Linear Li-Ion Battery Charger IC

General Description

The ET9513 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 28V but is disabled when the input voltage exceeds the OVP threshold, typically 6.9V, to prevent excessive power dissipation. The 28V rating eliminates the overvoltage 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 ET9513 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

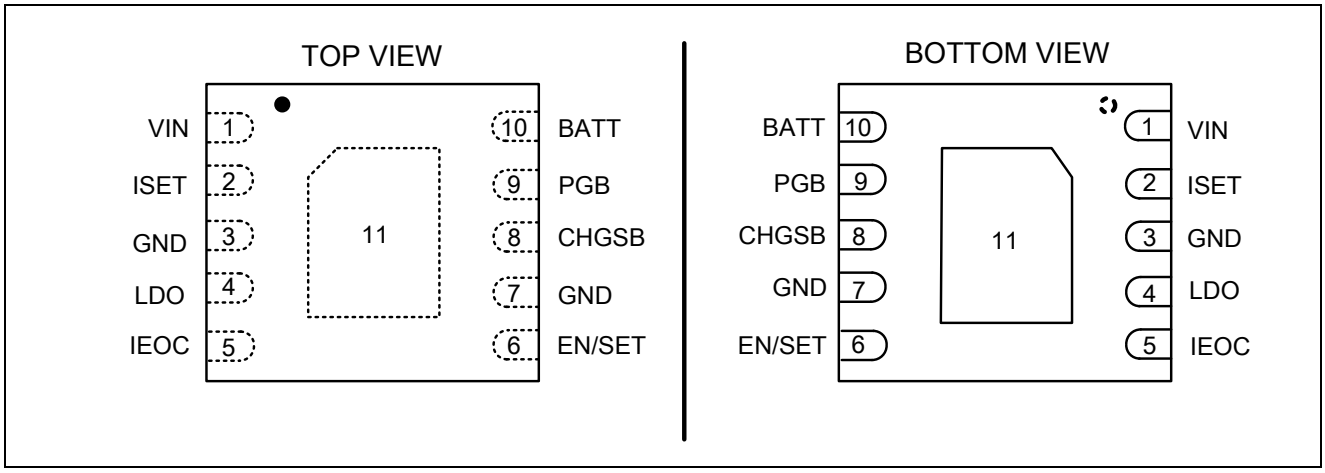
- 28V Maximum Voltage for the Power Input
- Internal Integrated Power MOSFETs
- An internal top off timer
- Support 4.175V or 4.314V/2.3A Factory Mode
- 50mA Low Dropout Voltage Regulator
- Status Pin Indicator
- Programmed Charging Current
- Programmed End-of-Charge Current
- Under Voltage Lockout
- Over Voltage Protection
- Over Temperature Protection
- Reverse Current Blocking
- Part No and Package

Part No.	Package
ET9513	DFN10(3*2)

