2.5A Switching Charger with USB OTG Operation and Power Path Management for Single Cell Li+ Battery

DESCRIPTION

The EUP8268 is a highly-integrated mode battery charger with power path management for single-cell Li-ion battery in a wide range of smart phone and other portable devices. It integrates a synchronous BUCK regulator to provide regulated voltage for powering the system output and at the same time charging the battery. This device supports both USB and AC adapter input. The EUP8268 also meets USB On-the-Go (OTG) operation power rating specification by supplying 5V (typical) on IN.

The smart power path management allows EUP8268 to regulate the system voltage for powering an external load and charging the battery independently and simultaneously. This allows immediate system operation even under missing or deeply discharged battery. Additionally, the smart power path control allows an internal connection from battery to the system in order to supplement additional power to the load in the event the system power demand increases over the input limited power or the input is removed.

The EUP8268 features high integration with all the power switches included inside. No external MOSFET, blocking diodes, or current sense resistor is required.

Status monitor output pins are provided to indicate the battery charge status. Other features include battery temperature monitoring and charging safe timer detector.

EUP8268 is available in 3mm×3mm UQFN-16 Package.

FEATURES

- 18V Absolute Maximum Input Voltage without External High Voltage Protection Circuit
- 4.5V-5.5V Input Operating Range
- Smart Power Path Management
- 1A Synchronous Boost Converter in OTG Mode up to 90% efficiency
- Control Loops: Input Voltage Limit, Constant Charge Current, Terminal Battery Control.
- 1.6MHz Switching Frequency
- Up to 2.5A Programmable Charge Current without Expensive Milliohm Sense Resistor
- Preset 4.2V or 4.35V Charge Voltage
- Single Input for USB and AC adapter
- High Integration includes all MOSFETs
- Charging Operation Indicator
- Battery Temperature Monitor
- Small Size Package Features
- 3mm×3mm UQFN-16 Package
- RoHS Compliant and 100% Lead (Pb)-Free Halogen-Free

APPLICATIONS

- Smart Phone
- Tablet PC
- GPS
- Portable Hand-held Devices

Typical Application Circuit

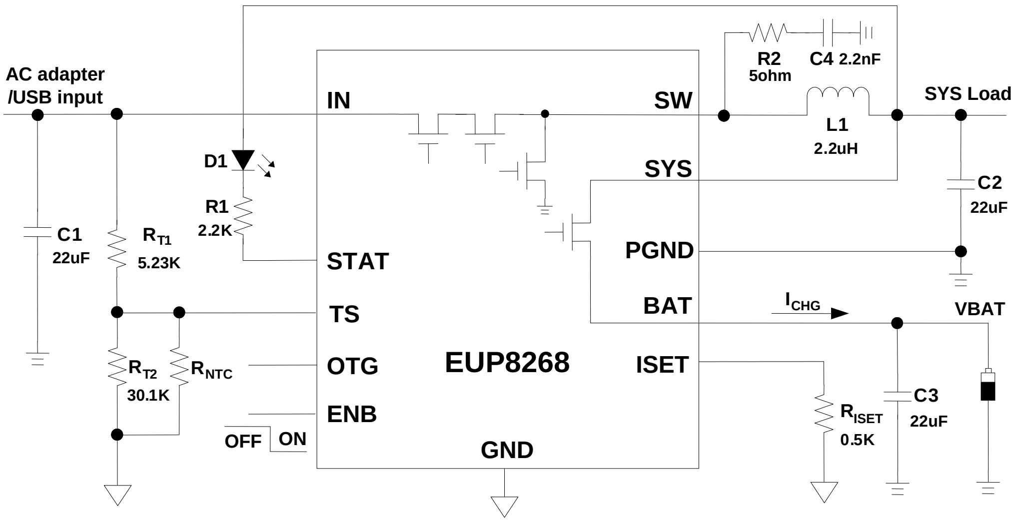
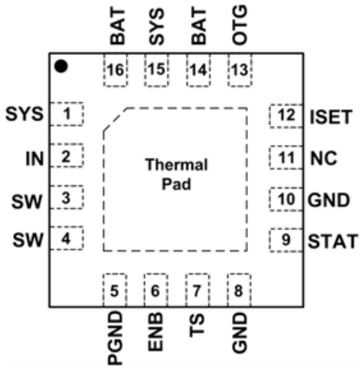


Figure 1.

Pin Configurations

Package Type	Pin Configurations
UQFN-16	(TOP VIEW) 

Pin Description

PIN	UQFN-16	I/O/P	DESCRIPTION
SYS	1,15	I/O/P	DC-DC regulator output to power the system load and charge the battery.
IN	2	I/P	Power input of the IC from adapter or USB.
SW	3,4	O	Switch output.
PGND	5	I/P	Power ground.
ENB	6	I	Active Low Enable pin. Tie this pin low to enable the chip, tie high to disable.
TS	7	I	Thermistor input. Connect this pin to a resistor divider point. The thermistor from this pin to ground. The thermistor is usually inside the battery pack.
GND	8,10	I	Analog ground.
STAT	9	O	Status pin for Charging status indications. Open drain output.
NC	11	-	No connect.
ISET	12	I	Fast charge current pin. Connecting a resistor between ISET and GND to set the fast charge current.
OTG	13	I	Active high enable Boost mode.
BAT	14,16	I/P	Battery terminal.

Ordering Information

Order Number	Package Type	Marking	Quantity per Reel	Operating Temperature Range
EUP8268-42SIR1	UQFN-16	xxxxx P8268	2500	-40°C to +85°C
EUP8268-435SIR1	UQFN-16	xxxxx P8268 AJ	2500	-40°C to +85°C

