MITSUMI

Ultra small size Linear charge control IC for Low-capacitance battery

MM3865A/B/C Series

Outline

This IC is a linear charge control IC for 1-cell lithium-ion and lithium-polymer batteries, capable of high-precision charge current control from 3 to 500 mA, and ideal for mobile devices with low-capacity batteries.

Application

Small mobile device(earphone, healthcare device, others)

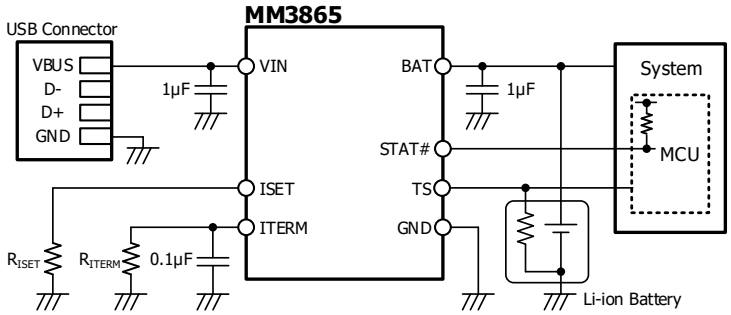
Feature

1. Low charge current control suitable for low-capacitance battery (charge current 3mA min.)
2. Multiple charge voltage (4.1V to 4.45V)
3. Adjustable Full charge current setting (ITERM pin)
4. High Rating input voltage(13V)
5. Low BAT leak current (10nA max.)
6. Multiple battery temperature profile
7. Space saving package (1.8mm x 1.6mm x 0.55mm)
8. Operating temperature range Ta=-40～85°C

Major Specification

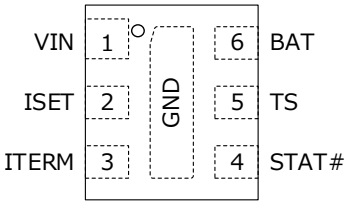
Parameter	Specification	Units
Rating voltage (VIN)	**13.0**	V
Operating voltage range (VIN)	4.4～6.0	V
Charge voltage	**4.10 - 4.45**	V
Fast charge current	**3 - 500**	mA
Pre-charge current	Fast charge current x0.1	mA
Fast charge starting voltage	2.5	V
Full charge current	**0.3 - 250**	mA
BAT leakage current (max.)	**10**	nA
Thermal regulation temperature	125	°C
Charging timer	Pre:0.5, Fast:10	Hour

Application Circuit



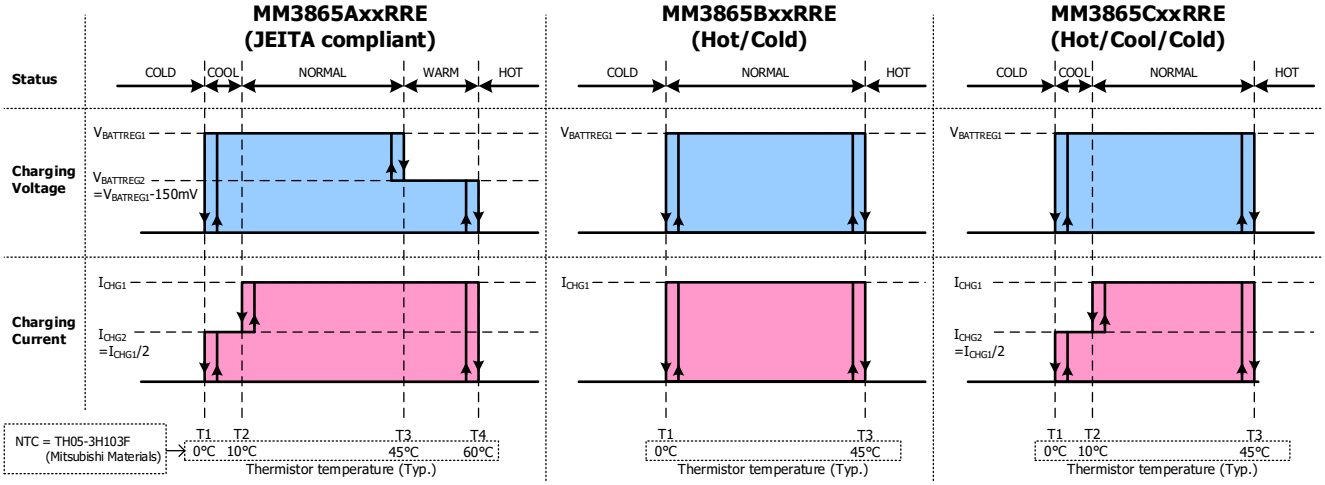
Package

SSON-6 (1.8mm x 1.6mm x 0.55mm)



(TOP VIEW)

Battery Temperature Profile



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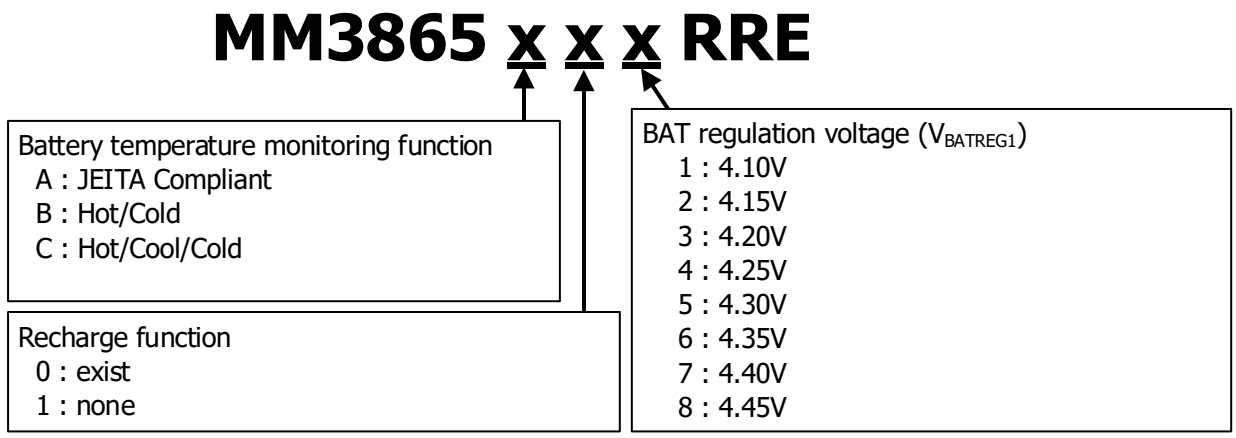
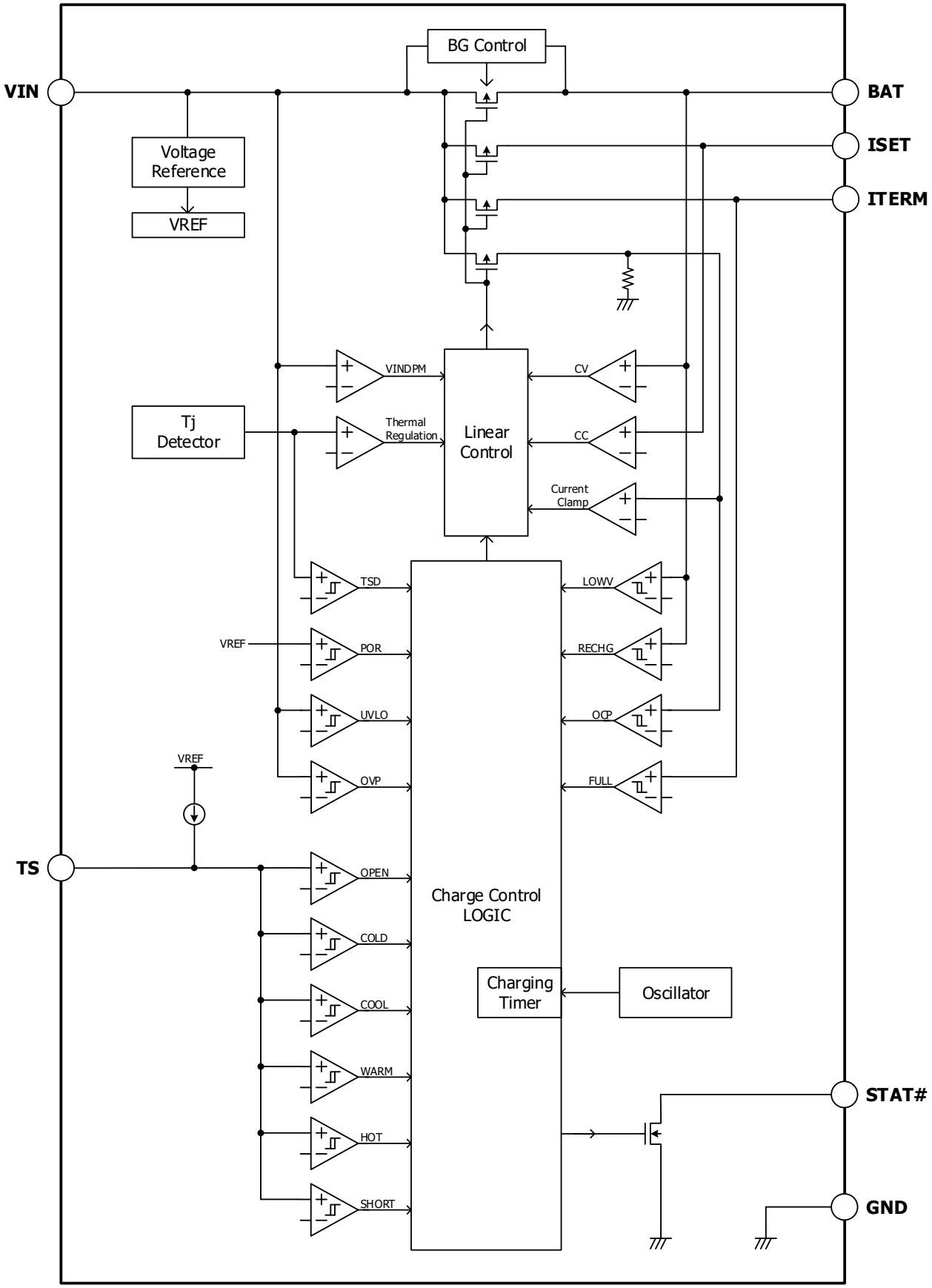
Model Name

