

## One Cell Lithium-ion/Polymer Battery Protection IC

### GENERAL DESCRIPTION

The XBL6042-SM Series product is a high integration solution for lithium-ion/polymer battery protection. XBL6042-SM Series contains advanced power MOSFET, high-accuracy voltage detection circuits and delay circuits. XBL6042-SM Series is put into an DFN1X1x0.37-4 package and external MCU, GPIO signal to high level to enable the chip to enter shipping mode makes it an ideal solution in limited space of battery pack.

XBL6042-SM Series has all the protection functions required in the battery application including overcharging, over discharging, overcurrent and load short circuiting protection etc. The accurate overcharging detection voltage ensures safe and full utilization charging. The low standby current drains little current from the cell while in storage.

The device is not only targeted for digital cellular phones, but also for any other Li-Ion and Li-Poly battery-powered information appliances requiring long-term battery life.

### FEATURES

- Protection of Battery Cell Reverse Connection without external load

- Protection of Charger Reverse Connection
- Integrate Advanced Power MOSFET with Equivalent of  $44\text{m}\Omega R_{\text{DS(ON)}}$
- DFN 1x1x0.37-4 Package
- Low Overcharge Release Voltage
- Over-temperature Protection
- Overcharge Current Protection 0.4A
- Two-step Overcurrent Detection:
  - Overdischarge Current 0.4A
  - Load Short Circuiting
- Charger Detection Function
- 0V Battery Charging Function
- Delay Times are generated inside
- High-accuracy Voltage Detection
- Low Current Consumption
  - Operation Mode:  $0.8\mu\text{A}$  typ.
  - Power-down Mode:  $1\text{nA}$  typ.
- RoHS Compliant and Lead (Pb) Free
- Be suitable for 100% shipping mode
- ESD HBM: 8KV

### APPLICATIONS

One-Cell Lithium-ion Battery Pack  
 Lithium-Polymer Battery Pack  
 Wearable Device  
 Bluetooth Earphone

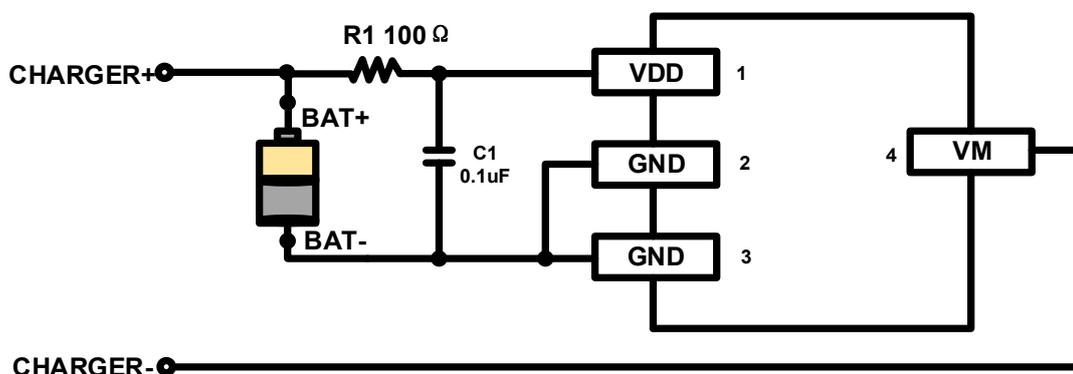


Figure 1. Typical Application Circuit

## ORDERING INFORMATION

PART NUMBER	OCV [VCU] (V) (Ta=25°C)	OCRV [VCL] (V)	ODV [VDL] (V)	ODRV [VDR] (V)	TOP MARK
XBL6042QS-SM	4.275±25mV	4.075±50mV	2.8±100mV	3.0*±100mV	YWxx(note)
XBL6042JS-SM	4.425±25mV	4.25±50mV	2.8±100mV	3.0*±100mV	
XBL6042MS-SM	4.475±25mV	4.30±50mV	2.8±100mV	3.0*±100mV	

Note:1)“YW” is manufacture date code, “Y” means the year, “W” means the week.  
 2)“xx” is internal product code of XySemi.

\*: Enter Sleep Mode after overdischarge, needs charging to activate normal discharge state.

