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MCP73123/223

Lithium Iron Phosphate ($LiFePO_4$) Battery Charge Management Controller with Input Overvoltage Protection

Features:

- Complete Linear Charge Management Controller:
  - Integrated Input Overvoltage Protection (OVP)
  - Integrated Pass Transistor
  - Integrated Current Sense
  - Integrated Reverse Discharge Protection
- Constant Current/Constant Voltage Operation with Thermal Regulation
- 4.15V Undervoltage Lockout (UVLO)
- 18V Absolute Maximum Input with OVP:
  - 6.5V - MCP73123
  - 13V - MCP73223
- High Accuracy Preset Voltage Regulation Through Full Temperature Range (-5°C to +55°C):
  - ±0.5% - MCP73123
  - ±0.6% - MCP73223
- Battery Charge Voltage Options:
  - 3.6V - MCP73123
  - 7.2V - MCP73223
- Resistor Programmable Fast Charge Current:
  - 130 mA - 1100 mA
- Preconditioning of Deeply Depleted Cells:
  - Available Options: 10% or Disable
- Integrated Precondition Timer:
  - 32 Minutes or Disable
- Automatic End-of-Charge Control:
  - Selectable Minimum Current Ratio: 5%, 7.5%, 10% or 20%
  - Elapse Safety Timer: 4 HR, 6 HR, 8 HR or Disable
- Automatic Recharge:
  - Available Options: 95% or Disable
- Factory Preset Charge Status Output:
  - On/Off or Flashing
- Soft Start
- Temperature Range: -40°C to +85°C
- Packaging: DFN-10 (3 mm x 3 mm)

Applications:

- Low-Cost $LiFePO_4$ Battery Chargers
- Power Tools
- Toys
- Backup Energy Storage Solutions

Description:

The MCP73123/223 is a highly integrated Lithium Iron Phosphate ($LiFePO_4$) battery charge management controller for use in space-limited and cost-sensitive applications. The MCP73123/223 provides specific charge algorithms for $LiFePO_4$ batteries to achieve optimal capacity and safety in the shortest charging time possible. Along with its small physical size, the low number of external components makes the MCP73123/223 ideally suitable for various applications. The absolute maximum voltage, up to 18V, allows the use of MCP73123/223 in harsh environments, such as low cost AC adapter or voltage spikes from plugging/unplugging.

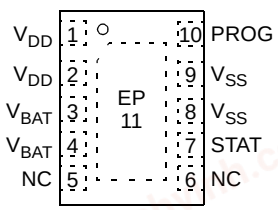
The MCP73123/223 employs a constant current/constant voltage charge algorithm. The 3.6V per cell factory preset reference voltage simplifies design with 2V preconditioning threshold. The fast charge, constant current value is set with one external resistor from 130 mA to 1100 mA. The MCP73123/223 also limits the charge current based on die temperature during high power or high ambient conditions. This thermal regulation optimizes the charge cycle time while maintaining device reliability.

The PROG pin of the MCP73123/223 also serves as the enable pin. When high impedance is applied, the MCP73123/223 will be in Standby mode.

The MCP73123/223 is fully specified over the ambient temperature range of -40°C to +85°C. The MCP73123/223 is available in a 10 lead DFN package.

Package Types (Top View)

MCP73123/223
3x3 DFN *



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

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Typical Application

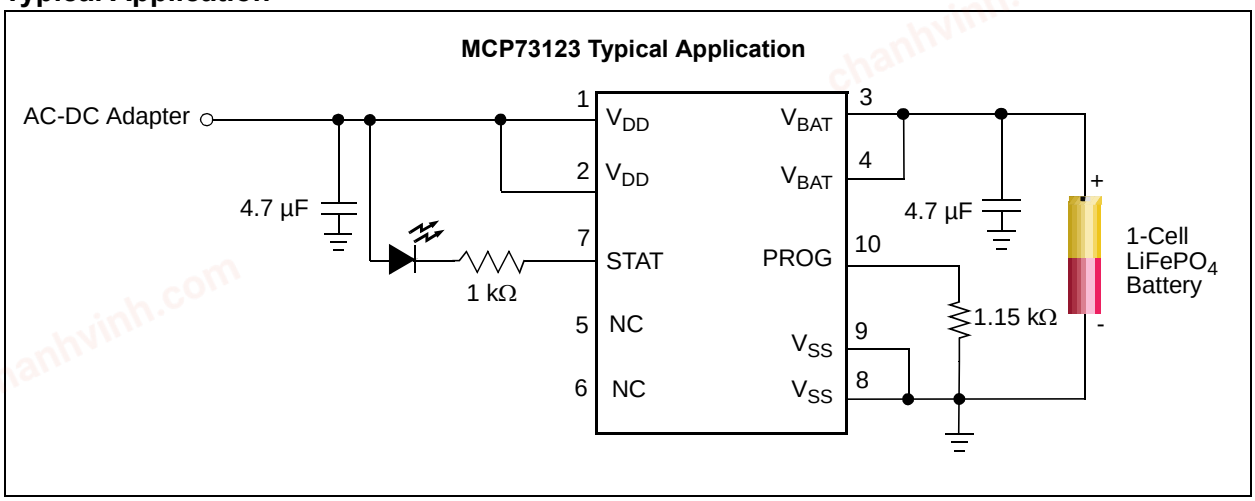


TABLE 1: AVAILABLE FACTORY PRESET OPTIONS

Charge Voltage	OVP	Preconditioning Charge Current	Preconditioning Threshold	Precondition Timer	Elapse Timer	End-of-Charge Control	Automatic Recharge	Output Status
3.6V	6.5V	Disable/10%	2V	Disable / 32 Minimum	Disable/4 hr./ 6 hr./8 hr.	5%/7.5%/ 10%/20%	No / Yes	Type 1/ Type 2
7.2V	13V	Disable/10%	4V	Disable / 32 Minimum	Disable/4 hr./ 6 hr./8 hr.	5%/7.5%/ 10%/20%	No / Yes	Type 1/ Type 2

Note 1: I_{REG}: Regulated fast charge current.
2: V_{REG}: Regulated charge voltage.
3: I_{PREG}/I_{REG}: Preconditioning charge current; ratio of regulated fast charge current.
4: I_{TERM}/I_{REG}: End-of-Charge control; ratio of regulated fast charge current.
5: V_{RTH}/V_{REG}: Recharge threshold; ratio of regulated battery voltage, 0% or 95%. 0% = Disabled.
6: V_{PTH}/V_{REG}: Preconditioning threshold voltage.
7: Type 1: On/Off; Type 2: Flashing. Please refer to Table 5-2.

