

## DESCRIPTION

The MP2703 is a linear charger for 1-cell to 2-cell Li-ion, Li-polymer, LiFePO<sub>4</sub>, and 2-cell to 6-cell NiMH batteries. The device can sustain a voltage up to 26V.

The MP2703 measures the battery voltage ( $V_{BATT}$ ) and automatically charges the battery in four phases: trickle charge, pre-charge, constant-current (CC) fast charge, and constant-voltage charge.

The MP2703 provides a dedicated ISET pin to set the charge current by connecting a resistor between ISET and ground. The device also has a minimum input voltage limit ( $V_{IN\_LIM}$ ) to reduce the charge current when the input power is overloaded.

The MP2703 provides robust protections including input over-voltage protection (OVP), battery OVP, charge safety timer, and battery temperature protection, which is compliant with the JEITA standard.

The MP2703 integrates a battery diagnostic function. The BATTSENS pin provides an output that is proportional to the real  $V_{BATT}$ , which can be directly delivered to an external analog-to-digital converter (ADC) input for  $V_{BATT}$  measurements. In addition, an internal dummy load can be controlled to discharge the battery. An external microcontroller (MCU) can detect the battery impedance with the  $V_{BATT}$  measurement and discharge function above.

The MP2703 also provides two open-drain pins to indicate the input power status and charge status. The ACOK pin can indicate whether the input power is present. The CHG pin can indicate several charging states, including charging, termination, and fault events.

The MP2703 offers flexible one-time programmable (OTP) memory to configure a variety of charge parameters.

The MP2703 is available in a QFN-10 (2mmx2.5mm) package.

## FEATURES

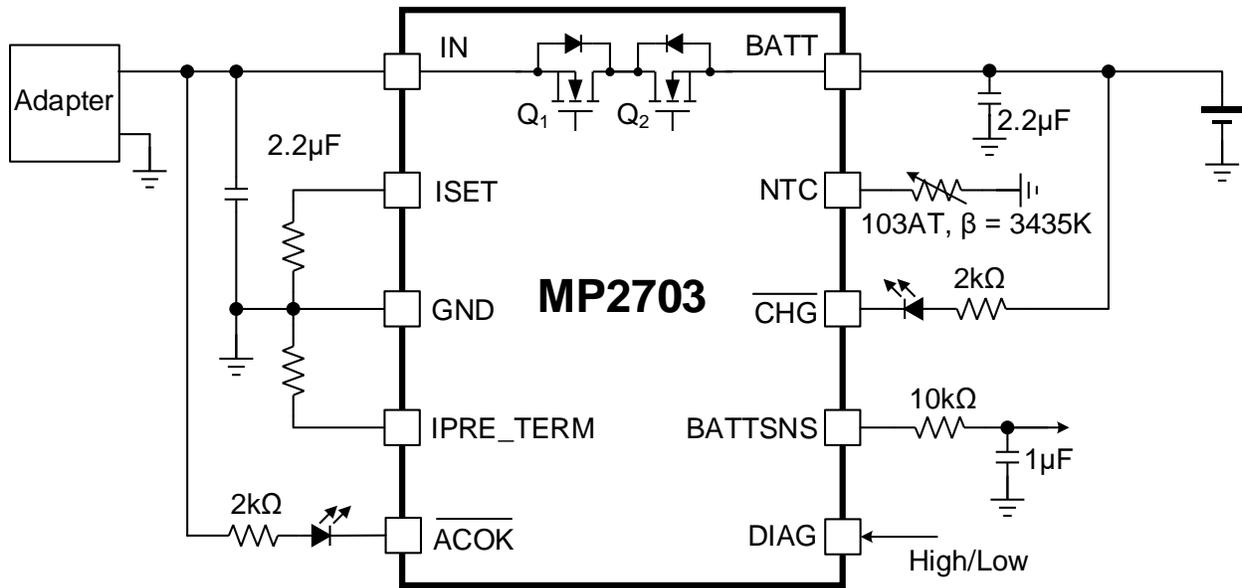
- Up to 26V of Sustainable Voltage
- Up to 1A of Configurable Charge Current via the ISET Pin
- ISET Pin Short-Circuit Protection (SCP)
- Configurable Pre-Charge Current
- Configurable Termination Current Threshold
- One-Time Programmable (OTP) Memory Selection for 3 Minimum Input Voltage Limit ( $V_{IN\_LIM}$ ) Levels
- OTP Selection for Battery Regulation Voltage from 2.4V to 4.5V Per Cell
- 0.5% Battery Regulation Voltage Accuracy
- OTP Selection for 1-Cell or 2-Cell Batteries
- Battery Voltage Monitoring Pin
- Battery Impedance Diagnostics
- Integrated Chip Junction Temperature ( $T_J$ ) Regulation
- Battery Temperature Protection Compliant with JEITA Standard
- 100nA Battery Leakage Current in Shutdown Mode
- Down to 3mA Termination Current
- Charge Status and Fault Indication
- Input Power Indication
- Integrated Charge Safety Timer
- OTP for Miscellaneous Parameters
- Provides Option to Charge 2-Cell to 6-Cell NiMH Batteries
- Compatible with LiFePO<sub>4</sub> Batteries
- Available in a Compact QFN-10 (2mmx2.5mm) Package

## APPLICATIONS

- Headphones
- Wearable Devices
- Emergency Calls

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TYPICAL APPLICATION



### ORDERING INFORMATION

Part Number*	Package	Top Marking	MSL Rating
MP2703GRP-xxxx**	QFN-10 (2mmx2.5mm)	See Below	1

\* For Tape & Reel, add suffix -Z (e.g. MP2703GRP-xxxx-Z).

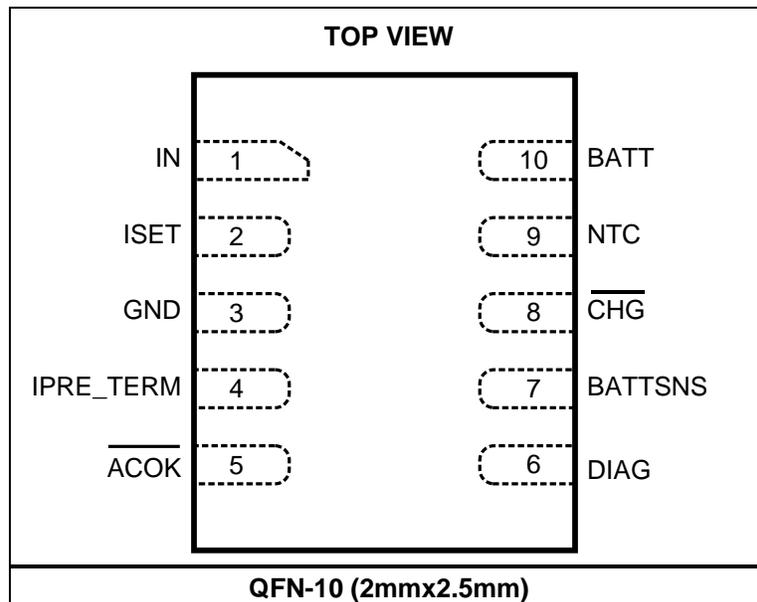
\*\*“xxxx” is the register setting option. The factory default code is “0000”. This content can be viewed in the OTP register map. Contact an MPS FAE to obtain an “xxxx” value.

### TOP MARKING

—  
**LBY**  
**LLL**

LB: Product code of MP2703GRP-xxxx  
 Y: Year code  
 LLL: Lot number

### PACKAGE REFERENCE



**PIN FUNCTIONS**

Pin #	Name	Type <sup>(1)</sup>	Description
1	IN	P	<b>Power input of the IC.</b> Place a 1 $\mu$ F to 10 $\mu$ F bypass capacitor between the IN and GND pins.
2	ISET	AI	<b>Charge current setting.</b> Connect a resistor between the ISET and GND pins to set the fast charge current, which should range between 20mA and 1A.
3	GND	P	<b>Ground terminal.</b>
4	IPRE_TERM	AI	<b>Pre-charge and termination current setting.</b> Connect a resistor between the IPRE_TERM and GND pins to set the pre-charge current ( $I_{PRE}$ ) and termination current ( $I_{TERM}$ ).
5	ACOK	DO	<b>Input power status indication.</b> The ACOK pin is an open-drain output. If the input voltage ( $V_{IN}$ ) exceeds its under-voltage lockout (UVLO) threshold ( $V_{IN\_UVLO}$ ) and the battery voltage ( $V_{BATT}$ ), then ACOK pulls low.
6	DIAG	DI	<b>Diagnostic control.</b> The DIAG pin is active high. When this pin is enabled, an internal 95mA dummy load is added at the battery.
7	BATTSNS	AO	<b>Battery voltage sense.</b> The voltage at the BATTSNS pin is 1/4 (1-cell) or 1/8 (2-cell) of the real $V_{BATT}$ .
8	CHG	DO	<b>Charge status indication.</b> If the CHG pin pulls low, this indicates that charging is in progress. If CHG is an open drain, this indicates that there is either no charging or charging is complete.
9	NTC	AI	<b>Temperature-sense input.</b> Connect a negative temperature coefficient (NTC) thermistor between the NTC and GND pins. Pull the NTC pin to ground to disable charging.
10	BATT	P	<b>Battery terminal.</b> Place a 1 $\mu$ F to 10 $\mu$ F bypass capacitor between the BATT and GND pins.

**Note:**

1) AI refers to analog input, DI refers to digital input, DO refers to digital output, and P refers to power.

**ABSOLUTE MAXIMUM RATINGS** <sup>(2)</sup>

IN, ACOK, CHG to GND .....	-0.3V to +26V
BATT to GND .....	- 0.3V to +26V
All other pins to GND .....	-0.3V to +5V
Continuous power dissipation (T <sub>A</sub> = 25°C) <sup>(3)</sup> .	1.78W
Junction temperature (T <sub>J</sub> ) .....	150°C
Lead temperature (solder) .....	260°C
Storage temperature.....	-65°C to +150°C

**ESD Ratings**

Human body model (HBM) <sup>(4)</sup> .....	1.5kV
Charged-device model (CDM) <sup>(5)</sup> .....	750V

**Recommended Operating Conditions** <sup>(6)</sup>

Input voltage (V <sub>IN</sub> ) .....	Up to 13.5V
Input current (I <sub>IN</sub> ) .....	Up to 1A
Charge current (I <sub>CC</sub> ) .....	Up to 1A
Battery voltage (V <sub>BATT</sub> ) .....	Up to 9V
Operating junction temp (T <sub>J</sub> ) ....	-40°C to +125°C

<b>Thermal Resistance</b> <sup>(7)</sup>	<b>θ<sub>JA</sub></b>	<b>θ<sub>JC</sub></b>
QFN-10 (2mmx2.5mm).....	88.....	13... °C/W

**Notes:**

- 2) Exceeding these ratings may damage the device.
- 3) The maximum allowable power dissipation is a function of the maximum junction temperature, T<sub>J</sub> (MAX), the junction-to-ambient thermal resistance, θ<sub>JA</sub>, and the ambient temperature, T<sub>A</sub>. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P<sub>D</sub> (MAX) = (T<sub>J</sub> (MAX) - T<sub>A</sub>) / θ<sub>JA</sub>. Exceeding the maximum allowable power dissipation can provide an excessive die temperature, and the regulator may go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- 4) Per ANSI/ESDA/JEDEC JS-001, all pins.
- 5) Per ANSI/ESDA/JEDEC JS-002, all pins.
- 6) The device is not guaranteed to function outside of its operating conditions.
- 7) Measured on a JESD51-7, 4-layer PCB.

