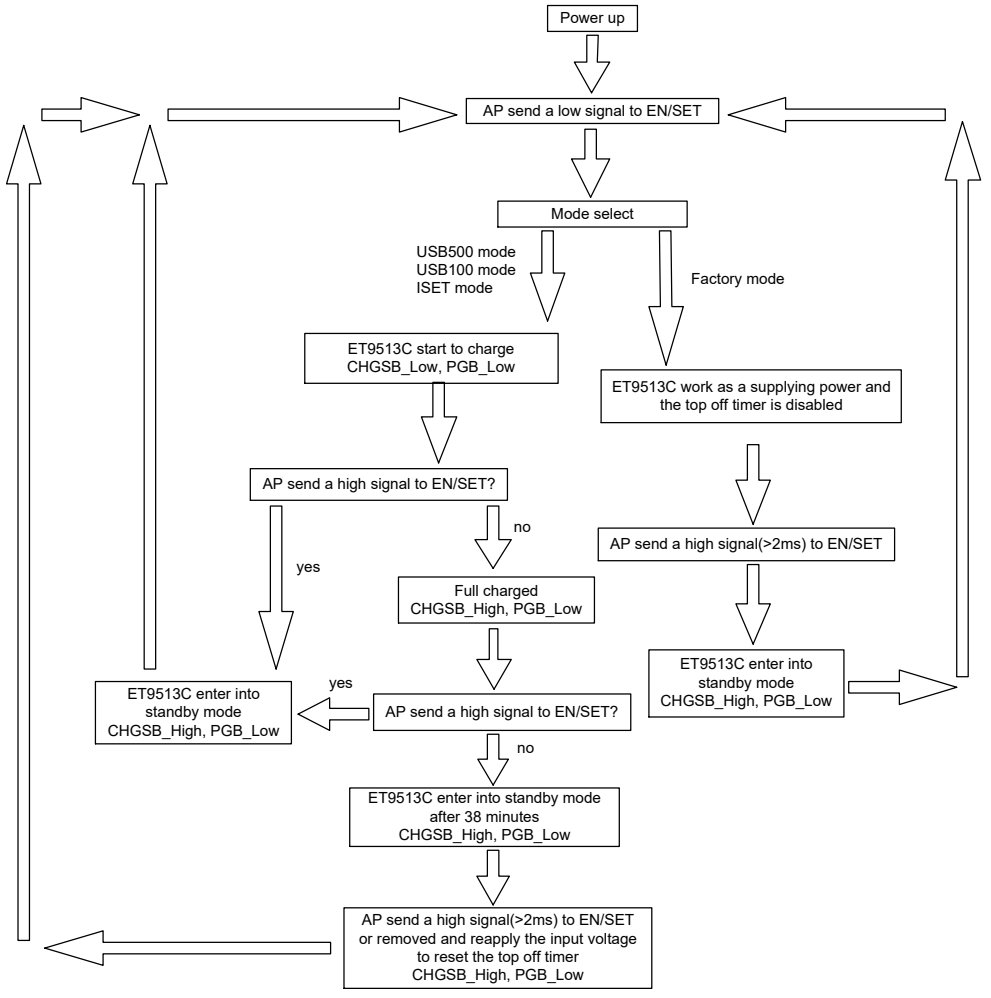


Figure 2. ET9513C charge flow

Charge Status Outputs (CHGSB and PGB)

The open-drain CHGSB and PGB outputs indicate various charger operations as shown in the following table. These status pins can be used to drive LEDs or communicate to the host processor. Note that ON indicates the open-drain transistor is turned on and LED is bright.

Condition	CHGSB	PGB
Input OVP	OFF	OFF
Input UVLO	OFF	OFF
Charge (CC Mode and CV Mode)	ON	ON
Charge Done (IFULL)	OFF	ON

Condition	PGB Deglitches Time	
	EN/SET is High	EN/SET is Low
Entering OVP (V_{IN}=5.5 V to 10 V)	0	100 μs
Leaving OVP (V_{IN}=10 V to 5.5 V)	500 μs	450 μs
Entering SLEEP (V_{IN}=5.5 V to 3.6 V)	0	32 ms
Leaving SLEEP (V_{IN}=3.6 V to 5.5 V)	500 μs	500 μs
Entering UVLO (V_{IN}=5.5 V to 2.5 V)	0	0
Leaving UVLO (V_{IN}=2.5 V to 5.5 V)	230 μs	230 μs

Sleep Mode

The ET9513C enters sleep mode if the power is removed from the input. This feature prevents draining the battery during the absence of input supply.