Application

- Cell Phones
- PDA, MP3
- Digital Cameras
- Other Handheld Devices

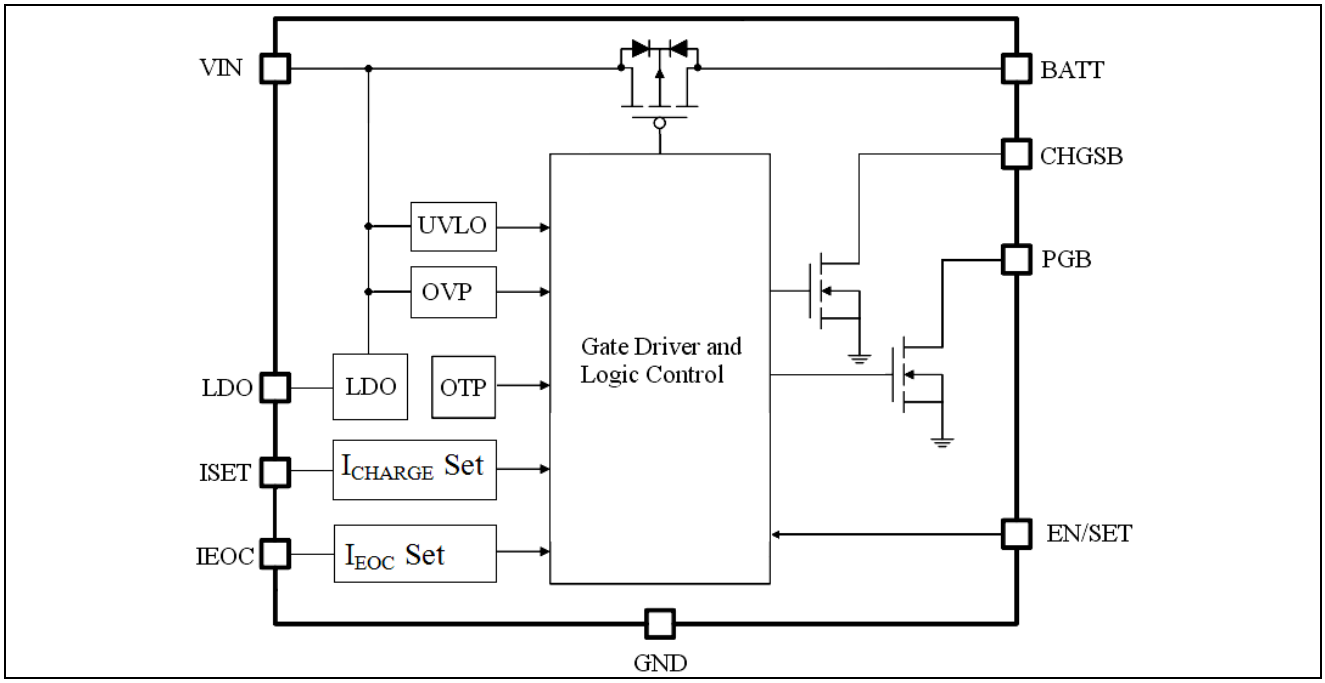
Pin Configuration



Pin Function

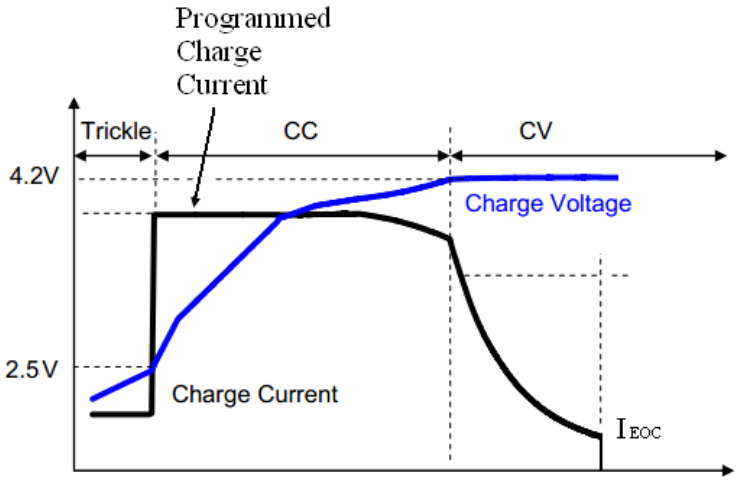
Pin No.	Name	Function
1	VIN	Power Supply Input.
2	ISET	Charging Current Setting
3,7	GND	Ground
4	LDO	LDO Output (4.9V).This pin provides 50mA output current
5	IEOC	End-of-Charge Current Setting.
6	EN/SET	Enable and Operation Mode Setting.
8	CHGSB	Indicator Output for Charging Status.
9	PGB	Indicator 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 ET9513 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 4.175V/4.314V. If the battery voltage is below the pre-charge threshold, the ET9513 charges the battery with a trickle current until the battery voltage rises above the pre-charge threshold. The pre-charge threshold is fixed at 2.6V. When the battery voltage reaches 4.175V/4.314V, the charger enters CV mode and regulates the battery voltage at 4.175V/4.314V to fully charge the battery without the risk of over charging. The ET9513 is capable of being powered up from AC adapter and USB (Universal Serial Bus) port inputs. Moreover, the ET9513 include a linear regulator (LDO 4.9V, 50mA) for supplying low power external circuitry.

