30V, 1A Single Cell Li-Ion & Li-Pol Linear Battery Charger And 2.5A , Low Quiescent Current Boost Converter

General Description

The DS6513 series of devices are highly integrated Li-Ion and Li-Pol linear chargers devices targeted at space-limited portable applications.

The battery is charged in three phases: conditioning, constant current and constant voltage. In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if an internal temperature threshold is exceeded.

The charger power stage and charge current sense functions are fully integrated. The charger function has high accuracy current and voltage regulation loops, charge status display, and charge termination.

The fast charge current value is also programmable via an external resistor.

The converter is based on a fixed frequency, current mode, pulse-width-modulation PWM controller that goes automatically into PSM mode at light load.

When converter operation into discontinuous mode, the internal anti-ringing switch will reduce interference and radiated electromagnetic energy.

Features

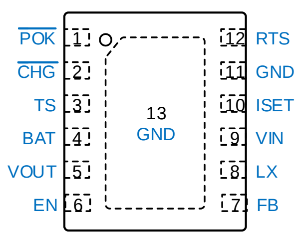
- 30V Input Rating ; with 7.3V Input Overvoltage Protection
- 1% Charge Voltage Accuracy
- Programmable Charger Current 50mA to 1A
- 125°C Thermal Regulation
- Fixed ISET / 10 for term
- Fixed ISET / 3 for Pre-charge
- Operation over JEITA Range via Battery NTC – 1/2 Fast-Charge-Current at Cold, 4.05V at Hot
- Adjustable Temperature Sense Current
- Very Low Battery leakage Current 0.1uA
- Built-In Synchronous Boost Converter
  - True Load Disconnection During Shutdown
  - 40uA Standby Current
  - High Efficiency up to 95%
  - Low Shutdown Current at 1uA
  - Output Overvoltage Protection
- DFN3x3-12L & ESOP-8 Package Available

Applications

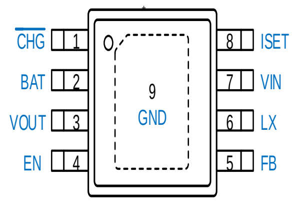
- Laptop, Palmtops and PDAs
- Smart Phones
- MP3 Players
- Low-Power Handheld Devices
- True Wireless Stereo (TWS)

Pin Configurations

DFN-3x3-12L



ESOP-8



Ordering Information

DS6513XYY

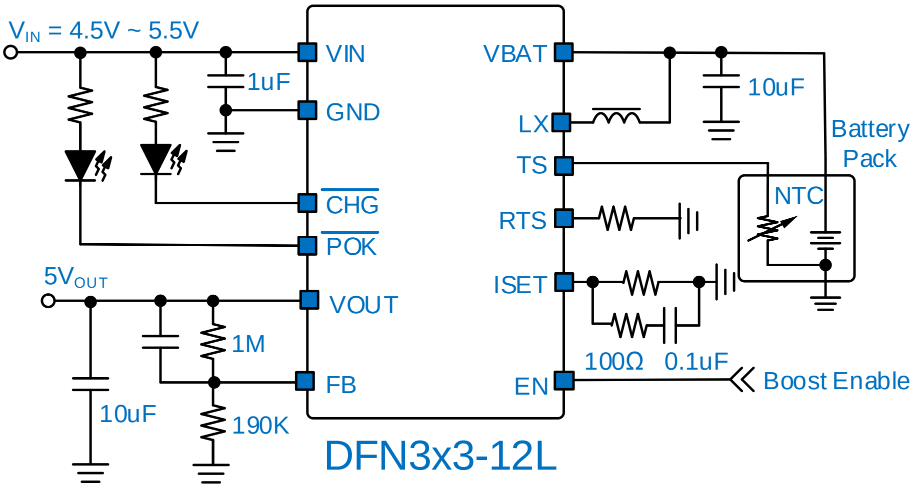
Designator	Description	Symbol	Description
X	V_{BAT}	A	4.2V
		B	4.35V
YY	Package type	F8	ESOP-8
		D12	DFN-3x3-12L

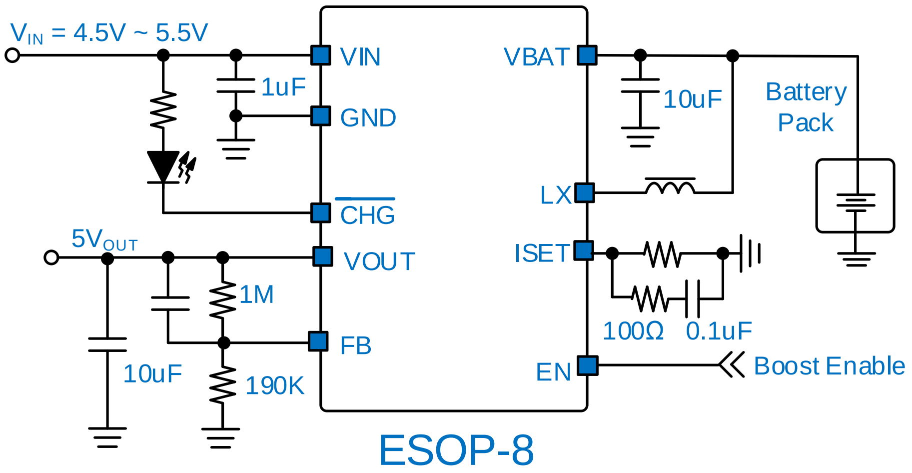
Example: V_{BAT}=4.2V, DFN-3X3-12L. Part no = DS6513AD12

