

33V withstand Voltage, Maximum Power Point Tracking (MPPT) for Solar Panels, Zero Power Ship Mode, Power Path Management, 1.5A Linear Single-cell Lithium Battery Charging Management IC

General Description

IU5070E is a linear charger for single-cell lithium-ion batteries with the Maximum Power Point Tracking (MPPT) function for solar panels. It supports a maximum charging current of 1.5A and also supports unregulated adapters. Meanwhile, the input current limit accuracy and startup sequence enable this chip to comply with the USB-IF inrush current specification.

IU5070E has the Dynamic Power Path Management (DPPM) function, which can charge the battery independently while powering the system. When the system output drops to the DPPM threshold due to the input current limit, the DPPM circuit will reduce the charging current. When IU5070E is powered by a solar panel, the internal circuit can automatically track the maximum power point of the solar panel. Users don't need to consider the worst-case scenario, and it can maximize the output power of the solar panel, making it highly suitable for applications powered by solar panels.

IU5070E has complete protection functions, including input under-voltage and over-voltage protection, output under-voltage and over-voltage protection, chip temperature regulation and protection, charging timeout protection, battery over-voltage and short-circuit protection, and battery temperature protection. In addition, through two external LED indicators, the chip can monitor the entire charging process.

Features

- Zero Power Ship Mode
- Operating Voltage: 3.6V~8.6V, 33V Over Voltage Protection
- Fully Comply with USB Charger Standard Maximum Power Point Tracking (MPPT) Function for Solar Panels
- The Effective Charging Current Can Be As Low As 1mA@Tracking MPPT
- Programmable Input Current Limit up to 1.5A for Wall Chargers
- Supports External Programming up to 1.5A Charging Current
- The integrated Dynamic Power Path Management (DPPM) Function, Independently Supply Power to System and Charge Battery Simultaneously
- NTC Function
- Programmable Charging Timeout Safety Timer
- Special Starting Sequence Can Limit Surge Current
- Support Dual LED Charge Status Indication

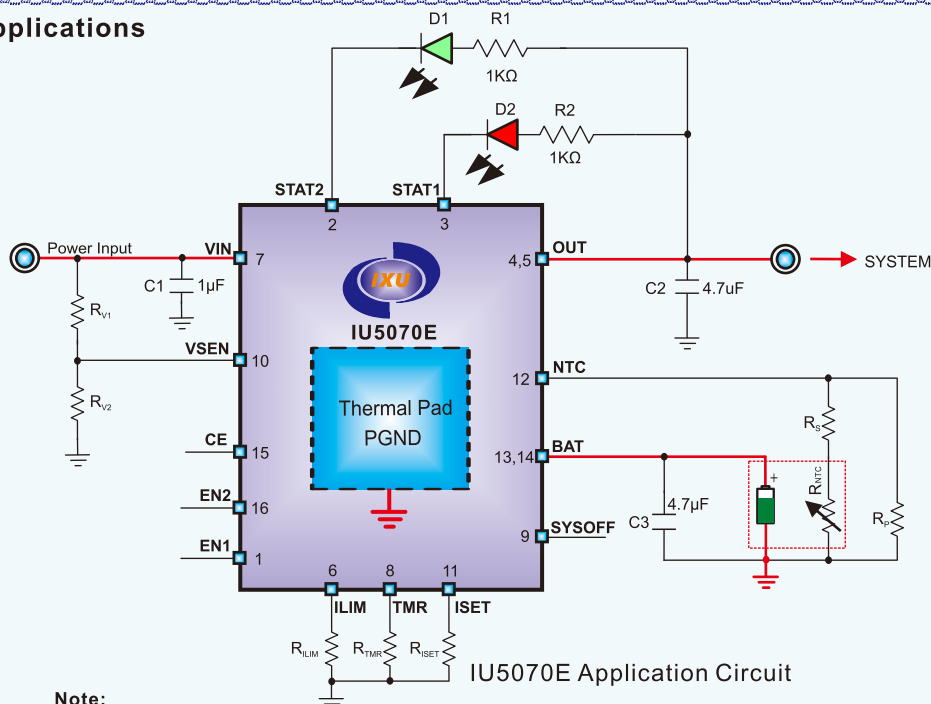
Applications

- Bluetooth Speakers
- POS Machine
- Headset
- Lithium Battery Pack
- Low Power Handheld
- Charge with Solar Panel

Package

- EQA16

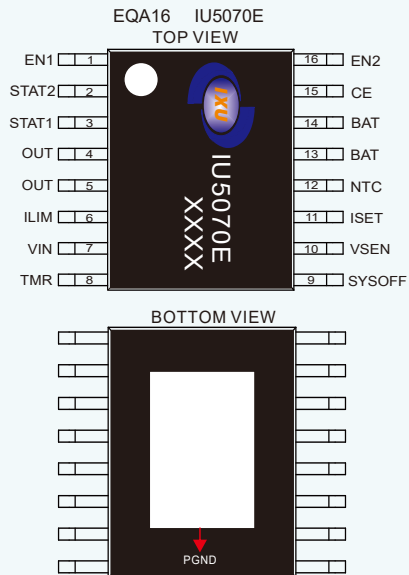
Typical Applications



Note:

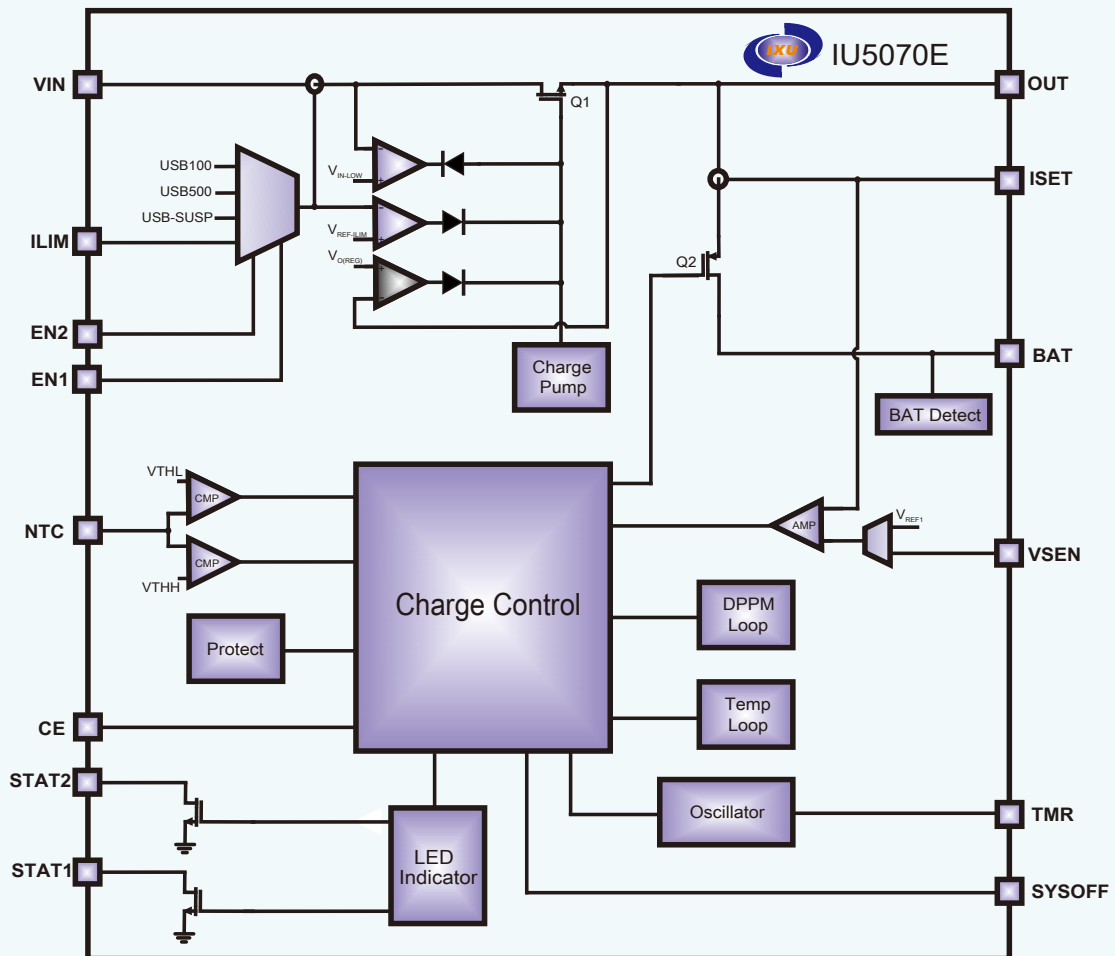
- (1) All surface-mounted capacitors should be laid out as close as possible to the pins of the chip.
- (2) The red solid line in the figure represents the path for large current flow.

PIN Configuration and Functions



PIN	NAME	TYPE	DESCRIPTION
1	EN1	I	Input current limit and chip enable select port 1
2	STAT2	O	Charge state indication port
3	STAT1	O	Charge state indication port
4,5	OUT	O	System power output
6	ILIM	I	Programmable input current setting port
7	VIN	P	Input power
8	TMR	I	Programmable control port for charging timeout
9	SYSOFF	I	Shipmode enable control port
10	VSEN	I	VIN voltage detection and the pin for maximum power point tracking of the solar panel
11	ISET	I/O	Programmable charging current setting port
12	NTC	I	The input terminal of the thermistor
13,14	BAT	I/O	Battery connection terminal
15	CE	I	Charging enable port
16	EN2	I	Input current limit and chip enable port 2
Thermal PAD	GND	-	Chip ground

Functional Block Diagram



Absolute Maximum Ratings ¹

SYMBOL	PARAMETER	VALUE	UNIT
V _{MAX}	V _{IN}	-0.3~33	V
	Others	-0.3~7	V
T _J	Junction operating temperature range	-40~150	°C
T _{STG}	Storage temperature range	-55~150	°C
T _{SDR}	Lead temperature (Soldering, 10 sec.)	260	°C

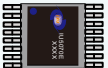
Recommended Operating Conditions

SYMBOL	PARAMETER	VALUE	UNIT
V _{IN}	Input voltage	3.6~8	V
T _J	Junction operating temperature range	-40~125	°C
T _A	Ambient temperature range	-40~85	°C

Thermal Information ²

SYMBOL	PARAMETER	VALUE	UNIT
θ _{JA}	Package thermal resistance - chip to environment thermal resistance	45	°C/W

Ordering Information

Device	Package	Making	Reel Size	Tape Width	Quantity
IU5070E	EQA16		13"	12mm	4000 units

ESD Range

HBM (Human Body Model) ----- ±2kV

MM (Machine model) ----- ±200V

1. The above parameters are only the limit values of device operation. It is not recommended that the working conditions of the device exceed the limit values. Otherwise, the reliability and life of the device will be affected, and even permanent damage will be caused.