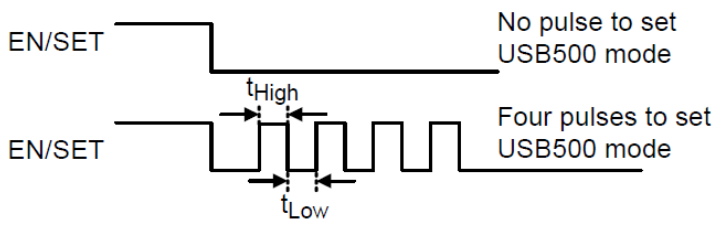


Charger Enable and mode Setting

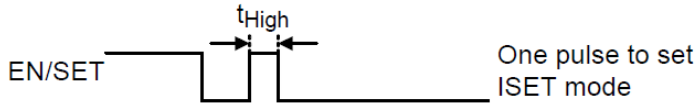
EN/SET is used to enable or disable the charger as well as to select the charge current limit. Drive the EN pin to low or leave it floating to enable the charger. The EN/SET pin has a 300kΩ internal pull down resistor. So, when left floating, the input is equivalent to logic low. Drive this pin to high to disable the charger. After the EN/SET pin pulls low for 50us, the ET9513 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 ET9513 will change its charge current by sending different pulse to EN/SET pin. If no signal is sent to EN/SET, the ET9513 will remain in USB500 mode. A correct period of time for high pulse is between 100us and 700us and the period of pulse to pulse must be between 100us and 700us to be properly read. Once EN/SET is held low for 1.5ms, the number of pulses is locked and sent to the control logic and then the mode changes. The ET9513 needs to be restarted to reset the charge current. Once the EN/SET input is held high for more than 2ms, the ET9513 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

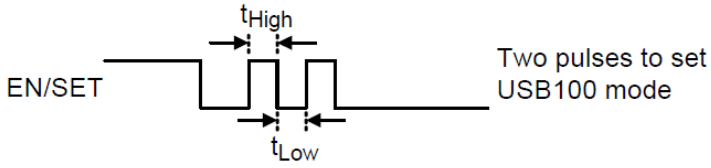
A. USB500 Mode with CV = 4.175V



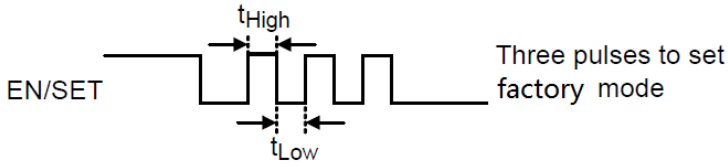
B. ISET Mode with CV = 4.175V



C. USB100 Mode with CV = 4.175V



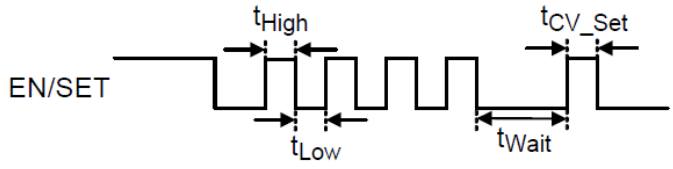
D. Factory Mode with CV = 4.175V



$100\mu s < t_{High}, t_{Low} < 700\mu s$

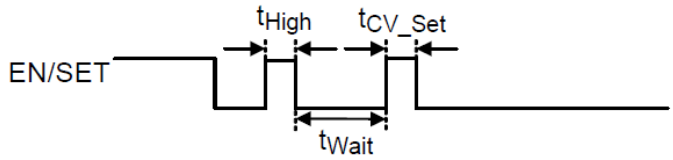
Figure 1 (a). CV is 4.175V

E. USB500 Mode with CV = 4.314V



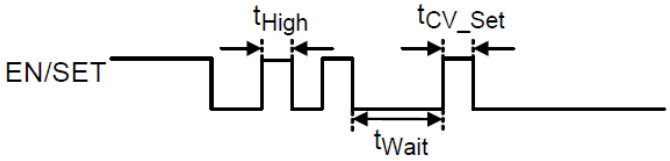
Four pulses to set USB500 mode
Besides, wait the time, t_{Wait} and send a pulse of t_{CV_SET} width for CV = 4.314V

F. ISET Mode with CV = 4.314V



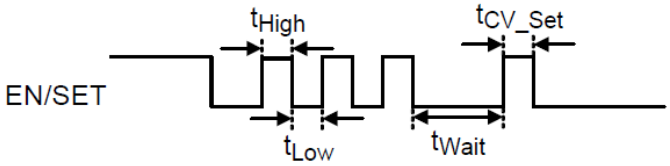
One pulse to set ISET mode
Besides, wait the time, t_{Wait} and send a pulse of t_{CV_SET} width for CV = 4.314V