Description of Functional Pins

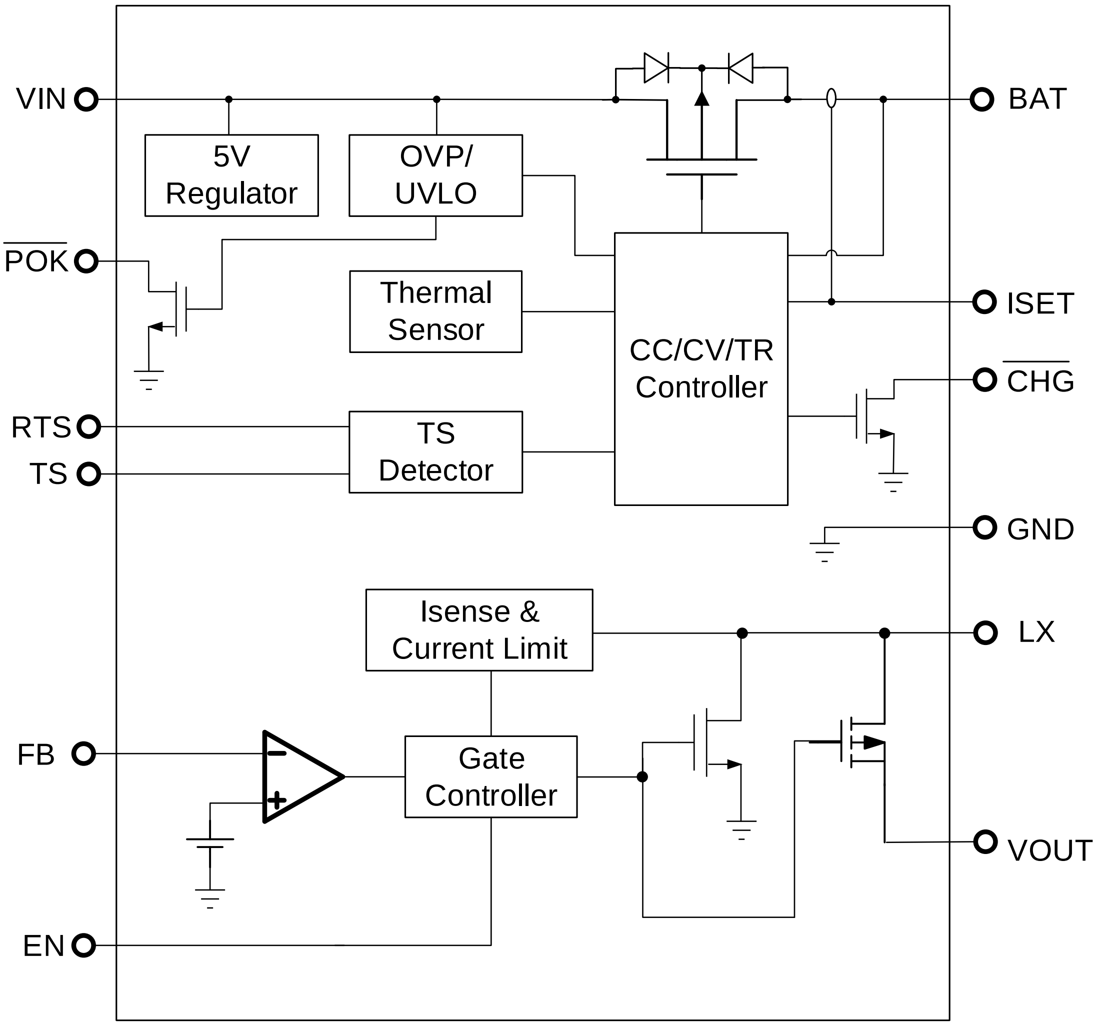
Pin No		Pin Name	Pin Function
DFN3X3-12L	ESOP-8		
1		$\overline{POK}$	Low (FET on) indicates the input voltage is above UVLO and the OUT (battery) voltage, and less than OVP threshold voltage.
2	1	$\overline{CHG}$	Low (FET on) indicates charging and Open Drain (FET off) indicates no Charging or Charge complete.
3		TS	Temperature sense terminal connected to 10k & 100k at 25°C NTC thermistor, in the battery pack. Floating TS terminal or pulling High disables TS monitoring. Pulling terminal Low disables the IC. Let the RTS pin floating if there is no TS requirement.
4	2	BAT	Battery Connection. System Load may be connected. Expected range of bypass capacitors 10μF to 22μF.
5	3	VOUT	Boost Converter Output Pin .
6	4	EN	Boost Converter Enable Input .
7	5	FB	The Boost Converter Feedback Input for Adjusting Output Voltage . The Pin Connects Resistor Divider that Output Voltage Could be Adjusted form 1.8V to 5.5V .
8	6	LX	Switch Input Pin Which is Connected to Inductor .
9	7	VIN	Input of Supply Voltage .
10	8	ISET	Programs the Fast-charge current setting. External resistor from ISET to VSS defines fast charge current value. Range is 16.9 KΩ (300mA) to 2.4KΩ (1000mA) .
11		GND	Ground .
12		RTS	Programs the Temperature Sense (TS) current setting. External resistor from RTS to VSS defines the output current of TS pin. Let the RTS pin floating if there is no TS requirement.
13 Exposed Pad	9 Exposed Pad	PGND	Substrate of Chip. Leave floating or tie to GND.

