Features

- **1.5MHz Synchronous Switching Charger with 3A Integrated MOSFETs**
- **Selectable 1/2 Cell Charging with 4.2V or 4.3V/Cell.**
- **Ultra Small 4X4mm QFN-20 Package**
- **4.5V~15V Operating Vin**
- **Up to 95% Efficiency**
- **Internal Soft Start**
- **Internal Loop Compensation**
- **Protection**
  - Internal Fixed 6.6V/16.5V OVP without External Resistors
  - Internal Fixed 7Hrs timer
  - Charger Input & Output Current Sensing
  - Cycle by Cycle Current Limit
  - I_chg Thermal Fold back @ Tj=125C
  - Battery Pack OTP
  - Status Pin
- **Accuracy**
  - +/- 1% V_chg Regulation
  - +/- 10% I_chg Regulation
- **Application**
  - Tablet PC
  - NetBook and Ultrabook
  - Battery Bank.

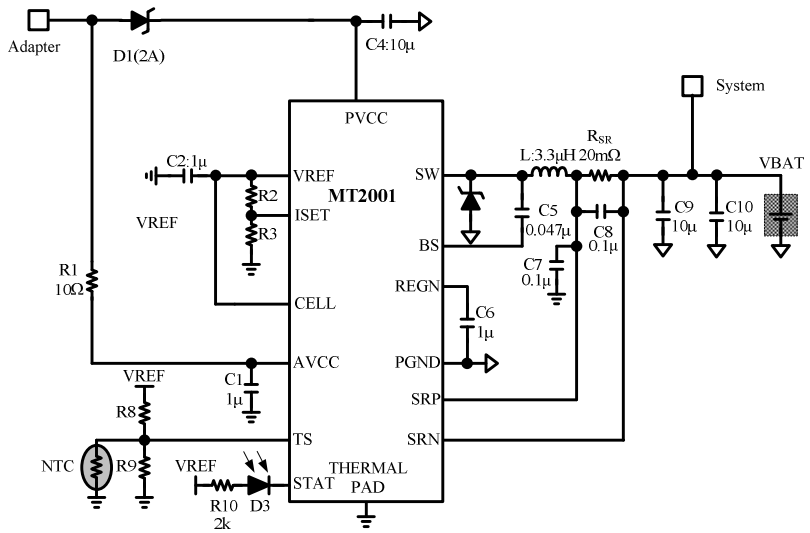


Figure 1. Typical Application Diagram

Ordering Information

Part No.	Marking	Temp. Range	Package	Remark
MT2001XQDR	MT2001 xxxxx X	-40℃ ~85℃	QFN4x4_20	MT2001X, 1/2cell selectable, 4.2V/Cell
MT2001AQDR	MT2001 xxxxx A	-40℃ ~85℃	QFN4x4_20	MT2001A, 1/2cell selectable, 4.3V/Cell

Pin Configuration

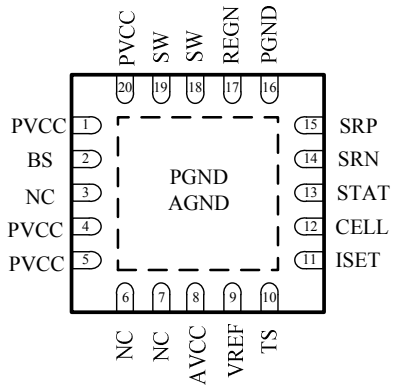


Figure2. MT2001/A(TOP View)

Pin description

Pin NO.	Pin Name	Description		
1, 4, 5, 20	PVCC	IC power supply of power device of Charger. Put 10uF MLCC from PVCC to PGND.		
2	BS	Boostrap pin. Place a 0.047u-F MLCC from SW to BS		
3, 6, 7	NC	No Connection.		
8	AVCC	IC power supply of internal bias. Put 1uF MLCC from AVCC to AGND. Add 10Ω resistor to filter the noise of power line.		
9	VREF	3.3V reference output. A 1uF MLCC is placed from VREF to GND to make it stable.		
10	TS	NTC resistor connection		
11	ISET	Fast charge current set pin.		
12	CELL	Cell selection pin. Set CELL pin LOW for 2-cell, HIGH for 1-cell, (MT2001)		
13	STAT	Open drain output		
		HIGH-Z	LOW	Blinking
		Charge complete or Sleep mode	Charging in progress	Fault
14	SRN	Charge current sense negative input.		
15	SRP	Charge current sense positive input. A 0.1-uF is recommended for common mode filtering from SRP to AGND. A 0.1uF is placed from SRP to SRN for differential mode filtering.		
16	PGND	Power ground		
17	REGN	5V power supply output, Bypass 1u-F MLCC to AGND.		

18, 19	SW	Switching node, charge current output inductor connection. Connect a 47-nF BS capacitor from SW to BS.

Absolute Maximum Rating (1)

PVCC, AVCC, STAT, SRP

SRN ..... -0.3V~20V

BS .....-0.3V~26V

SW ..... -2V~20V

REGN, TS, CELL..... -0.3V~7V

VREF, ISET.....-0.3~3.6V

PGND .....-0.3V~0.3V

SRP–SRN.....-0.5V~0.5V

Junction temperature range, T_J ..... -40℃ ~155℃

Storage temperature range, T_{stg} ..... -55℃ ~155℃

Lead Temperature ..... 260℃

Thermal Information

Maximum Power Dissipation(P_D) 2W

Thermal resistance(θ_{JA}) ..... 40℃/W

Recommended Operating Condition (2)

V_{IN} ..... 4.5V~15V

V_{OUT} 9V

I_{OUT} ..... 0.6A~4A

SRP–SRN ..... -200mV~200mV

Ambient Temperature Range..... -40℃ ~+85℃

Note (1): Stress beyond those listed under "Absolute Maximum Ratings" may damage the device.

