MITSUMI

4.5A switch mode charge control IC

MM3659

Outline

This IC is a 4.5A switch mode charge control IC with built-in power path supporting USB OTG. Synchronous rectification switching charge control allows for low heat generation and highly efficient system drive and charge control at the same time. By incorporating peripheral components, expensive current-sense resistors, power MOSFETs, and reverse-current-prevention diodes are no longer required, thus reducing the number of components. In addition, the power management, system drive, and charge control can be realized on a single chip, contributing to a reduction in design man-hours.

Application

Digital Still Cameras, Digital Video Cameras, Other Mobile Devices

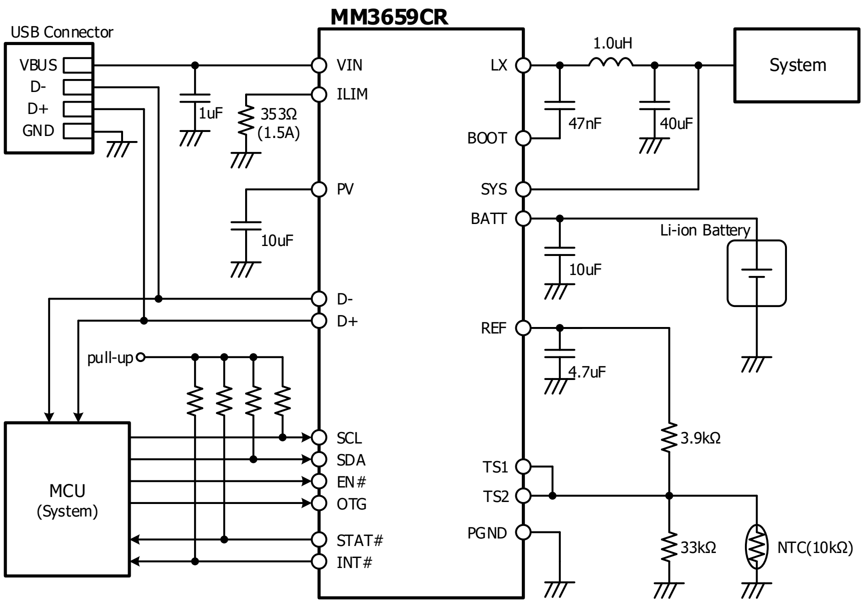
Feature

1. High efficiency 4.5A, 1.5MHz synchronous rectification switching for charge control and system path power management
2. Wide input voltage range (3.9V to 17V)
   e.g.) USB Power Delivery 5V, 9V, 15V
3. Configurable input current limits from 100mA to 3000mA in accordance with USB Battery Charging Spec. 1.2
4. Built-in 5V/1.3A USB OTG function for power supply to external devices
5. Optimal customization is possible through I2C communication
   e.g.) Charging voltage/charging current/charging timer, etc.

Major Specification

Parameter	Specification	Units
Rating voltage (VIN)	22.0	V
Operating voltage range (VIN)	3.9～17.0	V
Input current limit	100 – 3000	mA
Switching frequency	1.5	MHz
Charge voltage	3.50 – 4.40	V
Fast charge current	512 – 4544	mA
Pre-charge current	128 – 2048	mA
Fast charge starting voltage	2.8 -3.0	V
Full charge current	128 - 2048	mA
Thermal regulation temperature	60 - 120	°C
Charging timer	5 - 20	Hour

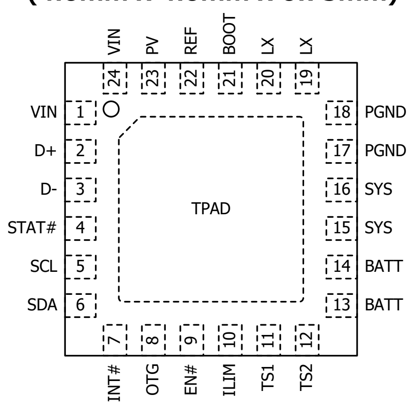
Application Circuit



Package

SQFN-24

(4.0mm x 4.0mm x 0.75mm)



(TOP VIEW)

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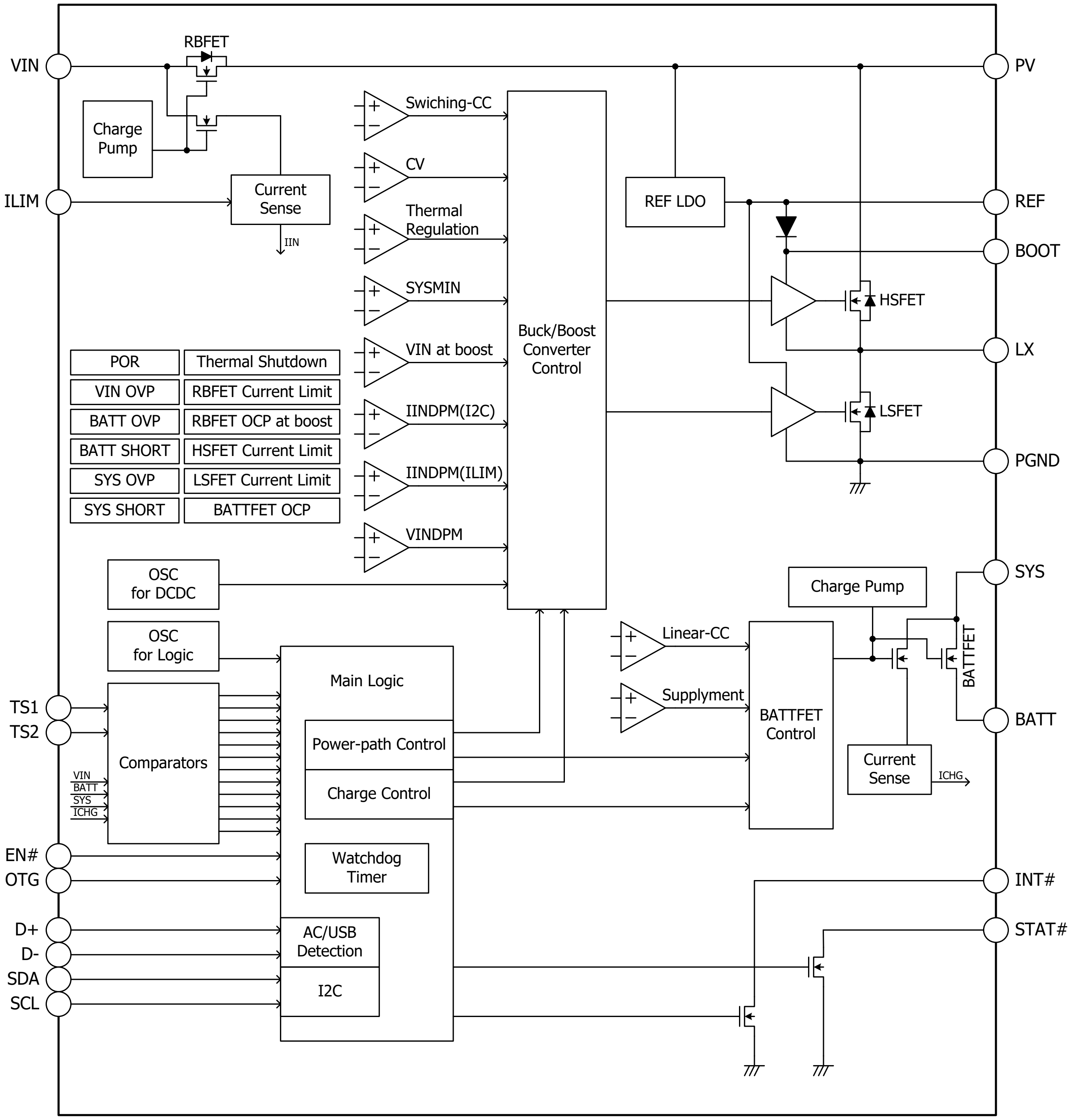
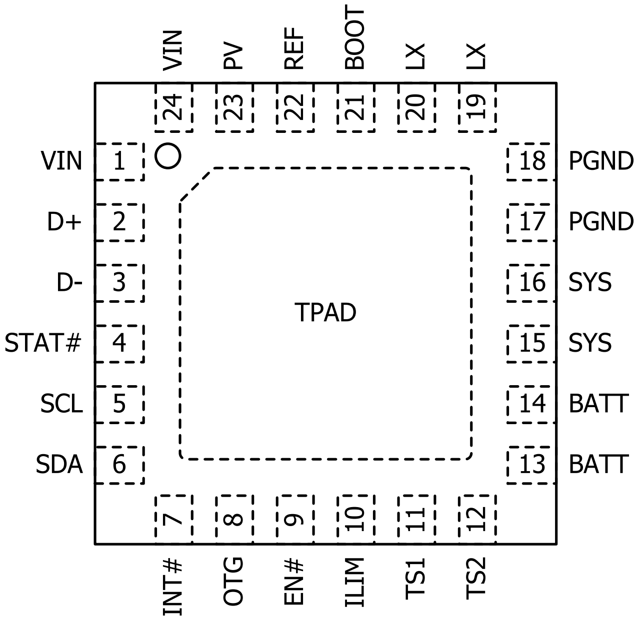
1. Block Diagram



2. PIN CONFIGURATION



3. PIN DESCRIPTION

Pin No.	Pin Name	Pin Description
1,24	VIN	Power supply input for charging.
2	D+	USB bus D+ input. USB host/charging port detection complying with data contact detection (DCD) and primary detection of USB Battery Charging Specification1.2.
3	D-	USB bus D- input. USB host/charging port detection complying with data contact detection (DCD) and primary detection of USB Battery Charging Specification1.2.
4	STAT#	Charging status indicator. NchMOS open drain output. "L" indicates charge in progress. When fault condition occurs, blink in 1Hz.
5	SCL	I2C clock input pin.
6	SDA	I2C data input and output pin.
7	INT#	Interrupt signal output. NchMOS open drain output. When an interrupt factor occurs, output 256μs "L"-pulse.
8	OTG	In the buck convert mode, USB current limit selection pin. Otherwise, active high OTG operation enable pin. "H/L" input.
9	EN#	Active low charge enable pin. "H/L" input.
10	ILIM	Input current limit setting pin. Connect a resistor between this pin and PGND.
11	TS1	Thermistor temperature detection pin 1. Connect a negative temperature coefficient thermistor
12	TS2	Thermistor temperature detection pin 2. Connect a negative temperature coefficient thermistor
13,14	BATT	Battery connection pin. Charging to battery and discharging to SYS pin.
15,16	SYS	System connection pin. Output power to the system.

Pin No.	Pin Name	Pin Description
17,18	PGND	Power ground pin.
19,20	LX	DCDC converter inductor connection pin. In addition, connecting the bootstrap capacitor 47nF between BOOT pin.
21	BOOT	HSFET drive supply. Connect the bootstrap capacitor 47nF between LX pin.
22	REF	LSFET drive supply. In addition, reference voltage output pin for the themistor. Connect TS1/TS2 pin through a resistor.
23	PV	The input bypass capacitor connect pin. Connect the ceramic capacitor between PGND pin, and place it as close as possible to IC.
Expose pad	TPAD	Heat dissipation 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	-65	150	°C
Junction temperature		Tj_{MAX}	-40	150	°C
Input voltage	VIN, PV	Vin_{MAX1}	-0.3	22	V
	STAT#	Vin_{MAX2}	-0.3	20	V
	BOOT(*1)	Vin_{MAX3}	-0.3	26	V
	LX(*1)	Vin_{MAX4}	-0.3	20	V
	BATT, SYS	Vin_{MAX5}	-0.3	6	V
	BOOT to LX Pin Voltage(*1)	Vin_{MAX6}	-6	-0.3	V
	SDA, SCL, INT#, OTG, ILIM, REF, TS1, TS2, EN#, D+, D-	Vin_{MAX7}	-0.3	6	V
Sink current	STAT#, INT#	$Isink_{MAX}$	-	10	mA
Power dissipation	Board mounted (*2)	Pd	-	4.8	W

(*1) The inherent switching noise voltage spikes should not exceed the absolute maximum rating on either the BOOT or LX.
(*2) Board size ： 70mm × 70mm × 1.0mm　Material ： grass epoxy　Layer ： 4Layers　Wire rate ： 90%

5. RECOMMENDED OPERATING CONDITIONS

(Unless otherwise specified : Ta=25°C)

Parameter	Symbol	Min.	Max.	Units
Operating ambient temperature **エラー! 参照元が見つかりません。**	Topr	-40	85	°C
Junction temperature	Tj	-40	125	°C
VIN pin voltage	V_{VIN}	3.9	17	V
VIN pin current	I_{VIN}	-	3	A
Buck converter output current (System load + charging current)	I_{TOTAL_LOAD}	-	4.5	A
BATT pin voltage	V_{BATT}	-	4.4	V
BATT pin current	I_{BATT}	-	4.5	A

エラー! 参照元が見つかりません。 Board size ： 70mm × 70mm × 1.0mm　Material ： grass epoxy　Layer ： 4Layers　Wire rate ： 90%