Typical Application Circuits





Function Block Diagram



Absolute Maximum Ratings (Note 1)

VIN to GND -- -0.3V to 30V

BAT to GND -- -0.3V to 12V

Other to GND -- -0.3V to 6V

Package Thermal Resistance (Note 2)

DFN-12L 3x3, θ_{JA} --- 70 °C /W

ESOP-8 , θ_{JA} -- 75 °C /W

Lead Temperature (Soldering, 10 sec.) -- 260 °C

Junction Temperature -- 150 °C

Storage Temperature Range -- -60 °C to 150 °C

ESD Susceptibility

HBM --- 2KV

MM -- 200V

Recommended Operating Conditions

Input Voltage VIN -- 4.5V to 30V

Junction Temperature Range -- -40 °C to 125 °C

Ambient Temperature Range -- -40 °C to 85 °C

Electrical Characteristics

(V_{IN} =5V, T_A=25°C unless otherwise specified)

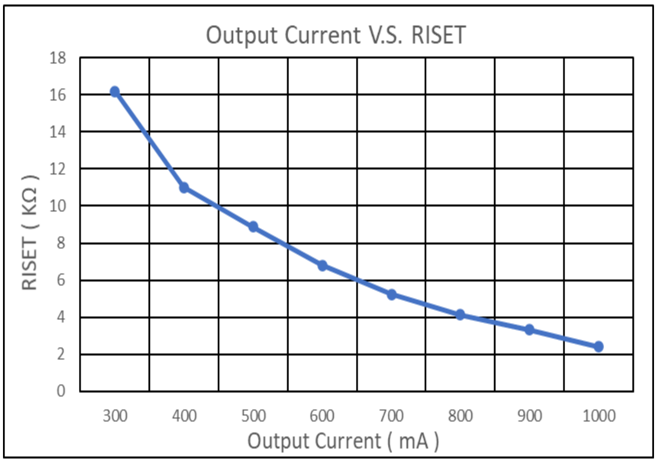
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Linear Charger						
Supply Voltage	V_{IN}		4.6	--	24	V
UVLO Threshold Voltage	V_{IN_UVLO}	V_{IN} Falling	--	4.5	--	V
UVLO Hysteresis Voltage	V_{UVLO_HYS}		--	100	--	mV
Input Over-Voltage Protection	V_{OVP}			7.36		V
Input Over-Voltage Protection Hysteresis	V_{OVP_HYS}			0.1		V
Input Supply Current (Charge mode)	I_{QA}	TS = open, V IN = 5V,no load on OUT terminal,		70		μA
Input Standby Current	I_{QS}	TS = 0V, V IN = 5V		95		μA
Battery leakage current into BAT terminal	I_{BAT}	V_{IN} = 0V, V_{BAT} = 4.2V	--	0.1	--	μA
Battery Regulation Voltage	V_{BAT} / Type A	I_{OUT} = 25mA	4.16	4.2	4.24	V
	V_{BAT} / Type B		4.31	4.35	4.39	
Output Current	I_{OUT}	R_{ISET} = 2.4 KΩ to 523KΩ	50		1000	mA
Pre-charge to fast-charge transition threshold	V_{LOWV}	V_{BAT} Falling	--	2.81	--	V
Temperature Sense Current	I_{TS}	R_{RTS} = 54kΩ	--	100	--	μA
Low temperature CHG Pending	V_{TS}-0°C	TS Rising	--	2.53	--	V
Hysteresis at 0°C	V_{HYS}-0°C		--	60	--	mV
Low temperature, half charge	V_{TS}-10°C	TS Rising	--	1.71	--	V
Hysteresis at 10°C	V_{HYS}-10°C		--	60	--	mV
High temperature at 4.1V	V_{TS}-45°C	TS Falling	--	0.45	--	V
Hysteresis at 45°C	V_{HYS}-45°C		--	17	--	mV
High temperature Disable	V_{TS}-60°C	TS Falling	--	0.28	--	mV
Hysteresis at 60°C	V_{HYS}-60°C		--	17	--	mV
Charge Shutdown Threshold	V_{TS_SD}	TS Falling		110		mV
Hysteresis of TS Shutdown	V_{TS_SD-HYS}			17		mV
Temperature regulation limit	$T_{J(REG)}$			125		°C
Thermal shutdown temperature	T_{J_OFF}			155		°C