Temperature Regulation and Thermal Protection

In order to maximize charge rate, the ET9513C features a junction temperature regulation loop. If the power dissipation of the IC results in a junction temperature greater than the thermal regulation threshold (125 °C), the ET9513C limits the charge current in order to maintain a junction temperature around the thermal regulation threshold (125 °C). The ET9513C monitors the junction temperature, T_J, of the die and disconnects the battery from the input if T_J exceeds 125 °C. This operation continues until junction temperature falls below thermal regulation threshold (125 °C)by the hysteresis level. This feature prevents maximum power dissipation from exceeding typical design conditions.

Selecting the Input and Output Capacitors

In most applications, all that is needed is a high-frequency decoupling capacitor on the input. A 1 μF ceramic capacitor, placed in close proximity to input to GND, works well. In some applications depending on the power supply characteristics and cable length, it may be necessary to add an additional 10 μF ceramic capacitor to the input. The ET9513C requires a small output capacitor for loop stability. A typical 1 μF ceramic capacitor placed between the BATT pin and GND is sufficient.

Thermal Considerations

For continuous operation, do not exceed absolute maximum operation junction temperature. The maximum power dissipation depends on thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by the following formula:

$P_{D(MAX)} = (T_{J(MAX)} - T_A)/\theta_{JA}$

Where $T_{J(MAX)}$ is the maximum operation junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125 °C. The junction to ambient thermal resistance, θ_{JA} , is layout dependent.

For DFN10L(3×2) package, the thermal resistance θ_{JA} , is $90\,℃/W$ on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at $T_A = 25\,℃$ can be calculated by the following formula:

$P_{D(MAX)} = (125\,℃ - 25\,℃)/(90\,℃/W) = 1.111\,W$ for DFN10L(3×2) package.

Layout Consideration

The ET9513C is a fully integrated low cost single-cell Li-Ion battery charger IC ideal for portable applications. Careful PCB layout is necessary. For best performance, place all peripheral components as close to the IC as possible. A shout connection is highly recommended. The following guidelines should be strictly followed when designing a PCB layout for the ET9513C.

- Input capacitor should be placed close to the IC and connected to ground plane. The trace of input in the PCB should be placed far away from the sensitive devices or shielded by the ground.
- The GND should be connected to a strong ground plane for heat sinking and noise protection.
- The connection of RISET and RIEOC should be isolated from other noisy traces. The short wire is recommended to prevent EMI and noise coupling.
- Output capacitor should be placed close to the IC and connected to ground plane to reduce nose coupling.

Absolute Maximum Ratings

Parameter	Rating	Unit
Supply Input Voltage, VIN	-0.3 ~ 28	V
Other Pins	-0.3 ~ 6	V
Power Dissipation, P_D@T_A=25 °C (DFN10 3×2)	1.1	W
Junction Temperature	150	°C
Storage Temperature Range	-65 ~ 150	°C
Lead Soldering Temperature, 10 Sec	260	°C
Factory Mode Maximum Output Current	2.3	A

Recommended Operating Conditions (Refer to the typical application circuit)

Parameter	Range	Unit
Supply Input Voltage, VIN	4.3 ~ 6.2	V
Junction Temperature Range	-40 ~ 125	°C
Ambient Temperature Range	-40 ~ +85	°C

Electrical Characteristics

Unless otherwise specified, these specifications apply over V_{IN}=5 V, V_{BATT}=4 V, T_A=25 °C.