6. ELECTRICAL CHARACTERISTICS

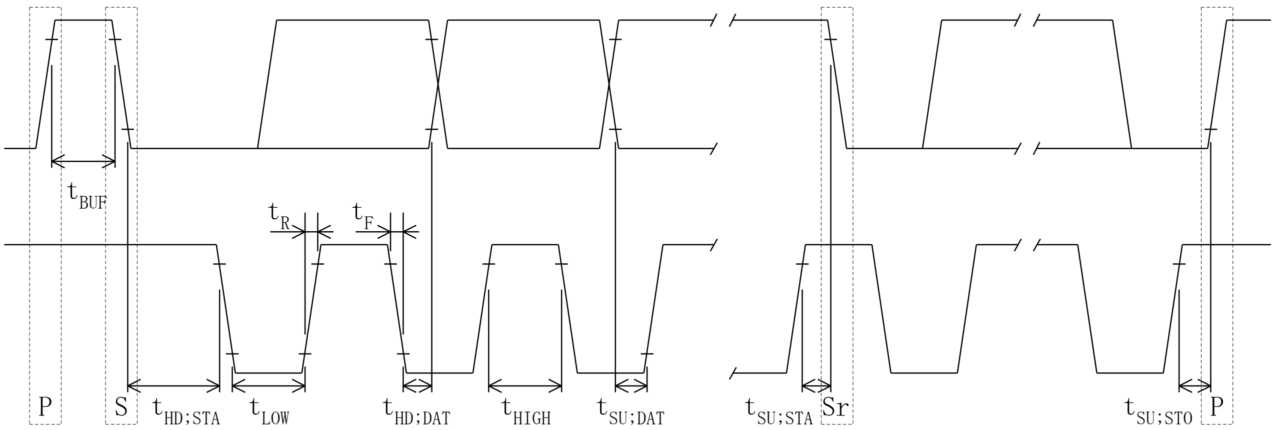
(Unless otherwise specified : V_{VIN_UVLOZ} < V_{VIN} < V_{ACOV} and V_{VIN} > V_{BATT} + V_{INDET}, Ta = 25°C)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
POWER SUPPLY INPUT						
Battery consumption current (BATT,LX,SYS)	I_{BATT_LEAK}	V_{VIN} < V_{VIN_UVLOZ}, V_{BATT} = 4.2V, leakage between BATT and VIN	-	-	5	μA
	I_{BATT_SHIP}	High-Z State, or no VIN, BATTFET disabled (REG07[5] = 1), SDA = SCL = "L"	-	12	20	μA
	I_{BATT_DISCHG}	High-Z State, or no VIN, REG07[5] = 0	-	55	85	μA
	I_{BATT_BOOST}	V_{BATT}=4.2V, Boost mode, I_{VIN} = 0, converter switching	-	4	-	mA
VIN consumption current	I_{VIN_HIZ1}	V_{VIN} = 5V, High-Z state	-	30	60	μA
	I_{VIN_HIZ2}	V_{VIN}= 15V, High-Z state	-	60	100	μA
	I_{VIN1}	V_{VIN} > V_{UVLO}, V_{VIN} > V_{BATT}, converter not switching	-	1.5	3	mA
	I_{VIN2}	V_{VIN} > V_{UVLO}, V_{VIN} > V_{BATT}, converter switching, V_{BATT}=3.2V, I_{SYS}=0	-	2	-	mA
	I_{VIN3}	V_{VIN} > V_{UVLO}, V_{VIN} > V_{BATT}, converter switching, V_{BATT}=3.8V, I_{SYS}=0	-	15	-	mA
VIN I2C operating range (no BATT)	V_{VIN_UVLOZ}	V_{VIN} rising	3.6	-	-	V
Input power detection voltage	V_{INDET}	V_{VIN} rising, V_{VIN}-V_{BATT}	170	250	300	mV
Input power detection return voltage	V_{INDETZ}	V_{VIN} falling, V_{VIN}-V_{BATT}	35	80	120	mV
Power over-voltage detection voltage	V_{ACOV}	V_{VIN} rising	17.4	18	-	V
Hysteresis on V_{ACOV}	V_{ACOV_HYS}	V_{VIN} falling	-	700	-	mV
BATT I2C operating range (no VIN)	V_{BATT_UVLOZ}	V_{BATT} rising	2.3	-	-	V
Battery over-discharge detection voltage	V_{BATT_DPL}	V_{BATT} falling	-	2.4	2.6	V
Hysteresis on V_{BATT_DPL}	$V_{BATT\_DPL\_HYS}$	V_{BATT} rising	-	170	230	mV
Bad adapter detection voltage	V_{VINMIN}	V_{VIN} falling	-	3.7	-	V
Bad adapter detection current	I_{BADSRC}		-	30	-	mA
Bad adapter detection time	t_{BADSRC}		-	30	-	ms
Bad adapter detection interval time	t_{BADCYC}		-	2	-	sec
POWER-PATH･BATTERY-PATH						
ON resistance of RBFET	R_{ON_RBFET}	REG00[2:0]=100 Measured between VIN and PV	-	65	-	mΩ
ON resistance of HSFET	R_{ON_HSFET}		-	50	-	mΩ
ON resistance of LSFET	R_{ON_LSFET}		-	55	-	mΩ
ON resistance of BATTFET	$R_{ON\_BATTFET}$		-	15	18	mΩ
SYSTEM POWER MANAGEMENT						
SYS regulation voltage 1	V_{SYS_REG1}	BATTFET OFF, V_{BATT} < V_{SYS_MIN}	-	V_{SYS_MIN} +100	-	mV
SYS regulation voltage 2	V_{SYS_REG2}	BATTFET OFF, V_{BATT} > V_{SYS_MIN}	-	V_{BATT} +100	-	mV
Minimum SYS output DC voltage	V_{SYS_REGMIN}	V_{BATT} = 0 V, REG01[3:1]=101, V_{SYS_MIN} = 3.5 V	3.5	3.6	-	V
Maximum SYS output DC voltage	V_{SYS_REGMAX}	V_{BATT} = 4.35 V	-	4.45	4.55	V
Battery support voltage	V_{SUP}	BATT discharge current 10mA, V_{SYS} = V_{BATT} – V_{SUP} in Battery support mode	-	30	-	mV
Start voltage of battery support	V_{SYS_BATT}	Battery support function start when V_{SYS} < V_{BATT} - V_{SYS_BATT}	-	90	-	mV
BATTERY CHARGE CONTROL						
Trickle charge current	$I_{BATTSHORT}$	V_{BATT} < V_{SHORT}	-	85	-	mA

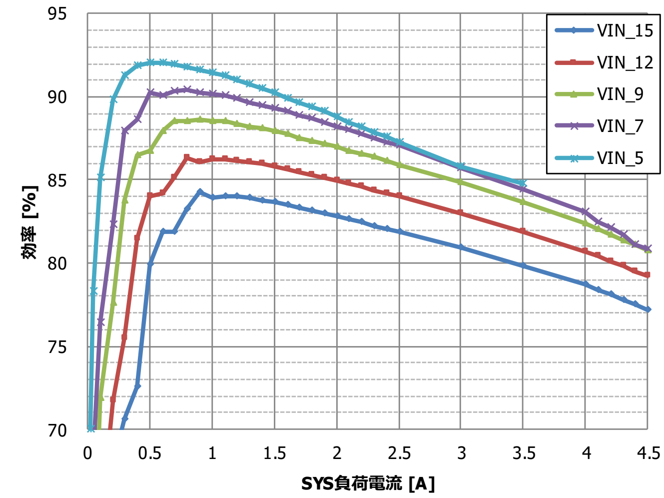
Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Pre-charge current accuracy	I_{PRECHG_ACC}	V_{BATT} = 2.6V, I_{PRECHG} = 256mA	-20	-	20	%
Fast charge current accuracy	I_{CHG_ACC}	V_{BATT} = 3.8V, I_{CHG} = 1792mA	-5	-	5	%
Charge current with charging current reduction option	I_{CHG_50pct}	REG09[2:0] = 011 or REG02[0] = 1	-	I_{CHG} x50	-	%
End-of-charge current accuracy	I_{EOC_ACC1}	I_{EOC} = 128mA, I_{CHG} = 960mA	-40	-	40	%
	I_{EOC_ACC2}	I_{EOC} = 256mA, I_{CHG} = 960mA	-20	-	20	%
800mA Charge current detection	I_{TERM_800MA}		-	800	-	mA
Battery short detection voltage	$V_{BATTSHORT}$	V_{BATT} falling	-	2.0	-	V
Hysteresis on $V_{BATTSHORT}$	$V_{BATTSHORT\_HYS}$	V_{BATT} rising	-	200	-	mV
Battery low-voltage detection voltage	$V_{BATTLOWV}$	V_{BATT} falling, REG04[1] = 1	2.6	2.8	2.9	V
Hysteresis on $V_{BATTLOWV}$	$V_{BATTLOWV\_HYS}$	V_{BATT} rising, REG04[1] = 1	-	200	-	mV
Constant voltage control accuracy	$V_{BATTREG\_ACC}$	$V_{BATTREG}$ = 4.304V	-0.5	-	0.5	%
Constant voltage control voltage in warm	$V_{BATTREG\_WARM}$	REG09[2:0] = 100	-	$V_{BATTREG}$ -160	-	mV
Recharge detection voltage	V_{RECHG}	V_{BATT} falling, REG04[0] = 1	-	300	-	mV
Recharge detection deglitch time	t_{RECHG}	V_{BATT} falling, REG04[0] = 1	-	20	-	ms
VIN VOLTAGE･CURRENT REGULATION						
Input voltage regulation accuracy	V_{VINDPM_ACC}		-2	-	2	%
USB Input current limit	$I_{IINDPM1}$	USB100	85	-	100	mA
	$I_{IINDPM2}$	USB150	125	-	150	mA
	$I_{IINDPM3}$	USB500	440	-	500	mA
	$I_{IINDPM4}$	USB900	750	-	900	mA
Input current limit	$I_{IINDPM5}$	Input current limit 1.2A	1	-	1.2	A
	$I_{IINDPM6}$	Input current limit 1.5A	1.3	-	1.5	A
	$I_{IINDPM7}$	Input current limit 2A	1.7	-	2	A
	$I_{IINDPM8}$	Input current limit 3A	2.6	-	3	A
Input current limit when SYS start	I_{VIN_START}	$V_{SYS} < V_{SYS\_START}$	-	100	-	mA
SYS start detection voltage	V_{SYS_START}	V_{SYS} rising	-	2.2	-	V
ILIM setting factor	K_{ILIM}	$I_{IN} = K_{ILIM}/R_{ILIM}$, I_{INDPM} = 1.5A	440	485	530	A x Ω
ILIM voltage when current regulation	V_{ILIM}		-	1	-	V
INPUT POWER SUPPLY DETECT						
D+ detection voltage for DCD	$V_{DAT\_REF\_DCD}$		0.7	-	0.8	V
D+ clamp voltage for DCD	V_{LGC_HI}		2	-	3.6	V
D+ current source for DCD	I_{DP_SRC}		7	-	13	μA
D- pull down resistance for DCD	R_{DM_DWN}		14.25	-	24.8	kΩ
DCD timeout	t_{DCDOUT}		-	500	-	ms
DCD deglitch time	t_{DCD}		-	40	-	ms
D+ detection voltage for Primary detection	$V_{DAT\_REF\_PRID}$		0.25	-	0.4	V
D+ voltage source for Primary detection	V_{DP_SRC}		0.5	-	0.7	V
D- sink current for Primary detection	I_{DM_SINK}		25	-	175	μA
Primary detection deglitch time	t_{PRID}		-	40	-	ms
Charging timer when 100mA USB host	$t_{SDP\_DEFAULT}$	Default mode	-	-	45	min
D+/D- pin leakage current	I_{D_LKG}	D+/D- switch open	-1	-	1	μA
Good-Battery detection voltage	V_{BATTGD}	V_{BATT} rising	3.4	3.55	3.7	V
Hysteresis on V_{BATTGD}	V_{BATTGD_HYS}	V_{BATT} falling	-	100	-	mV
BATT･SYS PROTECTION						
Battery over-voltage detection voltage	$V_{BATTOVP}$	V_{BATT} rising, as percentage of $V_{BATTREG}$	-	104	-	%
Hysteresis on $V_{BATTOVP}$	$V_{BATTOVP\_HYS}$	V_{BATT} falling, as percentage of $V_{BATTREG}$	-	2	-	%
Battery over-voltage detection deglitch time	$t_{BATTOVP}$		-	1	-	μs
BATTFET over-current detection current	$I_{BATTFET\_OCP}$		9	-	-	A