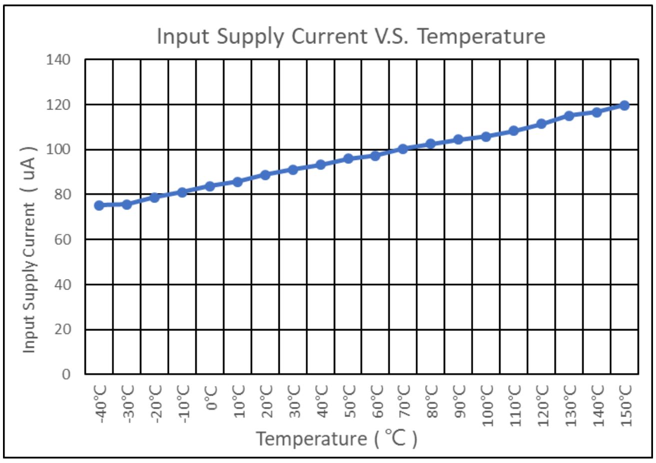
Boost Converter						
Output Voltage Range	V_{OUT}	$V_{IN} < V_{OUT}$	1.9		5.0	V
Over Voltage Protection	V_{OVP}			5.7		V
Shutdown Current form Power Source	I_{SD}	EN = 0V		1		uA
Feedback Voltage	V_{FB}		784	800	816	mV
FB Input Bias Current	I_{FB}			0.01	0.1	uA
Under Voltage Lockout Threshold for Turn Off	V_{UVLO}	V_{IN} Decreasing		1.85		V
Quiescent Current	I_Q	$V_{EN}=V_{IN}=3.3V$, $V_{FB}=0.9V$, Non-Switch		15		uA
Standby Current	I_Q	$V_{EN}=V_{IN}=3.3V$, $V_{OUT}=5V$,		40		uA
NMOS Switch On-Resistance	$R_{DS(ON)}$	$V_{OUT} = 3.3V$	--	80	--	mΩ
PMOS Switch On-Resistance	$R_{DS(ON)}$	$V_{OUT} = 3.3V$	--	85	--	mΩ
NMOS Current Limit			2.5			A
Oscillation Frequency	F_S			500		KHz
EN Input Low Voltage	VIL				0.4	V
EN Input High Voltage	VIH		1.4			V
EN Input Current	IEN			0.01	0.1	uA
Thermal shutdown temperature	T_{SD}			150		°C
Thermal shutdown temperature Threshold	ΔT_{SD}	Hysteresis		20		°C

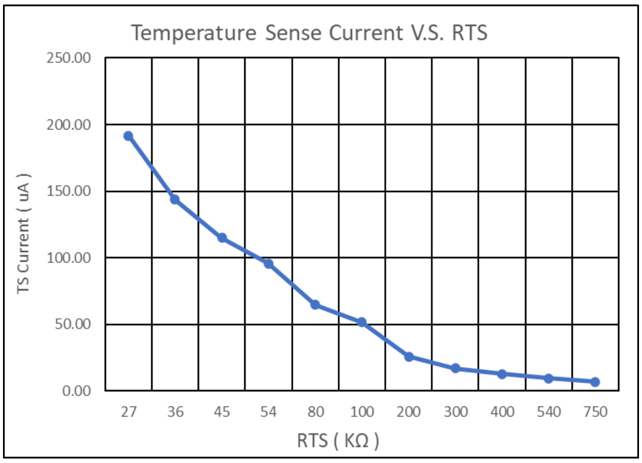
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

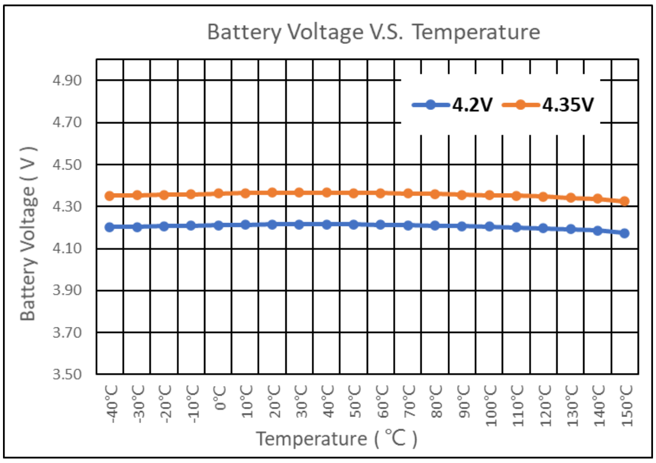
Note 2. θ_{JA} is measured at $T_A = 25°C$ on a DSTECH EVB board.