2. Where the PCB board is placed in IU5070E, a heat dissipation design is needed. The heat sink at the bottom of IU5070E is connected with the heat sink area of PCB board.

Electrical Characteristics ($V_{IN}=5V$, unless otherwise specified)

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input Voltage						
V _{IN}	Supply voltage		3.6		8	V
V _{IN(UVLO)}	VIN under voltage lockout threshold	VIN falling		3.6		V
ΔV _{IN(UVLO)}	VIN under voltage lockout hysteresis			200		mV
V _{IN(OVP)}	VIN over voltage protection	VIN rising		8.6		V
ΔV _{IN(OVP)}	VIN over voltage protection hysteresis			400		mV
V _{ACOK}	ACOK voltage threshold	VIN rising, V _{IN} -V _{BAT}		100		mV
ΔV _{ACOK}	ACOK voltage threshold			40		mV
Quiescent Current						
I _Q	quiescent current	V _{IN} =5V, V _{EN2} ,V _{EN1} =HI,HI		850		μA
I _{IN}	standby input current	V _{IN} =5V, V _{EN2} ,V _{EN1} =HI,HI		500		μA
I _{BAT}	Battery leakage current	V _{IN} =5V, V _{BAT} =4.2 V		9		μA
		NO V _{IN} , V _{BAT} =4.2 V		7		μA
Path Management						
V _{DO1}	V _{IN} -V _{OUT}	I _{IN} =1A, V _{IN} =5 V		300		mV
R _{DSON}	Conduction impedance of path tube	V _{BAT} >3 V		90		mΩ
V _{O(REG)}	Output voltage of out terminal	V _{IN} > V _{OUT} + V _{DO1} , V _{BAT} <3.2V		3.4		V
		V _{IN} > V _{OUT} + V _{DO1} , V _{BAT} ≥3.2V		V _{BAT} +0.2		
		V _{IN} > V _{OUT} + V _{DO1} , The battery is full		4.5		
I _{IN(MAX)}	Maximum input limiting current	EN2=LO, EN1=LO		100		mA
		EN2=LO, EN1=HI		500		mA
		EN2=HI, EN1=LO		K _{ILIM} /R _{LILIM}		A

Electrical Characteristics ($V_{IN}=5V$, unless otherwise specified)

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
K_{ILIM}	Maximum input current limiting factor	$I_{LIMIT}=0.2A$ to $1.5A$		415		$A\Omega$
V_{VSEN}	The modulation voltage of the VSEN pin			1		V
V_{DPPM}	Dynamic path management output voltage threshold			$V_{BAT}+0.1$		V
V_{BSUP}	Discharge voltage threshold of battery to output terminal	$V_{BAT}=3.6V$		$V_{OUT}\leq V_{BAT}$ -40mV		V
ΔV_{BSUP}	Voltage hysteresis of battery discharging to output terminal	$V_{BAT}=3.6V$		20		mV
$I_{DISC-MAX}$	Battery over discharge protection current	$V_{BAT}=3.6V$		5		A
$V_{O(SCP)}$	Output short circuit protection threshold	V_{OUT} falling		0.9		V
$\Delta V_{O(SCP)}$	Output short circuit protection hysteresis			70		mV
$V_{O(OVP)}$	Output overvoltage protection threshold	V_{OUT} rising		6		V
$\Delta V_{O(OVP)}$	Output overvoltage protection hysteresis			150		mV
Battery Charging						
$V_{BAT(SCP)}$	Battery short threshold	V_{BAT} falling		2		V
$V_{BAT(TC)}$	TC charge mode battery voltage threshold	V_{BAT} rising		3		V
$V_{BAT(CV)}$	Terminal battery voltage		4.16	4.2	4.24	V
$V_{BAT(RCH)}$	Recharge voltage threshold	V_{BAT} falling		4.1		V
$V_{BAT(OVP)}$	BAT over voltage threshold	V_{BAT} rising		4.6		V
K_{ISET}	Charge current factor			400		$A\Omega$
I_{TC}	TC charge mode current			$0.1 \cdot I_{CC}$		A