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
SYS over-voltage detection voltage	V_{SYSOVP}		-	400	-	mV
SYS over-voltage detection voltage in switch mode charge	V_{SYSOVP_SW}		-	650	-	mV
SYS sink current	$I_{SYSSINK}$		-	30	-	mA
THERMAL REGULATION･THERMAL SHUTDOWN						
Thermal regulation temperature	$T_{Junction\_REG}$	REG06[1:0] = 11	-	120	-	°C
Thermal shutdown temperature	T_{SHUT}	Temperature increasing	-	160	-	°C
Hysteresis on T_{SHUT}	T_{SHUT_HYS}		-	30	-	°C
Thermal shutdown detection deglitch time	t_{TSD}		-	1	-	ms
BATTERY TEMPERATURE DETECTION						
T1 temperature detection TS1 pin voltage	V_{T1}	As Percentage to V_{REF}	78.5	79.2	79.9	%
T1R temperature detection TS1 pin voltage	V_{T1R}	As Percentage to V_{REF}	-	77.2	-	%
T2 temperature detection TS2 pin voltage	V_{T2}	As Percentage to V_{REF}	74.0	74.9	75.8	%
T2R temperature detection TS2 pin voltage	V_{T2R}	As Percentage to V_{REF}	-	72.3	-	%
T3R temperature detection TS2 pin voltage	V_{T3R}	As Percentage to V_{REF}	-	56.0	-	%
T3 temperature detection TS2 pin voltage	V_{T3}	As Percentage to V_{REF}	50.9	52.3	53.7	%
T4R temperature detection TS1 pin voltage	V_{T4R}	As Percentage to V_{REF}	-	45.1	-	%
T4 temperature detection TS1 pin voltage	V_{T4}	As Percentage to V_{REF}	40.3	41.6	42.9	%
Battery temperature detection deglitch time	t_{TS}	$V_{TS1} > V_{T1}$, or $V_{TS2} > V_{T2}$, or $V_{TS2} < V_{T3}$, or $V_{TS1} < V_{T4}$	-	10	-	ms
DCDC CONVERTER						
Switching frequency	f_{LX}		1300	1500	1700	kHz
Maximum duty	D_{MAX}		-	97	-	%
Bootstrap refresh detection	$V_{BOOT\_REFRESH}$	V_{BOOT}-V_{LX} when LSFET refresh pulse is requested, V_{IN}=5V	-	3	-	V
DCDC CONVERTER　BUCK MODE OPERATION						
HSFET over-current detection current	I_{HSFET_OCP}		6	7.5	-	A
LSFET under-current detection current	I_{LSFET_UCP}	From sync mode to non-sync mode	-	100	-	mA
DCDC CONVERTER　BOOST MODE OPERATION						
Battery low-voltage detection voltage in boost	$V_{OTGBTLV}$	V_{BATT} falling	3.1	3.2	3.3	V
Hysteresis on $V_{OTGBTLV}$	$V_{OTGBTLV\_HYS}$	V_{BATT} rising	-	200	-	mV
Boost converter output voltage	V_{BOOST_REG}	I_{VIN} = 0	4.9	5.0	5.1	V
Boost converter current ability	I_{BOOST1}	REG01[0] = 0	0.5	-	-	A
	I_{BOOST2}	REG01[0] = 1	1.3	-	-	A
Boost converter output over-voltage detection voltage	V_{BOOST_OVP}		-	5.3	5.5	V
LSFET over-current detection current	I_{LSFET_OCP}		3.2	4.6	-	A
HSFET under-current detection current	I_{HSFET_UCP}		-	100	-	mA
RBFET over-current detection current	I_{RBFET_OCP1}	REG01[0] = 0	0.6	1.0	1.4	A
	I_{RBFET_OCP2}	REG01[0] = 1	1.4	1.8	2.2	A
REFLDO						
REFLOD output voltage	V_{REF1}	V_{VIN} = 10V, I_{REF} = 40mA	4.8	5.2	5.5	V
	V_{REF2}	V_{VIN} = 5V, I_{REF} = 20mA	4.75	4.85	-	V
REFLDO current ability	I_{REF}	V_{VIN} = 10V, V_{REF} = 3.8V	50	-	-	mA
REFLDO start delay time	$t_{REFDELAY}$		-	220	-	ms
LOGIC INPUT AND OUTPUT (INT#, OTG, EN#, STAT#)						
Low level input voltage	V_{ILO}		-	-	0.4	V
High level input voltage	V_{IHI}		1.3	-	-	V
Open drain pin output voltage	V_{OUT_LO}	Sink current = 5mA when pin="L"	-	-	0.4	V
Input leakage current	I_{BIAS}	Pull up rail 1.8V	-	-	1	μA

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Units
DIGITAL CLOCK AND TIMER						
Clock frequency	f_{CLK}		35	70	105	kHz
Timer accuracy	t_{TIMER_ACC}	watchdog timer, charging safety timer, STAT# blinking cycle	-15	-	15	%
INT# output pulse width	t_{INT}		-	256	-	µs
I^{2}C INTERFACE (SDA, SCL)						
Input voltage L	V_{IL}	VPULL-UP = 1.8V, SDA and SCL	-	-	0.4	V
Input voltage H	V_{IH}	VPULL-UP = 1.8V, SDA and SCL	1.3	-	-	V
SDA low level output voltage	V_{OL}	Sink current = 5 mA	-	-	0.4	V
High level input current	I_{BIAS}	VPULL-UP = 1.8V, SDA and SCL	-	-	1	µA
Clock frequency	f_{SCL}		-	-	400	kHz
Data transfer wait time	t_{BUF}		1.3	-	-	µs
SCL start hold time	$t_{HD;STA}$		0.6	-	-	µs
SCL low level hold time	t_{LOW}		1.3	-	-	µs
SCL high level hold time	t_{HIGH}		0.6	-	-	µs
Start condition setup	$t_{SU;STA}$		0.6	-	-	µs
SDA data hold time	$t_{HD;DAT}$		0	-	-	µs
SDA data setup time	$t_{SU;DAT}$		100	-	-	ns
SDA,SCL rise time	t_R		-	-	300	ns
SDA,SCL fall time	t_F		-	-	300	ns
Stop condition setup time	$t_{SU;STO}$		0.6	-	-	µs