## ELECTRICAL CHARACTERISTICS

$V_{IN} = 5V$ ,  $V_{BATT} = 3.7V$ ,  $V_{BATT\_REG} = 4.2V/cell$ ,  $T_A = -40$  to  $+125^{\circ}C$ , unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
<b>Input Power Characteristics</b>						
Input voltage ( $V_{IN}$ ) under-voltage lockout (UVLO) threshold	$V_{IN\_UVLO}$	$V_{IN}$ falling	3.4	3.6	3.8	V
$V_{IN}$ UVLO threshold hysteresis	$V_{IN\_UV\_HYS}$	$V_{IN}$ rising		340		mV
Input voltage vs. battery voltage headroom threshold	$V_{HDRM}$	$V_{IN}$ rising, 1 cell		200		mV
		$V_{IN}$ rising, 2 cells		240		mV
		$V_{IN}$ falling, 1 cell	10	100	190	mV
		$V_{IN}$ falling, 2 cells	20	130	240	mV
Input power good rising deglitch time	$t_{VIN\_GD}$	$V_{IN}$ rising		30		ms
$V_{IN}$ over-voltage protection (OVP) threshold	$V_{IN\_OVP}$	$V_{IN}$ rising, 1 cell	5.8	6	6.2	V
		$V_{IN}$ rising, 2 cells	13.8	14.4	15	V
$V_{IN}$ OVP hysteresis	$V_{IN\_OV\_HYS}$	$V_{IN}$ falling, 1 cell		220		mV
	$V_{IN\_OV\_HYS}$	$V_{IN}$ falling, 2 cells		550		mV
$V_{IN}$ OVP deglitch time	$t_{VIN\_OVP}$	$V_{IN}$ rising		100		$\mu s$
$V_{IN}$ OVP recovery deglitch time		$V_{IN}$ falling		30		ms
Input shutdown current	$I_{IN\_Q}$	$V_{IN} = 5V$ , charge disabled by pulling NTC to GND		290	335	$\mu A$
		$V_{IN} = 5V$ , charge termination		490	585	$\mu A$
BATT leakage current in shutdown mode	$I_{BATT\_SHDN}$	$V_{BATT} = 4.2V$ (1 cell) / $8.4V$ (2 cells), $V_{IN} = GND$		0.1	1	$\mu A$
Battery quiescent current after termination	$I_{BATT\_Q}$	$V_{IN} = 5V$ , 1 cell, charge terminated		3.8	5	$\mu A$
		$V_{IN} = 9V$ , 2 cells, charge terminated		5.6	7.2	$\mu A$
<b>Battery Charger (<math>T_A = 0^{\circ}C</math> to <math>70^{\circ}C</math>)</b>						
IN to BATT on resistance	$R_{ON\_Q1+Q2}$			370		m $\Omega$
Trickle charge to pre-charge threshold	$V_{BATT\_TC}$	$V_{BATT}$ rising	0.9	1	1.1	V/cell
Trickle charge to pre-charge threshold hysteresis	$V_{BATT\_TC\_HYS}$	$V_{BATT}$ falling		100		mV/cell

**ELECTRICAL CHARACTERISTICS (continued)**
 $V_{IN} = 5V$ ,  $V_{BATT} = 3.7V$ ,  $V_{BATT\_REG} = 4.2V/cell$ ,  $T_A = -40$  to  $+125^{\circ}C$ , unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Trickle charge current	$I_{TC}$	$R_{ISET} = 550\Omega$	28	50	72	mA
		Minimum clamp	1	3	5.5	mA
Pre-charge to fast charge threshold	$V_{BATT\_PRE}$	$V_{BATT\_PRE} = 2.5V/cell$	2.4	2.5	2.6	V/cell
		$V_{BATT\_PRE} = 2.8V/cell$	2.7	2.8	2.9	
		$V_{BATT\_PRE} = 3V/cell$	2.9	3	3.1	
		$V_{BATT\_PRE} = 3.2V/cell$	3.1	3.2	3.3	
Pre-charge to fast charge deglitch time	$t_{PRE\_CC}$			30		ms
Fast charge to pre-charge deglitch time	$t_{CC\_PRE}$			30		ms
Pre-charge current	$I_{PRE}$	$I_{PRE\_TERM}$ floating, $R_{ISET} = 1.1k\Omega$	88	100	112	mA
		$I_{PRE\_TERM}$ floating, $R_{ISET} = 550\Omega$	160	200	240	mA
		$R_{I_{PRE\_TERM}} = 2.26k\Omega$ , $R_{ISET} = 1.1k\Omega$	75	100	125	mA
		$R_{I_{PRE\_TERM}} = 2.26k\Omega$ , $R_{ISET} = 550\Omega$	145	202	258	mA
		$R_{I_{PRE\_TERM}} = 1.13k\Omega$ , $R_{ISET} = 1.1k\Omega$	32	50	66	mA
		$R_{I_{PRE\_TERM}} = 1.13k\Omega$ , $R_{ISET} = 550\Omega$	70	100	130	mA
		Minimum clamp	1	3	5.5	mA
Constant-current fast charge current	$I_{CC}$	$R_{ISET} = 786\Omega$	665	700	735	mA
		$R_{ISET} = 11k\Omega$	45	50	55	mA
		$R_{ISET} = 27.5k\Omega$	15	20	25	mA
Over charge current protection	$I_{OC}$	$R_{ISET} = 0\Omega$		1.25		A
Battery charge voltage regulation	$V_{BATT\_REG}$	$V_{BATT\_REG} = 3.6V/cell$	3.582	3.6	3.618	V/cell
		$V_{BATT\_REG} = 4.1V/cell$	4.080	4.1	4.121	
		$V_{BATT\_REG} = 4.2V/cell$	4.179	4.2	4.221	
		$V_{BATT\_REG} = 4.35V/cell$	4.328	4.35	4.372	
		$V_{BATT\_REG} = 4.5V/cell$	4.478	4.5	4.523	
Battery charge termination threshold	$I_{TERM}$	$R_{I_{PRE\_TERM}} = 2.26k\Omega$ , $R_{ISET} = 1.1k\Omega$	38	50	62	mA
		$R_{I_{PRE\_TERM}} = 2.26k\Omega$ , $R_{ISET} = 550\Omega$	74	100	126	mA
		$R_{I_{PRE\_TERM}} = 1.13k\Omega$ , $R_{ISET} = 1.1k\Omega$	12	22	31	mA
		$R_{I_{PRE\_TERM}} = 1.13k\Omega$ , $R_{ISET} = 550\Omega$	32	48	64	mA
		Minimum clamp	1	3	5.5	mA

**ELECTRICAL CHARACTERISTICS (continued)**
 $V_{IN} = 5V$ ,  $V_{BATT} = 3.7V$ ,  $V_{BATT\_REG} = 4.2V/cell$ ,  $T_A = -40$  to  $+125^{\circ}C$ , unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Charge termination deglitch time	$t_{TERM\_DGL}$			30		ms
Auto recharge voltage threshold	$V_{RECH}$	Lower than $V_{BATT\_REG}$	135	200	265	mV/cell
Auto recharge voltage deglitch time	$t_{RECH\_DGL}$			30		ms
Battery OVP threshold	$V_{BATT\_OVP}$	Comparing with $V_{BATT\_REG}$ , $V_{BATT}$ rising	85	150	215	mV/cell
Battery OVP threshold hysteresis	$V_{BATT\_OVP\_HYS}$	Comparing with $V_{BATT\_OVP}$ , $V_{BATT}$ falling		30		mV/cell
<b>Minimum Input Voltage Regulation (<math>T_A = 0^{\circ}C</math> to <math>70^{\circ}C</math>)</b>						
Minimum input voltage limit	$V_{IN\_LIM}$	$V_{IN\_LIM} = 4.375V/cell$	4.25	4.37	4.49	V/cell
		$V_{IN\_LIM} = 4.5V/cell$	4.37	4.5	4.6	V/cell
		$V_{IN\_LIM} = 4.75V/cell$	4.63	4.75	4.87	V/cell
<b>Thermal Protection</b>						
Thermal shutdown rising threshold <sup>(7)</sup>	$T_{J\_SHDN}$	$T_J$ rising		160		$^{\circ}C$
Thermal shutdown hysteresis <sup>(7)</sup>	$T_{J\_SHDN\_HYS}$			20		$^{\circ}C$
Thermal regulation point <sup>(7)</sup>	$T_{J\_REG}$			120		$^{\circ}C$
<b>Battery Diagnostics (<math>T_A = 0^{\circ}C</math> to <math>70^{\circ}C</math>)</b>						
Battery dummy load current	$I_{BATT\_DUMMY}$	$V_{BATT} = 4V$	92.3	95	96.6	mA
Battery sense percentage	$V_{BATTSENS}$	$V_{BATT} = 4V$ , 1 cell	24.5	25	25.5	%
		$V_{BATT} = 8V$ , 2 cells	11.9	12.5	13.1	%
<b>Battery Temperature Monitoring and Protection</b>						
NTC biased current	$I_{NTC}$	$T_A = 0^{\circ}C$ to $70^{\circ}C$	47.5	50	52	$\mu A$
Cold temperature threshold	$V_{COLD}$	$V_{NTC} = 1V$ to $1.5V$ , $V_{COLD} = 0^{\circ}C$	1363	1377	1391	mV
Hysteresis of cold temperature threshold	$V_{COLD\_HYS}$	$V_{NTC} = 1.5V$ to $1V$ , $V_{COLD} = 0^{\circ}C$		90		mV
Cool temperature threshold	$V_{COOL}$	$V_{NTC} = 0.5V$ to $1V$ , $V_{COOL} = 10^{\circ}C$	893	902	915	mV
Hysteresis of cool temperature threshold	$V_{COOL\_HYS}$	$V_{NTC} = 1V$ to $0.5V$ , $V_{COOL} = 10^{\circ}C$		34		mV
Warm temperature threshold	$V_{WARM}$	$V_{NTC} = 0.5V$ to $0.2V$ , $V_{WARM} = 45^{\circ}C$	239	245	251	mV
Hysteresis of warm temperature threshold	$V_{WARM\_HYS}$	$V_{NTC} = 0.2V$ to $0.5V$ , $V_{WARM} = 45^{\circ}C$		11		mV