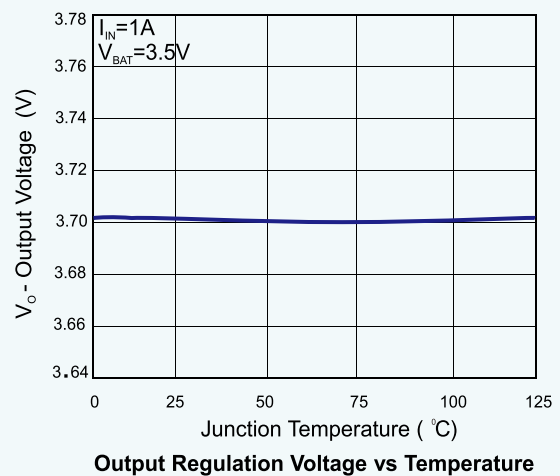
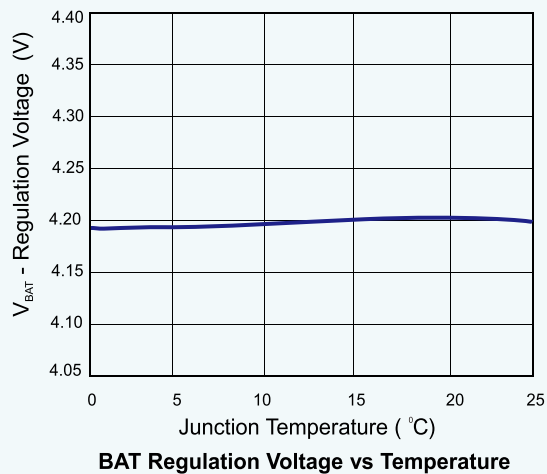
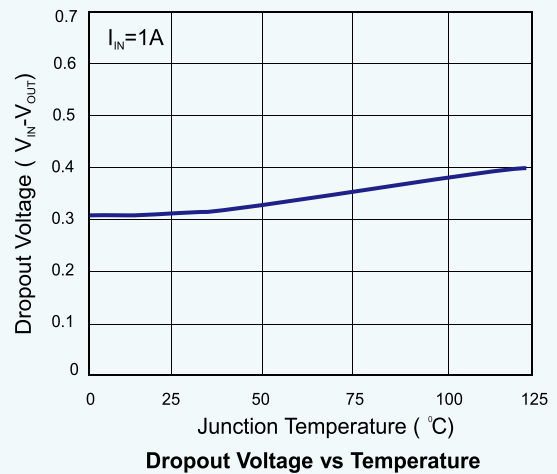
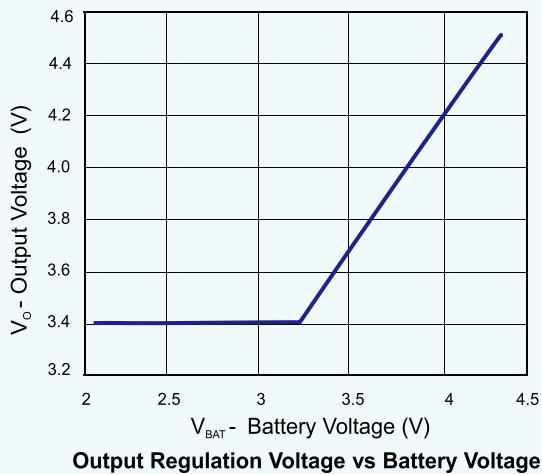
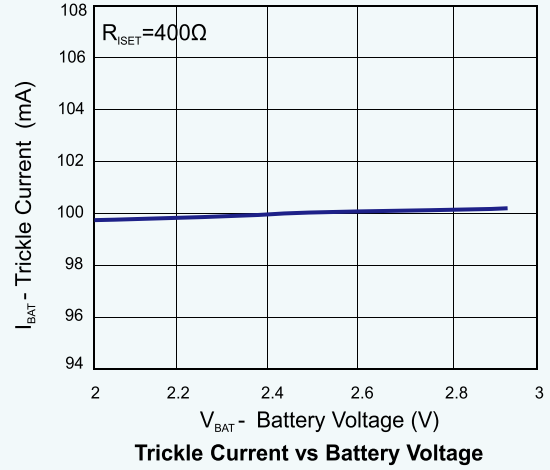
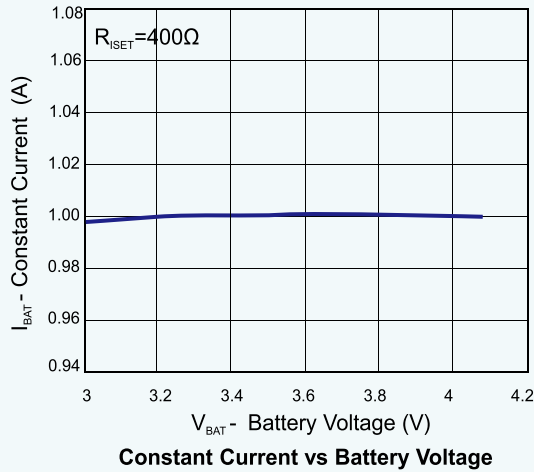
Electrical Characteristics ($V_{IN}=5V$, unless otherwise specified)

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CC}	CC charge mode current	Not DPPM, not high temperature, no load and $I_{IN(MAX)} > I_{CC}$		K_{ISET} / R_{ISET}		A
I_{BF}	Charging termination current	Default not USB100 mode		$0.1 \cdot I_{CC}$		A
		Default USB100 mode		$0.033 \cdot I_{CC}$		
T_{DGL}	Filter time of charging state transition			32		ms
Enable Input						
V_{INH}	Input high-level threshold	EN1,EN2,CE,SYSOFF	1.4			V
V_{INL}	Input low-level threshold	EN1,EN2,CE,SYSOFF			0.4	V
Charging Time						
R_{TMR}	Charging time limit programming resistor		18		75	K Ω
$TMR_{(TC)}$	TC cycle charging time limit	TMR pin floating or connected to high level		0.5		Hour
		TMR pin connected to R_{TMR}	0.22		0.9	
$TMR_{(CC/CV)}$	CC/CV cycle charging time limit	TMR pin floating or connected to high level		4.5		Hour
		TMR pin connected to R_{TMR}	2		8.3	