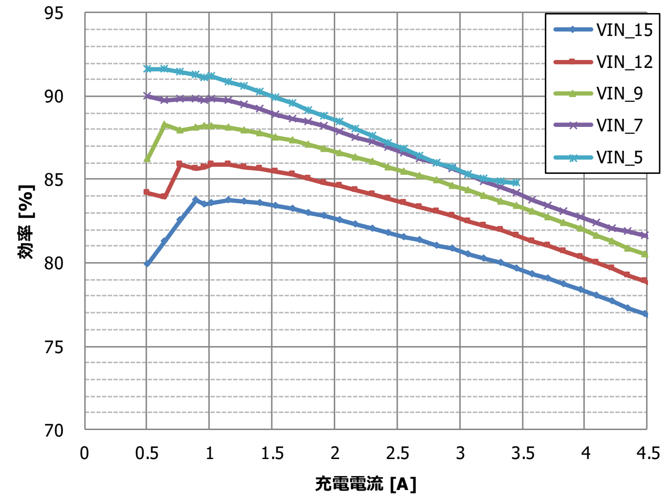


7. Typical Characteristics



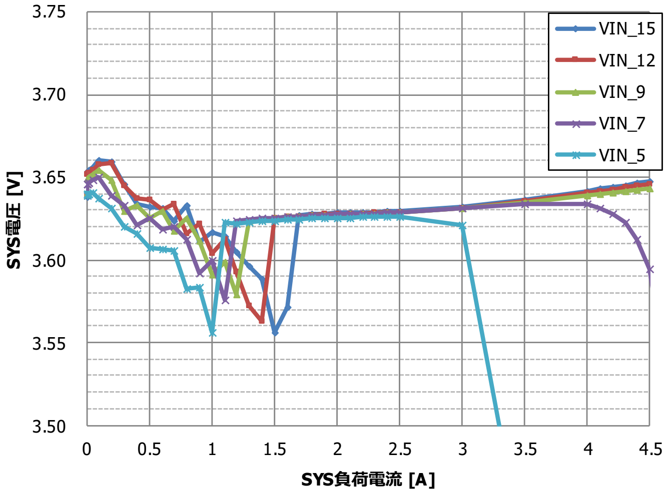
V_{BATT} = 3.8V

Figure 1. SYS Load Efficiency



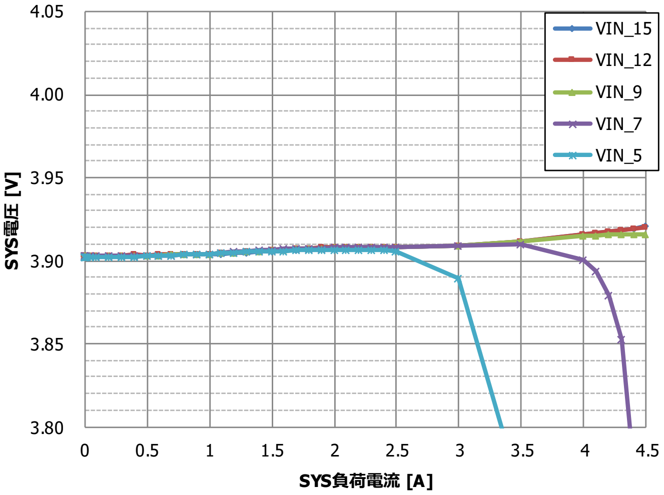
V_{BATT} = 3.8V

Figure 2. Charge Efficiency



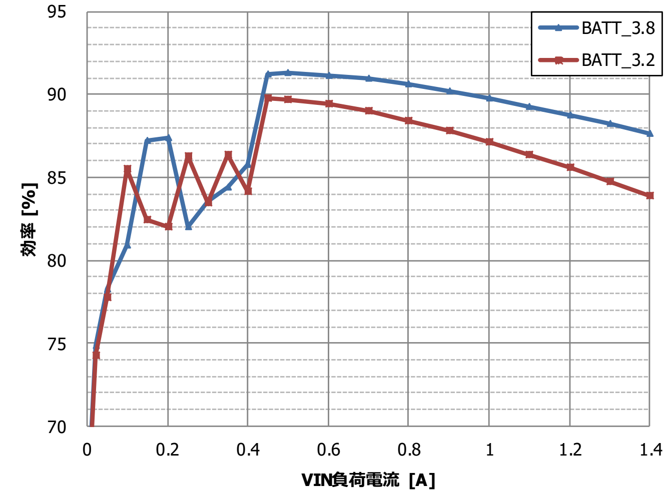
V_{BATT} = 3.2V

Figure 3. SYS Load Regulation 1



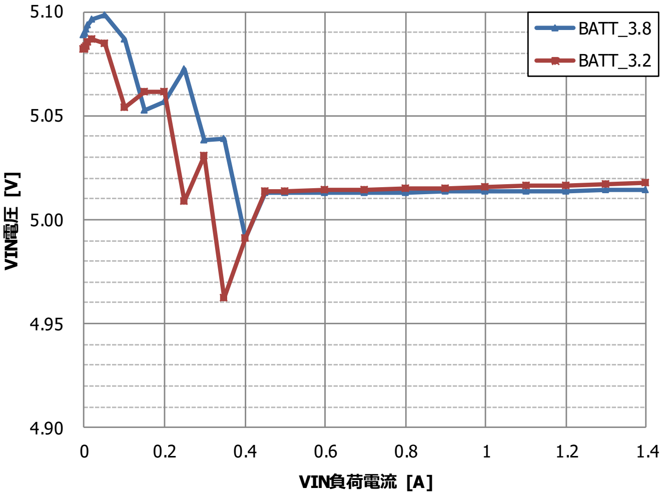
V_{BATT} = 3.8V

Figure 4. SYS Load Regulation 2



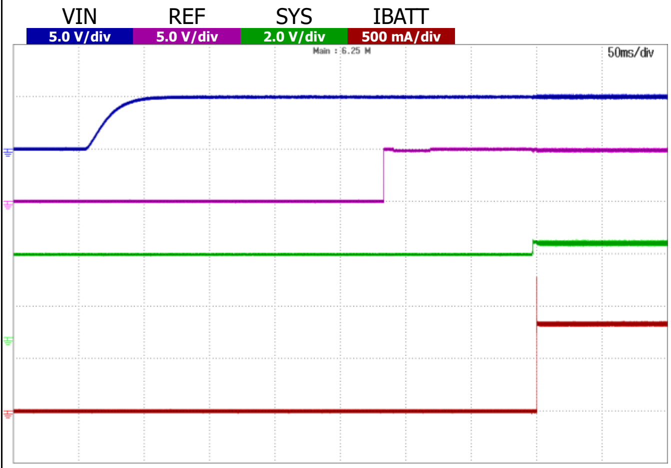
V_{BATT} = 3.2V

Figure 5. VIN Load Efficiency in Boost



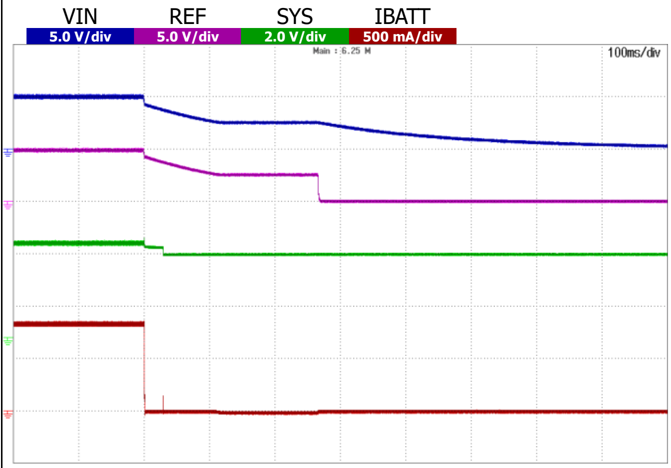
V_{BATT} = 3.2V

Figure 6. VIN Load Regulation in Boost



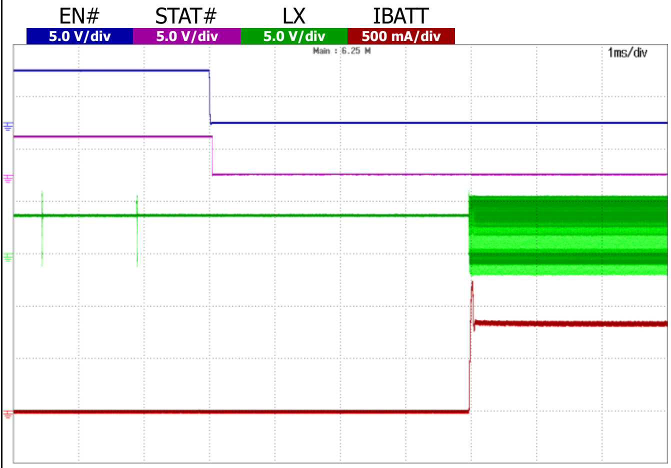
V_{BATT} = 3.2V
Charge Enable

Figure 7. VIN ON



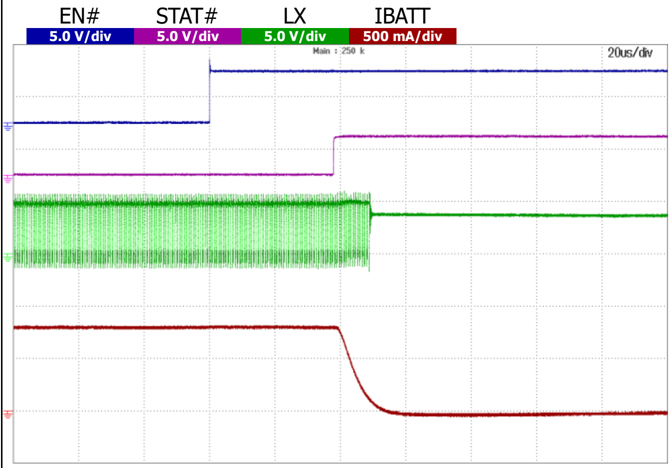
V_{BATT} = 3.2V
Charge Enable

Figure 8. VIN OFF



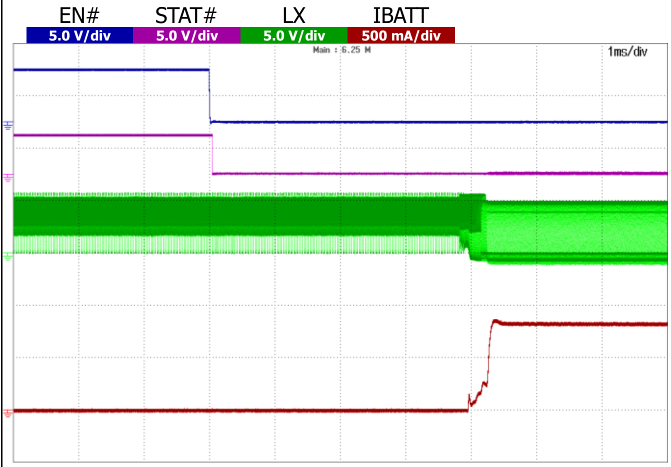
V_{VIN} = 5V, V_{BATT} = 3.2V

Figure 9. Charging Start 1



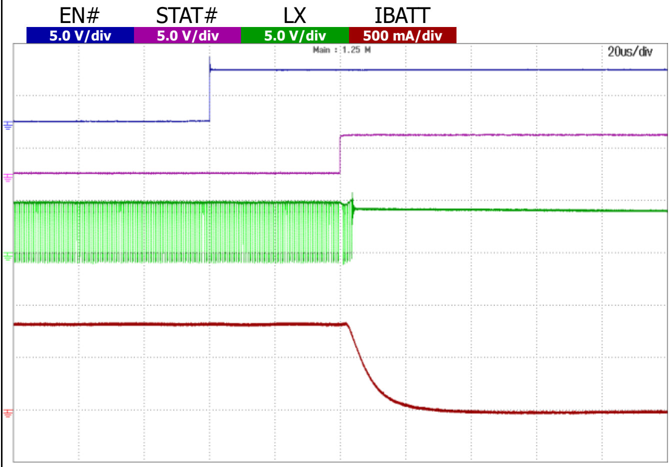
V_{VIN} = 5V, V_{BATT} = 3.2V

Figure 10. Charging Stop 1



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

Figure 11. Charging Start 2



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

Figure 12. Charging Stop 2

8. Feature Description

MM3659 is "4.5A switch mode charge control IC with power path with USB OTG". It has Built-in four power FETs, such as input reverse blocking FET (RBFET), high-side switching FET (HSFET), low-side switching FET (LSFET), battery FET (BATTFET), and also built-in a bootstrap diode for driving the HSFET. MM3659 has REFLDO as an internal regulator, it is for power supply of the many internal circuits. In addition, because it is output to the REF terminal, you can use the battery temperature detected with a thermistor.

8-1. Power-on Reset (POR)

Some of the internal circuit, such as main logic will work with either the higher voltage of the input power source (VIN terminal) or the battery (BATT terminal). If any of the voltage enters the I2C communication operating range (= V_{VIN_UVLOZ} or V_{BATT_UVLOZ}), it will be in the state capable of I2C communication. In this case, I2C registers are reset to their default values. It is to be noted, I2C register is also writing "1" in I2C Reset (REG01[7]), will be reset to their default values.

8-2. Default mode and Host mode

MM3659 has a built-in watchdog timer. You can set the time of watchdog timer by WATCHDOG register (REG05[5:4]).

It called a state in which the watchdog timer is operating as the host mode, WD_FAULT (REG09[7]) is set to "0". It called a state in which the watchdog timer is the time is up as the default mode, WD_FAULT (REG09[7]) is set to "1".

After POR, MM3659 will start in default mode. When you do something of I2C writing in the default mode changes to the host mode. When it becomes to host mode the watchdog timer starts operation, if the watchdog timer is the time is up return to the default mode. In order to maintain the host mode, the watchdog timer is set the WDT Reset (REG01[6]) to "1" before the time is up, or disable the watchdog timer by WATCHDOG (REG05[5:4]) to "00". It should be noted, WDT Reset (REG01[6]) automatically returns to "0".

Basically, MM3659 will still be controlled by the I2C master, state the I2C master does not exist, and even in a state such as I2C master cannot be started for the battery voltage is low, it is possible to perform a charging operation as a default mode.

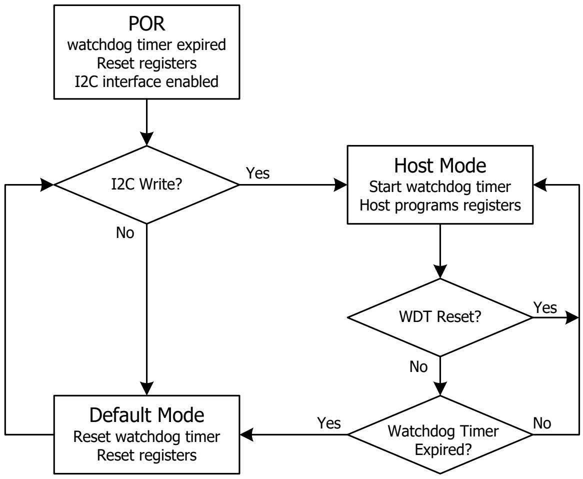


Figure 13. Watchdog Timer Flow Chart

8-3. MM3659 Start-up sequence

The MM3659's start-up sequence is divided into two types of "start-up by the battery (BATT)" and "start-up by the input power source (VIN)".

8-3-1. Start-up by the battery (BATT)

The input power is not connected, and the battery the battery over-discharge detection voltage (= V_{BATT_DPL}) or more is connected, MM3659 will supply power to the system from the battery by turning on the BATTFET. In addition, when running only in the battery, by OTG start condition is satisfied and then transition to the boost mode.

BATTFET forced OFF

When BATTFET_Disable (REG07[5]) ="1", you can OFF forcibly the BATTFET. When the BATTFET forced OFF does not perform charging and discharging of the battery.

Shipping mode

When the input power is not connected, BATTFET forced OFF and SDA = SCL = "L", MM3659 is not done power supply to the system to enter the shipping mode. This time, MM3659 minimize the consumption current from the battery. At the same time, by disabling the watchdog timer, it is possible to minimize consumption current permanently. In this way, such as during shipping, MM3659 minimize the discharge of the battery during the after set completion to actually operating the set.

BATTFET over-current protection (BATTFETOCP)

Such as the SYS terminal to ground fault, when the discharge current flowing to the BATTFET exceeds the BATTFET over-current detection current (= $I_{BATTFET\_OCP}$), MM3659 do latch-OFF the BATTFET. In order to release the latch OFF, you must disconnect the input power.

8-3-2. Start-up by the input power source (VIN)

When connect the input power source, MM3659 will start the step-down DCDC converter and supply power to the system after perform the three steps of "REFLDO start", "bad adapter detection" and "input power source determination".

Start-up the REFLDO

When you connect the input power, REFLDO that is internal regulator will start at first. REFLDO is the power of many internal circuits, such as DCDC converter. Start-up conditions of REFLDO are as follows.

・VIN voltage is in the I2C communication operating range (VIN> V_{VIN_UVLOZ})
・VIN voltage is higher than the BATT voltage (VIN> BATT + V_{INDET})
・The above two conditions are maintained during 220msec

Bad adapter detection

After REFLDO has started, perform the detection operation to make sure that the input power is not a bad adapter. Conditions that are determined to be normal adapter, is as follows.

・The input power supply has the current capability or more of the bad adapter detection current (= I_{BADSRC})
・VIN voltage is lower than the VIN overvoltage detection voltage (VIN <V_{ACOV})

How to check the current capability of the input power is that it does not fall below the bad adapter detection voltage (= V_{VINMIN}) when pulling out the bad adapter detection current (= I_{BADSRC}) during the bad adapter detection time (= t_{BADSRC}). If it is determined that the bad adapter lack current capability, MM3659 repeats the current capability confirmation operation every 2sec.

When it is determined that the normal adapter, MM3659 outputs an INT# interrupt signal and then to PG_STAT (REG08 [2]) = "1".

Input Power Supply Detect

After the input power is determined to be normal adapter, MM3659 will determine the initial value of the input current limit value by performing the input power source discrimination. When the input power determination is completed, the output of the INT# interrupt signal, and then DCDC converter will start.

MM3659 performs the input power supply detect using the D+/D- terminals, conform to the Primary Detection of Battery Charging Specification1.2 (BCS1.2). Determination by D+/D- terminals has two steps of Data Contact Detect (DCD) and Primary Detection.

DCD is a step of detecting the connection of the D+/D- terminals. Internal circuit at the time of the DCD is as shown in Figure 14. When the D+ terminal maintain the low during DCD deglitch time (= t_{DCD}), MM3659 will determine that D+/D- terminals is connected. Then move on to the next step. DCD time-out (= t_{DCDOUT}) time has elapsed without the detection, the input power supply detect will be terminated to not move to the next step.

Primary Detection is the distinguishing step into two types of "Standard Down Stream Port (SDP)" and "Dedicated Charging Port (DCP) / Charging Down Stream Port (CDP)". Internal circuit at the time of the Primary Detection is as shown in Figure 15. After the elapse of Primary Detection deglitch time (= t_{PRID}), if the D- pin is to low MM3659 will determine the SDP (= USB Host), if high DCP / CDP (= Charging Port).

By the above determination result and the logic of OTG terminal the initial value of input current limit will be determined. In addition, MM3659 will display the discrimination results to VIN_STAT(REG08 [7: 6]) (Table 1).

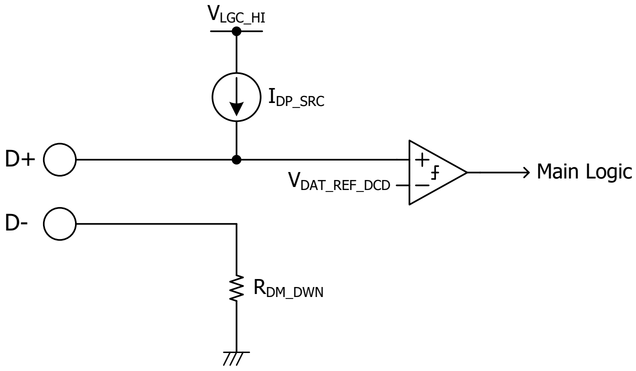


Figure 14. Block Diagram in DCD

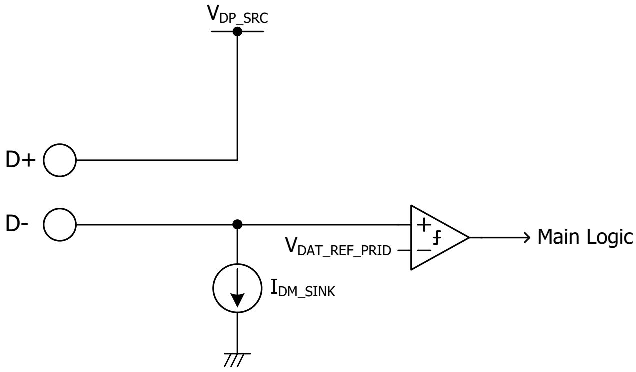


Figure 15. Block Diagram in Primary detection

Table 1. USB D+/D- Detection

D+/D- DETECTION	OTG	INPUT CURRENT LIMIT	REG08[7:6]
0.5 sec timer expired in DCD (D+/D- floating)	–	100mA	00
USB Host	Low	100mA	01
USB Host	High	500mA	01
Charging Port	–	1.5A	10

HiZ state

Result of the input power source discrimination, input current limit is set to 100mA, and when the BATT voltage is higher than the Good-Battery detection voltage (= V_{BATTGD}), and then transition to the HiZ state. When it comes to HiZ state, MM3659 stops REFLDO and DCDC converter, and supplies the power from the battery to the system.

After the transition to the HiZ state, by EN_HIZ(REG00[7]) to "0" or removing the input power, MM3659 will be released from the HiZ state. If you release the HiZ state by removing the input power, EN_HIZ(REG00[7]) will be automatically set to "0".

It should be noted, also possible to EN_HIZ(REG00[7]) set to "1", you can transition to the HiZ state.