TABLE 2: STANDARD SAMPLE OPTIONS

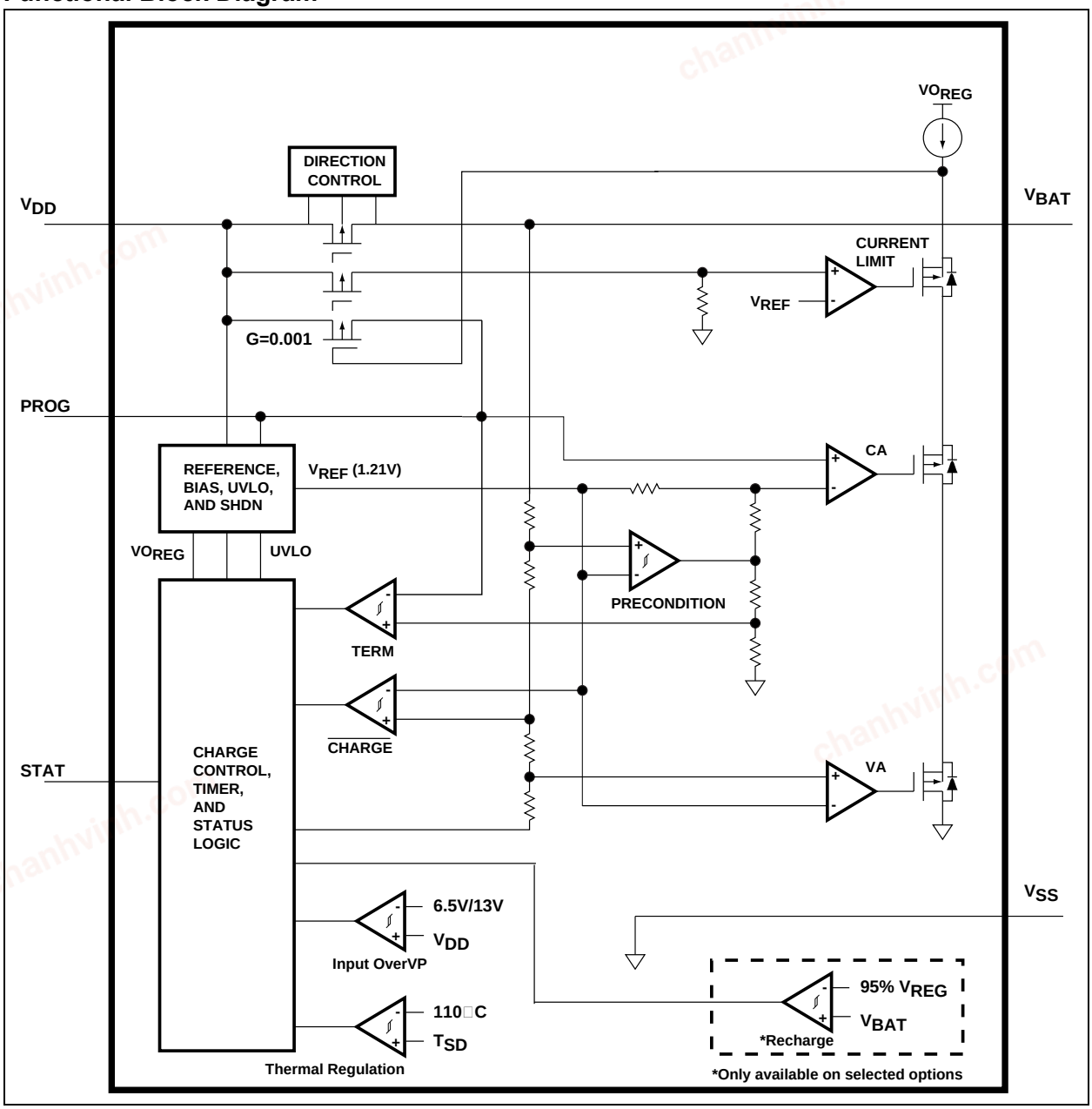
Part Number	V_{REG}	OVP	I_{PREG}/I_{REG}	Precharge Timer	Elapse Timer	I_{TERM}/I_{REG}	Auto Recharge Threshold (0% = Disabled)	V_{PTH}/V_{REG}	Output Status
MCP73123-22S/MF	3.6V	6.5V	10%	32 Min.	6 hr.	10%	95%	2V	Type 1
MCP73123-22A/MF	3.6V	6.5V	10%	32 Min.	6 hr.	10%	0%	2V	Type 1
MCP73223-C2S/MF	7.2V	13V	10%	32 Min.	6 hr.	10%	95%	4V	Type 1
MCP73223-C2A/MF	7.2V	13V	10%	32 Min.	6 hr.	10%	0%	4V	Type 1

Note 1: Customers should contact their distributor, representatives or field application engineer (FAE) for support and samples. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document. Technical support is available through the web site at: http//support.microchip.com.
2: Contact your local Microchip sales office for alternative device options.

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Functional Block Diagram



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1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings†

V_{DD} 18.0V
V_{PROG} 6.0V
All Inputs and Outputs w.r.t. V_{SS} ..... -0.3 to (V_{DD}+0.3)V
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 (200pF, 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_{DD}= [V_{REG}(Typical) + 0.3V] to 12V, T_A = -40°C to +85°C. Typical values are at +25°C, V_{DD} = [V_{REG} (Typical) + 1.0V]

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Supply Input						
Input Voltage Range	V_{DD}	4	—	16	V	
Operating Supply Voltage	V_{DD}	4.2	—	6.5	V	MCP73123
Operating Supply Voltage	V_{DD}	4.2	—	13.0	V	MCP73223
Supply Current	I_{SS}	—	4	5.5	µA	Shutdown ($V_{DD} \le V_{BAT}$ - 150 mV)
		—	700	1500	µA	Charging
		—	30	100	µA	Standby (PROG Floating)
		—	50	150	µA	Charge Complete; No Battery; $V_{DD} < V_{STOP}$
Battery Discharge Current						
Output Reverse Leakage Current	$I_{DISCHARGE}$	—	0.5	2	µA	Standby (PROG Floating)
		—	0.5	2	µA	Shutdown ($V_{DD} \le V_{BAT}$, or $V_{DD} < V_{STOP}$)
		—	6	17	µA	Charge Complete; V_{DD} is present
Undervoltage Lockout						
UVLO Start Threshold	V_{START}	4.10	4.15	4.25	V	
UVLO Stop Threshold	V_{STOP}	4.00	4.05	4.15	V	
UVLO Hysteresis	V_{HYS}	—	100	—	mV	
Overvoltage Protection						
OVP Start Threshold	V_{OVP}	6.4	6.5	6.6	V	MCP73123
OVP Start Threshold	V_{OVP}	12.8	13	13.2	V	MCP73223
OVP Hysteresis	V_{OVPHYS}	—	150	—	mV	
Voltage Regulation (Constant Voltage Mode)						
Regulated Output Voltage	V_{REG}	3.582	3.60	3.618	V	T_A= -5°C to +55°C, I_{OUT} = 50 mA - MCP73123
Output Voltage Tolerance	V_{RTOL}	-0.5	—	+0.5	%	T_A= -5°C to +55°C - MCP73123
Regulated Output Voltage	V_{REG}	7.157	7.20	7.243	V	T_A= -5°C to +55°C, I_{OUT} = 50 mA - MCP73223
Output Voltage Tolerance	V_{RTOL}	-0.6	—	+0.6	%	T_A= -5°C to +55°C - MCP73223

Note 1: Not production tested. Ensured by design.

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DC CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated, all limits apply for V_{DD}= [V_{REG}(Typical) + 0.3V] to 12V, T_A = -40°C to +85°C. Typical values are at +25°C, V_{DD} = [V_{REG} (Typical) + 1.0V]

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Line Regulation	$\lvert(\Delta V_{BAT}/V_{BAT})/\Delta V_{DD}\rvert$	—	0.05	0.20	%/V	V_{DD} = [V_{REG}(Typical)+1V] to 6V - MCP73123 V_{DD} = [V_{REG}(Typical)+1V] to 12V - MCP73223 I_{OUT} = 50 mA
Load Regulation	$\lvert\Delta V_{BAT}/V_{BAT}\rvert$	—	0.05	0.20	%	I_{OUT} = 50 mA - 150 mA V_{DD} = [V_{REG}(Typical)+1V]
Supply Ripple Attenuation	PSRR	—	-46	—	dB	I_{OUT} = 20 mA, 10 Hz to 1 kHz
		—	-30	—	dB	I_{OUT} = 20 mA, 10 Hz to 10 kHz
Battery Short Protection						
BSP Start Threshold	V_{SHORT}	—	1.45	—	V	MCP73123
BSP Start Threshold	V_{SHORT}	—	2.90	—	V	MCP73223
BSP Hysteresis	V_{BSPHYS}	—	150	—	mV	
BSP Regulation Current	I_{SHORT}	—	25	—	mA	
Current Regulation (Fast Charge, Constant-Current Mode)						
Fast Charge Current Regulation	I_{REG}	130	—	1100	mA	T_A=-5°C to +55°C
		—	130	—	mA	PROG = 10 kΩ
		—	1000	—	mA	PROG = 1.1 kΩ
Preconditioning Current Regulation (Trickle Charge Constant Current Mode)						
Precondition Current Ratio	I_{PREG}/I_{REG}	—	10	—	%	PROG = 1 kΩ to 10 kΩ T_A=-5°C to +55°C
		—	100	—	%	No Preconditioning
Precondition Voltage Threshold Ratio	V_{PTH}	1.9	2.0	2.1	V	MCP73123, V_{BAT} Low-to-High
	V_{PTH}	3.8	4.0	4.2	V	MCP73223, V_{BAT} Low-to-High
Precondition Hysteresis	V_{PHYS}	—	100	—	mV	V_{BAT} High-to-Low **(Note 1)**
Charge Termination						
Charge Termination Current Ratio	I_{TERM}/I_{REG}	3.7	5	6.3	%	PROG = 1 kΩ to 10 kΩ T_A=-5°C to +55°C
		5.6	7.5	9.4		
		7.5	10	12.5		
		15	20	25		
Automatic Recharge						
Recharge Voltage Threshold Ratio	V_{RTH}/V_{REG}	93	95	97	%	V_{BAT} High-to-Low
		—	0	—		No Automatic Recharge
Pass Transistor ON-Resistance						
ON-Resistance	R_{DSON}	—	350	—	mΩ	V_{DD} = 4.5V, T_J = 105°C **(Note 1)**
Status Indicator - STAT						
Sink Current	I_{SINK}	—	20	35	mA	
Low Output Voltage	V_{OL}	—	0.2	0.5	V	I_{SINK} = 4 mA
Input Leakage Current	I_{LK}	—	0.001	1	µA	High Impedance, V_{DD} on pin
PROG Input						
Charge Impedance Range	R_{PROG}	1	—	10	kΩ	
Shutdown Impedance	R_{PROG}	—	200	—	kΩ	Impedance for Shutdown
PROG Voltage Range	V_{PROG}	0	—	5	V	

Note 1: Not production tested. Ensured by design.