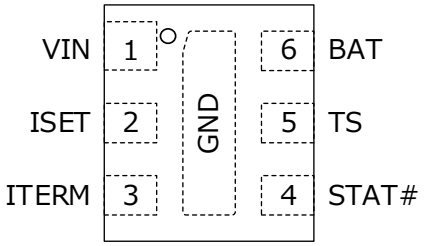


For details on the battery temperature monitoring function, refer to 8-2-1 on page 12.
For details on the recharge function, refer to 8-1-2 on page 10.

1. BLOCK DIAGRAM



2. PIN CONFIGURATION



(TOP VIEW)

3. PIN DESCRIPTION

Pin No.	Pin Name	Pin Description
1	VIN	Power supply input pin for charging. Connect a DC power supply (AC adapter or USB port). Connect a bypass capacitor of about 1μF.
2	ISET	Charge current setting pin. Connect a register R_{ISET} to GND. For details, refer to 8-1-2 on page 10.
3	ITERM	Full charge current setting pin. Connect a register R_{ITERM} to GND. Also, connect a bypass capacitor of about 0.1μF. For details, refer to 8-1-2 on page 10.
4	STAT#	Charging status indicator. It is NchMOS open drain output. "Low" output during charging, blinks when an error occurs. For details, refer to 8-9 on page 14.
5	TS	Thermistor temperature detection pin. By connecting an NTC thermistor of 10kΩ at 25°C, the charging operation using the battery temperature monitoring function is performed. Also, switch between float charge mode and charge disable mode. For details, refer to 8-2 on page 12.
6	BAT	Charge current output pin. Connect to the positive side of the battery. Connect a bypass capacitor of 1 μF to 10 μF.
Exposed pad	GND	Ground pin. It also serves as a heat radiation PAD. It is recommended to connect to the board ground plane.

4. ABSOLUTE MAXIMUM RATINGS

(Unless otherwise specified : Ta=25°C)

Parameter		Symbol	Min.	Max.	Units
Storage temperature		Tstg	-55	150	°C
Junction temperature		Tj_{MAX}	-40	150	°C
Input voltage	VIN	Vin_{MAX1}	-0.3	13	V
	ISET, ITERM, TS, STAT#, BAT	Vin_{MAX2}	-0.3	6	V
Output current	BAT	$Iout_{MAX}$	-	800	mA
Sink current	STAT#	$Isink_{MAX}$	-	15	mA
Power dissipation	Board mounted(*1)	Pd	-	1040	mW

(*1) Board size : 50mm × 50mm × 0.8mm Material : grass epoxy Layer : 2Layers Copper foil area : 90%

5. RECOMMENDED OPERATING CONDITIONS

(Unless otherwise specified : Ta=25°C)

Parameter		Symbol	Min.	Max.	Units
Operating ambient temperature(*2)		Topr	-40	85	°C
Junction temperature		Tj	-40	125	°C
Input voltage	VIN	V_{VIN}	4.4	6	V
Output current	BAT	I_{BAT}	-	500	mA
ISET resistor		R_{ISET}	0.2	33	kΩ
ITERM resistor		R_{ITERM}	0.62	430	kΩ
Thermistor resistor	Resistor range without entering "Charge Disable" or "Float Charge"	R_{TS}	3.75	250	kΩ

(*2) Board size : 50mm × 50mm × 0.8mm Material : grass epoxy Layer : 2Layers Copper foil area : 90%