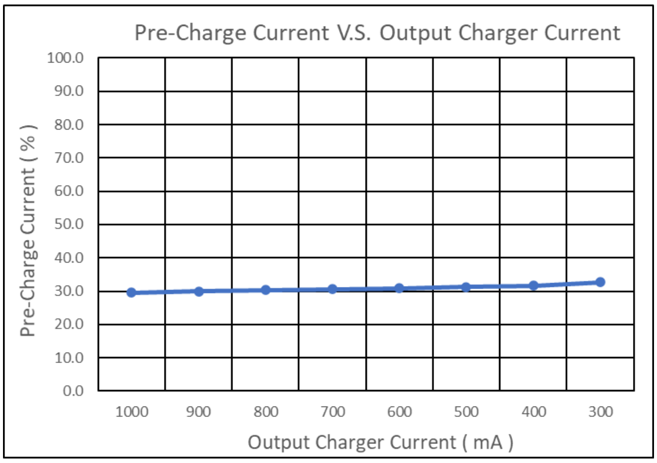
Typical Characteristics

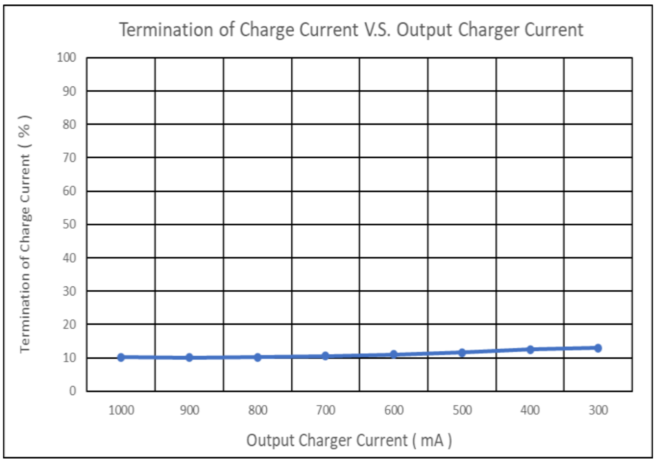


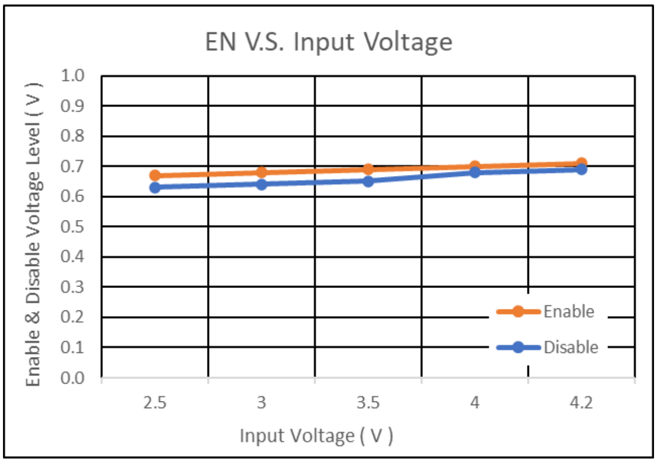


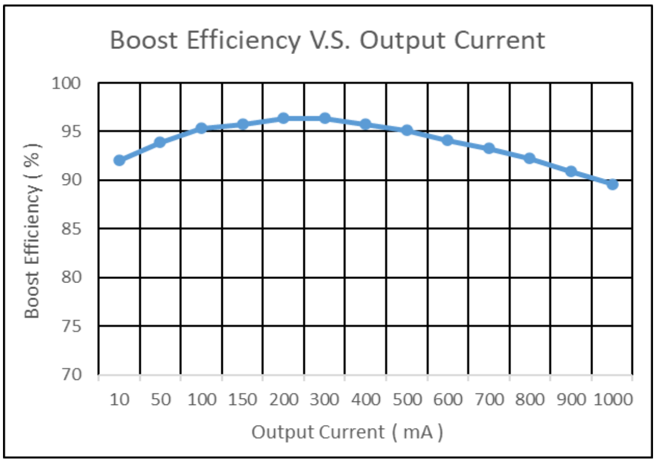


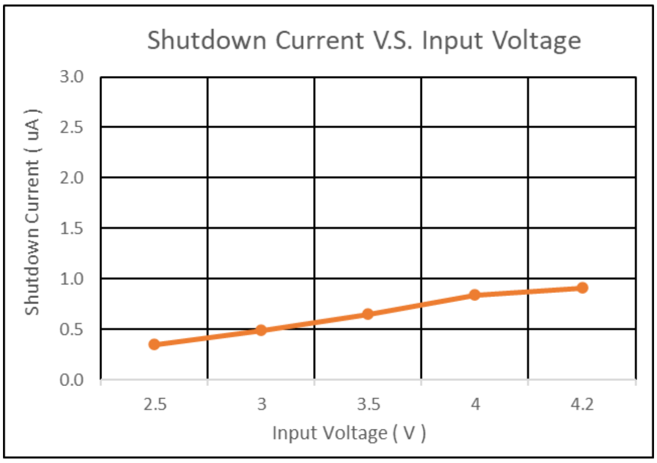


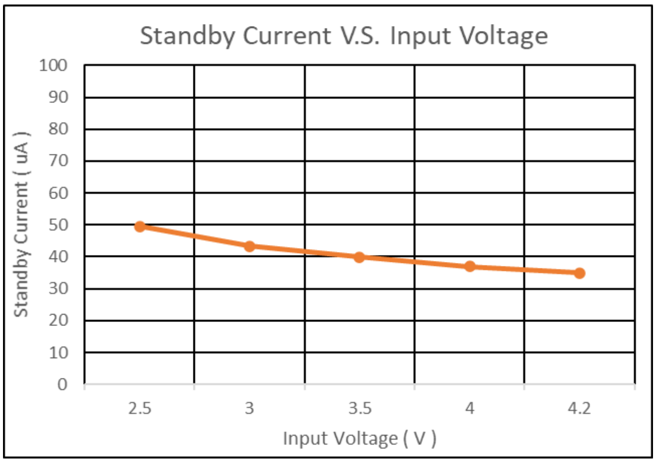


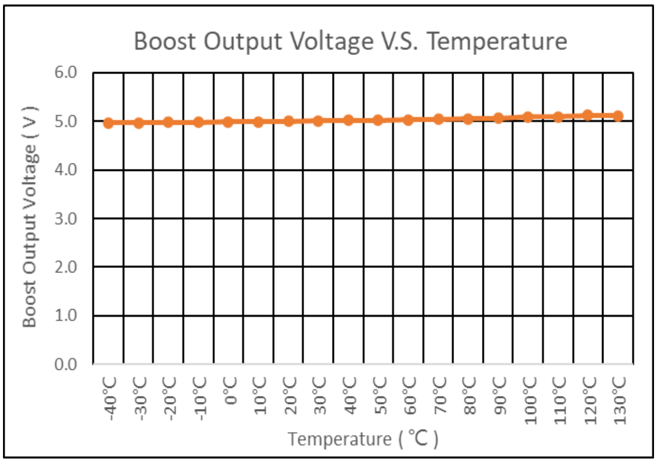



EN V.S. Input Voltage
Enable & Disable Voltage Level (V)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2.5
3
3.5
4
4.2
Input Voltage (V)
Enable
Disable