## PIN CONFIGURATION

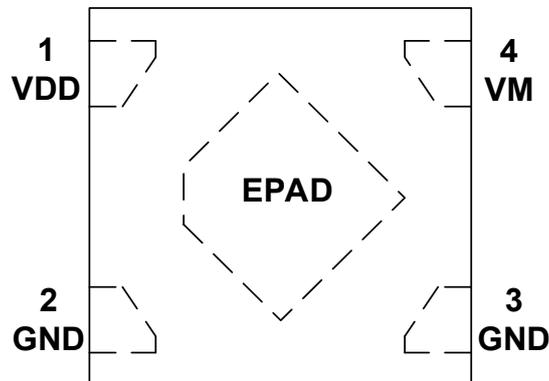


Figure 2. PIN Configuration

## PIN DESCRIPTION

XBL6042-SM SERIES PIN NUMBER	PIN NAME	PIN DESCRIPTION
1	VDD	Power Supply.
2,3	GND	Ground, connect the negative terminal of the battery to these pins.
4	VM	The negative terminal of the battery pack. The internal FET switch connects this terminal to GND.Power Supply.
EPAD	NC	Not Use. Suggest to connect with GND.

## ABSOLUTE MAXIMUM RATINGS

(NOTE: DO NOT EXCEED THESE LIMITS TO PREVENT DAMAGE TO THE DEVICE. EXPOSURE TO ABSOLUTE MAXIMUM RATING CONDITIONS FOR LONG PERIODS MAY AFFECT DEVICE RELIABILITY.)

PARAMETER	VALUE	UNIT
VDD input pin voltage	-0.3 to 6	V
VM input pin voltage	-6 to 10	V
Operating Ambient Temperature	-40 to 85	°C
Maximum Junction Temperature	150	°C
Storage Temperature	-55 to 150	°C
Lead Temperature ( Soldering, 10 sec)	300	°C
Power Dissipation at T=25°C	0.3	W
Package Thermal Resistance (Junction to Ambient) $\theta_{JA}$	250	°C/W
Package Thermal Resistance (Junction to Case) $\theta_{JC}$	130	°C/W
ESD HBM	8000	V

## ELECTRICAL CHARACTERISTICS

Typical and limits appearing in normal type apply for TA = 25°C, unless otherwise specified.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>Detection Current</b>						
Overdischarge Current Detection	IIOV1	VDD=3.6V	0.25	0.4	0.50	A
Overcharge Current Detection	ICHOC	VDD=3.6V	0.25	0.4	0.50	A
Load Short-Circuiting Detection	*ISHORT	VDD=3.6V	0.6	0.75	0.9	A
<b>Current Consumption</b>						
Current Consumption in Normal Operation	IOPE	VDD=3.6V VM =0V		0.8	1.0	μA
Current Consumption in Power Down	IPD	VDD=2.0V VM pin floating		1	10	nA
<b>VM Internal Resistance</b>						
Internal Resistance between VM and VDD	RVMD	VDD =2.0V VM pin floating	200	300	400	kΩ
Internal Resistance between VM and GND	RVMS	VDD=3.6V VM=3.6V	10	20	30	kΩ
<b>FET on Resistance</b>						
Equivalent FET on Resistance	*RDS(ON)	VDD=3.6V IVM =0.2A		44		mΩ
<b>Over Temperature Protection</b>						
Over Temperature Protection	*TSHD+			150		°C
Over Temperature Recovery Degree	*TSHD-			110		°C
<b>Detection Delay Time</b>						
Overcharge Voltage Detection Delay Time	tCU		100	200	300	mS
Overdischarge Voltage Detection Delay Time	tDL		25	50	75	mS
Overdischarge Current1 Detection Delay Time	tIOV1	VDD=3.6V	6	13	20	mS
Overcharge Current Detection Delay Time	tCHOC	VDD=3.6V	6	13	20	mS
Load Short-Circuiting Detection Delay Time	*tSHORT	VDD=3.6V	150	300	600	μS

Note1:

\*: Since products are not screened at high and low temperatures, the specification for this temperature range is guaranteed by design, not tested in production.