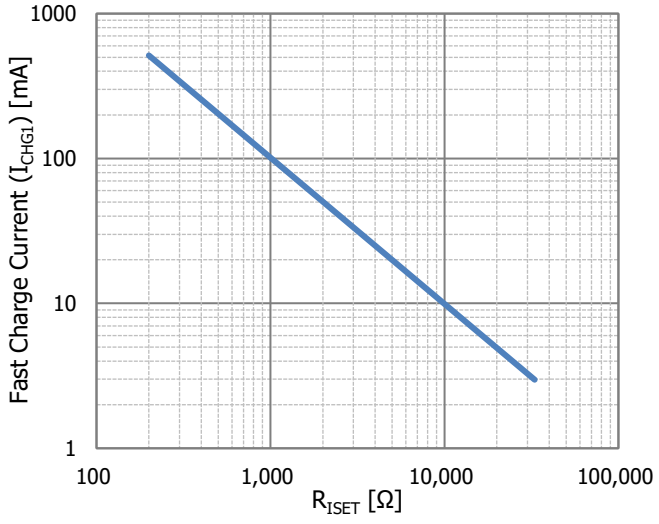
6. ELECTRICAL CHARACTERISTICS

(Unless otherwise specified : $V_{UVLO} < V_{VIN} < V_{OVP}$ and $V_{VIN} > V_{BAT} + V_{INDET}$, Ta = 25°C)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
POWER SUPPLY INPUT						
Power-on reset	V_{POR}	V_{VIN} rising	2.6	2.8	3.0	V
Start-up delay time	t_{POR}	After V_{VIN}=0 V→5 V, the time to accept charge start signal	-	51	-	ms
Start charging delay time	t_{INIT}		-	43	-	ms
Input power detection voltage	V_{INDET}	V_{VIN} rising, V_{VIN}-V_{BAT}	30	-	145	mV
Input power detection return voltage	V_{INDETZ}	V_{VIN} falling, V_{VIN}-V_{BAT}	10	-	75	mV
Input power detection deglitch time	t_{INDET}		-	27	-	ms
Input UVLO voltage	V_{UVLO}	V_{VIN} rising	3.6	3.8	4.0	V
Hysteresis on V_{UVLO}	V_{UVLO_HYS}		-	200	-	mV
Input OVP voltage	V_{OVP}	V_{VIN} rising	6.1	6.3	6.5	V
Hysteresis on V_{OVP}	V_{OVP_HYS}		-	200	-	mV
Input OVP insensitive time	t_{OVP}	V_{VIN} rising	-	84	-	µs
Input OVP release time	t_{OVP_HYS}	V_{VIN} falling	-	450	-	µs
Charge overcurrent detection resistance	R_{OCP}	R_{ISET} reducing	-	155	190	Ω
Charge overcurrent detection deglitch time	t_{OCP}		-	750	-	µs
Charge current limit	I_{INLIM}	Current flowing during t_{OCP} when ISET is short to GND	-	670	780	mA
Input voltage regulation voltage	V_{VINDPM}	Restricts charge current at V_{VINDPM}	4.14	4.28	4.42	V
CURRENT CONSUMPTION						
VIN current consumption	I_{VIN1}	V_{VIN}=5V, TS=GND, chip disable	-	85	115	µA
	I_{VIN2}	V_{VIN}=5V, TS=OPEN, BAT=OPEN	-	190	250	µA
	I_{VIN3}	V_{VIN}=5V, R_{TS}=10kΩ, charging terminated	-	85	115	µA
Battery current consumption	I_{BAT1}	V_{BAT}=$V_{BATREG1}$, V_{VIN}=0V	-	1	10	nA
	I_{BAT2}	V_{BAT}=$V_{BATREG1}$, V_{VIN}=5V, charging terminated	-	2	3	µA
FAST CHARGE						
BAT regulation voltage	$V_{BATREG1}$	MM3865xx1RRE	4.07	4.10	4.13	V
		MM3865xx2RRE	4.12	4.15	4.18	V
		MM3865xx3RRE	4.17	4.20	4.23	V
		MM3865xx4RRE	4.22	4.25	4.28	V
		MM3865xx5RRE	4.27	4.30	4.33	V
		MM3865xx6RRE	4.32	4.35	4.38	V
		MM3865xx7RRE	4.37	4.40	4.43	V
		MM3865xx8RRE	4.42	4.45	4.48	V
BAT regulation voltage at WARM	$V_{BATREG2}$		$V_{BATREG1}$ -0.18	$V_{BATREG1}$ -0.15	$V_{BATREG1}$ -0.12	V
Fast charge current setting range	I_{CHG_RNG}		3	-	500	mA
Fast charge current formula	I_{CHG1}		108 / ($R_{ISET}^{1.01}$)			A
Fast charge current accuracy	I_{CHG1_ACC}		-5	-	+5	%
Fast charge current at COOL	I_{CHG2}		-	I_{CHG1} x0.5	-	A
ON resistance of charge FET	R_{ON}		-	1	2	Ω
PRE-CHARGE						
Fast charge starting voltage	V_{LOWV}	V_{BAT} rising	2.4	2.5	2.6	V
Hysteresis on V_{LOWV}	V_{LOWV_HYS}		-	100	-	mV
Pre-charge current accuracy	I_{PRE_ACC}	I_{PRE}=I_{CHG1}/10	-10	-	+10	%

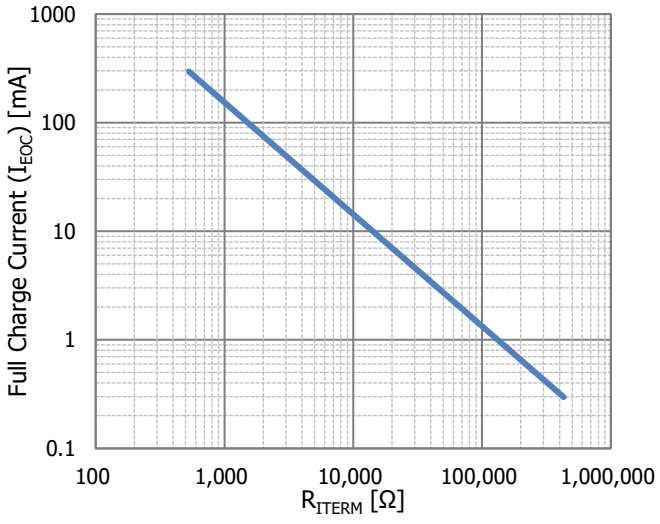
Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
FULL CHARGE						
Full charge current setting range	I_{EOC_RNG}		0.3	-	250	mA
Full charge current formula	I_{EOC}			189 / ($R_{ITERM}^{1.03}$)		A
Full charge current accuracy	I_{EOC_ACC1}	R_{ITERM} ≤ 10kΩ	-6.5	-	+6.5	%
	I_{EOC_ACC2}	10kΩ < R_{ITERM} ≤ 100kΩ	-10.5	-	+10.5	%
	I_{EOC_ACC3}	100kΩ < R_{ITERM}	-13	-	+13	%
Full charge detection deglitch time	t_{EOC}		-	27	-	ms
RECHARGE						
Recharge detection voltage	V_{RECHG}	V_{BAT} falling	$V_{BATREG1}$ -330	$V_{BATREG1}$ -300	$V_{BATREG1}$ -270	mV
Recharge detection deglitch time	t_{RECHG}		-	20	-	ms
CHARGING TIMERS						
Oscillation frequency	f_{OSC}		56.0	65.5	75.0	kHz
STAT# blinking frequency	f_{BLINK}		0.85	1.00	1.15	Hz
Pre-charging timer	t_{PRE}		0.425	0.5	0.575	hour
Fast charging timer	t_{CHG}		8.5	10	11.5	hour
BATTERY TEMPERATURE MONITOR						
NTC bias current	I_{TS1}	When charge enable	48	50	52	µA
	I_{TS2}	When charge disable	27	30	33	µA
	I_{TS3}	When V_{TS_FB}<V_{TS}<V_{TS_MAX}	4	5	6	µA
TS pin maximum output voltage	V_{TS_MAX}	TS=OPEN	-	5	-	V
TS regulation voltage when NTC low temp.	V_{TS_FB}		-	1500	-	mV
TS open detection voltage	V_{OPEN}	V_{TS} rising	1650	1700	1750	mV
Hysteresis on V_{OPEN}	V_{OPEN_HYS}		-	100	-	mV
T1 temperature detection voltage	V_{T1}	At 0°C (TH05-3H103F), V_{TS} rising	1260	1290	1320	mV
Hysteresis on V_{T1}	V_{T1_HYS}		-	110	-	mV
T2 temperature detection voltage	V_{T2}	At 10°C (TH05-3H103F), V_{TS} rising	810	840	870	mV
Hysteresis on V_{T2}	V_{T2_HYS}		-	70	-	mV
T3 temperature detection voltage	V_{T3}	At 45°C (TH05-3H103F), V_{TS} falling	253	268	283	mV
Hysteresis on V_{T3}	V_{T3_HYS}		-	25	-	mV
T4 temperature detection voltage	V_{T4}	At 60°C (TH05-3H103F), V_{TS} falling	158	168	178	mV
Hysteresis on V_{T4}	V_{T4_HYS}		-	25	-	mV
TS short detection voltage	V_{SHORT}	V_{TS} falling	65	75	85	mV
Hysteresis on V_{SHORT}	V_{SHORT_HYS}		-	15	-	mV
THERMAL REGULATION·THERMAL SHUTDOWN						
Thermal regulation temperature	T_{REG}		-	125	-	°C
Thermal shutdown temperature	T_{SHUT}	Temperature increasing	-	155	-	°C
Thermal shutdown detection deglitch time	t_{TSD}		-	750	-	µs
LOGIC OUTPUT (STAT#)						
Output voltage at sink	V_{OL}	at low, Sink current=5mA	-	-	0.4	V
Input leakage current	I_{LEAK}	at Hi-Z, $V_{STAT\#}$=5V	-	-	1	µA

