The Future of Analog IC Technology®

MP2626

USB-Compliant Single Cell Li-ion Switching Charger with USB-OTG Boost

DESCRIPTION

The MP2626 is a highly-integrated, flexible, switch-mode battery charger with system power management, designed for single-cell Li-ion and Li-Polymer batteries used in a wide range of portable applications.

The MP2626 can operate in both charge mode and boost mode to allow full system and battery power management. It is also able to work as a boost regulator to power a USB peripheral from the battery.

The MP2626 automatically detects the battery voltage and charges the battery in the three phases: trickle current charge, constant current charge and constant voltage charge. Other features include charge termination and auto-recharge. This IC also integrates both input-current limit and input-voltage regulation in order to ensure USB compliant and minimize the charging time.

The MP2626 can operate as a boost regulator by setting the MODE pin to a HIGH logic. The boost regulator includes output current limit and short circuit protection. As long as MODE pin is high, the MP2626 will discharge the battery in the boost mode.

To guarantee safe operation, the MP2626 limits the die temperature to a preset value of 120^{o}C. Other safety features include input over-voltage protection, battery over-voltage protection, thermal shutdown, battery temperature monitoring, and a programmable timer to prevent prolonged charging of a dead battery.

FEATURES

- 20V Absolute Maximum Input Voltage
- 6V Maximum Input Operating Voltage
- Selectable 4.2V/ 4.35V Charge Voltage with 0.5% Accuracy at 25ºC
- Power Management Function
  Integrated Input-Current Limit and Input-Voltage Regulation
- Up to 2A Programmable Charge Current
- Trickle-Charge Function
- Negative Temperature Coefficient Pin for Battery Temperature Monitoring
- Programmable Timer Back-Up Protection
- Thermal Regulation and Thermal Shutdown
- Internal Battery Reverse Leakage Blocking
- Reverse Boost Operation Mode for USB Peripheral
- Up to 91% 5V Boost Mode Efficiency @ 1A
- Programmable Output Current Limit for Boost Mode
- Integrated Short Circuit Protection for Boost Mode

APPLICATIONS

- Sub-Battery Application
- Power-Bank Applications for Smart-Phone Tablet and other Portable Device

TYPICAL APPLICATION

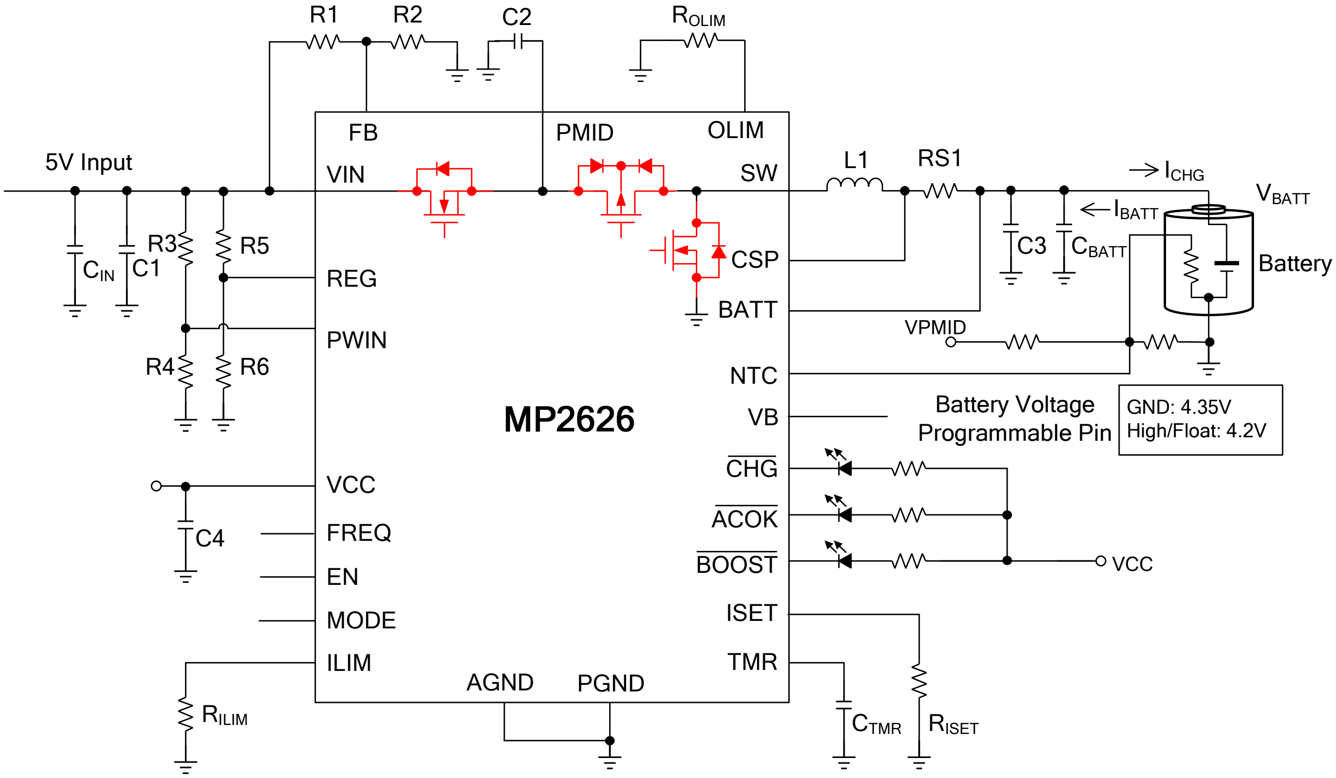


Table 1: Operation Mode

MODE	EN	$\overline{\text{ACOK}}$	Operating Mode
Low	High	Low	Charge Mode, Enable Charging
	Low		Sleep Mode
High	X	High	Boost Mode

X=Don't Care.

ORDERING INFORMATION

Part Number*	Package	Top Marking
MP2626GR	QFN-24 (4mm×4mm)	*See Below*

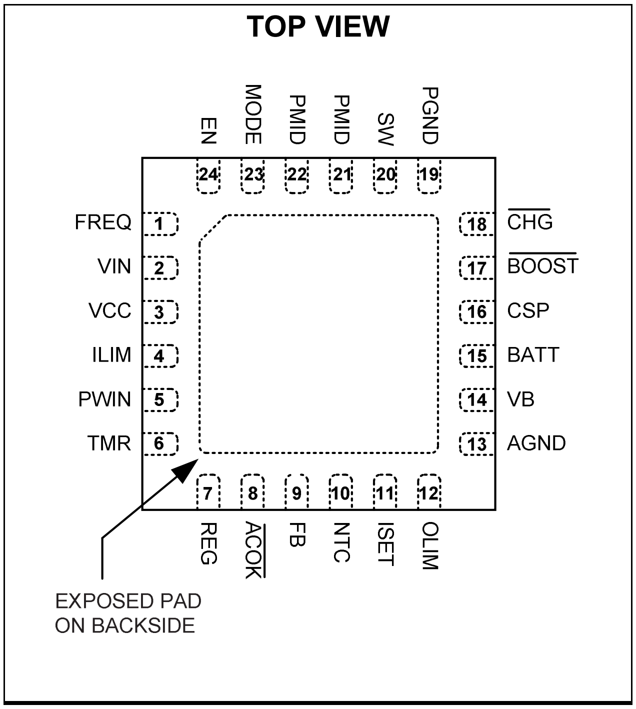
*For Tape & Reel, add suffix – Z (e.g. MP2626GR-Z);

TOP MARKING

MPSYWW
MP2626
LLLLLL

MPS: MPS prefix;
Y: year code;
WW: week code:
MP2626: product code of MP2626GR;
LLLLLL: lot number;

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS (1)

VIN	–0.3V to 20V
SW	–0.3V (-2V for <10ns) to 6.5V (8.5V for <20ns)
PMID, BATT	–0.3V to 6.5V
ACOK, CHG, BOOST	–0.3V to 6.5V
All Other Pins	–0.3V to 6.5V
Junction Temperature	150°C
Lead Temperature	260°C
Continuous Power Dissipation (T_A = +25°C) **(2)**	2.97W
Junction Temperature	150°C
Operating Temperature	–20°C to +85°C

Recommended Operating Conditions (3)

Supply Voltage VIN	4.5V to 6V
Battery Voltage V_{OUT}	2.5V to 4.35V
Operating Junction Temp. (T_J)	−40°C to +125°C

Thermal Resistance (4)	θ_{JA}	θ_{JC}	
QFN-24 (4mm×4mm)	42	9	°C/W

Notes:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX)-T_A)/θ_{JA}. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

V_{IN} = 5.0V, T_A = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
VIN to PMID NMOS ON Resistance	$R_{IN\ to\ PMID}$			100		mΩ
High-side PMOS ON Resistance	$R_{H\ DS}$			72		mΩ
Low-side NMOS ON Resistance	$R_{L\ DS}$			70		mΩ
High-Side PMOS Peak Current Limit	I_{PEAK_HS}	CC Charge Mode/Boost Mode		4.5		A
		TC Charge Mode		1.5		A
Low-Side NMOS Peak Current Limit	I_{PEAK_LS}			4.5		A
Switching Frequency	f_{SW}	FREQ = 0		600		kHz
		FREQ = Float/ High		1200		
VCC UVLO	$V_{CC\ UVLO}$		2	2.2	2.4	V
VCC UVLO Hysteresis				100		mV
PWIN, Lower Threshold	$V_{PWIN\ L}$		0.75	0.8	0.85	V
Lower Threshold Hysteresis				50		mV
PWIN, Upper Threshold	$V_{PWIN\ H}$		1.1	1.15	1.2	V
Upper Threshold Hysteresis				50		mV
Charge Mode						
Input Quiescent Current	I_{IN}	EN = 5V, Battery Float			2.5	mA
		EN = 0			1.5	mA
Input Current Limit	I_{IN_LIMIT}	R_{ILIM} = 90.9kΩ	400	450	500	mA
		R_{ILIM} = 49.9kΩ	720	810	900	
		R_{ILIM} = 20kΩ	1800	2000	2200	
Input Over-Current Threshold	$I_{IN(OCP)}$			3		A
Input Over-Current Blanking Time(5)	$\tau_{INOCBLK}$			120		μs
Input Over-Current Recovery Time(5)	$\tau_{INRECVR}$			100		ms
Terminal Battery Voltage	V_{BATT_FULL}	Leave VB floating or connect to logic HIGH	4.179	4.200	4.221	V
		Connect VB to GND	4.328	4.350	4.372	
Recharge Threshold	V_{RECH}	Leave VB floating or connect to logic HIGH	3.950	4.015	4.080	V
		Connect to VB to GND	4.091	4.157	4.223	
Recharge Threshold Hysteresis				250		mV
Battery Over Voltage Threshold				103.3%		$V_{BATT\ FULL}$
Constant Charge (CC) Current	I_{CC}	RS1=40mΩ, R_{ISET} = 69.8kΩ	900	1000	1100	mA
		RS1=40mΩ, R_{ISET} = 46.4kΩ	1350	1500	1650	
Trickle-Charge Current	I_{TC}			250		mA

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 5.0V, T_A = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Trickle-Charge Voltage Threshold	V_{BATT_TC}	Leave VB floating or connect to high logic	2.860	2.960	3.060	V
		Connect to VB to GND	2.970	3.070	3.170	
Trickle-Charge Hysteresis				200		mV
Termination Charge Current	I_{BF}	RS1=40mΩ, R_{ISET}=69.8kΩ	2.5%	10%	17.5%	I_{CC}
Input-Voltage-Regulation Reference	V_{REG}		1.18	1.2	1.22	V
Boost Mode						
IN Voltage Range			4.2		6	V
Feedback Voltage			1.18	1.2	1.22	V
Feedback Input Current		V_{FB}=1V			200	nA
Boost Over-Voltage Protection Threshold	$V_{IN(OVP)}$)	Threshold to turn off the converter during boost mode	5.8	6	6.2	V
Boost Over-Voltage Protection Threshold Hysteresis		V_{IN} falling from $V_{IN(OVP)}$		125		mV
Boost Quiescent Current		I_{IN} = 0A, MODE = 5V			2.0	mA
Programmable Boost Output Current Limit Accuracy	I_{OLIM}	RS1 = 40mΩ, R_{OLIM} = 100kΩ	0.896	1.120	1.344	A
Programmable Boost Output Current(5)		RS1 = 50mΩ, R_{OLIM}=49.9kΩ V_{BATT} = 4.2V	1.52			A
Boost Over-Current Blanking Time(5)	$\tau_{OUTOCBLK}$			120		µs
Boost Over-Current Recovery Time(5)	$\tau_{OUTRECVR}$			1		ms
Weak-Battery Threshold	$V_{BATT(LOW)}$	During Boost mode		2.5		V
		Before Boost mode		2.9	3.05	V
Sleep Mode						
Battery Leakage Current	$I_{LEAKAGE}$	V_{BATT} = 4.2V, V_{IN}= 0V, MODE = 0V		15	30	µA
Indication and Logic						
$\overline{\text{ACOK}}$, $\overline{\text{CHG}}$, $\overline{\text{BOOST}}$ pin output low voltage		Sinking 1.5mA			400	mV
$\overline{\text{ACOK}}$, $\overline{\text{CHG}}$, $\overline{\text{BOOST}}$ pin leakage current		Connected to 5V			1	µA
NTC and Time-Out Fault Blinking Frequency(5)	f_{BLK}	C_{TMR}=0.1µF, ***I_{CHG}=1A***		13.7		Hz
EN Input Logic LOW Voltage					0.4	V
EN Input High Voltage			1.4			V
Mode Input Logic LOW Voltage					0.4	V
Mode Input Logic HIGH Voltage			1.4			V

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 5.0V, T_A = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Protection						
Trickle-Charge Time		C_{TMR}=0.1μF, remains in TC mode, I_{TC}= ***0.25A***		16.6		Min
Total Charge Time		C_{TMR}=0.1μF, I_{CHG}= 1A		400		Min
NTC Low Temp, Rising Threshold		R_{NTC}=NCP18XH103(0°C)	65.3%	66.3%	67.3%	V_{PMID}
NTC Low Temp, Rising Threshold Hysteresis				1%		
NTC High Temp, Rising Threshold		R_{NTC}=NCP18XH103(50°C)	34%	35%	36%	
NTC High Temp, Rising Threshold Hysteresis				1%		
Charging Current Fold-back Threshold(5)		Charge Mode		120		°C
Thermal Shutdown Threshold(5)				150		°C

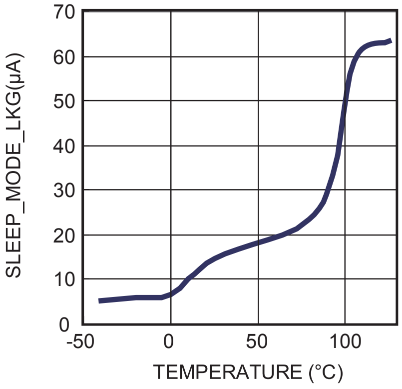
Notes:

5) Guaranteed by design.