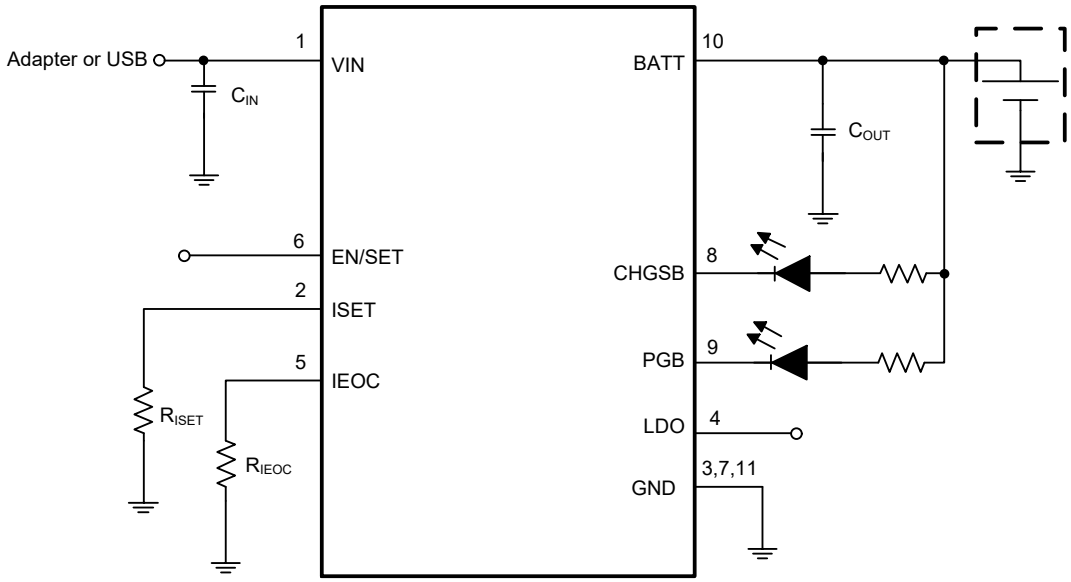
Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{POR}	VIN POR Rising Threshold Voltage		3.15	3.3	3.45	V
V_{POR_HYS}	VIN POR Threshold Voltage Hysteresis		50	150	300	mV
V_{OVP}	VIN OVP Threshold Voltage		6.7	6.9	7.1	V
V_{OVP_HYS}	VIN OVP Threshold Voltage Hysteresis		50	150	300	mV
I_{Q_OFF}	VIN Standby Current	V_{BATT}=4.5 V, EN/SET=High	100	250	300	μA
I_Q	VIN Supply Current	V_{BATT}=4.5 V, EN/SET=Low	0.2	0.5	2	mA
I_{BAT}	Sleep Leakage Current		1	5	10	μA
Reg_{BAT}	V_{BATT} Regulation	0 °C to 85 °C, I_{LOAD}=0 mA	4.155	4.175	4.2	V
	V_{BATT} Regulation		4.283	4.314	4.35	
	Thermal Regulation (1)		--	125	--	°C
T_{OTP}	OTP (1)		--	155	--	°C
T_{OTP_HYS}	OTP Hysteresis (1)		--	20	--	°C
	Top off Time		30	38	45	min
	PGB/CHGSB Sink Current	$V_{PGB/CHGSB}$=0.1 V	20	--	--	mA
V_{PRE}	Pre-Charge Threshold	V_{BATT} Rising	2.5	2.6	2.7	V
I_{PRE}	Pre-Charge Current	USB100 Mode	90	95	100	mA
		USB500 Mode or ISET Mode, ratio of fast-charge current	15	20	25	%
	End of Charge Current (EOC)		--	R_{EOC}/ K_{EOC}	--	%
	IEOC Setting K_{EOC}		180	200	220	Ω/%
I_{EOC}	IEOC Setting Current		70	75	80	μA
	VIN Power FET $R_{DS(ON)}$	I_{OUT}=1 A	--	250	500	mΩ
V_{ISET}	ISET Set Voltage		1.3	1.5	1.7	V
	ISET Short Protect Threshold		320	390	460	Ω
I_{CHRG}	VIN Charge Current	As ISET Mode, R_{ISET}=530Ω	0.9	1	1.1	A
		As USB100 Mode	90	95	100	mA
		As USB500 Mode	380	395	415	mA

Electrical Characteristics (Continued)