Forced Input Power Supply Detect

When DPDM_EN(REG07[7]) set to "1", you can do to force the input power supply detection. After the input power supply detection is completed, automatically DPDM_EN(REG07[7]) returns to "0". When done the forced input power supply detection, MM3659 is not able to transition to the HiZ state by the results.

The value of input current limit

The initial value of the input current limit is determined by the results of the input power supply detection, and will be reflected in IINDPM(REG00[2: 0]). When the input current limit is set to 900 mA or less (IINDPM[2: 0] = 000 to 011), increase the ON resistance of the RBFET to increase the current detection accuracy.

Also input current limit is possible to put a clamp by resistor connected between ILIM and PGND terminal. Clamp value by the ILIM pin is estimated by the following calculation formula. The actual input current limit value will be set to whichever smaller IINDPM(REG00[2: 0]) or clamp value (I_{ILIM}).

$$I_{ILIM} = \frac{1V}{R_{ILIM}} \times K_{ILIM}$$

It should be noted that, by checking the voltage of the ILIM terminal, you can grasp the input current in a simple manner. Calculation formula for determining the input current from ILIM terminal voltage is as follows. When ILIM terminal voltage is higher than the 1V is ready to DPM function is operating.

$$I_{VIN} = \frac{V_{ILIM}}{1V} \times I_{ILIM}$$

8-3-3. Step-down DCDC converter operation (Buck mode)

When the input current limit value is determined by the input power source discrimination, the step-down DCDC converter starts and supplies the power to the system. If the charge condition is satisfied, also performs the charging operation at the same time.

Order to perform a soft start of the SYS voltage, when the SYS voltage <2.2V MM3659 will reduce the input current to the system start-up input current limit (= I_{IN_START}). In addition, in order to improve the efficiency at light loads, if detects a light load when "BATT voltage = Minimum system operating voltage (= V_{SYS_MIN}) or less", and "IINDPM setting = more than 500mA", MM3659 will automatically transition to the PFM control. PFM control of MM3659 is carried out in a pulse-skipping type, switching duty ratio is determined by the ratio of the VIN voltage and SYS voltage.

System over-voltage protection (SYSOVP)

When the step-down DCDC converter is operating, MM3659 is monitoring the SYS voltage, stops the switching operation when the SYS voltage exceeds the value of the overvoltage. At the same time MM3659 also pulls current 30mA to the internal, to prevent over-voltage destruction of the post-stage device that is connected to the SYS terminal.

8-3-4. Step-up DCDC converter operation (Boost mode)

MM3659 has a boost DCDC converter mode (USB On-The-Go) with the Battery power. The Conditions to become a boost mode is as follows.

・Running with only the battery
・BATT voltage is above the battery low-voltage detection voltage in boost (BATT> $V_{OTGBTLV}$)
・CHG_CONFIG (REG01[5:4]) is set to "10" or "11"
・OTG terminal is High

In boost mode, MM3659 will output a voltage (= V_{BOOST_REG}) to VIN terminal. And VIN_STAT (REG08[7:6]) become "11". In addition, in order to improve the efficiency at light loads, if detects a light load MM3659 will automatically transition to the PFM control.

Output over-voltage protection at the boost mode (OTGOV)

MM3659 monitors the VIN voltage at the boost mode, when the VIN voltage exceeds the OTG output overvoltage (=V_{BOOST_OVP}), to stop the boost DCDC converter, and exit from the boost mode. In addition, outputs INT# the interrupt signal, and BOOST_FAULT (REG09[6]) is set to "1".

Output over-current protection at the boost mode (RBFETOCP)

At the boost mode, when the output current from the VIN terminal exceeds the RBFET over-current (=I_{RBFET_OCP}), it will be the over-current judging. When the over-current judging is 20msec continue, MM3659 stops the switching operation, outputs the INT# the interrupt signal, and BOOST_FAULT (REG09[6]) is set to "1". However, resumes the switching operation after 30msec stop. In the case that the over-current is continued such as VIN pin is grounded, the switching operation will repeat stop and resume. RBFET over-current (=I_{RBFET_OCP}) is possible to change in BOOST_LIM (REG01 [0]).

8-4. System power management

MM3659 will supply the power from either or both of the input power and the battery to the system.

8-4-1. Architecture of Narrow VDC

MM3659 is equipped with Narrow VDC architecture that system and battery have been separated by a BATTFET. Voltage supplied to the system is controlled to BATT+100mV. However, at the same time, for it is controlled so as not to fall below a minimum system operating voltage (=V_{SYS_MIN}) set by SYS_MIN (REG01[3:1]), if the battery voltage is low, the voltage supplied to the system is kept constant.

Not in charging

・In the case of BATT<VSYS_MIN, SYS voltage is controlled to VSYS_MIN+100mV. (In VSYSMIN Regulation)
・In the case of BATT>VSYS_MIN, SYS voltage is controlled to BATT+100mV. (Not In VSYSMIN Regulation)

In charging

・In the case of BATT<VSYS_MIN, MM3659 is kept the SYS voltage to VSYS_MIN + 100mV, controls the BATTFET to linear, performs linear charging operation.
・In the case of BATT>VSYS_MIN, MM3659 is the BATTFET in full ON, performs switching charge operation by the step-down DCDC converter. SYS voltage is BATT voltage plus the voltage generated in BATTFET on-resistance (= $R_{ON\_BATTFET}$) and the charging current.

Also, by reading the VSYS_STAT (REG08 [0]), you can see the status of the SYS.

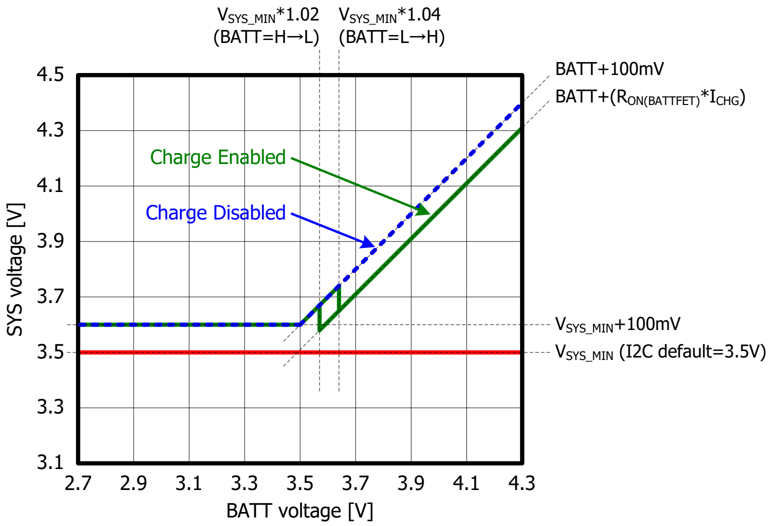


Figure 16. SYS Voltage Chart

8-4-2. Dynamic Power Management (DPM)

In order to comply with the current limit of the USB standard, also, because of the adapter over-current protection, MM3659 is monitoring the voltage and current of the VIN terminal, it is the control of the following.

・As the VIN voltage does not drop below the voltage set by VINDPM (REG00[6:3]), MM3659 decreases the charging current.
・As the VIN current does not increase from the current set by IINDPM (REG00[2:0]), MM3659 decreases the charging current.

Please note because the IINDPM also be affected clamp value set by the ILIM terminal.

When the DPM function is operating, DPM_STAT (REG08[3]) is set to "1". In addition, the count rate of the charging timer is cut in half, also it will not be carried out end-of-charge decision.

If the charging current reaches zero and the DPM function is continued operation, SYS voltage will drop.

8-4-3. Battery Support

If the SYS voltage reaches the battery support start voltage lower than the BATT voltage (SYS <BATT-V_{SYS_BATT}), MM3659 will enter the battery support mode. In the battery support mode, MM3659 provides power from both of the input power supply and battery by turning ON the BATTFET, to prevent a reduction in the SYS voltage. However, if the BATT voltage is below the battery over-discharge detection voltage (= V_{BATT_DPL}), it does not go into the battery support mode.

In the battery support mode, SYS voltage is controlled linear by BATTFET so that the voltage dropped battery support voltage than BATT voltage.

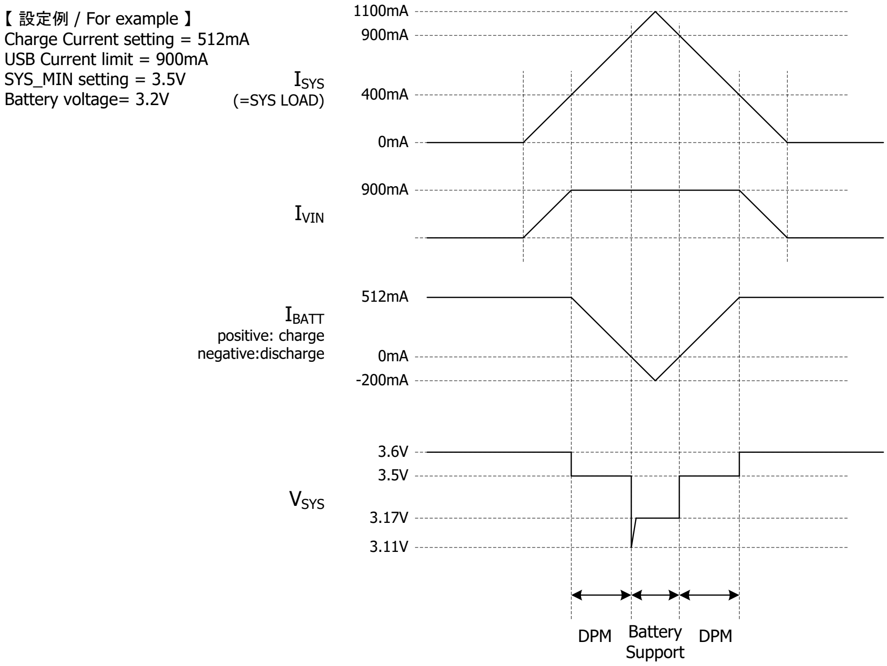


Figure 17. DPM and Battery Support

8-5. Charge control

8-5-1. Charge control cycle

When the step-down DCDC converter is operating, charging operation works by the following conditions are satisfied.

・Battery temperature abnormality is not occurring
・CHG_CONFIG (REG01[5:4]) is set to "01"
・EN# terminal is Low
・Not to force OFF the BATTFET

The charge control of the MM3659 is general CCCV control. Because many of the parameter regarding the charge control is possible to modify with I2C, MM3659 corresponds to various applications. In addition, charge state is indicated to CHG_STAT(REG08[5:4]). Charge state is output to also STAT# terminal. While charging STAT# will be "L", while not charging and end-of-charge it will be "H", if occurrence of the charge error it will blink. Refer to Figure 18 for charge timing chart, Table 2 for charging parameter.

Furthermore when DPM function or thermal regulation is operational, count speed of the charge timer is cut in half, also end-of-charge detection becomes unable to do.