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DC CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated, all limits apply for V_{DD}= [V_{REG}(Typical) + 0.3V] to 12V, T_A = -40°C to +85°C. Typical values are at +25°C, V_{DD} = [V_{REG} (Typical) + 1.0V]

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Automatic Power Down						
Automatic Power Down Entry Threshold	$V_{PDENTRY}$	V_{BAT} + 10 mV	V_{BAT} + 50 mV	—	V	V_{DD} Falling
Automatic Power Down Exit Threshold	V_{PDEXIT}	—	V_{BAT} + 150 mV	V_{BAT} + 250 mV	V	V_{DD} Rising
Thermal Shutdown						
Die Temperature	T_{SD}	—	150	—	°C	
Die Temperature Hysteresis	T_{SDHYS}	—	10	—	°C	

Note 1: Not production tested. Ensured by design.

AC CHARACTERISTICS

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

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Elapsed Timer						
Elapsed Timer Period	$t_{ELAPSED}$	—	0	—	Hours	Timer Disabled
		3.6	4.0	4.4	Hours	
		5.4	6.0	6.6	Hours	
		7.2	8.0	8.8	Hours	
Preconditioning Timer						
Preconditioning Timer Period	t_{PRECHG}	—	0	—	Hours	Disabled Timer
		0.4	0.5	0.6	Hours	
Status Indicator						
Status Output turn-off	t_{OFF}	—	—	500	µs	I_{SINK} = 1 mA to 0 mA (Note 1)
Status Output turn-on	t_{ON}	—	—	500		I_{SINK} = 0 mA to 1 mA (Note 1)

Note 1: Not production tested. Ensured by design.

TEMPERATURE SPECIFICATIONS

Electrical Specifications: Unless otherwise indicated, all limits apply for V_{DD} = [V_{REG} (Typical) + 0.3V] 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, DFN-10 (3x3)	θ_{JA}	—	64	—	°C/W	4-Layer JC51-7 Standard Board, Natural Convection
	θ_{JC}	—	12	—	°C/W	

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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_{DD} = [V_{REG} (Typical) + 1V], I_{OUT} = 50 mA and T_A= +25°C, Constant Voltage mode.

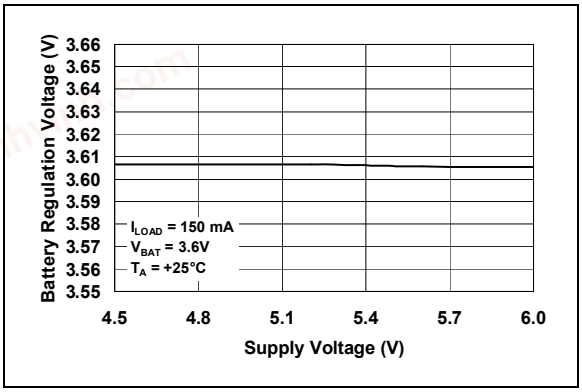


FIGURE 2-1: *Battery Regulation Voltage (V_{BAT}) vs. Supply Voltage (V_{DD}).*

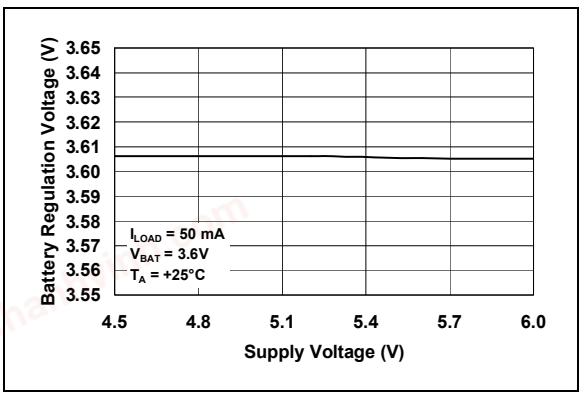


FIGURE 2-2: *Battery Regulation Voltage (V_{BAT}) vs. Supply Voltage (V_{DD}).*

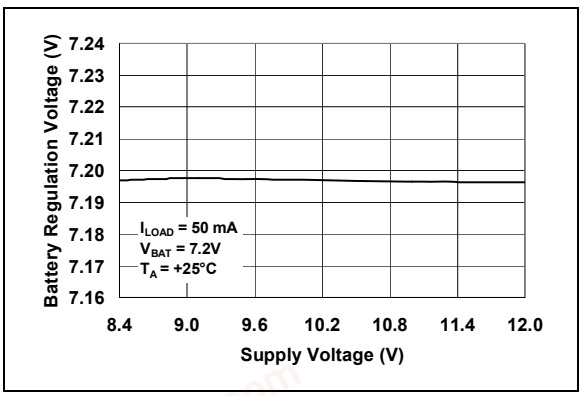


FIGURE 2-3: *Battery Regulation Voltage (V_{BAT}) vs. Supply Voltage (V_{DD}).*

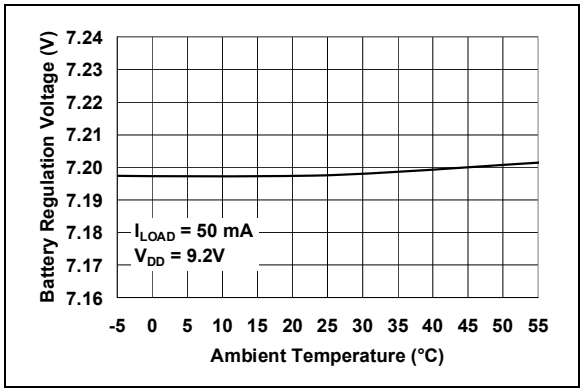


FIGURE 2-4: *Battery Regulation Voltage (V_{BAT}) vs. Ambient Temperature (T_A).*

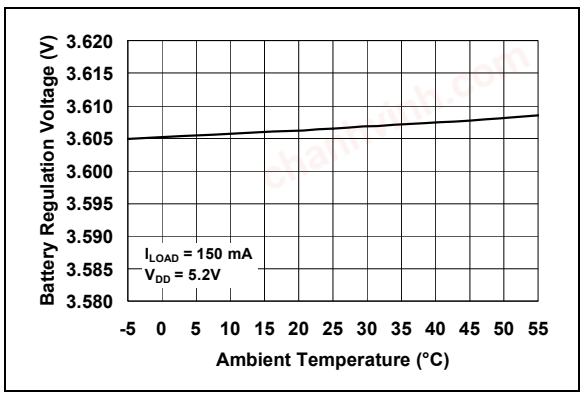


FIGURE 2-5: *Battery Regulation Voltage (V_{BAT}) vs. Ambient Temperature (T_A).*

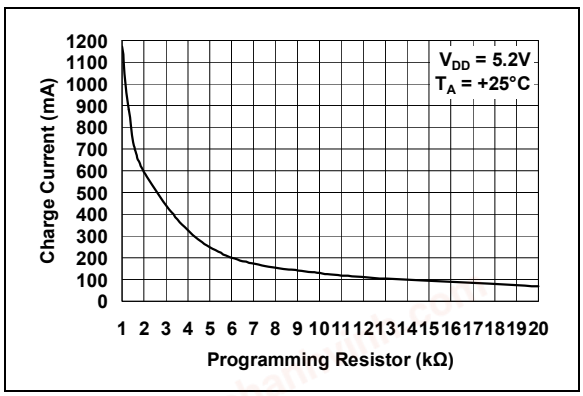


FIGURE 2-6: *Charge Current (I_{OUT}) vs. Programming Resistor (R_{PROG}).*

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TYPICAL PERFORMANCE CURVES (CONTINUED)