7. TYPICAL CHARACTERISTICS



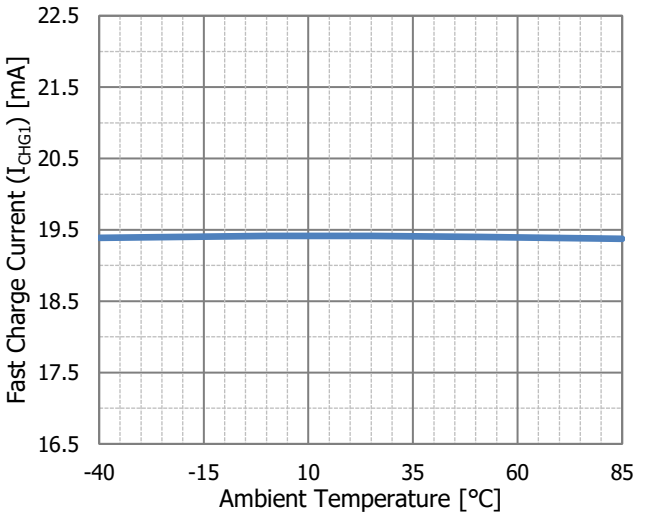
V_{VIN} = 5V, V_{BAT} = 3.8V

Figure 1. Fast charge current vs. R_{ISET}



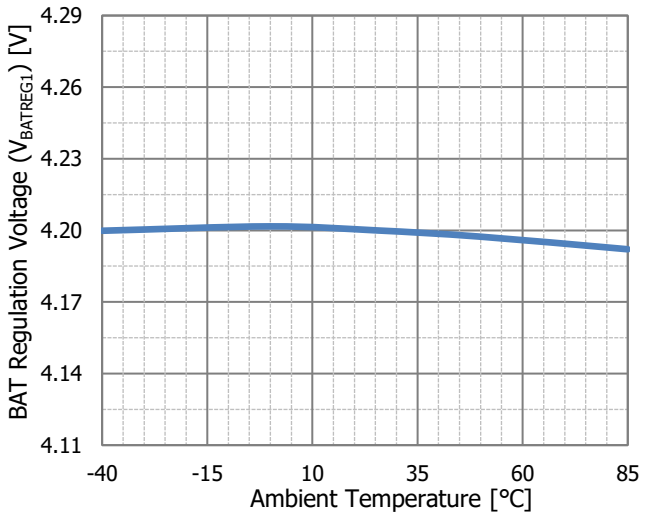
V_{VIN} = 5V

Figure 2. Full charge current vs. R_{ITERM}



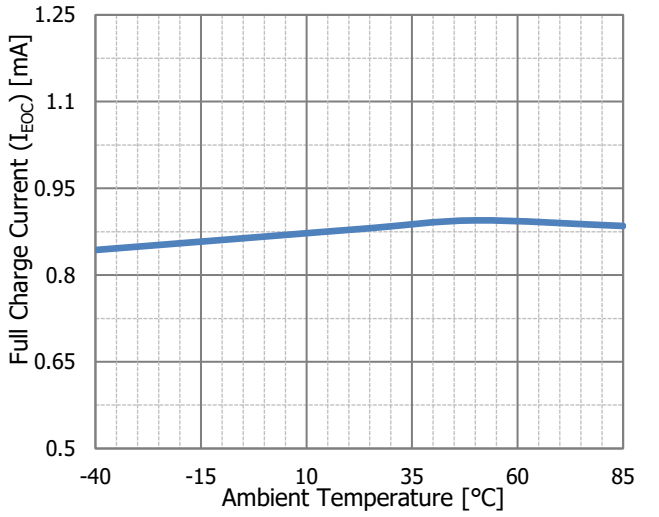
V_{VIN} = 5V, V_{BATT} = 3.8V, R_{ISET} = 5.1kΩ

Figure 3. Fast charge current vs. Ambient temp.



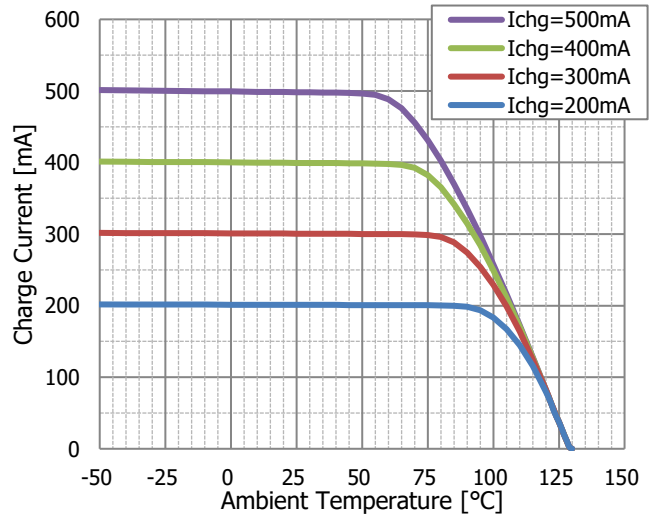
V_{VIN} = 5V, $V_{BATREG1}$ = 4.20V (MM3865xx3RRE)

Figure 4. BAT regulation voltage vs. Ambient temp.



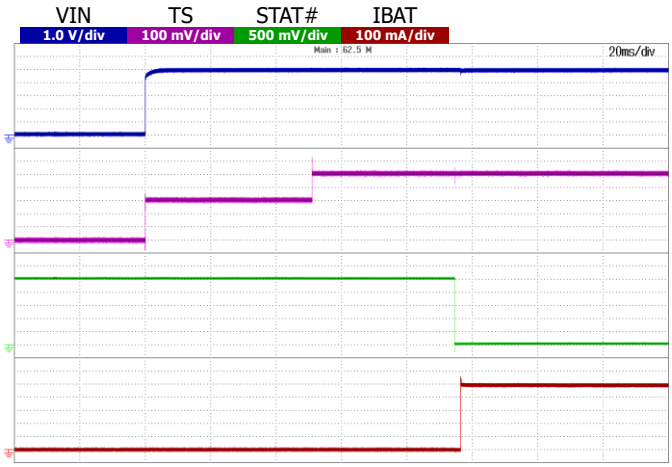
V_{VIN} = 5V, R_{ITERM} = 150kΩ

Figure 5. Full charge current vs. Ambient temp.



