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MCP73871

Stand-Alone System Load Sharing and Li-Ion/Li-Polymer Battery Charge Management Controller

Features

- Integrated System Load Sharing and Battery Charge Management
  - Simultaneously Power the System and Charge the Li-Ion Battery
  - Voltage Proportional Current Control (VPCC) ensures system load has priority over Li-Ion battery charge current
  - Low-Loss Power-Path Management with Ideal Diode Operation
- Complete Linear Charge Management Controller
  - Integrated Pass Transistors
  - Integrated Current Sense
  - Integrated Reverse Discharge Protection
  - Selectable Input Power Sources: USB Port or AC-DC Wall Adapter
- Preset High Accuracy Charge Voltage Options:
  - 4.10V, 4.20V, 4.35V or 4.40V
  - ±0.5% Regulation Tolerance
- Constant Current/Constant Voltage (CC/CV) Operation with Thermal Regulation
- Maximum 1.8A Total Input Current Control
- Resistor Programmable Fast Charge Current Control: 50 mA to 1A
- Resistor Programmable Termination Set Point
- Selectable USB Input Current Control
  - Absolute Maximum: 100 mA (L)/500 mA (H)
- Automatic Recharge
- Automatic End-of-Charge Control
- Safety Timer With Timer Enable/Disable Control
- 0.1C Preconditioning for Deeply Depleted Cells
- Battery Cell Temperature Monitor
- Undervoltage Lockout (UVLO)
- Low Battery Status Indicator ($\overline{\text{LBO}}$)
- Power Good Status Indicator ($\overline{\text{PG}}$)
- Charge Status and Fault Condition Indicators
- Numerous Selectable Options Available for a Variety of Applications:
  - Refer to **Section 1.0 "Electrical Characteristics"** for Selectable Options
  - Refer to the **Product Identification System** for Standard Options
- Temperature Range: -40°C to +85°C
- Packaging: 20-Lead QFN (4 mm x 4 mm)

Applications

- GPSs/Navigators
- PDAs and Smart Phones
- Portable Media Players and MP3 Players
- Digital Cameras
- Bluetooth® Headsets
- Portable Medical Devices
- Charge Cradles/Docking Stations
- Toys

Description

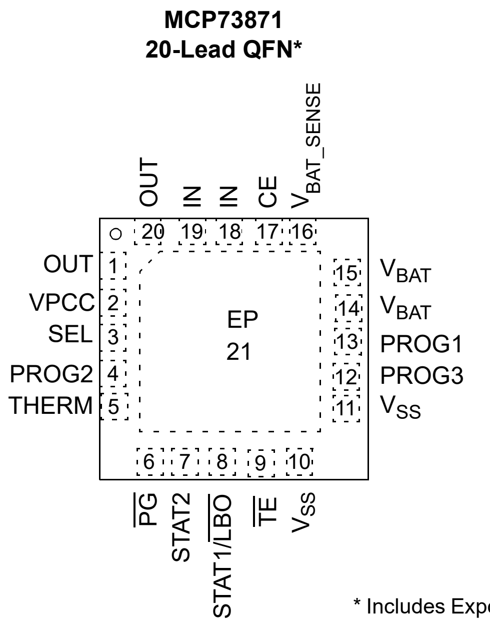
The MCP73871 device is a fully integrated linear solution for system load sharing and Li-Ion/Li-Polymer battery charge management with AC-DC wall adapter and USB port power sources selection. It is also capable of autonomous power source selection between input and battery. Along with its small physical size, the low number of required external components makes the device ideally suited for portable applications.

The MCP73871 device automatically obtains power for the system load from a single-cell Li-Ion battery or an input power source (AC-DC wall adapter or USB port). The MCP73871 device specifically adheres to the current drawn limits governed by the USB specification. With an AC-DC wall adapter providing power to the system, an external resistor sets the magnitude of 1A maximum charge current while supporting up to 1.8A total current for system load and battery charge current.

The MCP73871 device employs a constant current/constant voltage (CC/CV) charge algorithm with selectable charge termination point. To accommodate new and emerging battery charging requirements, the constant voltage regulation is fixed with four available options: 4.10V, 4.20V, 4.35V or 4.40V. The MCP73871 device also limits the charge current based on the die temperature during high power or high ambient conditions. This thermal regulation optimizes the charge cycle time while maintaining device reliability.

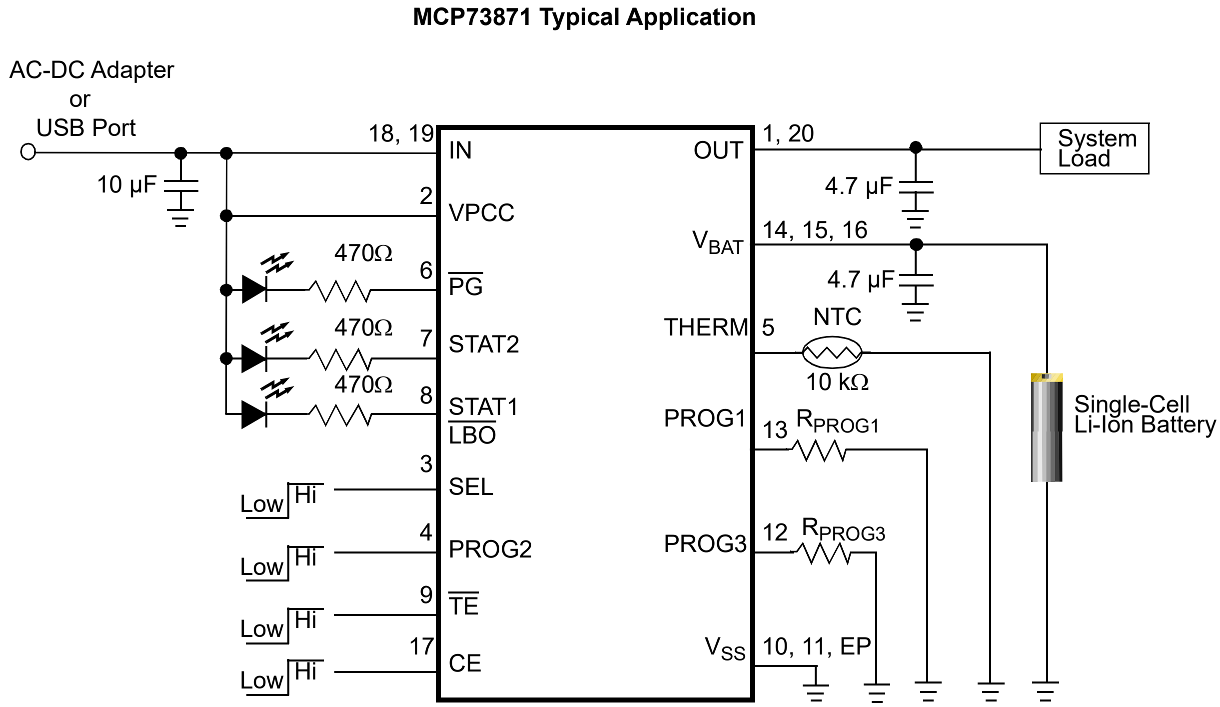
The MCP73871 device includes a low battery indicator, a power good indicator and two charge status indicators that allow for outputs with LEDs or communication with host microcontrollers. The MCP73871 device is fully specified over the ambient temperature range of -40°C to +85°C.

Package Types

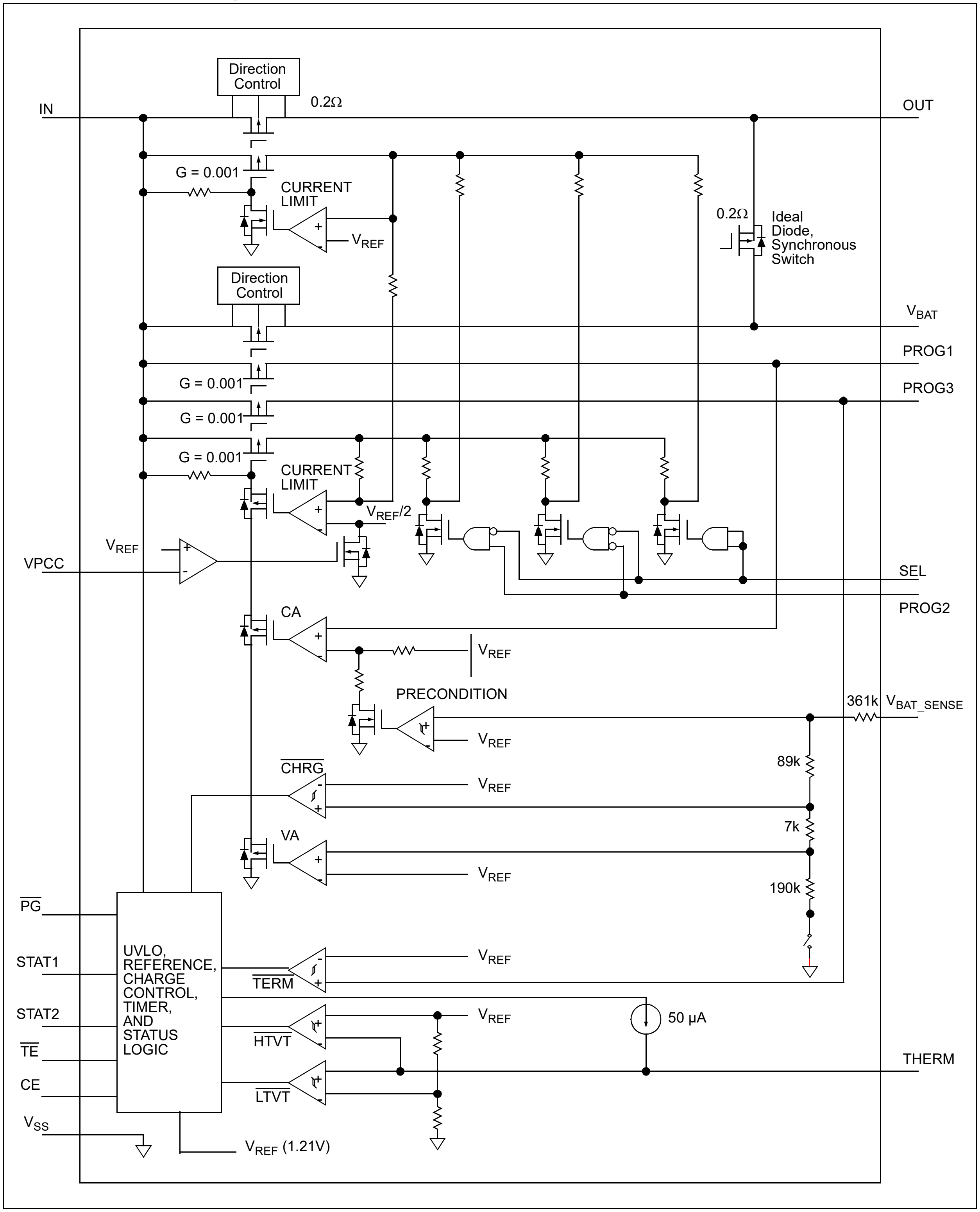


* Includes Exposed Thermal Pad (EP); see Table 3-1.