EUP8268-□□□ □ □ □ □

Lead Free Code
1: Lead Free, Halogen Free

Packing
R: Tape & Reel

Operating temperature range
I: Industry Standard

Package Type
S: UQFN

Output Voltage Option
42: 4.2V
435: 4.35V

Block Diagram

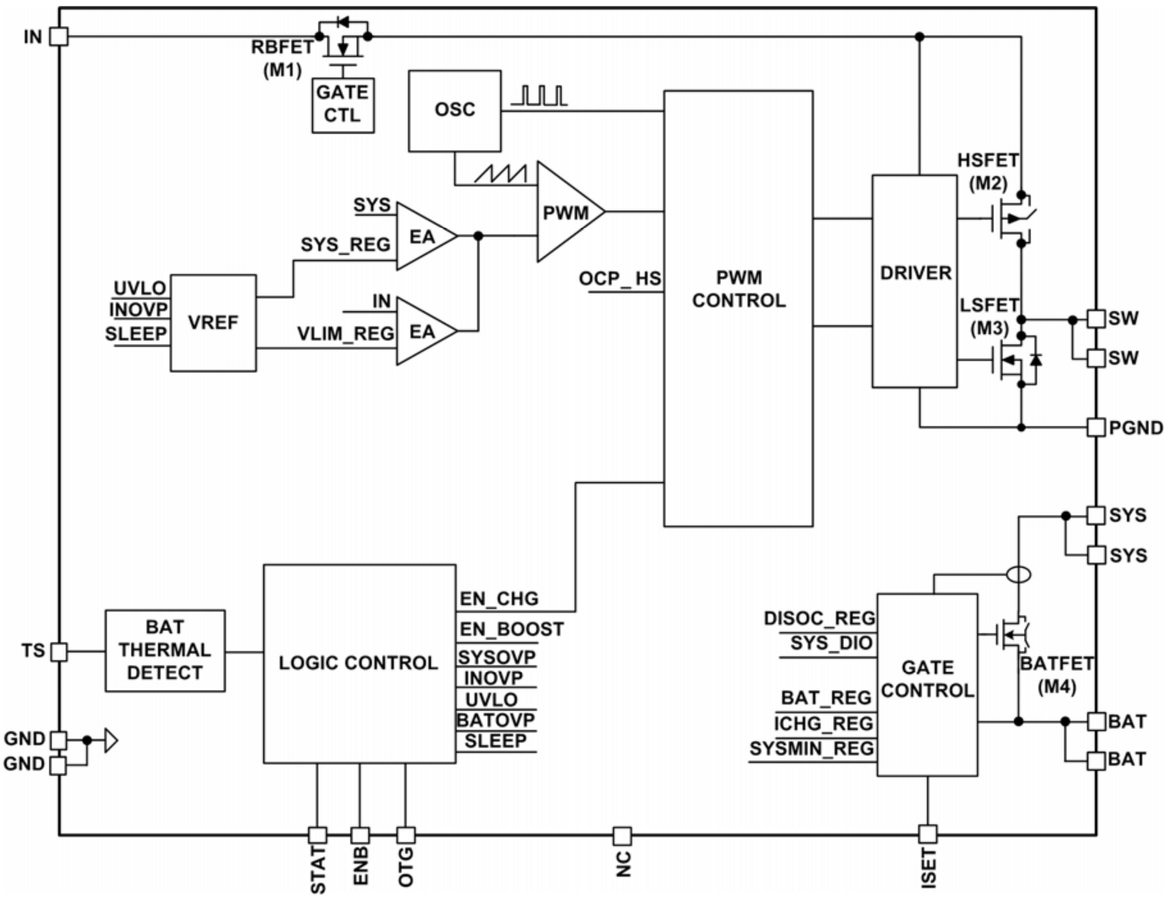


Figure 2

Absolute Maximum Ratings (1)

- IN -- -0.3V to 18V
- SW,ENB,TS,STAT,ISET,OTG,BAT,SYS-- -0.3V to 6V
- PGND,GND--- -0.3V to 0.3V
- Package Thermal Resistance ,UQFN-16, θ_{JA} ---------------------------- 50°C/W
- Junction temperature range, T_J --- 160°C
- Storage temperature range, Tstg --- -65°C to 160°C
- Lead temperature (soldering, 10s) -- 260°C

Recommend Operating Conditions (2)

- Input voltage V_{IN} -- 4.5V to 5.5V
- Charge Current --- 2.5A
- Operating Temperature Range -- -40°C to +85°C

Note (1): Stress beyond those listed under "Absolute Maximum Ratings" may damage the device.
Note (2): The device is not guaranteed to function outside the recommended operating conditions.

Electrical Characteristics

V_{IN}=5V, T_A = 25°C, unless otherwise noted.

Symbol	Parameter	Conditions	EUP8268-42/435			Unit
			Min.	Typ.	Max.	
Input Power						
V_{IN}	IN Operating Range		4.5		5.5	V
V_{UVLO}	IN Under Voltage Threshold	IN Falling		3.95		V
V_{UVLO_HYS}	IN Under Voltage Threshold Hysteresis	IN Rising		390		mV
V_{INOVP}	IN Over Voltage Threshold	IN Rising		5.7		V
V_{INOVP_HYS}	IN Over Voltage Threshold Hysteresis	IN Falling		50		mV
Quiescent Currents						
I_{AC}	Input Supply Current	No Switching		1.5		mA
I_{BAT_LKG}	Battery Leakage Current	SYS Floating, IN Floating, V_{BAT}=4.2V,ENB=0		70		µA
		SYS Floating ,IN Floating, V_{BAT}=4.2V,ENB=5V		20		µA
DC-DC and SYS Output						
V_{SYSREG}	SYS Regulation Voltage Range	V_{BAT}< 3.3V		3.6		V
		V_{BAT}> 3.3V		V_{BAT}+0.3V		V
F_{SW}	Switching Frequency		1.4	1.6	1.8	MHz
V_{SYSOVP}	SYS Over Voltage Threshold	SYS Rising		4.8		V
V_{SYSOVP_HYS}	SYS Over Voltage Threshold Hysteresis	SYS Falling		40		mV
V_{SYSSHT}	SYS Short Voltage Threshold	SYS Falling		2.16		V
V_{SYSSHT_HYS}	SYS Short Voltage Threshold Hysteresis	SYS Rising		180		mV
T_{SHUT}	Thermal Shutdown			160		°C
T_{SHUT_HYS}	Thermal Shutdown Hysteresis			30		°C
I_{HS_OCP}	High side switch peak current limit			5		A

Electrical Characteristics (continued)

V_{IN}=5V, T_A = 25°C, unless otherwise noted.

Symbol	Parameter	Conditions		EUP8268-42/435 Min.	Typ.	Max.	Unit
Input Voltage Limit Regulation							
V_{VLIM}	Input Voltage Limit	Measure on IN			4.5		V
V_{SYSFDB}	System Fold Back Voltage				3.3		V
Power Switch							
R_{ON_HS}	High side MOS On Resistance	IN to SW			100		mΩ
R_{ON_LS}	Low side MOS On Resistance	SW to PGND			60		mΩ
R_{BATFET_ON}	Charge MOS On Resistance	SYS to BAT			50		mΩ
Battery Charger							
V_{BATREG}	Constant Voltage Regulation	T_A= 0°C to 85°C	42	4.158	4.2	4.242	V
			435	4.306	4.35	4.394	V
$I_{FASTCHG}$	Charge Current Setting	R_{ISET}=500Ω			2		A
	Charge current regulation accuracy	V_{BAT}=3.8V, I_{CHG}=2A		-10		10	%
I_{PRECHG}	Pre-Charge Current	Percentage of $I_{FASTCHG}$			10		%
I_{TERM}	Termination current regulation range	Percentage of $I_{FASTCHG}$			10		%
V_{LOWV}	Pre-charge to Fast Charge	Measure on BAT			3		V
V_{LOWV_HYS}	Pre-charge to Fast Charge Hysteresis				200		mV
V_{RECHG}	Recharge Threshold	V_{BATREG}-V_{BAT} , BAT falling			200		mV
V_{BOVP}	Battery Over Voltage Rising Threshold	As percentage of V_{BATREG}			104		%
V_{BOVP_HYS}	Battery Over Voltage Hysteresis	As percentage of V_{BATREG}			2		%
T_{SAFE_PRE}	Pre-charge Safety Timer				60		min
T_{SAFE_FAST}	Fast Charge Safety Timer				780		min
Battery Discharge							
V_{BATDPL}	Battery depletion threshold				2.4		V
V_{BATDPL_HYS}	Battery depletion threshold Hysteresis				200		mV
V_{DIODE}	Discharge Clamp Threshold	V_{BAT}-V_{SYS}			70		mV
Negative Temperature Coefficient Control							
V_{TSH}	TS Cold Threshold	As percentage of V_{IN}		73	76.5	79	%
V_{TSH_HYS}	TS Cold Threshold Hysteresis				1.5		%
V_{TSL}	TS Hot Threshold	As percentage of V_{IN}		33	35	37	%
V_{TSL_HYS}	TS Hot Threshold Hysteresis				1.5		%
V_{TS_DIS}	TS Disable Threshold				100		mV
Logic IO Pin Characteristics							
V_{LGH}	ENB,OTG Logic Input high			1.3			V
V_{LGL}	ENB,OTG Logic Input low					0.4	V
V_{STAT_LO}	STAT Output Low Voltage	I_{STAT}=10mA				0.4	V