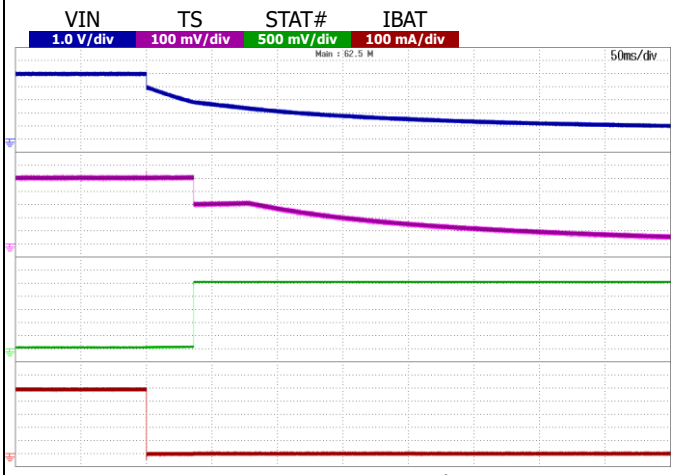
V_{VIN} = 5V, V_{BATT} = 3.8V

Figure 6. Thermal regulation



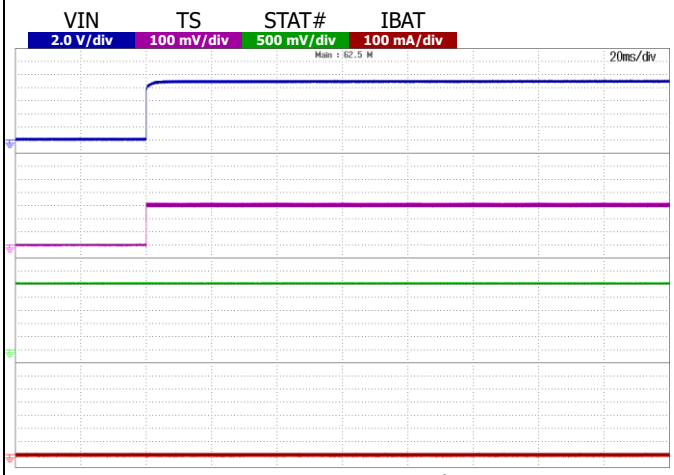
V_{BAT} = 3.8V, R_{TS} = 10kΩ
V_{VIN} = OPEN to 5V

Figure 7. Normal adaptor connect



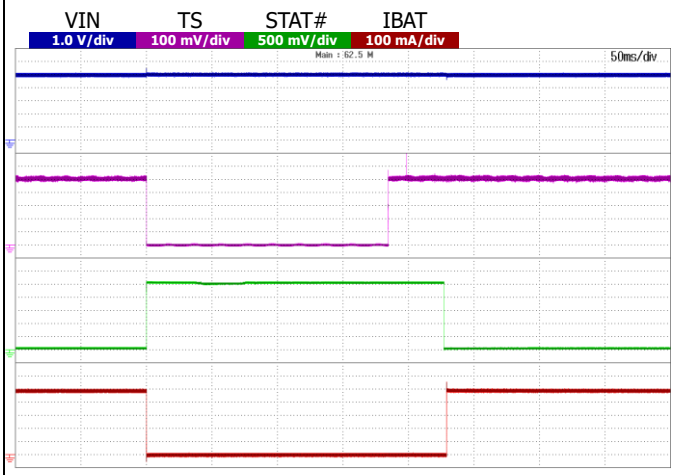
V_{BAT} = 3.8V, R_{TS} = 10kΩ
V_{VIN} = 5V to OPEN

Figure 8. Normal adaptor disconnect



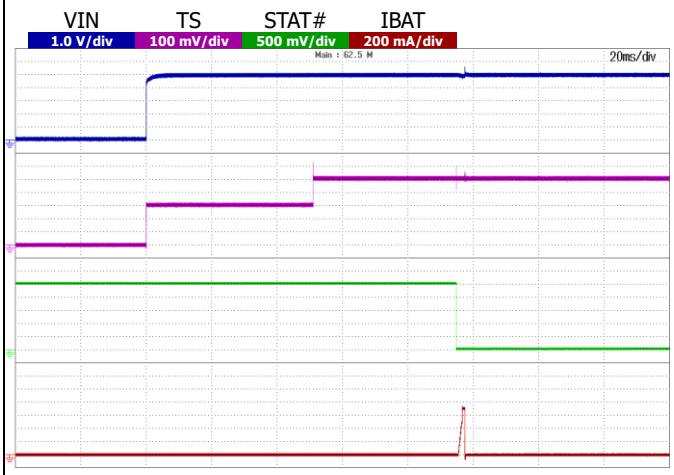
V_{BAT} = 3.8V, R_{TS} = 10kΩ
V_{VIN} = OPEN to 9V

Figure 9. Over voltage adaptor connect



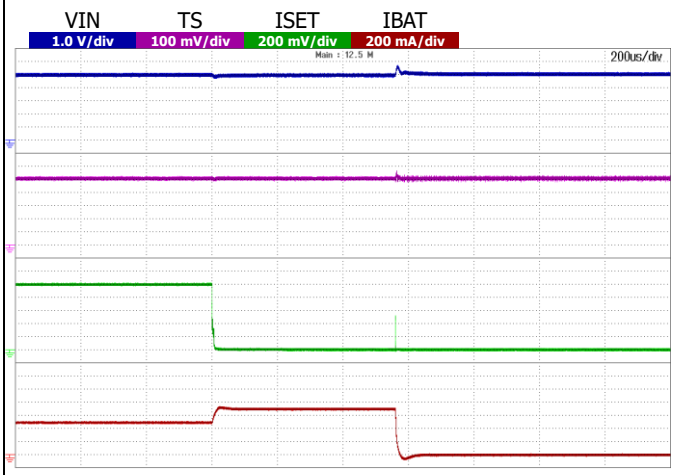
V_{VIN} = 5V, V_{BAT} = 3.8V
R_{TS} = 10kΩ to GND to 10kΩ

Figure 10. Charge Enable and Disable



V_{VIN} = 5V, V_{BATT} = 3.8V
ISET pin short prior to power up

Figure 11. Over current protection 1



V_{VIN} = 5V, V_{BATT} = 3.8V
ISET pin short during charging

Figure 12. Over current protection 2

8. FEATURE DESCRIPTION

MM3865 is a "charge control ICs for 1-cell Li-ion cells" with high function, flexibility, and compactness.
Pre-charge function for safely charging deep discharge batteries, fast charge function for CCCV control to quickly reach full charge, and charging timer/JEITA compliant battery temperature monitoring function/VIN dynamic power management function (VINDPM)/Thermal regulation/Thermal shutdown/Over current protection, all function required for charge control are included.
You can configure charge current and full charge detection current with external resistors and have flexibility for a variety of applications.
The package has a 1.8 mm x 1.6mm SSON-6E and requires at least five external components, requiring very little mounting space.