Typical Application Circuit



Functional Block Diagram



NOTES:

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings†

V_{IN} 7.0V
All Inputs and Outputs w.r.t. .... V_{SS}-0.3V to V_{DD}+0.3V
(V_{DD} = V_{IN} or V_{BAT})
Maximum Junction Temperature, T_J .... Internally Limited
Storage temperature ....-65°C to +150°C
ESD protection on all pins
Human Body Model (1.5 kΩ in Series with 100 pF).......≥ 4 kV
Machine Model (200 pF, No Series Resistance).............300V

† Notice: Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, all limits apply for V_{IN} = V_{REG} + 0.3V to 6V, T_A = -40°C to +85°C. Typical values are at +25°C, V_{IN} = [V_{REG} (typical) + 1.0V]

Parameters	Sym	Min	Typ	Max	Units	Conditions
Supply Input						
Supply Voltage	V_{IN}	V_{REG} + 0.3V	—	6	V	
Supply Current	I_{SS}	—	2500	3750	µA	Charging
		—	260	350	µA	Charge Complete
		—	180	300	µA	Standby
		—	28	50	µA	Shutdown (V_{DD} ≤ V_{BAT} – 100 mV or V_{DD} < V_{STOP})
UVLO Start Threshold	V_{START}	V_{REG} + 0.05V	V_{REG} + 0.15V	V_{REG} + 0.25V	V	V_{DD} = Low-to-High
UVLO Stop Threshold	V_{STOP}	V_{REG} – 0.07V	V_{REG} + 0.07V	V_{REG} + 0.17V	V	V_{DD} = High-to-Low
UVLO Hysteresis	V_{HYS}	—	90	—	mV	
Voltage Regulation (Constant Voltage Mode)						
Regulated Charge Voltage	V_{REG}	4.080	4.10	4.121	V	V_{DD} = [V_{REG}(typical) + 1V] I_{OUT} = 10 mA T_A = -5°C to +55°C
		4.179	4.20	4.221	V	
		4.328	4.35	4.372	V	
		4.378	4.40	4.422		
Regulated Charge Voltage Tolerance	V_{RTOL}	-0.5	—	+0.5	%	T_A = +25°C
		-0.75	—	+0.75	%	T_A = -5°C to +55°C
Line Regulation	$\lvert(\Delta V_{BAT}/V_{BAT}) / \Delta V_{DD}\rvert$	—	0.08	0.20	%/V	V_{DD} = [V_{REG}(typical) + 1V] to 6V I_{OUT} = 10 mA
Load Regulation	$\lvert\Delta V_{BAT}/V_{BAT}\rvert$	—	0.08	0.18	%	I_{OUT} = 10 mA to 150 mA V_{DD} = [V_{REG}(typical) + 1V]
Supply Ripple Attenuation	PSRR	—	-47	—	dB	I_{OUT} = 10 mA, 1 kHz
		—	-40	—	dB	I_{OUT} = 10 mA, 10 kHz

Note 1: The value is ensured by design and not production tested.
2: The maximum available charge current is also limited by the value set at PROG1 input.

DC CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated, all limits apply for $V_{IN} = V_{REG}$ + 0.3V to 6V, T_A = -40°C to +85°C. Typical values are at +25°C, $V_{IN} = [V_{REG}$ (typical) + 1.0V]

Parameters	Sym	Min	Typ	Max	Units	Conditions
Current Regulation (Fast Charge Constant Current Mode)						
AC-Adapter Fast Charge Current	I_{REG}	90	100	110	mA	PROG1 = 10 kΩ, T_A = -5°C to +55°C, SEL = High
		900	1000	1100	mA	PROG1 = 1 kΩ, T_A = -5°C to +55°C, SEL = High
USB Fast Charge Current	I_{REG}	80	90	100	mA	PROG2 = Low, SEL = Low, (Note 2) T_A = -5°C to +55°C
		400	450	500	mA	PROG2 = High, SEL = Low, (Note 2) T_A = -5°C to +55°C
Input Current Limit Control (ICLC)						
USB-Port Supply Current Limit	I_{LIMIT_USB}	80	90	100	mA	PROG2 = Low, SEL = Low T_A = -5°C to +55°C
		400	450	500	mA	PROG2 = High, SEL = Low T_A = -5°C to +55°C
AC-DC Adapter Current Limit	I_{LIMIT_AC}	1500	1650	1800	mA	SEL = High, T_A = -5°C to +55°C
Voltage Proportional Charge Control (VPCC - Input Voltage Regulation)						
VPCC Input Threshold	V_{VPCC}	—	1.23	—	V	I_{OUT} = 10 mA T_A = -5°C to +55°C
VPCC Input Threshold Tolerance	V_{RTOL}	-3	—	+3	%	
Input Leakage Current	I_{LK}	—	0.01	1	µA	$V_{VPCC} = V_{DD}$
Precondition Current Regulation (Trickle Charge Constant Current Mode)						
Precondition Current Ratio	I_{PREG}/I_{REG}	7.5	10	12.5	%	PROG1 = 1.0 kΩ to 10 kΩ T_A = -5°C to +55°C
Precondition Current Threshold Ratio	V_{PTH}/V_{REG}	69	72	75	%	V_{BAT} Low-to-High
Precondition Hysteresis	V_{PHYS}	—	105	—	mV	V_{BAT} High-to-Low
Automatic Charge Termination Set Point						
Charge Termination Current Ratio	I_{TERM}	75	100	125	mA	PROG3 = 10 kΩ T_A = -5°C to +55°C
		7.5	10	12.5	mA	PROG3 = 100 kΩ T_A = -5°C to +55°C
Automatic Recharge						
Recharge Voltage Threshold Ratio	V_{RTH}	V_{REG} – 0.21V	V_{REG} – 0.15V	V_{REG} – 0.09V	V	V_{BAT} High-to-Low
IN-to-OUT Pass Transistor ON-Resistance						
ON-Resistance	R_{DS_ON}	—	200	—	mΩ	V_{DD} = 4.5V, T_J = 105°C

Note 1: The value is ensured by design and not production tested.
2: The maximum available charge current is also limited by the value set at PROG1 input.

DC CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated, all limits apply for $V_{IN} = V_{REG}$ + 0.3V to 6V, T_A = -40°C to +85°C. Typical values are at +25°C, V_{IN} = [V_{REG} (typical) + 1.0V]

Parameters	Sym	Min	Typ	Max	Units	Conditions
Charge Transistor ON-Resistance						
ON-Resistance	$R_{DSON\_}$	—	200	—	mΩ	V_{DD} = 4.5V, T_J = 105°C
BAT-to-OUT Pass Transistor ON-Resistance						
ON-Resistance	R_{DS_ON}	—	200	—	mΩ	V_{DD} = 4.5V, T_J = 105°C
Battery Discharge Current						
Output Reverse Leakage Current	$I_{DISCHARGE}$	—	30	40	µA	Shutdown ($V_{BAT} < V_{DD} < V_{UVLO}$)
		—	30	40	µA	Shutdown ($0 < V_{DD} \le V_{BAT}$)
		—	30	40	µA	V_{BAT} = Power Out, No Load
		—	-6	-13	µA	Charge Complete
Status Indicators - STAT1 ($\overline{\text{LBO}}$), STAT2, $\overline{\text{PG}}$						
Sink Current	I_{SINK}	—	16	35	mA	
Low Output Voltage	V_{OL}	—	0.4	1	V	I_{SINK} = 4 mA
Input Leakage Current	I_{LK}	—	0.01	1	µA	High Impedance, V_{DD} on pin
Low Battery Indicator ($\overline{\text{LBO}}$)						
Low Battery Detection Threshold	V_{LBO}	—	Disable	—		$V_{BAT} > V_{IN}$, $\overline{\text{PG}}$ = Hi-Z T_A = -5°C to +55°C
		2.85	3.0	3.15	V	
		2.95	3.1	3.25	V	
		3.05	3.2	3.35	V	
Low Battery Detection Hysteresis	V_{LBO_HYS}	—	150	—	mV	V_{BAT} Low-to-High
PROG1 Input (PROG1)						
Charge Impedance Range	R_{PROG}	1	—	20	kΩ	
PROG3 Input (PROG3)						
Termination Impedance Range	R_{PROG}	5	—	100	kΩ	
PROG2 Input (PROG2)						
Input High Voltage Level	V_{IH}	1.8	—	—	V	
Input Low Voltage Level	V_{IL}	—	—	0.8	V	
Input Leakage Current	I_{LK}	—	0.01	1	µA	$V_{PROG2} = V_{DD}$
Timer Enable ($\overline{\text{TE}}$)						
Input High Voltage Level	V_{IH}	1.8	—	—	V	**Note 1**
Input Low Voltage Level	V_{IL}	—	—	0.8	V	**Note 1**
Input Leakage Current	I_{LK}	—	0.01	1	µA	$V_{\overline{TE}} = V_{DD}$

Note 1: The value is ensured by design and not production tested.