Electrical Characteristics (continued)

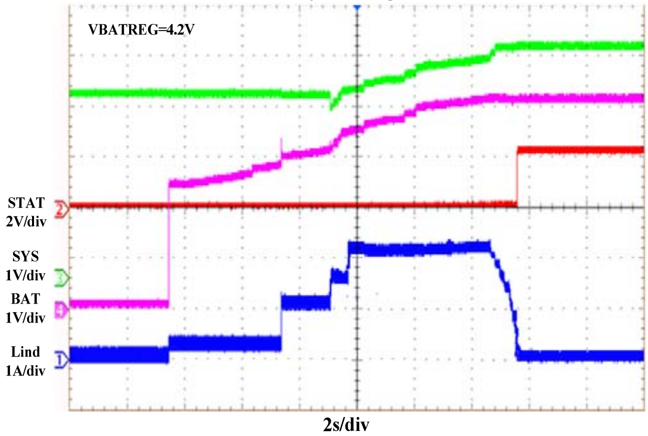
V_{IN}=5V, T_A = 25°C, unless otherwise noted.

Symbol	Parameter	Conditions	EUP8268-42/435			Unit
			Min.	Typ.	Max.	
Boost Mode						
F_{SW_BST}	Switching frequency		1.4	1.6	1.8	MHz
V_{UVLO_BST}	Boost input voltage UVLO	V_{BAT} falling		2.8		V
$V_{UVLO\_BST\_HYS}$	Boost input voltage UVLO hysteresis	V_{BAT} rising		0.2		V
V_{BST_REG}	Boost output voltage accuracy		-3		+3	%
I_{OCP_BST}	Boost low side current limit		4			A
V_{OV_BST}	Boost output over voltage threshold	Boost rising		5.7		V
V_{UV_BST}	Boost output under voltage threshold	Boost falling		3.9		V

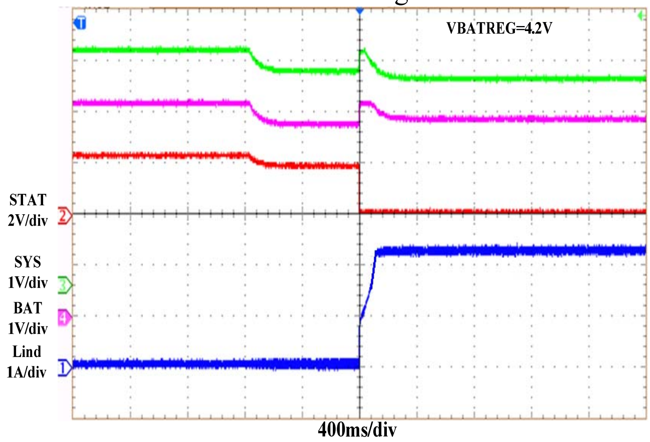
Typical Operating Characteristics

V_{IN}=5V, R_{ISET}=470Ω, VBATREG=4.2V, SYS no load, T_A=25°C, unless otherwise noted.