Electrical Characteristics ($V_{IN}=5V$, unless otherwise specified)

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
NTC Function						
I_{NTC}	NTC output current		47.5	50	52.5	uA
V_{COLD}	NTC terminal low temperature protection threshold	V_{NTC} rising	1.47	1.5	1.53	V
ΔV_{COLD}	NTC terminal low temperature protection hysteresis			30		mV
V_{HOT}	NTC terminal high temperature protection threshold	V_{NTC} falling	0.98	1	1.02	V
ΔV_{HOT}	NTC terminal high temperature protection hysteresis			30		mV
Chip Over Temperature Protection						
$T_{J(REG)}$	Chip thermal regulation temperature			120		°C
$T_{J(OFF)}$	Chip thermal protection temperature	Chip temperature rise		150		°C
$\Delta T_{J(OFF)}$	Temperature hysteresis of chip thermal protection			20		°C

Typical Characteristics ($V_{IN}=5V$, Battery Simulator, $T_A = 25^{\circ}C$, unless otherwise noted.)



IU5070E Application Points

1. Overview

The IU5070E integrates a lithium-ion linear charger and a system power path management, which is suitable for portable devices with limited space. It can independently supply power to the system and charge the battery simultaneously. This function reduces the number of charge-discharge cycles of the battery, enables normal termination of charging, and allows the system to operate when powered by a defective or incomplete battery pack. The input power source for charging can be an AC adapter, a USB port, or a solar panel.

The IU5070E has Dynamic Power Path Management (DPPM), which shares the source current between the system and battery charging. If the system load increases, the charging current will automatically decrease. When the IU5070E is powered by a solar panel, the internal circuit can automatically track the maximum power point of the solar panel. Users do not need to consider the worst-case scenario, and can maximize the output power of the solar panel, making it highly suitable for applications powered by solar panels. The power path system also allows the battery to supplement the system's current requirements when the adapter cannot provide the peak system current.

2. Input overvoltage / undervoltage protection

When the input V_{IN} voltage is lower than the undervoltage locking threshold $V_{IN(UVLO)}$, the chip is in the input undervoltage state. At this time, the linear transistor Q1 is turned off and the path transistor Q2 is turned on. The state indicates that the pins are in the high resistance state. The chip battery discharge over-current comparator continuously detects the discharge current. If the discharge current is too large, Q2 is forced to turn off; If the battery voltage is below the battery undervoltage threshold, Q2 will also be forced off. When the input voltage is higher than the over-voltage threshold $V_{IN(OVP)}$, the chip is in the input over-voltage state, the linear power transistor Q1 is closed, and the charging process is forced to terminate. At the same time, the charging timeout timer is reset, and the state indicate the charging state normally. The charging process will not continue until the input over-voltage state is released. The path tube Q2 is opened, unless the battery is under voltage or over discharged, the path tube Q2 will be forcibly disconnected.

3. Start up Process

If EN2, EN1 = (1,1), the system will enter the standby mode. At this time, the state indicates pins are in the high resistance state, most modules in the chip are in the off state, the linear tube Q1 is off, and the path tube Q2 is on.

When the input voltage $V_{IN(OVP)} > V_{IN} > V_{IN(UVLO)}$, $V_{IN} > V_{BAT} + V_{ACOK}$, and EN2, EN1 $\neq$ (1,1), the system starts normally, and the oscillator and other modules in the chip are in the working state. The system will first force to work in

USB100 mode for about 9ms to prevent the impact of surge current, and then enter the normal working mode. The chip continuously detects the states of EN1, EN2 and CE ports, The working mode of Q1 and Q2 is determined by the current set by ISET and ILIM ports and the load of out end. If the port CE is low or floating, it is allowed to charge the battery; If CE is high, it is forbidden to charge the battery.

4. Input limiting Current Setting

The input current limit can be easily selected through pins EN1 and EN2:

EN2	EN1	Maximum Input Current (V_{IN} PIN)
0	0	100mA USB100 mode
0	1	500mA USB500 mode
1	0	External programmable, set by the resistor R_{ILIM} from Ilim pin to ground
1	1	Standby USBsuspend mode

When the input current limit is in the programmable mode, the current limit value can be set by reasonably selecting the ILIM terminal resistance R_{ILIM} . The relationship between the $I_{IN(MAX)}$ and the R_{ILIM} is determined by the following formula:

$$I_{IN(MAX)} = K_{ILIM} / R_{ILIM}$$

Where $K_{ILIM} = 415A\Omega$, The value range of R_{ILIM} is $270\Omega \sim 2.2K\Omega$, The corresponding programmable input limiting current range is 0.2A ~ 1.5A.

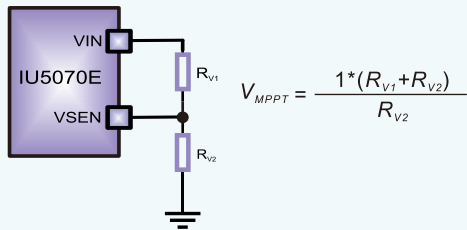
5. Maximum Power Point Tracking (MPPT) Function of The Solar Panel

When the chip is operating normally, the system continuously monitors the input V_{IN} voltage. If the input current limit value is set too high and the input voltage keeps decreasing to the point where V_{SEN} is very close to V_{VSEN} , the system will enter the input voltage dynamic path management mode. In this mode, the battery charging termination function is disabled, and the input current limit value will be continuously reduced to stabilize the input voltage at V_{MPPT} . This function can effectively prevent the adapter from being over-loaded under improper conditions.