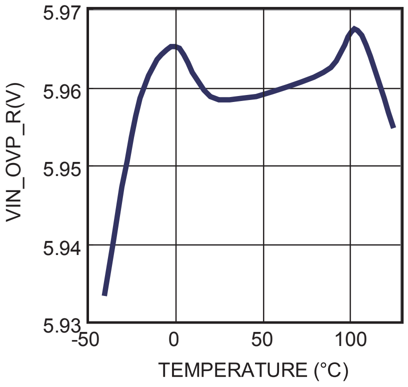
TYPICAL CHARACTERISTICS

C_{IN}=C_{BATT}=C_{PMID}=C3=22μF, C1=C2=1μF, L1=4.7μH, RS1=50mΩ, C4=C_{TMR}=0.1μF, Battery Simulator, unless otherwise noted.

Sleep_Mode_Battery Current vs. Temperature

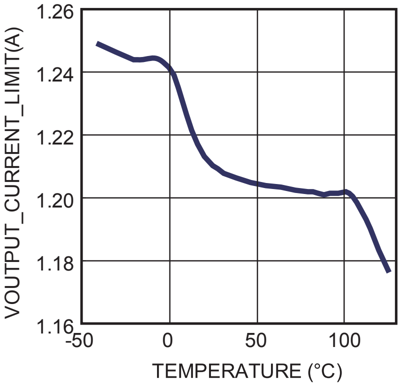


VIN_OVP vs. Temperature



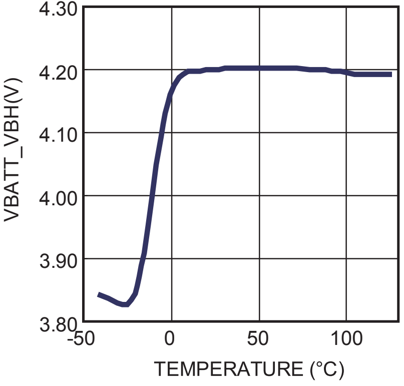
Output_Current_Limit_1.2A vs. Temperature

R_{OLIM}=73.2kΩ



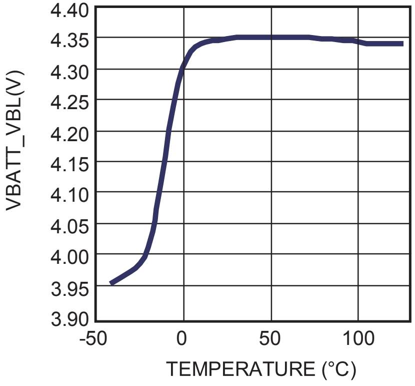
BATT_full VBH vs. Temperature

BATT_full V_{BH} = 4.2V

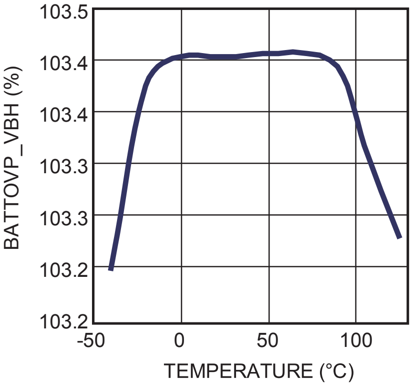


Batt_full VBL vs. Temperature

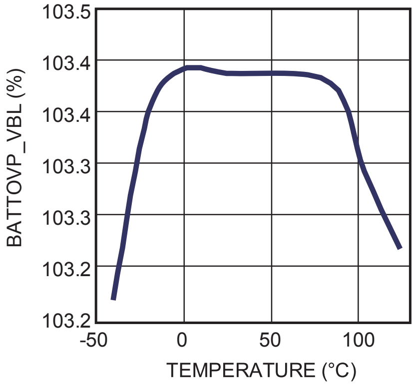
BATT_full V_{BL} = 4.35V



BATTOVP_VBH_% vs. Temperature



BATTOVP_VBL_% vs. Temperature

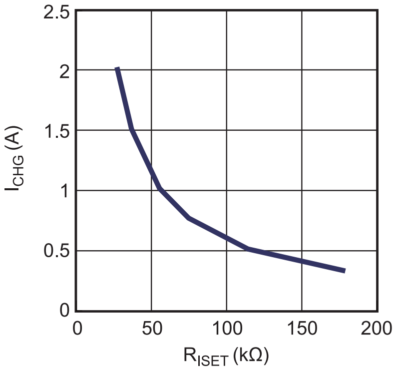


TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN}=5V, C_{IN}=C_{BATT}=C_{PMID}=C3=22µF, C1=C2=1µF, L1=4.7µH, RS1=50mΩ, C4=C_{TMR}=0.1µF, Battery Simulator, unless otherwise noted.

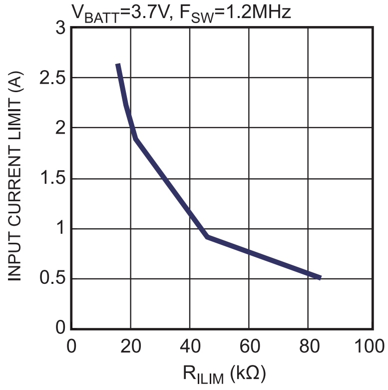
Programmable Charge Current, Charge Mode

V_{IN}=5V, V_{BATT_FULL}=4.2V, V_{BATT}=3.7V, F_{SW}=1.2MHz



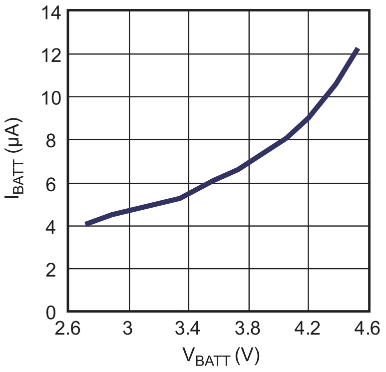
Programmable Input Current Limit, Charge Mode

V_{IN}=5V, V_{BATT_FULL}=4.2V, V_{BATT}=3.7V, F_{SW}=1.2MHz



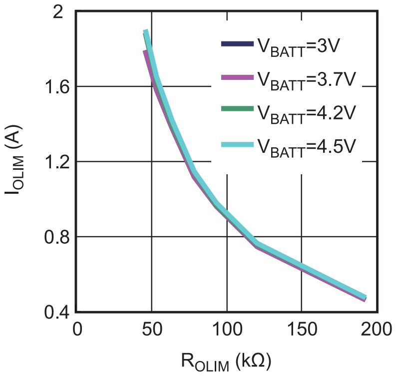
Battery Leakage Current, Sleep Mode

MODE=Low



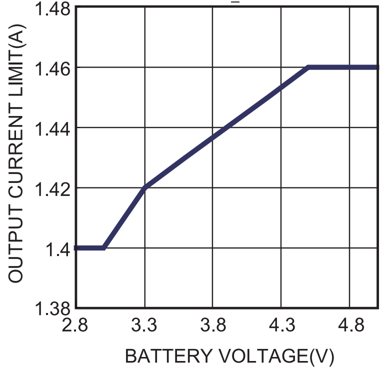
Programmable Output Current Limit, Boost Mode

F_{SW}=1.2MHz, V_{IN_SET}=5V

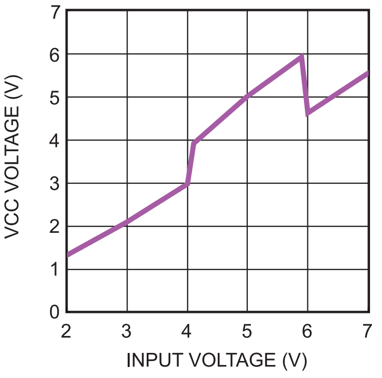


Programmable Output Current Limit vs. Battery, Boost Mode

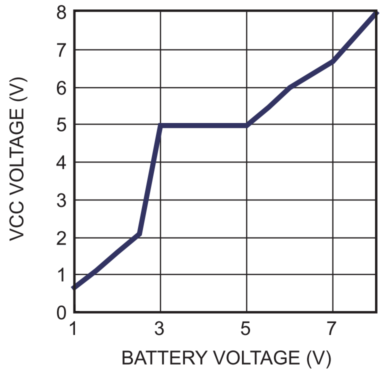
R_{OLIM}=63.4kΩ, V_{IN_SET}=5V



V_{CC} @ Charge Mode

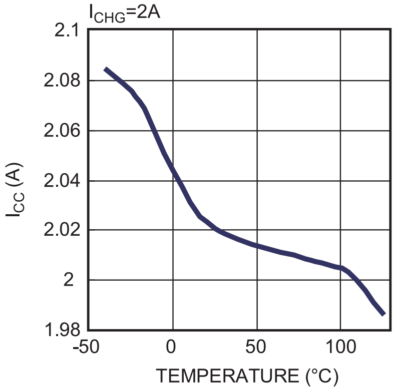


VCC @ Boost Mode



CC Chagre Current vs. Temperature

I_{CHG}=2A

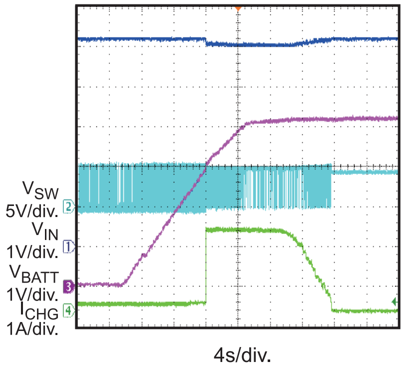


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN}=5V, C_{IN}=C_{BATT}=C_{PMID}=C3=22µF, C1=C2=1µF, L1=4.7µH, RS1=50mΩ, C4=C_{TMR}=0.1µF, Battery Simulator, unless otherwise noted.

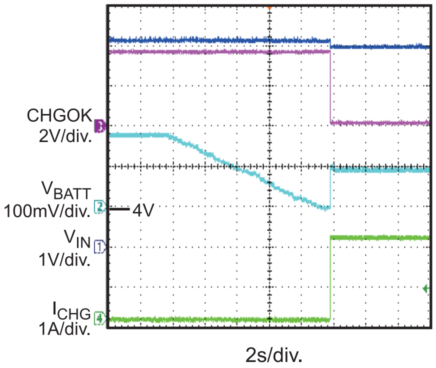
Battery Charge Curve

V_{BATT_FULL}=4.2V



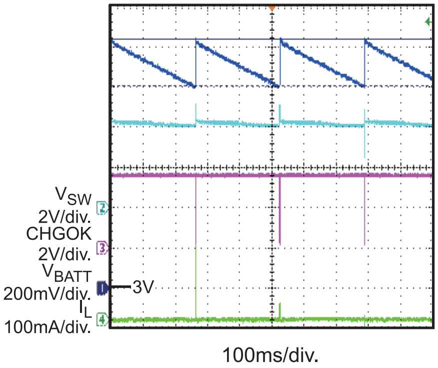
Auto Recharge

V_{BATT_FULL}=4.2V



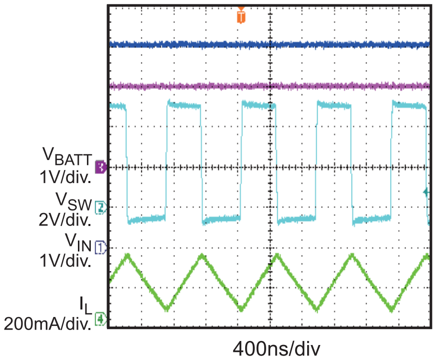
Battery Float Steady State

V_{BATT_FULL}=4.2V



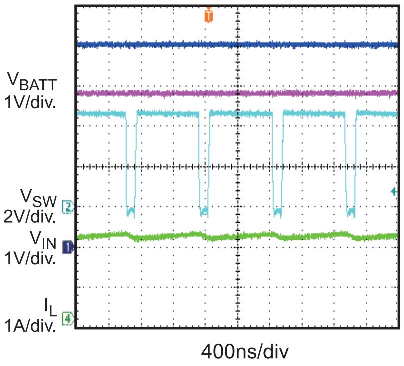
TC Charge Steady State

V_{BATT_FULL}=4.2V, V_{BATT} =2V, F_{SW}=1.2MHz



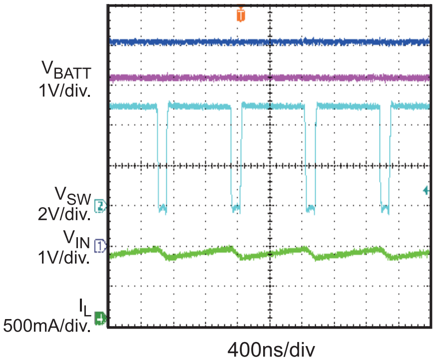
CC Charge Steady State

V_{BATT_FULL}=4.2V, V_{BATT} =3.7V, F_{SW}=1.2MHz



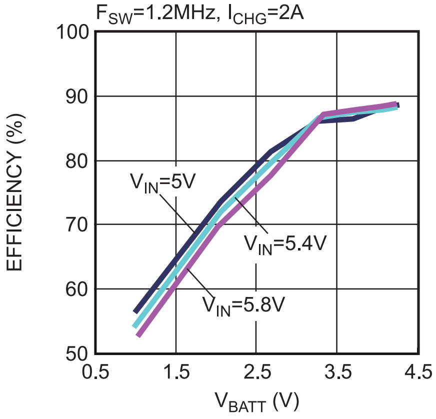
CV Charge Steady State

V_{BATT_FULL}=4.2V, V_{BATT} =4.2V, F_{SW}=1.2MHz



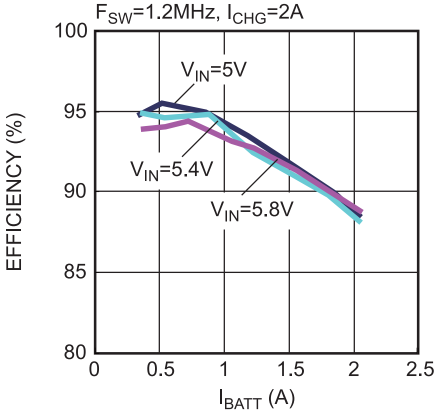
Constant Current Charge Efficiency

V_{BATT_FULL}=4.2V, V_{BATT} =1-4.2V, F_{SW}=1.2MHz, I_{CHG}=2A



Constant Voltage Charge Efficiency

V_{BATT_FULL}=4.2V, V_{BATT} =4.2V, F_{SW}=1.2MHz, I_{CHG}=2A

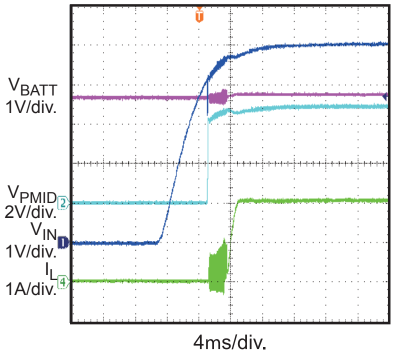


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN}=5V, C_{IN}=C_{BATT}=C_{PMID}=C3=22µF, C1=C2=1µF, L1=4.7µH, RS1=50mΩ, C4=C_{TMR}=0.1µF, Battery Simulator, unless otherwise noted.