**Note:**

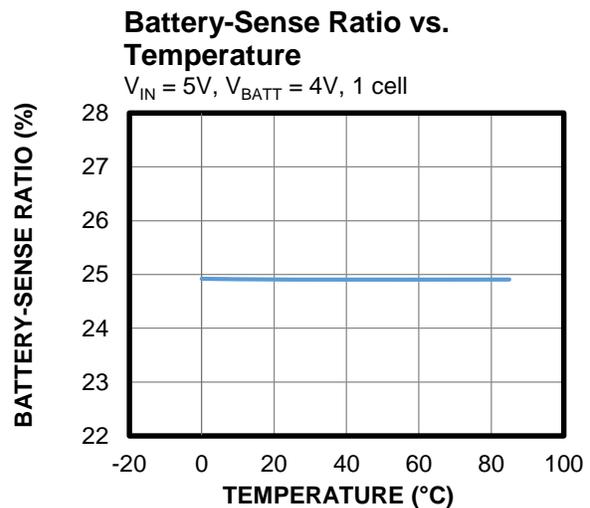
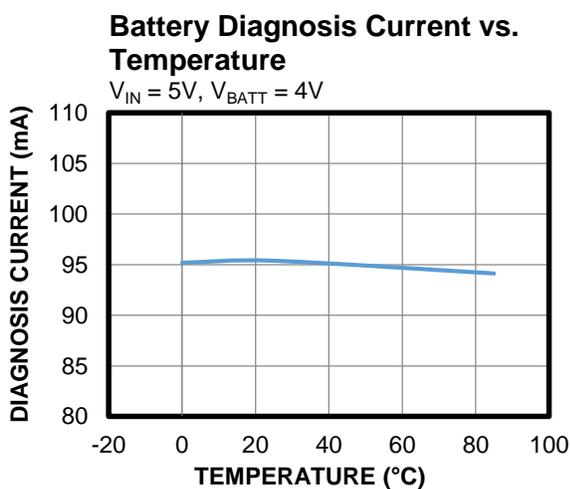
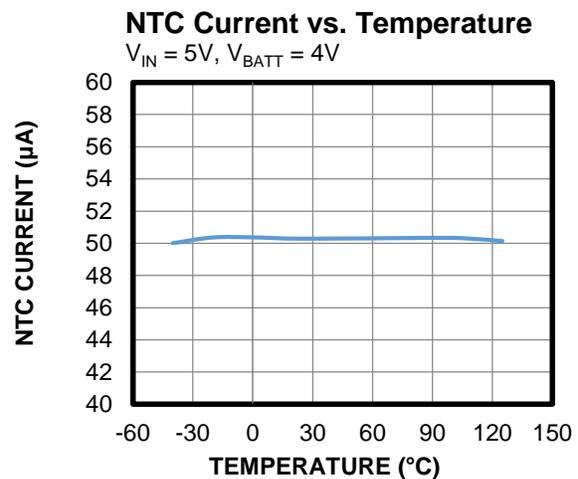
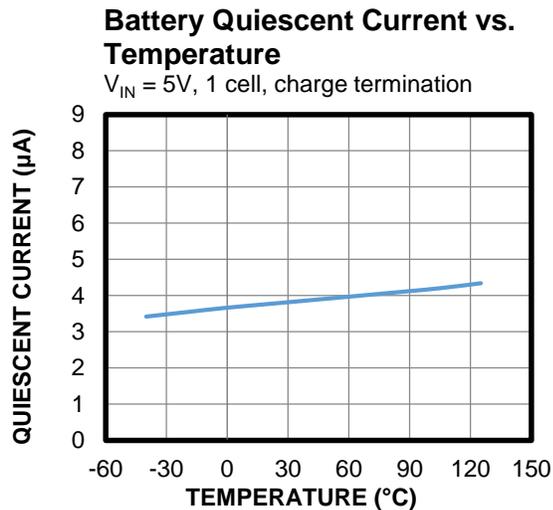
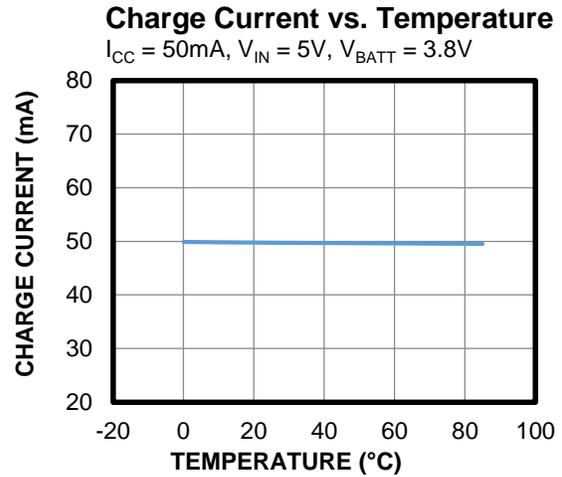
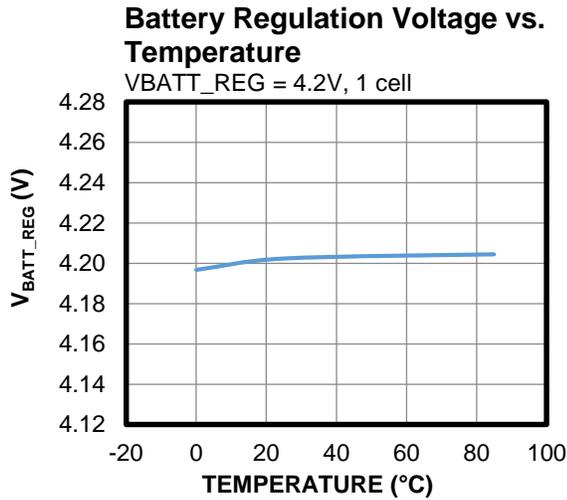
7) Guaranteed by design.

**ELECTRICAL CHARACTERISTICS (continued)**
 $V_{IN} = 5V$ ,  $V_{BATT} = 3.7V$ ,  $V_{BATT\_REG} = 4.2V/cell$ ,  $T_A = -40$  to  $+125^{\circ}C$ , unless otherwise noted.

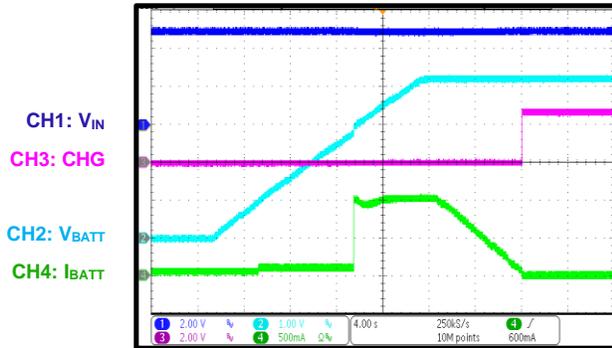
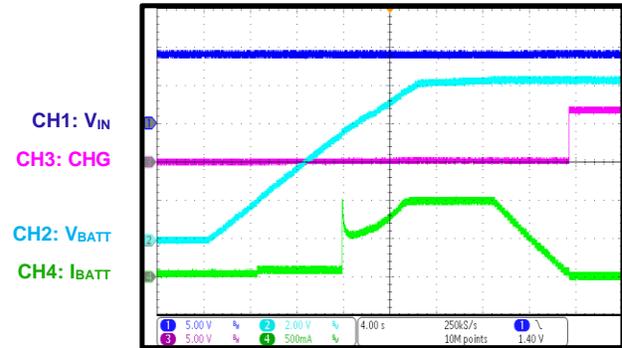
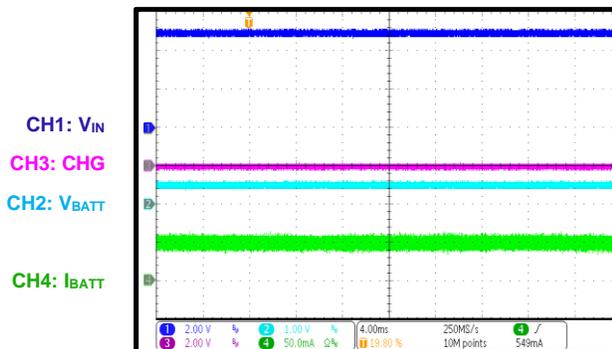
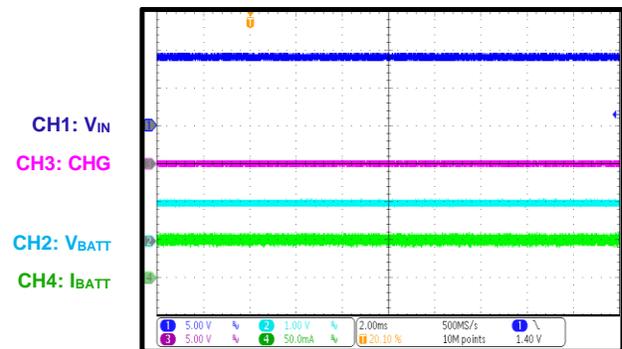
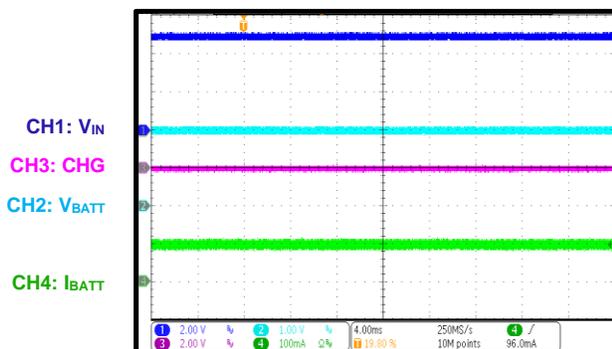
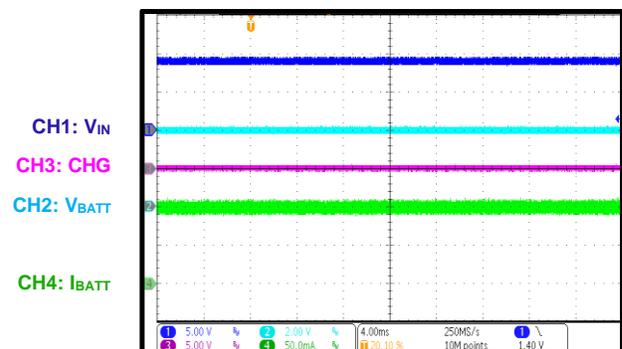
Parameter	Symbol	Condition	Min	Typ	Max	Units
Hot temperature threshold	$V_{HOT}$	$V_{NTC} = 0.2$ to $0.1V$ , $V_{HOT} = 60^{\circ}C$	138	151	157	mV
Hysteresis of hot temperature threshold	$V_{HOT\_HYS}$	$V_{NTC} = 0.1$ to $0.2V$ , $V_{HOT} = 60^{\circ}C$		11		mV
NTC enable charge threshold		$V_{NTC} = 0V$ to $0.15V$	75	90	105	mV
NTC enable charge threshold hysteresis		$V_{NTC} = 0.15V$ to $0V$		15		mV
NTC bias current when charge is disabled by NTC pin		$V_{NTC} = 0V$	20	30	40	$\mu A$
NTC charge termination disable threshold		$V_{NTC}$ rising	2.4	2.5	2.6	V
NTC charge termination disable threshold hysteresis		$V_{NTC}$ falling		100		mV
NTC minimum bias current when NTC is floating	$I_{NTC\_FLT}$	$V_{NTC} = 3V$	3	4.5	6	$\mu A$
NTC float voltage	$V_{NTC\_FLT}$			3.6		V
<b>Open-Drain Pin Characteristics</b>						
CHG pin output voltage		$I_{SINK} = 5mA$			0.4	V
ACOK pin output voltage		$I_{SINK} = 5mA$			0.4	V
<b>Logic Levels on the DIAG Pin</b>						
Logic low input voltage					0.4	V
Logic high input voltage			1.6			V
<b>Timing Characteristics (<math>T_A = 0^{\circ}C</math> to <math>70^{\circ}C</math>)</b>						
Charge timer	$t_{TMR}$	$TMR\_SET = 10$ hours	8	10	12	hr
Trickle charge and pre-charge timer			0.8	1	1.2	hr

## TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 5V$ ,  $I_{CC} = 1A$ ,  $V_{BATT} = \text{full range}$ , 1 cell,  $T_A = 25^\circ C$ , unless otherwise noted.



**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**
 $V_{IN} = 5V$ ,  $I_{CC} = 1A$ ,  $V_{BATT} = \text{full range}$ , 1 cell,  $T_A = 25^\circ C$ , unless otherwise noted.

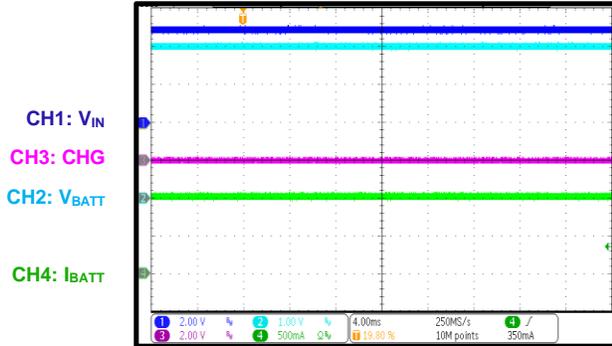
**Battery Charge Profile**
 $V_{IN} = 5V$ ,  $I_{PRE} = 10\%$ ,  $I_{CC} = 1A$ , 1 cell

**Battery Charge Profile**
 $V_{IN} = 9V$ ,  $I_{PRE} = 10\%$ ,  $I_{CC} = 1A$ , 2 cells

**Trickle Charge**
 $V_{IN} = 5V$ ,  $V_{BATT} = 0.5V$ ,  $I_{TC} = 50mA$ , 1 cell

**Trickle Charge**
 $V_{IN} = 9V$ ,  $V_{BATT} = 1V$ ,  $I_{TC} = 50mA$ , 2 cells

**Pre-Charge**
 $V_{IN} = 5V$ ,  $V_{BATT} = 2V$ ,  $I_{PRE} = 100mA$ , 1 cell

**Pre-Charge**
 $V_{IN} = 9V$ ,  $V_{BATT} = 4V$ ,  $I_{PRE} = 100mA$ , 2 cells


### TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 5V$ ,  $I_{CC} = 1A$ ,  $V_{BATT} = \text{full range}$ , 1 cell,  $T_A = 25^\circ C$ , unless otherwise noted.