2: The maximum available charge current is also limited by the value set at PROG1 input.

DC CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated, all limits apply for $V_{IN} = V_{REG}$ + 0.3V to 6V, T_A = -40°C to +85°C. Typical values are at +25°C, V_{IN} = [V_{REG} (typical) + 1.0V]						
Parameters	**Sym**	**Min**	**Typ**	**Max**	**Units**	**Conditions**
Chip Enable (CE)						
Input High Voltage Level	V_{IH}	1.8	—	—	V	
Input Low Voltage Level	V_{IL}	—	—	0.8	V	
Input Leakage Current	I_{LK}	—	0.01	1	µA	$V_{CE} = V_{DD}$
Input Source Selection (SEL)						
Input High Voltage Level	V_{IH}	1.8	—	—	V	
Input Low Voltage Level	V_{IL}	—	—	0.8	V	
Input Leakage Current	I_{LK}	—	0.01	1	µA	$V_{SEL} = V_{DD}$
Thermistor Bias						
Thermistor Current Source	I_{THERM}	47	50	53	µA	2 kΩ < R_{THERM} < 50 kΩ
Thermistor Comparator						
Upper Trip Threshold	V_{T1}	1.20	1.24	1.26	V	V_{T1} Low-to-High
Upper Trip Point Hysteresis	V_{T1HYS}	—	-40	—	mV	
Lower Trip Threshold	V_{T2}	0.23	0.25	0.27	V	V_{T2} High-to-Low
Lower Trip Point Hysteresis	V_{T2HYS}	—	40	—	mV	
Thermal Shutdown						
Die Temperature	T_{SD}	—	150	—	°C	
Die Temperature Hysteresis	T_{SDHYS}	—	10	—	°C	

Note 1: The value is ensured by design and not production tested.
2: The maximum available charge current is also limited by the value set at PROG1 input.

AC CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, all limits apply for V_{IN} = 4.6V to 6V. Typical values are at +25°C, V_{DD} = [V_{REG} (typical) + 1.0V]						
Parameters	**Sym**	**Min**	**Typ**	**Max**	**Units**	**Conditions**
UVLO Start Delay	t_{START}	—	—	5	ms	V_{DD} Low-to-High
Current Regulation						
Transition Time Out of Precondition	t_{DELAY}	—	—	10	ms	V_{BAT} < V_{PTH} to V_{BAT} > V_{PTH}
Current Rise Time Out of Precondition	t_{RISE}	—	—	10	ms	I_{OUT} Rising to 90% of I_{REG}
Precondition Comparator Filter Time	t_{PRECON}	0.4	1.3	3.2	ms	Average V_{BAT} Rise/Fall
Termination Comparator Filter Time	t_{TERM}	0.4	1.3	3.2	ms	Average I_{OUT} Falling
$\overline{\text{Charge}}$ Comparator Filter Time	t_{CHARGE}	0.4	1.3	3.2	ms	Average V_{BAT} Falling
Thermistor Comparator Filter Time	t_{THERM}	0.4	1.3	3.2	ms	Average THERM Rise/Fall
Elapsed Timer						
Elapsed Timer Period	$t_{ELAPSED}$	—	0	—	Hours	
		3.6	4.0	4.4	Hours	
		5.4	6.0	6.6	Hours	
		7.2	8.0	8.8	Hours	
Status Indicators						
Status Output Turn-off	t_{OFF}	—	—	500	µs	I_{SINK} = 1 mA to 0 mA
Status Output Turn-on	t_{ON}	—	—	500	µs	I_{SINK} = 0 mA to 1 mA

Note 1: Internal safety timer is tested based on internal oscillator frequency measurement.

TEMPERATURE SPECIFICATIONS

Electrical Specifications: Unless otherwise indicated, all limits apply for V_{IN} = 4.6V to 6V. Typical values are at +25°C, V_{DD} = [V_{REG} (typical) + 1.0V]						
Parameters	**Sym**	**Min**	**Typ**	**Max**	**Units**	**Conditions**
Temperature Ranges						
Specified Temperature Range	T_A	-40	—	+85	°C	
Operating Temperature Range	T_J	-40	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 20LD-QFN, 4x4	θ_{JA}	—	50	—	°C/W	4-Layer JC51-7 Standard Board, Natural Convection
	θ_{JC}	—	8	—		—

NOTES:

2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated, V_{IN} = [V_{REG}(typical) + 1V], I_{OUT} = 10 mA and T_A = +25°C, Constant Voltage mode.

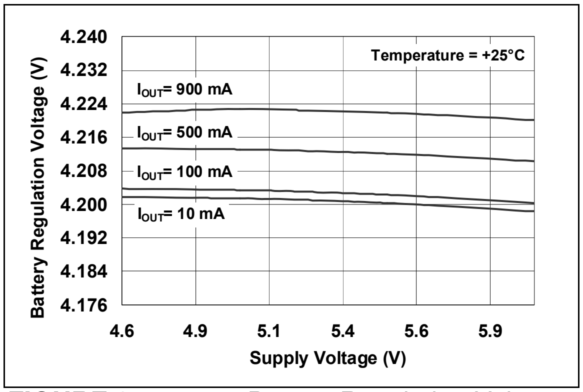


FIGURE 2-1: *Battery Regulation Voltage (V_{BAT}) vs. Supply Voltage (V_{DD}).*

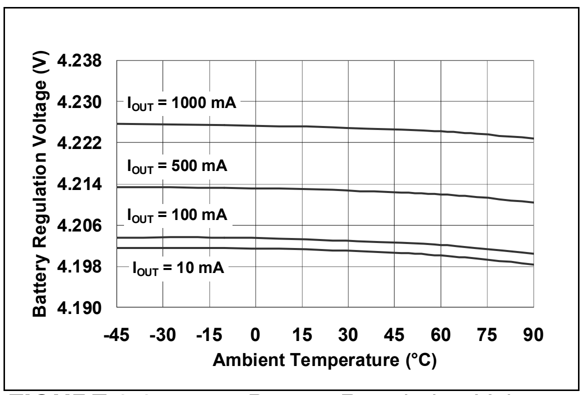


FIGURE 2-2: *Battery Regulation Voltage (V_{BAT}) vs. Ambient Temperature (T_A).*

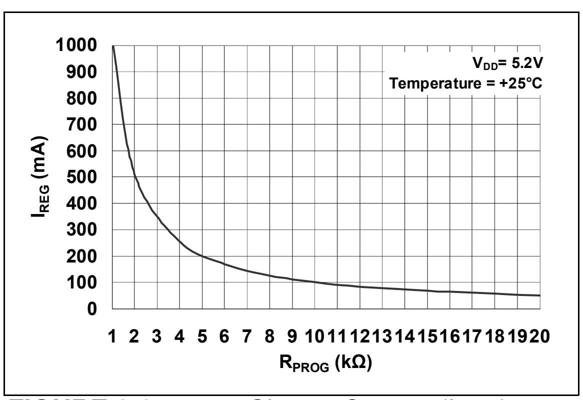


FIGURE 2-3: *Charge Current (I_{OUT}) vs. Programming Resistor (R_{PROG}).*

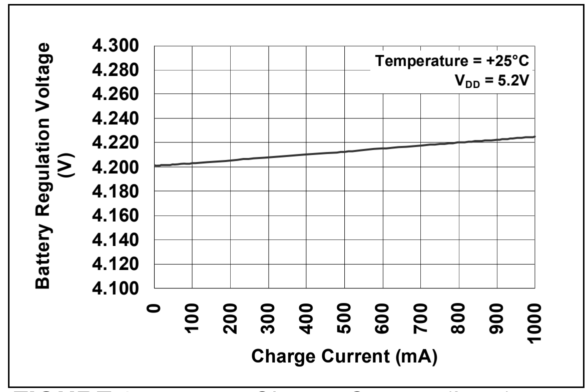


FIGURE 2-4: *Charge Current (I_{OUT}) vs. Battery Regulation Voltage (V_{BAT}).*

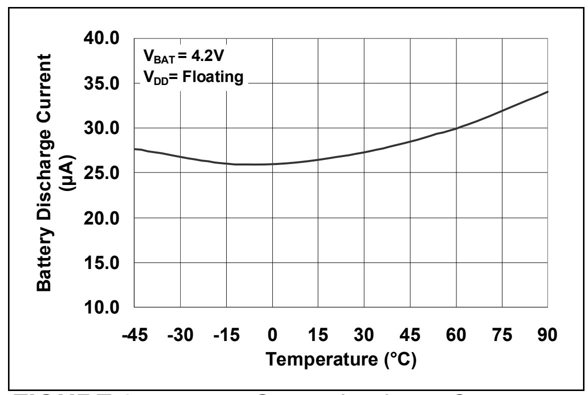


FIGURE 2-5: *Output Leakage Current ($I_{DISCHARGE}$) vs. Ambient Temperature (T_A).*

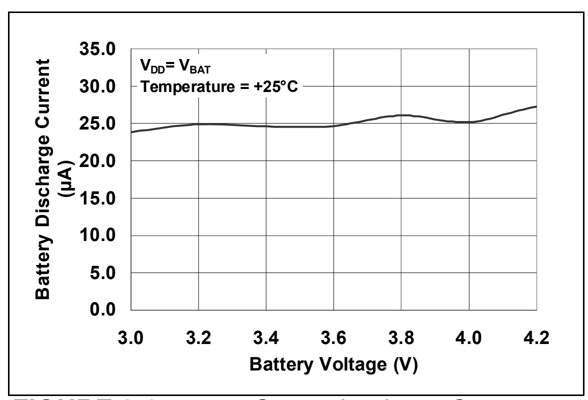


FIGURE 2-6: *Output Leakage Current ($I_{DISCHARGE}$) vs. Battery Regulation Voltage (V_{BAT}).*

Note: Unless otherwise indicated, V_{IN} = [V_{REG}(typical) + 1V], I_{OUT} = 10 mA and T_A = +25°C, Constant Voltage mode.