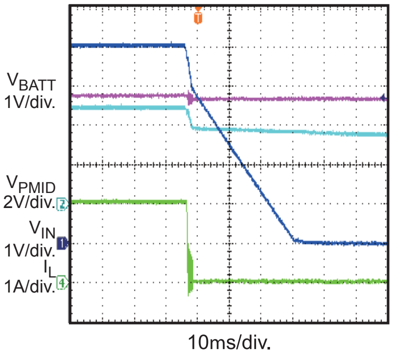
Power On, Charge Mode

V_{BATT_FULL}=4.2V, V_{BATT}=3.7V, I_{CHG}=2A



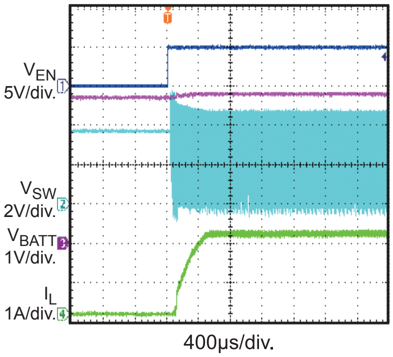
Power Off, Charge Mode

V_{BATT_FULL}=4.2V, V_{BATT}=3.7V, I_{CHG}=2A



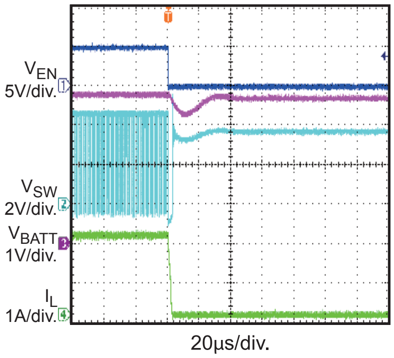
EN On, Charge Mode

V_{BATT_FULL}=4.2V, V_{BATT}=3.7V, I_{CHG}=2A



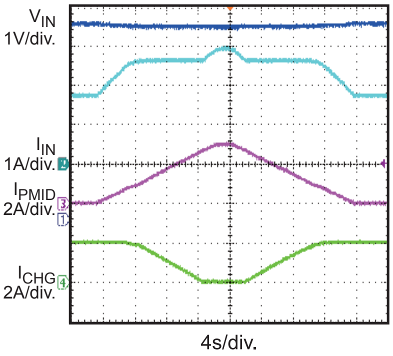
En Off, Charge Mode

V_{BATT_FULL}=4.2V, V_{BATT}=3.7V, I_{CHG}=2A



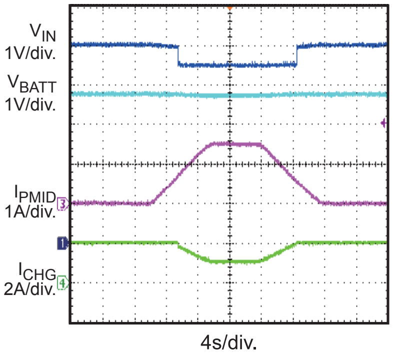
Input Current Limit

V_{BATT_FULL}=4.2V, V_{BATT}=3.7V

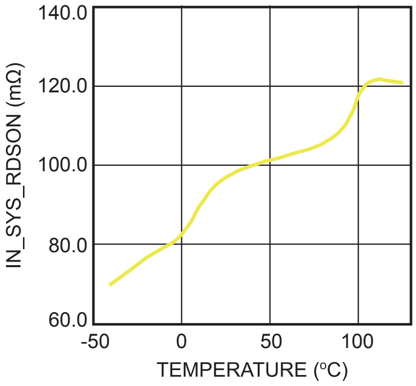


Input Voltage Clamp

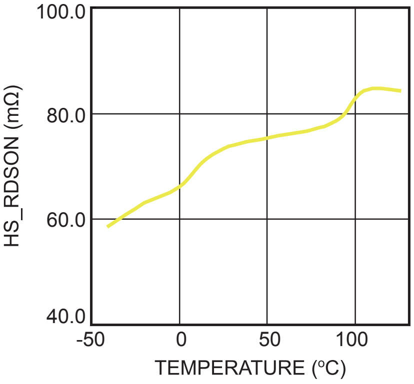
V_{BATT_FULL}=4.2V, V_{BATT}=3.7V



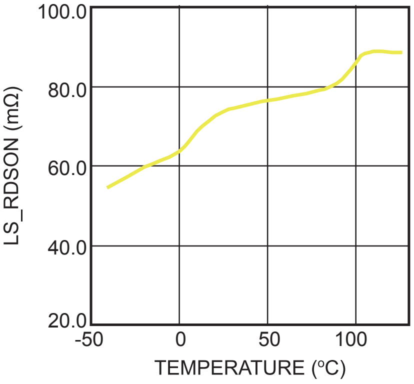
IN_PMID_Rdson vs. Temperature



HS_Rdson vs. Temperature



LS_Rdson vs. Temperature

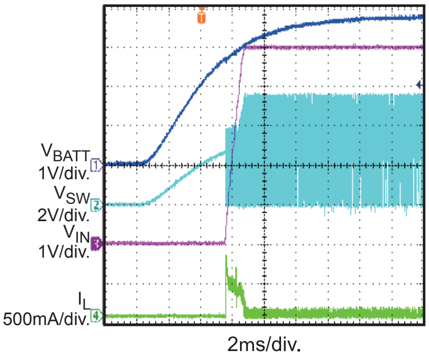


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN}=5V, C_{IN}=C_{BATT}=C_{PMID}=C3=22µF, C1=C2=1µF, L1=4.7µH, RS1=50mΩ, C4=C_{TMR}=0.1µF, Battery Simulator, unless otherwise noted.

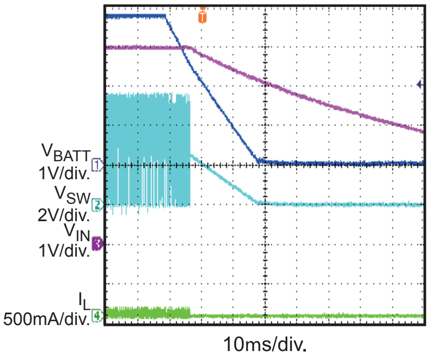
Power On, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
No Load



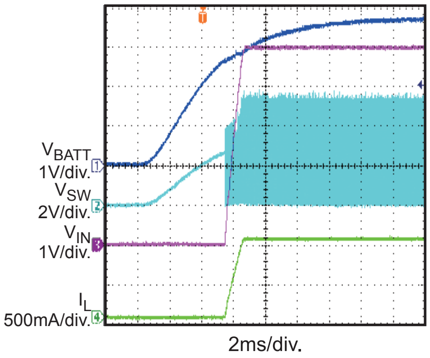
Power Off, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
No Load



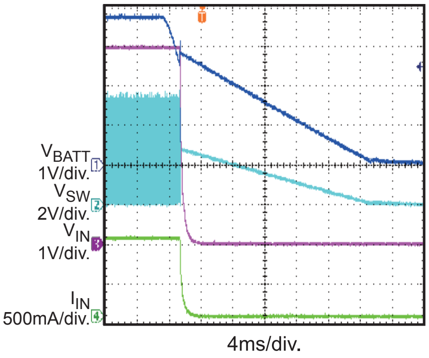
Power On, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
R_{IN_LOAD}=5Ω



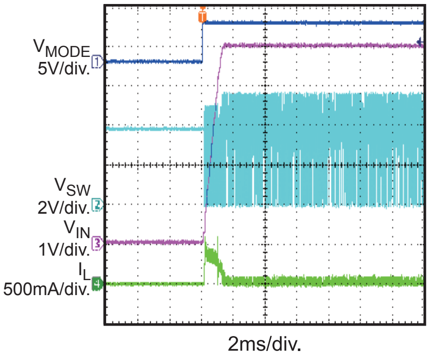
Power Off, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
R_{IN_LOAD}=5Ω



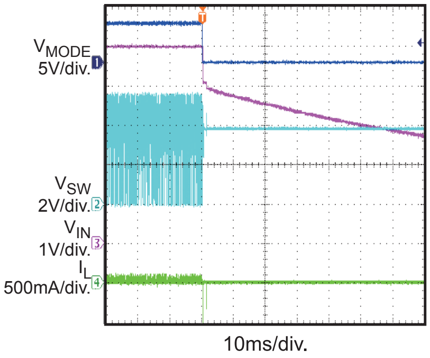
Mode On, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
No Load



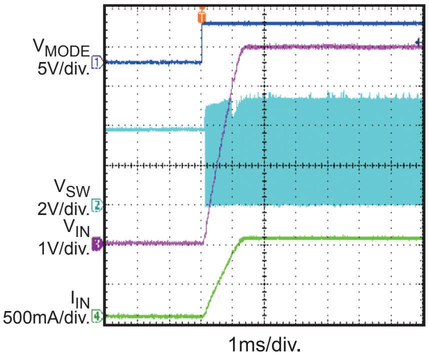
Mode Off, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
No Load



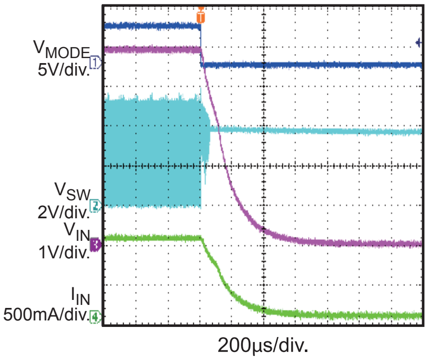
Mode On, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
R_{IN_LOAD}=5Ω



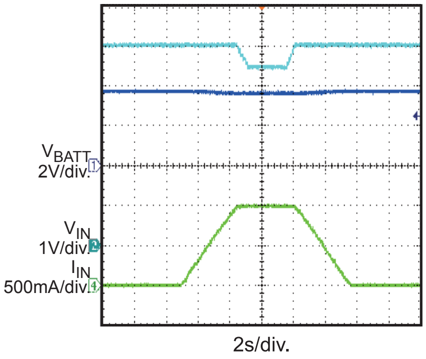
Mode Off, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
R_{IN_LOAD}=5Ω



VIN Output Current Limit, Boost Mode

V_{IN_SET}=5V, V_{BATT}=3.7V,
I_{OLIM_SET}=1A

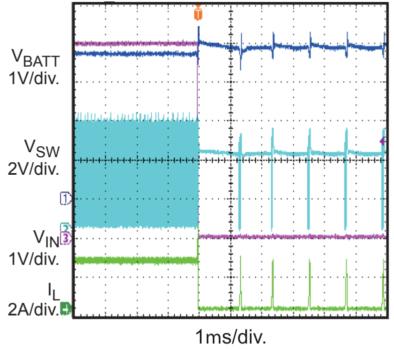


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN}=5V, C_{IN}=C_{BATT}=C_{PMID}=C3=22µF, C1=C2=1µF, L1=4.7µH, RS1=50mΩ, C4=C_{TMR}=0.1µF, Battery Simulator, unless otherwise noted.