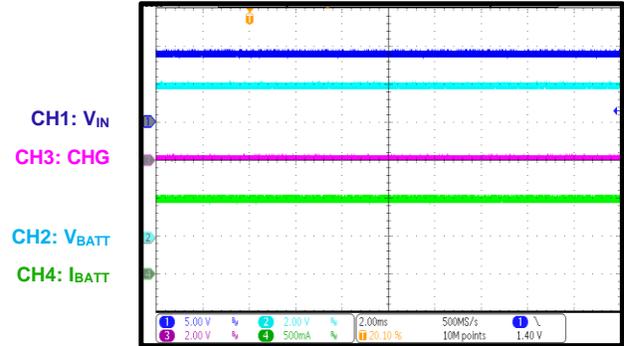
#### Constant-Current Charge

$V_{IN} = 5V$ ,  $V_{BATT} = 4V$ ,  $I_{CC} = 1A$ , 1 cell



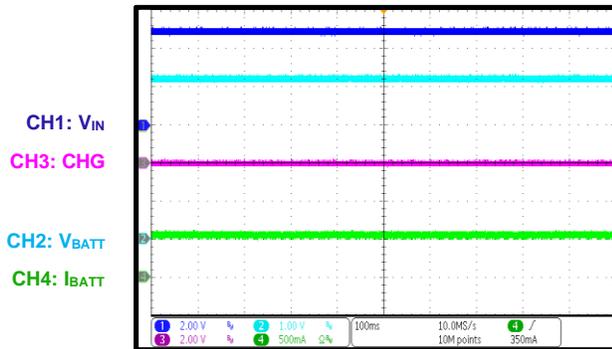
#### Constant-Current Charge

$V_{IN} = 9V$ ,  $V_{BATT} = 8V$ ,  $I_{CC} = 1A$ , 2 cells



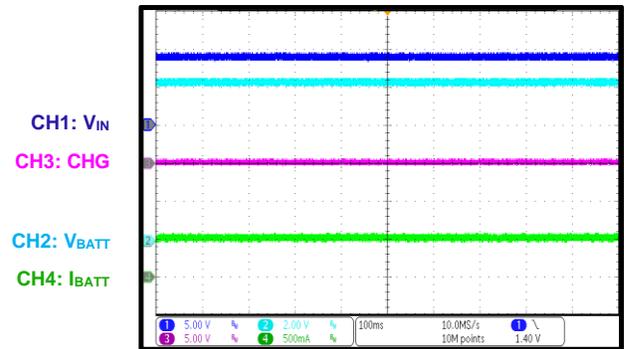
#### Constant Voltage Charge

$V_{IN} = 5V$ ,  $V_{BATT} = 4.185V$ ,  $I_{CC} = 1A$ , 1 cell



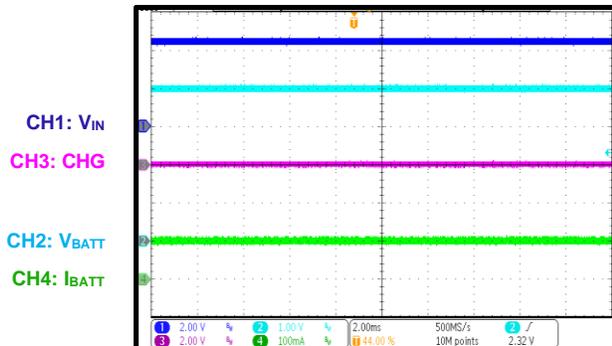
#### Constant Voltage Charge

$V_{IN} = 9V$ ,  $V_{BATT} = 8.389V$ ,  $I_{CC} = 1A$ , 2 cells



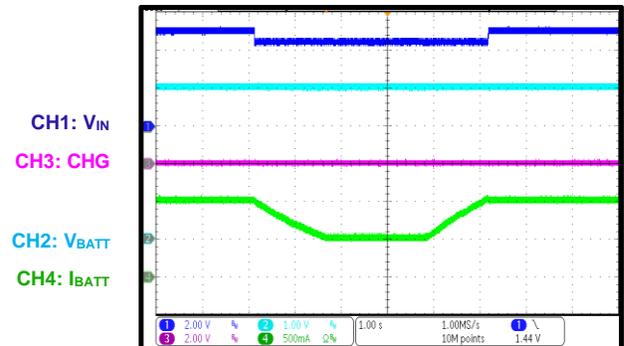
#### Input Voltage Limit Steady State

$V_{IN} = 5V$  (0.1A),  $V_{IN\_LIM} = 4.5V$ ,  $V_{BATT} = 4V$ ,  $I_{CC} = 1A$ , 1 cell

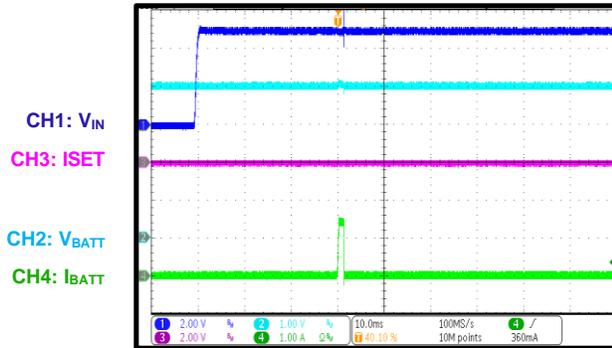
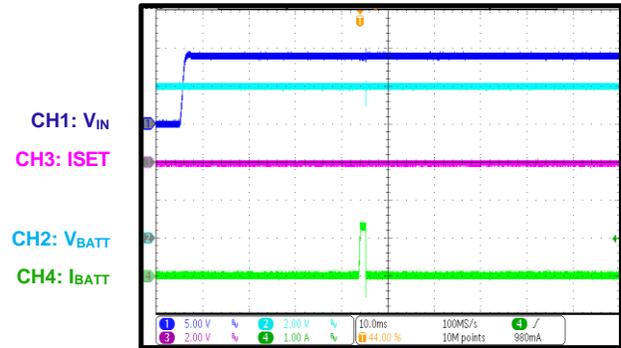
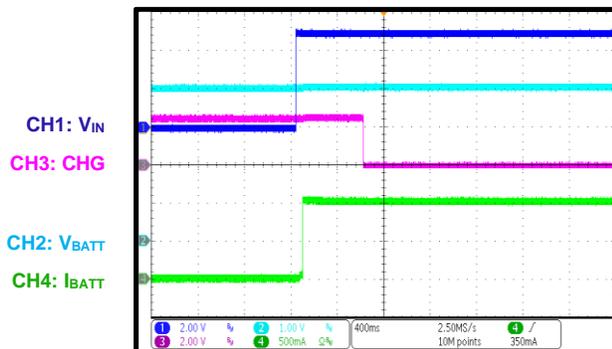
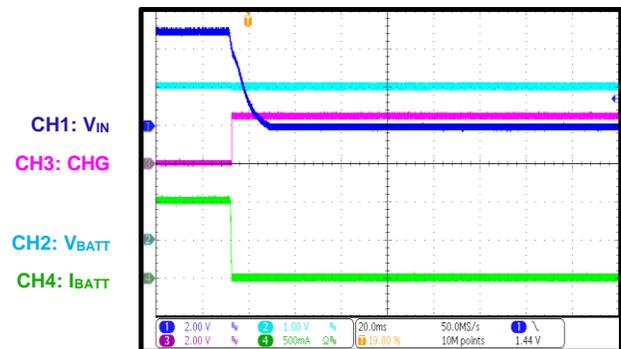
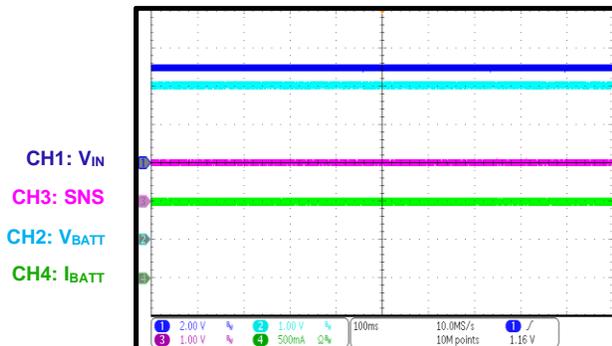
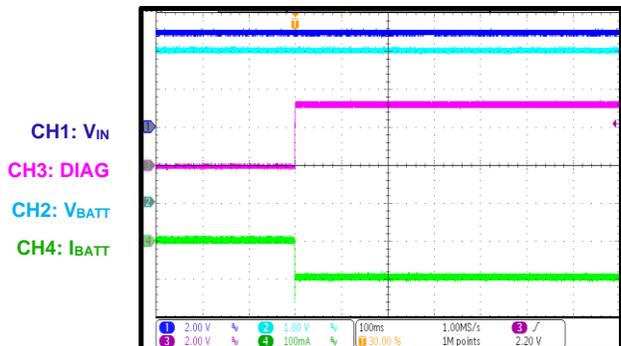


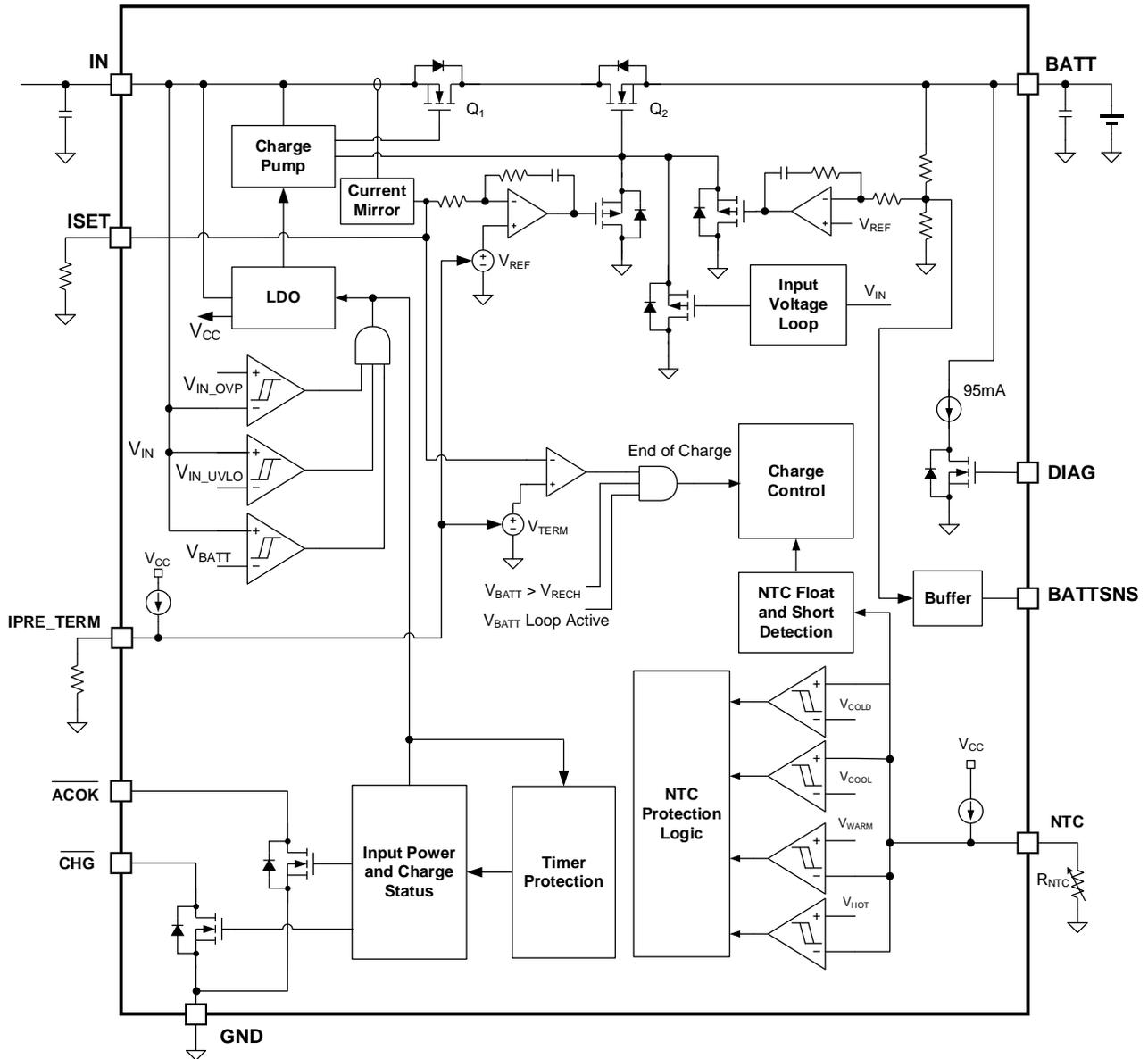
#### Input Voltage Limit

$V_{IN} = 5V$  (1A to 0.5A to 1A),  $V_{IN\_LIM} = 4.5V$ ,  $V_{BATT} = 4V$ ,  $I_{CC} = 1A$ , 1 cell



**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**
 $V_{IN} = 5V$ ,  $I_{CC} = 1A$ ,  $V_{BATT} = \text{full range}$ , 1 cell,  $T_A = 25^\circ C$ , unless otherwise noted.

**Start-Up with ISET Short**
 $V_{IN} = 5V$ ,  $V_{BATT} = 4V$ , ISET short, 1 cell

**Start-Up with ISET Short**
 $V_{IN} = 9V$ ,  $V_{BATT} = 8V$ , ISET short, 2 cells

**Start-Up**
 $V_{IN} = 5V$ ,  $V_{BATT} = 4V$ ,  $I_{CC} = 1A$ , 1 cell

**Shutdown**
 $V_{IN} = 5V$ ,  $V_{BATT} = 4V$ ,  $I_{CC} = 1A$ , 1 cell

**BATTSNS Output**
 $V_{IN} = 5V$ ,  $V_{BATT} = 4V$ ,  $I_{CC} = 1A$ , 1 cell

**Battery Dummy Load**
 $V_{IN} = 5V$ ,  $V_{BATT} = 4V$ ,  $V_{NTC} = 0V$ , 1 cell


**FUNCTIONAL BLOCK DIAGRAM**

**Figure 1: Functional Block Diagram**

## OPERATION

### Introduction

The MP2703 is a linear charger for 1-cell to 2-cell Li-ion, Li-polymer, and LiFePO<sub>4</sub> battery applications, and 2-cell to 6-cell NiMH battery applications. The device can sustain an input voltage ( $V_{IN}$ ) up to 26V and achieve up to 1A of charge current.

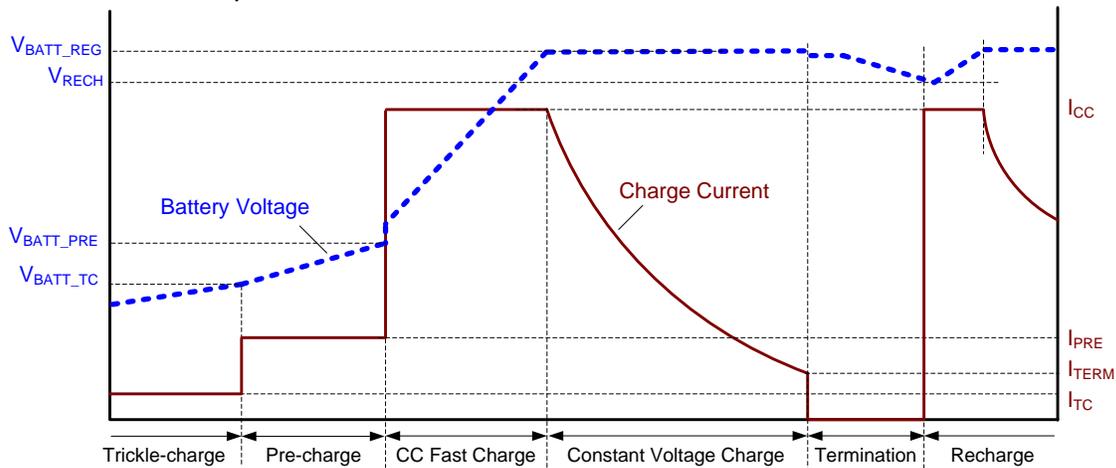
### Power Supply

The IC is powered by the input. Once  $V_{IN}$  exceeds its under-voltage lockout (UVLO) threshold ( $V_{IN\_UVLO}$ ), the internal control and logic circuit starts to operate. If  $V_{IN}$  exceeds

both  $V_{IN\_UVLO}$  and the sum of the battery voltage ( $V_{BATT}$ ) and the  $V_{IN}$  vs.  $V_{BATT}$  headroom threshold ( $V_{HDRM}$ ) ( $V_{BATT} + V_{HDRM}$ ), the MP2703 indicates power good (PG), and the ACOK pin is pulled down to GND.

### Charge Cycle

When the input power is qualified as a good power supply, the IC checks  $V_{BATT}$  and provides four charging phases: trickle charge, pre-charge, constant-current (CC) fast charge, and constant-voltage charge (see Figure 2).