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

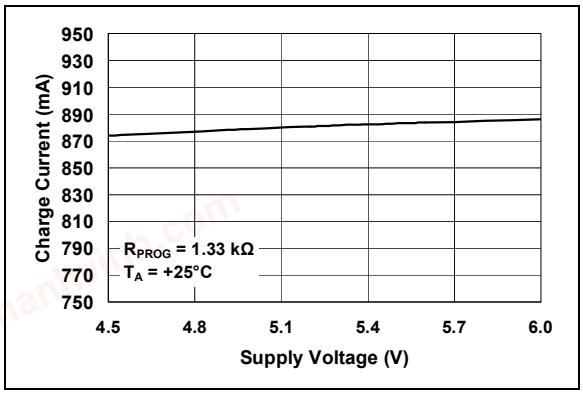


FIGURE 2-7: *Charge Current (I_{OUT}) vs. Supply Voltage (V).*

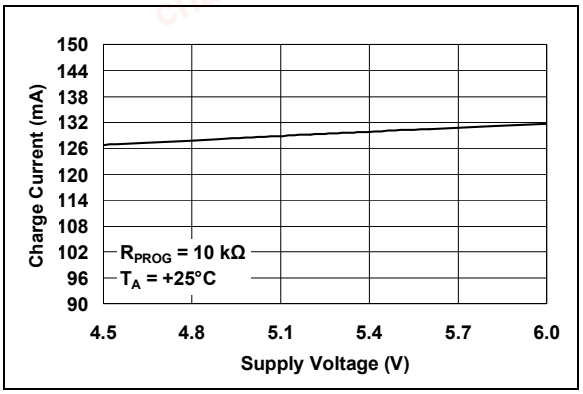


FIGURE 2-10: *Charge Current (I_{OUT}) vs. Programming Resistor (R_{PROG}).*

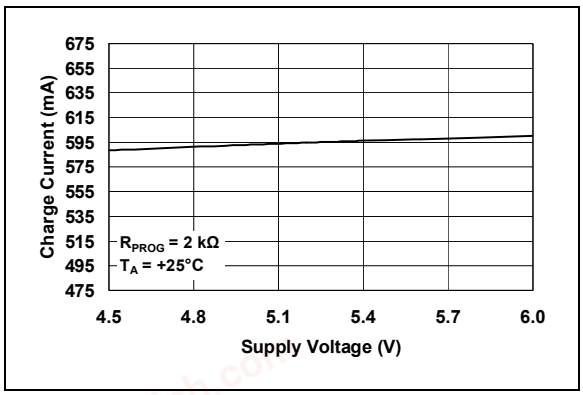


FIGURE 2-8: *Charge Current (I_{OUT}) vs. Supply Voltage (V).*

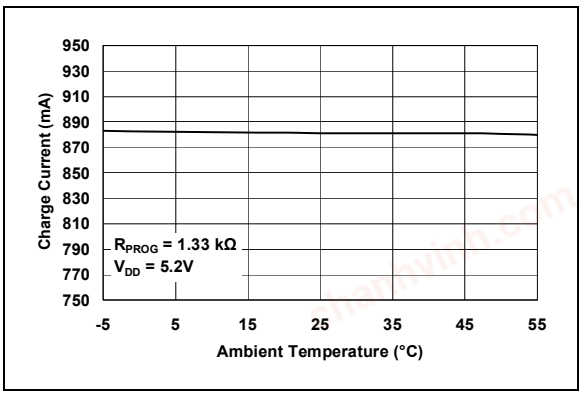


FIGURE 2-11: *Charge Current (I_{OUT}) vs. Ambient Temperature (T_A).*

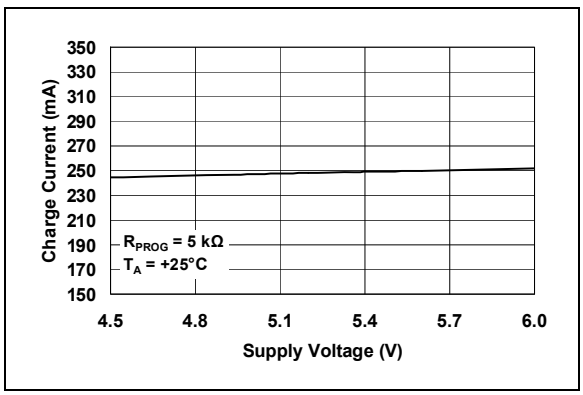


FIGURE 2-9: *Charge Current (I_{OUT}) vs. Supply Voltage (V).*

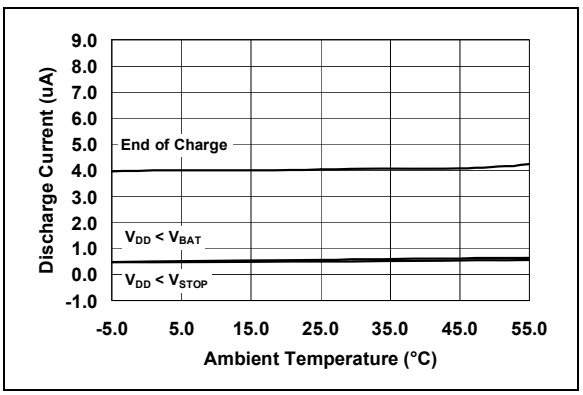


FIGURE 2-12: *Output Leakage Current ($I_{DISCHARGE}$) vs. Ambient Temperature (T_A).*

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TYPICAL PERFORMANCE CURVES (CONTINUED)

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

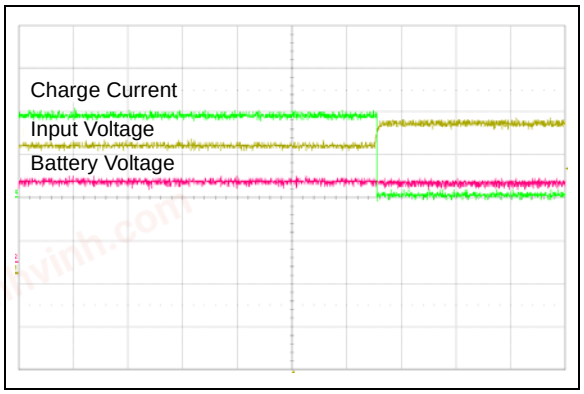


FIGURE 2-13: *Overvoltage Protection Start (50 ms/Div).*

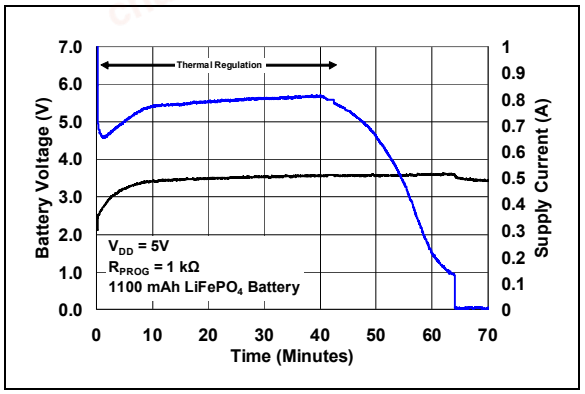


FIGURE 2-16: *Complete Charge Cycle (1100 mAh $LiFePO_4$ Battery).*

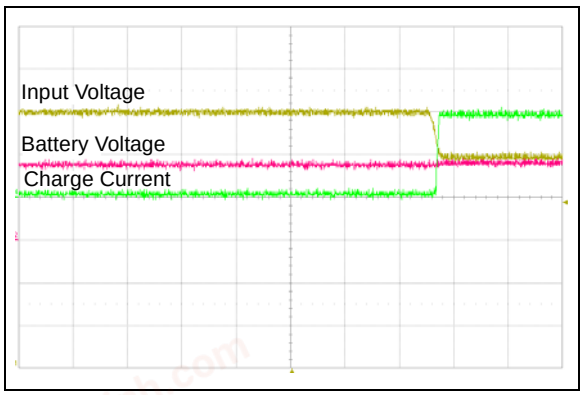


FIGURE 2-14: *Overvoltage Protection Stop (50 ms/Div).*

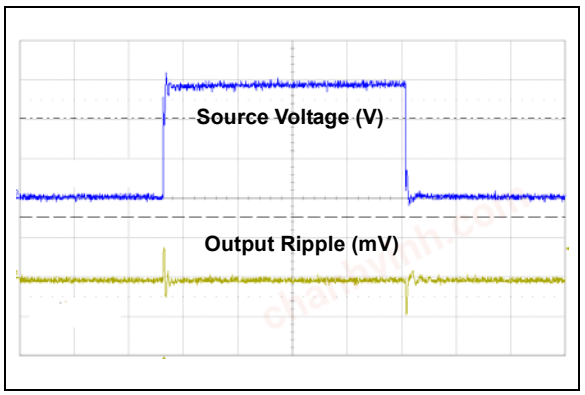


FIGURE 2-17: *Line Transient Response (I_{LOAD} = 10 mA, Source Voltage: 2V/Div, Output Ripple: 100 mV/Div, Time: 100 µs/Div).*

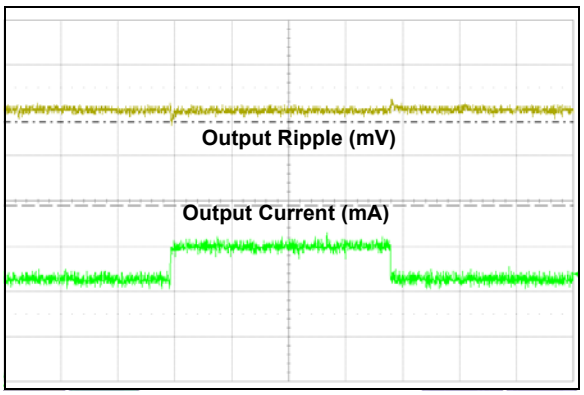


FIGURE 2-15: *Load Transient Response (I_{LOAD} = 50 mA, Output Ripple: 100 mV/Div, Output Current: 50 mA/Div, Time: 100 µs/Div).*