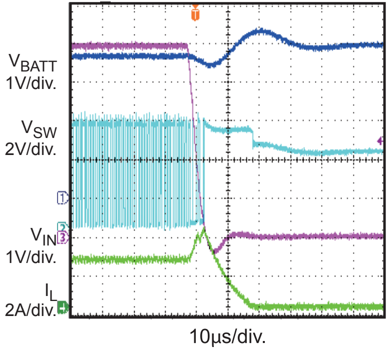
Boost Output Short Circuit Entry

V_{IN_SET}=5V, V_{BATT}=3.7V, I_{IN}= 1.5A



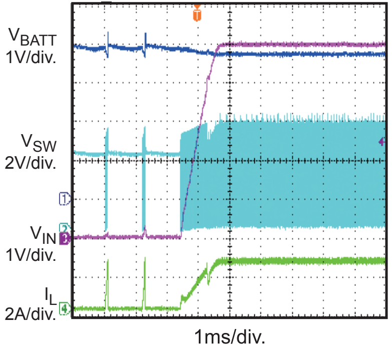
Boost Output Short Circuit Entry

V_{IN_SET}=5V, V_{BATT}=3.7V, I_{IN}= 1.5A



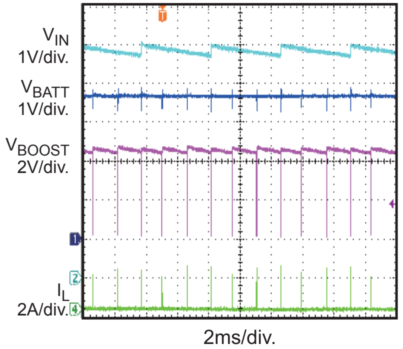
Boost Output Short Circuit Recovery

V_{IN_SET}=5V, V_{BATT}=3.7V, I_{IN}= 1.5A



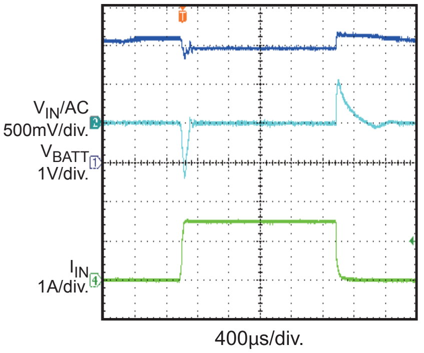
Boost Output Over Voltage Protection

V_{IN_SET}=6.6V, V_{BATT}=3.7V



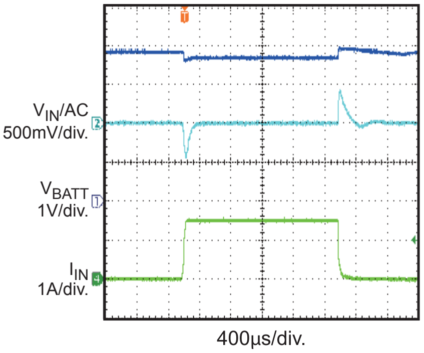
Load Transient Response

V_{IN_SET}=5V, V_{BATT}=3V, I_{IN}= 0A to 1.5A



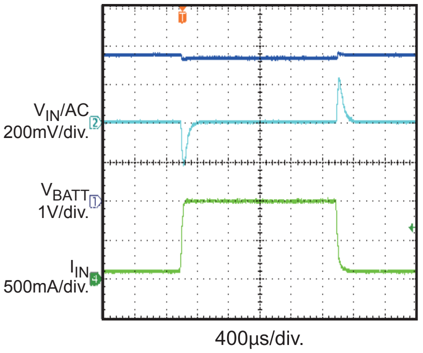
Load Transient Response

V_{IN_SET}=5V, V_{BATT}=3.7V, I_{IN}= 0A to 1.5A



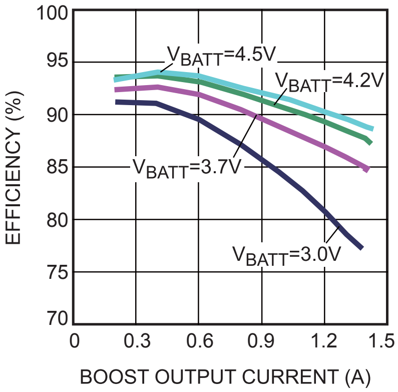
Load Transient Response

V_{IN_SET}=5V, V_{BATT}=3.7V, I_{IN}= 0.1A to 1A



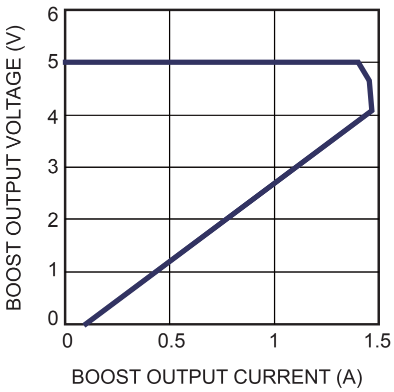
Boost Efficiency

V_{IN_SET}=5V, F_{SW}=1.2MHz



Boost Output V-I Curve

V_{IN_SET}=5V, V_{BATT}=3.7V, R_{OLIM}=63.4kΩ



PIN FUNCTIONS

Pin #	Name	Description
1	FREQ	Connect to GND to program the operating frequency to 600kHz. Leave floating or connect to HIGH to program the operating frequency to 1.2MHz.
2	VIN	Adapter Input. Place a bypass capacitor close to this pin to prevent large input voltage spikes.
3	VCC	Internal Circuit Power Supply. Bypass to GND with a 100nF ceramic capacitor. This pin **CANNOT** carry any load.
4	ILIM	Input Current Set. Connect to GND with an external resistor to program input current limit in charge mode.
5	PWIN	Input pin to detect the presence of valid input power. Pulling this pin to GND will turn off the IN-to-PMID pass through MOSFET.
6	TMR	Oscillator Period Timer. Connect a timing capacitor between this pin and GND to set the oscillator period. Short to GND to disable the Timer function.
7	REG	Input Voltage Feedback for input voltage regulation loop. Connect to tap of an external resistor divider from VIN to GND to program the input voltage regulation. Once the voltage at REG pin drops to the inner threshold, the charge current is reduced to maintain the input voltage at the regulation value.
8	$\overline{\text{ACOK}}$	Valid Input Supply Indicator. Logic LOW on this pin indicates the presence of a valid power supply.
9	FB	Boost Output Voltage Feedback.
10	NTC	Negative Temperature Coefficient (NTC) Thermistor.
11	ISET	Programmable Charge Current Pin. Connect an external resistor to GND to program the charge current.
12	OLIM	Programmable Output-Current Limit for boost mode. Connect an external resistor to GND to program the system current in boost mode.
13	AGND	Analog Ground
14	VB	Programmable Battery-Full Voltage. Leave floating or connect to logic HIGH for 4.2V, while Connect to GND for 3.6V.
15	BATT	Positive Battery Terminal / Battery Charge Current Sense Negative Input.
16	CSP	Battery Charge Current Sense, Positive Input.
17	$\overline{\text{BOOST}}$	Boost Mode Indicator. Logic LOW indicates boost mode in operation. This is an open drain pin during charge mode or sleep mode.
18	$\overline{\text{CHG}}$	Charge Completion indicator. Logic LOW indicates charge mode. This is an open drain pin during charge complete or suspended.
19	PGND, Exposed Pad	Power Ground. Connect the exposed pad and GND pin to the same ground plane.
20	SW	Switch Output Node. It is recommended not to place vias on the SW plane during PCB layout.
21, 22	PMID	Connect Point of Blocking Switch and High-side switch. A minimum of 22μF ceramic cap is required to be placed as close as possible to the **PMID** and **GND** pins.
23	MODE	Mode Select. Logic HIGH→boost mode. Logic LOW→charge mode.
24	EN	Charge Control Input. Logic HIGH enables charging. Logic LOW disables charging. Active only when $\overline{\text{ACOK}}$ is low (input power is OK)