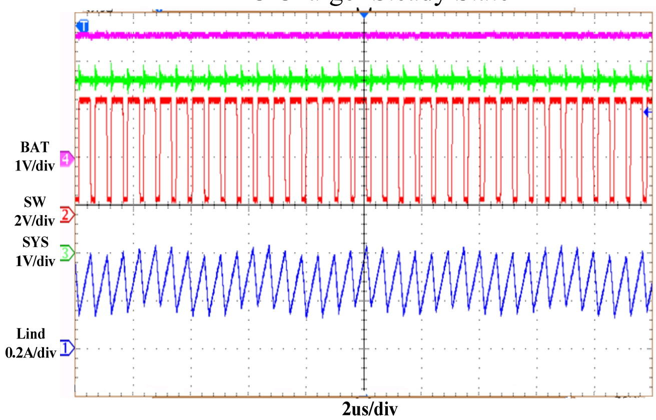
Battery Charger Curve



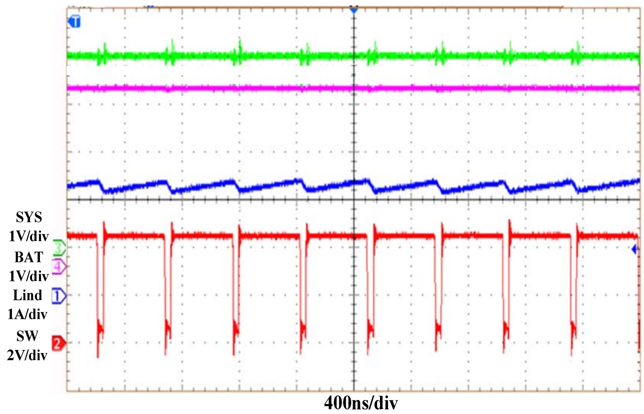
Auto Recharger



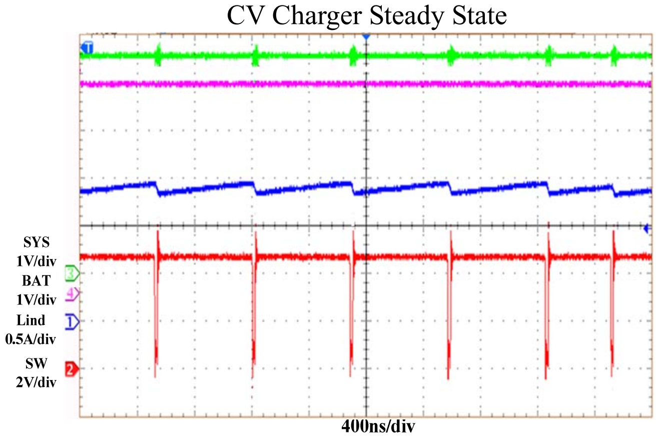
PC Charger Steady State



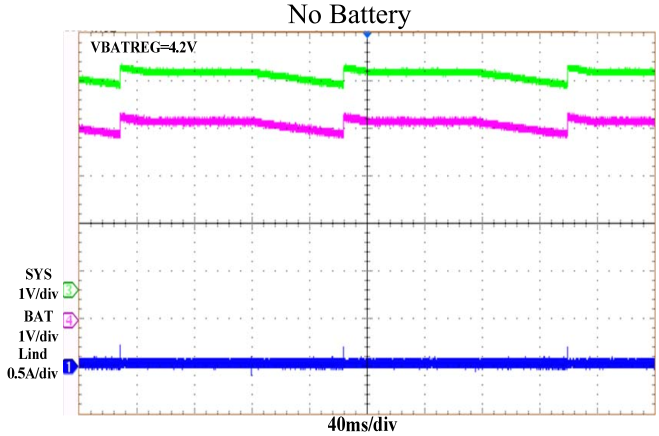
CC Charger Steady State



CV Charger Steady State



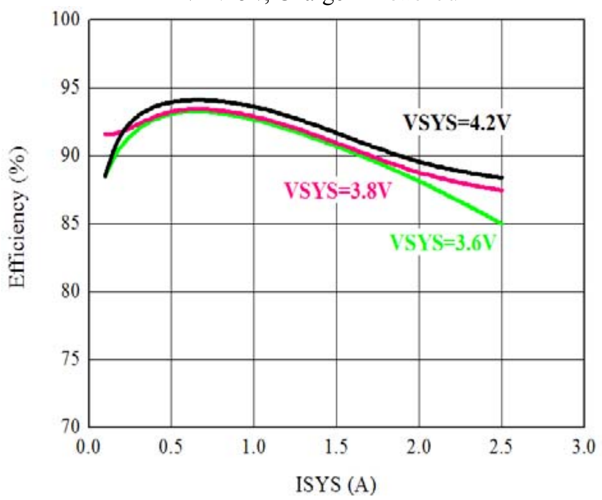
No Battery



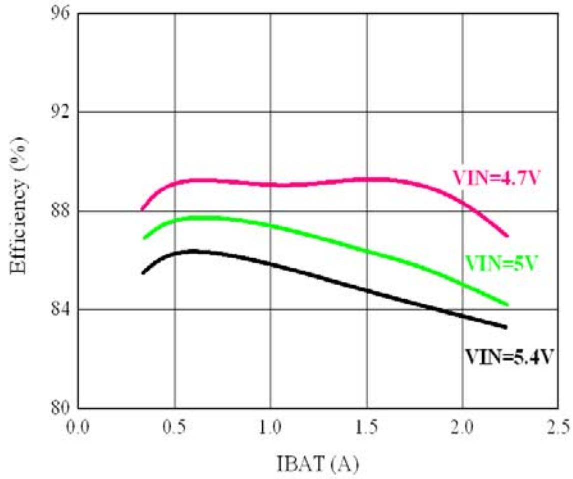
Typical Operating Characteristics（continued）

V_{IN}=5V, R_{ISET}=470Ω, VBATREG=4.2V, SYS no load, T_A=25°C, unless otherwise noted.

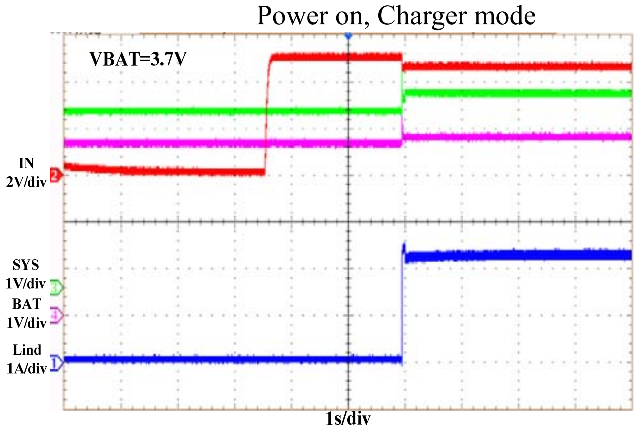
Efficiency vs system current
VIN=5V, Charger Disabled



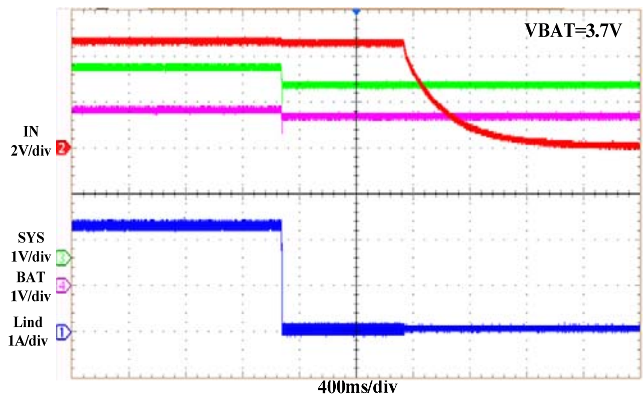
Efficiency vs battery current
VBAT=4.2V



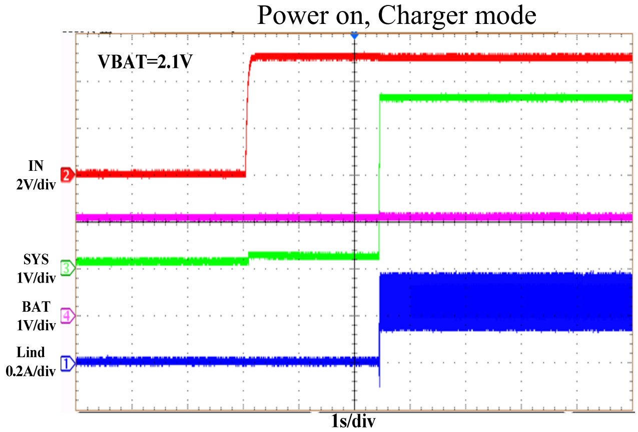
Power on, Charger mode



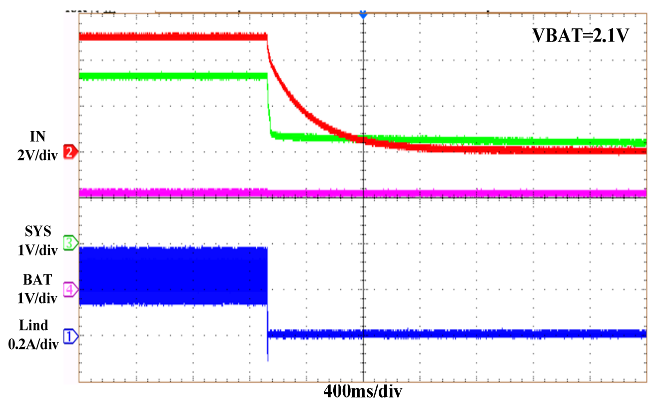
Power off, Charger mode



Power on, Charger mode



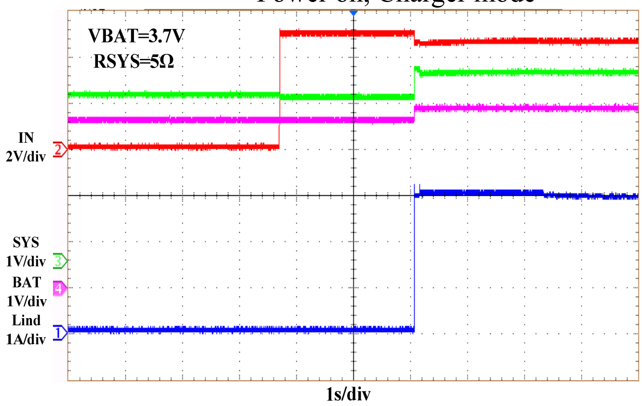
Power off, Charger mod



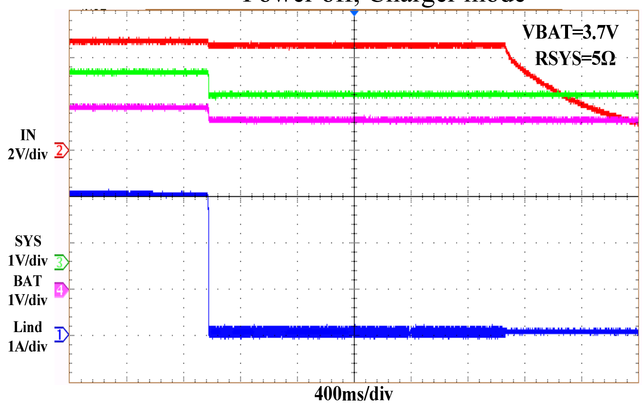
Typical Operating Characteristics（continued）

V_{IN}=5V, R_{ISET}=470Ω, VBATREG=4.2V, SYS no load, T_A=25°C, unless otherwise noted.