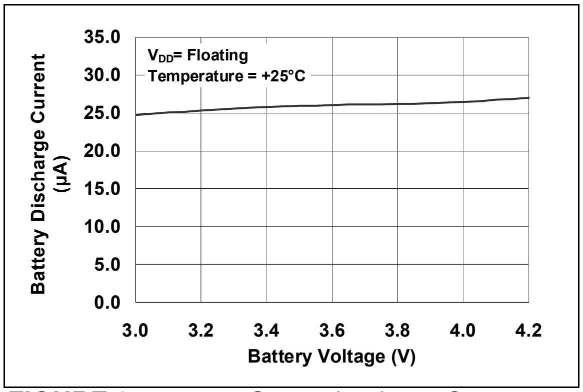


FIGURE 2-7: *Output Leakage Current ($I_{DISCHARGE}$) vs. Battery Voltage (V_{BAT}).*

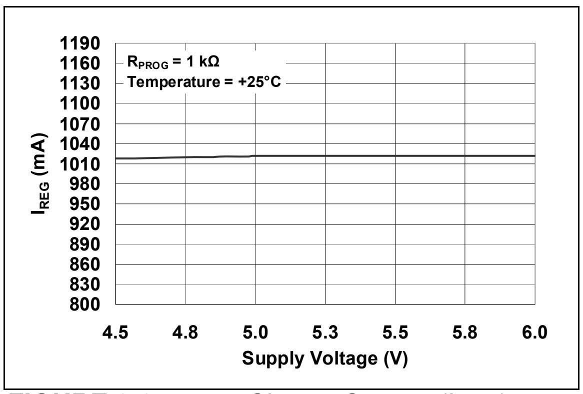


FIGURE 2-8: *Charge Current (I_{OUT}) vs. Supply Voltage (V_{DD}).*

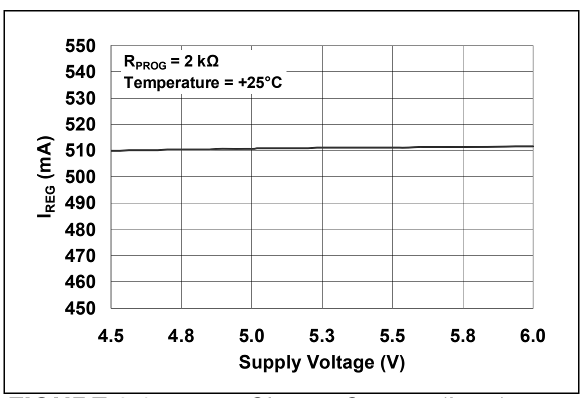


FIGURE 2-9: *Charge Current (I_{OUT}) vs. Supply Voltage (V_{DD}).*

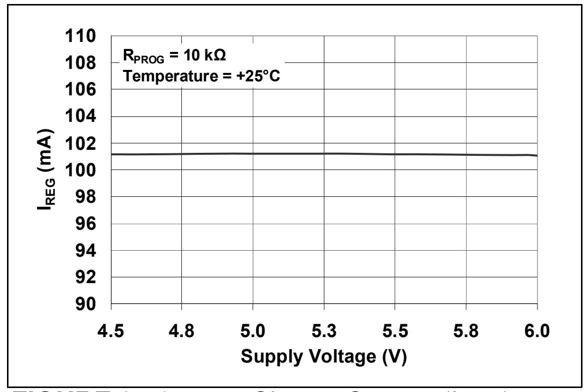


FIGURE 2-10: *Charge Current (I_{OUT}) vs. Supply Voltage (V_{DD}).*

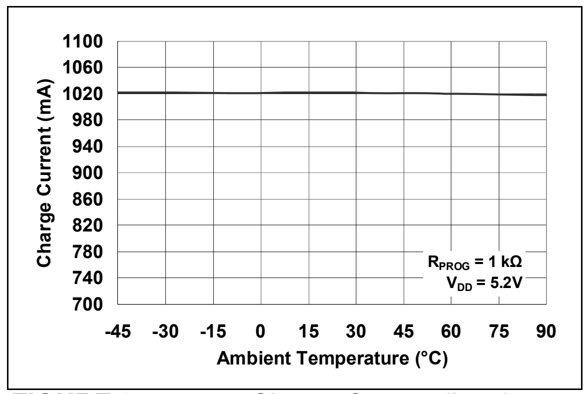


FIGURE 2-11: *Charge Current (I_{OUT}) vs. Ambient Temperature (T_A).*

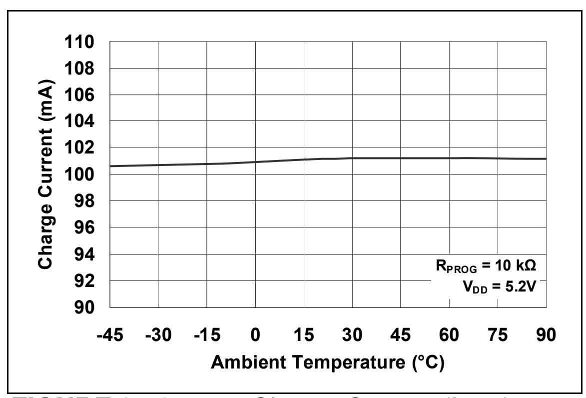


FIGURE 2-12: *Charge Current (I_{OUT}) vs. Ambient Temperature (T_A).*

Note: Unless otherwise indicated, V_{IN} = [V_{REG}(typical) + 1V], I_{OUT} = 10 mA and T_A = +25°C, Constant Voltage mode.