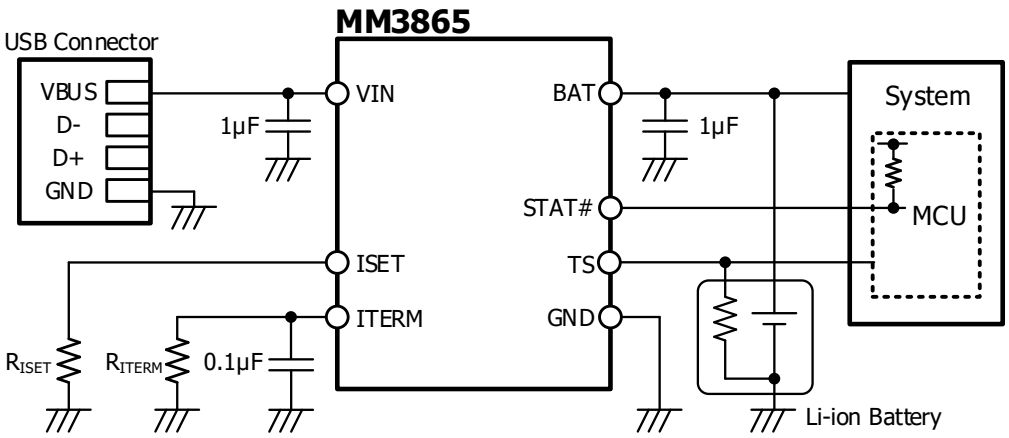


Figure 13. Typical circuit example

8-1. Charging operation

8-1-1. Power-on ~ Start charging

After the VIN power is turned on, the TS pin is ready to switch modes after the start-up delay time (=t_{POR}) has elapsed. Setting a mode other than the TS short circuit causes the mode to shift to charging mode, and setting the TS short circuit causes the mode to change to the charge disable mode.

8-1-2. Charging mode

After charging mode starts, charge current starts to flow after the start charging delay time (=t_{INIT}).

Pre-charge

If the battery voltage is less than fast charge starting voltage (=V_{LOWV}), it will be pre-charge operation. During pre-charge, the IC is charged at a pre-charge current (= I_{PRE}) that is 1/10 the fast charge current (=I_{CHG1}) set by the external resistor R_{ISET}.

$I_{PRE} = I_{CHG1} / 10 = 10.8 / (R_{ISET}^{1.01})$

During pre-charge, the pre-charge timer is operating. When the time is up, the IC enters the charging error mode.

Fast charge

It goes into fast charge operation when the battery voltage reaches fast charge starting voltage (=V_{LOWV}). During fast charge, the IC is charged at the fast charge current (=I_{CHG1}) set by the external resistor R_{ISET}.

$I_{CHG1} = 108 / (R_{ISET}^{1.01})$

During fast charge, the fast charge timer is operating. When the time is up, the IC enters the charging error mode.

Full charge

When it is detected that the battery voltage is higher than the recharge detection voltage (=V_{RECHG}) and the charge current is lower than the full charge detection current (=I_{EOC}) set by the external resistor R_{ITERM} (deglitch time: t_{EOC}), it becomes full charge.

$I_{EOC} = 189 / (R_{ITERM}^{1.03})$

Recharge function (MM3865x0xRRE)

After full charge, when it is detected that the battery voltage has dropped below the recharge detection voltage (=V_{RECHG}) (deglitch time: t_{RECHG}), the fast charge operation restarts after the start charging delay time (=t_{INIT}).

Float charge

Setting the TS open circuit enables float charge operation. During float charge operation, full charge detection operation and fast charge timer operation are not performed. Also, STAT# pin is turned Hi-Z.

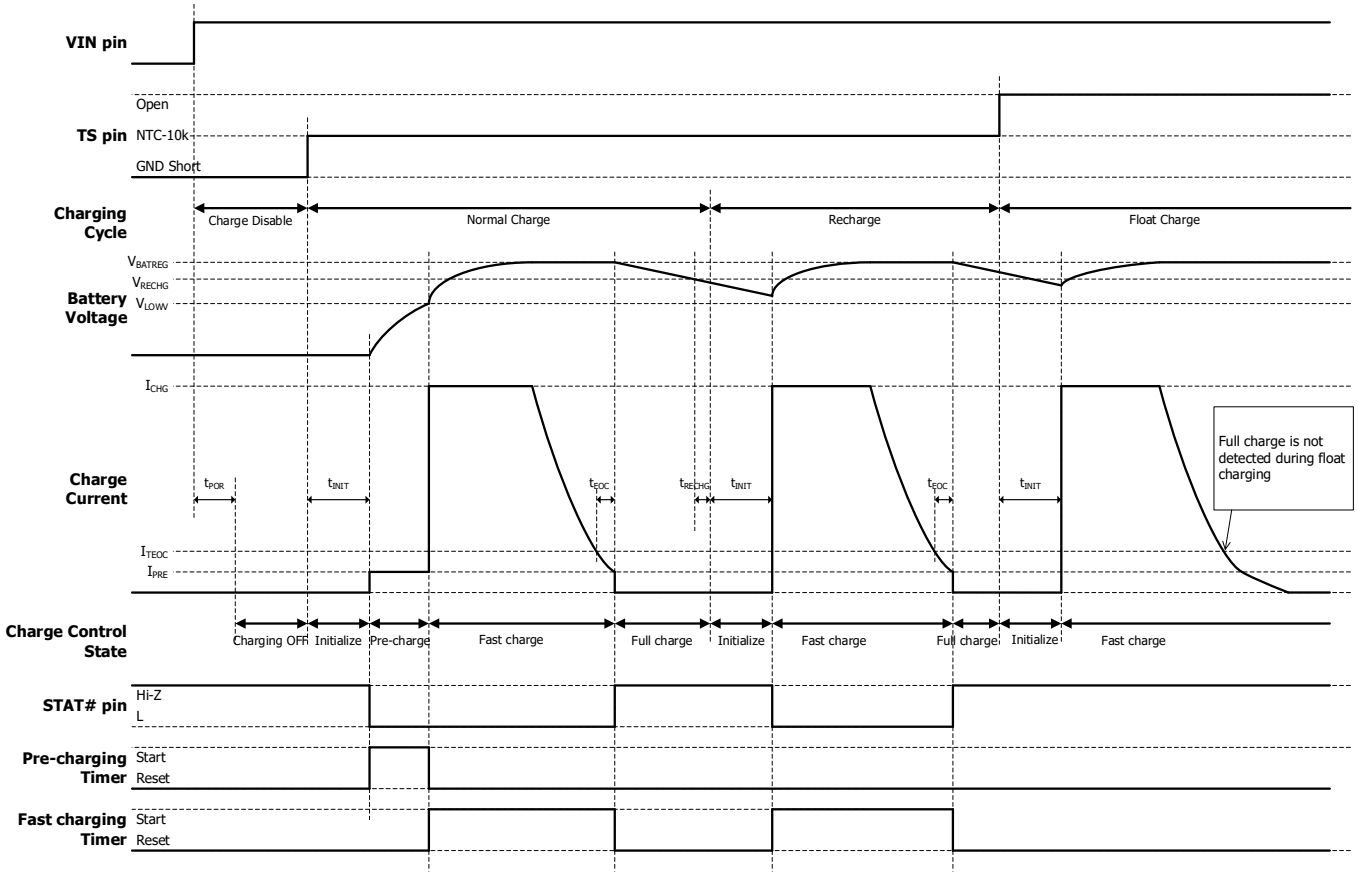


Figure 14. Charge Timing Chart

8-1-3. Charging error mode

If the charging timer times up, thermal shutdown occurs, or charge overcurrent is detected during charging mode, the mode is changed to the charging error mode. During the charging error mode, charging operation is stopped and STAT# blinks. To cancel the charging error, a TS short circuit or the VIN power supply must be turned on again.

8-1-4. Charging timer

Two types of safety timers are provided: pre-charging timer (=t_{PRE})/fast charging timer (=t_{CHG}). The pre-charging timer is counted during pre-charge and the fast charging timer is counted during fast charge. When the time is up, the charging error mode is set. The pre-charging timer is reset when it is not pre-charge, and the fast charging timer is reset when it is not fast charge. Counting after reset starts from zero. However, when the battery temperature monitoring function's HOT or COLD charging operation is stopped, each timer temporarily stops counting, and restarts counting when the charging stop is canceled.