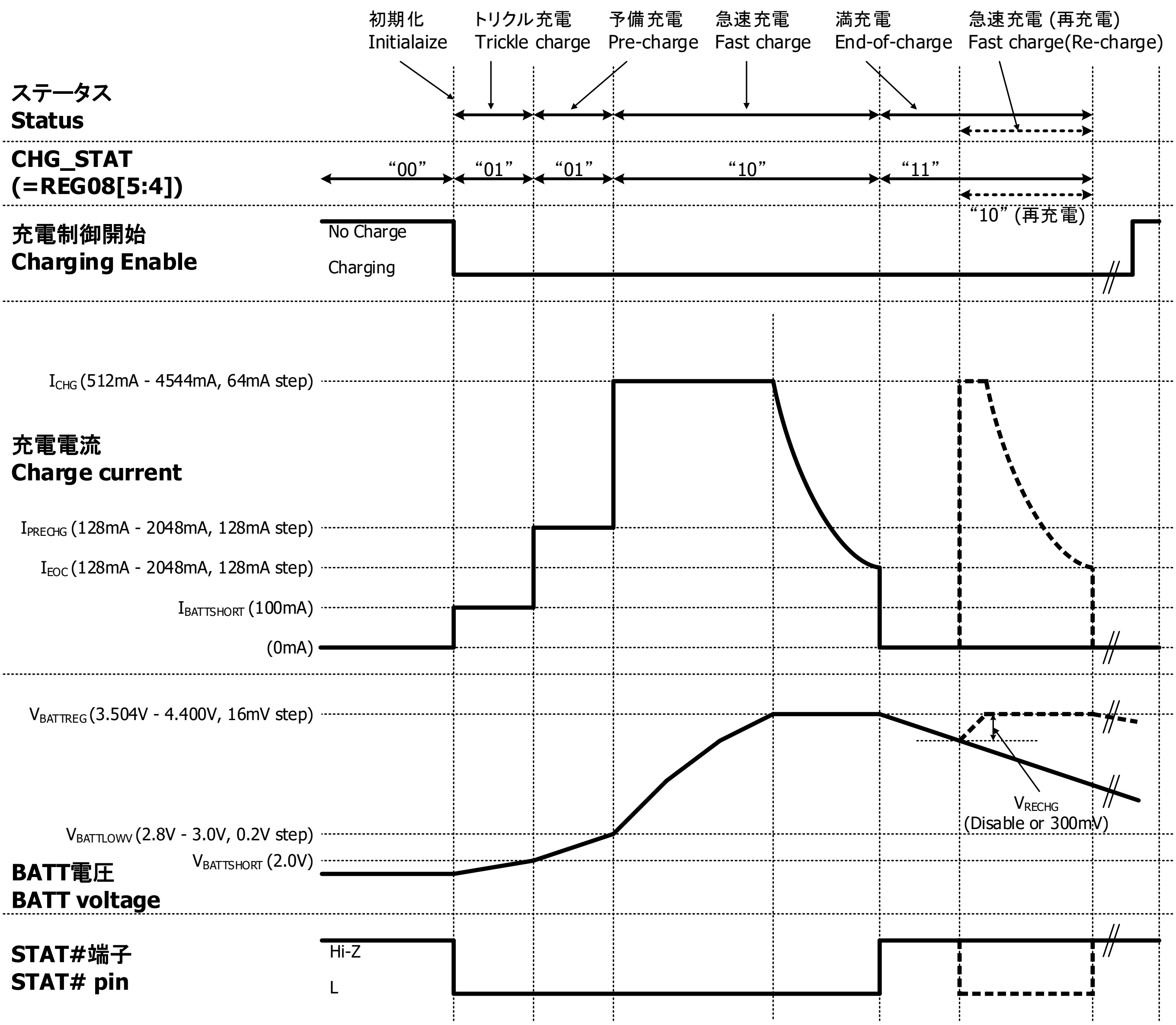


Figure 18. Charge Timing Chart

Table 2. Charging Parameter

Parameter	Symbol	I2C REG	I2C Default	I2C setting range
Trickle charge current	$I_{BATTSHORT}$	–	85mA	–
Pre-charge current	I_{PRECHG}	REG03[7:4]	256mA	128~2048mA, 128mA step
Fast charge current	I_{CHG}	REG02[7:2]	832mA	512~4844mA, 64mA step
End-of-charge current	I_{EOC}	REG03[3:0]	256mA	128~2048mA, 128mA step
Battery short detection voltage	$V_{BATTSHORT}$	–	2.0V	–
Battery low-voltage detection voltage	$V_{BATTLOWV}$	REG04[1]	3.0V	2.8~3.0V, 0.2V step
Constant voltage control voltage	$V_{BATTREG}$	REG04[7:2]	4.304V	3.504~4.400V, 16mV step
Recharge detection voltage	V_{RECHG}	REG04[0]	Disable	Disable or 300mV

Battery over-voltage protection (BATTOVP)

When the step-down DCDC converter is operating, MM3659 is monitoring the BATT voltage. When the BATT voltage exceeds the battery overvoltage detection voltage (=$V_{BATTOVP}$), MM3659 stops the switching operation and discharge from the battery preferentially. At the same time MM3659 also sink current 30mA inside, prompting a recovery from an over-voltage condition of the battery.

If the battery is later inserted into the BATT terminal while the step-down DCDC converter is operating, there is a possibility that power supply to the SYS terminal will stop for about 1 ms due to the battery overvoltage protection function detecting the ringing occurring at the BATT terminal There is so, please be careful.

8-5-2. Charging current reduction option

You can reduce the charging current by 50PCT(REG02[0]) set to "1".

Because the end-of-charge detection is performed even if the charging current is reduced by this function, the charging operation may stop by the end-of-charge detection. If not want the end-of-charge detection, please set to EN_TERM(REG05[7]) "0".

8-5-3. Impedance compensation of charge route

In fact of the application, impedance such as contact resistance of the connector, the sense resistor in the battery pack, the ON resistance of the protection FET exists in the charge current route. Because this impedance is to shorten the period of the CC control, and lengthen the period of CV control, it will be the charge complete time becomes longer.

By setting this impedance to BATT_RES(REG06[7:5]) as a parameter, MM3659 lifts the CV control voltage by taking into account the voltage drop caused by the charging current and impedance, and by lengthen the period of the CC control, possible to carry out the reduction of the charging time. In addition, lifted voltage is safe since it is possible to apply a clamp by set to BATT_VCLAMP(REG06[4:2]), Actual CV control voltage is, you will be asked by the following formula.

$$V_{BATTREG\_ACTUAL} = V_{BATTREG\_I2C} + \min((I_{CHG\_ACTUAL} \times BATT\_RES), BATT\_VCLAMP)$$

8-5-4. Battery temperature detection

There are two thermistor connection pin TS1 and TS2. The device charging operates with JEITA battery temperature profile by short TS1 and TS2. When not use TS2 thermistor, the device charging operates with Hot/Cold battery temperature profile.

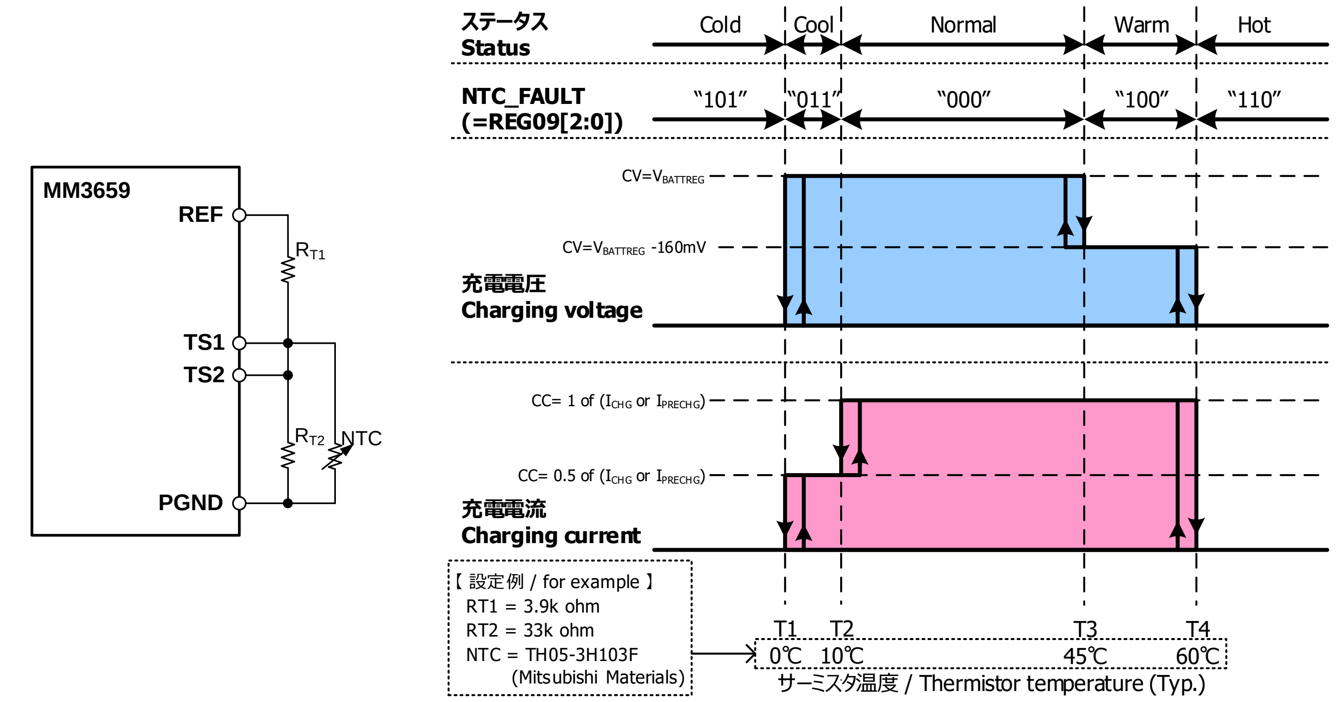


Figure 19. Circuit around TS1/TS2 with JEITA Battery Temperature Profile

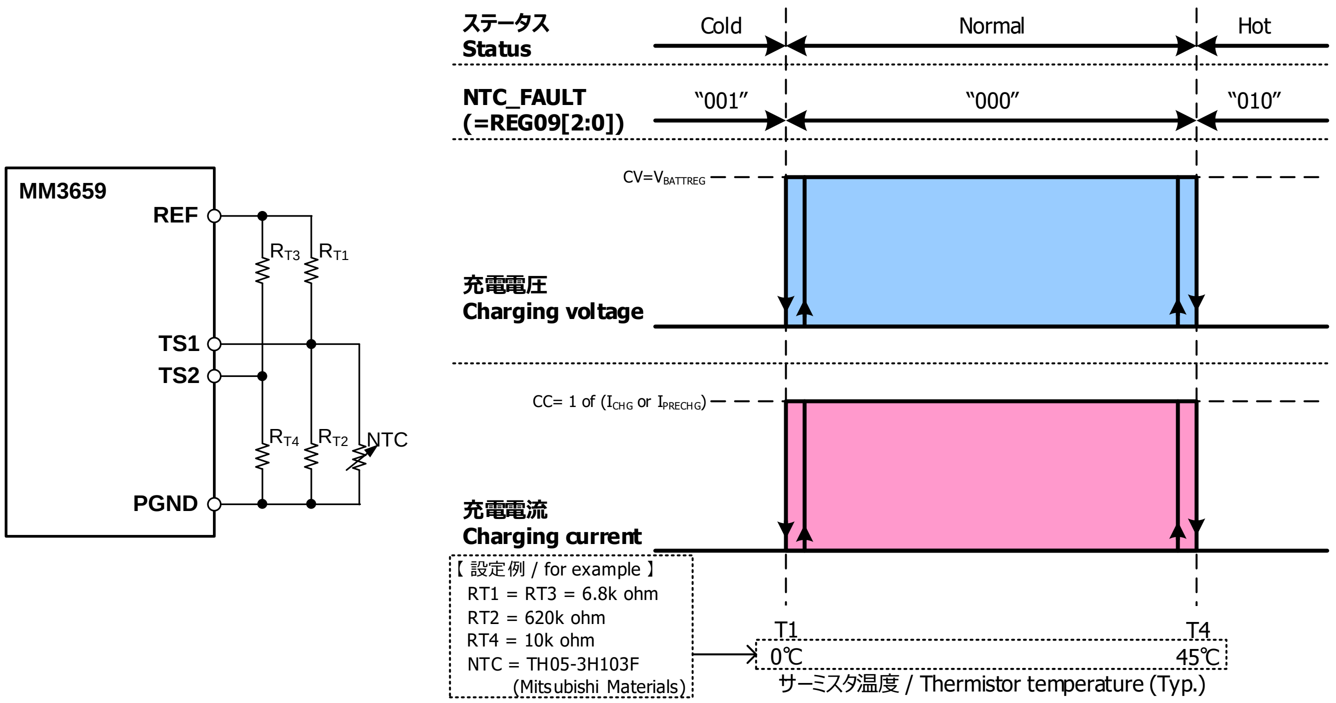


Figure 20. Circuit around TS1/TS2 with Hot/Cold Battery Temperature Profile

8-5-5. 満充電検出動作 / End-of-charge detection

電池電圧が再充電検出電圧を上回っている状態で、充電電流が満充電検出電流を下回ると、満充電になります。満充電判定は、EN_TERM(REG05[7])で有効・無効が切り替えられ、"1"の時に満充電判定有効、"0"の時に満充電判定無効になります。満充電判定無効の場合、充電タイマーがタイムアップするまでフローティング充電の状態になります。

If to be state the battery voltage is above the recharge detection voltage, and the charge current is less than the end-of-charge detection current, it will be the end-of-charge. The end-of-charge determination is switched valid or invalid in EN_TERM (REG05[7]), when "1" it will be the end-of-charge detection valid, when "0" it will be the end-of-charge detection invalid. In the case of f the end-of-charge detection invalid, it will be in the state of floating charge until the charge timer is up.

8-5-6. End-of-charge indicator threshold

When TERM_STAT(REG05 [6]) is "1" and the charging current less than 800mA charge current detection (=I_{TERM_800MA}) occur, STAT# goes "H". Charging operation continue until be end-of-charge. If disable end-of-charge detect function, while STAT# becomes "H", will be in the state of floating charge until the charging timer expiration.

8-5-7. Charging safety timer

In MM3659, There are two timers that pre-charge timer and fast charge timer. Pre-charge charge timer also counts up during the trickle charge. Fast charge timer at the time of the host mode, can be changed by I2C.

When charge timer expiration happen, stop charging operation and CHG_FAULT (REG09 [5: 4]) is set to "11". In addition, go to HiZ state when charging timer expiration in default mode or pre-charge timer expiration with VIN supply detected as USB100mA in default mode.

During charging current reduced with DPM or thermal regulation, the charging timer counts at half clock rate except the case that VIN supply detected as USB100mA in default mode. Also, if you TMR2X_EN(REG07 [6]) set to "0", the count rate in either mode remains unchanged.

Charging timer of each mode, operation when timer expiration happens, the clock rate in DPM or thermal regulation is as Table 3.
EN_TIMER(REG05[3]) is enable bit of charging timer, "1" is enable, "0" is disable.
After charging timer expiration, reset charging timer to restart charging cycle by any of the following.

・Start new charging cycle (VIN power remove and insert, recover from HiZ state)
・Toggle EN# High to Low
・Write CHG_CONFIG(REG05[3]) from "00" to "01"
・Write EN_TIMER(REG05[3]) to "0"
・Write I2C Reset(REG01[7]) to "1"

Table 3. Charging Safety Timer

Parameter	Default mode (USB100mA)	Default mode (not USB100mA)	Host mode
Pre-charge Timer	Total 45min (Max.)	1h	1h
Fast charge Timer		5h	REG05[2:1] setting
Pre-charge Timer expiration	HiZ state	Charging stop	Charging stop
Fast charge Timer expiration		HiZ state	
In DPM or Thermal regulation	Use original clock	Use half clock	Use half clock

8-6. Status output

8-6-1. PG_STAT

PG_STAT(REG08[2]) indicate the state of VIN supply connection. It is set to "1" when meet the following conditions.