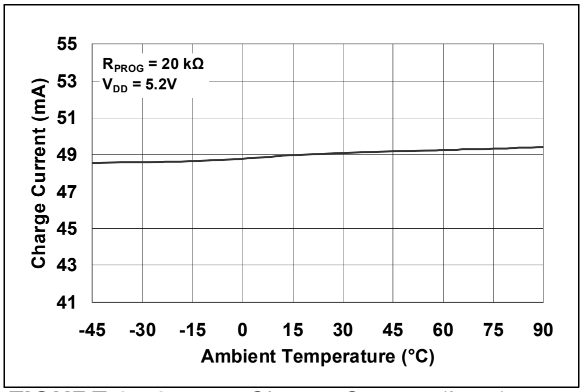


FIGURE 2-13: *Charge Current (I_{OUT}) vs. Ambient Temperature (T_A).*

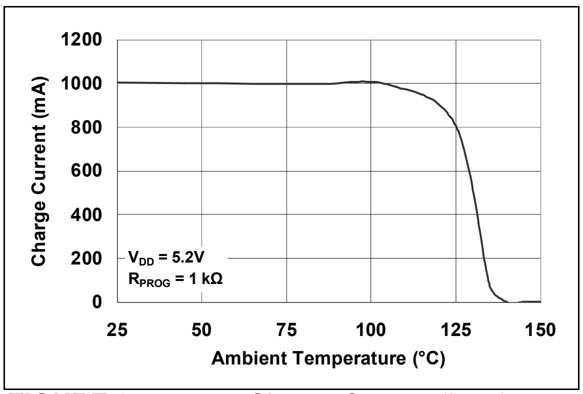


FIGURE 2-14: *Charge Current (I_{OUT}) vs. Junction Temperature (T_J).*

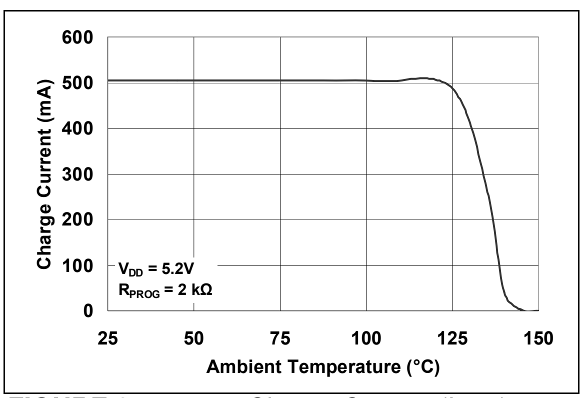


FIGURE 2-15: *Charge Current (I_{OUT}) vs. Junction Temperature (T_J).*

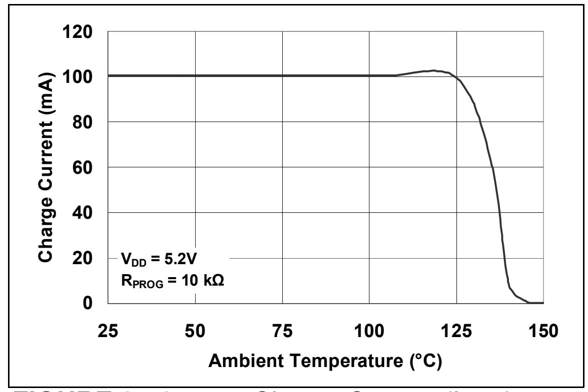


FIGURE 2-16: *Charge Current (I_{OUT}) vs. Junction Temperature (T_J).*

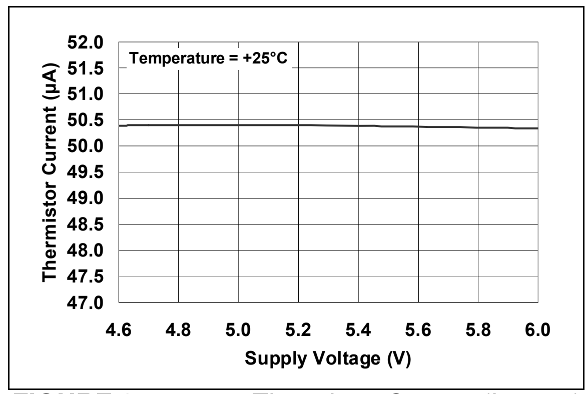


FIGURE 2-17: *Thermistor Current (I_{THERM}) vs. Supply Voltage (V_{DD}).*

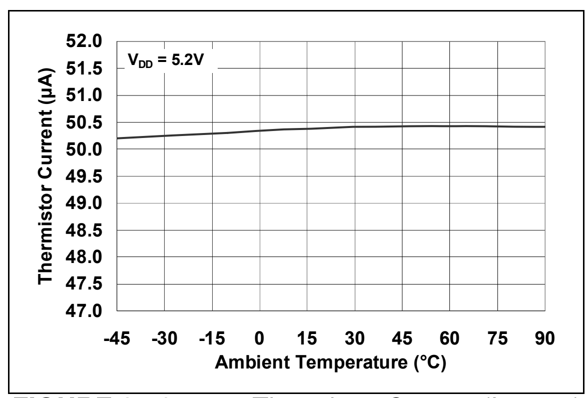


FIGURE 2-18: *Thermistor Current (I_{THERM}) vs. Ambient Temperature (T_A).*

Note: Unless otherwise indicated, V_{IN} = [V_{REG}(typical) + 1V], I_{OUT} = 10 mA and T_A = +25°C, Constant Voltage mode.

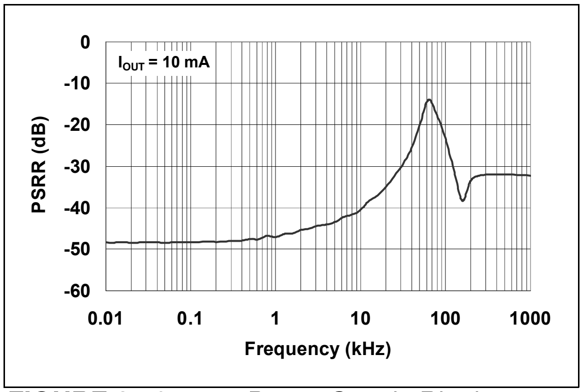


FIGURE 2-19: *Power Supply Ripple Rejection (PSRR).*

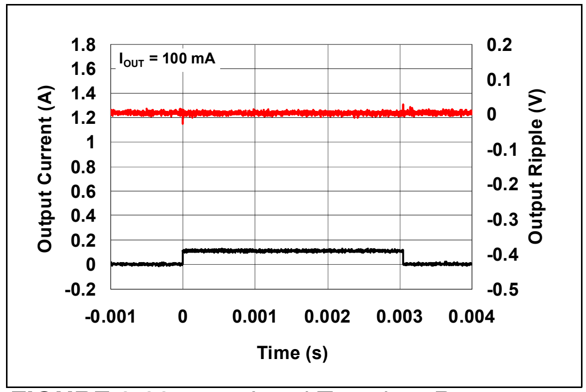


FIGURE 2-22: *Load Transient Response. I_{OUT} = 100 mA.*

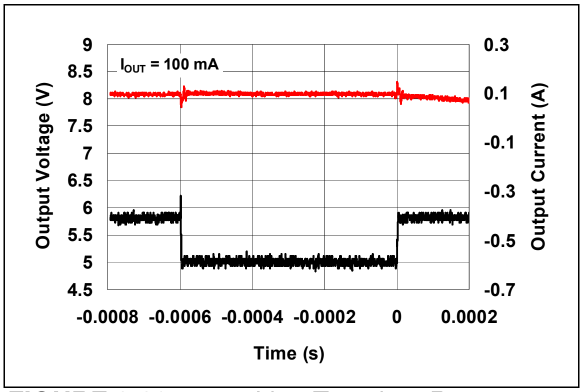


FIGURE 2-20: *Line Transient Response. I_{OUT} = 100 mA.*

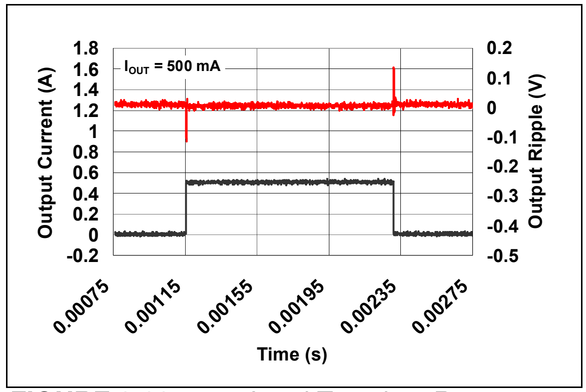


FIGURE 2-23: *Load Transient Response. I_{OUT} = 500 mA.*

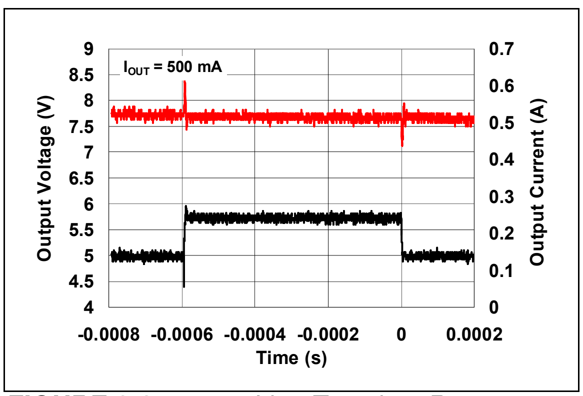


FIGURE 2-21: *Line Transient Response. I_{OUT} = 500 mA.*

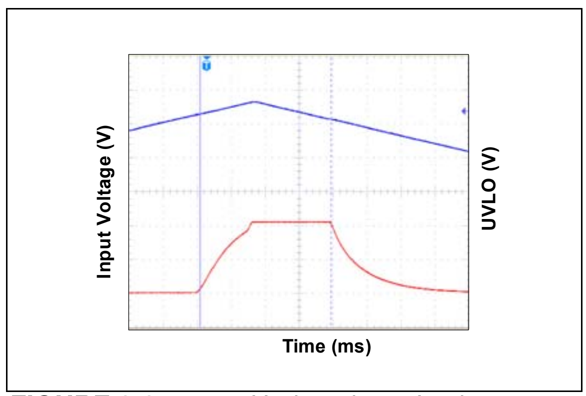


FIGURE 2-24: *Undervoltage Lockout.*

Note: Unless otherwise indicated, V_{IN} = [V_{REG}(typical) + 1V], I_{OUT} = 10 mA and T_A = +25°C, Constant Voltage mode.

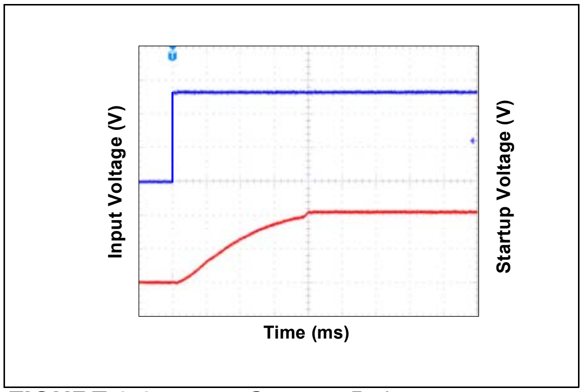


FIGURE 2-25: *Start-up Delay.*

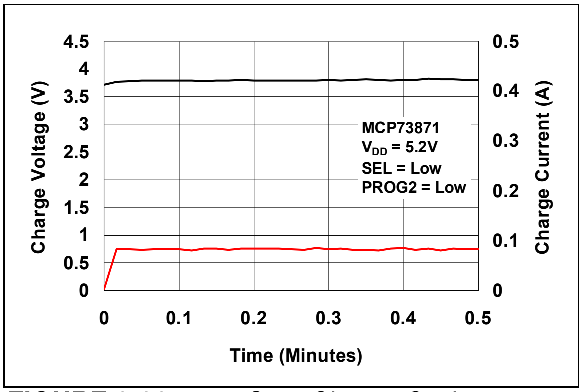


FIGURE 2-26: *Start Charge Cycle (130 mAh Li-Ion Battery).*

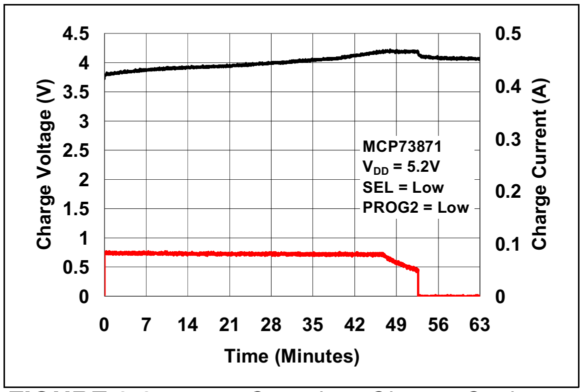


FIGURE 2-27: *Complete Charge Cycle (130 mAh Li-Ion Battery).*

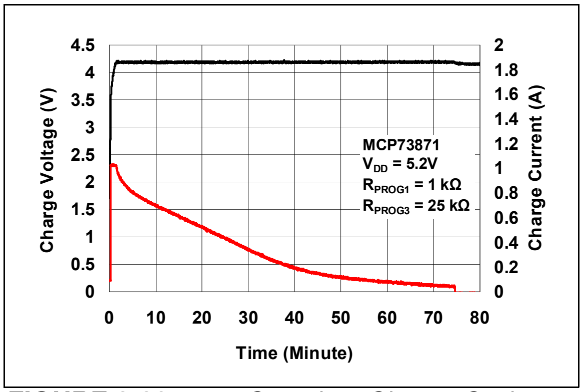


FIGURE 2-28: *Complete Charge Cycle (1000 mAh Li-Ion Battery).*

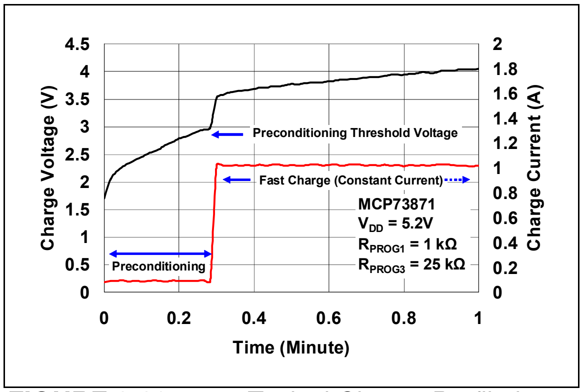


FIGURE 2-29: *Typical Charge Profile in Preconditioning (1000 mAh Battery).*

NOTES:

3.0 PIN DESCRIPTION

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin Number	Symbol	I/O	Function
1, 20	OUT	O	System Output Terminal
2	VPCC	I	Voltage proportional charge control
3	SEL	I	Input type selection (low for USB port, high for AC-DC adapter)
4	PROG2	I	USB port input current limit selection when SEL = Low (Low = 100 mA, High = 500 mA)
5	THERM	I/O	Thermistor monitoring input and bias current
6	$\overline{PG}$	O	Power Good Status Output (Open-Drain)
7	STAT2	O	Charge Status Output 2 (Open-Drain)
8	STAT1/$\overline{LBO}$	O	Charge Status Output 1 (Open-Drain). Low battery output indicator when $V_{BAT} > V_{IN}$
9	$\overline{TE}$	I	Timer Enable; Enables Safety Timer when active-low
10, 11, EP	V_{SS}	—	Battery Management 0V Reference. EP (Exposed Thermal Pad). There is an internal electrical connection between the exposed thermal pad and V_{SS}. The EP must be connected to the same potential as the V_{SS} pin on the Printed Circuit Board (PCB)
12	PROG3	I/O	Termination set point for both AC-DC adapter and USB port
13	PROG1	I/O	Fast charge current regulation setting with SEL = high. Preconditioning set point for both USB port and AC-DC adapter
14, 15	V_{BAT}	I/O	Battery Positive Input and Output connection
16	V_{BAT_SENSE}	I/O	Battery Voltage Sense
17	CE	I	Device Charge Enable; Enabled when CE = high
18, 19	IN	I	Power Supply Input
Legend: I = Input, O = Output, I/O = Input/Output			

Note: To ensure proper operation, the input pins must not allow floating and should always tie to either high or low.

3.1 Power Supply Input (IN)

A supply voltage of V_{REG} + 0.3V to 6V is recommended. Bypass to V_{SS} with a minimum of 4.7 µF.

3.2 System Output Terminal (OUT)

The MCP73871 device powers the system via output terminals while independently charging the battery. This feature reduces the charge and discharge cycles on the battery, allowing proper charge termination and the system to run with an absent or defective battery pack. It also gives the system priority on input power, allowing the system to power-up with deeply depleted battery packs. Bypass to V_{SS} with a minimum of 4.7 µF is recommended.

3.3 Voltage Proportional Charge Control (VPCC)

If the voltage on the IN pin drops to a preset value determined by the threshold established at the VPCC input due to a limited amount of input current or input source impedance, the battery charging current is reduced. If possible, further demand from the system is supported by the battery. To enable this feature, simply supply 1.23V or greater to the VPCC pin. This feature can be disabled by connecting the VPCC pin to IN.

For example, a system is designed with a 5.5V rated DC power supply with ±0.5V tolerance. The worst condition of 5V is selected, which is used to calculate the VPCC supply voltage with divider.

The voltage divider equation is shown below:

EQUATION 3-1:

$$V_{VPCC} = \left(\frac{R_2}{R_1 + R_2}\right) \times V_{IN} = 1.23V$$

$$1.23V = \left(\frac{110k\Omega}{110k\Omega + R_1}\right) \times 5V$$

$$R_1 = 337.2k\Omega$$

The calculated R_1 equals 337.2 kΩ when 110 kΩ is selected for R_2. The 330 kΩ resistor is selected for R_1 to build the voltage divider for VPCC.

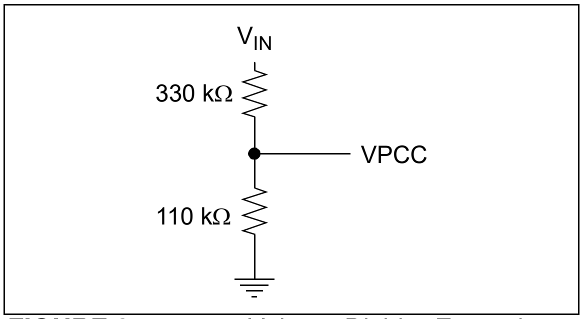


FIGURE 3-1: *Voltage Divider Example.*

3.4 Input Source Type Selection (SEL)

The input source type selection (SEL) pin is used to select the input power source for the input current limit control feature. With the SEL input high, the MCP73871 device is capable of providing 1.65 (typical) total amperes to be shared by the system load and Li-Ion battery charging. The MCP73871 device limits the input current up to 1.8A. When SEL active-low, the input source is designed to provide system power and Li-Ion battery charging from a USB Port input while adhering to the current limits governed by the USB specification.

3.5 Battery Management 0V Reference (V_{SS})

Connect to the negative terminal of the battery, system load and input supply.

3.6 Battery Charge Control Output (V_{BAT})

Connect to positive terminal of the Li-Ion/Li-Polymer battery. Bypass to V_{SS} with a minimum of 4.7 µF to ensure loop stability when the battery is disconnected.

3.7 Battery Voltage Sense (V_{BAT_SENSE})

Connect to the positive terminal of the battery. A precision internal voltage sense regulates the final voltage on this pin to V_{REG}.

3.8 Charge Current Regulation Set (PROG1)

The maximum constant charge current is set by placing a resistor from PROG1 to V_{SS}. PROG1 sets the maximum constant charge current for both the AC-DC adapter and USB port. However, the actual charge current is based on the input source type and the system load requirement.

3.9 USB-Port Current Regulation Set (PROG2)

The MCP73871 device USB-Port current regulation set input (PROG2) is a digital input selection. A logic Low selects a one unit load input current from the USB port (100 mA) while a logic high selects a five unit load input current from the USB port (500 mA).

3.10 Charge Status Output 1 (STAT1)

STAT1 is an open-drain logic output for connection to an LED for charge status indication. Alternatively, a pull-up resistor can be applied for interfacing to a host microcontroller. Refer to Table 5-1 for a summary of the status output during a charge cycle.

3.11 Charge Status Output 2 (STAT2)

STAT2 is an open-drain logic output for connection to an LED for charge status indication. Alternatively, a pull up resistor can be applied for interfacing to a host microcontroller. Refer to Table 5-1 for a summary of the status output during a charge cycle.

3.12 Power Good ($\overline{PG}$)

The power good ($\overline{PG}$) is an open-drain logic output for input power supply indication. The $\overline{PG}$ output is low whenever the input to the MCP73871 device is above the UVLO threshold and greater than the battery voltage. The $\overline{PG}$ output may be used with an LED or as an interface to a host microcontroller to signal when an input power source is supplying power to the system and the battery. Refer to Table 5-1 for a summary of the status output during a charge cycle.

3.13 Low Battery Output ($\overline{LBO}$)

STAT1 also serves as low battery output ($\overline{LBO}$) if the selected MCP73871 is equipped with this feature. It provides an indication to the system or end user when the Li-Ion battery voltage level is low. The $\overline{LBO}$ feature is enabled when the system is running from the Li-Ion battery. The $\overline{LBO}$ output may be used with an LED or as an interface to a host microcontroller to signal when the system is operating from the battery and the battery is running low on charge. Refer to Table 5-1 for a summary of the status output during a charge cycle.

3.14 Timer Enable ($\overline{TE}$)

The timer enable ($\overline{TE}$) feature is used to enable or disable the internal timer. A low signal enables and a high signal disables the internal timer on this pin. The $\overline{TE}$ input can be used to disable the timer when the system load is substantially limiting the available supply current to charge the battery. The $\overline{TE}$ input is compatible with 1.8V logic.

Note:	The built-in safety timer is available for the following options: 4 HR, 6 HR and 8 HR.

3.15 Battery Temperature Monitor (THERM)

The MCP73871 device continuously monitors battery temperature during a charge cycle by measuring the voltage between the THERM and V_{SS} pins. An internal 50 µA current source provides the bias for most common 10 kΩ Negative Temperature Coefficient (NTC) thermistors. The MCP73871 device compares the voltage at the THERM pin to factory set thresholds of 1.24V and 0.25V, typically. Once a voltage outside the thresholds is detected during a charge cycle, the MCP73871 device immediately suspends the charge cycle. The charge cycle resumes when the voltage at the THERM pin returns to the normal range. The charge temperature window can be set by placing fixed value resistors in series-parallel with a thermistor. Refer to **Section 6.0 "Applications"** for calculations of resistance values.

3.16 Charge Enable (CE)

With the CE input Low, the Li-Ion battery charger feature of the MCP73871 is disabled. The charger feature is enabled when CE is active-high. Allowing the CE pin to float during the charge cycle may cause system instability. The CE input is compatible with 1.8V logic. Refer to **Section 6.0 "Applications"** for various applications in designing with CE features.

3.17 Exposed Thermal Pad (EP)

An internal electrical connection exists between the Exposed Thermal Pad (EP) and the V_{SS} pin. They must be connected to the same potential on the Printed Circuit Board (PCB).