## FUNCTIONAL BLOCK DIAGRAM

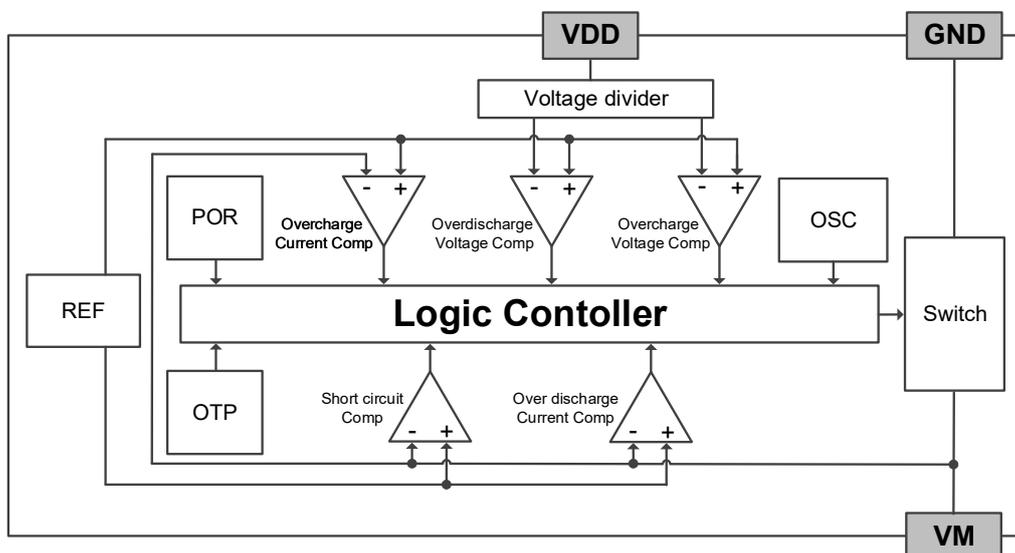


Figure 3. Functional Block Diagram

## FUNCTIONAL DESCRIPTION

The XBL6042-SM Series monitors the voltage and current of a battery and protects it from being damaged due to overcharge voltage, overdischarge voltage, over discharge current, and short circuit conditions by disconnecting the battery from the load or charger. These functions are required in order to operate the battery cell within specified limits.

The device has built in R1 and C1 circuitry to ensure the proper operation of the chip, and built-in R2 and C2 to enhance the anti-interference circuitry. The MOSFET is integrated and its  $R_{DS(ON)}$  is as low as 44 mΩ typical.

### Normal operating mode

If no exception condition is detected, charging and discharging can be carried out freely. This condition is called the normal operating mode.

### Overcharge Condition

When the battery voltage becomes higher than the overcharge detection voltage

( $V_{CU}$ ) during charging under normal condition and the state continues for the overcharge detection delay time ( $t_{CU}$ ) or longer, the XBL6042-SM Series turns the charging control FET off to stop charging. This condition is called the overcharge condition. The overcharge condition is released in the following two cases:

1. When the connected charger battery voltage drops below the overcharge release voltage ( $V_{CL}$ ), the XBL6042-SM Series turns the charging control FET on and returns to the normal condition.

2. When a load is connected and discharging starts, the XBL6042-SM Series turns the charging control FET on and returns to the normal condition. The release mechanism is as follows: the discharging current flows through an internal parasitic diode of the charging FET immediately after a load is connected and discharging starts, and the VM pin voltage increases about 0.7V (forward voltage of the diode) from the GND pin voltage momentarily. The XBL6042-SM Series detects this voltage and releases the overcharge condition. Consequently, in the case that the battery voltage is

equal to or lower than the overcharge detection voltage ( $V_{CU}$ ), the XBL6042-SM Series returns to the normal condition immediately, but in the case the battery voltage is higher than the overcharge detection voltage ( $V_{CU}$ ), the chip does not return to the normal condition until the battery voltage drops below the overcharge detection voltage ( $V_{CU}$ ) even if the load is connected. In addition, if the VM pin voltage is equal to or lower than the overcurrent detection voltage when a load is connected and discharging starts, the chip does not return to the normal condition.

#### Remark :

If the battery is charged to a voltage higher than the overcharge detection voltage ( $V_{CU}$ ) and the battery voltage does not drop below the overcharge detection voltage ( $V_{CU}$ ) even when a heavy load, which causes an overcurrent, is connected, the overcurrent does not work until the battery voltage drops below the overcharge detection voltage ( $V_{CU}$ ). Since an actual battery has, however, an internal impedance of several dozens of  $m\Omega$ , and the battery voltage drops immediately after a heavy load which causes an overcurrent is connected, the overcurrent works. Detection of load short-circuiting works regardless of the battery voltage.