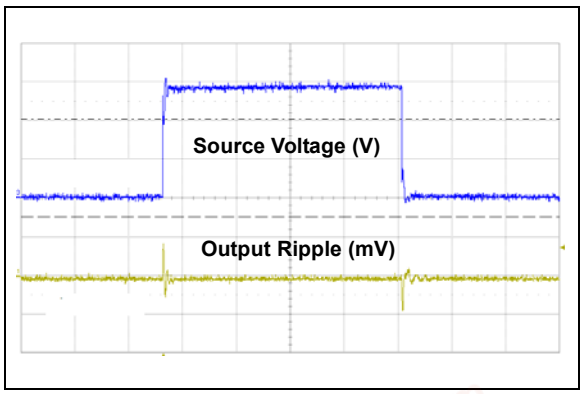


FIGURE 2-18: *Line Transient Response (I_{LOAD} = 100 mA, Source Voltage: 2V/Div, Output Ripple: 100 mV/Div, Time: 100 µs/Div).*

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3.0 PIN DESCRIPTION

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

TABLE 3-1: PIN FUNCTION TABLE

MCP73123/223 DFN-10	Symbol	I/O	Description
1, 2	V_{DD}	I	Battery Management Input Supply
3, 4	V_{BAT}	I/O	Battery Charge Control Output
5, 6	NC	—	No Connection
7	STAT	O	Battery Charge Status Output
8, 9	V_{SS}	—	Battery Management 0V Reference
10	PROG	I/O	Battery Charge Current Regulation Program and Charge Control Enable
11	EP	—	Exposed Pad

3.1 Battery Management Input Supply (V_{DD})

A supply voltage of [V_{REG} (Typical) + 0.3V] to 6.0V is recommended for MCP73123, while a supply voltage of [V_{REG} (Typical) + 0.3V] to 12.0V is recommended for MCP73223. Bypass to V_{SS} with a minimum of 1 µF. The V_{DD} pin is rated 18V absolute maximum to prevent sudden rise of input voltage from spikes or low cost AC-DC wall adapter.

3.2 Battery Charge Control Output (V_{BAT})

Connect to the positive terminal of the battery. Bypass to V_{SS} with a minimum of 1 µF to ensure loop stability when the battery is disconnected. The MCP73123 is designed to provide 3.6V battery regulation voltage for $LiFePO_4$ batteries. Undercharge may occur if a typical Li-Ion or Li-Poly battery is used.

3.3 No Connect (NC)

No connect.

3.4 Status Output (STAT)

STAT is an open-drain logic output for connection to an LED for charge status indication in stand-alone applications. 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.

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

Connect to the negative terminal of the battery and input supply.

3.6 Current Regulation Set (PROG)

The fast charge current is set by placing a resistor from PROG to V_{SS} during constant current (CC) mode.

The PROG pin also serves as a charge control enable pin. Allowing the PROG pin to float or connecting the pin to an impedance greater than 200 kΩ will disable the MCP73123/223 charger. Refer to **Section 5.5, "Constant Current Mode – Fast Charge"**, for details.

3.7 Exposed Pad (EP)

The Exposed Thermal Pad (EP) shall be connected to the exposed copper area on the Printed Circuit Board (PCB) to enhance thermal power dissipation. Additional vias on the copper area under the MCP73123/223 device will improve the performance of heat dissipation and simplify the assembly process. Connecting EP to V_{SS} is recommended.

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4.0 DEVICE OVERVIEW

The MCP73123/223 are simple, but fully integrated linear charge management controllers. Figure 4-1 depicts the operational flow algorithm.

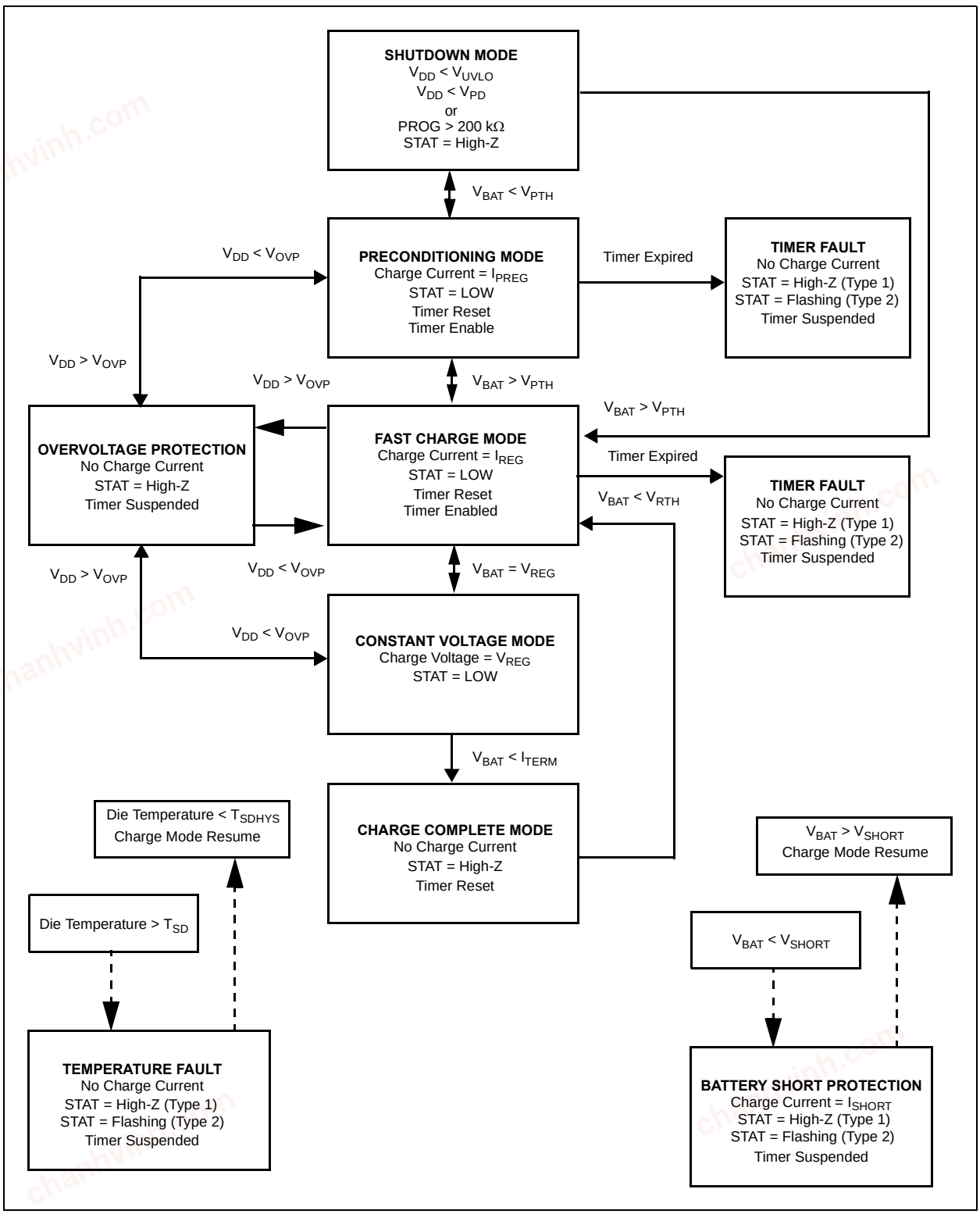


FIGURE 4-1: *The MCP73123/223 Flow Chart.*

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5.0 DETAILED DESCRIPTION

5.1 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 150 mV above the battery voltage before the MCP73123/223 becomes operational.

The UVLO circuit places the device in Shutdown mode if the input supply falls to approximately 150 mV above the battery voltage.The UVLO circuit is always active. At any time, the input supply is below the UVLO threshold or approximately 150 mV of the voltage at the V_{BAT} pin, the MCP73123/223 device is placed in a Shutdown mode.

5.2 Overvoltage Protection (OVP)

An internal OVP circuit monitors the input voltage and keeps the charger in Shutdown mode when the input supply rises above the OVP threshold. The hysteresis of OVP is approximately 150 mV for the MCP73123/223 device.

The MCP73123/223 device is operational between UVLO and OVP threshold. The OVP circuit is also recognized as an overvoltage lockout (OVLO).

5.3 Charge Qualification

When the input power is applied, the input supply must rise 150 mV above the battery voltage before the MCP73123/223 becomes operational.

The automatic power down circuit places the device in Shutdown mode if the input supply falls to within +50 mV of the battery voltage.

The automatic circuit is always active. At any time the input supply is within +50 mV of the voltage at the V_{BAT} pin, the MCP73123/223 is placed in a Shutdown mode.

For a charge cycle to begin, the automatic power down conditions must be met and the charge enable input must be above the input high threshold.

Note:	In order to extend the battery cycle life, the charge will initiate only when battery voltage is below 3.4V per cell.

5.3.1 BATTERY MANAGEMENT INPUT SUPPLY (V_{DD})

The V_{DD} input is the input supply to the MCP73123/223. The MCP73123/223 automatically enters a Power-down mode if the voltage on the V_{DD} input falls to within +50 mV of the battery voltage. This feature prevents draining the battery pack when the V_{DD} supply is not present.