BLOCK DIAGRAM

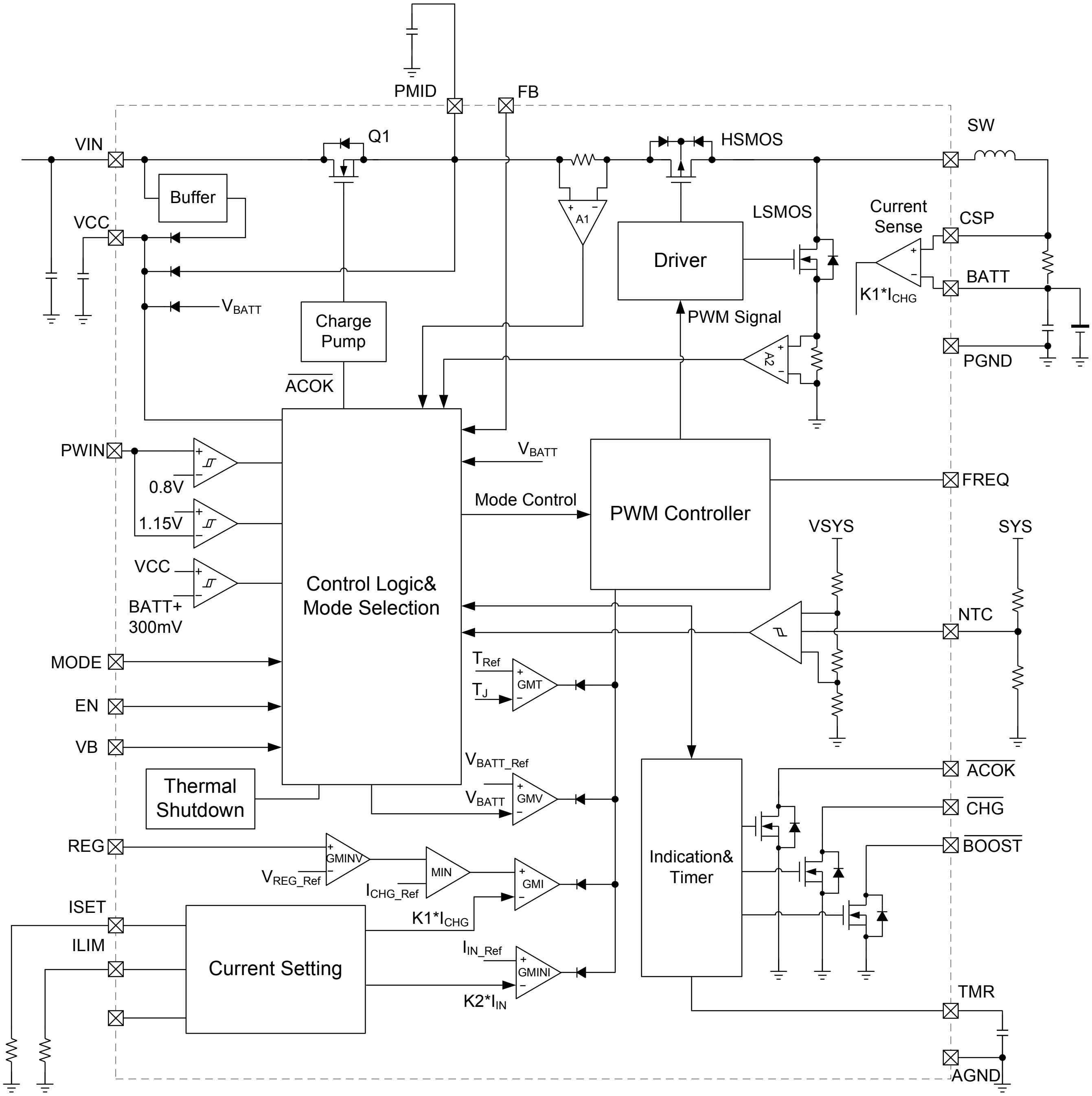


Figure 1: Functional Block Diagram in Charge Mode

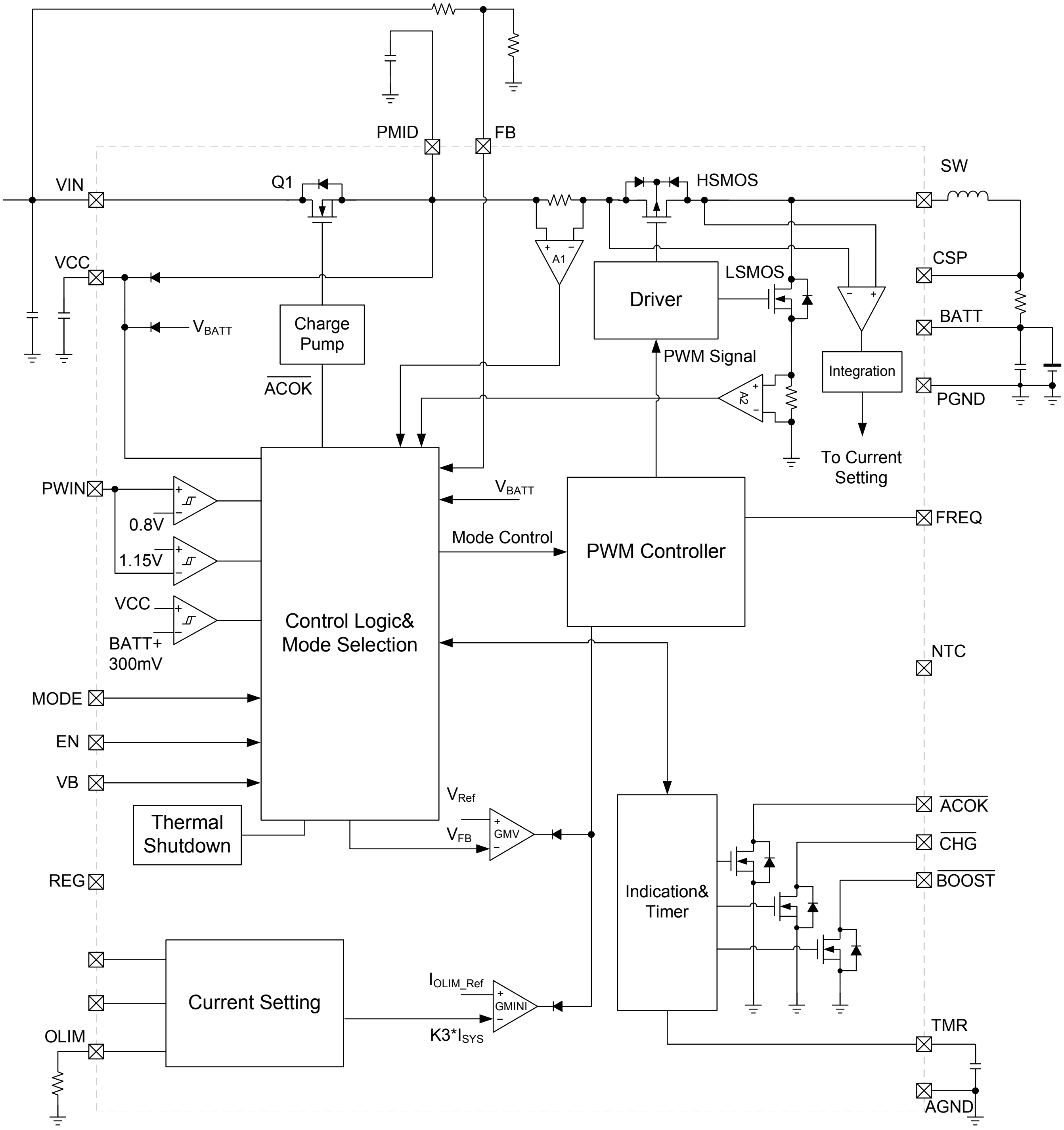


Figure 2: Functional Block Diagram in Boost Mode

OPERATION FLOW CHART

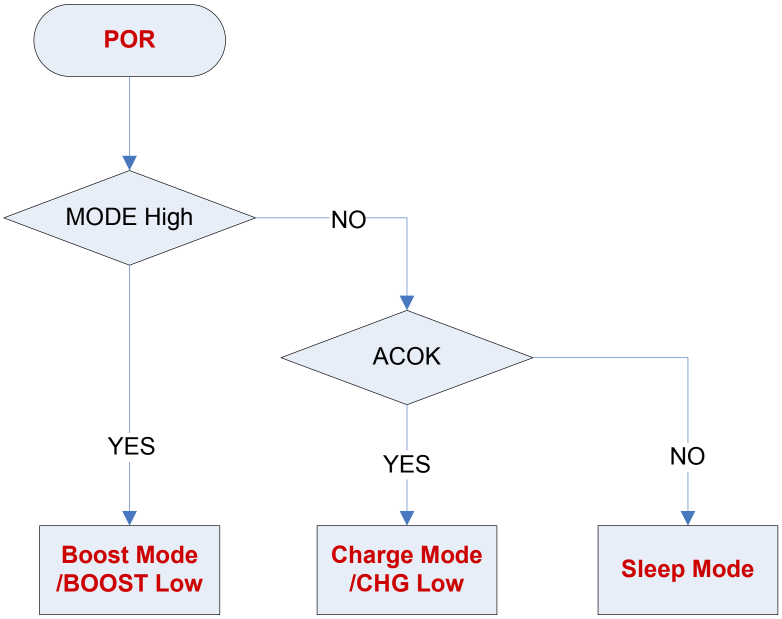


Figure 3: Mode Selection Flow Chart

OPERATION FLOW CHART *(continued)*

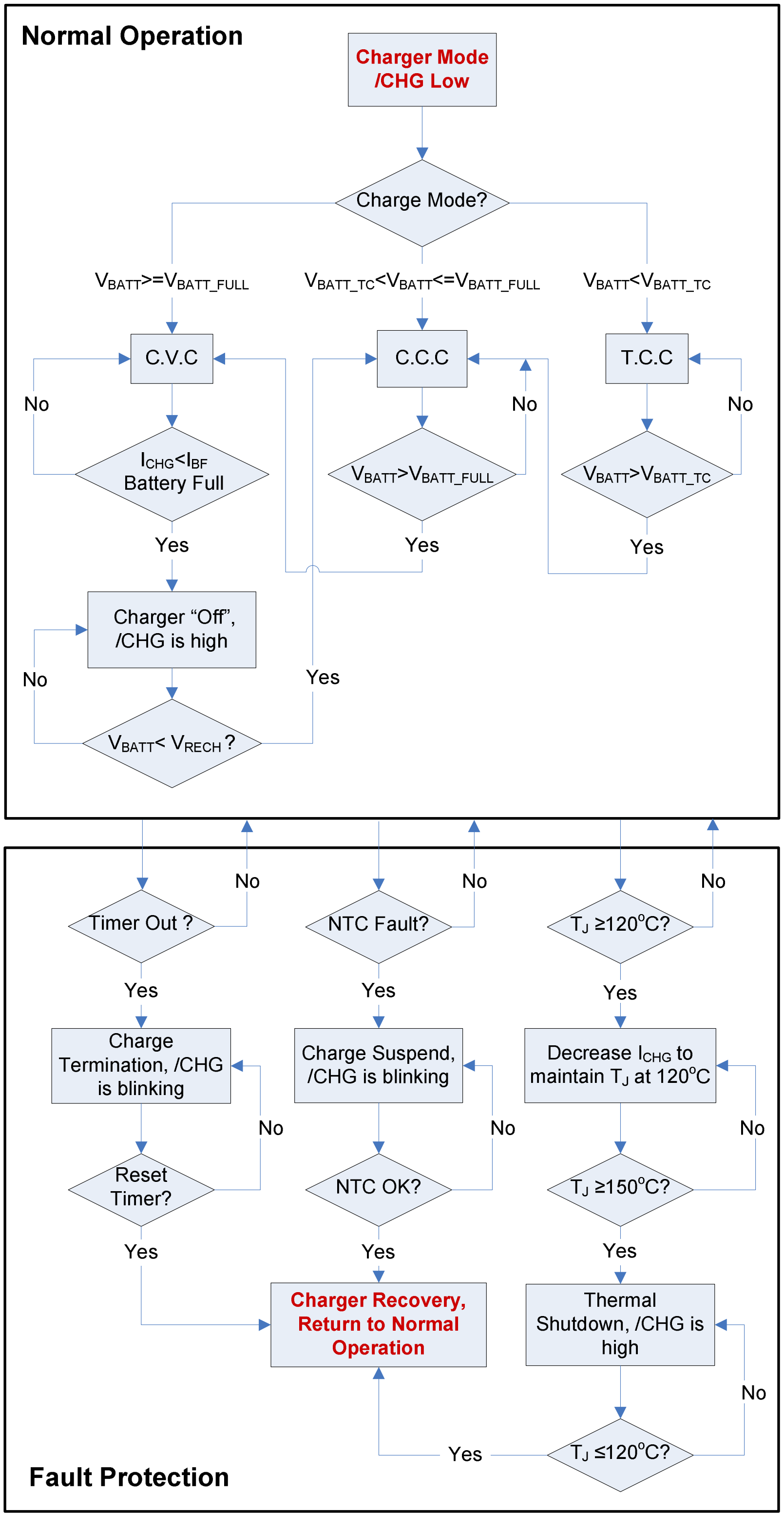


Figure 4: Normal Operation and Fault Protection in Charge Mode

OPERATION FLOW CHART *(continued)*

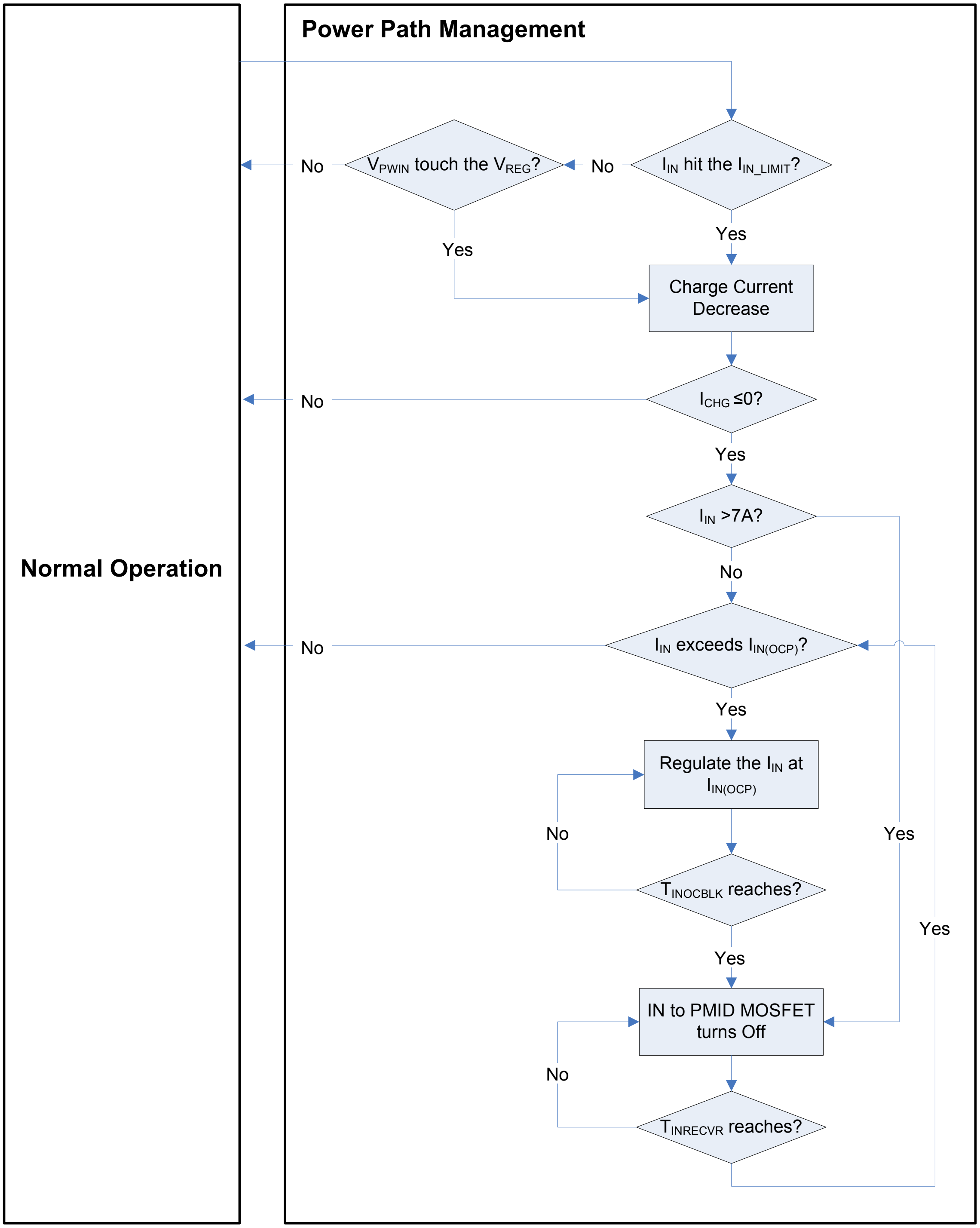


Figure 5: Power-Path Management in Charge Mode

OPERATION FLOW CHART *(continued)*

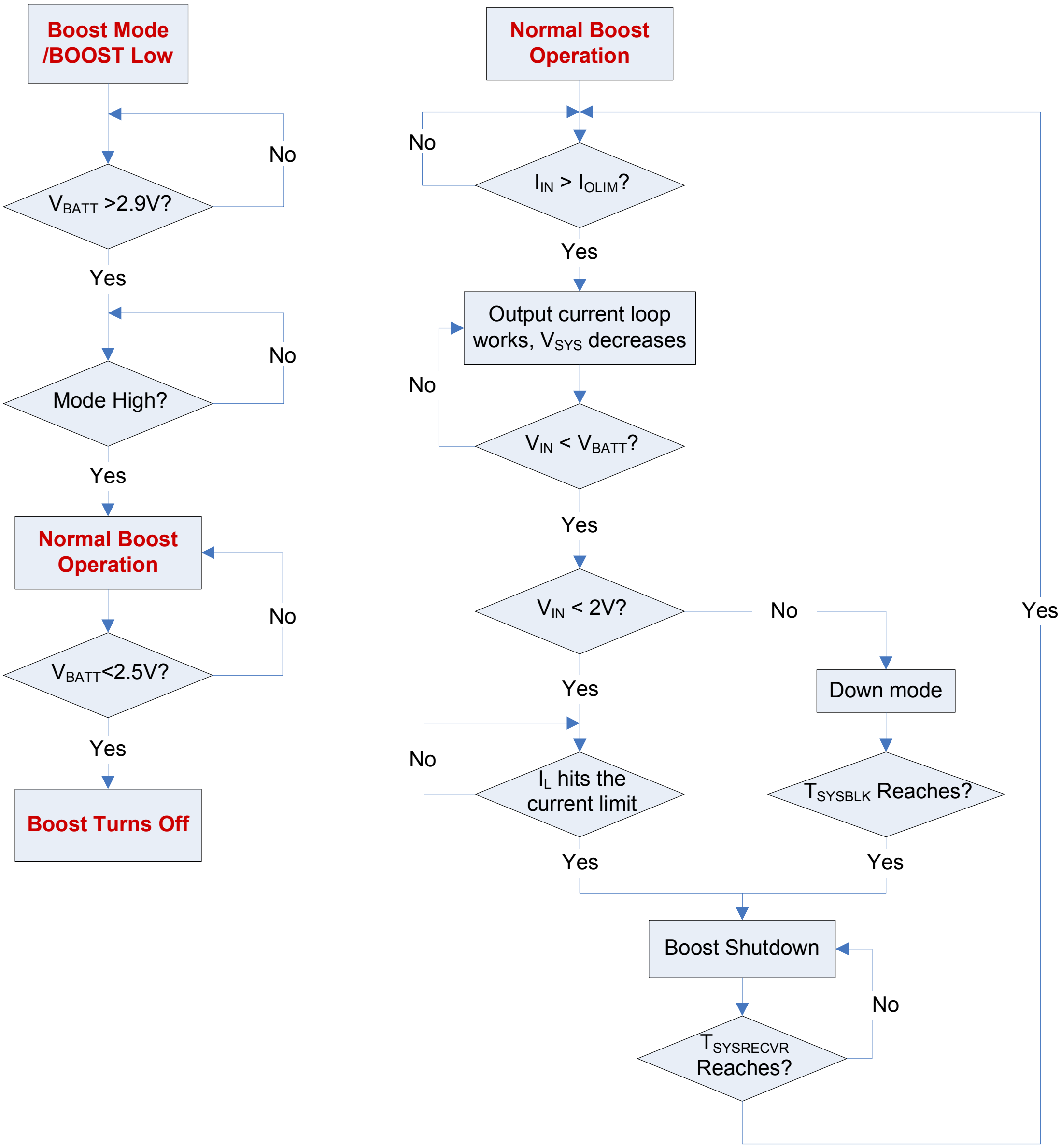


Figure 6: Operation Flow Chart in Boost Mode

START UP TIME FLOW IN CHARGE MODE

Condition: EN = 5V, Mode = 0V, /ACOK and /CHG are always pulled up to an external constant 5V

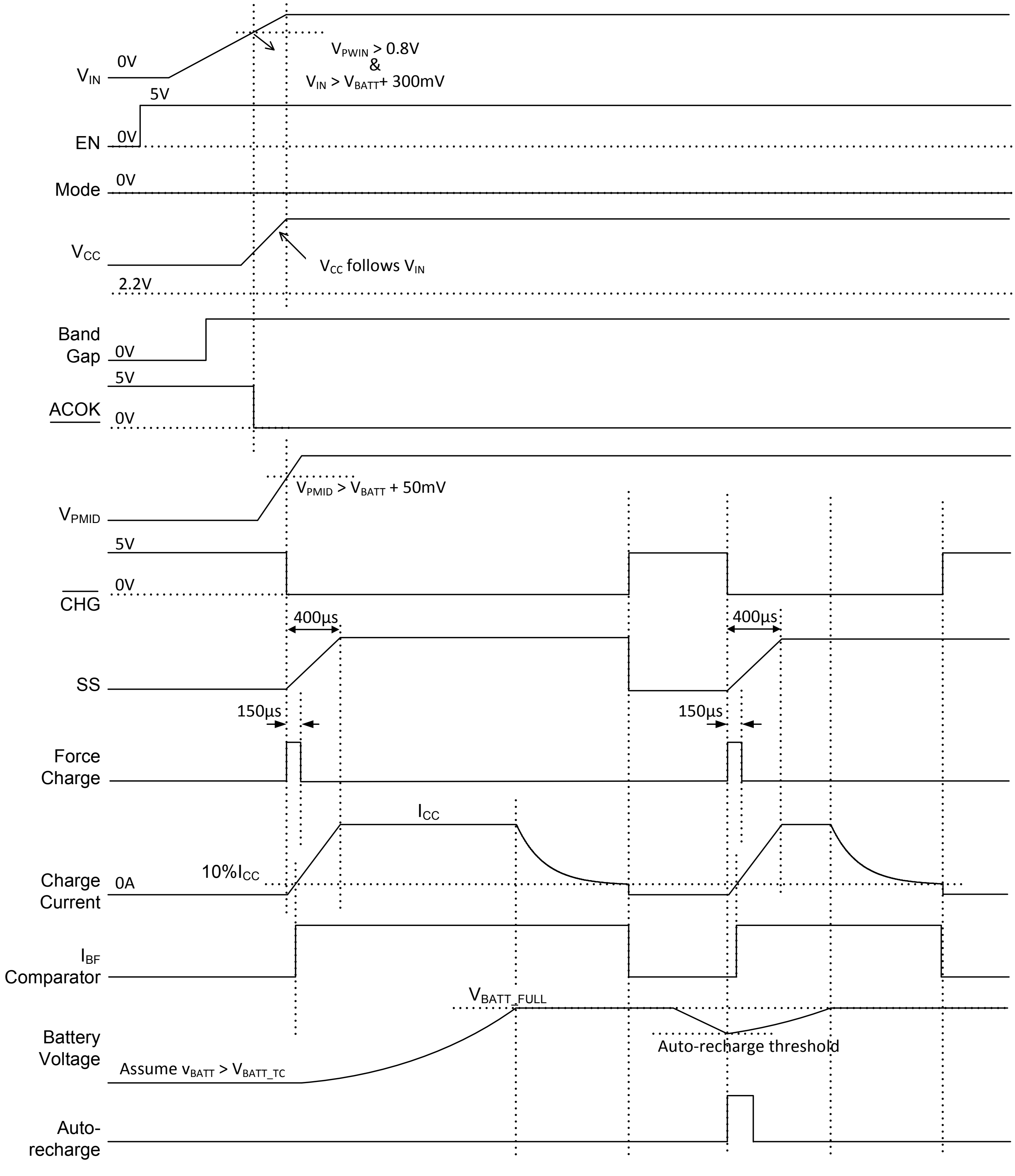


Figure 7: Input Power Start-Up Time Flow in Charge Mode

START UP TIME FLOW IN CHARGE MODE

Condition: V_{IN} = 5V, Mode = 0V, /ACOK and /CHG are always pulled up to an external constant 5V.