#### Overdischarge Condition

When the battery voltage drops below the overdischarge detection voltage ( $V_{DL}$ ) during discharging under normal condition and it continues for the overdischarge detection delay time ( $t_{DL}$ ) or longer, the XBL6042-SM Series turns the discharging control FET off and stops discharging. This condition is called overdischarge condition. After the discharging control FET is turned off, the VM pin is pulled up by the  $R_{VMD}$  resistor between VM and VDD in XBL6042-SM Series. The current of the chip is reduced to the power-down current ( $I_{PDN}$ ). This condition is called power-down condition. The VM and VDD pins are shorted by the  $R_{VMD}$  resistor in the IC under the overdischarge and power-down conditions.

The power-down condition is released when a charger is connected and the poten-

tial difference between VM and VDD becomes 2.0V (typ.) or higher (0V charger voltage when charging). At this time, the FET is still off. When the battery voltage becomes 1.7V or higher (see note), the XBL6042-SM Series turns the FET on and changes to the normal condition from the overdischarge condition.

#### Remark:

If the VM pin voltage is no less than the GND voltage, when the battery under overdischarge condition is connected to a charger, the overdischarge condition is released (the discharging control FET is turned on) as usual, provided that the battery voltage reaches the overdischarge release voltage ( $V_{DU}$ ) or higher.

#### Overcurrent Condition

When the discharging current becomes equal to or higher than a specified value (the VM pin voltage is equal to or higher than the overcurrent detection voltage) during discharging under normal condition and the state continues for the overcurrent detection delay time or longer, the XBL6042-SM Series turns off the discharging control FET to stop discharging. This condition is called overcurrent condition. (The overcurrent includes overcurrent, or load short-circuiting.)

The VM and GND pins are shorted internally by the  $R_{VMS}$  resistor under the overcurrent condition. When a load is connected, the VM pin voltage equals the VDD voltage due to the load.

The overcurrent condition returns to the normal condition when the load is released and the impedance between the B+ and B- pins becomes higher than the automatic recoverable impedance. When the load is removed, the VM pin goes back to the GND potential since the VM pin is shorted to the GND pin with the  $R_{VMS}$  resistor. Detecting that the VM pin potential is lower than the overcurrent detection voltage, the IC returns to the normal condition.

#### Abnormal Charge Current Detection

If the VM pin voltage drops below the charger detection voltage during charging under the normal condition and it continues for the overcharge detection delay time ( $t_{choc}$ ) or longer, the XBL6042-SM Series turns the charging control FET off and stops charging. This action is called abnormal charge current detection.

Abnormal charge current detection works when the charging control FET is on and the VM pin voltage drops below the charge detection voltage. When an abnormal charge current flows into a battery in the overcharge condition, the XBL6042-SM Series consequently turns the charging control FET off and stops charging after the battery voltage becomes the overcharge detection voltage and the overcharge detection delay time ( $t_{choc}$ ) elapses.

Abnormal charge current detection is released when the voltage difference between VM pin and GND pin becomes lower than the charger detection voltage by separating the charger. Since the 0 V battery charging function has higher priority than the abnormal charge current detection function, abnormal charge current may not be detected by the product with the 0 V battery charging function while the battery voltage is low.

## Load Short-circuiting condition

If voltage of VM pin is equal or above short circuiting protection voltage, the XBL6042-SM Series will stop discharging and battery is disconnected from load. The maximum delay time to switch current off is  $t_{SHORT}$ . This status is released when voltage of VM pin is lower than short protection voltage, such as when disconnecting the load.

## Delay Circuits

The detection delay time for load short-circuiting starts when overdischarge current 1 is detected. As soon as load short-circuiting is detected over detection delay time for load short-circuiting, the XBL6042-SM Series stops discharging. When battery voltage falls below overdischarge detection volt-

age due to overdischarge current, the XBL6042-SM Series stop discharging by overdischarge current detection. In this case the recovery of battery voltage is so slow that if battery voltage after overdischarge voltage detection delay time is still lower than overdischarge detection voltage, the XBL6042-SM Series shifts to power-down.