8-2. TS pin

8-2-1. Battery temperature monitoring function

By connecting a thermistor to GND, charging operation according to temperature is performed. MM3865 is designed to be optimized for Mitsubishi Materials TH05-3H103F.

- ・HOT judgment / COLD judgment suspends the charging operation including the count of the charging timer.
- ・In WARM judgment, the BAT regulation voltage is decreased by 150mV. (MM3865AxxRRE)
- ・In the COOL judgment, the fast charge current is reduced by 50%. (MM3865AxxRRE / MM3865CxxRRE)

If this function is not required, connect 10kΩ to GND.

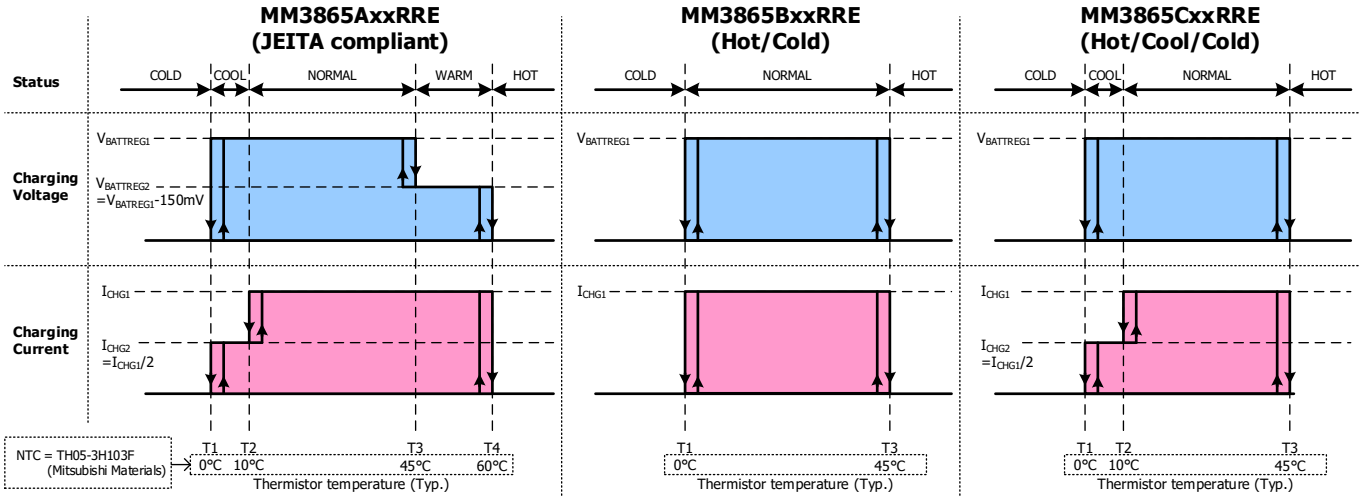


Figure 15. Battery temperature monitoring function

8-2-2. TS open (float charge mode)

Float charge operation can be performed by not connecting thermistors to TS pin or applying above TS open detection voltage (=V_{OPEN}). During float charge operation, full charge detection operation and fast charging timer operation are not performed. Also, STAT# pin is turned Hi-Z.

8-2-3. TS short (charge disable mode)

Applying the TS short detection voltage (=V_{SHORT}) or lower to the TS pin stops the charging operation and enters the charge disable mode. Current consumption in MM3865 is reduced to VIN current consumption (=I_{VIN1}) upon TS short.

8-3. VIN dynamic power management (VINDPM)

To protect the VIN power supply from overload, this function detects a voltage drop in the VIN power supply and decreases charge current to prevent the VIN voltage from falling below the input voltage regulation voltage (=V_{VINDPM}). Full charge detection operation is not performed even if charge current drops below full charge detection current by VINDPM function.

8-4. Thermal regulation

To prevent thermal breakdown due to self-heating during charging, reduce charge current so that the junction temperature does not reach the thermal regulation temperature (=T_{REG}) End of document. Full charge detection operation is not performed even if charge current drops below full charge detection current by thermal regulation function. The Figure 16 shows the charge profile including thermal regulation operation.

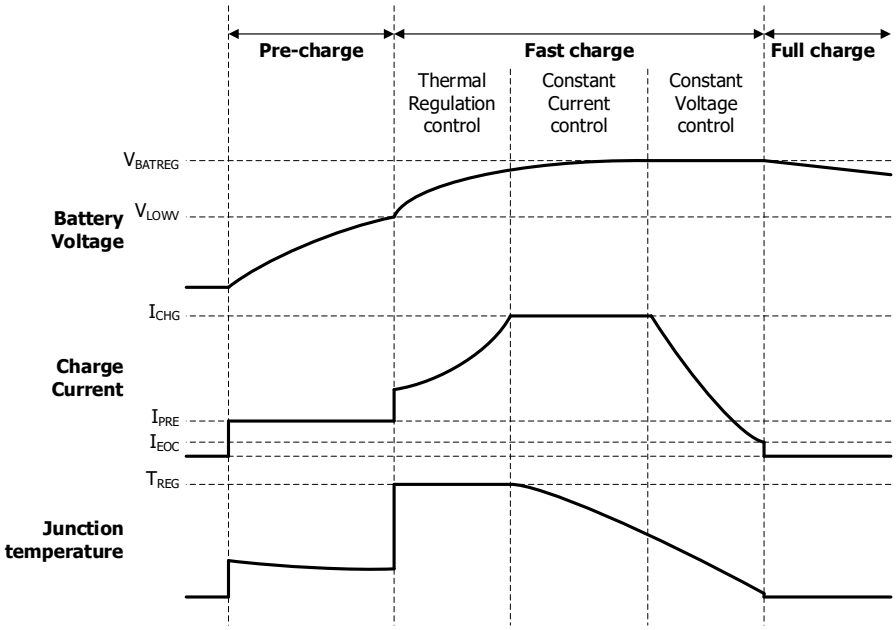


Figure 16. Charging Profile with Thermal Regulation

8-5. Thermal shutdown

Thermal shutdown circuits are built-in to prevent thermal damage caused by external heat. Thermal shutdown occurs when the junction temperature exceeds the thermal shutdown temperature (=T_{SHUT}). If thermal shutdown is activated in charging off mode, the mode does not go to charging mode. When thermal shutdown is activated during charging mode, charge error mode is activated.

Thermal shutdown operates above absolute maximum ratings. Therefore, avoid designing applications that actively use this function.

8-6. ISET pin

Set fast charge current (=I_{CHG1}) and pre-charge current (=I_{PRE}) by the resistor R_{ISET} connected between ISET pin and GND. Pre-charge current is 1/10 of fast charge current. When setting I_{CHG1} to less than 50mA, it is recommended to add an external RC circuit to stabilize the charging current.

$I_{CHG1} = 108 / (R_{ISET}^{1.01})$
$I_{PRE} = I_{CHG1} / 10 = 10.8 / (R_{ISET}^{1.01})$

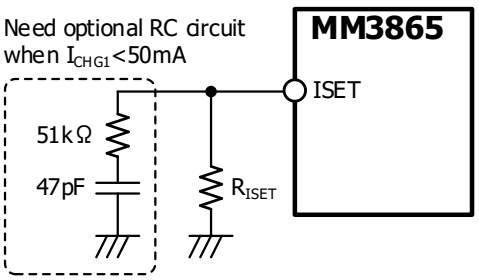


Figure 17. Optional RC circuit at ISET pin

When the R_{ISET} falls below the charge overcurrent detection resistance (=R_{OCP}), such as when ISET pin is shorted to GND, the IC detects charge overcurrent and enters the charging error mode. To prevent erroneous detection, the charge overcurrent detection has a deglitch time (=t_{OCP}). However, the current is limited to the charge current limit (=I_{INLIM}) during this deglitch time.