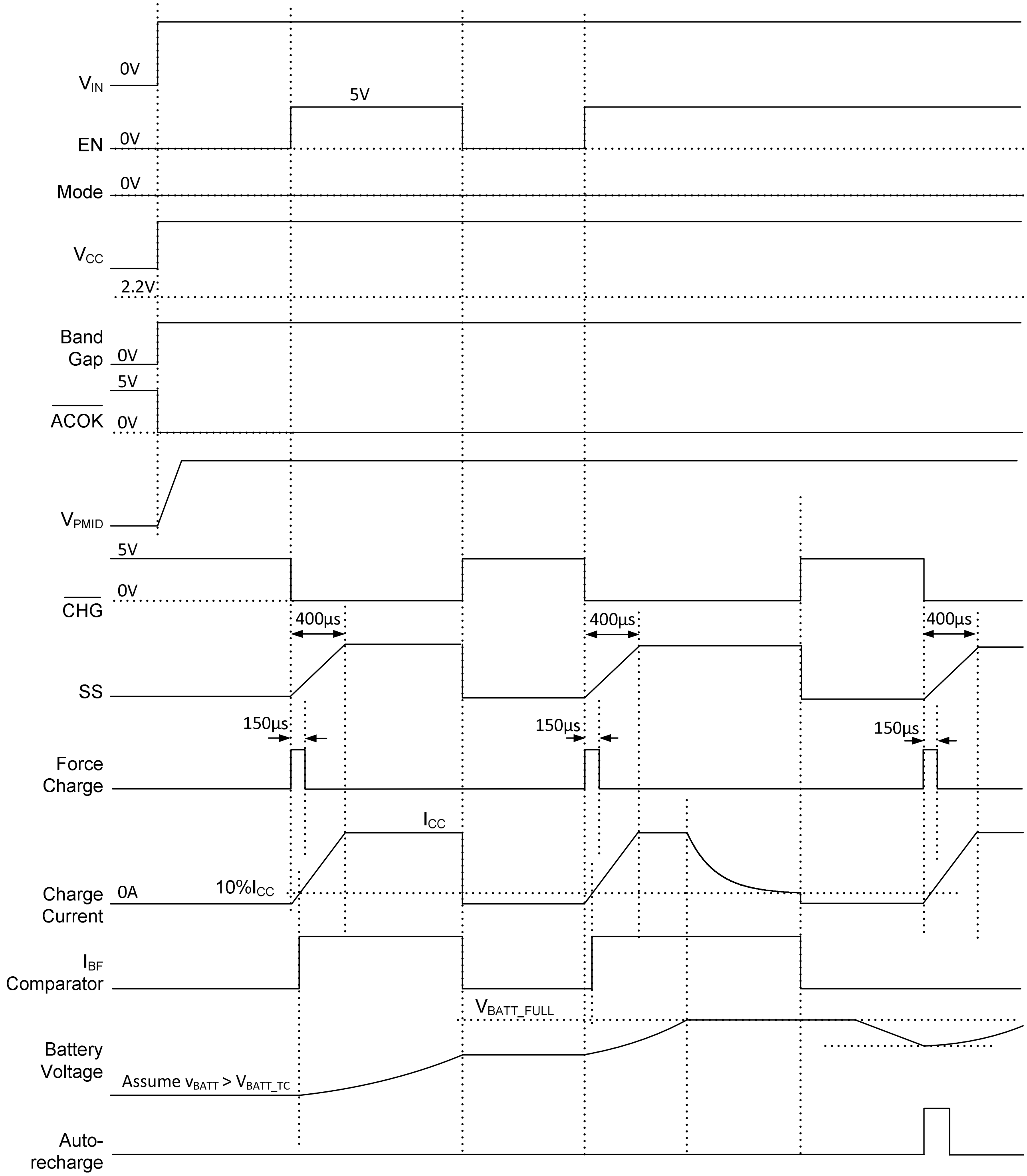


Figure 8: EN Start-Up Time Flow in Charge Mode

START UP TIME FLOW IN BOOST MODE

Condition: V_{IN_SET} = 5V, Mode = 5V, /Boost is always pulled up to an external constant 5V.

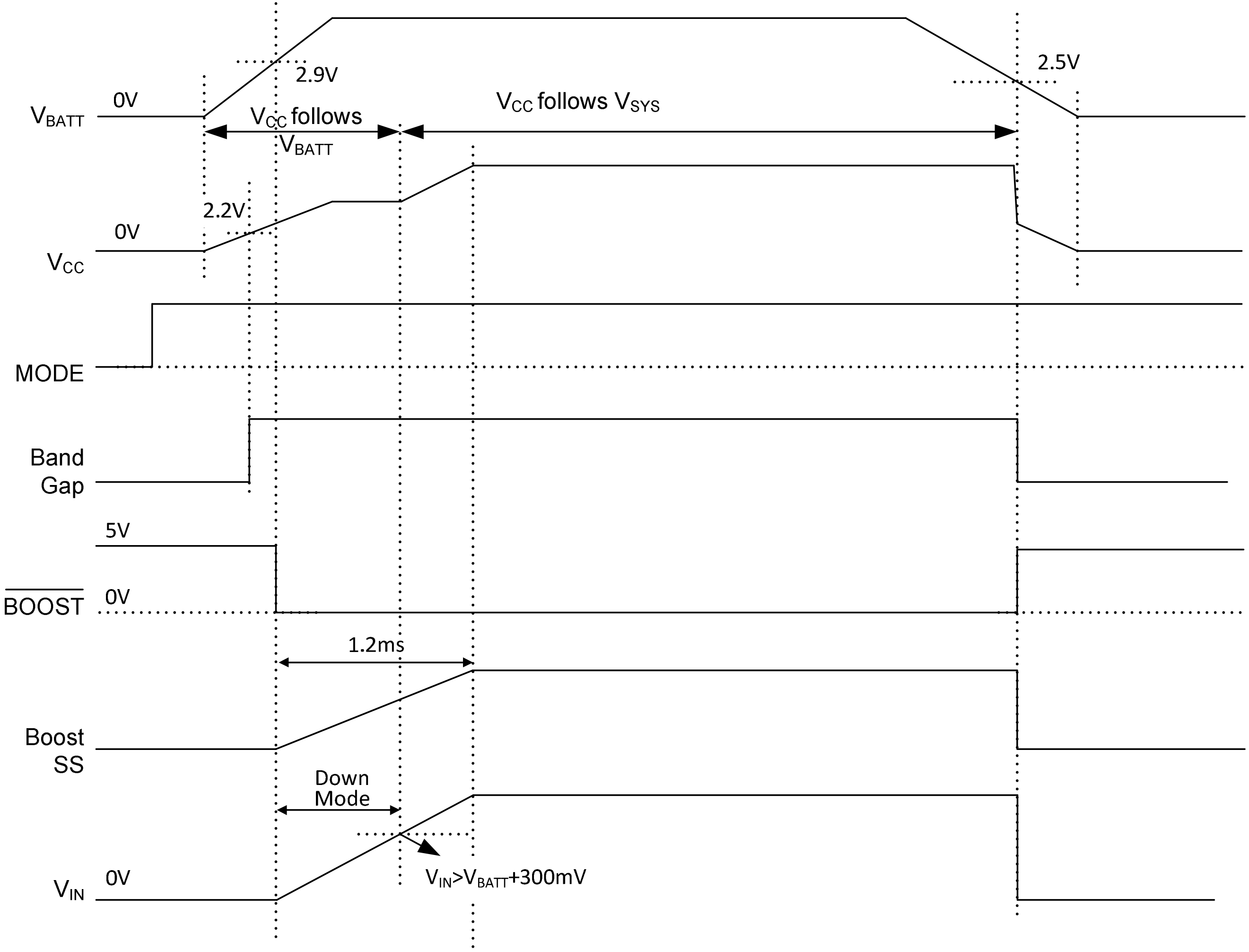


Figure 9: Battery Power Start-Up Time Flow in Boost Mode

START UP TIME FLOW IN BOOST MODE

Condition: V_{IN_SET} = 5V, /Boost is always pulled up to an external constant 5V.

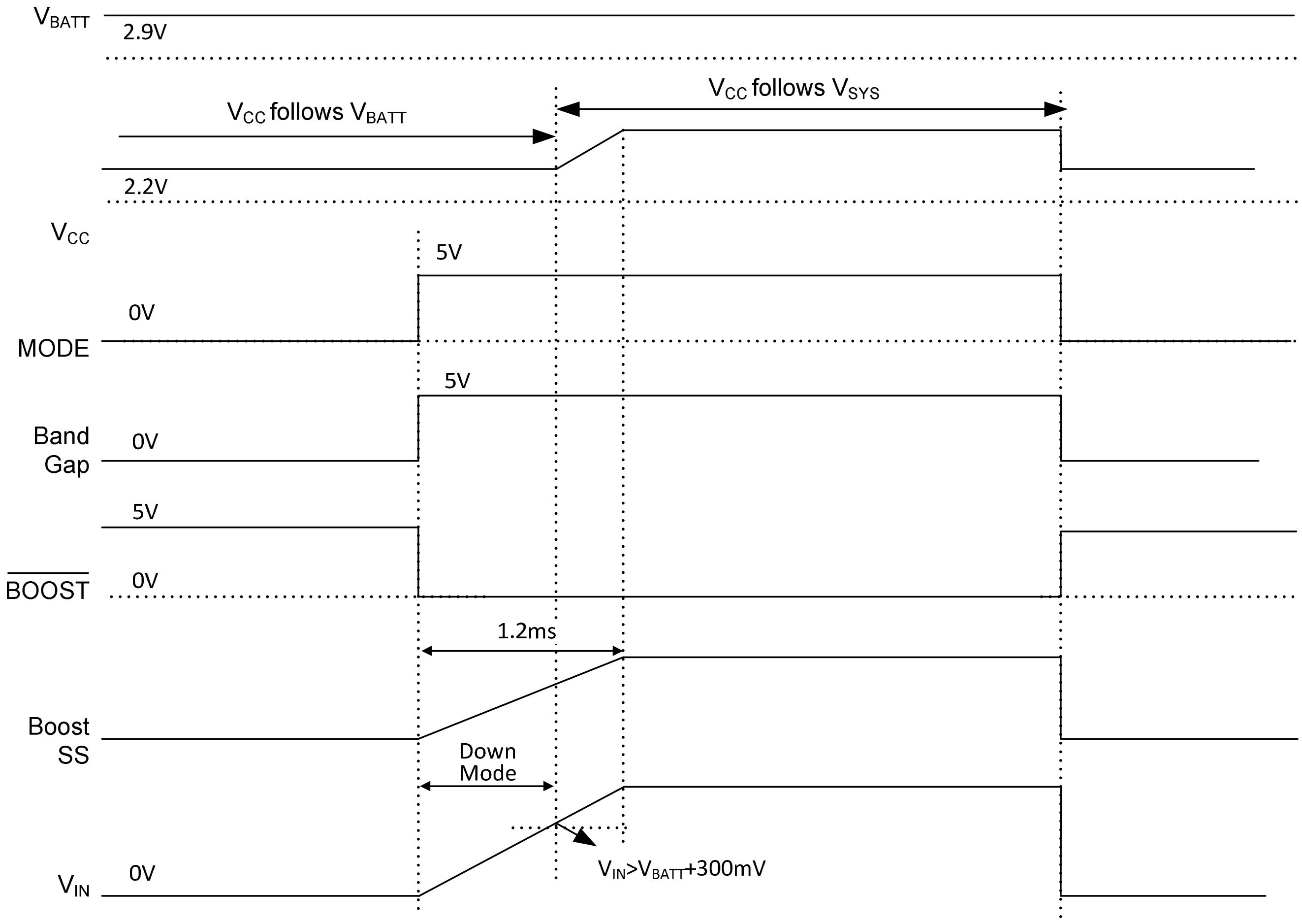


Figure 10: Mode Start-Up Time Flow in Boost Mode

OPERATION

INTRODUCTION

The MP2626 is a highly-integrated, flexible, switch-mode battery charger with bi-directional operation for a boost function that can step-up the battery voltage to power the USB peripheral. Depending on the status of MODE and VIN, it operates in three different modes: charge mode, boost mode and sleep mode.

In charge mode, the MP2626 can work with a single cell Li-ion or Li-polymer battery. In boost mode, MP2626 boosts the battery voltage to VIN to power higher-voltage systems. In sleep mode, both charging and boosting operations are disabled and the device enters a power saving mode to help reduce the overall power consumption. The MP2626 monitors MODE and VIN to allow smooth transition between different modes of operation.

CHARGE MODE OPERATION

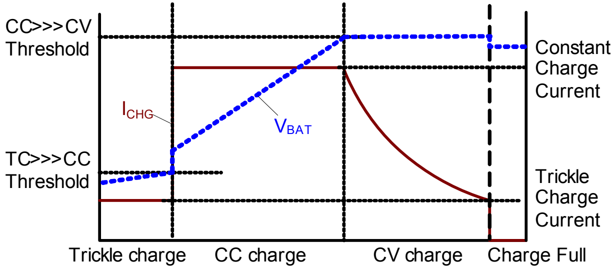
Charge Cycle (TC Charge→CC Charge→CV Charge)

In charge mode, the MP2626 has five control loops to regulate the input current, input voltage, charge current, charge voltage, and device junction temperature. The MP2626 charges the battery in three phases: trickle current (TC), constant current (CC), and constant voltage (CV). While charging operation is enabled, all five loops are active but only one determines the IC behavior. A typical battery charge profile is depicted in Figure 11(a). The charger stays in TC charge mode until the battery voltage reaches a TC-to-CC threshold. Otherwise the charger enters CC charge mode. When the battery voltage rises to the CV-mode threshold, the charger operates in constant voltage mode. Figure 11 (b) shows a typical charge profile when the input-current-limit loop dominates during the CC charge mode. And in this case the charger maximizes the charging current due to the switching-mode charger solution, resulting in faster charging than a traditional linear solution.

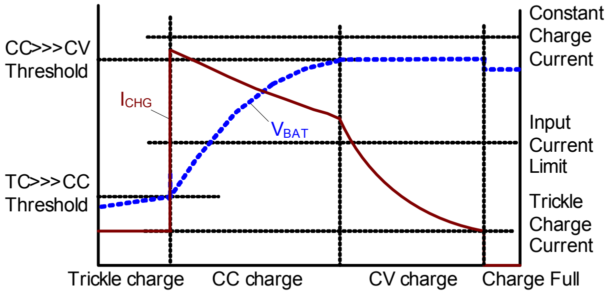
Auto-Recharge

Once the battery charge cycle is completed, the charger remains off. During this time, the system load may consume battery power, or the battery may self discharge. To ensure the battery will not go into depletion, a new charge cycle automatically begins when the battery voltage falls below the auto-recharge threshold and the input power is present. The timer is reset when the auto-recharge cycle begins.

During the off state after the battery is fully charged, if the input power re-starts or the EN signal refreshes, the charge cycle will start and the timer will reset no matter what the battery voltage is.



(a) Without input current limit



(b) With input current limit

Figure 11: Typical Battery Charging Profile

Battery Over-Voltage Protection

The MP2626 has battery over-voltage protection. If the battery voltage exceeds the battery over-voltage threshold (103.3% of the battery-full voltage), charging is disabled. Under this condition, an internal current source draws a current from the BATT pin to decrease the battery voltage and protect the battery.

Timer Operation in Charge Mode

The MP2626 uses an internal timer to terminate the charging. The timer remains active during the charging process. An external capacitor between TMR and GND programs the charge cycle duration.

If charging remains in TC mode beyond the trickle-charge time τ_{TOTAL_TMR}, charging will terminate. The following equation determines the length of the trickle-charge period:

$$\tau_{TRICKLE\_TMR} = \frac{4.5\times10^{4}\times1.6(V)\times C_{TMR}(\mu F)}{0.52\times I_{TC}(A)\times RS1(m\Omega)+2(\mu A)} \quad (1)$$

The maximum total charge time is:

$$\tau_{TRICKLE\_TMR} = \frac{3.4\times10^{6}\times1.6(V)\times C_{TMR}(\mu F)}{0.52\times I_{TC}(A)\times RS1(m\Omega)+2(\mu A)} \quad (2)$$

Negative Temperature Coefficient (NTC) Input for Battery Temperature Monitoring

The MP2626 has a built-in NTC resistance window comparator, which allows the MP2626 to monitor the battery temperature via the battery-integrated thermistor. Connect an appropriate resistor from V_{PMID} to the NTC pin and connect the thermistor from the NTC pin to GND. The resistor divider determines the NTC voltage depending on the battery temperature. If the NTC voltage falls out of the NTC window, the MP2626 stops charging. The charger will then restart if the temperature goes back into NTC window range. Please refer to Application Information section for the appropriate resistance selection.