## 0V Battery Charging Function <sup>(1) (2) (3)</sup>

This function enables the charging of a disconnected battery whose voltage is 0 V by self-discharge. When a charger having 0 V battery start charging charger voltage ( $V_{0CH}$ ) or higher is connected between B+ and B- pins, the charging control FET gate is fixed to VDD potential. When the voltage between the gate and the source of the charging control FET becomes equal to or higher than the turn-on voltage by the charger voltage, the charging control FET is turned on to start charging. At this time, the discharging control FET is off and the charging current flows through the internal parasitic diode in the discharging control FET. If the battery voltage becomes equal to or higher than the overdischarge release voltage ( $V_{DU}$ ), the normal condition returns.

### Note:

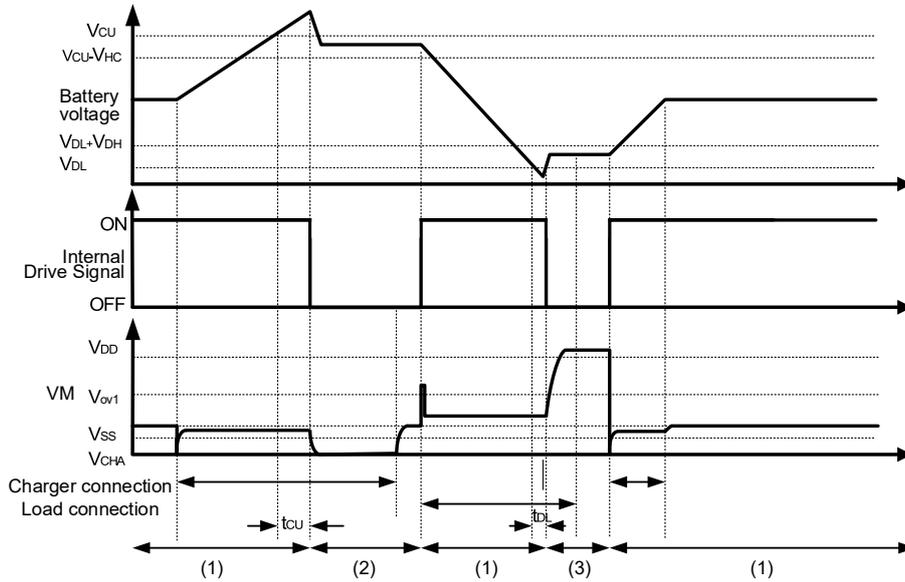
(1) Some battery providers do not recommend charging of completely discharged batteries. Please refer to battery providers before the selection of 0 V battery charging function.

(2) The 0V battery charging function has higher priority than the abnormal charge current detection function. Consequently, a product with the 0 V battery charging function charges a battery and abnormal charge current cannot be detected during the battery voltage is low (at most 1.8 V or lower).

(3) When a battery is connected to the IC for the first time, the IC may not enter the normal condition in which discharging is possible. In this case, set the VM pin voltage equal to the GND voltage (short the VM and GND pins or connect a charger) to enter the normal condition.

## TIMING CHART

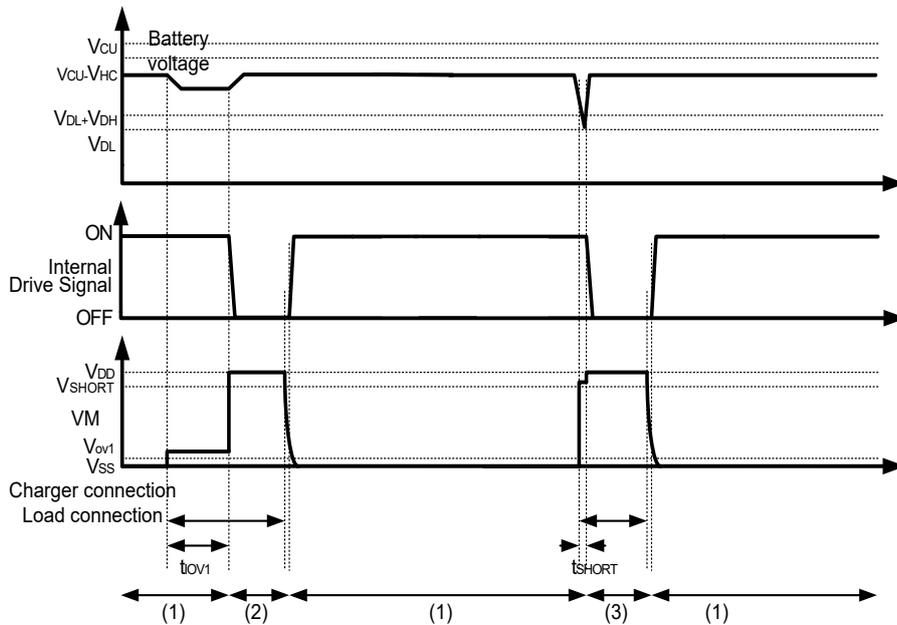
### 1. Overcharge and Overdischarge voltage detection