5.3.2 BATTERY CHARGE CONTROL OUTPUT (V_{BAT})

The battery charge control output is the drain terminal of an internal P-channel MOSFET. The MCP73123/223 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.

5.3.3 BATTERY DETECTION

The MCP73123/223 detects the battery presence by monitoring the voltage at V_{BAT}. The charge flow will initiate when the voltage on V_{BAT} is below the $V_{RECHARGE}$ threshold. Refer to the **Section 1.0, "Electrical Characteristics"**, for $V_{RECHARGE}$ values.

When $V_{BAT} > V_{REG}$ + Hysteresis, the charge will be suspended or not started, depending on the current charge status, to prevent overcharging.

5.4 Preconditioning

If the voltage at the V_{BAT} pin is less than the preconditioning threshold, the MCP73123/223 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 MCP73123/223 device supplies 10% of the fast charge current (established with the value of the resistor connected to the PROG pin) to the battery.

When the voltage at the V_{BAT} pin rises above the preconditioning threshold, the MCP73123/223 device enters the Constant Current (Fast Charge) mode.

Note:	The MCP73123/223 also offers options with no preconditioning.

5.4.1 TIMER EXPIRED DURING PRECONDITIONING MODE

If the internal timer expires before the voltage threshold is reached for Fast Charge mode, a timer fault is indicated and the charge cycle terminates. The MCP73123/223 device remains in this condition until the battery is removed or input power is cycled. If the battery is removed, the MCP73123/223 device enters Standby mode, where it remains until a battery is reinserted.

Note:	The typical preconditioning timer for MCP73123/223 is 32 minutes. The MCP73123/223 also offers options with no preconditioning timer.

5.5 Constant Current Mode – Fast Charge

During the Constant Current mode, the programmed charge current is supplied to the battery or load.

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The charge current is established using a single resistor from PROG to V_{SS}. The program resistor and the charge current are calculated using Equation 5-1 and Equation 5-2.

EQUATION 5-1:

$$I_{REG} = 1104 \times R^{-0.93}$$

Where:

R_{PROG} = kilo-ohms (kΩ)

I_{REG} = milliampere (mA)

EQUATION 5-2:

$$R_{PROG} = 10^{(\log(I_{REG}/1104)/(-0.93))}$$

Where:

R_{PROG} = kilo-ohms (kΩ)

I_{REG} = milliampere (mA)

Table 5-1 provides commonly seen E96 (1%) and E24 (5%) resistors for various charge current to reduce design time.

TABLE 5-1: RESISTOR LOOKUP TABLE

Charge Current (mA)	Recommended E96 Resistor (Ω)	Recommended E24 Resistor (Ω)
130	10k	10k
150	8.45k	8.20k
200	6.20k	6.20k
250	4.99k	5.10k
300	4.02k	3.90k
350	3.40k	3.30k
400	3.00k	3.00k
450	2.61k	2.70k
500	2.32k	2.37k
550	2.10k	2.20k
600	1.91k	2.00k
650	1.78k	1.80k
700	1.62k	1.60k
750	1.50k	1.50k
800	1.40k	1.50k
850	1.33k	1.30k
900	1.24k	1.20k
950	1.18k	1.20k
1000	1.10k	1.10k
1100	1.00k	1.00k

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.

5.5.1 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 MCP73123/223 device remains in this condition until the battery is removed. If the battery is removed or input power is cycled, the MCP73123/223 device enters the Standby mode, where it remains until a battery is reinserted.

5.6 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 3.6V for a single cell, with a tolerance of ±0.5%; or 7.2V for dual cells, with a tolerance of ±0.6%.

5.7 Charge Termination

The charge cycle is terminated when, during Constant Voltage mode, the average charge current diminishes below a threshold established with the value of 5%, 7.5%, 10% or 20% of fast charge current or internal timer has expired. 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.

5.8 Automatic Recharge

The MCP73123/223 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 once again supplied to the battery or load. The recharge threshold is factory set. Refer to **Section 1.0, "Electrical Characteristics"**, for recharge threshold options.

Note: The MCP73123/223 also offer options with no automatic recharge.

For the MCP73123/223 device with no recharge option, the MCP73123/223 will go into Standby mode when the termination condition is met. The charge will not restart until at least one of the following conditions have been met:

- The battery is removed from the system and inserted again
- V_{DD} is removed and plugged in again
- R_{PROG} is disconnected (or high impedance) and reconnected

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5.9 Thermal Regulation

The MCP73123/223 limits the charge current, based on the die temperature. This thermal regulation optimizes the charge cycle time while maintaining device reliability. Figure 5-1 depicts the thermal regulation for the MCP73123/223 device. Refer to **Section 1.0, "Electrical Characteristics"**, for thermal package resistances and **Section 6.1.1.2 "Thermal Considerations"**, for calculating power dissipation.

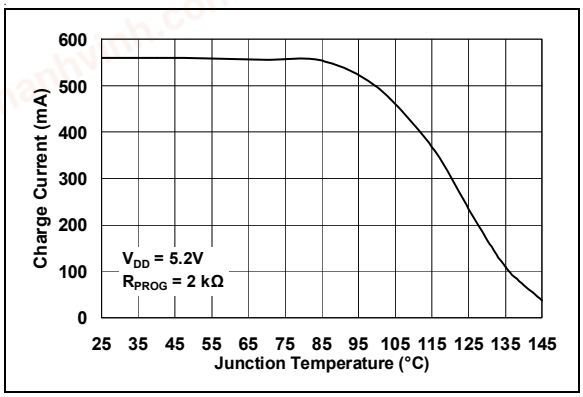


FIGURE 5-1: *Thermal Regulation.*

5.10 Thermal Shutdown

The MCP73123/223 suspends charge if the die temperature exceeds +150°C. Charging will be resumed when the die temperature has cooled by approximately 10°C. This thermal shutdown is a secondary safety feature in the event that there is a failure within the thermal regulation circuitry.

5.11 Status Indicator

The charge status outputs are open-drain outputs with two different states: Low (L) and High Impedance (High-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 5-2 summarizes the state of the status outputs during a charge cycle.

TABLE 5-2: STATUS OUTPUTS

CHARGE CYCLE STATE	STAT
Shutdown	High-Z
Standby	High-Z
Preconditioning	L
Constant Current Fast Charge	L
Constant Voltage	L
Charge Complete - Standby	High-Z
Temperature Fault	1.6 second 50% DC Flashing (Type 2) High-Z (Type 1)
Timer Fault	1.6 second 50% DC Flashing (Type 2) High-Z (Type 1)
Preconditioning Timer Fault	1.6 second 50% DC Flashing (Type 2) High-Z (Type 1)

5.12 Battery Short Circuit Protection

When a lithium iron phosphate battery is detected, an internal battery short circuit protection circuit starts monitoring the battery voltage. When V_{BAT} is below the typical 1.7V battery short circuit protection threshold voltage per cell, the charging behavior is postponed. A 25 mA (typical) detection current is supplied for recovering from the battery short circuit condition.

Preconditioning mode resumes when V_{BAT} rises above the battery short circuit protection threshold. The battery voltage must rise approximately 150 mV above the battery short circuit protection voltage before the MCP73123/223 device becomes operational.

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6.0 APPLICATIONS

The MCP73123/223 is designed to operate with a host microcontroller or in stand-alone applications. The MCP73123/223 provides the preferred charge algorithm for lithium iron phosphate cells, Constant Current mode followed by Constant Voltage mode.

Figure 6-1 depicts a typical stand-alone application circuit, while Figure 6-2 depicts the accompanying charge profile.