Input-Current Limiting in Charge Mode

The MP2626 has a dedicated pin used to program the input current limit. The current at ILIM is a fraction of the input current; the voltage at ILIM indicates the average input current of the switching regulator as determined by the resistor value between ILIM and GND. As the input current approaches the programmed input current limit, charge current is reduced to allow priority to system power.

Use the following equation to determine the input current limit threshold,

$$I_{ILIM} = \frac{40.5(k\Omega)}{R_{ILIM}(k\Omega)}(A) \quad (3)$$

Input Voltage Regulation in Charge Mode

In charge mode, if the input power source is not sufficient to support both the charge current and system load current, the input voltage will decrease. As the input voltage approaches the programmed input voltage regulation value, charge current is reduced to allow priority of system power and maintain proper regulation of the input voltage.

The input voltage can be regulated by a resistor divider from IN pin to REG pin to AGND according to the following equation:

$$V_{REG} = V_{IN\_R}\times\frac{R6}{R6+R5} \quad (4)$$

where the V_{REG} is the internal voltage reference, 1.2V, and the V_{IN_R} is the desired regulation voltage.

Input Over-Current Protection and Over Voltage Protection for Pass-through Path

The MP2626 has an integrated IN to PMID pass-through path to allow direct connection of the input voltage to the system even if charging is disabled. Based on the above, the MP2626 continuously monitors both input current and voltage. In the event of an OCP or OVP, charge current will be reduced to ensure priority of the system power requirements.

In addition, the MP2626 also features input over current and voltage protection for the IN to PMID pass-through path.

Input over-current protection (OCP)

When the total input current exceeds 3A, Q2 (Fig 12) is controlled linearly to regulate the current. If the current continuous to exceed 3A after a 120μs blanking time, Q2 will be turned off. In the event of input current exceeding 7A, Q2 will be turned off almost instantaneously and without any blanking time, this to protect both Q1 and Q2.

Input over-voltage protection (OVP)

The MP2626 uses the PWIN pin to sense the status of input voltage. When the voltage at the PWIN pin is lower than 0.8V or higher than 1.15V, an invalid input power source is detected by the MP2626. At this time the IN to PMID pass-through path will be turned off. An OVP threshold can be programmed via PWIN pin to prevent an over voltage event happening at PMID side when plugging in a wrong adapter.

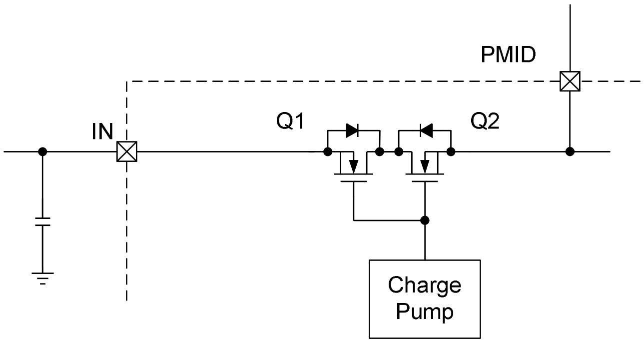


Figure12: Integrated Pass-through Path

Charge Current Setting

The external sense resistors, RS1 and R_{ISET}, program the battery charge current, I_{CHG}. Select R_{ISET} based on RS1:

$$I_{CHG}(A)=\frac{2800}{R_{ISET}(k\Omega)\times RS1(m\Omega)} \tag{5}$$

Battery Short Protection

The MP2626 has two current limit thresholds. CC and CV modes have a peak current limit threshold of 4.5A, while TC mode has a current limit threshold of 1.5A. Therefore, the current limit threshold decreases to 1.5A when the battery voltage drops below the TC threshold. Moreover, the switching frequency also decreases when the BATT voltage drops to 40% of the charge-full voltage.

Thermal Foldback Function

The MP2626 implements thermal protection to prevent thermal damage to the IC and the surrounding components. An internal thermal sense and feedback loop automatically decreases the programmed charge current when the die temperature reaches 120°C. This function is called the charge-current-thermal foldback. Not only does this function protect against thermal damage, it can also set the charge current based on requirements rather than worst-case conditions while ensuring safe operation. Furthermore, the part includes thermal shutdown protection where the ceases charging if the junction temperature rises to 150°C.

Non-sync Operation Mode

During charging mode, the MP2626 continuously monitors the total input current flowing from IN pin to PMID pin. When the input current is lower than **170**mA, the low side switch operates as a non-synchronous MOSFET.

Fully Operation Indication

The MP2626 integrates indicators for the following conditions as shown in Table 2.
When timer or NTC fault happens, charging will terminate or be suspended and indication of $\overline{\text{CHG}}$ blinks in a frequency f_{BLK}:

$$f_{BLK}=\frac{2(\mu A)}{1.46(V)\times C_{TMR}(\mu F)} \tag{6}$$

Table 2: Indicator for Each Operation Mode

Operation		$\overline{\text{ACOK}}$	$\overline{\text{CHG}}$	$\overline{\text{BOOST}}$
Charge Mode	Charging	Low	Low	High
	End of Charge, charging disabled		High	
	NTC Fault, Timer Out		Blinking	
Boost Mode		High	High	Low
Sleep Mode, VCC absent		High	High	High

BOOST MODE OPERATION

Low-Voltage Start-Up

The minimum battery voltage required to start up the circuit in boost mode is 2.9V. Initially, when $V_{PMID} < V_{BATT}$, the MP2626 works in down mode. In this mode, the synchronous P-MOSFET stops switching and its gate connects to V_{BATT} statically. The P_MOSFET keeps off as long as the voltage across the parasitic C_{DS} (V_{SW}) is lower than V_{BATT}. When the voltage across C_{DS} exceeds V_{BATT}, the synchronous P-MOSFET enters a linear mode allowing the inductor current to decrease and flowing into the PMID pin. Once V_{PMID} exceeds V_{BATT}, the P-MOSFET gate is released and normal closed-loop PWM operation is initiated. In boost mode, the battery voltage can drop to as low as 2.5V without affecting circuit operation.

Output Disconnect and Inrush Limiting

The MP2626 allows for true output disconnect by eliminating body diode conduction of the internal P-MOSFET rectifier. VIN can go to 0V during shutdown, drawing no current from the input source. It also allows for inrush current limiting at start-up, minimizing surge currents from the input supply. To optimize the benefits of output disconnect, avoid connecting an external Schottky diode between the SW and PMID pins.

Board layout is extremely critical to minimize voltage overshoot at the SW pin due to stray inductance. Keep the output filter capacitor as close as possible to the PMID pin and use very low ESR/ESL ceramic capacitors tied to a good ground plane.

Boost Output Voltage Setting

In boost mode, the MP2626 programs the output voltage via the external resistor divider at FB pin, and provides built-in output over-voltage protection (OVP) to protect the device and other components against damage when VIN goes beyond 6V. Once the output over-voltage occurs, the MP2626 turns off the boost converter. When the voltage on VIN drops to a normal level, the boost converter restarts again as long as the MODE pin remains active.

Boost Output-Current Limiting

The MP2626 integrates a programmable output current limit function in boost mode. If the boost output current exceeds this programmable limit, the output current will be limited at this level and the VIN voltage will start to drop down. The OLIM pin programs the current limit threshold up to 1.5A as per the following equation:

$$I_{OLIM}(A) = \frac{2800}{R_{OLIM}(k\Omega) \times RS1((m\Omega)} \times 1.6 \tag{7}$$

Boost Output Over-Current Protection

The MP2626 integrates three-phase output over-current protection.

Phase one (boost mode output current limit): when the output current exceeds the programmed output current limit, the output constant current loop controls the output current, the output current remains at its limit of I_{OLIM}, and VIN decreases.

Phase two (down mode): when VIN drops below V_{BATT}+100mV and the output current loop remains in control, the boost converter enters down mode and shutdown after a 120µs blanking time.

Phase three (short circuit mode): when VIN drops below 2V, the boost converter shuts down immediately once the inductor current hits the fold-back peak current limit of the low side N-MOSFET. The boost converter can also recover automatically after a 1ms deglitch period.

Thermal Shutdown Protection

Thermal shutdown protection is also active in boost mode. Once the junction temperature rises higher than 150°C, the MP2626 enters thermal shutdown. It will not resume normal operation until the junction temperature drops below 120°C.

APPLICATION INFORMATION

COMPONENT SELECTION

Setting the Charge Current in Charge Mode

In charge mode, both the external sense resistor, RS1, and the resistor R_{ISET} connect to the ISET pin to set the charge current (I_{CHG}) of the MP2626.

(see the Typical Application Circuit)

Given I_{CHG} and RS1, RISET can be calculated as:

$$R_{ISET}(k\Omega) = \frac{2800}{I_{CHG}(A) \times RS1((m\Omega)} \tag{8}$$

For example, for I_{CHG}=2A, and RS1=50mΩ, thus: R_{ISET}=28kΩ.

Setting the input Current Limiting in Charge Mode

In charge mode, connect a resistor from the ILIM pin to AGND to program the input current limit. The relationship between the input current limit and setting resistor is as following:

$$R_{ILIM}(k\Omega) = \frac{40.5(k\Omega) \times 1(A)}{I_{IN\_LIM}(A)} \tag{9}$$

Where, R_{ILIM} must exceed 15kΩ so that I_{IN_LIM} is in the range of 0A to 2.7A.

For most applications, use R_{ILIM}=45kΩ (I_{USB_LIM}=900mA) for USB3.0 mode, and use R_{ILIM}=81kΩ (I_{USB_LIM}=500mA) for USB2.0 mode.

Setting the Input Voltage Range for Different Operation Modes

A resistive voltage divider from the input to PWIN pin determines the operation mode of MP2626.

$$V_{PWIN} = V_{IN} \times \frac{R4}{R4 + R3} \tag{10}$$

When MP2626 works in the charge mode (see Table1), the voltage on PWIN should be between 0.8V and 1.15V. For a wide operating range, use a maximum input voltage of 6V as the upper threshold for a voltage ratio of:

$$\frac{V_{PWIN}}{V_{IN}} = \frac{1.15}{6} = \frac{R4}{R4 + R3} \tag{11}$$

With the given R4 and R3,

$$R3 = \frac{V_{IN} - V_{PWIN}}{V_{PWIN}} \times R4 \tag{12}$$

For a typical application, start with R4=5.1kΩ, R3 is 21.5kΩ.

Setting the Input Voltage Regulation in Charge Mode

In Charge mode, connect a resistor divider from the VIN to GND with tapped to REG pin to program the input voltage regulation.

$$V_{IN\_R} = V_{REG} \times \frac{R6 + R5}{R6}(V) \tag{13}$$

With the given R6, R5 is:

$$R5 = \frac{V_{IN\_R} - V_{REG}}{V_{REG}} \times R6(V) \tag{14}$$

For a preset input voltage regulation value, say 4.75V, start with R6=5.1kΩ, R5 is 15kΩ.

NTC Function in Charge Mode

Figure 13 shows that an internal resistor divider sets the low temperature threshold (V_{TL}) and high temperature threshold (V_{TH}) at 66.3%·V_{PMID} and 35%·V_{PMID} respectively. For a given NTC thermistor, select an appropriate R_{T1} and R_{T2} to set the NTC window.

$$\frac{V_{TL}}{V_{SYS}} = \frac{R_{T2} // R_{NTC\_Cold}}{R_{T1} + R_{T2} // R_{NTC\_Cold}} = TL = 66.3\% \tag{15}$$

$$\frac{V_{TH}}{V_{SYS}} = \frac{R_{T2} // R_{NTC\_Hot}}{R_{T1} + R_{T2} // R_{NTC\_Hot}} = TH = 35\% \tag{16}$$

Where R_{NTC_Hot} is the value of the NTC resistor at the upper bound of its operating temperature range, and R_{NTC_Cold} is its lower bound.

The two resistors, R_{T1} and R_{T2}, independently determine the upper and lower temperature limits. This flexibility allows the MP2626 to operate with most NTC resistors for different temperature range requirements. Calculate R_{T1} and R_{T2} as follows:

$$R_{T1} = \frac{R_{NTC\_hot} \times R_{NTC\_Cold} \times (TL - TH)}{TH \times TL \times (R_{NTC\_Cold} - R_{NTC\_Hot})} \tag{17}$$

$$R_{T2} = \frac{R_{NTC\_hot} \times R_{NTC\_Cold} \times (TL - TH)}{(1 - TL) \times TH \times R_{NTC\_Cold} - (1 - TH) \times TH \times R_{NTC\_Hot}} \quad (18)$$

For example, the NCP18XH103 thermistor has the following electrical characteristic:

At 0°C, R_{NTC_Cold}=27.445kΩ;
At 50°C, R_{NTC_Hot}=4.1601kΩ;

Base on equation (17) and equation (18), R_{T1}=6.65kΩ and R_{T2}=24.9kΩ are suitable for an NTC window between 0°C and 50°C

If no external NTC is available, connect R_{T1} and R_{T2} to keep the voltage on the NTC pin within the valid NTC window: e.g., R_{T1}=R_{T2}=10kΩ.

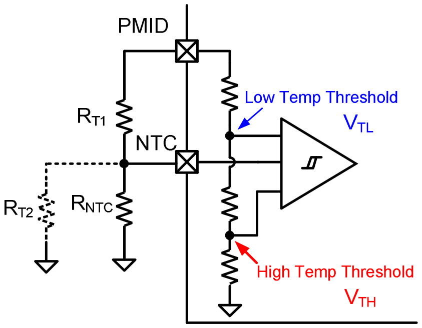


Figure 13: NTC Function Block

For Convenience, an NTC thermistor design spreadsheet is also provided, please inquire if necessary.

Setting the Output Voltage in Boost Mode

In the boost mode, the output voltage on the VIN pin can be regulated to the value customer required between 4.2V and 6V by the resistor divider at FB pin as R1 and R2 in the typical application circuit.

$$V_{IN} = 1.2V \times \frac{R1 + R2}{R2} \quad (19)$$

Where, 1.2V is the voltage reference of boost output voltage. With a typical value for R2, 10kΩ, R1 can be determined by:

$$R1 = \frac{V_{IN} - 1.2V}{1.2V} \times R2 \quad (20)$$

For example, for a 5V output voltage, R2 is 10kΩ, and R1 is 31.6kΩ.