**Figure4-1 Overcharge and Overdischarge Voltage Detection**

Remark: (1) Normal condition (2) Overcharge voltage condition (3) Overdischarge voltage condition

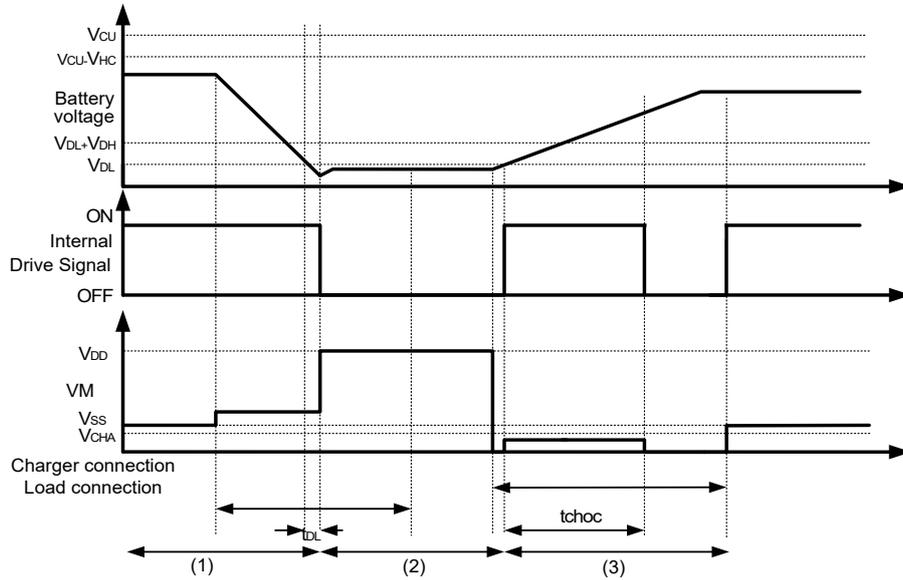
### 2. Overdischarge Current and Load Short detection



**Figure4-2 Overdischarge Current and Short Detection**

Remark: (1) Normal condition (2) Overcharge voltage condition (3) Overdischarge voltage condition

## 3. Abnormal Charger Detection



**Figure4-3 Abnormal Charger Detection**

Remark: (1) Normal condition (2) Overdischarge voltage condition (3) Overcharge voltage condition

## TYPICAL APPLICATION

As shown in Figure 5, the current path which must be kept as short as possible. For thermal management, ensure that these trace widths are adequate. C is a decoupling capacitor which should be placed as close as possible to XBL6042-SM SERIES.

If add one 0.1uF capacitor between VM pin and GND pin closely, the system ESD level and anti-interference capability of circuit will improve greatly.