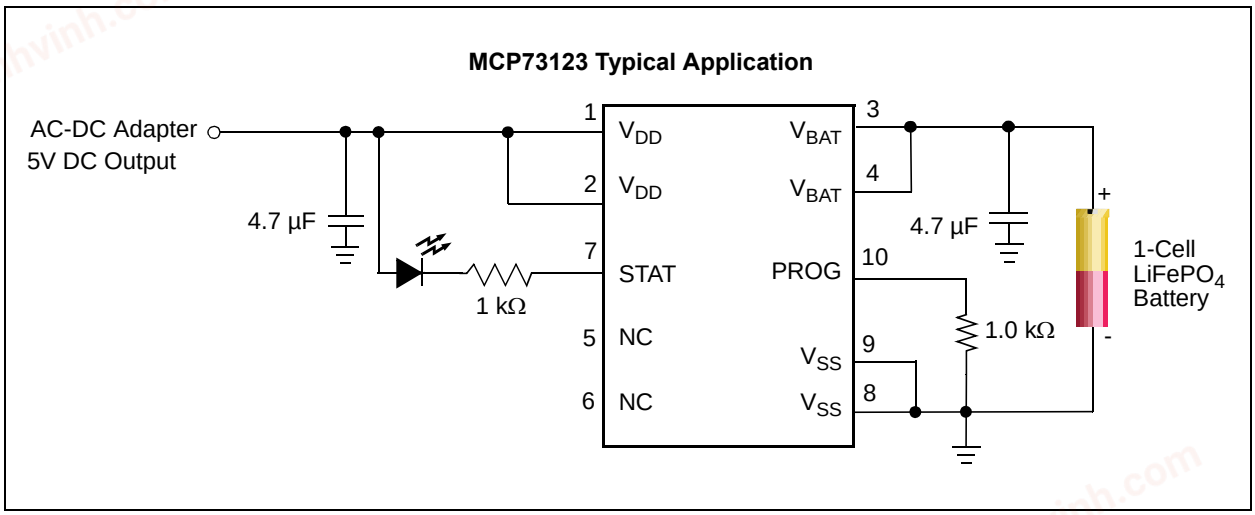


FIGURE 6-1: *Typical Application Circuit.*

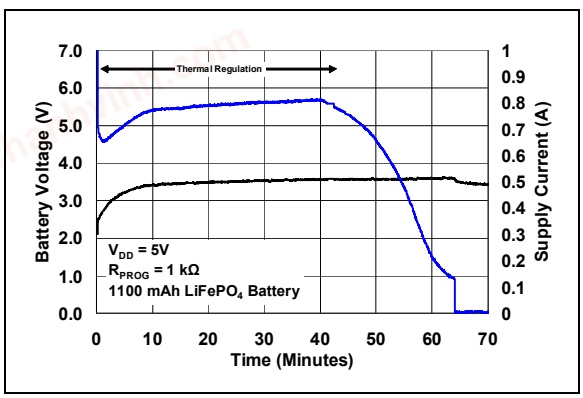


FIGURE 6-2: *Typical Charge Profile for Single-Cell $LiFePO_4$ Battery.*

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6.1 Application Circuit Design

Due to the low efficiency of linear charging, the most important factors are thermal design and cost, which are a direct function of the input voltage, output current and thermal impedance between the battery charger and the ambient cooling air. The worst-case situation is when the device has transitioned from the Preconditioning mode to the Constant Current mode. In this situation, the battery charger has to dissipate the maximum power. A trade-off must be made between the charge current, cost, and thermal requirements of the charger.

6.1.1 COMPONENT SELECTION

Selection of the external components in Figure 6-1 is crucial to the integrity and reliability of the charging system. The following discussion is intended as a guide for the component selection process.

6.1.1.1 Charge Current

The recommended fast charge current should be obtained from the battery manufacturer. For example, a 1000 mAh battery pack with 2C preferred fast charge current has a charge current of 1000 mA. Charging at this rate provides the shortest charge cycle times without degradation of the battery pack performance or life.

Note:	Please consult with your battery supplier or refer to the battery data sheet for the preferred charge rate.

6.1.1.2 Thermal Considerations

The worst-case power dissipation in the battery charger occurs when the input voltage is at the maximum and the device has transitioned from the Preconditioning mode to the Constant Current mode. In this case, the power dissipation is calculated using Equation 6-1.

EQUATION 6-1:

$$PowerDissipation = (V_{DDMAX} - V_{PTHMIN}) \times I_{REGMAX}$$

Where:

- V_{DDMAX} = the maximum input voltage
- I_{REGMAX} = the maximum fast charge current
- V_{PTHMIN} = the minimum transition threshold voltage

Power dissipation with a 5V, ±10% input voltage source, 500 mA ±10% and preconditioning threshold voltage at 2V is calculated using Equation 6-2.

EQUATION 6-2:

$$PowerDissipation = (5.5V - 2V) \times 550mA = 1.925W$$

This power dissipation with the battery charger in the DFN-10 package will raise the temperature approximately 83°C above room temperature.

6.1.1.3 External Capacitors

The MCP73123/223 is stable with or without a battery load. In order to maintain good AC stability in the Constant Voltage mode, a minimum capacitance of 1 µF is recommended to bypass the V_{BAT} pin to V_{SS}. This capacitance provides compensation when there is no battery load. In addition, the battery and interconnections appear inductive at high frequencies. These elements are in the control feedback loop during Constant Voltage mode. Therefore, the bypass capacitance may be necessary to compensate for the inductive nature of the battery pack.

A minimum of 1 µF is recommended for the output capacitor, and a minimum of 1 µF is recommended for the input capacitor in typical applications.

TABLE 6-1: MLCC CAPACITOR EXAMPLE

MLCC Capacitors	Temperature Range	Tolerance
X7R	-55°C to +125°C	±15%
X5R	-55°C to +85°C	±15%

Virtually any good quality output filter capacitor can be used, independent of the capacitor's minimum Effective Series Resistance (ESR) value. The actual value of the capacitor (and its associated ESR) depends on the output load current. A 1 µF ceramic, tantalum, or aluminum electrolytic capacitor at the output is usually sufficient to ensure stability.

6.1.1.4 Reverse-Blocking Protection

The MCP73123/223 provides protection from a faulted or shorted input. Without the protection, a faulted or shorted input would discharge the battery pack through the body diode of the internal pass transistor.

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6.2 PCB Layout Issues

For optimum voltage regulation, place the battery pack as close as possible to the device's V_{BAT} and V_{SS} pins to minimize voltage drops along the high-current-carrying PCB traces.

If the PCB layout is used as a heat sink, adding multiple vias in the heat sink pad can help conduct more heat to the backplane of the PCB, thus reducing the maximum junction temperature. Figure 6-3, Figure 6-4 and Figure 6-5 depict a typical layout with PCB heatsinking.

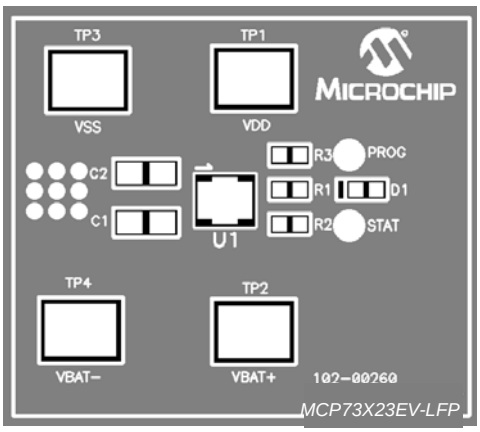


FIGURE 6-3: *Typical Layout (Top).*

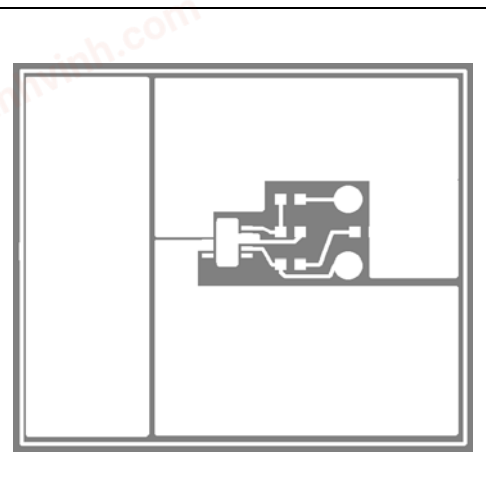


FIGURE 6-4: *Typical Layout (Top Metal).*

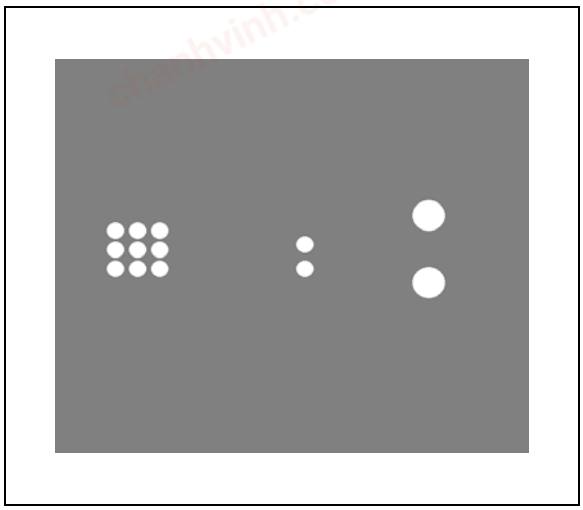


FIGURE 6-5: *Typical Layout (Bottom).*

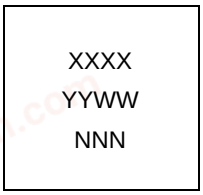
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7.0 PACKAGING INFORMATION

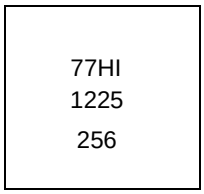
7.1 Package Marking Information

10-Lead DFN (3x3)



Standard *	
Part Number	**Code**
MCP73123-22SI/MF	77HI
MCP73223-C2SI/MF	X7HI

Example:



Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.