・VIN voltage is in the I2C communication operating range (VIN> V_{VIN_UVLOZ})
・VIN voltage is higher than the BATT voltage (VIN> BATT + V_{INDET})
・The input power supply has the current capability or more of the bad adapter detection current (= I_{BADSRC})
・VIN voltage is lower than the VIN overvoltage detection voltage (VIN <V_{ACOV})

8-6-2. STAT#

STAT#端子は充電状態を表示し、充電中は"L"、充電していない時や満充電の時は"H"、充電エラーの時は点滅します。

STAT# pin indicate the state of charge. It goes "L" while charging, "H" when not-charging or end-of-charge, and blink when charging error.

Table 4. STAT# Pin State

CHARGING STATE	STAT#
Charging in progress (including recharge)	Low
Charge Disable Charging complete	High
Input over-voltage Safety timer expiration Battery over-voltage in Buck Converter mode NTC fault (TS1/TS2 Cold or Hot)	blinking at 1Hz

8-6-3. INT#

To eliminate the need for the microcontroller to constantly monitor the status of the MM3659, the MM3659 outputs a Low pulse signal with an INT# output pulse width (=t_{INT}) from the INT# pin to notify the microcontroller when the following events occur. Some conditions can be masked by I2C.

① POR occurs
② Logic of the OTG terminal changes
③ Input Source Qualification completes
④ Logic of PG_STAT (REG08[2]) changes
⑤ Charge completes
⑥ The battery voltage crosses V_{BATT_DPL} (rising or falling)
⑦ WATCHDOG_FAULT (REG09[7]), becoming Fault state
⑧ BOOST_FAULT (REG09[6]), becoming Fault state
⑨ CHARG_FAULT (REG09[5:4]) becomes Fault state (with REG07[1] masking possibility)
⑩ BAT_FAULT (REG09[3]) becomes Fault state (with REG07[0] masking possibility)
⑪ NTC_FAULT (REG09[2:0]) becomes Fault state (Cold or Hot)

⑦~⑪ are factors that display the Fault in the fault register. If INT# interrupt occurs on these factors, any INT# interrupt would not occur, until goes to condition that the Fault information is not been latched.

8-6-4. Fault register (REG09h)

When Fault occurs except NTC_FAULT, the information is latched in the fault register. The information does not update until the Read Fault register. For example, when BATT voltage rise; BATTOVP occur; BATT voltage fall and release BATTOVP. The first Read is Fault, the second Read is Normal. Like this, the first reads fault register status from the last INT# and the second reads the current fault register status. For NTC_FAULT, it does not have this latch function. At any time, display the information at the time of the fault register reads.

8-7. Protect functions

8-7-1. Clamp of input current limit value

Input current limit is possible to put a clamp by resistor connected between ILIM and PGND terminal. Clamp value by the ILIM pin is estimated by the following calculation formula. The actual input current limit value will be set to whichever smaller IINDPM(REG00[2:0]) or clamp value (IILIM).

$$I_{ILIM} = \frac{1V}{R_{ILIM}} \times K_{ILIM}$$

It should be noted that, by checking the voltage of the ILIM terminal, you can grasp the input current in a simple manner. Calculation formula for determining the input current from ILIM terminal voltage is as follows. When ILIM terminal voltage is higher than the 1V is ready to DPM function is operating.

$$I_{VIN} = \frac{V_{ILIM}}{1V} \times I_{ILIM}$$

8-7-2. Thermal Regulation

When the step-down DCDC converter is operating, MM3659 is monitoring the junction temperature, TREG(REG06[1:0]) do the thermal regulation control so as not to exceed the temperature that can be set in. During thermal regulation operation, THERM_STAT(REG08[1]) is set to "1". In addition, the count rate of the charging timer is cut in half, it will not be carried out also fully charged decision.

8-7-3. Thermal shutdown

In order to prevent the MM3659 from thermal destruction, it has a built-in thermal shutdown circuit, will go into thermal shutdown when the junction temperature exceeds about 160°C. When thermal shutdown, stop the DCDC converter. In addition, CHG_FAULT(REG09[5:4]) is set to "10". In addition, thermal shutdown will be operating in the state that exceeds the absolute maximum rating. Therefore, please avoid application designed to actively use this feature.

8-7-4. Input power source over-voltage protection (VINOVP)

When the VIN voltage exceeds the VIN overvoltage detection voltage (= V_{ACOV}), to stop the switching operation. In addition, output INT# interrupt signal, CHG_FAULT (REG09[5:4]) is set to "01".

8-7-5. System over-voltage protection (SYSOVP)

When the step-down DCDC converter is operating, MM3659 is monitoring the SYS voltage. When the SYS voltage exceeds the value of the overvoltage, MM3659 stops the switching operation. At the same time MM3659 also pulls current 30mA to the internal, to prevent over-voltage destruction of the post-stage device that is connected to the SYS terminal.

8-7-6. Output overvoltage protection at the boost mode (OTGOV)

MM3659 monitors the VIN voltage at the boost mode, when the VIN voltage exceeds the OTG output overvoltage (=V_{BOOST_OVP}), to stop the boost DCDC converter, and exit from the boost mode. In addition, outputs INT# the interrupt signal, and BOOST_FAULT (REG09[6]) is set to "1".

8-7-7. Output over-current protection at the boost mode (RBFETOCP)

At the boost mode, when the output current from the VIN terminal exceeds the RBFET over-current (= I_{RBFET_OCP}), it will be the over-current judging. When the over-current judging is 20msec continue, MM3659 stops the switching operation, outputs the INT# the interrupt signal, and BOOST_FAULT (REG09[6]) is set to "1". However, resumes the switching operation after 30msec stop. In the case that the over-current is continued such as VIN pin is grounded, the switching operation will repeat stop and resume. RBFET over-current (=I_{RBFET_OCP}) is possible to change in BOOST_LIM (REG01 [0]).

8-7-8. Battery over-voltage protection (BATTOVP)

When the step-down DCDC converter is operating, MM3659 is monitoring the BATT voltage. When the BATT voltage exceeds the battery overvoltage detection voltage (=$V_{BATTOVP}$), MM3659 stops the switching operation and discharge from the battery preferentially. At the same time MM3659 also sink current 30mA inside, prompting a recovery from an over-voltage condition of the battery.

If the battery is later inserted into the BATT terminal while the step-down DCDC converter is operating, there is a possibility that power supply to the SYS terminal will stop for about 1 ms due to the battery overvoltage protection function detecting the ringing occurring at the BATT terminal There is so, please be careful.

8-7-9. BATTFET over-current protection (BATTFETOCP)

Such as the SYS terminal to ground fault, when the discharge current flowing to the BATTFET exceeds the BATTFET over-current detection current (= $I_{BATTFET\_OCP}$), MM3659 do latch-OFF the BATTFET. In order to release the latch OFF, you must disconnect the input power.

8-8. I2C communicate function

8-8-1. About I2C-bus

I2C BUS is inter bus system controlled by 2 lines (SDA, SCL). Data are transmitted and received in the units of byte and Acknowledge. It is transmitted by MSB first from the Start condition.

The protocol of Read and Write of MM3659 are as in the figures below.

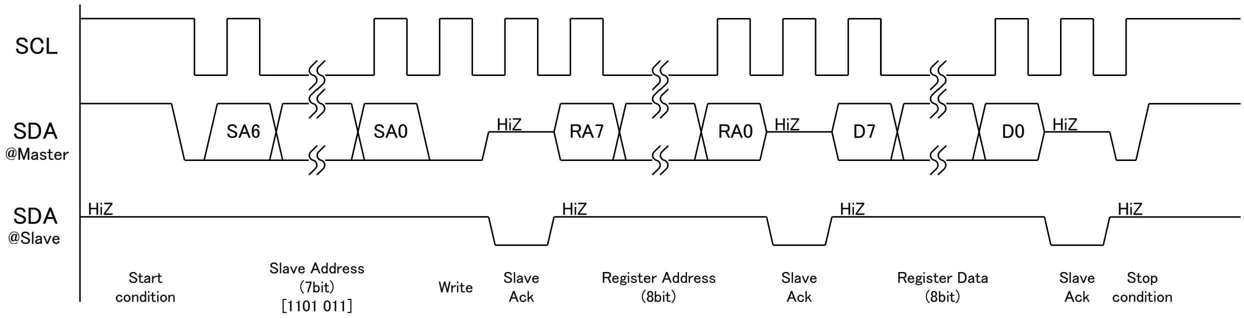


Figure 21. 1byte Data Write

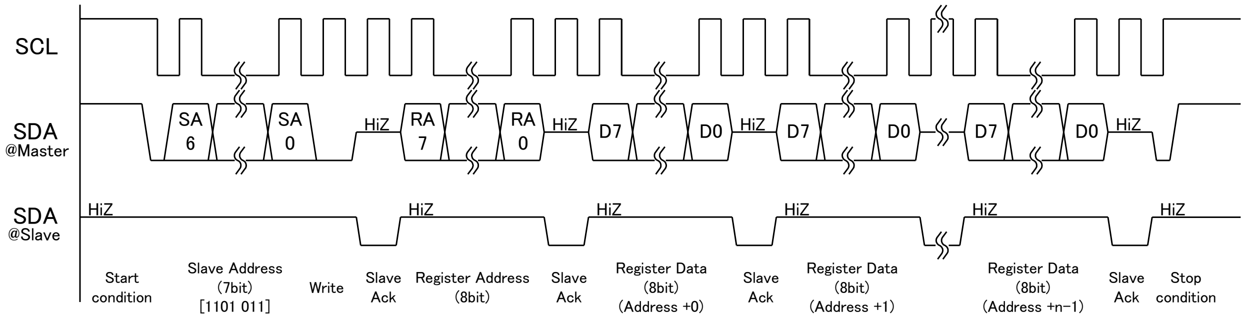


Figure 22. n bytes Data Write

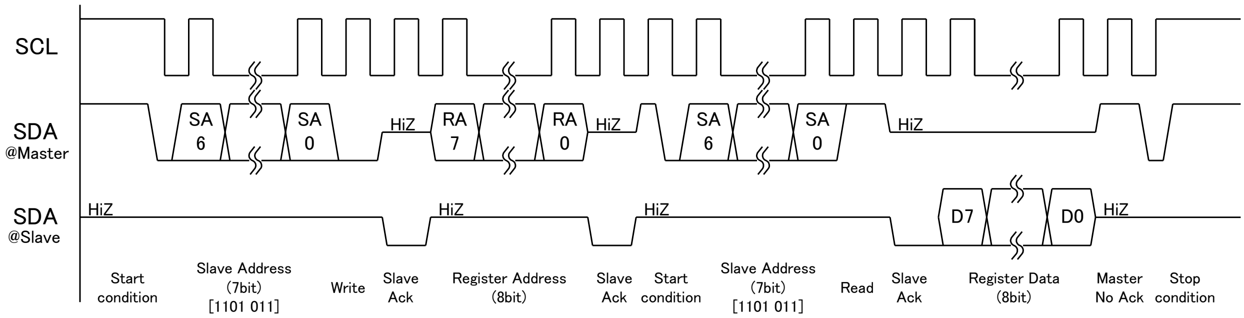


Figure 23. 1byte Data Read

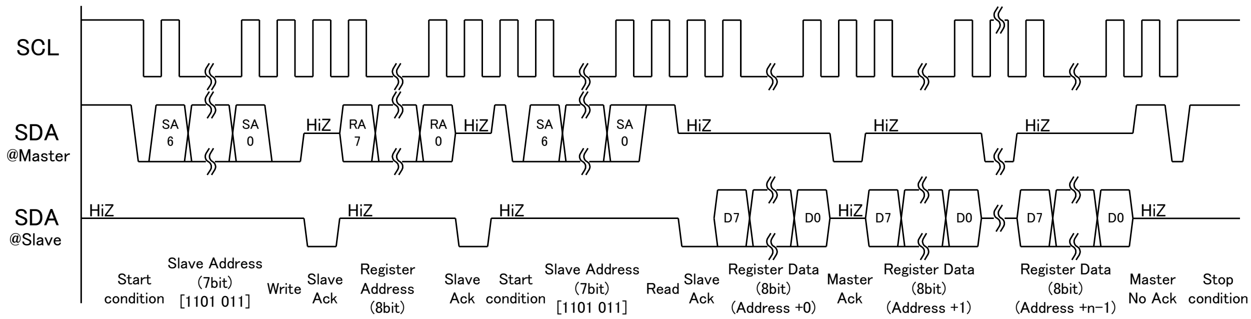


Figure 24. n bytes Data Read

8-8-2. I²C Register MAP

<table>
<tr><th colspan="2"></th><th>b07</th><th>b06</th><th>b05</th><th>b04</th><th>b03</th><th>b02</th><th>b01</th><th>b00</th></tr>
<tr><td colspan="2">Slave Address</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>R = 1
W = 0</td></tr>
<tr><td rowspan="11">Register Address</td><td>00h</td><td>EN_HIZ</td><td colspan="4">VINDPM[3:0]</td><td colspan="3">IINDPM[2:0]</td></tr>
<tr><td>01h</td><td>I2C Reset</td><td>WDT Reset</td><td colspan="2">CHG_CONFIG[1:0]</td><td colspan="3">SYS_MIN[2:0]</td><td>BOOST_LIM</td></tr>
<tr><td>02h</td><td colspan="6">ICHG[5:0]</td><td></td><td>50PCT</td></tr>
<tr><td>03h</td><td colspan="4">IPRECHG[3:0]</td><td colspan="4">ITERM[3:0]</td></tr>
<tr><td>04h</td><td colspan="6">BATTREG[5:0]</td><td>BATTLOWV</td><td>RECHG</td></tr>
<tr><td>05h</td><td>EN_TERM</td><td>TERM_STAT</td><td colspan="2">WATCHDOG[1:0]</td><td>EN_TIMER</td><td colspan="2">CHG_TIMER[1:0]</td><td></td></tr>
<tr><td>06h</td><td colspan="3">BATT_RES[2:0]</td><td colspan="3">BATT_VCLAMP[2:0]</td><td colspan="2">TREG[1:0]</td></tr>
<tr><td>07h</td><td>DPDM_EN</td><td>TMR2X_EN</td><td>BATTFET_
Disable</td><td></td><td></td><td></td><td colspan="2">INT_MASK[1:0]</td></tr>
<tr><td>08h</td><td colspan="2">VIN_STAT[1:0]</td><td colspan="2">CHG_STAT[1:0]</td><td>DPM_STAT</td><td>PG_STAT</td><td>THERM_
STAT</td><td>VSYS_STAT</td></tr>
<tr><td>09h</td><td>WD_FAULT</td><td>BOOST_
FAULT</td><td colspan="2">CHG_FAULT[1:0]</td><td>BATT_FAULT</td><td colspan="3">NTC_FAULT[2:0]</td></tr>
<tr><td>0Ah</td><td></td><td></td><td colspan="6">PN[5:0]</td></tr>
</table>