NOTES:

4.0 DEVICE OVERVIEW

The MCP73871 device is a simple but fully integrated linear charge management controller with system load sharing feature. Figure 4-1 depicts the operational flow algorithm.

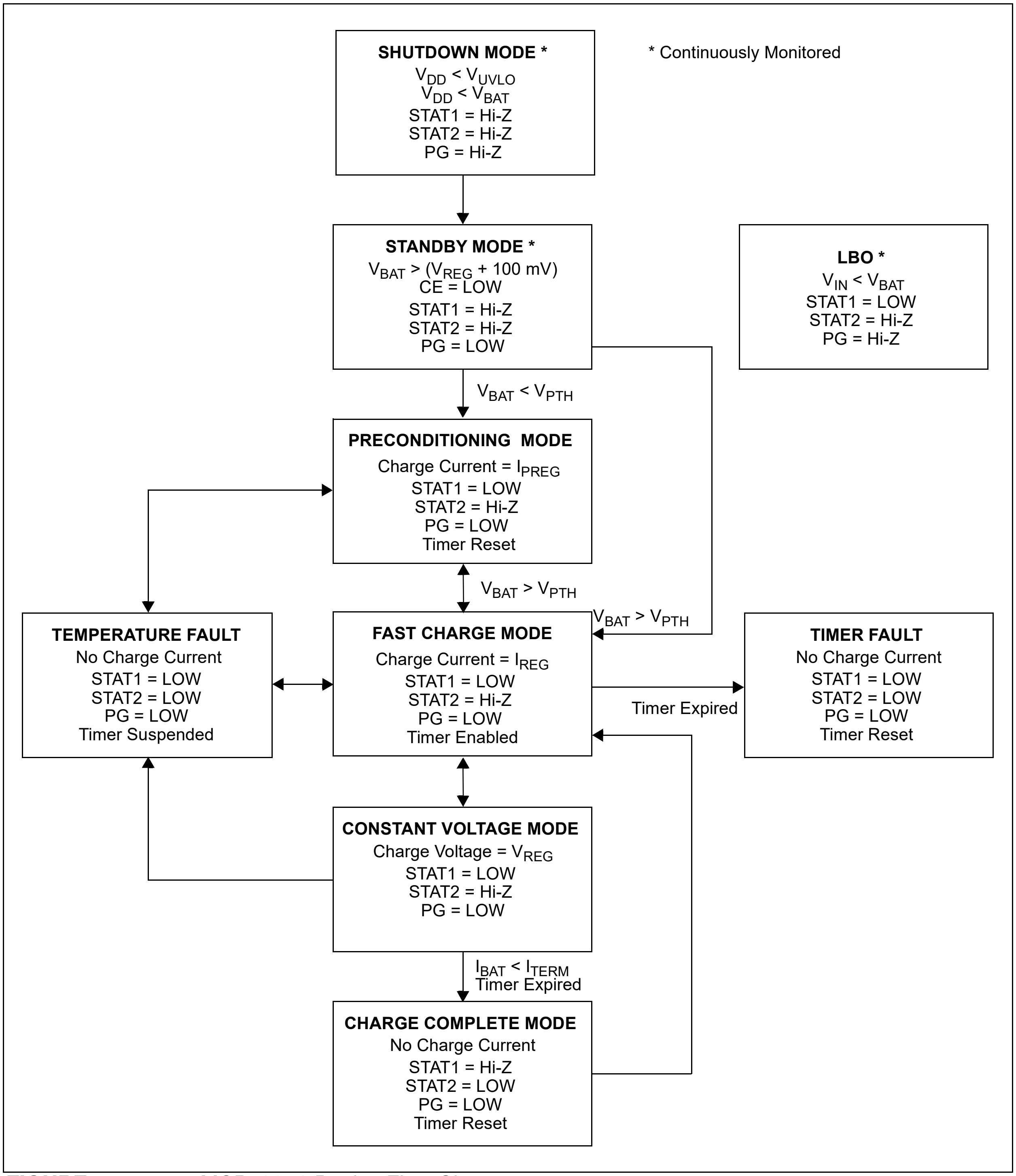


FIGURE 4-1: *MCP73871 Device Flow Chart.*

Table 4-1 shows the chip behavior based upon the operating conditions.

TABLE 4-1: CHIP BEHAVIOR REFERENCE TABLE

<table>
<tr><th></th><th>V_{IN} ? V_{BAT}</th><th>V_{IN} > 2V</th><th>V_{IN} > UVLO</th><th>CE</th><th>V_{BAT} ? V_{OUT}</th><th>State</th><th>Bias + V_{REF}</th><th>Thermal Block</th><th>Synchronous Diode</th><th>I_{OUT}</th><th>Charge</th></tr>
<tr><td>1</td><td rowspan="2">$V_{BAT} > V_{IN}$</td><td rowspan="2">0</td><td rowspan="2">0</td><td>0</td><td rowspan="2">—</td><td>Shutdown</td><td colspan="3">OFF</td><td colspan="2" rowspan="2">OFF</td></tr>
<tr><td>2</td><td>1</td><td>Battery powered system</td><td colspan="3">ON</td></tr>
<tr><td>3</td><td>$V_{IN} > V_{BAT}$</td><td>0</td><td>0</td><td>X</td><td>—</td><td>Shutdown</td><td colspan="5">OFF</td></tr>
<tr><td>4</td><td rowspan="6">$V_{IN} > V_{BAT}$</td><td rowspan="6">1</td><td rowspan="2">0</td><td>0</td><td rowspan="2">—</td><td>Shutdown</td><td rowspan="2">ON</td><td colspan="2">OFF</td><td colspan="2" rowspan="2">OFF</td></tr>
<tr><td>5</td><td>1</td><td>Battery powered system</td><td colspan="2">ON</td></tr>
<tr><td>6</td><td rowspan="4">1</td><td rowspan="2">0</td><td>$V_{BAT} < V_{OUT}$</td><td>Standby</td><td colspan="2" rowspan="4">ON</td><td>OFF</td><td rowspan="4">ON</td><td rowspan="2">OFF</td></tr>
<tr><td>7</td><td>$V_{BAT} > V_{OUT}$</td><td>IN + BAT powered system</td><td>ON</td></tr>
<tr><td>8</td><td rowspan="2">1</td><td>$V_{BAT} < V_{OUT}$</td><td>IN powered, Charge possible</td><td>OFF</td><td>ON/OFF</td></tr>
<tr><td>9</td><td>$V_{BAT} > V_{OUT}$</td><td>IN + BAT powered system</td><td>ON</td><td>OFF</td></tr>
</table>

4.1 UnderVoltage Lockout (UVLO)

An internal undervoltage lockout (UVLO) circuit monitors the input voltage and keeps the charger in shutdown mode until the input supply rises above the UVLO threshold.

In the event a battery is present when the input power is applied, the input supply must rise approximately 100 mV above the battery voltage before the MCP73871 device becomes operational.

The UVLO circuit places the device in Shutdown mode if the input supply falls to within approximately 100 mV of the battery voltage.

The UVLO circuit is always active. At any time the input supply is below the UVLO threshold or falls within approximately 100 mV of the voltage at the V_{BAT} pin, the MCP73871 device is placed in Shutdown mode.

During any UVLO condition, the battery reverse discharge current is less than 2 μA.

4.2 System Load Sharing

The system load sharing feature gives the system output pin (OUT) priority, allowing the system to power-up with deeply depleted battery packs.

With the SEL input active-low, the MCP73871 device is designed to provide system power and Li-Ion battery charging from a USB input while adhering to the current limits governed by the USB specification.

With the SEL input active-high, the MCP73871 device limits the total supply current to 1.8A (system power and charge current combined).

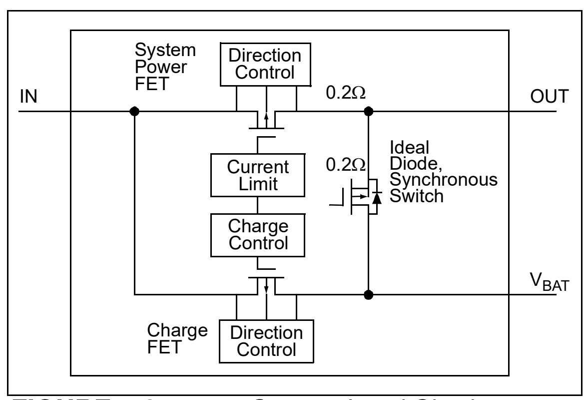


FIGURE 4-2: *System Load Sharing Diagram.*

4.3 Charge Qualification

For a charge cycle to begin, all UVLO conditions must be met and a battery or output load must be present.

A charge current programming resistor must be connected from PROG1 to V_{SS} when SEL = high. When SEL = low, PROG2 needs to be tied high or low for proper operation.

4.4 Preconditioning

If the voltage at the V_{BAT} pin is less than the preconditioning threshold, the MCP73871 device enters a preconditioning mode. The preconditioning threshold is factory set. Refer to **Section 1.0 "Electrical Characteristics"** for preconditioning threshold options.

In this mode, the MCP73871 device supplies 10% of the fast charge current (established with the value of the resistor connected to the PROG1 pin) to the battery.

When the voltage at the V_{BAT} pin rises above the preconditioning threshold, the MCP73871 device enters the Constant Current (fast charge) mode.

4.5 Constant Current Mode – Fast Charge

During the Constant Current mode, the programmed charge current is supplied to the battery or load. The charge current is established using a single resistor from PROG1 to V_{SS}. The program resistor and the charge current are calculated using the following equation:

EQUATION 4-1:

$$I_{REG} = \frac{1000V}{R_{PROG1}}$$

Where:

R_{PROG}	=	kilo-ohms (kΩ)
I_{REG}	=	milliampere (mA)

Constant Current mode is maintained until the voltage at the V_{BAT} pin reaches the regulation voltage, V_{REG}.