**Figure 2: Charge Cycle Profile**

### Phase 1 (Trickle Charge)

If  $V_{BATT}$  is below the trickle charge to pre-charge threshold ( $V_{BATT\_TC}$ ), a trickle charging current is applied on the battery to reset the protection circuit in the battery pack. The trickle charge current ( $I_{TC}$ ) is 5% of the set fast charge current ( $I_{CC}$ ). Once 5% of  $I_{CC}$  drops below 3mA,  $I_{TC}$  is clamped at 3mA.

### Phase 2 (Pre-Charge)

If  $V_{BATT}$  exceeds  $V_{BATT\_TC}$  but remains below the pre-charge to fast charge threshold ( $V_{BATT\_PRE}$ ), the IC charges the battery with the pre-charge current ( $I_{PRE}$ ). There are four one-time programmable (OTP) memory options available for  $V_{BATT\_PRE}$ .

$I_{PRE}$  is proportional to the fast charge current and this proportion can be configured via the  $I_{PRE\_TERM}$  pin.

### Phase 3 (Constant-Current Fast Charge)

If  $V_{BATT}$  exceeds  $V_{BATT\_PRE}$ , the IC enters the constant-current fast charge phase.  $I_{CC}$  can be set via the ISET pin.

### Phase 4 (Constant-Voltage Charge)

If  $V_{BATT}$  rises to the battery charge regulation voltage ( $V_{BATT\_REG}$ ), the charge current starts to decrease. Once the charge current reaches the battery charge termination threshold ( $I_{TERM}$ ), the charge cycle is considered complete after the charge termination deglitch time ( $t_{TERM\_DGL}$ ). If  $I_{TERM}$  is not reached before the safety charge timer expires, then the charge cycle stops and the corresponding timeout fault signal asserts.

### Charge Termination

If  $V_{BATT}$  reaches the full voltage regulation threshold and the charge current is below  $I_{TERM}$ , charging is terminated after a deglitch time of 30ms. Charge termination can be disabled by floating the NTC pin.

### Automatic Recharge

Once the battery charge cycle completes, the IC remains off. During this time, the external load consumes battery power or the battery self-discharges. A new charge cycle automatically begins once  $V_{BATT}$  drops below the automatic recharge threshold for the 30ms deglitch time. The safety charge timer resets when the automatic recharge cycle begins.

### Minimum Input Voltage Limit ( $V_{IN\_LIM}$ )

The MP2703 also has a minimum input voltage limit ( $V_{IN\_LIM}$ ) regulation loop. If the charge current exceeds the input power supply's current rating, the MP2703 automatically reduces the charge current when  $V_{IN}$  reaches  $V_{IN\_LIM}$ . There are three options for  $V_{IN\_LIM}$ , set via the OTP.

### Cell Selection

The MP2703 can support both 1-cell and 2-cell batteries. The battery cell counts can be set by via the OTP. See the One-Time Programmable (OTP) Memory Map section on page 20 for details.

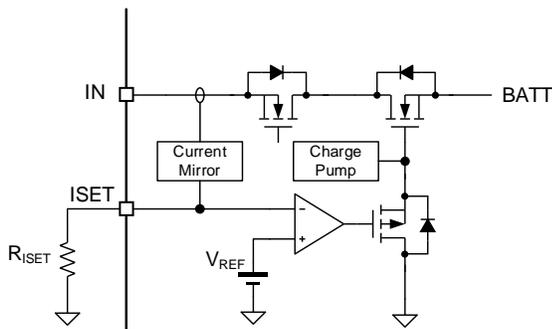
For 2-cell applications, battery hot insertion or shorting is not allowed when  $V_{IN}$  is present and charging is enabled.

### Battery Regulation Voltage

The MP2703 supports a variety of battery-full voltages, which can be set via the OTP. This voltage ranges between 2.4V/cell and 4.5V/cell, with 50mV per step.

### Fast Charge Current Setting

An external resistor between ISET and GND pin configures the fast charge current (see Figure 3).



**Figure 3: Functional Diagram Setting the Charge Current via the ISET Pin**

The relationship between the fast charge current and  $R_{ISET}$  can be calculated with Equation (1):

$$V_{REF} = k \times I_{CC} \times R_{ISET} \quad (1)$$

Where  $k$  is the current mirror's sense gain. The expected  $I_{CC}$  can be estimated with Equation (2):

$$I_{CC} = \frac{V_{REF} / k}{R_{ISET}} \quad (2)$$

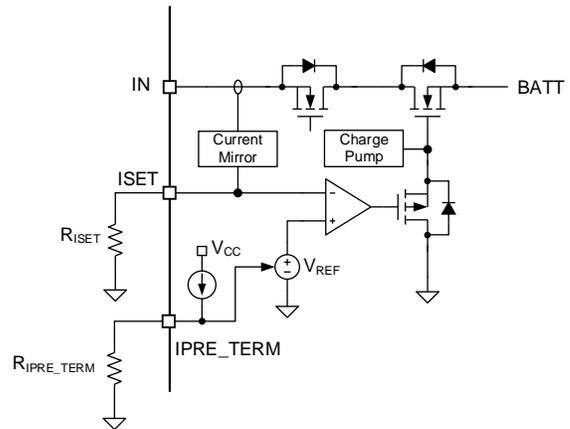
Where  $V_{REF}$  is 1.2V, and  $k$  is  $2.18 \times 10^{-3}$ .

### Over-Current Protection (OCP)

The MP2703 provides OCP if the charge current is set too high by mistake. For example, if the ISET pin is shorted to GND, the charge current is clamped at 1.25A, and the MP2703 latches off after a 1ms deglitch time. The only way to reset the fault is to re-plug the input power or pull NTC to GND.

### Pre-Charge Current Setting

Connect a resistor from the IPRE\_TERM pin to GND to configure the ratio of  $I_{PRE}$  to  $I_{CC}$ .



**Figure 4: The Functional Diagram of Pre-charge Current Setting**

The ratio of  $I_{PRE}$  to  $I_{CC}$  can be calculated with Equation (3):

$$I_{PRE} / I_{CC} = R_{IPRE\_TERM} / K_{PRE\_CC} \quad (3)$$

Where  $K_{PRE\_CC}$  is 112.36Ω/%.

For example, to set the proportion of  $I_{PRE} / I_{CC}$  to 10%, connect a 1.13kΩ resistor between the IPRE\_TERM pin and ground.

### Setting the Charge Termination Threshold

If  $V_{BATT}$  reaches the full voltage, the battery voltage loop is initiated and the charge current drops. Once the three conditions below are satisfied, charging terminates:

- The  $V_{BATT}$  loop is active.
- $V_{BATT}$  exceeds the automatic recharge voltage threshold ( $V_{RECH}$ ).
- The battery current ( $I_{BATT}$ ) is below  $I_{TERM}$ .

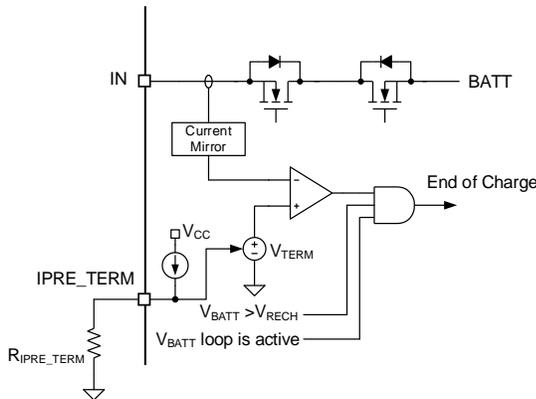
$I_{TERM}$  is also proportional to  $I_{CC}$ . This threshold ( $I_{TERM} / I_{CC}$ ) can be configured via the resistor placed between  $IPRE\_TERM$  and ground, and can be estimated with Equation (4):

$$I_{TERM} / I_{CC} = R_{IPRE\_TERM} / K_{TERM-CC} \quad (4)$$

Where  $K_{TERM-CC}$  is  $224.72\Omega/\%$ . For example, if  $R_{IPRE\_TERM}$  is  $1.13k\Omega$ , then the proportion between  $I_{TERM}$  and  $I_{CC}$  is 5%.

When the  $IPRE\_TERM$  pin is floating,  $I_{TERM}$  is fixed at 10% of the set  $I_{CC}$ .

Figure 5 shows the functional diagram to set  $I_{TERM}$ .



**Figure 5: The Functional Diagram of Termination Current Threshold**

### Battery Temperature Monitor via the Negative Thermal Coefficient (NTC) Thermistor

Thermistor is the generic name for thermally sensitive resistors. Negative temperature coefficient (NTC) thermistors are typically called thermistors. Depending on the manufacturing method and structure, thermistors come in many shapes with characteristics for various purposes. Unless otherwise specified, the thermistor resistance values are classified at a standard temperature of 25°C. The thermistor

resistance is solely a function of its absolute temperature.

Refer to the thermistor datasheet for the mathematic expression that relates the resistance and absolute temperature of a thermistor. The resistance at the absolute temperature  $T_1$  ( $R_1$ ) can be calculated with Equation (5):

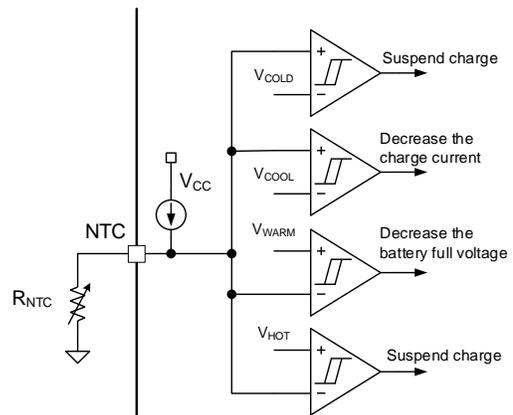
$$R_1 = R_2 \times e^{\beta \times \left( \frac{1}{T_1} - \frac{1}{T_2} \right)} \quad (5)$$

Where  $R_2$  is the resistance at the absolute temperature ( $T_2$ ), and  $\beta$  is a constant that depends on the material of the thermistor.

The MP2703 continuously monitors the battery's temperature by measuring the NTC pin voltage ( $V_{NTC}$ ), which is generated by a precise current flowing from the NTC pin through the NTC resistor ( $R_{NTC}$ ) to ground.

The MP2703 compares  $V_{NTC}$  to an internal threshold to determine the fault type that occurs and takes different actions accordingly. The current from the NTC pin is only active when  $V_{IN}$  is present.