G. USB100 Mode with CV = 4.314V



Two pulses to set USB100 mode
Besides, wait the time, t_{Wait} and send a pulse of t_{CV_SET} width for CV = 4.314V

H. Factory Mode with CV = 4.314V



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

$100\mu s < t_{High,}t_{Low} < 700\mu s$, $1.5ms < t_{Wait}\, 750\mu s < t_{CV\_Set} < 1ms$

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 6.9V. However, input voltage over 28V will still cause damage to the ET9513. 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 ET9513 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 95mA. When the ET9513 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 ET9513 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.

$I_{Charge} = K_{ISEF} / R_{ISET}$; $K_{ISEF} = 530$

USB500 and USB100 Mode

The fast-charge current is 95mA in USB100 mode and 395mA in USB500 mode. Note that if the fast-charge current set by external resistor is smaller than that inUSB500 mode (395mA), the ET9513 charges the battery in ISET mode.

Battery Voltage Regulation (CV Mode)

The battery voltage regulation feedback is through the BATT pin. The ET9513 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 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 ET9513 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 ET9513 provides factory mode for supplies up to 2.3A for powering external loads with no battery installed and BATT is regulated to 4.175V/4.314V. 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 1.5A in factory mode, the user must limit the duty cycle at the maximum current to 20% with a maximum period of 10ms.

LDO

The ET9513 integrates one low dropout linear regulator (LDO) that supplies up to 50mA. 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 2ms it will make ET9513 enter into standby mode after 38 minutes from full charged condition. When ET9513 enter into standby mode, the charging FET is closed and the OVP, UVP, thermal protection are

still working.

When ET9513 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, ET9513 enter into standby mode.

If top off timer checking the EN/SET input pin is held high for more 2ms 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.