Register Address 00h~07h : Readable and Writable
Register Address 08h~0Ah : Read Only (Write data is ignored)

8-8-3. I²C Register Description

Register Address 00h (REG00)

R/W	EN_HIZ	
00h	b07	Status
default	0	Disable
	1	Enable

R/W	IINDPM[2:0]			
00h	b02	b01	b00	mA
	0	0	0	100
	0	0	1	150
	0	1	0	500
	0	1	1	900
	1	0	0	1200
	1	0	1	1500
	1	1	0	2000
	1	1	1	3000

R/W	VINDPM[3:0]				
00h	b06	b05	b04	b03	V
default	0	0	0	0	3.88
	0	0	0	1	3.96
	0	0	1	0	4.04
	0	0	1	1	4.12
	0	1	0	0	4.20
	0	1	0	1	4.28
	0	1	1	0	4.36
	0	1	1	1	4.44
	1	0	0	0	4.52
	1	0	0	1	4.60
	1	0	1	0	4.68
	1	0	1	1	4.76
	1	1	0	0	4.84
	1	1	0	1	4.92
	1	1	1	0	5.00
	1	1	1	1	5.08

Register Address 01h (REG01)

R/W	I2C Reset	
01h	b07	Status
default	0	Keep current
	1	Reset to default

R/W	WDT Reset	
01h	b06	Status
default	0	Normal
	1	Reset WDT

R/W	CHG_CONFIG[1:0]		
01h	b05	b04	Status
	0	0	Charge Disable
default	0	1	Charge Battery
	1	0	OTG
	1	1	OTG

R/W	SYS_MIN[2:0]			
01h	b03	b02	b01	V
	0	0	0	3.0
	0	0	1	3.1
	0	1	0	3.2
	0	1	1	3.3
	1	0	0	3.4
default	1	0	1	3.5
	1	1	0	3.6
	1	1	1	3.7

R/W	BOOST_LIM	
01h	b00	mA
	0	500
default	1	1300

Register Address 02h (REG02)

R/W	ICHG[5:0]						
02h	b07	b06	b05	b04	b03	b02	mA
	0	0	0	0	0	0	512 ~ 4544 mA (64mA step)
	~						
	1	1	1	1	1	1	
default	0	0	0	1	0	1	832 mA

R/W	50PCT	
02h	b00	Status
default	0	ICHG
	1	50% of ICHG

Register Address 03h (REG03)

R/W	IPRECHG[3:0]				
03h	b07	b06	b05	b04	mA
	0	0	0	0	128
default	0	0	0	1	256
	0	0	1	0	384
	0	0	1	1	512
	0	1	0	0	640
	0	1	0	1	768
	0	1	1	0	896
	0	1	1	1	1024
	1	0	0	0	1152
	1	0	0	1	1280
	1	0	1	0	1408
	1	0	1	1	1536
	1	1	0	0	1664
	1	1	0	1	1792
	1	1	1	0	1920
	1	1	1	1	2048

R/W	ITERM[3:0]				
03h	b03	b02	b01	b00	mA
	0	0	0	0	128
default	0	0	0	1	256
	0	0	1	0	384
	0	0	1	1	512
	0	1	0	0	640
	0	1	0	1	768
	0	1	1	0	896
	0	1	1	1	1024
	1	0	0	0	1152
	1	0	0	1	1280
	1	0	1	0	1408
	1	0	1	1	1536
	1	1	0	0	1664
	1	1	0	1	1792
	1	1	1	0	1920
	1	1	1	1	2048

Register Address 04h (REG04)

R/W	BATTREG[5:0]						
04h	b07	b06	b05	b04	b03	b02	V
	0	0	0	0	0	0	3.504 ~ 4.400 V (16mV step)
	~						
	1	1	1	0	0	0	
	1	1	1	0	0	1	Ignored
	1	1	1	0	1	0	Ignored
	1	1	1	0	1	1	Ignored
	1	1	1	1	0	0	Ignored
	1	1	1	1	0	1	Ignored
	1	1	1	1	1	0	Ignored
	1	1	1	1	1	1	Ignored
default	1	1	0	0	1	0	4.304 V

R/W	BATTLOWV	
04h	b01	V
	0	2.8
default	1	3.0

R/W	RECHG	
04h	b00	mV
default	0	Disable
	1	300

Register Address 05h (REG05)

R/W	EN_TERM	
05h	b07	Status
	0	Disable
default	1	Enable

R/W	TERM_STAT	
05h	b06	Status
default	0	Match ITERM
	1	Below 800mA

R/W	WATCHDOG[1:0]		
05h	b05	b04	sec
	0	0	Disable
default	0	1	40
	1	0	80
	1	1	160

R/W	EN_TIMER	
05h	b03	Status
	0	Disable
default	1	Enable

R/W	CHG_TIMER[1:0]		
05h	b02	b01	hours
	0	0	5
default	0	1	8
	1	0	12
	1	1	20

Register Address 06h (REG06)

R/W	BATT_RES[2:0]			
06h	b07	b06	b05	mohm
default	0	0	0	0
	0	0	1	10
	0	1	0	20
	0	1	1	30
	1	0	0	40
	1	0	1	50
	1	1	0	60
	1	1	1	70

R/W	BATT_VCLAMP[2:0]			
06h	b04	b03	b02	mV
default	0	0	0	0
	0	0	1	16
	0	1	0	32
	0	1	1	48
	1	0	0	64
	1	0	1	80
	1	1	0	96
	1	1	1	112

R/W	TREG[1:0]		
06h	b01	b00	°C
	0	0	60
	0	1	80
	1	0	100
default	1	1	120

Register Address 07h (REG07)

R/W	DPDM_EN	
07h	b07	Status
default	0	Not in detection
	1	Force detection

R/W	TMR2X_EN	
07h	b06	Status
	0	Disable
default	1	Enable

R/W	BATTFET_Disable	
07h	b05	Status
default	0	Allow BATTFET turn on
	1	Turn off BATTFET

R/W	INT_MASK[1]	
07h	b01	Status
	0	No INT during CHG_FAULT
default	1	INT on CHG_FAULT

R/W	INT_MASK[0]	
07h	b00	Status
	0	No INT during BATT_FAULT
default	1	INT on BATT_FAULT

Register Address 08h (REG08)

R	VIN_STAT[1:0]		
08h	b07	b06	Status
	0	0	Unknown
	0	1	USB host
	1	0	Adapter port
	1	1	OTG

R	CHG_STAT[1:0]		
08h	b05	b04	Status
	0	0	Not Charging
	0	1	Pre-charge
	1	0	Fast Charging
	1	1	Charge Done

R	DPM_STAT	
08h	b03	Status
	0	Not in DPM
	1	In VINDPM or IINDPM

R	PG_STAT	
08h	b02	Status
	0	Not Power Good
	1	Power Good

R	THERM_STAT	
08h	b01	Status
	0	Normal
	1	In Thermal regulation

R	VSYS_STAT	
08h	b00	Status
	0	Not in VSYSMIN regulation
	1	In VSYSMIN regulation

Register Address 09h (REG09)

R	WD_FAULT	
09h	b07	Status
	0	Normal
	1	Watchdog timer expiration

R	BOOST_FAULT	
09h	b06	Status
	0	Normal
	1	VIN OCP or OVP

R	CHG_FAULT[1:0]		
09h	b05	b04	Status
	0	0	Normal
	0	1	Input fault
	1	0	Thermal shutdown
	1	1	Safety timer expiration

R	BATT_FAULT	
09h	b03	Status
	0	Normal
	1	BATTOVP

R	NTC_FAULT[2:0]				
09h	b02	b01	b00	JEITA	Cold/Hot
	0	0	0	Normal	Normal
	0	0	1	N/A	Cold
	0	1	0	N/A	Hot
	0	1	1	Cool	N/A
	1	0	0	Warm	N/A
	1	0	1	Cold	N/A
	1	1	0	Hot	N/A
	1	1	1	N/A	N/A

Register Address 0Ah (REG0A)

R/W	PN[5:0]						
0Ah	b05	b04	b03	b02	b01	b00	-
	0	1	1	0	0	1	MM3659C

9. Typical Application Circuit

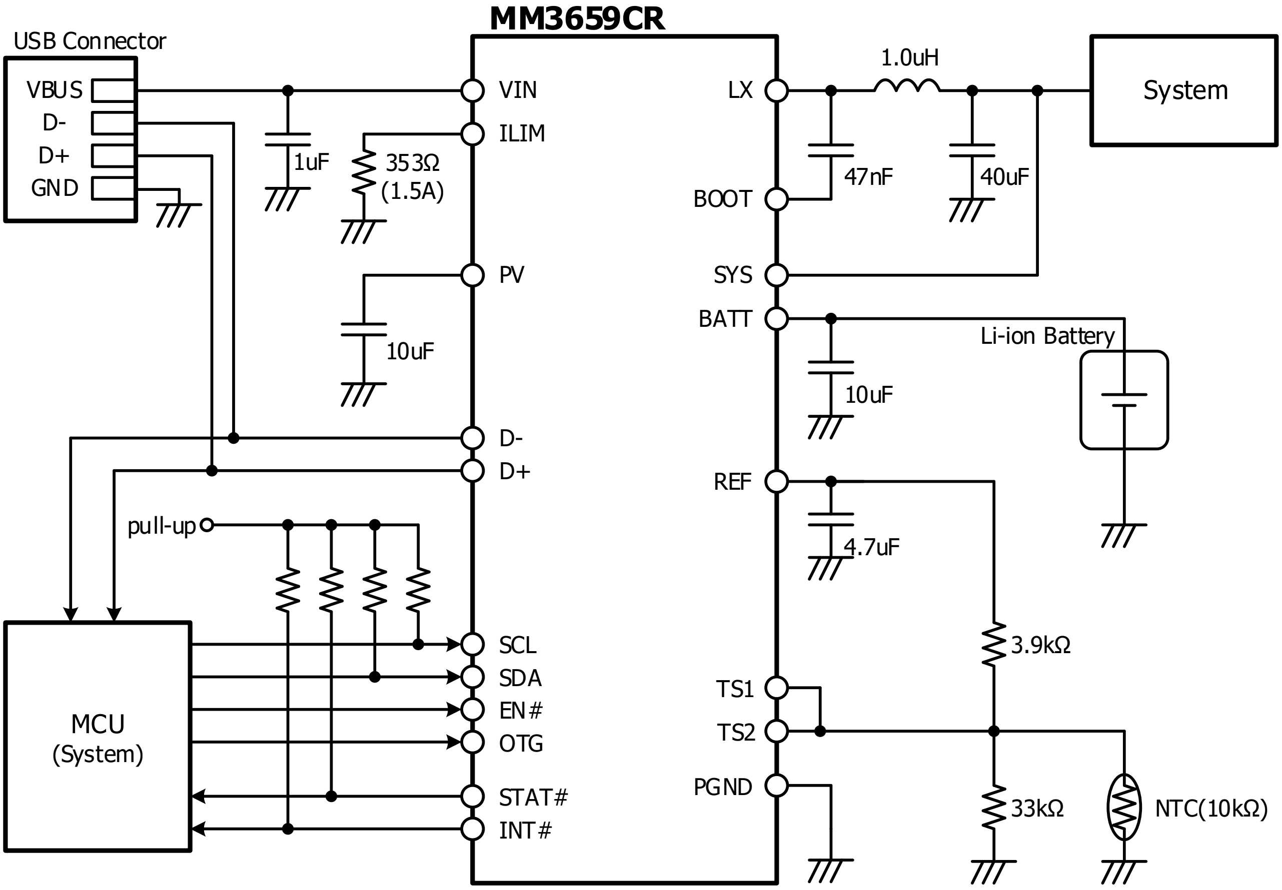


Figure 25. Typical application circuit

These circuits are typical examples provided for reference purposes, so in actual applications, the circuit constants, conditions and operations should be thoroughly studied. Mitsumi Electric Co., Ltd. assumes no responsibility for any trouble or damage as a result of the use of these circuits. Mitsumi Electric Co., Ltd. assumes no responsibility for any infringement of industrial property or any other right of a third party or us, as a result of the use of these circuits.