When Constant Current mode is invoked, the internal timer is reset.

4.5.1 TIMER EXPIRED DURING CONSTANT CURRENT - FAST CHARGE MODE

If the internal timer expires before the recharge voltage threshold is reached, a timer fault is indicated and the charge cycle terminates. The MCP73871 device remains in this condition until the battery is removed. If the battery is removed, the MCP73871 device enters the Standby mode where it remains until a battery is reinserted.

4.6 Constant Voltage Mode

When the voltage at the V_{BAT} pin reaches the regulation voltage, V_{REG}, constant voltage regulation begins. The regulation voltage is factory set to 4.10V or 4.20V with a tolerance of ±0.5%.

4.7 Charge Termination

The Constant Voltage mode charge cycle terminates either when the average charge current diminishes below a threshold established by the value of the resistor connected from PROG3 to V_{SS} or when the internal charge timer expires. When the charge cycle terminates due to a fully charged battery, the charge current is latched off and the MCP73871 device enters the Charge Complete mode. A 1 ms filter time on the termination comparator ensures that transient load conditions do not result in premature charge cycle termination. The timer period is factory set and can be disabled. Refer to **Section 1.0 "Electrical Characteristics"** for timer period options.

The program resistor and the charge current are calculated using the following equation:

EQUATION 4-2:

$$I_{TERMINATION} = \frac{1000V}{R_{PROG3}}$$

Where:

R_{PROG}	=	kilo-ohms (kΩ)
I_{REG}	=	milliampere (mA)

The recommended PROG3 resistor values are between 5 kΩ and 100 kΩ.

4.8 Automatic Recharge

The MCP73871 device continuously monitors the voltage at the V_{BAT} pin in the Charge Complete mode. If the voltage drops below the recharge threshold, another charge cycle begins and current is supplied again to the battery or load. The recharge threshold is factory set. Refer to **Section 1.0 "Electrical Characteristics"** for recharge threshold options.

Note: Charge termination and automatic recharge features avoid constantly charging Li-Ion batteries, resulting in prolonged battery life while maintaining full cell capacity.

4.9 Thermal Regulation

The MCP73871 device limits the charge current based on the die temperature. The thermal regulation optimizes the charge cycle time while maintaining device reliability. Figure 4-3 depicts the thermal regulation for the MCP73871 device. Refer to **Section 1.0 "Electrical Characteristics"** for thermal package resistances and **Section 6.1.1.2 "Thermal Considerations"** for calculating power dissipation.

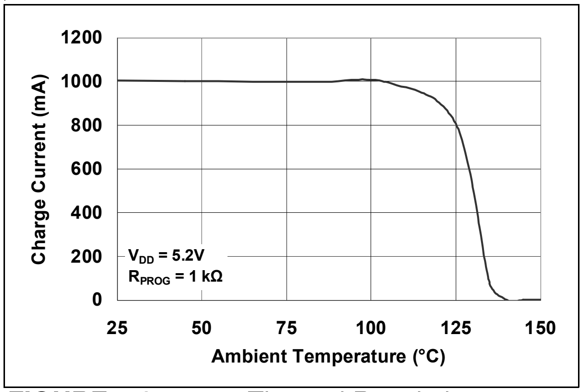


FIGURE 4-3: *Thermal Regulation.*

4.10 Thermal Shutdown

The MCP73871 device suspends charge if the die temperature exceeds 150°C. Charging resumes when the die temperature has cooled by approximately 10°C. The thermal shutdown is a secondary safety feature in the event that there is a failure within the thermal regulation circuitry.

4.11 Temperature Qualification

The MCP73871 device continuously monitors battery temperature during a charge cycle by measuring the voltage between the THERM and V_{SS} pins. An internal 50 µA current source provides the bias for most common 10 kΩ NTC thermistors. The MCP73871 device compares the voltage at the THERM pin to factory set thresholds of 1.24V and 0.25V, typically. Once a voltage outside the thresholds is detected during a charge cycle, the MCP73871 device immediately suspends the charge cycle. The MCP73871 device suspends charging by turning off the charge pass transistor and holding the timer value. The charge cycle resumes when the voltage at the THERM pin returns to the normal range.

4.12 Voltage Proportional Charge Control (VPCC)

If the voltage on the IN pin drops to a preset value determined by the threshold established at the VPCC input due to a limited amount of input current or input source impedance, the battery charging current is reduced. The VPCC control tries to reach a steady state condition where the system load has priority and the battery is charged with the remaining current. Therefore, if the system demands more current than the input can provide, the ideal diode becomes forward-biased and the battery may supplement the input current to the system load.

The VPCC sustains the system load as its highest priority. It does this by reducing the noncritical charge current while maintaining the maximum power output of the adapter. Further demand from the system is supported by the battery, if possible.

The VPCC feature functions identically for USB port or AC-DC adapter inputs. This feature can be disabled by connecting the VPCC to IN pin.

4.13 Input Current Limit Control (ICLC)

If the input current threshold is reached, then the battery charging current is reduced. The ICLC tries to reach a steady state condition where the system load has priority and the battery is charged with the remaining current. No active control limits the current to the system. Therefore, if the system demands more current than the input can provide or the ICLC is reached, the ideal diode becomes forward biased and the battery may supplement the input current to the system load.

The ICLC sustains the system load as its highest priority. This is done by reducing the non-critical charge current while adhering to the current limits governed by the USB specification or the maximum AC-DC adapter current supported. Further demand from the system is supported by the battery, if possible.

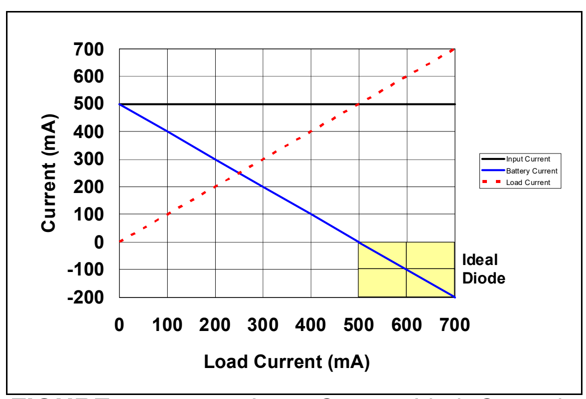


FIGURE 4-4: *Input Current Limit Control - USB Port.*

5.0 DETAILED DESCRIPTION

5.1 Analog Circuitry

5.1.1 LOAD SHARING AND LI-ION BATTERY MANAGEMENT INPUT SUPPLY (V_{IN})

The V_{IN} input is the input supply to the MCP73871 device. The MCP73871 device can be supplied by either AC Adapter (V_{AC}) or USB Port (V_{USB}) with SEL pin. The MCP73871 device automatically powers the system with the Li-Ion battery when the V_{IN} input is not present.

5.1.2 FAST CHARGE CURRENT REGULATION SET (PROG1)

For the MCP73871 device, the charge current regulation can be scaled by placing a programming resistor (R_{PROG1}) from the PROG1 pin to V_{SS}. The program resistor and the charge current are calculated using the following equation:

EQUATION 5-1:

$$I_{REG} = \frac{1000V}{R_{PROG1}}$$

Where:

R_{PROG}	=	kilo-ohms (kΩ)
I_{REG}	=	milliampere (mA)

The fast charge current is set for maximum charge current from AC-DC adapter and USB port. The preconditioning current is 10% (0.1C) of the fast charge current.

5.1.3 BATTERY CHARGE CONTROL OUTPUT (V_{BAT})

The battery charge control output is the drain terminal of an internal P-channel MOSFET. The MCP73871 device provides constant current and voltage regulation to the battery pack by controlling this MOSFET in the linear region. The battery charge control output should be connected to the positive terminal of the battery pack.

5.1.4 TEMPERATURE QUALIFICATION (THERM)

The MCP73871 device continuously monitors battery temperature during a charge cycle by measuring the voltage between the THERM and V_{SS} pins. An internal 50 µA current source provides the bias for most common 10 kΩ NTC or Positive Temperature Coefficient (PTC) thermistors.The current source is controlled, avoiding measurement sensitivity to fluctuations in the supply voltage (V_{DD}). The MCP73871 device compares the voltage at the THERM pin to factory set thresholds of 1.24V and 0.25V, typically. Once a voltage outside the thresholds is detected during a charge cycle, the MCP73871 device immediately suspends the charge cycle.

The MCP73871 device suspends the charge by turning off the pass transistor and holding the timer value. The charge cycle resumes when the voltage at the THERM pin returns to the normal range.

If temperature monitoring is not required, place a standard 10 kΩ resistor from THERM to V_{SS}.

5.2 Digital Circuitry

5.2.1 STATUS INDICATORS AND POWER GOOD ($\overline{PG}$)

The charge status outputs have two different states: Low-Impedance (L) and High-Impedance (Hi-Z). The charge status outputs can be used to illuminate LEDs. Optionally, the charge status outputs can be used as an interface to a host microcontroller. Table 5-1 summarizes the state of the status outputs during a charge cycle.

TABLE 5-1: STATUS OUTPUTS

CHARGE CYCLE STATE	STAT1	STAT2	$\overline{PG}$
Shutdown (V_{DD} = V_{BAT})	Hi-Z	Hi-Z	Hi-Z
Shutdown (V_{DD} = IN)	Hi-Z	Hi-Z	L
Shutdown (CE = L)	Hi-Z	Hi-Z	L
Preconditioning	L	Hi-Z	L
Constant Current	L	Hi-Z	L
Constant Voltage	L	Hi-Z	L
Charge Complete - Standby	Hi-Z	L	L
Temperature Fault	L	L	L
Timer Fault	L	L	L
Low Battery Output	L	Hi-Z	Hi-Z
No Battery Present	Hi-Z	Hi-Z	L
No Input Power Present	Hi-Z	Hi-Z	Hi-Z