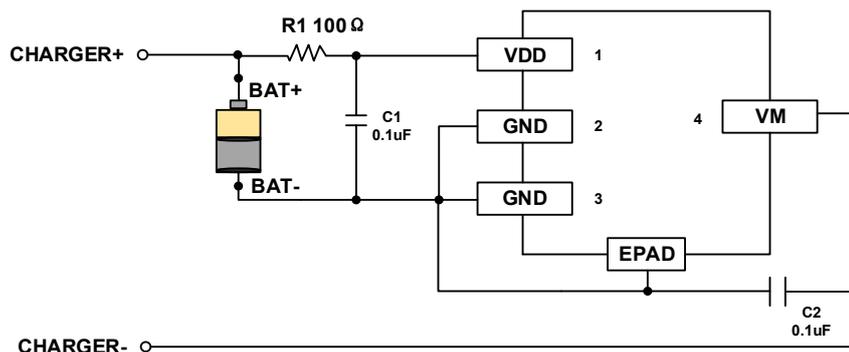


Figure 5 XBL6042-SM SERIES in a Typical Battery Protection Circuit

Symbol	Typ	Value range	Unit
R1	100	100 ~1000	Ω
C1	0.1	0.1~2.2	μF

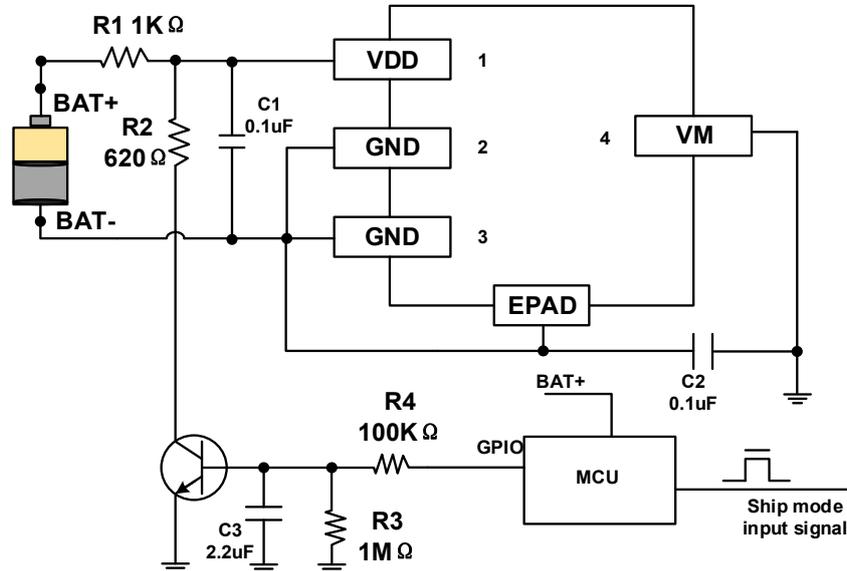
Remark:

- 1.The above parameters may be changed without notice;
- 2.The schematic diagram and parameters of the IC are not used as the basis to ensure the operation of the circuit. Please conduct full measurement on the actual application circuit before setting the parameters.
- 3.If the resistance value is large , the overcharging voltage will be correspondingly larger by several mV.

## Precautions

- Pay attention to the operating conditions for input/output voltage and load current so that the power loss in XBL6042-SM SERIES does not exceed the power dissipation of the package.
- Do not apply an electrostatic discharge to this XBL6042-SM SERIES that exceeds the performance ratings of the built-in electrostatic protection circuit.
- If < 50 mAh Li-Battery is shorted, the voltage of battery maybe drop down to 0V~1V quickly so that the short-circuiting protection logic may not work properly. Increasing the value of resistor and capacitor can solve this problem, such as 1K and 1uF.

## APPLICATION OF SHIP MODE



### Description of shipping patterns

When the product is transported by overseas ship, the voltage of lithium battery maybe drop down a lot in a long time normally.

There are two ways to enter SM mode:

1. The voltage of VDD is higher than 1.25V and less than ODRV;
2. When the voltage of VDD rebounds to ODRV,  $VM > 2V$ .

Then XBL6042-SM series will be in self-locking mode, and shutdown current will be less than 10nA even if the battery voltage recovery to as high as 4.0V.

The way to exit SM mode: Plug in the charger again.

## APPLIED MEASUREMENT METHOD

### (1).Overcharge characteristic test method:

a. According to the figure6-1, connect the power supply DC1 to the B + and GND pins of the system board and set the voltage to about 3.6V. Connect the power supply from GND to VM to DC2 power supply and set 100mV current limiting 10mA. Observe the waveform.

b. Adjust the power supply voltage V1 and increase it by 0.001V until the output level of VM pin c -changes from 0 to negative (-100mV). Record the overcharge protection voltage and measure the protection delay.

c. Adjust the power supply voltage V1 to decrease by 0.001V until the output voltage of VM pin is recovered from negative (-100mV) to 0 level, and record the overcharge recovery voltage.