Note (2): The device is not guaranteed to function outside the recommended operating conditions.

Electrical Characteristics

4.5V ≤ V(PVCC, AVCC) ≤ 15V, typical values are at TA = 25℃, with respect to AGND (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
OPERATING CONDITIONS						
V_{AVCC_OP}	AVCC input voltage operating range during charging.		4.5		15	V
QUIESCENT CURRENTS						
I_{BAT}	Battery discharge current (sum of currents into AVCC, PVCC)	V_{AVCC} > V_{UVLO}, V_{SRN} > V_{AVCC} (SLEEP),			15	μA
		BTST, SW, SRP, SRN, V_{AVCC} > V_{UVLO}, V_{AVCC} > V_{SRN}, ISET < 40mV, V_{BAT}=8.4V, Charge disabled			25	μA
I_{AC}	Adapter supply current (sum of current into AVCC)	V_{AVCC} > V_{UVLO}, V_{AVCC} > V_{SRN}, V_{BAT}=8.4V, Charge disabled		1.2	2	mA
CHARGE VOLTAGE REGULATION						
V_{BAT_REG}	SRN regulation voltage T_A = 0℃ to +85℃	CELL = VREF, 1 cell, MT2001X T_A = 0℃ to +85℃	4.158	4.20	4.242	V
		CELL = VREF, 1 cell, MT2001A T_A = 0℃ to +85℃	4.257	4.30	4.343	V
		CELL = AGND, 2 cells, MT2001X T_A = 0℃ to +85℃	8.316	8.40	8.484	V
		CELL = AGND, 2 cells, MT2001A T_A = 0℃ to +85℃	8.514	8.60	8.686	V

ELECTRICAL CHARACTERISTICS (continued)

4.5V ≤ V(PVCC, AVCC) ≤ 15V, typical values are at TA = 25℃, with respect to AGND (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
CHARGE CURRENT REGULATION – FAST CHARGE						
V_{ISET}	ISET Voltage Range	R_{SENSE} = 20mΩ	0		VREF	V
$V_{SRP-SRN\_CC}$	Charge Current Full Scale Sense Voltage	VISET=VREF, R_{SENSE} = 20mΩ		75		mV
		VISET=Float, R_{SENSE} = 20mΩ		50		mV
		VISET=AGND, R_{SENSE} = 20mΩ		25		mV
CURRENT REGULATION –PRE- CHARGE						
$V_{SRP-SRN\_PC}$	Charge Current Full Scale Sense Voltage in Pre-Charge	VISET=VREF, R_{SENSE} = 20mΩ		7.5		mV
		VISET=Float , R_{SENSE} = 20mΩ		5		mV
		VISET=AGND , R_{SENSE} = 20mΩ		2.5		mV
CHARGE TERMINATION						
K_{TERM}	Termination set factor	Termination of fast charge current		10%		
INPUT UNDER-VOLTAGE LOCK-OUT COMPARATOR (UVLO)						
V_{UVLO}	AC under-voltage rising	Measure on AVCC		3.3		V
V_{UVLO_HYS}	AC under-voltage	Measure on AVCC		0.3		V
SLEEP COMPARATOR (REVERSE DISCHARGING PROTECTION)						
V_{SLEEP}	SLEEP mode threshold	V_{AVCC} – V_{SRN} falling		100		mV
V_{SLEEP_HYS}	Hysteresis	V_{AVCC} – V_{SRN} rising		200		mV
BAT LOW COMPARATOR						
V_{LOWV}	Precharge to fast charge transition threshold	CELL = VREF, 1 cell, measured on SRN	2.8	2.9	3.0	V
		CELL = AGND, 2 cells, measured on SRN	5.6	5.8	6.0	
V_{LOWV_HYS}	Fast charge to precharge hysteresis	CELL = VREF, 1 cell, measured on SRN		200		mV
		CELL = AGND or floating, 2 cells, measured on SRN		400		
RECHARGE COMPARATOR						
V_{RECHG}	Recharge Threshold, below regulation voltage limit, V_{BAT_REG}-V_{SRN}	CELL = VREF, 1 cell, measured on SRN		140		mV
		CELL = AGND, 2 cells, measured on SRN		280		
BAT OVER-VOLTAGE COMPARATOR						
V_{OV_RISE}	Over-voltage rising threshold	As percentage of V_{BAT_REG}		104%		
V_{OV_FALL}	Over-voltage falling threshold	As percentage of V_{SRN}		102%		
INPUT OVER-VOLTAGE COMPARATOR (ACOV)						
V_{ACOV}	AC Over-Voltage Rising Threshold to turn off ACFET	CELL = VREF, 1 cell, AVCC rising	6.3	6.6	6.9	V
		CELL = AGND, 2 cells, AVCC rising	15.5	16.5	17.5	V
V_{ACOV_HYS}	AC over-voltage falling hysteresis	CELL = VREF, 1 cell, AVCC falling		200		mV
		CELL = AGND or floating, 2 cells, AVCC falling		500		mV
THERMAL REGULATION						
T_{J_REG}	Junction Temperature	Charging		125		℃
THERMAL SHUTDOWN COMPARATOR						
T_{SHUT}	Thermal shutdown temperature	Temperature rising		160		℃
T_{SHUT_HYS}	Thermal shutdown hysteresis	Temperature falling		30		℃
THERMISTOR COMPARATOR						
V_{LTF}	Cold Temperature Threshold, TS pin Voltage Rising Threshold	Charger suspends charge. As percentage to V_{VREF}	71%	73%	75%	
V_{LTF_HYS}	Cold Temperature Hysteresis, TS pin voltage Falling	As percentage to V_{VREF}		0.4%		
V_{HTF}	Hot Temperature TS pin voltage rising Threshold	As percentage to V_{VREF}	44%	46.5%	49%	
V_{TCO}	TS pin Charging Disable Threshold				0.15	V