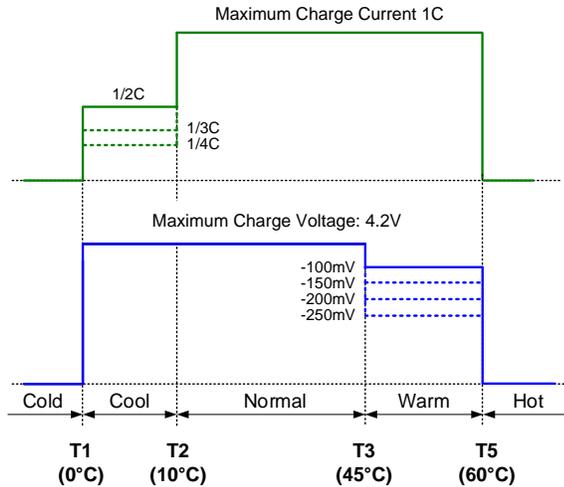
Figure 6 shows the functional diagram of the NTC protection circuit.



**Figure 6: Functional Diagram of NTC Protection Circuit**

To satisfy the JEITA requirements, the MP2703 provides four temperature thresholds: cold (0°C by default), cool (10°C by default), warm (45°C by default), and hot (60°C by default). For a given NTC thermistor, these temperatures correspond to  $V_{COLD}$ ,  $V_{COOL}$ ,  $V_{WARM}$ , and  $V_{HOT}$ , respectively. If  $V_{NTC}$  is below  $V_{HOT}$ , or  $V_{NTC}$  exceeds  $V_{COLD}$ , then charging and the timers are suspended.

If  $V_{HOT} < V_{NTC} < V_{WARM}$ , or if  $V_{COOL} < V_{NTC} < V_{COLD}$ , then the charging behavior is configured via the OTP. The preset thresholds are defined based on a thermistor where  $\beta = 3435K$ . Figure 7 shows the NTC JEITA profile.



**Figure 7: NTC JEITA Profile**

### Charge Enable Control

Charging can be disabled by pulling the NTC pin to GND. The ACOK pin stays low as long as a normal input is available. To enable charging, the following conditions must be met:

- The NTC pin is not pulled to GND.
- There is no NTC fault that could suspend charging.
- There is no timer fault.
- There is no thermal fault.

### Floated NTC Mode

When the NTC pin is floated,  $V_{NTC}$  is 3.6V. Since this exceeds the 2.5V charge termination disable threshold, the charge termination and safety timer are disabled.

To avoid overlap between the termination disable threshold and the cold temperature threshold, an internal loop can decrease the NTC bias current when  $V_{NTC}$  exceeds 2V. This prevents a cold thermistor from setting  $V_{NTC}$  above 2.5V.

### Input Over-Voltage Protection (OVP)

The MP2703 provides input OVP. When  $V_{IN}$  rises to the OVP threshold ( $V_{IN\_OVP}$ ), the MP2703 stops charging. When  $V_{IN}$  returns to its

normal range, the MP2703 starts charging automatically.

The  $V_{IN\_OVP}$  threshold is 6V for 1-cell applications and 14.4V for 2-cell applications.

### Battery Over-Voltage Protection (OVP)

If  $V_{BATT}$  exceeds the battery OVP threshold ( $V_{BATT\_OVP}$ ), charging stops. If  $V_{BATT}$  is below the  $V_{BATT\_OVP}$  falling threshold, the battery state transitions from battery OVP to charge termination.

### Safety Charge Timer

The MP2703 provides a backup charge timer to ensure charge safety. When any new charge cycle starts, if the charging stays in trickle charge and pre-charge for 1 hour, or the entire charge process lasts for 10 hours (configurable via the OTP), charging automatically stops and the fault is reported. Once charging transitions from fast charge to pre-charge, the pre-charge timer resets.

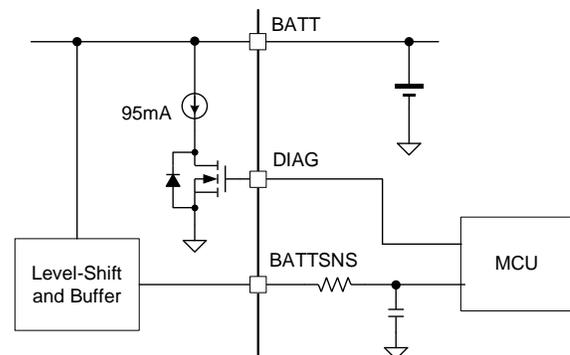
After the safety timer expires, it can be reset by one of the actions below:

- Re-plug  $V_{IN}$
- Pull the NTC pin to GND

### Battery Dummy Load

The MP2703 integrates an internal 95mA dummy load on the BATT pin, which is controlled by the DIAG pin.

When  $V_{IN}$  is present, this dummy load is connected between BATT and GND if DIAG is high (see Figure 8).



**Figure 8: Dummy Load Control Function Block**

### Battery Voltage ( $V_{BATT}$ ) Measurement

The MP2703 integrates a high-accuracy level-shift circuit to convert the high battery voltage to a lower value. This allows the MCU to measure this voltage directly. The voltage-sense gain is 1/4 for 1-cell applications and 1/8 for 2-cell applications.

This function is enabled when  $V_{IN}$  is present. The MCU measures  $V_{BATT}$  via the BATTSENS pin.

### Battery Age Diagnosis

The internal battery dummy load and battery voltage measurement function can be used to diagnose the battery age.

When  $V_{IN}$  is present, the host should follow the steps below to diagnose a battery:

1. Pull the NTC pin low to disable the charge.

2. Measure  $V_{BATT}$  via BATTSENS.
3. Enable the dummy load by pulling the DIAG pin high.
4. Measure the BATTSENS voltage again.
5. Disable the dummy load by pulling the DIAG pin low.
6. Re-enable charge by releasing the NTC pin.

The host can use the voltage difference between two measurements to estimate the battery's age.

### Operation Indication

The MP2703 has two open-drain indicators to report the status of the input power and charging. Table 1 shows the truth table for the ACOK pin.

**Table 1: ACOK Indication Truth Table**

$V_{IN}$ Status	ACOK
$V_{IN}$ UVLO	Hi-Z
$V_{IN}$ OVP	Hi-Z
$V_{IN} < V_{BATT} + V_{HDRM}$	Hi-Z
Normal Input ( $V_{IN} > V_{BATT} + V_{HDRM}$ , and $V_{IN\_UVLO} < V_{IN} < V_{IN\_OVP}$ )	Low

For CHG indication, the CHG pin pulls low when charging is in progress. After charge termination, the CHG pin enters a high-impedance (Hi-Z) state. When charging is disabled by the NTC pin, the CHG pin is in Hi-Z.

The CHG pin also can indicate certain fault events, such as an NTC fault, timer fault, and charge OCP.

After the input powers on or charging is enabled, there is a 600ms deglitch time for CHG indication, which is always Hi-Z during the blanking time (see Table 2).

**Table 2: CHG Indication Truth Table**

Charging Status	CHG
Invalid input	High-Z
Charge disable by pulling NTC to ground	High-Z
Charge termination	High-Z
Charge in process	Low
NTC fault, Timer fault, Charge OCP	Blinking (1Hz)

### Thermal Regulation and Thermal Shutdown

During the battery charging process, the MP2703 continuously monitors the internal junction temperature ( $T_J$ ) to avoid overheating the chip. If the internal temperature reaches the thermal regulation threshold ( $T_{J\_REG}$ ), the MP2703 starts to reduce the charge current to prevent higher power dissipation.

If  $T_J$  reaches the thermal shutdown threshold ( $T_{J\_SHDN}$ ), the MP2703 stops charging immediately. Once  $T_J$  drops below the  $T_{J\_SHDN}$  falling threshold, the device resumes normal operation.

### One-Time Programmable (OTP) Memory

The MP2703 provides OTP memory to configure the default value of several parameters. See the One-Time Programmable (OTP) Memory Map section on page 20 for the configurable parameters. Contact MPS to obtain a custom OTP setting.

## ONE-TIME PROGRAMMABLE (OTP) MEMORY MAP

### REG00h: Battery Voltage Threshold Setting

This register sets the battery cells' information and battery regulation voltage for each cell.

Bits	Bit Name	Default	Description
7	CELLS	1'b0	Selects the battery cell. 0: 1 cell (default) 1: 2 cells
6	RESERVED	1'b0	Reserved.
5:0	VBATT_REG	6'b100100	Sets the battery regulation voltage. Range: 2.4V/cell (000000) to 4.5V/cell (101010) Offset: 2.4V/cell Step: 50mV/cell Default: 4.2V/cell (100100)

### REG01h: Timer and Thermal Setting

This register sets the safety charge timer and internal junction temperature ( $T_J$ ) regulation threshold.

Bits	Bit Name	Default	Description
7	TMR_PRE	1'b1	Sets the safety timer for trickle charge and pre-charge. 0: Disabled 1: 1 hour (default)
6	TMR_EN	1'b1	Enables safety timer control. 0: Disabled 1: Enabled (default)
5:3	TMR_SET	3'b010	Sets the safety timer for the entire charge process. Range: 2 hours (000) to 30 hours (111) Offset: 2 hours Step: 4 hours Default: 10 hours (010)
2	RESERVED	1'b0	Reserved.
1	TJ_REG	1'b1	Sets the $T_J$ regulation loop. 0: 100°C 1: 120°C
0	RESERVED	1'b0	Reserved.

### REG02h: Input Voltage Limit Setting

This register sets the input voltage limit ( $V_{IN\_LIM}$ ) loop threshold. If  $V_{IN}$  drops below this threshold, the charge current decreases to prevent  $V_{IN}$  from dropping further.

Bits	Bit Name	Default	Description
7:6	RESERVED	2'b00	Reserved.
5:4	VIN_LIM[1]	2'b10	Sets the $V_{IN}$ limit. 00: Reserved 01: 4.375V/cell 10: 4.5V/cell (default) 11: 4.75V/cell
3:0	RESERVED	4'b0000	Reserved.

**REG03h: JEITA Temperature Threshold Setting**

This register sets the JEITA hot, warm, cool, and cold temperature thresholds.

Bits	Bit Name	Default	Description
7:6	VHOT	2'b10	Sets the hot falling threshold. 00: 0.208V (50°C) 01: 0.176V (55°C) 10: 0.151V (60°C, default) 11: 0.129V (65°C)
5:4	VWARM	2'b01	Sets the warm falling threshold. 00: 0.291V (40°C) 01: 0.245V (45°C, default) 10: 0.205V (50°C) 11: 0.176V (55°C)
3:2	VCOOL	2'b10	Sets the cool rising threshold. 00: 1.377V (0°C) 01: 1.111V (5°C) 10: 0.902V (10°C, default) 11: 0.737V (15°C)
1:0	VCOLD	2'b01	Sets the cold rising threshold. 00: 1.732V (-5°C) 01: 1.377V (0°C, default) 10: 1.111V (+5°C) 11: 0.902V (+10°C)

**REG04h: JEITA Protection Setting**

This register sets the charging behavior within the JEITA warm and cool temperature windows.