Boost Efficiency V.S. Output Current
Boost Efficiency (%)
100
95
90
85
80
75
70
10
50
100
150
200
300
400
500
600
700
800
900
1000
Output Current (mA)


Shutdown Current V.S. Input Voltage
Shutdown Current (uA)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2.5
3
3.5
4
4.2
Input Voltage (V)


Standby Current V.S. Input Voltage
Standby Current (uA)
100
90
80
70
60
50
40
30
20
10
0
2.5
3
3.5
4
4.2
Input Voltage (V)


Boost Output Voltage V.S. Temperature
Boost Output Voltage (V)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-40°C
-30°C
-20°C
-10°C
0°C
10°C
20°C
30°C
40°C
50°C
60°C
70°C
80°C
90°C
100°C
110°C
120°C
130°C
Temperature (℃)

Application Guideline

Charger Power-Down or Undervoltage Lockout (UVLO)

The DS6513 is in power down mode if the VIN terminal voltage is less than UVLO. The part is considered "dead" and all the terminals are high impedance. Once the VIN voltage rises above the UVLO threshold the IC will enter Active mode.

Charger Power-up

The IC is alive after the VIN voltage ramps above UVLO, resets all logic, and starts to perform many of the continuous monitoring routines. Typically, the input voltage quickly rises through the UVLO and declares power good.

Charger Overvoltage-Protection (OVP)

If the input source applies an overvoltage, the pass FET, if previously on, turns off after a deglitch (OVP). The $\overline{CHG}$ and $\overline{POK}$ terminal goes to a high impedance state. Once the overvoltage returns to a normal voltage, the $\overline{POK}$ terminal goes low, charge continues and the $\overline{CHG}$ terminal goes low after a deglitch period.

Program the Temperature Sense Current , RTS

From the Electrical Characteristics table:

RTS (KΩ)	for Battery NTC
54	10K
540	100K

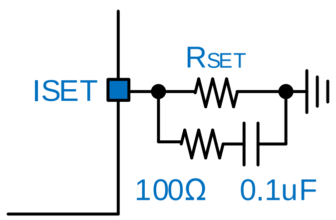
Selecting the closest standard value, use a resistor between RTS and GND.

Program the Fast Charge Current , ISET

From the Electrical Characteristics table:

RSET (KΩ)	Charge Current (mA)
523.00	50
118.00	100
32.40	200
16.20	300
11.00	400
8.87	500
6.81	600
5.23	700
4.12	800
3.32	900
2.40	1000

Selecting the closest standard value, use a R_{SET} resistor between ISET and GND.



It is recommended to connect a set of RC (100Ω & 0.1uF) in parallel with the RSET resistor, which can make the charging current more stable.

$\overline{\text{CHG}}$ and $\overline{\text{POK}}$ LED Pull-up Source

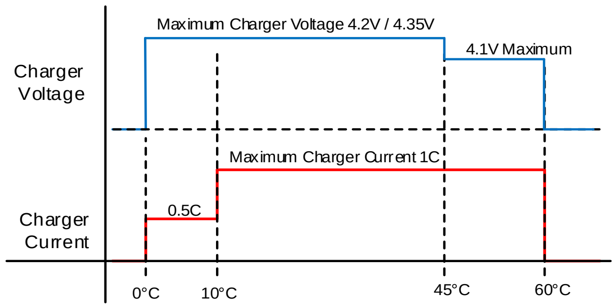
For host monitoring, a pull-up resistor is used between the "STATUS" terminal and the VCC of the host and for a visual indication a resistor in series with an LED is connected between the "STATUS" terminal and a power source. If the $\overline{\text{CHG}}$ or $\overline{\text{POK}}$ source is capable of exceeding 7V, a 6.2V Zener diode should be used to clamp the voltage. If the source is the BAT terminal, note that as the battery changes voltage, and the brightness of the LEDs vary.

Charging State	$\overline{\text{CHG}}$ FET/LED
1st Charge after VIN applied	ON
OVP or UVLO	OFF

VIN Power Good State	$\overline{\text{POK}}$ FET/LED
UVLO	OFF
OVP Mode	
Normal Input (UVLO < VIN < V_{OVP})	ON
POK is independent of chip disable	

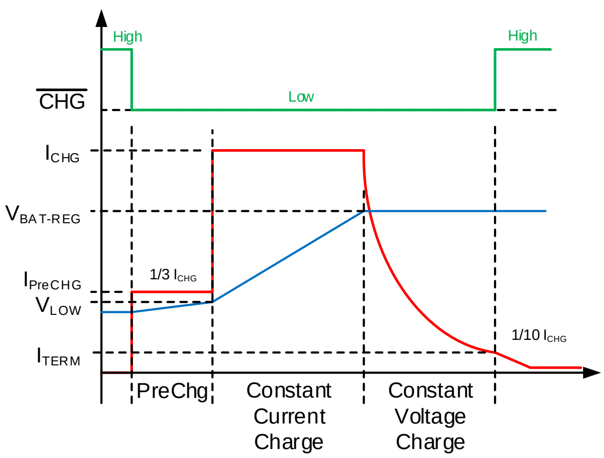
Temperature Sense (TS)

The TS function for the DS6513 is designed to follow the new JEITA temperature standard for Li-Ion and Li-Pol batteries. There are now four thresholds, 60°C, 45°C, 10°C, and 0°C. Normal operation occurs between 10°C and 45°C. If between 0°C and 10°C the charge current level is cut in half and if between 45°C and 60°C the regulation voltage is reduced to 4.1Vmax.