ELECTRICAL CHARACTERISTICS (continued)

4.5V ≤ V(PVCC, AVCC) ≤ 15V, typical values are at TA = 25℃, with respect to AGND (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
THERMISTOR COMPARATOR						
V_{LTF}	Cold Temperature Threshold, TS pin Voltage Rising Threshold	Charger suspends charge. As percentage to V_{VREF}	71%	73%	75%	
V_{LTF_HYS}	Cold Temperature Hysteresis, TS pin voltage Falling	As percentage to V_{VREF}		0.4%		
V_{HTF}	Hot Temperature TS pin voltage rising Threshold	As percentage to V_{VREF}	44%	46.5%	49%	
V_{TCO}	TS pin Charging Disable Threshold				0.15	V
HSFET OVER-CURRENT COMPARATOR (CYCLE-BY-CYCLE)						
I_{OCP_HSFET}	Current limit on HSFET	Measure on HSFET		6		A
VREF REGULATOR						
V_{VREF_REG}	VREF regulator voltage	V_{AVCC} > V_{UVLO}, No load	3.1	3.3	3.5	V
I_{VREF_LIM}	VREF current limit	V_{VREF} = 0 V, V_{AVCC} > V_{UVLO}		40		mA
REGN REGULATOR						
V_{REGN_REG}	REGN regulator voltage	V_{AVCC} > 10 V,	4.7	5.3	5.9	V
I_{REGN_LIM}	REGN current limit	V_{REGN} = 0 V, V_{AVCC} > 10V		50		mA
INTERNAL PWM						
Fsw	PWM Switching Frequency		1.2	1.45	1.7	MHz
T_{SW_DEAD}	Driver Dead Time	V_{AVCC} > 5V		20		nS
R_{DS_HI}	High-Side Ron	V_{BS}-V_{SW}=5V		110		mΩ
R_{DS_LO}	Low-Side Ron	V_{REGN}=5V		110		mΩ
SAFETY TIMER						
$T_{PRE-CHARGE}$	Pre-Charge Timer			2100		S
$T_{FAST-CHARGE}$	Fast-Charge Timer			25200		S