In the volt - ampere characteristic curve of a solar panel, when the ambient temperature is constant, at different sunlight intensities, the output voltage corresponding to the maximum output power point is basically the same. That is to say, as long as the output voltage of the solar panel is maintained at a constant voltage, it can be ensured that the solar panel outputs the maximum power at different light intensities under this temperature. Based on the above principle, by using the input adaptive function, the chip uses the solar panel as the input. According to the characteristics of different solar panels, the constant - voltage method is used to track the maximum power point of the solar panel, thereby

maximizing the utilization of the output power of the solar panel.

When the voltage at the VSEN pin of the maximum power point tracking terminal of the IU5070E solar panel is modulated to 1V, the effective charging current can be as low as 1mA (on rainy or cloudy days). By selecting two resistors, R_{V1} and R_{V2} , the lowest value V_{MPPT} to which the input voltage can be reduced is determined. The specific calculation formula is as follows:



If this function is disabled, a resistor with a resistance value of more than 100KΩ needs to be connected in series to this pin, and then connected to VIN.

6. Load Dynamic Path Management

When the sum of load current and charging current is greater than the limit value of input current, the output voltage of out terminal will decrease. When $V_{OUT} < V_{DPPM}$, the system will enter the load dynamic path management mode. In this mode, the battery charging termination function is disabled, and the charging current will automatically decrease to give priority to the power supply output of the out end load. When the charging current is reduced to zero and still can not meet the load demand, the out terminal voltage will continue to decrease until $V_{OUT} < V_{BUSB}$. If the battery voltage is greater than the battery under voltage threshold, the path tube Q2 will be fully opened, and then the battery and the input will supply power to the load at the same time.

In order to prevent excessive discharge current of the battery, when $I_{DISC} > 5A$, the path tube Q2 will be forced to turn off for about 50ms and then turn on again. If the discharge over-current state is released, it will return to normal operation. If the discharge over-current state still exists, the previous protection mode will be repeated, and it will be forced to turn off for about 50ms and then turn on again (burping mode). Similarly, when the input VIN does not exist, the out load side can only rely on battery power supply, and the battery discharge conditions and protection mechanism are the same as above.

7. Battery Charging Current Setting

When the battery voltage $V_{BAT} < V_{BAT(SCP)}$, the battery is in short circuit state, and the charging current is $0.5 * I_{TC}$; When the battery voltage $V_{BAT(SCP)} \leq V_{BAT} < V_{BAT(TC)}$, it is in trickle charging state and the charging current is I_{TC} ; When the battery voltage $V_{BAT} \geq V_{BAT(TC)}$, the battery is in trickle charging state and the charging current is I_{TC} ; When the battery voltage $V_{BAT} \geq V_{BAT(TC)}$, the battery is in

constant current charging state and the charging current is I_{CC} ; When the battery voltage gradually increases to $V_{BAT(CV)}$, the battery is in constant voltage charging mode, and then the charging current decreases until the charging current is less than I_{BF} . When the battery voltage drops below the recharging voltage $V_{BAT(RCH)}$ due to battery self discharge or power supply to the load, the system will restart the charging process. The constant current charging current I_{CC} can be set by reasonably selecting the resistance value R_{ISET} at Iset terminal. The relationship between constant current charging current I_{CC} and resistance R_{ISET} is determined by the following formula:

$$I_{CC} = K_{ISET} / R_{ISET}$$

And the trickle charging current is:

$$I_{TC} = 0.1 * I_{CC}$$

Where $K_{ISET} = 400A\Omega$, The range of R_{ISET} is 267Ω ~ 1KΩ, The corresponding programmable constant current charging current range is 0.4A ~ 1.5A.

8. Charging Termination Current Setting

When the system is in the non-USB100 mode, the internally fixed charge termination current I_{BF} is selected as $I_{BF} = 0.1 * I_{CC}$;

When the system is in the USB100 mode, the charge termination current $I_{BF} = 0.033 * I_{CC}$.

Note that when the system is in the Load Dynamic Power Path Management mode (DPPM), the temperature regulation mode, and the Input Power Dynamic Power Path Management mode, the charge termination function will be blocked.

9. Maximum Charging Time Setting

In order to prevent long charging time caused by battery damage or other reasons, the chip has built-in maximum trickle charging time limit function and constant current and constant voltage charging time limit function.

When the pin TMR is grounded, the maximum charging time limit function is disabled.