Symbol	Parameter		Test Conditions	Min	Typ	Max	Unit
	EN/SET Pull Low Resistor			200	250	300	kΩ
V_{IH}	EN/SET Voltage	Logic-High		1.4	--	--	V
V_{IL}		Logic-Low		--	--	0.4	
$R_{DS(ON)}$	LDO On-Resistance				3	6	Ω
V_{LDO}	LDO Output Voltage			4.7	4.9	5.05	V
	LDO Maximum Output Current			60	120	180	mA
	Factory Mode V_{BATT}			4.116	4.2	4.284	V
	Factory Mode V_{BATT}			4.263	4.35	4.437	
	EN/SET Off Time		Timer to disable chip	2	--	--	ms
	EN/SET Lock Time		Timer to lock pulse count	1.5	--	--	ms
	EN/SET	Logic-High Duration		100	--	700	μs
		Logic-Low Duration		100	--	700	μs
	EN/SET Set Time		Timer to set V_{CV}=4.314 V	750		1000	μs

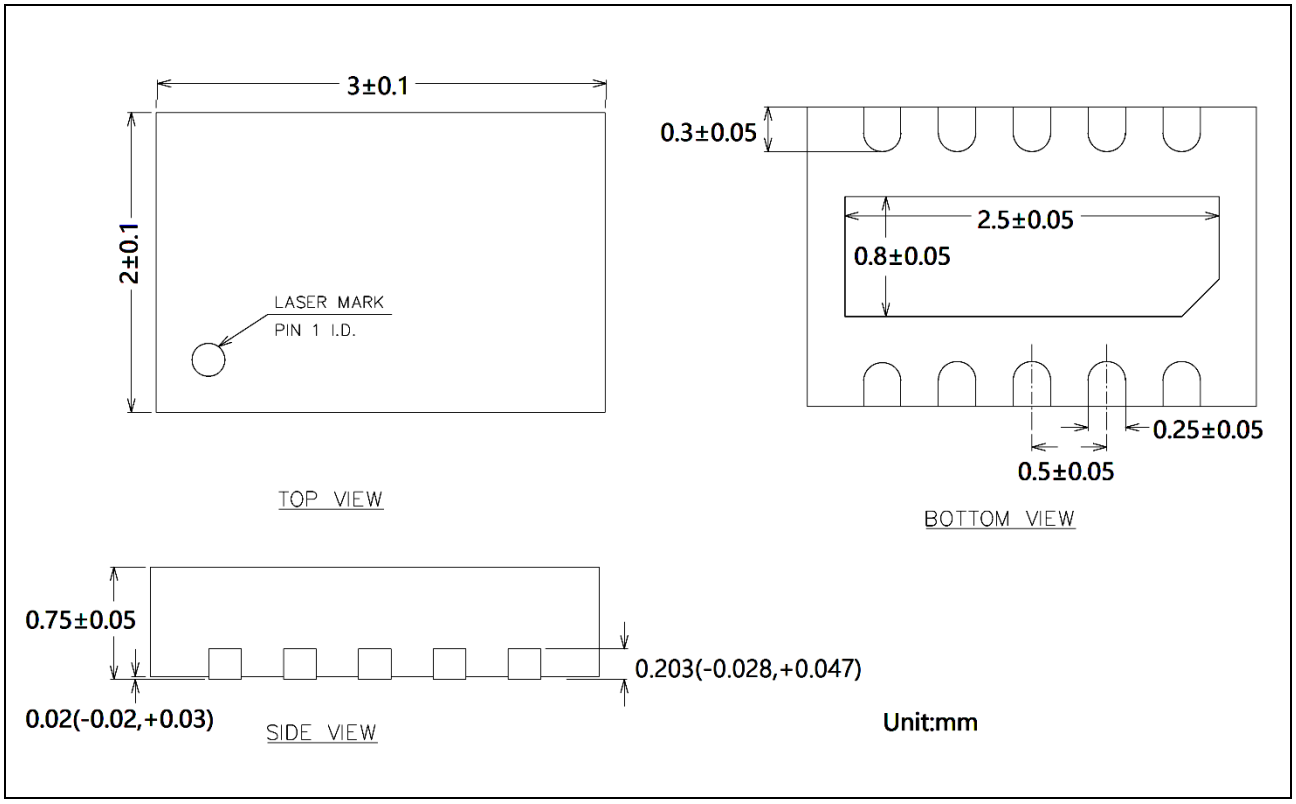
Note (1): Guaranteed by design and characterization. not a FT item.