MT2001 Functional Block Diagram

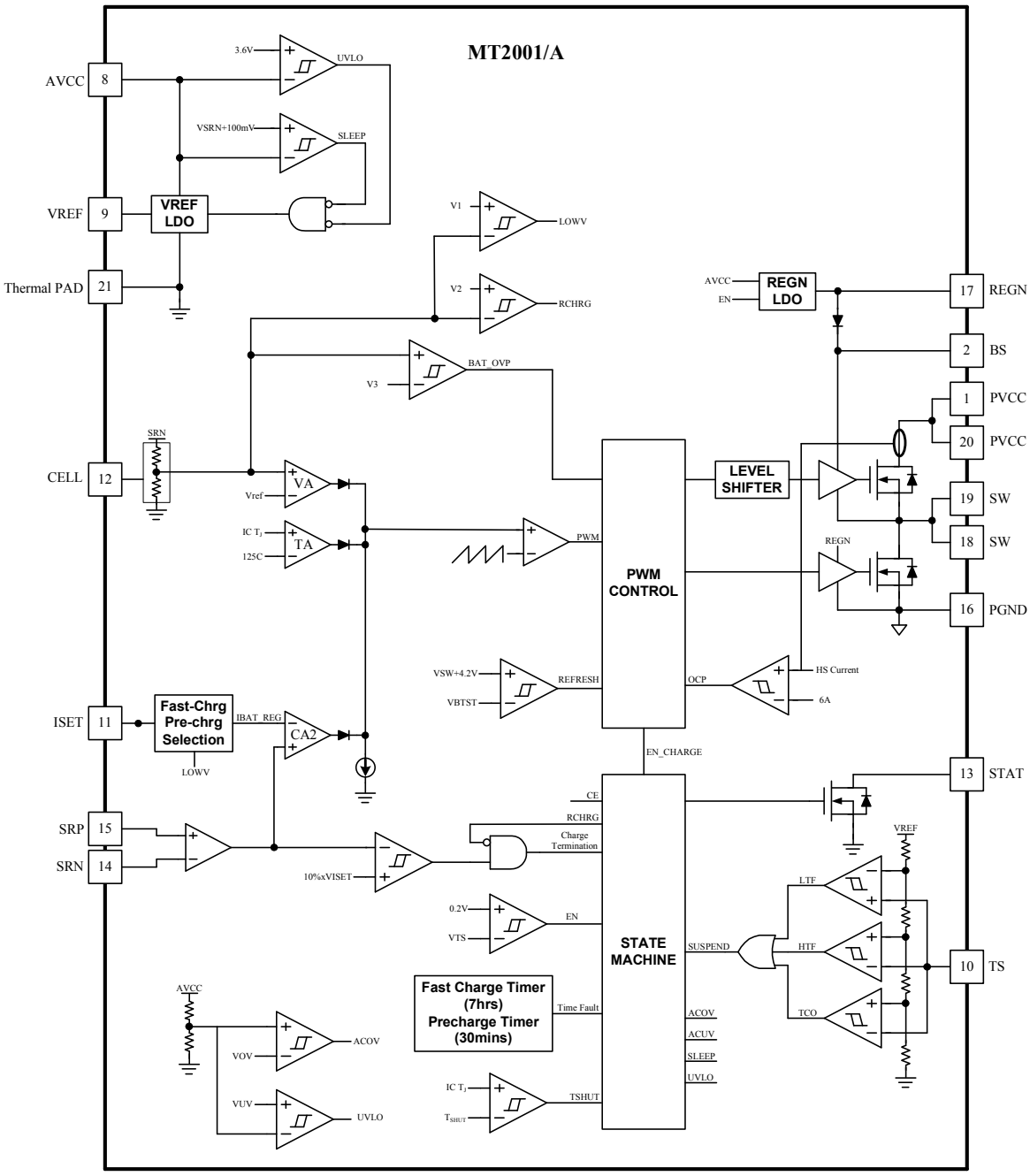
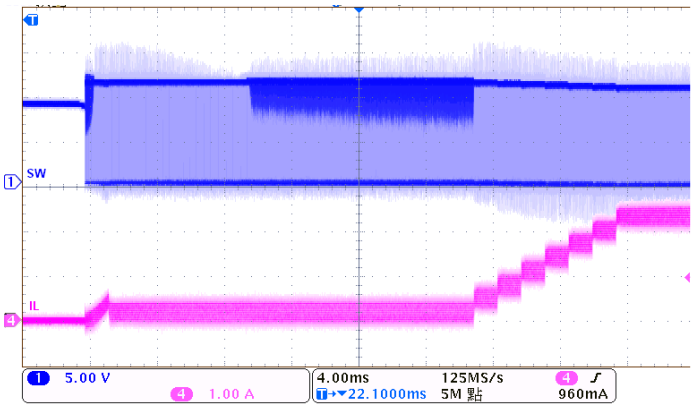


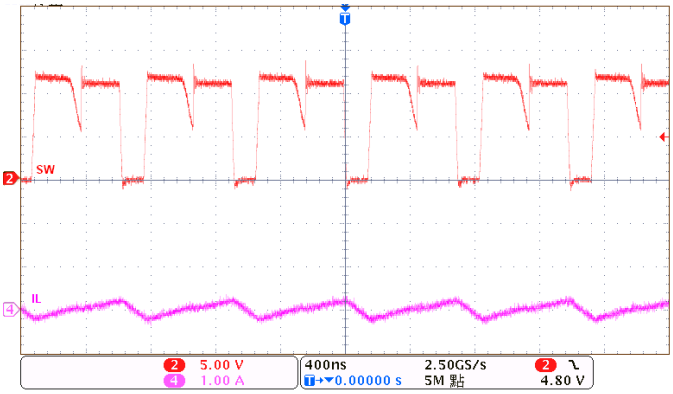
Figure 2. Function Block Diagram

TYPICAL PERFORMANCE CHARACTERISTICS

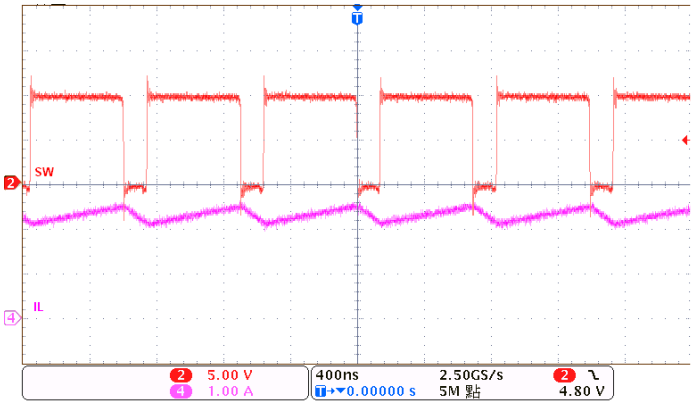
V_{IN} = 12V, MT2001 typical application circuit (Figure 1.), TA = +25℃, unless otherwise noted.