When the TMR of the pin is floating or connected to high level, select the internal fixed maximum charging time:

$$TMR_{(TC)} = 0.5 \text{ Hour}$$

$$TMR_{(CC+CV)} = 4.5 \text{ Hour}$$

When the TMR pin is attached 18KΩ~75KΩ resistance R_{TMR} , the maximum charging time can be set externally. The specific range is:

$$TMR_{(TC)} : 0.22 \text{ Hour} \sim 0.9 \text{ Hour}$$

$$TMR_{(CC+CV)} : 2 \text{ Hour} \sim 8.3 \text{ Hour}$$

The relationship between the maximum charging time and the resistance R_{TMR} is determined by the following formula:

$$TMR_{(TC)} = 12 * R_{TMR} / 1000 \text{ (Hour)}$$

$$TMR_{(CC+CV)} = 111 * R_{TMR} / 1000$$

(Hour)

When the system is in the dynamic power path management (DPPM) mode and temperature adjustment mode, the maximum charging time automatically doubles;

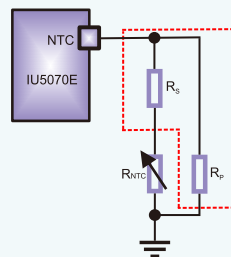
The timer will reset automatically when the system is

powered on again or when the input overvoltage, CE state change or chip enabled state change. Timing pauses when the chip is in the overtemperature protection state, and continues after the overtemperature state is released.

10. NTC Resistor Setting

The chip supports the NTC protection function during battery charging. It detects the battery temperature through the NTC pin, and its specific application is shown in the following figure. When the detected temperature exceeds the set window value, the system will stop charging. Its working mode is to output a constant current of 50 μ A from the NTC pin. The NTC pin is externally connected to a resistor network to the ground. The temperature range of the battery is judged by the voltage drop generated by this current on the resistor network. The internal judgment point for too low a temperature is 1.5V, and that for too high a temperature is 1V.

If the NTC function is not needed, this pin needs to be left floating.



11. Protection Functions

In addition to the input over-voltage protection, charging over-time protection and NTC protection described above, the chip also has the following protection functions: chip temperature regulation and over-temperature protection, output OUT short circuit and over-voltage protection, battery under-voltage and over-voltage protection, as described below:

- (1) When the chip temperature reaches $T_{J(REG)}$, the chip temperature is adjusted and the chip temperature is stabilized at $T_{J(REG)}$ by continuously reducing the charging current; If the chip temperature continues to rise to $T_{J(OFF)}$ for other reasons, the overtemperature protection function starts and the chip stops charging until the temperature drops $\Delta T_{J(OFF)}$ will be unprotected.
- (2) When the output OUT voltage is lower than $V_{O(SCP)}$, the output short-circuit protection function starts, the battery charging function is prohibited, and the input current is limited to 100mA; When the output OUT voltage is higher than $V_{O(OVP)}$, the output overvoltage protection function is activated, the battery charging function is prohibited, and the linear tube Q1 is forcibly switched off.
- (3) When the BAT terminal voltage of the battery is lower than $V_{BAT(SCP)}$, triggering the battery short-circuit protection function, the battery charging current is reduced to half of the trickle value I_{TC} ; When the BAT

terminal voltage of the battery is greater than $V_{BAT(OVP)}$, triggering the output overvoltage protection function, the battery charging function is prohibited, and the linear tube Q1 can still supply power to the load normally.

12. Charge Indication Function

- (1) Charging process:
STAT2 port LED light is off;
STAT1 port LED lights are always on.
- (2) Charging complete:
STAT2 port LED lights are always on;
STAT1 port LED lights are off.
- (3) In the case of battery short circuit, battery overvoltage, abnormal battery temperature, charging timeout, two port LED lights flash alternately at 1.5Hz frequency.
- (4) When the input VIN end is under-voltage, CE prohibits chip charging at high level, and the chip is in standby mode, the two ports of LED lights are completely off.
- (5) If no battery is detected after the system is powered on, the two LED lights will alternately blink and become fully charged.