Application Circuits

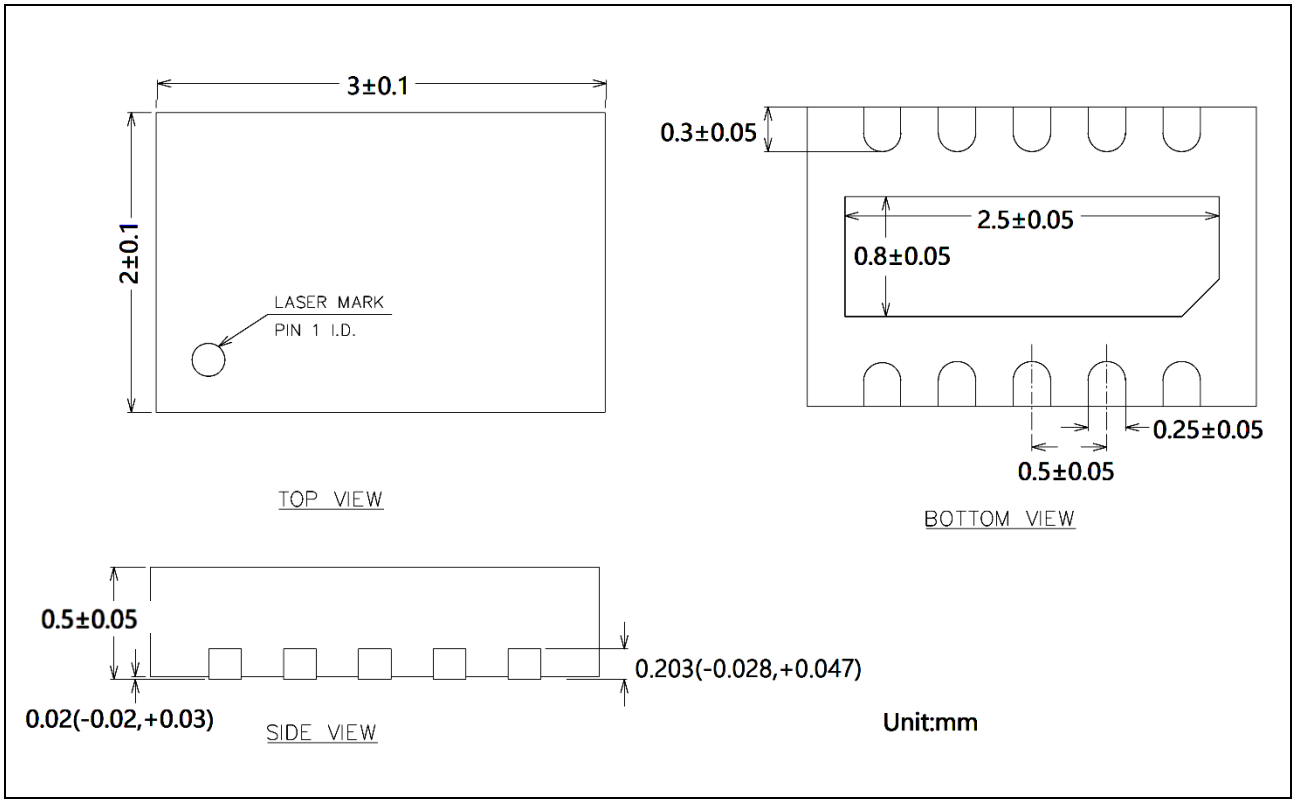


Package Dimension

ET9513C



ET9513CY



Revision History and Checking Table

Version	Date	Revision Item	Modifier	Function & Spec Checking	Package & Tape Checking
1.0	2018-10-11	Initial Version	Zhujl	Xiayj	Zhujl
1.1	2020-03-23	Document check and formalize	Liujy	Shib	Liujy
1.2	2022-09-30	Update Typeset	Chenzx	Chenzx	Liujy
1.3	2023-08-22	Add ET9513CY	Shibo	Chenzx	Liujy