The TS feature is implemented using an internal by RTS set current source to bias the thermistor (designed for use with a 10K NTC β = 4050) connected from the TS terminal to VSS. If this feature is not needed, a fixed 10KΩ can be placed between TS and VSS to allow normal operation. This may be done if the host is monitoring the thermistor and then the host would determine when to pull the TS terminal low to disable charge.

Charge Cycle



Boost Controller Circuit

The device is based on a current-mode control topology and uses a constant frequency pulse-width modulator to regulate the output voltage. The controller limits the current through the power switch on a pulse by pulse basis. The current sensing circuit is integrated in the device; therefore, no additional components are required. Due to the nature of the boost converter topology used here, the peak switch current is the same as the peak inductor current, which will be limited by the integrated current limiting circuits under normal operating conditions.

Boost Synchronous Rectifier

The device integrates a N-channel and a P- channel MOSFET transistor to realize a synchronous rectifier. There is no additional Schottky diode required. Because the device uses a integrated low RDS(ON) PMOS switch for rectification, the power conversion efficiency reaches 93%.

A special circuit is applied to disconnect the load from the input during shutdown of the converter. In conventional synchronous rectifier circuits, the backgate diode of the high-side PMOS is forward biased in shutdown and allows current flowing from the battery to the output. This device, however, uses a special circuit to disconnect the backgate diode of the high-side PMOS and so, disconnects the output circuitry from the source when the regulator is not enabled (EN=low).

Boost Converter Enable

The device will be shut down when EN is set to GND. In this mode, the regulator stops switching, all internal control circuitry including the low-battery comparator will be switched off, and the load will be disconnected from the input (as described in above synchronous rectifier section). This also means that the output voltage may drop below the input voltage during shutdown.

The device is put into operation when EN is set high. During start-up of the converter, the duty cycle is limited in order to avoid high peak currents drawn from the battery. The limit is set internally by the current limit circuit.

Boost PSM Mode

The DS6513 is designed for high efficiency over wide output current range. Even at light load, the efficiency stays high because the switching losses of the converter are minimized by effectively reducing the switching frequency. The controller will enter a power saving mode if certain conditions are met. In this mode, the controller only switches on the transistor if the output voltage trips below a set threshold voltage. It ramps up the output voltage with one or several pulses, and goes again into PSM mode once the output voltage exceeds a set threshold voltage.

Boost Anti-Ringing Switch

The device integrates a circuit which removes the ringing that typically appears on the SW node when the converter enters the discontinuous current mode. In this case, the current through the inductor ramps to zero and the integrated PMOS switch turns off to prevent a reverse current from the output capacitors back to the battery. Due to remaining energy that is stored in parasitic components of the semiconductors and the inductor, a ringing on the SW pin is induced. The integrated anti-ringing switch clamps this voltage internally to VIN; therefore, dampens this ringing.

Boost Adjustable Output Voltage

The accuracy of the output voltage is determined by the accuracy of the internal voltage reference, the controller topology, and the accuracy of the external resistor. The reference voltage has an accuracy of ± 2%. The controller switches between fixed frequency and PSM mode, depending on load current. The tolerance of the resistors in the feedback divider determines the total system accuracy.

Boost Programming the Output Voltage

The output voltage of the DS6513 can be adjusted with an external resistor divider. The typical value of the voltage on the FB pin is 800mV in fixed frequency operation. The maximum allowed value for the output voltage is 5.25V. The current through the resistive divider should be about 100 times greater than the current into the FB pin. The typical current into the FB pin is 0.01μA, and the voltage across R2 is typically 800mV. Based on those two values, the recommended value for R2 is in the range of 80kΩ in order to set the divider current at 10μA. From that, the value of resistor R1, depending on the needed output voltage (VO), can be calculated using Equation 1.

$V_{OUT} = V_{FB} * [R_{TOP} / (R_{TOP} + R_{BOT})]$

Boost Design Procedure

The DS6513 boost converter family is intended for systems that are powered by a single-cell Ion battery with a typical terminal voltage between 3V to 4.2V.

Thermal Application

For continuous operation, do not exceed the absolute maximum junction temperature. The maximum power dissipation depends on the 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 as below:

T_A=25°C, DSTECH PCB,

The max PD(Max) = (125°C − 25°C) / (70°C/W) = 1.43W for DFN3x3-12L packages.

The max PD(Max) = (125°C − 25°C) / (75°C/W) = 1.33W for ESOP-8 packages.