Bits	Bit Name	Default	Description
7:6	WARM_ACT	2'b01	Sets the charge action when the NTC is warm. 00: No action. Charging stops when the NTC is hot 01: Reduce $V_{BATT\_REG}$ when the NTC is warm (default) 10: Reduce $I_{CC}$ when the NTC is warm 11: Reduce both $V_{BATT\_REG}$ and $I_{CC}$ when the NTC is warm
5:4	COOL_ACT	2'b10	Sets the charge action when the NTC is cool. 00: No action. Charging stops when NTC is cold 01: Reduce $V_{BATT\_REG}$ when the NTC is cool 10: Reduce $I_{CC}$ when the NTC is cool (default) 11: Reduce both $V_{BATT\_REG}$ and $I_{CC}$ when the NTC is cool
3:2	JEITA_VSET	2'b00	00: $V_{BATT\_REG} - 100\text{mV/cell}$ (default) 01: $V_{BATT\_REG} - 150\text{mV/cell}$ 10: $V_{BATT\_REG} - 200\text{mV/cell}$ 11: $V_{BATT\_REG} - 250\text{mV/cell}$
1:0	JEITA_ISET	2'b00	00: 50% of $I_{CC}$ (default) 01: 33% of $I_{CC}$ 10: 25% of $I_{CC}$ 11: 0% of $I_{CC}$ (disable charge)

**REG05h: Pre-Charge Threshold Setting**

This register sets the pre-charge threshold.

Bits	Bit Name	Default	Description
7:2	RESERVED	6'b000000	Reserved.
1:0	VBATT_PRE	2'b01	Sets the pre-charge threshold. 00: 2.5V/cell 01: 2.8V/cell (default) 10: 3V/cell 11: 3.2V/cell

## APPLICATION INFORMATION

### Setting the Fast Charge Current

A resistor connected from ISET to GND sets  $I_{CC}$ . The relationship between  $I_{CC}$  and the setting resistor can be estimated with Equation (6):

$$I_{CC} = \frac{V_{REF}/k}{R_{ISET}} \quad (6)$$

Where  $V_{REF}$  is 1.2V, and  $k$  is  $2.18 \times 10^{-3}$ .

For example, to set  $I_{CC}$  to 1A, then  $R_{ISET}$  is calculated to be 550Ω.

### Setting the Pre-Charge Current and Termination Current

The pre-charge current is set as a percentage of fast charge current by connecting a resistor from the IPRE\_TERM pin to GND.

The ratio of  $I_{PRE}$  to  $I_{CC}$  can be calculated with Equation (7):

$$I_{PRE} / I_{CC} = R_{IPRE\_TERM} / K_{PRE-CC} \quad (7)$$

Where  $K_{TERM-CC}$  is 112.36Ω/%. For example, if  $R_{IPRE\_TERM}$  is 1.13kΩ, then the proportion between  $I_{TERM}$  and  $I_{CC}$  is 10%.

When the IPRE\_TERM pin is floating,  $I_{TERM}$  is fixed at 20% of the set  $I_{CC}$ .

The termination current is fixed at 50% of the pre-charge current.

### Setting the Battery Cell

The MP2703 supports 1-cell and 2-cell batteries, the battery cell number is configured via the OTP.

For 2-cell applications, battery hot insertion or shorting is not allowed when  $V_{IN}$  is present and charging is enabled.

### Selecting the Input Capacitor

An input capacitor is required for stability. Connect a minimum 1μF capacitor between IN and GND for stable operation across full load current range. The capacitor's voltage rating should exceed the normal input voltage level. A low-ESR, X5R/X7R ceramic capacitor is recommended.

### Selecting the BATT to GND Capacitor

The MP2703 requires that a capacitor be connected from BATT to GND. A minimum 1μF ceramic capacitor with X5R/X7R dielectrics is sufficient for most applications.

### Selecting the NTC Resistor

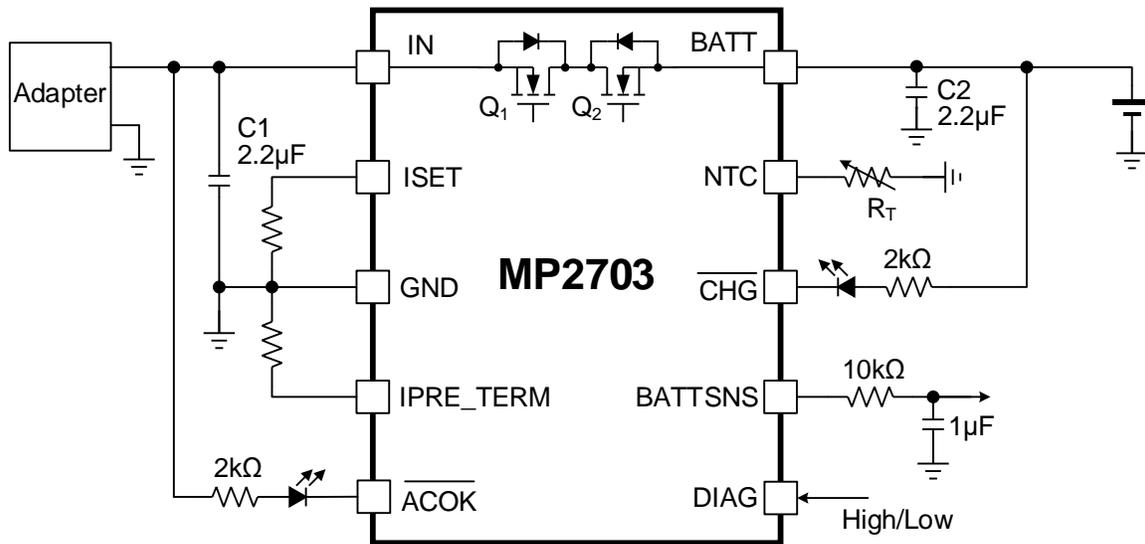
The MP2703 supports a configurable JEITA, which is based on a precise 50μA current source flowing through the external NTC thermistor. To use this function, connect a 10kΩ NTC thermistor with a  $\beta = 3435K$  from the NTC pin to GND.

The JEITA threshold can be configured via the OTP.

If the NTC pin is not used, connect a fixed 10kΩ resistor from NTC to GND.

### PCB Layout Guidelines

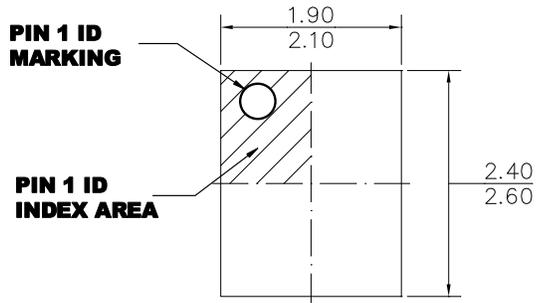
Place the external capacitors as close to the IC as possible to ensure the smallest input/output inductance and ground impedance.

**TYPICAL APPLICATION CIRCUIT**

**Figure 9: Typical Application Circuit**
**Table 3: Key BOM of Figure 9**

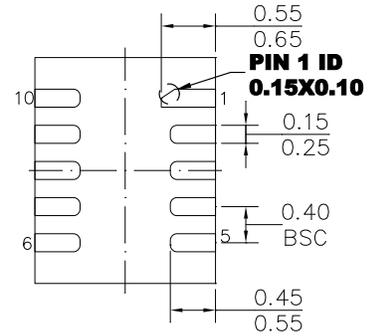
Qty	Ref	Value	Description	Package	Manufacturer
1	C1	2.2µF	Ceramic capacitor, 25V, X5R or X7R	0603	Any
1	C2	2.2µF	Ceramic capacitor, 16V, X5R or X7R	0603	Any
1	R <sub>T</sub>	10kΩ	β = 3435K	Any	Any

PACKAGE INFORMATION

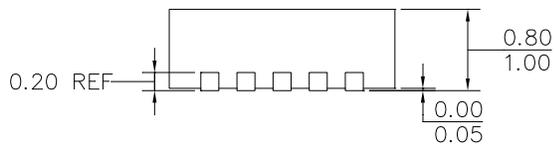
QFN-10 (2mmx2.5mm)



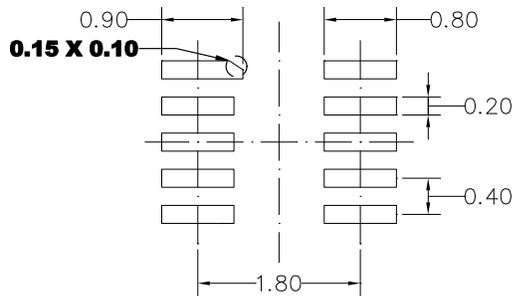
TOP VIEW



BOTTOM VIEW



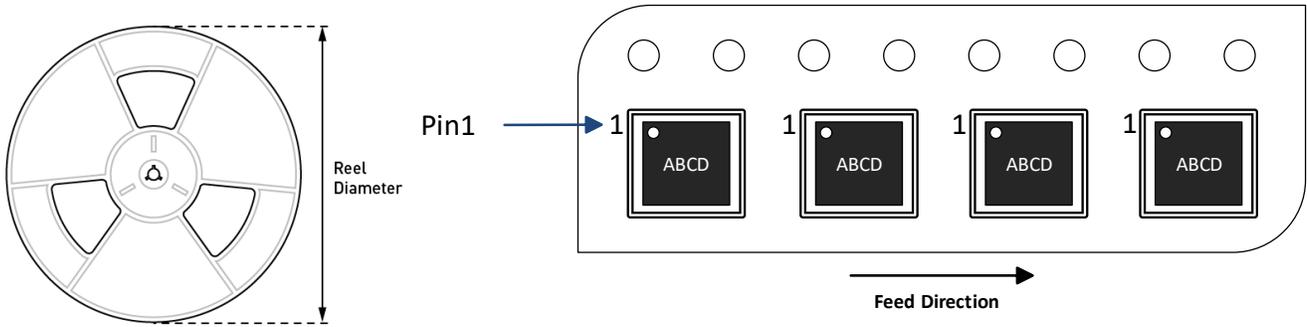
SIDE VIEW



RECOMMENDED LAND PATTERN

NOTE:

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
- 3) JEDEC REFERENCE IS MO-220.
- 4) DRAWING IS NOT TO SCALE.

**CARRIER INFORMATION**


Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Quantity/ Tray	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MP2703GRP-xxxx-Z	QFN-10 (2mmx2.5mm)	5000	N/A	N/A	13in	12mm	8mm

## REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	10/12/2023	Initial Release	-

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