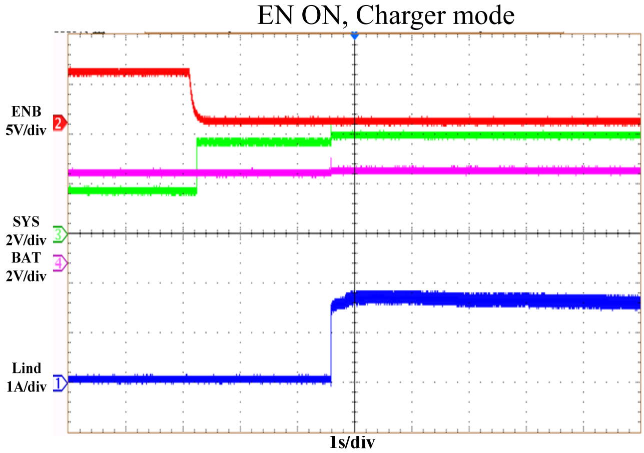
Power on, Charger mode



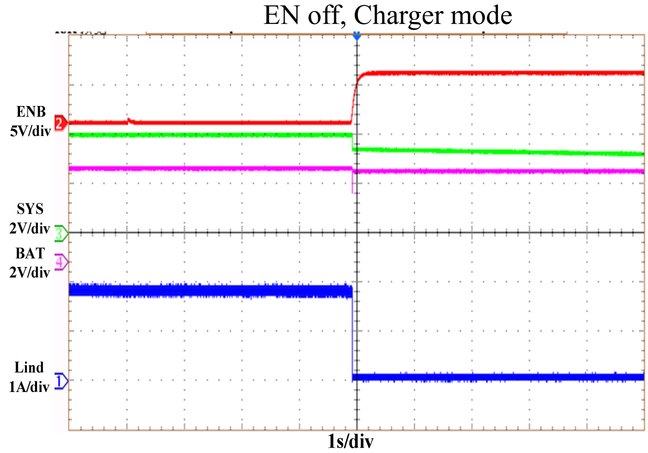
Power off, Charger mode



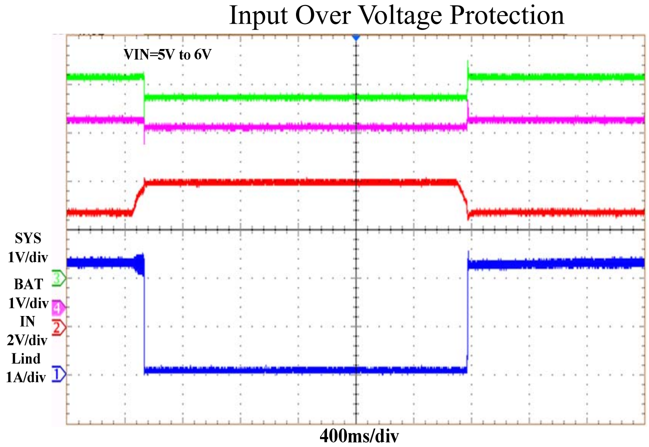
EN ON, Charger mode



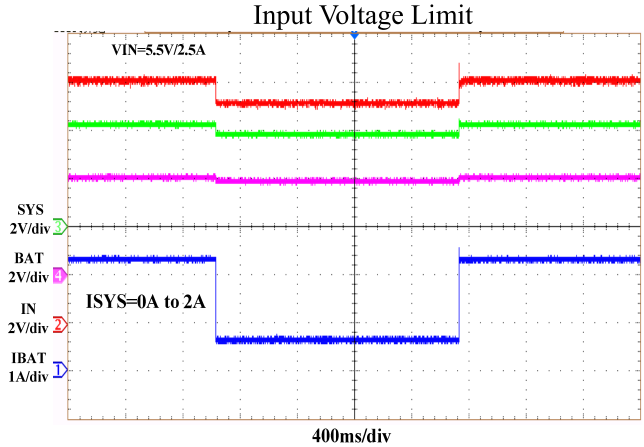
EN off, Charger mode



Input Over Voltage Protection



Input Voltage Limit

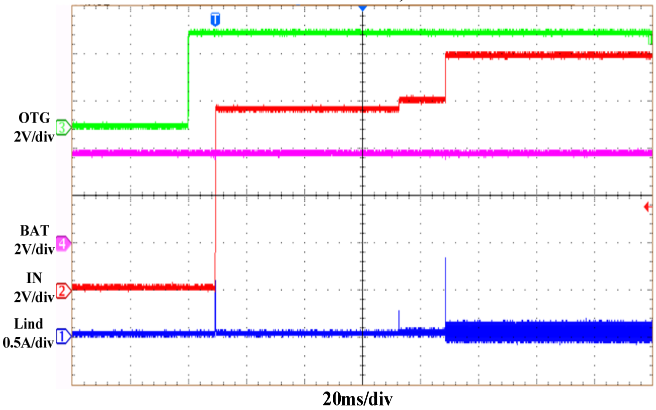


Typical Operating Characteristics（continued）

V_{IN}=5V, R_{ISET}=470Ω, VBATREG=4.2V, SYS no load, T_A=25°C, unless otherwise noted.