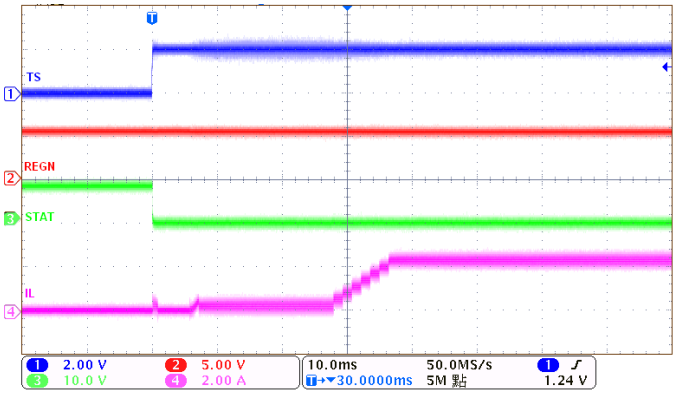
Soft Start



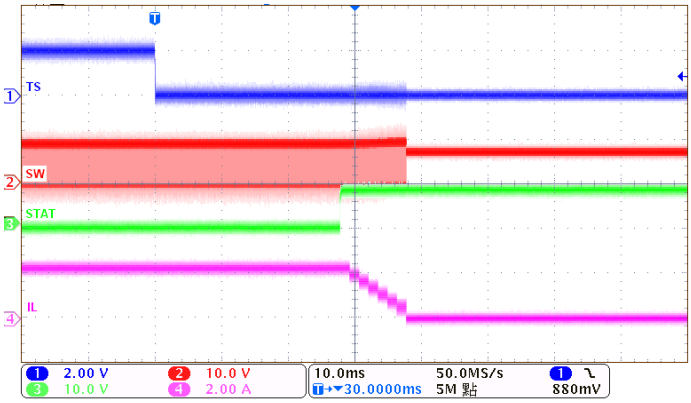
Discontinuous Conduction Mode Switching



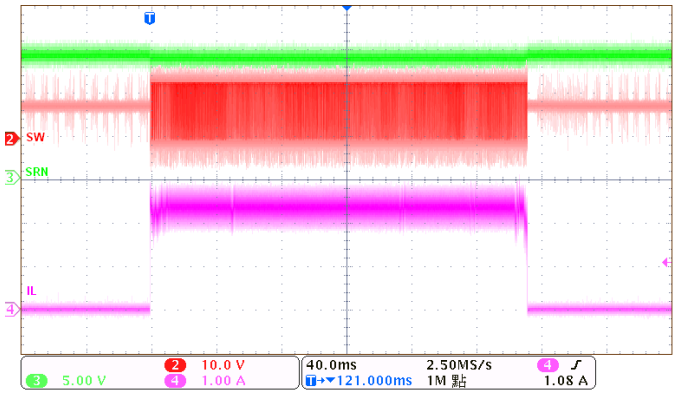
Continuous Conduction Mode Switching



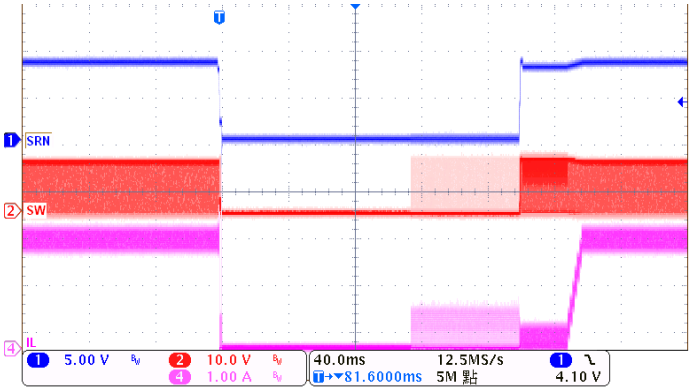
Charge Enable by TS



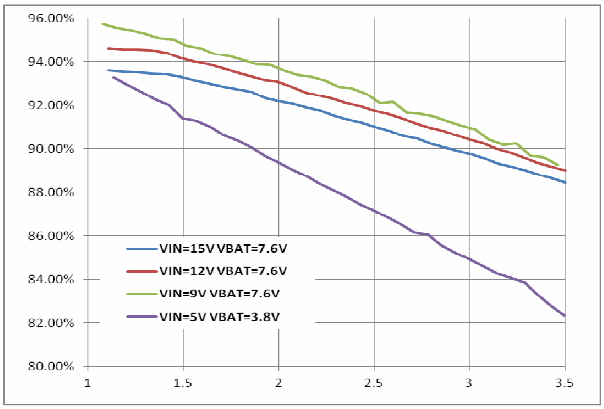
Charge Disabled by TS



Battery Insertion and Removal



Battery to Ground Short Protection



Efficiency vs. Output Current

MT2001 Typical Application Circuits

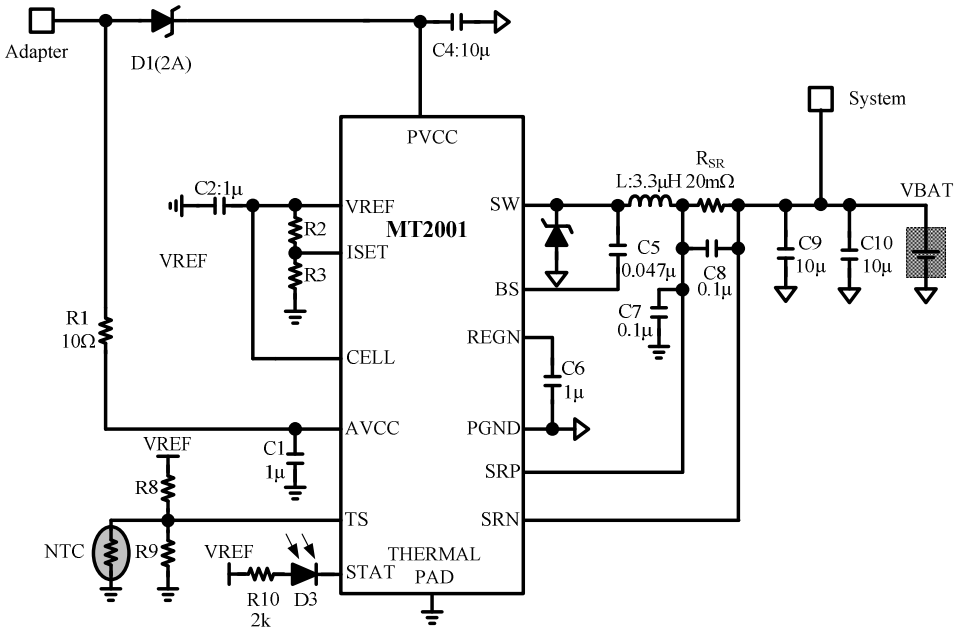


Figure 3. MT2001 Application Circuit (1Cell)

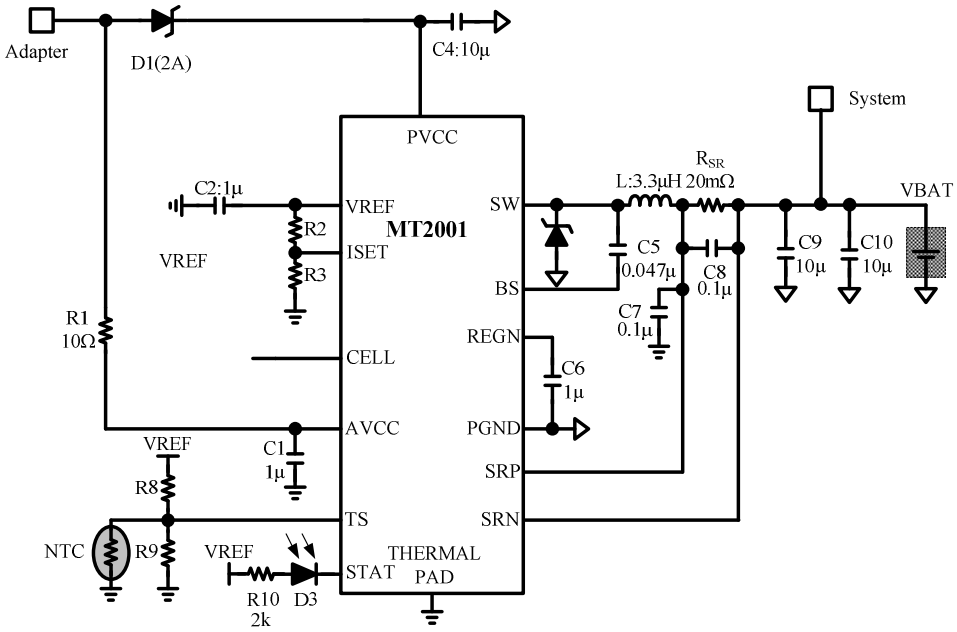


Figure 4. MT2001 Application Circuit (2Cells)

Theory of Operation

The MT2001 family is an integrated charger optimized for charging 1-cell and 2-cell Li-ion or Li-polymer batteries. It charges a battery with constant current (CC) and constant voltage (CV) profile. The typical charge profile is illustrated in Figure 5.

BATTERY VOLTAGE REGULATION

The MT2001 series offers a high accuracy voltage regulator on for the charging voltage. **The** MT2001 uses CELL pin to select number of cells with a fixed 4.2V/cell. Connecting CELL to AGND or floating sets 2 cell output, and connecting to VREF sets 1 cell output.

CELL PIN	VOLTAGE REGULATION
AGND or Floating	8.4V (MT2001), 8.6V (MT2001A)
VREF	4.2 V (MT2001), 4.3V (MT2001A)