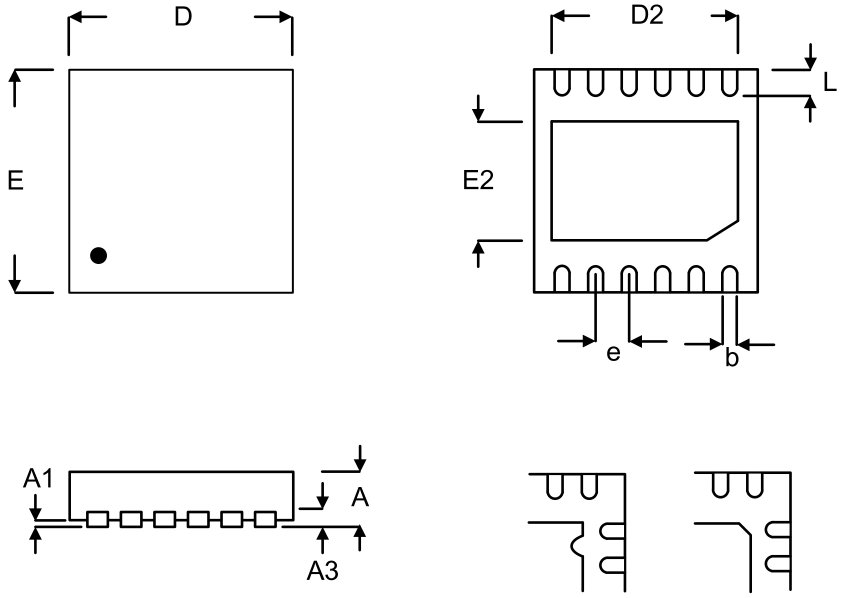
Power dissipation (PD) is equal to the product of the output current and the voltage drop across the output pass element, as shown in the equation below:

PD = (VIN – VOUT) × IOUT

Layout Consideration

By placing input and output capacitors on the same side of the PCB as the Charger, and placing them as close as is practical to the package can achieve the best performance. The ground connections for input and output capacitors must be back to the DS6513 ground pin using as wide and as short of a copper trace as is practical. Connections using long trace lengths, narrow trace widths, and/or connections through via must be avoided. These add parasitic inductances and resistance that results in worse performance especially during transient conditions.

Package Information:

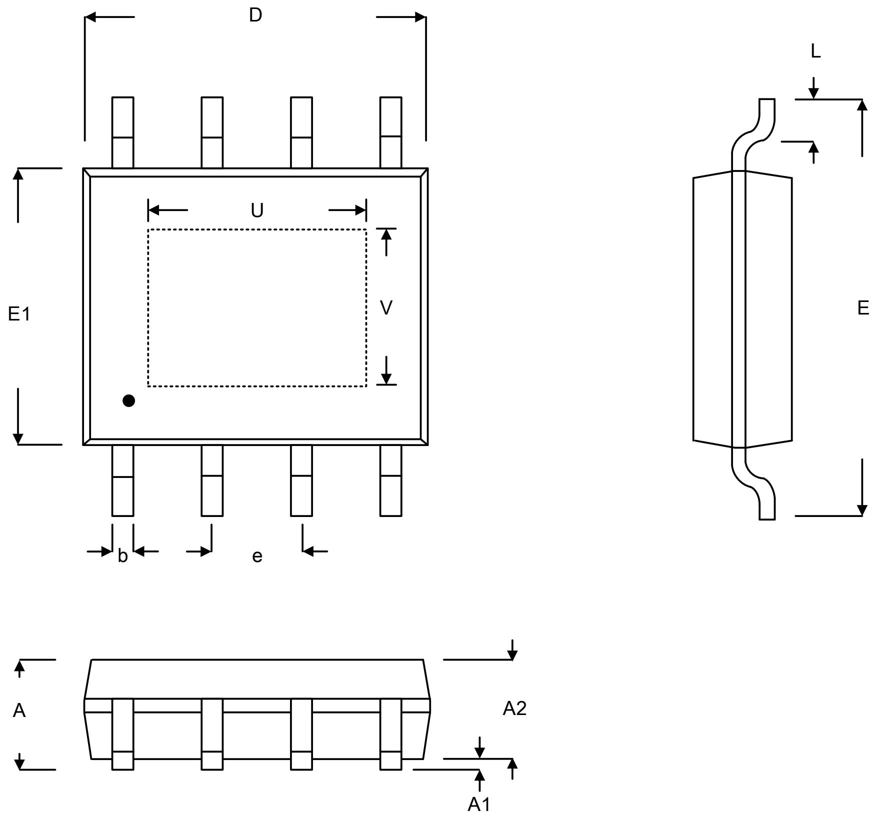


DETAILA
PIN #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.150	0.250	0.006	0.010
D	2.900	3.100	0.114	0.122
D1	0.260	0.360	0.010	0.014
D2	2.500		0.098	
E	2.900	3.100	0.114	0.122
E2	1.550		0.061	
e	0.450		0.018	
L	0.300	0.500	0.012	0.020

DFN3x3-12L



Symbol	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	1.300	1.800	0.051	0.071
A1	0.000	0.152	0.000	0.006
A2	1.300	1.500	0.051	0.059
b	0.330	0.510	0.013	0.020
D	4.800	5.000	0.189	0.197
e	1.270		0.050	
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
L	0.400	1.200	0.016	0.047
U	3.100		0.122	
V	2.210		0.087	

ESOP-8