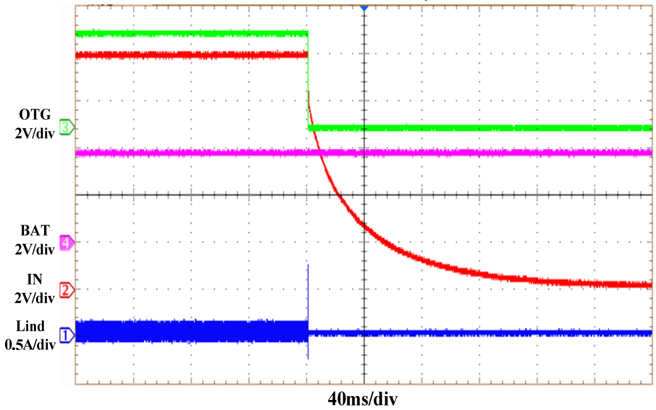
OTG Enable, Boost mode

VBAT=3.7V, no load

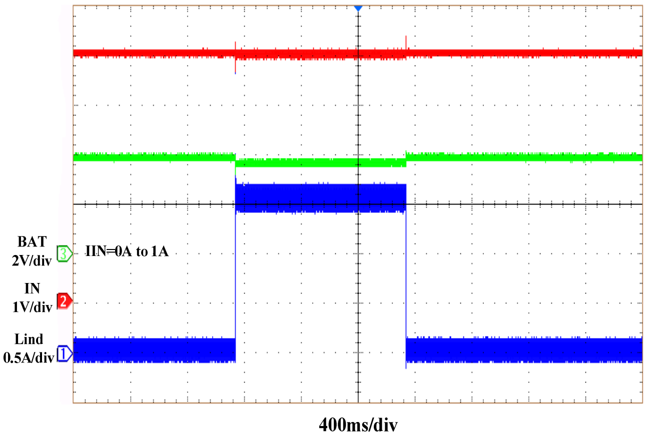


OTG Disable, Boost mode

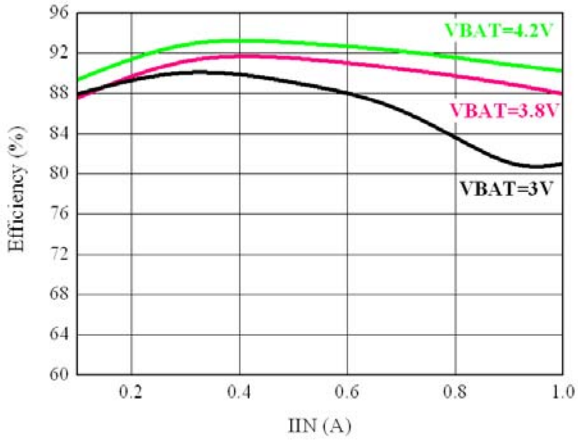
VBAT=3.7V, no load



Boost Output Load Transient



Boost Efficiency



Operational Flow Chart

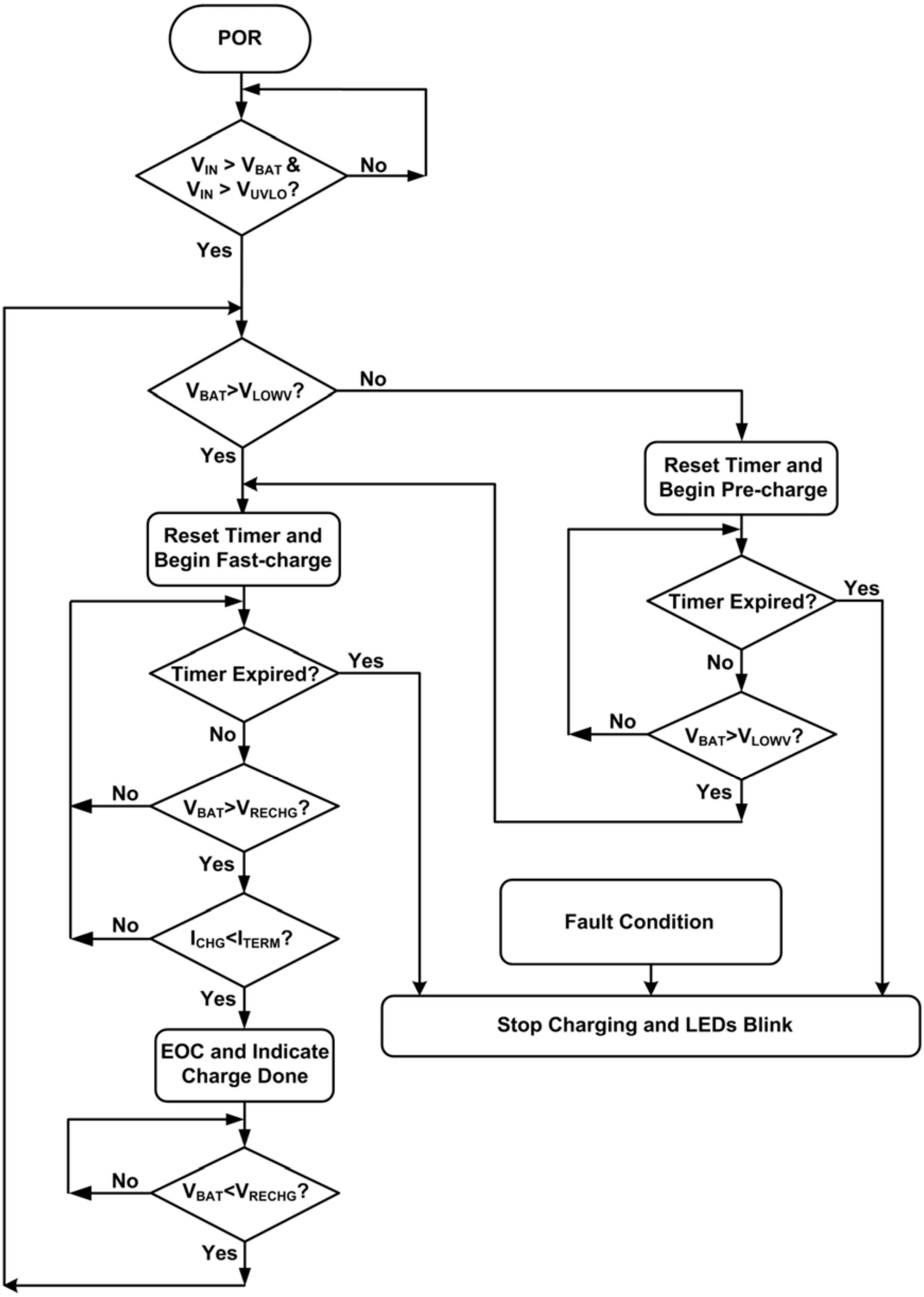


Figure 3.

FUNCTIONAL DESCRIPTION

The EUP8268 is a highly-integrated 2.5A switch-mode battery charge management and system power path management device for single cell Li-Ion and Li-polymer battery. The device deploys a highly efficient 1.6MHz step-down switching regulator. The fixed frequency oscillator keeps tight control of the switching frequency under all conditions. The device provides automatic power path selection to supply the system from input source, battery, or both. The low impedance power path optimizes switch-mode operation efficiency, reduces battery charging time and extends battery life. The EUP8268 also supports USB OTG operation mode by supplying 5V (typical) on IN pin.

Device Power Up

When an input source is plugged in, the device checks if the input voltage is bigger than input UVLO threshold and battery voltage. If input source is appropriate, after 2 second system begin rising at soft start mode. When soft start mode is finished, the device begins charging and the charge current rising gradually.

When input source is absent and battery voltage is bigger than battery depletion threshold, the MOSFET between SYS and BAT is open and system is powered by battery. The device is disabled when ENB is high.

Buck Converter Control

The device deploys Narrow VDC architecture (NVDC) with BATFET separating system from battery. When the battery is below minimum system voltage (3.3V) the BATFET operates in linear mode and the system is regulated at 3.6V. As the battery voltage rises above the minimum system voltage, BATFET is turn on gradually and the voltage difference between the system and battery is regulated at 300mV.

Dynamic Path Management (DPM)

The device provides automatic power path selection to supply the system from input source, battery, or both.

To avoid over loading the input source, the device features Dynamic Power Management (DPM), which continuously monitors input voltage. When input source is over-loaded or the voltage falls below the input voltage limit. The device then reduces the charge current until the input voltage rises above the input voltage limit.

When the charge current is reduced to zero, but the input source is still overloaded, the system voltage starts to drop. Once the system voltage falls below the battery voltage, the device automatically enters the Supplement Mode where the BATFET turns on and battery starts discharging so that the system is supported from both the input source and battery.