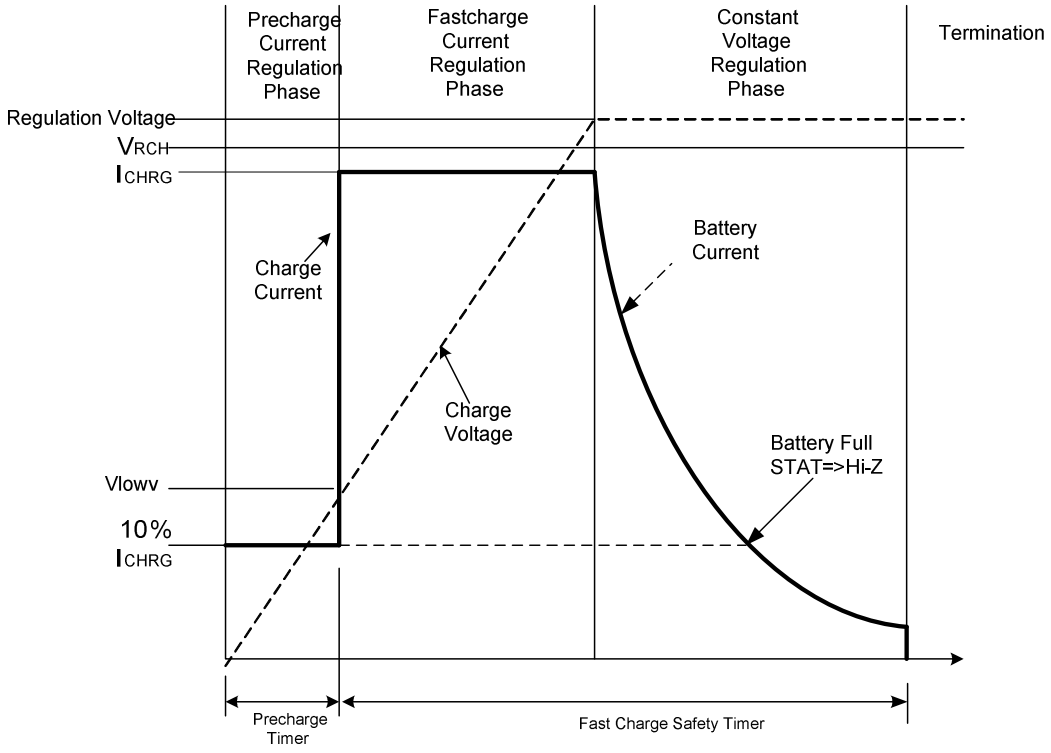


Figure 5. Typical Charging Profile

BATTERY FAST CHARGE CURRENT REGULATION

The ISET input sets the maximum charging current. Battery charge current is sensed by the current sensing resistor R_{SR} connected between SRP and SRN. The full-scale differential voltage between SRP and SRN is $V_{SRP\_SRN\_CC}$ (75mV ISET=REF; 50mV, ISET float; 25mV ISET=AGND). The equation for fast charge current is:

$$I_{CHG}=V_{SRP\_SRN\_CC}/R_{SR}$$

Under high ambient temperature, the charge current will fold back to keep IC temperature not exceeding 125℃.

BATTERY PRECHARGE CURRENT REGULATION

On Power-up, if the battery voltage is below the V_{LOWV} threshold, the MT2001 series applies the pre-charge current to the battery. This pre-charge feature is intended to revive deeply discharged cells. If the VLOWV threshold is not reached within 30 minutes of initiating pre-charge, the charger turns off and a FAULT is indicated on the status pins.

For MT2001 series, the pre-charge current is set as 10% of the fast charge rate set by ISET voltage. The equation for fast charge current is:

$$I_{PRECHG}= V_{SRP\_SRN\_PC}/R_{SR} = 0.1* V_{SRP\_SRN\_CC}/R_{SR}$$

CHARGE TERMINATION

The charger monitors the charging current during the voltage regulation phase. Termination is detected when the SRN voltage is higher than battery recharge threshold and the charge current is less than the termination current threshold, as calculated below. Termination only indicates “Charge Complete” at STAT pin with Hi-Z, and MT2001 will not stop switching charging battery until the fast charge timer is expired.

$$I_{TERM} = 0.1 * I_{CHG} = 0.1 * V_{SRP\_SRN\_CC} / R_{SR}$$

RECHARGE

A new charge cycle is initiated when one of the following conditions occurs:

- The battery voltage falls below the recharge threshold
- A power-on-reset (POR) event occurs
- TS pin toggled below 200mV (disable charge) and above 240mV (enable charge)

SAFETY TIMERS

As a safety backup, the charger also provides an internal fixed 35 minutes pre-charge safety timer and an internal fixed 7 hours fast charge timer.

SOFT-START CHARGER CURRENT

The charger automatically soft-starts the charger regulation current every time the charger goes into fast-charge to ensure there is no overshoot or stress on the output capacitors or the power converter. The soft-start consists of stepping-up the charge regulation current into 8 evenly divided steps up to the programmed charge current. Each step lasts around 1.4ms, for a typical rise time of 11.2ms. No external components are needed for this function.

TEMPERATURE QUALIFICATION

The controller continuously monitors battery temperature by measuring the voltage between the TS pin and AGND. A negative temperature coefficient thermistor (NTC) and an external voltage divider typically develop this voltage. The controller compares this voltage against its internal thresholds to determine if charging is allowed. To initiate a charge cycle, the battery temperature must be within the V_{LTF} to V_{HTF} thresholds. If battery temperature is outside of this range, the controller suspends charge and waits until the battery temperature is within the V_{LTF} to V_{HTF} range. During the charge cycle the battery temperature must be within the V_{LTF} to V_{TCO} thresholds. If battery temperature is outside of this range, the controller suspends charge and waits until the battery temperature is within the V_{LTF} to V_{HTF} range. The controller suspends charge by turning off the PWM charge MOSFETs.

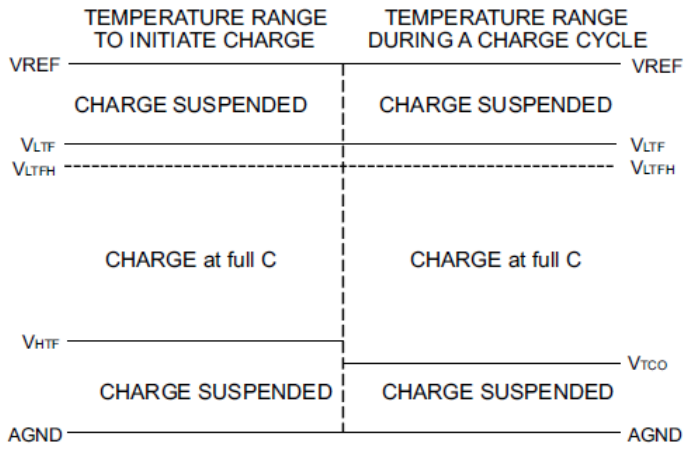


Figure 6. TS Pin, Thermistor Sense Threshold

Assuming a NTC thermistor on the battery pack have resistance at 0℃ and 45℃ are RTHCOLD and RTHHOT, the values of RT1 and RT2 can be determined by using below equations.