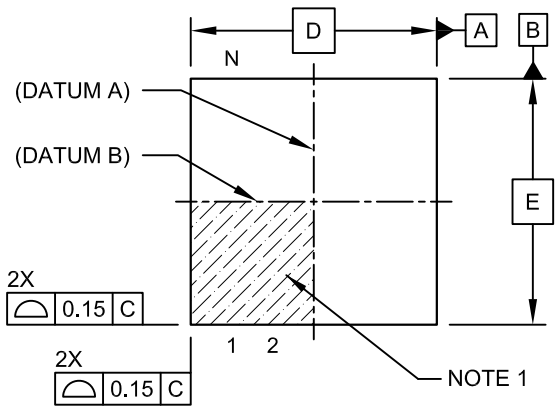
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

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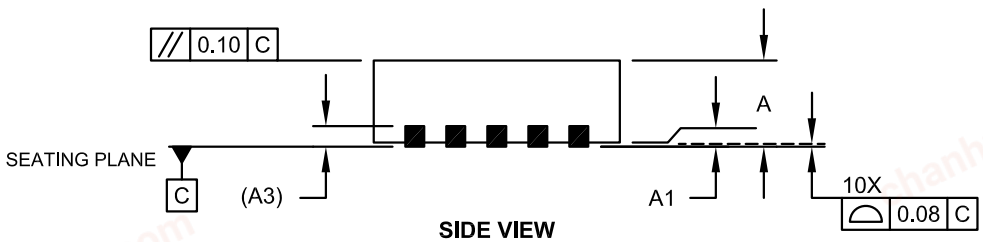
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10-Lead Plastic Dual Flat, No Lead Package (MF) - 3x3x0.9mm Body [DFN]

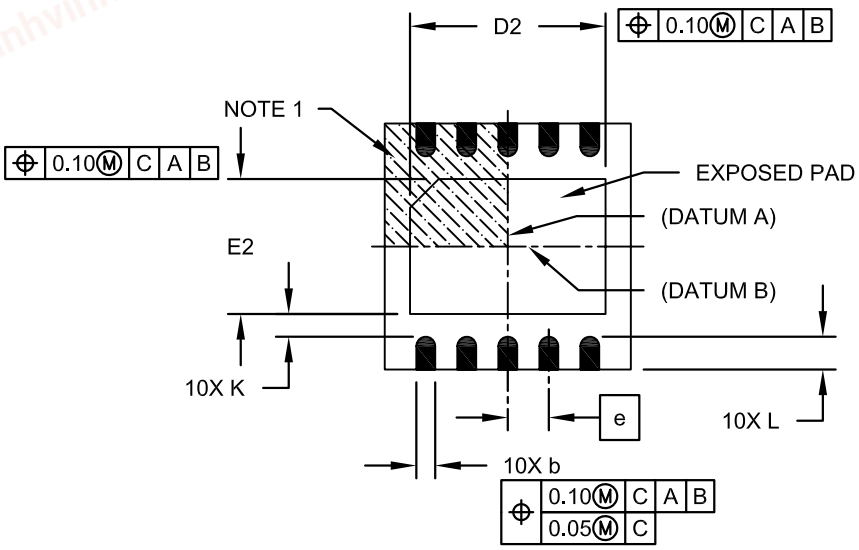
Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



TOP VIEW



SIDE VIEW



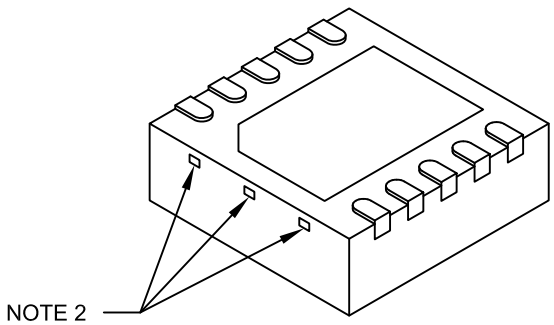
BOTTOM VIEW

Microchip Technology Drawing No. C04-063C Sheet 1 of 2

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10-Lead Plastic Dual Flat, No Lead Package (MF) - 3x3x0.9mm Body [DFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		10	
Pitch	e		0.50 BSC	
Overall Height	A	0.80	0.90	1.00
Standoff	A1	0.00	0.02	0.05
Contact Thickness	A3		0.20 REF	
Overall Length	D		3.00 BSC	
Exposed Pad Length	D2	2.15	2.35	2.45
Overall Width	E		3.00 BSC	
Exposed Pad Width	E2	1.40	1.50	1.75
Contact Width	b	0.18	0.25	0.30
Contact Length	L	0.30	0.40	0.50
Contact-to-Exposed Pad	K	0.20	-	-

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package may have one or more exposed tie bars at ends.
3. Package is saw singulated.
4. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
REF: Reference Dimension, usually without tolerance, for information purposes only.

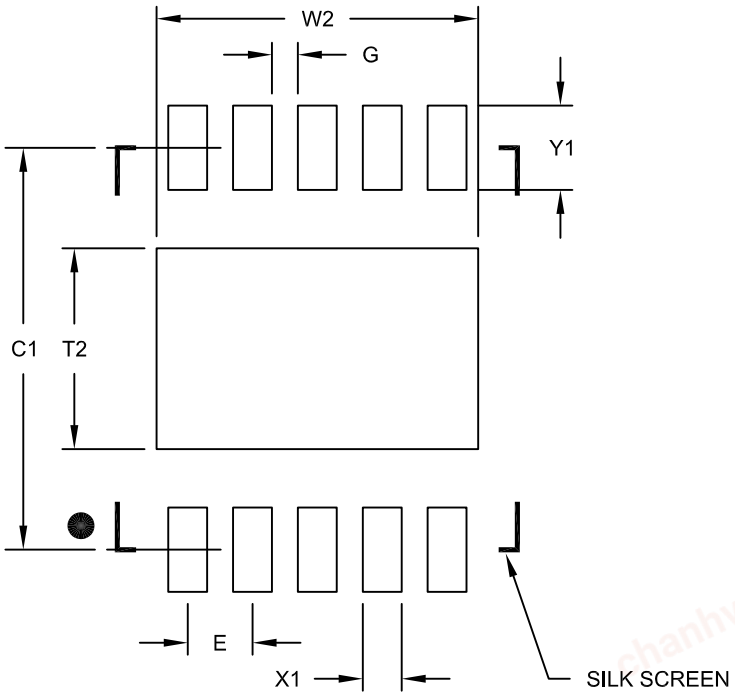
Microchip Technology Drawing No. C04-063C Sheet 2 of 2

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10-Lead Plastic Dual Flat, No Lead Package (MF) - 3x3x0.9mm Body [DFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.50 BSC	
Optional Center Pad Width	W2			2.48
Optional Center Pad Length	T2			1.55
Contact Pad Spacing	C1		3.10	
Contact Pad Width (X10)	X1			0.30
Contact Pad Length (X10)	Y1			0.65
Distance Between Pads	G	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2063B

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NOTES:

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APPENDIX A: REVISION HISTORY

Revision E (February 2013)

The following is the list of modifications:

1. Updated the Functional Block Diagram.
2. Updated the Temperature Specifications table.
3. Updated **Section 3.6 "Current Regulation Set (PROG)"**.
4. Updated **Section 5.3.3 "Battery Detection"**.
5. Updated Equation 5-2.

Revision D (June 2011)

The following is the list of modifications:

1. Updated the land pattern drawing of the 3x3 DFN package on page 27.

Revision C (January 2011)

The following is the list of modifications:

1. Added two more part numbers in Table 2.
2. Updated the flowchart in Figure 4-1.

Revision B (January 2010)

The following is the list of modifications:

1. Updated the OVP value for MCP73223-C2S/MF in Table 2.
2. Updated the Battery Short Protection values in the DC Characteristics table.

Revision A (July 2009)

- Original Release of this Document.

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PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip sales office.

PART NO.	X	XX
Device	Temperature Range	Package

Device:	MCP73123:	Single Cell Lithium Iron Phosphate Battery Device
	MCP73123T:	Single Cell Lithium Iron Phosphate Battery Device, Tape and Reel
	MCP73223:	Dual Cell Lithium Iron Phosphate Battery Device
	MCP73223T:	Dual Cell Lithium Iron Phosphate Battery Device, Tape and Reel
Temperature Range:	I =	-40°C to +85°C (Industrial)
Package:	MF =	Plastic Dual Flat No Lead, 3x3 mm Body (DFN), 10-Lead

Examples:

a) MCP73123-22SI/MF: Single Cell Lithium Iron Phosphate Battery Device

b) MCP73123T-22SI/MF: Tape and Reel, Single Cell Lithium Iron Phosphate Battery Device

a) MCP73223-C2SI/MF: Dual Cell Lithium Iron Phosphate Battery Device

a) MCP73223T-C2SI/MF: Tape and Reel, Dual Cell Lithium Iron Phosphate Battery Device

Consult your local Microchip sales office for alternative device options.

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