Supplement Mode

When the system voltage falls below the battery voltage, the BATFET turns on and the BATFET gate is regulated by the gate drive of BATFET so that the minimum BATFET VDS when the current is low. As the discharge current increases, the BATFET gate is regulated with a higher voltage to reduce RDSON until the BATFET is in full conduction. At this point onwards, the BATFET VDS linearly increases with discharge current. BATFET turns off to exit Supplement Mode when the battery is below battery depletion threshold.

Battery Charging Management

The device charges 1-cell Li-Ion battery with up to 2.5A charge current for high capacity battery. The low resistant BATFET improves charging efficiency and minimize the voltage drop during discharging.

The device charges the battery in three phases: preconditioning, constant current and constant voltage.

The charger device automatically terminates the charging cycle when the charging current is below termination threshold and charge voltage is above recharge threshold. When a full battery voltage is discharged below recharge threshold, the device automatically starts a new charging cycle.

The STAT output indicates the charging status of charging, charging complete or charge disable or charging fault.

Battery Precondition Current Regulation (PC)

A new charging cycle begins with the precondition state, and exits this state when battery voltage exceeds the precondition threshold voltage. When operating in precondition state, the cell is charged at pre-charge current. Once battery voltage reaches the precondition threshold voltage the charge state jumps to the fast charge state.

Battery Fast Current Regulation (CC)

If battery voltage is above preconditioning threshold, the device charges battery with constant current. In fast charge state, the device charges at the current set by the external resistor connected at the ISET pin. During a normal charge cycle fast charge continues in fast current mode until VBAT reaches the charge termination voltage, at which point the device charges in constant voltage state. The equation for charge current is:

$$I_{CC}(A) = \frac{1}{R_{ISET}(K\Omega)}$$

Constant Voltage Regulation (CV)

With the battery voltage approaches the constant voltage. Charge current decreases as charging continues. The cell is charged in constant voltage (CV) mode. During a normal charging cycle charging proceeds until the charge current decreases below termination current.

Charging Termination (EOC)

The device terminates a charge cycle when the battery voltage is above recharge threshold, and the current is below termination current. After the charging cycle is completed, the BATFET turns off. The converter keeps running to power the system, and BATFET can turn on again to engage Supplement Mode.

Recharge

When battery voltage discharged below recharge threshold, the device automatically starts a new charging cycle. The charger is reinitiated with constant current charge.

Boost Mode Operation

EUP8268 operates at 1.6 MHz for boost converter allowing tiny external inductor and capacitors. In OTG mode, the boost converter outputs 5V (typical) voltage on IN pin. And the boost operation can be enabled if the following conditions are valid:

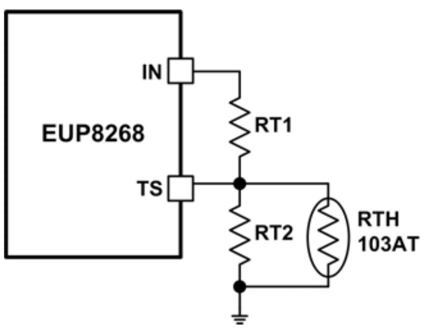
1. BAT above V_{UVLO_BST}
2. VIN less than BAT+50mV (typical)
3. OTG pin = high
4. No happening TS fault and V_{OV_BST} fault

When the VIN voltage rises above regulation target and exceeds V_{OV_BST}, the device enters over voltage protection and stops switching.

In boost mode the VIN voltage should drop as the load increases. If VIN voltage drops below 3.9V, the boost converter will turn off for 2s and then attempt to restart.

Battery Temperature Monitoring (TS-FAULT)

The controller continuously monitors battery temperature by measuring the voltage between the TS pin and GND. A negative temperature coefficient thermistor (NTC) and an external voltage divider typically develop this voltage. The controller compares this voltage against its internal thresholds to determine if charging is allowed.



To initiate a charge cycle, the battery temperature must be within the VTSH to VTSL thresholds. If battery temperature is outside of this range, the controller suspends charge and waits until the battery temperature is within the VTSH to VTSL range. During the charge cycle the battery temperature must be within the VTSH to VTSL threshold. If battery temperature is outside of this range, the controller suspends charge and waits until the battery temperature is within the VTSH to VTSL range. The controller suspends charge by turning off the charge MOSFETs.

Assuming a 103AT NTC thermistor on the battery pack as shown in Figure 4, the values of RT1 and RT2 can be determined by using following equations.

$$TL = \frac{V_{TSH}}{V_{IN}} = \frac{R_{T2} \,//\, RTH_{COLD}}{R_{T1} + R_{T2} \,//\, RTH_{COLD}} = 76.5\%$$

$$TH = \frac{V_{TSL}}{V_{IN}} = \frac{R_{T2} \,//\, RTH_{HOT}}{R_{T1} + R_{T2} \,//\, RTH_{HOT}} = 35\%$$

$$RT1 = \frac{RTH_{HOT} \times RTH_{COLD} \times (TL - TH)}{TL \times TH \times (RTH_{COLD} - RTH_{HOT})}$$

$$RT2 = \frac{RTH_{HOT} \times RTH_{COLD} \times (TL - TH)}{(1-TL) \times TH \times RTH_{COLD} - (1-TH) \times TL \times RTH_{COLD}}$$

Select 0°C to 60°C range for Li-ion or Li-polyme battery,

$RTH_{COLD} = 27.28k\Omega$

$RTH_{HOT} = 3.02k\Omega$

RT1 = 5.23kΩ

RT2 = 41.2kΩ-

After select closest standard resistor value, by calculating the thermistor resistance at temperature threshold, the final temperature range can be gotten from thermistor datasheet temperature-resistance table.

Safety Timers (TIME FAULT)

As a safety backup, the charger also provides an internal fixed 60 minutes pre-charge safety timer and an internal fixed 780 minutes fast charge safety timer. When the charging time is reached, the set safety timer stops charging and LED blinking. Input voltage reset will also clear the fault.

Charging Status Indicator (STAT)

The device indicates charging state on the open drain STAT pin. The STAT pin can drive LED as shown in table1.

Table1. Charger Status Indication

STAT	Charger Status
Low	In charging, Supplement mode
High	End of charge, ENB disable, IN absent
Blinking(0.75Hz)	Fault (TS-FAULT, TIME FAULT, SYSSHT, BATOVP)

Thermal Shutdown Protection (OTP)

The TQFN package has low thermal impedance, which provides good thermal conduction from the silicon to the ambient, to keep junctions temperatures low. As added level of protection, the charger converter turns off and self-protects whenever the junction temperature exceeds the TSHUT threshold of 160°C. The charger will charge when the junction temperature falls below 130°C.

Input Over Voltage Protection (INOVP)

The converter enters input over voltage mode when the input voltage goes above input over voltage threshold. Charger stops charging in input over voltage condition. The charger will charge again when converter exits input over voltage mode.

System Over Voltage Protection (SYSOVP)

The charger device clamps the system voltage during load transient so that the components connect to system would not be damaged due to high voltage. When SYSOVP is detected, the converter stops immediately to clamp the overshoot.

System Short Protection (SYSSHT)

When input is present, system voltage goes below system short threshold. The charger stops charging and is latch-up. It will charge again until input power on.
When input is absent, system voltage goes below system short threshold. The BATFET is shut down. Battery will discharge to system again until input power on or battery inserts again.