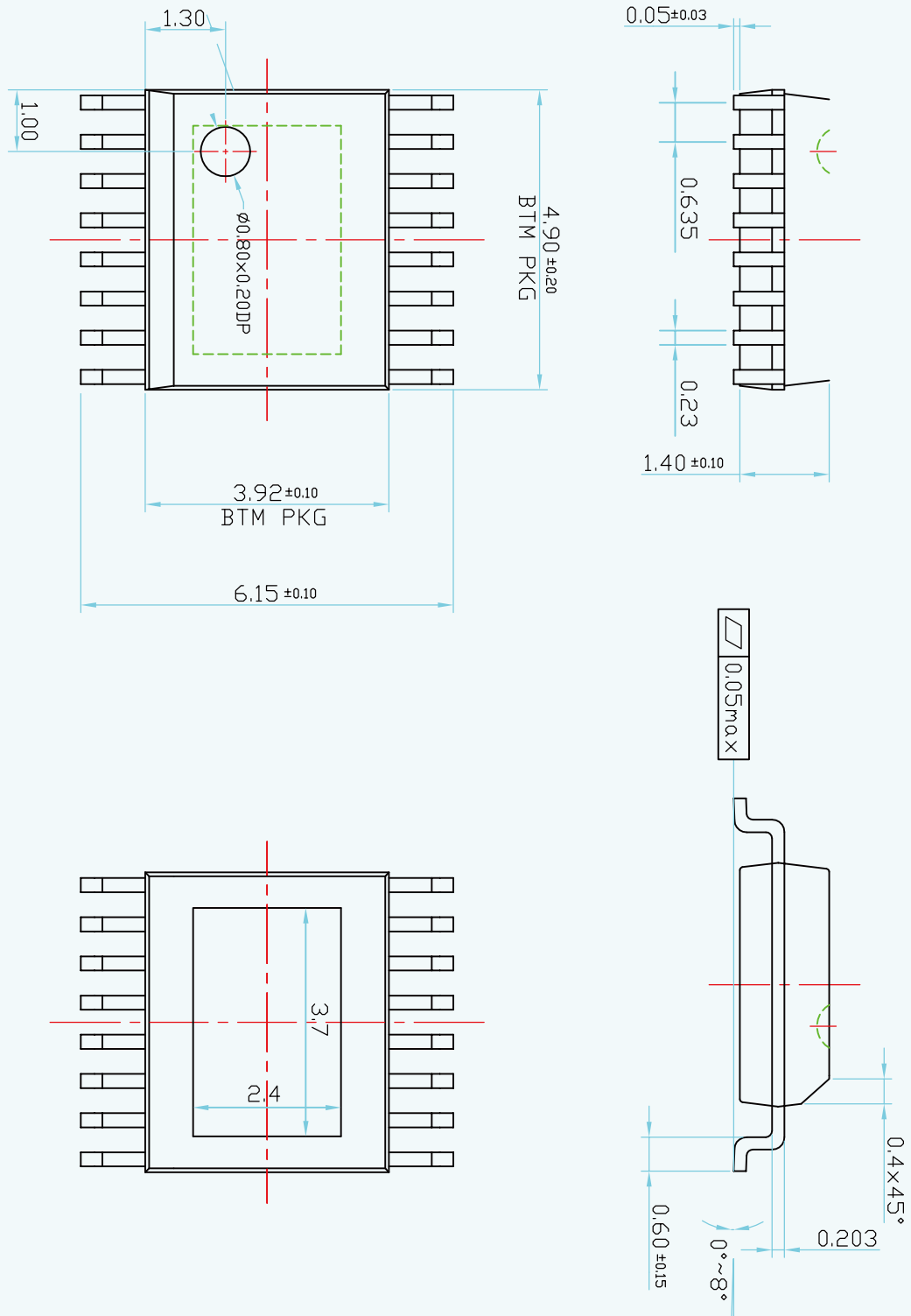
13. Zero Leakage Current Ship Mode

In practical applications, batteries are often not removable. To prevent battery leakage during transportation, SYSOFF pin are specially set up on the chip to start zero leakage current ship mode. The mode works as follows:

- (1) If no input VIN exists, the route tube Q2 is open. Pull the SYSOFF pin to a low level, and the low level lasts longer than 8s before it becomes floating. Q2 will be shut down, forcing the battery and load to be disconnected, entering the zero leakage current ship mode, and the battery will hardly leak from the BAT pin of the chip.
- (2) When the system is already in zero leakage current ship mode, pull the SYSOFF pin to the low level again, and the low level lasts longer than 2s; Or enter power on and satisfy $V_{IN} > V_{BAT} + V_{ACOK}$, both cases can exit zero power mode.
- (3) If the SYSOFF pin keeps floating, the system will not enter the zero leakage current ship mode.

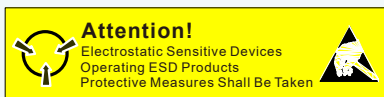
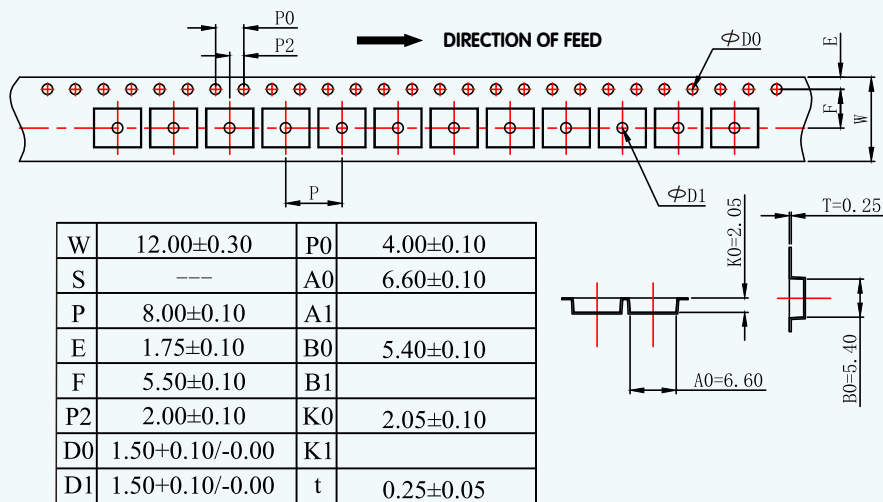
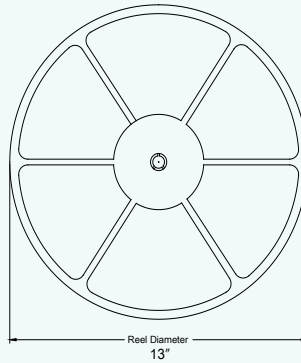
Package Information

IU5070E EQA16(95*145) PACKAGE OUTLINE DIMENSIONS UNITS:MM



TAPE AND REEL INFORMATION

REEL DIMENSIONS



Precautions for MOS Circuit Operation:

Static electricity can be generated in many places. The following precautions can effectively prevent MOS circuit from being damaged due to the sound of electrostatic discharge:

- Operators shall be grounded through anti-static wrist strap.
- The equipment enclosure must be grounded.
- Tools used during assembly must be grounded.
- Conductor packaging or anti-static materials must be used for packaging or transportation.

Declaration:

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