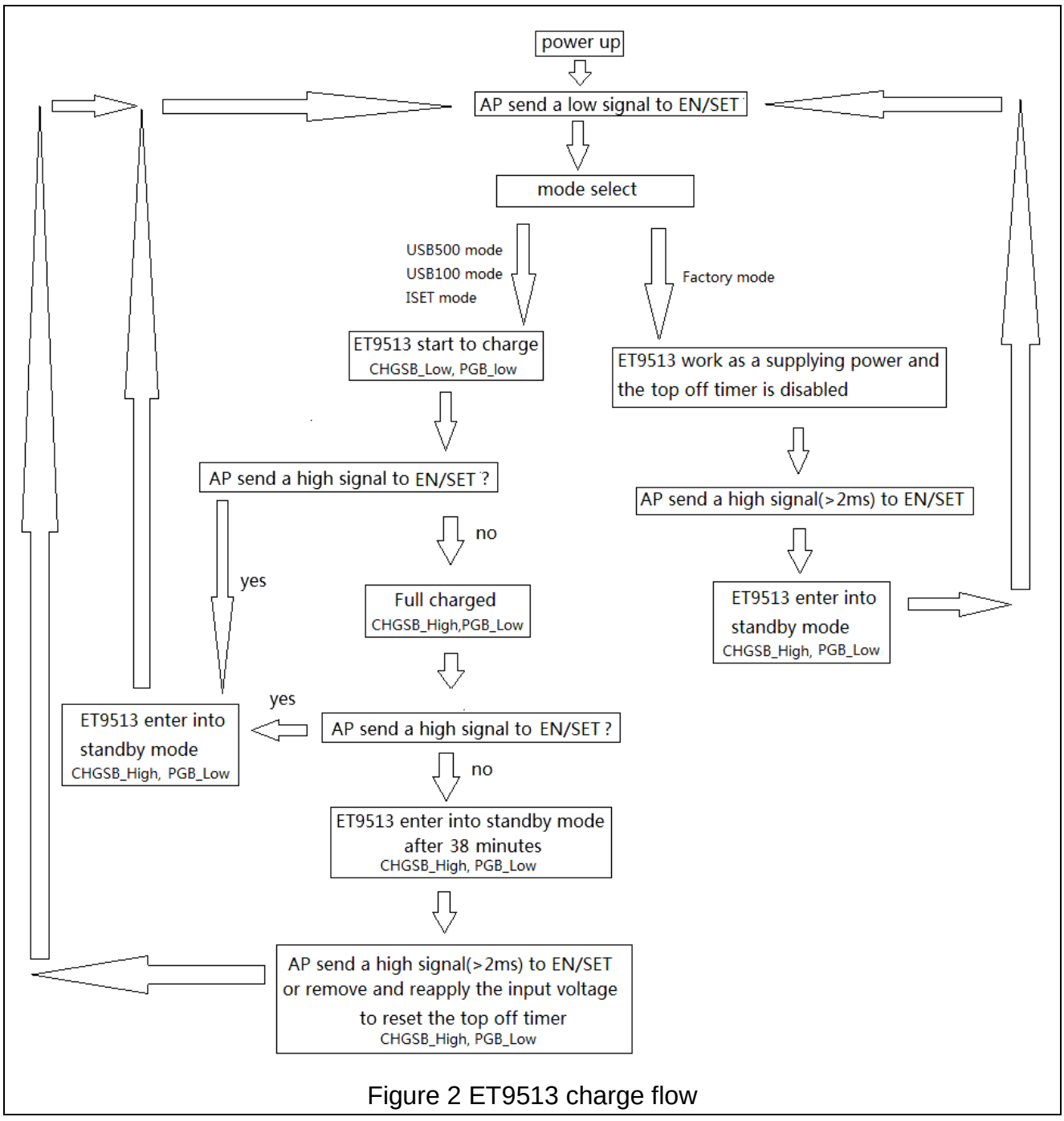


Figure 2 ET9513 charge flow

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 (VIN=5.5V to 10V)	0	100us
Leaving OVP (VIN=10V to 5.5V)	500us	450us
Entering SLEEP (VIN=5.5V to 3.6V)	0	32ms
Leaving SLEEP (VIN=3.6V to 5.5V)	500us	500us
Entering UVLO (VIN=5.5V to 2.5V)	0	0
Leaving UVLO (VIN=2.5V to 5.5V)	230us	230us

Sleep Mode

The ET9513 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 ET9513 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℃), the ET9513 limits the charge current in order to maintain a junction temperature around the thermal regulation threshold (125℃). The ET9513 monitors the junction temperature, T_J, of the die and disconnects the battery from the input if T_J exceeds 125℃. This operation continues until junction temperature falls below thermal regulation threshold (125℃) 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 1uF 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 10uF ceramic capacitor to the input. The ET9513 requires a small output capacitor for loop stability. A typical 1uF 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℃. The junction to ambient thermal resistance, θ_{JA}, is layout dependent.

For WFDN-10L 3x2 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:

PD(MAX)=(125℃-25℃)/(90℃/W) = 1.111W for WFDN-10L 3x2 package

Layout Consideration

The ET9513 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 ET9513.

1. 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.
2. The GND should be connected to a strong ground plane for heat sinking and noise protection.
3. The connection of RISET and RIEOC should be isolated from other noisy traces. The short wire is recommended to prevent EMI and noise coupling.
4. 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, PD@T_A=25℃ (WFDN-10L 3x2)	1.111	W
Junction Temperature	150	℃
Storage Temperature Range	-65~150	℃
Lead Soldering Temperature, 10 Sec	260	℃

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	℃
Ambient Temperature Range	-40~85	℃