Buck Over Current Protection (OCPHS)

The charger monitors top side MOSFET current by high side sense MOSFET. When the system is shorted or significantly overloaded so that the current exceeds the over current limit, it will turn off the top side MOSFET and automatically resumes when the current falls below the over-current threshold.
If peak current exceeds high side MOSFET limit and keeps for 5ms, high-side MOSFET will turn off until power on.

Battery Over Voltage Protection (BATOVP)

The converter enters battery over voltage mode when the battery voltage goes above battery over voltage threshold. Charger stops charging in battery over voltage condition and LED indicates blinking. The charger will charge again when converter exits battery over voltage mode.

Battery Over Discharge Protection (BATDPL)

When battery is discharged below battery depletion threshold, the BATFET is turned off to protect battery from over discharge. To recover from over discharge, an input source is required at IN. When an input source is plugged in, the BATFET turns on. Battery is charged with pre-charge current.

APPLICATION INFORMATION

Inductor Selection

The device has 1.6 MHz switching frequency to allow the use of small inductor and capacitor values. The Inductor saturation current should be higher than the charging current (I_{CHG}) plus half the ripple current (I_{RIPPLE}):

$$I_{SAT} \geq I_{CHG} + (1/2)I_{RIPPLE}$$

The inductor ripple current depends on input voltage (V_{IN}), duty cycle ($D = V_{BAT}/V_{IN}$), switching frequency (fs) and inductance (L):

$$I_{RIPPLE} = \frac{V_{IN} \times D \times (1-D)}{fs \times L}$$

The maximum inductor ripple current happens with D = 0.5 or close to 0.5. Usually inductor ripple is designed in the range of (20–40%) maximum charging current as a trade-off between inductor size and efficiency for a practical design.

Buck Input Capacitor

Input capacitor should have enough ripple current rating to absorb input switching ripple current. The worst case RMS ripple current is half of the charging current when duty cycle is 0.5. If the converter does not operate at 50% duty cycle, then the worst case capacitor RMS current I_{IN} occurs where the duty cycle is closest to 50% and can be estimated:

$$I_{IN} = I_{CHG} \times \sqrt{D \times (1-D)}$$

Low ESR ceramic capacitor such as X7R or X5R is preferred for input decoupling capacitor and should be placed to the drain of the high side MOSFET and source of the low side MOSFET as close as possible. Voltage rating of the capacitor must be higher than normal input voltage level. 25V rating or higher capacitor is preferred for up to 20V input voltage. 22µF capacitance is suggested for typical of 0.5A-2.0A charging current.

System Output Capacitor

Output capacitor also should have enough ripple current rating to absorb output switching ripple current. The output capacitor RMS current I_{CSYS} is given:

$$I_{CSYS} = \frac{I_{RIPPLE}}{2\sqrt{3}} \approx 0.29 \times I_{RIPPLE}$$

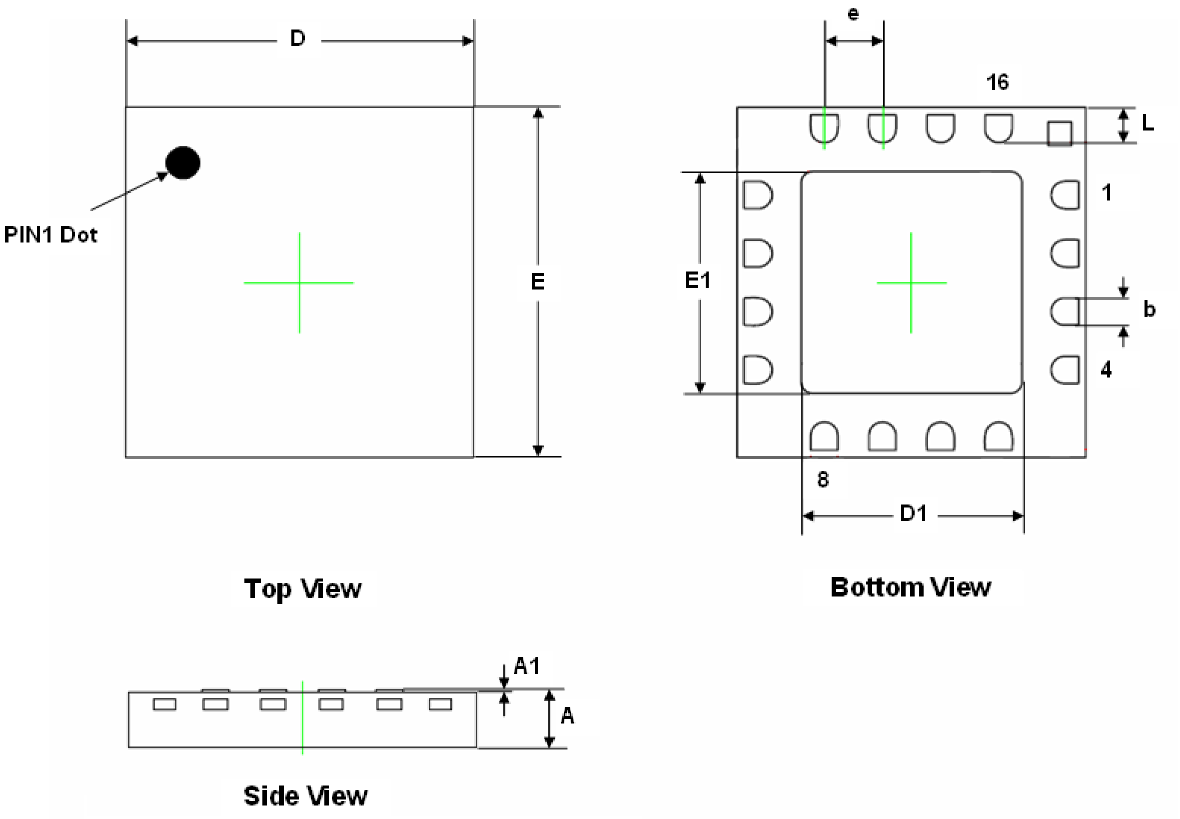
The output capacitor voltage ripple can be calculated as follows:

$$\Delta V_O = \frac{V_{SYS}}{8LC_{SYS}fs^2}\left(1 - \frac{V_{SYS}}{V_{IN}}\right)$$

At certain input/output voltage and switching frequency, the voltage ripple can be reduced by increasing the output filter LC. The charger device has internal loop compensator. To get good loop stability, 2.2µH and minimum of 22µF output capacitor is recommended. The preferred ceramic capacitor is 6V or higher rating, X7R or X5R.

Packaging Information

UQFN-16



Note: The exposed pad outline drawing is for reference only.

SYMBOLS	MILLIMETERS			INCHES		
	MIN.	Normal	MAX.	MIN.	Normal	MAX.
A	0.50	0.55	0.60	0.020	0.022	0.024
A1	0.00	-	0.05	0.000	-	0.002
b	0.20	-	0.35	0.008	-	0.014
D	2.90	3.00	3.10	0.114	0.118	0.122
D1	1.80	1.90	2.00	0.070	0.075	0.080
E	2.90	3.00	3.10	0.114	0.118	0.122
E1	1.80	1.90	2.00	0.070	0.075	0.080
e	0.50 REF			0.020 REF		
L	0.25	0.30	0.35	0.010	0.012	0.014