Setting the Output Current Limit in Boost Mode

In the boost mode, connect a resistor form the OLIM pin to AGND to program the output current limit. The relationship between the output current limit and setting resistor is as follows:

$$R_{OLIM}(k\Omega) = \frac{2800}{I_{OLIM}(A) \times RS1(m\Omega)} \times 1.6 \quad (21)$$

The output current limit of the boost can be programmed up to 1.5A (min). Considering 15% output current limit accuracy, typical 1.79A output current limit is required. According to the above equation, given 50mΩ sense resistor, 49.9kΩ ROLIM will get 1.79A output current limit.

Selecting the Inductor

Inductor selection trades off between cost, size, and efficiency. A lower inductance value corresponds with smaller size, but results in higher ripple currents, higher magnetic hysteretic losses, and higher output capacitances. However, a higher inductance value benefits from lower ripple current and smaller output filter capacitors, but results in higher inductor DC resistance (DCR) loss.

Choose an inductor that does not saturate under the worst-case load condition.

1. In Charge Mode

When MP2626 works in charge mode (as a Buck Converter), estimate the required inductance as:

$$L = \frac{V_{IN} - V_{BATT}}{\Delta I_{L\_MAX}} \times \frac{V_{BATT}}{V_{IN} \times f_S} \quad (22)$$

Where VIN, V_{BATT}, and f_{SW} are the typical input voltage, the CC charge threshold, and the switching frequency, respectively. ΔI_{L_MAX} is the maximum inductor ripple current, which is usually designed at 30% of the CC charge current.

With a typical 5V input voltage, 30% inductor current ripple at the corner point between trickle charge and CC charge (V_{BATT}=3V), the inductance is 2.2µH (for a 1.2MHz switching frequency) and 4.4µH (for a 600kHz switching frequency).

2 In Boost Mode

When the MP2626 is in boost mode (as a Boost Converter), the required inductance value is calculated as:

$$L = \frac{V_{IN} - V_{BATT}}{\Delta I_{L\_MAX}} \times \frac{V_{IN}}{V_{BATT} \times f_S} \tag{23}$$

$$\Delta I_{L\_MAX} = (30\% - 40\%) \times I_{BATT(MAX)} \tag{24}$$

$$I_{BATT(MAX)} = \frac{V_{IN} \times I_{IN\_MAX}}{V_{BATT} \times \eta} \tag{25}$$

Where V_{BATT} is the minimum battery voltage, f_{SW} is the switching frequency, and ΔI_{L_MAX} is the peak-to-peak inductor ripple current, which is approximately 30% of the maximum battery current $I_{BATT(MAX)}$, I_{IN_MAX} is the maximum output current and η is the efficiency.

In the worst case where the battery voltage is 3V, a 30% inductor current ripple, and a typical boost output voltage (VIN=5V), the inductance is 2.0µH (for a 1.2MHz switching frequency) and 4.0µH (for a 600 kHz switching frequency) when the efficiency is about 90% and I_{IN_MAX}1.5A.

For Best results, use an inductor with an inductance of 2.2µH (for a 1.2MHz switching frequency) and 4.4µH (for a 600kHz switching frequency) with a DC current rating that is at least 30% higher maximum charge current for applications. For higher efficiency, minimize the inductor's DC resistance. For higher efficiency, minimize the inductor's DC resistance.

Selecting the Input Capacitor C_{IN}

The input capacitor C_{IN} reduces both the surge current drawn from the input and the switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent high frequency switching current from passing to in the input. For best cases, use ceramic capacitors with X7R dielectrics because of their low ESR and small temperature coefficients. For most applications, a 22µF capacitor will suffice.

Selecting the PMID Capacitor C_{PMID}

Select C_{PMID} based on the demand of the current ripple.

1. Charge Mode

The capacitor C_{PMID} acts as the input capacitor of the buck converter in the charge mode. The input effective ripple current:

$$I_{RMS\_MAX} = I_{CC\_MAX} \times \frac{\sqrt{V_{TC} \times (VIN_{MAX} - V_{TC})}}{VIN_{MAX}} \tag{26}$$

2. Boost Mode

The capacitor, C_{PMID}, is the output capacitor of the boost converter. C_{PMID} keeps the output voltage ripple small and ensures feedback loop stability. The output effective ripple current is given by:

$$I_{RMS\_MAX} = I_{CC\_MAX} \times \frac{\sqrt{V_{TC} \times (VIN_{MAX} - V_{TC})}}{VIN_{MAX}} \tag{27}$$

Since the input voltage is passes to PMID directly, V_{IN_MAX}=V_{PMID_MAX}, both charge mode and boost mode have the same current ripple.

For I_{CC_MAX}=1.5A, V_{TC}=3V, V_{IN_MAX}=6V, the maximum effective ripple current is 0.75A, Select the PMID capacitors base on the ripple-current temperature rise not exceeding 10°C. For best results, use ceramic capacitors with X7R dielectrics with low ESR and small temperature coefficients. For most applications, use one 22µF capacitor.

Selecting the Battery Capacitor C_{BATT}

C_{BATT} is in parallel with the battery to absorb the high-frequency switching ripple current.

1. Charge Mode

The capacitor C_{BATT} is the output capacitor of the buck converter. The output voltage ripple is then:

$$\Delta r_{BATT} = \frac{\Delta V_{BATT}}{V_{BATT}} = \frac{1 - V_{BATT} / V_{IN}}{8 \times C_{BATT} \times f_S^2 \times L} \tag{28}$$

2. Boost Mode

The capacitor C_{BATT} is the input capacitor of the boost converter. The input voltage ripple is the same as the output voltage ripple from equation (28).

Both charge mode and boost mode have the same battery voltage ripple. The capacitor C_{BATT} can be calculated as:

$$C_{BATT} = \frac{1 - V_{TC} / V_{IN\_MAX}}{8 \times \Delta r_{BATT\_MAX} \times f_S^2 \times L} \quad (29)$$

To guarantee the ±0.5% BATT voltage accuracy, the maximum BATT voltage ripple must not exceed 0.5% (e.g. 0.2%). The worst case occurs at the minimum battery voltage of the CC charge with the maximum input voltage.

For VIN_{MAX}=6V, $V_{CC\_MIN}=V_{TC}$=3V, L=4.4µH, f_{SW}=600kHz or 1.2MHz, Δr_{BATT_MAX}=0.1%, C_{BATT} is 8.9µF (for a 600kHz switching frequency) or 5.6µF (for a 1.2MHz switching frequency).

A 22µF ceramic with X7R dielectrics capacitor will suffice.

PCB LAYOUT GUIDE

PCB layout is very important to meet specified noise, efficiency and stability requirements. The following design considerations can improve circuit performance:

1) Route the power stage adjacent to their grounds. Aim to minimize the high-side switching node (SW, inductor) trace lengths in the high-current paths

Keep the switching node short and away from all small control signals, especially the feedback network.

Place the input capacitor as close as possible to the VIN and PGND pins. The local power input capacitors, connected from the PMID to GND, must be placed as close as possible to the IC.

Place the output inductor close to the IC and connect the output capacitor between the inductor and PGND of the IC.

2) For high-current applications, the power pads for IN, SW, BATT and PGND should be connected to as many copper planes on the board as possible. The exposed pad should connect to as many GND copper planes on the board as possible, too. This improves thermal performance because the board conducts heat away from the IC.

3) The PCB should have a ground plane connected directly to the return of all components through vias (e.g. two vias per capacitor for power stage capacitors, one via per capacitor for small-signal components). If possible, add vias inside the exposed pads for the IC. A star ground design approach is typically used to keep the circuit block currents isolated (power-signal / control-signal), which reduces noise-coupling and ground-bounce issues. A single ground plane for this design gives good results.

4) Place ISET, OLIM and ILIM resistors very close to their respective IC pins.

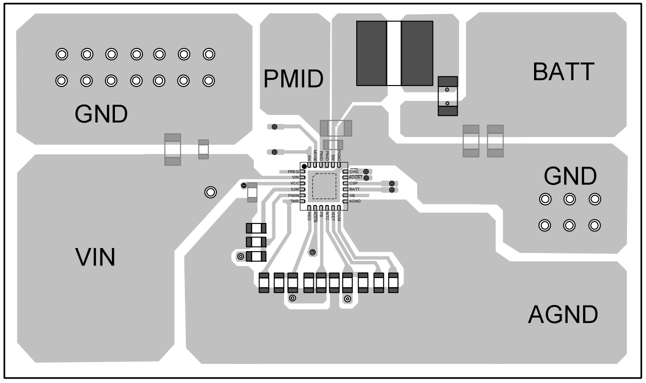


Figure 14: PCB Layout Guide

DESIGN EXAMPLE

Below is a design example following the application guides for the specifications:

Table 3 Design Example

V_{IN}	5V
V_{OUT}	3.7V
f_{SW}	1200KHz

Figure 15 shows the detailed application schematic. The Typical Performance Characteristics section shows the typical performance and circuit waveforms. For more possible applications of this chip, please refer to the related Evaluation Board datasheets.

TYPICAL APPLICATION CIRCUITS

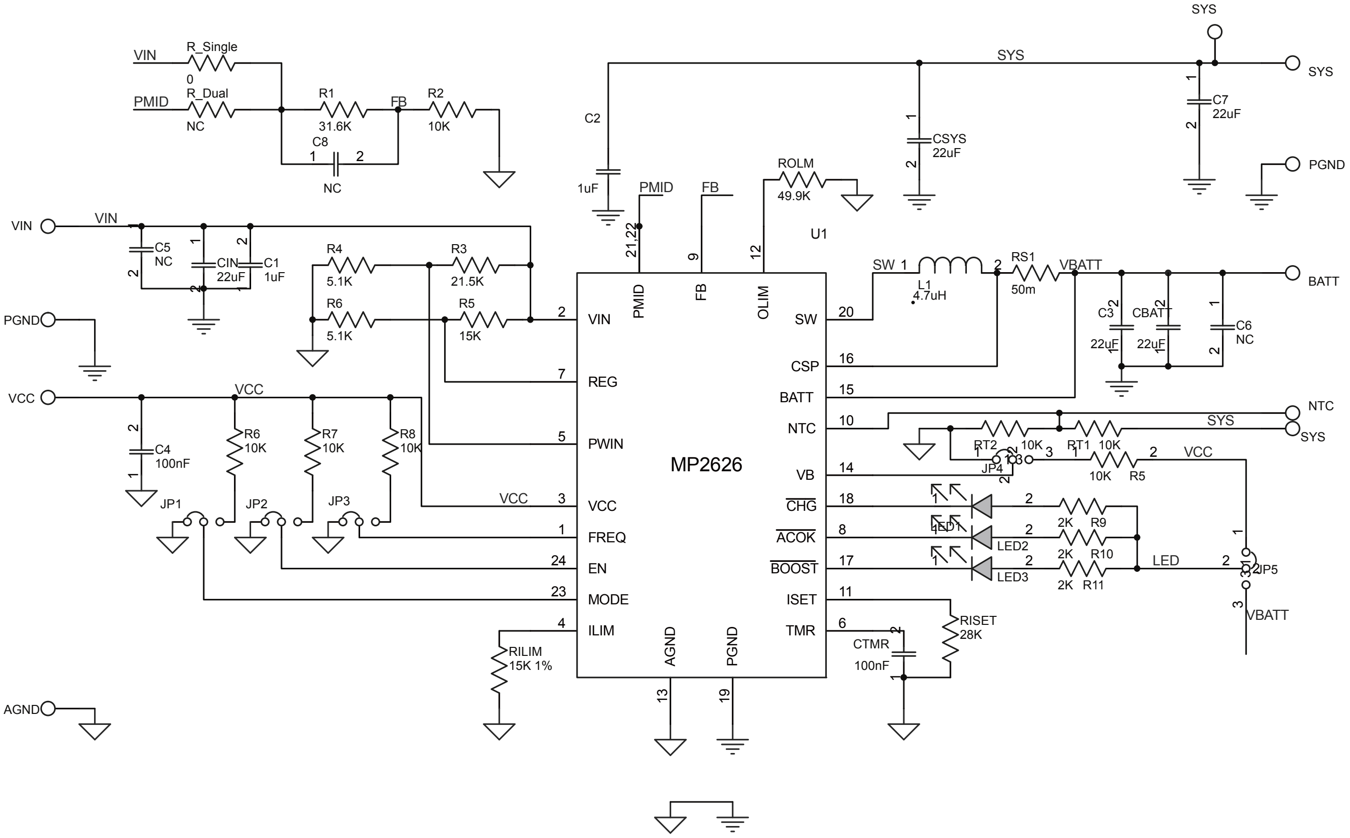
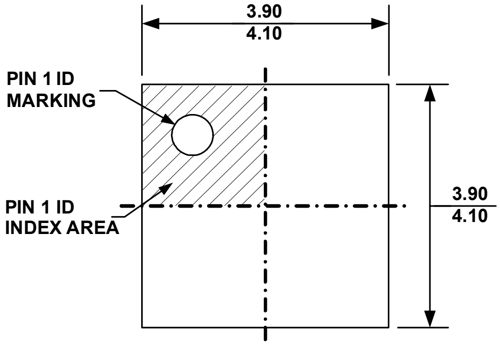


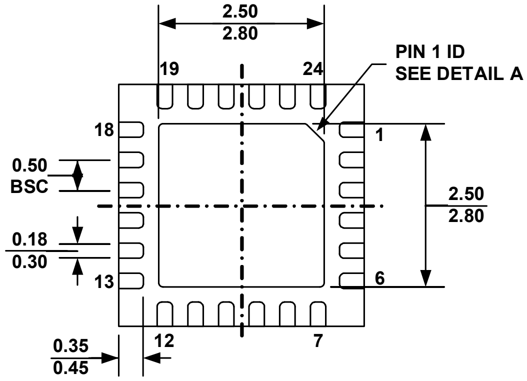
Figure 15: Detailed Application Circuit

PACKAGE INFORMATION

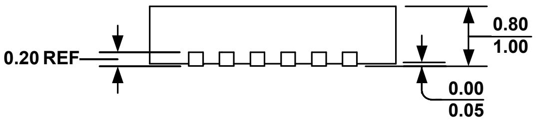
QFN-24 (4mmx4mm)



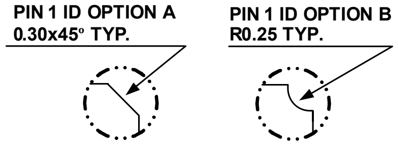
TOP VIEW



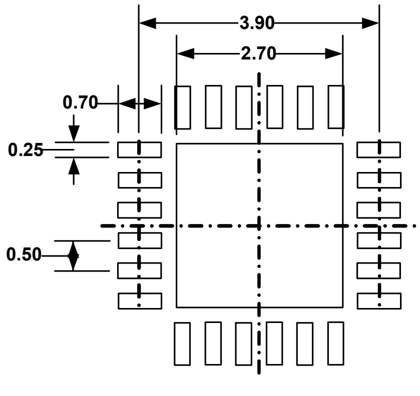
BOTTOM VIEW



SIDE VIEW



DETAIL A



RECOMMENDED LAND PATTERN

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH
3) LEAD COPLANARITY SHALL BE0.10 MILLIMETER MAX
4) DRAWING CONFIRMS TO JEDEC MO-220, VARIATION VGGD.
5) DRAWING IS NOT TO SCALE