Electrical Characteristics

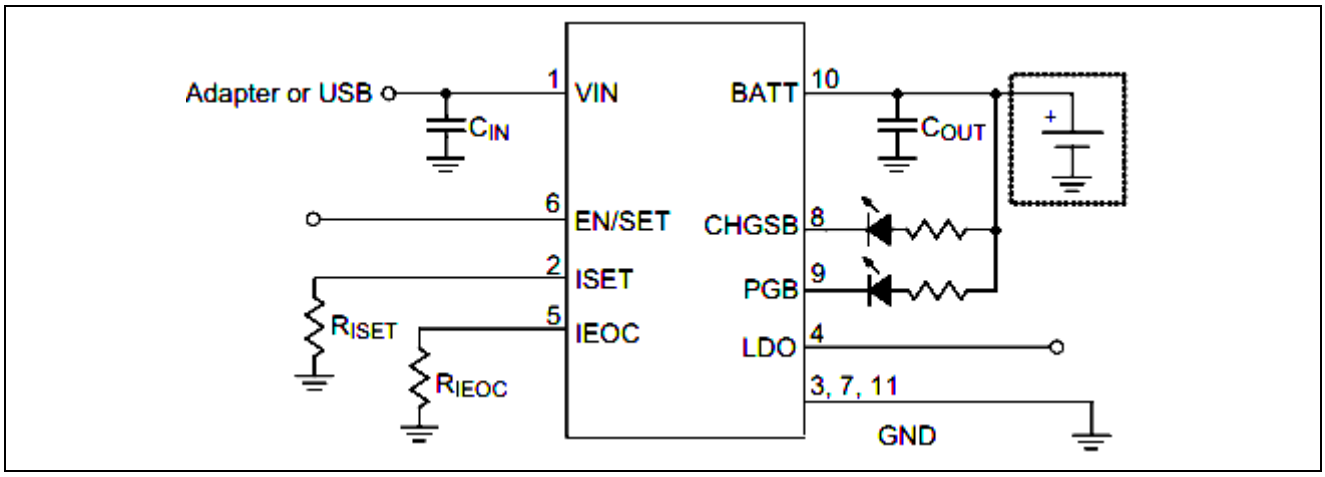
Unless otherwise specified, these specifications apply over VIN=5V, V_{BATT}=4V, T_A=25℃.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{POR}	VIN POR Rising Threshold Voltage		3.15	3.3	3.45	V
	VIN POR Threshold Voltage Hysteresis		--	200	300	mV
V_{OVP}	VIN OVP Threshold Voltage		6.7	6.9	7.1	V
	VIN OVP Threshold Voltage Hysteresis		--	200	300	mV
	VIN Standby Current	V_{BATT}=4.5V, EN/SET=High	--	250	300	uA
	VIN Supply Current	V_{BATT}=4.5V, EN/SET=Low	--	1	2	mA
	Sleep Leakage Current		--	1	10	uA
	V_{BATT} Regulation	0℃ to 85℃, ILOAD=0mA	4.155	4.175	4.2	V
	V_{BATT} Regulation	0℃ to 85℃, ILOAD=0mA	4.283	4.314	4.35	
	Thermal Regulation(1)		--	125	--	℃
	OTP(1)		--	155	--	℃
	OTP Hysteresis(1)		--	20	--	℃
	Top off Time		30	38	45	min
	PGB/CHGSB Sink Current		20	--	--	mA
	Pre-Charge Threshold	V_{BATT} Rising	2.5	2.6	2.7	V
	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	uA
	VIN Power FET $R_{DS(ON)}$	IOUT=1A	--	250	500	mΩ
V_{ISET}	ISET Set Voltage		--	1.5	--	V
	ISET Short Protect Threshold		320	--	460	Ω
	ISET Short Protect Deglitch Time(1)		--	1.5	--	ms
	ISET Short Protect Maximum Current(1)			2		A
I_{CHRG}	VIN Charge Current	As ISET Mode, R_{ISET}=530	0.9	1	1.1	A
		As USB100 Mode	90	95	100	mA