8-7. ITERM pin

Set full charge detection current (=I_{EOC}) by the resistor R_{ITERM} connected between ITERM pin and GND. Also, connect a bypass capacitor of about 0.1µF.

I_{EOC} = 189 / ($R_{ITERM}^{1.03}$)

8-8. VIN pin (Power-on)

8-8-1. UVLO

If the VIN pin voltage is lower than the input UVLO voltage (=V_{UVLO}), the IC is in the shutdown status and does not operate.

8-8-2. Backflow preventing function

The charging FET is turned off to prevent backflow from the battery in the following conditions.

$V_{UVLO} < V_{VIN} < V_{BAT}+V_{INDET}$

8-8-3. OVP

When the VIN pin voltage becomes the input OVP voltage (=V_{OVP}) in a mode other than the charge error mode, the charging operation including the charging timer counter is reset and the charging operation is stopped. After that, when VIN pin drops, charging operation resumes.

8-9. STAT# pin

Charging status indicator of NMOS open drain output type. "Low" during charging operation other than float charging. "Hi-Z" when not charging or in the case of float charging. Blinks in charge error mode.

Table 1. STAT# Pin State

CHARGING STATUS	STAT# pin
Pre-charge/fast charge when not float charge	Low
Charging OFF	Hi-Z
Full charge	Hi-Z
Float charge	Hi-Z
Charging error mode	Blink at STAT# blinking frequency (=f_{BLINK})

9. APPLICATION CIRCUIT EXAMPLE

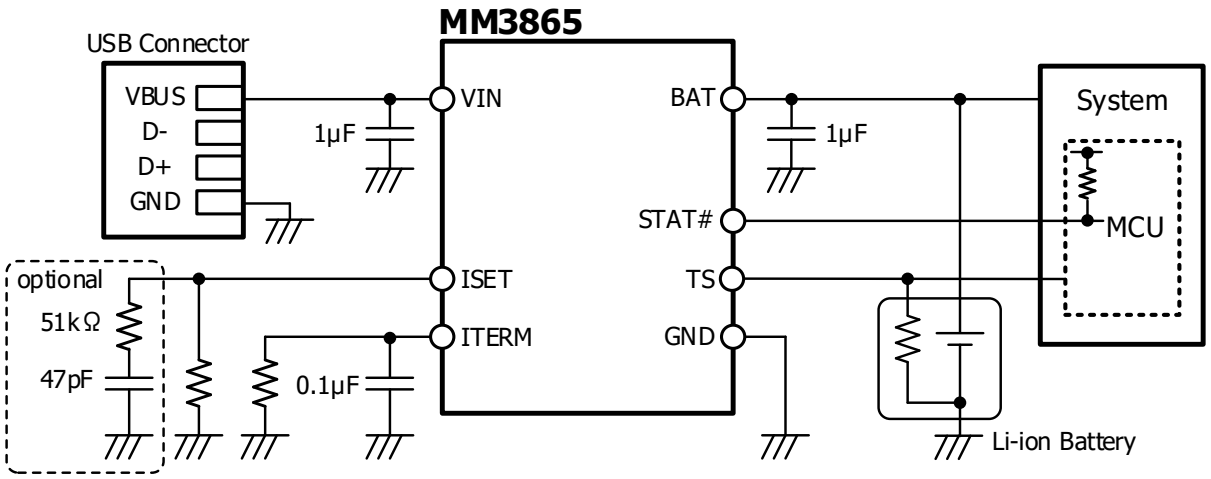


Figure 18. Charge Enable/Disable controlled by MCU

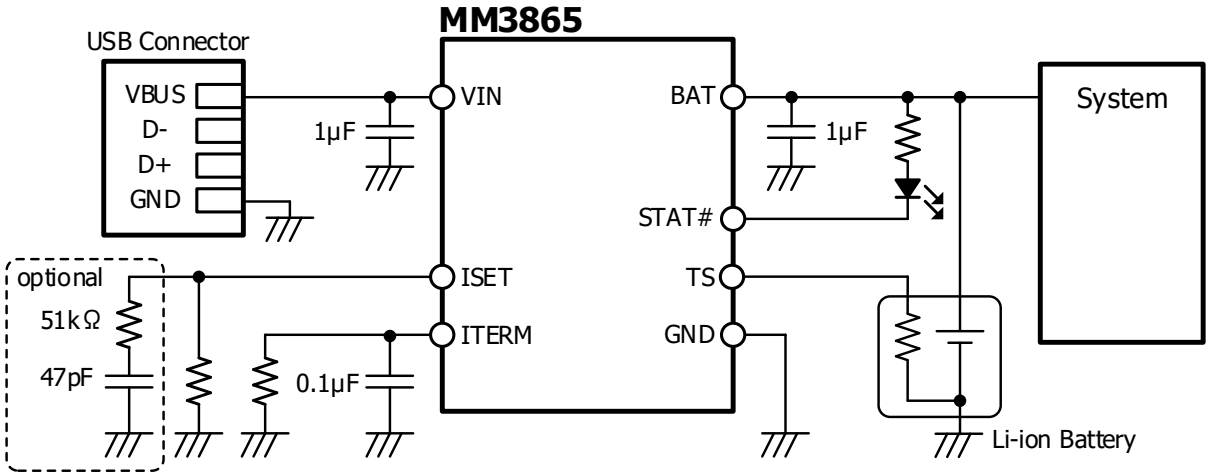


Figure 19. Use as Stand-alone (LED current flows from the Li-ion battery)

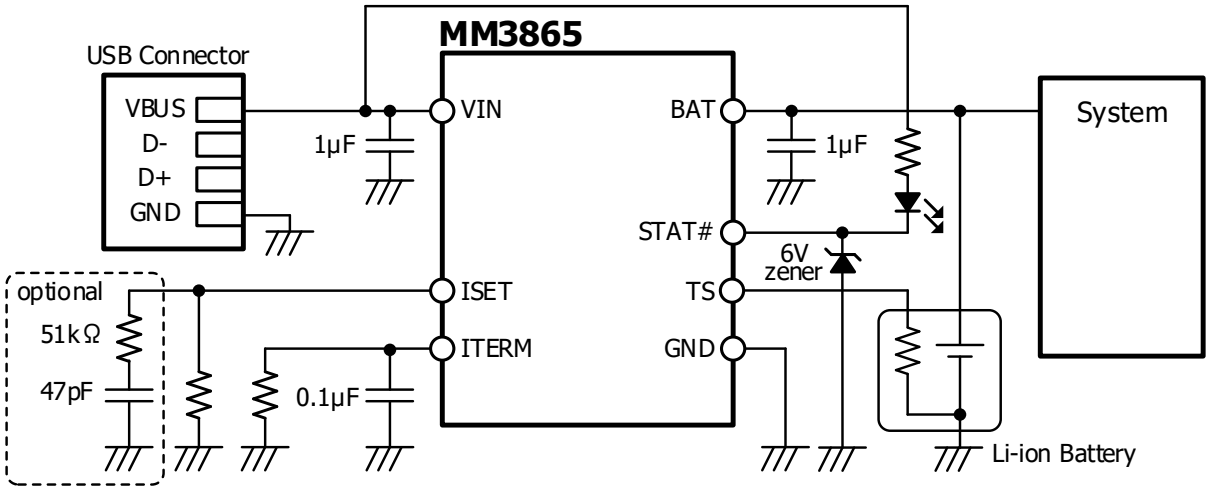


Figure 20. Use as Stand-alone (LED current flows from the Power-supply)