$$RT2 = \frac{V_{VREF} \times RTH_{COLD} \times RTH_{HOT} \times \left(\frac{1}{V_{LTF}} - \frac{1}{V_{TCO}}\right)}{RTH_{HOT} \times \left(\frac{V_{VREF}}{V_{TCO}} - 1\right) - RTH_{COLD} \times \left(\frac{V_{VREF}}{V_{LTF}} - 1\right)}$$

$$RT1 = \frac{\frac{V_{VREF}}{V_{LTF}} - 1}{\frac{1}{RT2} + \frac{1}{RTH_{COLD}}}$$

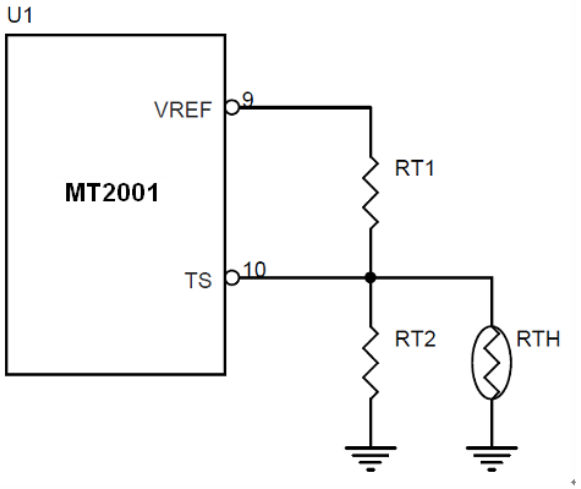
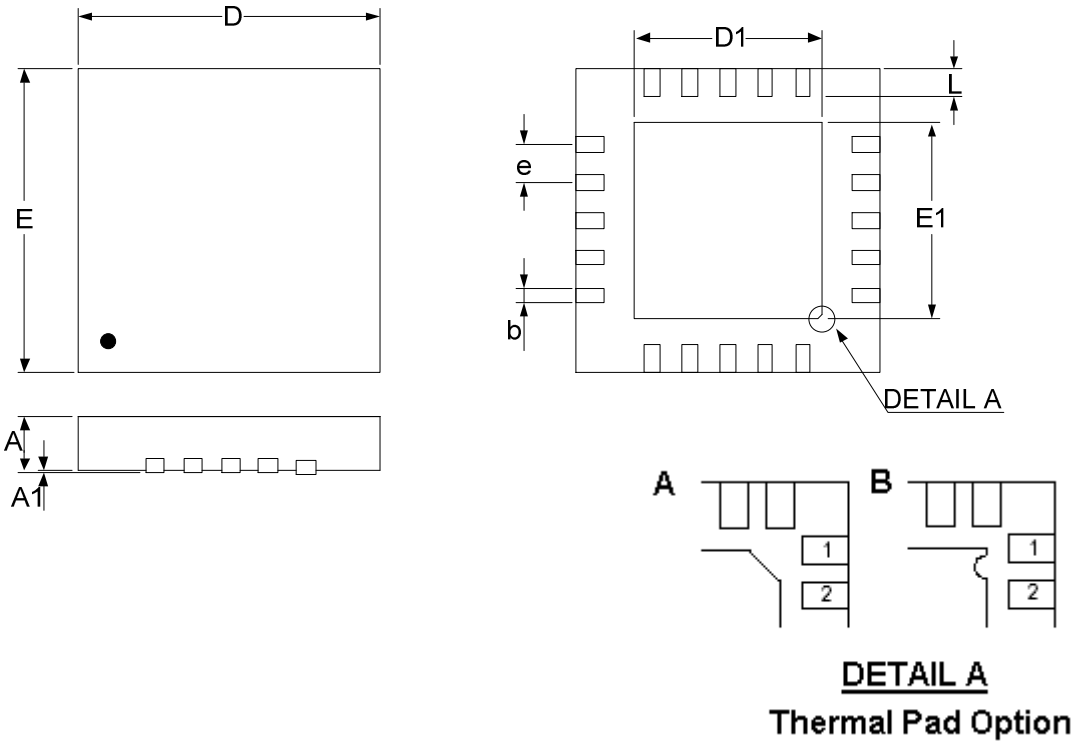


Figure 7. TS Resister Setup

PACKAGING INFORMATION



DETAIL A

Thermal Pad Option

SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	0.80	0.028	0.031
A1	0.00	0.05	0.000	0.002
b	0.18	0.30	0.007	0.012
E	3.90	4.10	0.154	0.161
D	3.90	4.10	0.154	0.161
D1	2.00		0.080	
E1	2.00		0.080	
e	0.50		0.020	
L	0.30	0.50	0.012	0.020

Datasheet Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
1.0	12/25/2012	Initial release	—
1.1	04/02/2013	Update V_CHG, I_CHG, I_In, TS EC Table spec. And description sections.	Pg 1,3, 4,5