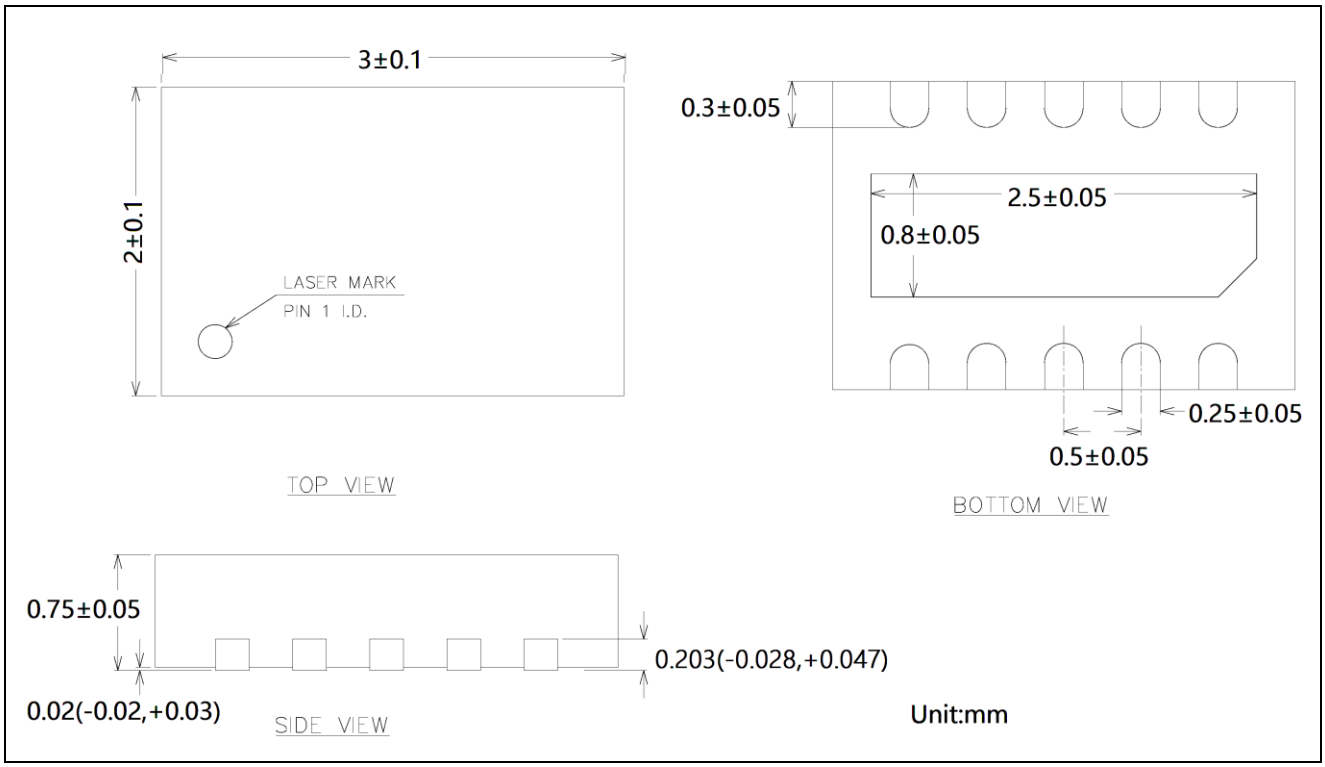
			As USB500 Mode	380	395	415	mA
	EN/SET Pull Low Resistor			--	300	--	kΩ
V_{IH}	EN/SET Voltage	Logic-High		1.4	--	--	V
V_{IL}		Logic-Low		--	--	0.4	
$R_{DS(ON)}$	LDO On-Resistance				3	6	Ω
V_{LDO}	LDO Output Voltage			4.7	4.9	5.05	V
	LDO Maximum Output Current			60	120	180	mA
	Factory Mode V_{BATT}			4.116	4.2	4.284	V
	Factory Mode V_{BATT}			4.263	4.35	4.437	
	Factory Mode Maximum Output Current(1)			2.3	--	--	A
	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	us
		Logic-Low Duration		100	--	700	us
	EN/SET Set Time		Timer to set V_{CV}=4.314V	750		1000	us

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

Application Circuits



Package Dimension



Revision History and Checking Table

No.	Version	Date	Revision Item	Request	Function and characteristic checking	Package dimension checking	Typos checking
1	1.0	2016-02-25	Original Version	Xia Yong Jie	Xia Yong Jie	Zhu Jun Li	Zhu Jun Li
2	1.1	2016-06-14	1.Modified functional description for‘Top off timer’ 2.Modified PGB state in charge flow for ‘Top off’	Xia Yong Jie	Xia Yong Jie	Zhu Jun Li	Zhu Jun Li
3	1.2	2016-07-15	Make the dimension package image more clear	Xia Yong Jie	Xia Yong Jie	Zhu Jun Li	Zhu Jun Li
4	1.3	2016-09-01	Update charge flow	Xia Yong Jie	Xia Yong Jie	Zhu Jun Li	Zhu Jun Li
5	1.4	2017-11-01	Updated Pre-Charge Threshold	Xia Yong Jie	Xia Yong Jie	Zhu Jun Li	Zhu Jun Li
6	1.5	2018-04-12	Changed VBATT Regulation from min 4.135V to 4.155V Typical 4.165V to 4.175V.	Yinp	Yinp	Zhu Jun Li	Zhu Jun Li
7	1.6	2018-09-04	Add note on page 12	Xia Yong Jie	Xia Yong Jie	Liu Jia ying	Liu Jia ying