### (2).Over discharge characteristic test method:

a. According to the figure6-2, connect the power supply DC1 to the B + and GND pins of the system board and set the voltage to about 3.6V. Connect the DC2 power supply from VM to GND, set the 100mV current limiting 10mA, and observe the waveform.

b. Adjust the power supply voltage V1 and increase it by 0.001V until the output level of VM pin c -changes from 0 to positive (100mV). Record the overcharge protection voltage and measure the protection delay.

c. Adjust the power supply voltage V1 to decrease by 0.001 V until the output voltage of VM pin is restored from positive (100 mV) to 0 level, and record the overcharge recovery voltage.

### (3).Discharge over current test method:

a. According to the figure6-3, connect the DC1 power supply to the B + and GND pins of the system board and set the voltage to about 3.0V/3.6V/4.2V. Connect the electronic load from B + to VM and observe the waveform.

b. Adjust the electronic load increase it by 1mA step, detect that the current from B + to VM is turned off and meet the delay standard (about 10ms), and record the discharge delay time.

### (4).Charging over current test method:

a. According to the figure6-4, connect the DC1 power supply to the B + and GND pins of the system board and set the voltage to about 3.0V/3.6V/4.2V, and load DC2 power supply from GND to VM.

b. Adjust the current limiting value of DC2 power supply to increase by 1mA step, detect that the current from GND to VM is turned off and meet the delay standard(about 10ms), and record the charging over-current delay time.

### (5).Iq test method:

a. As shown in the figure6-5, connect the positive pole of DC1 to B +, and the negative pole to GND, and set the voltage to 3.6V;

b. VM grounding, record the current passing through DC1 (Iq).

### (6).Isd test method:

a. As shown in the figure6-6, connect the positive pole of DC1 to B + and the negative pole to GND, and set the voltage to 2V;

b. VM is suspended and the current passing through DC1 is recorded as Isd.

## SCHEMATIC DIAGRAM OF TEST METHOD

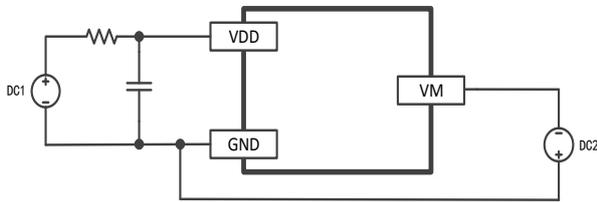


Figure6-1

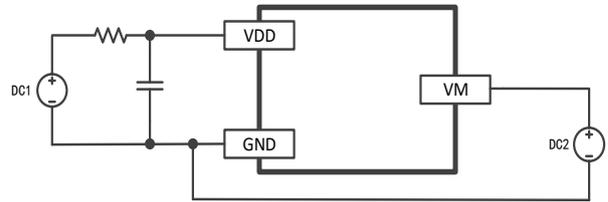


Figure6-2

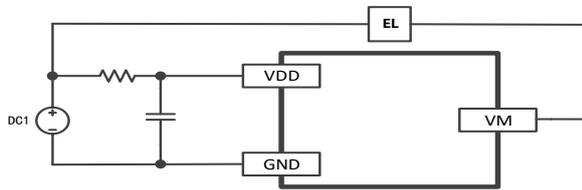


Figure6-3

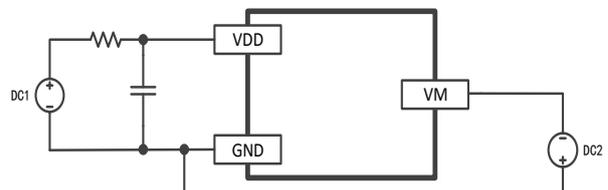


Figure6-4

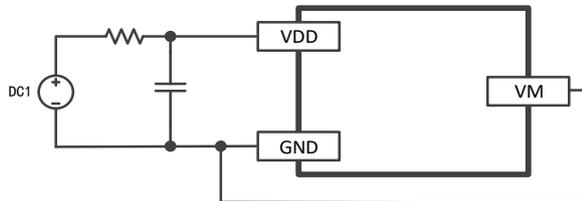


Figure6-5

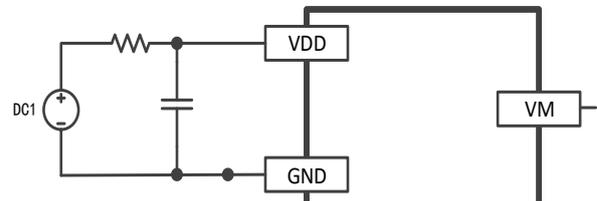
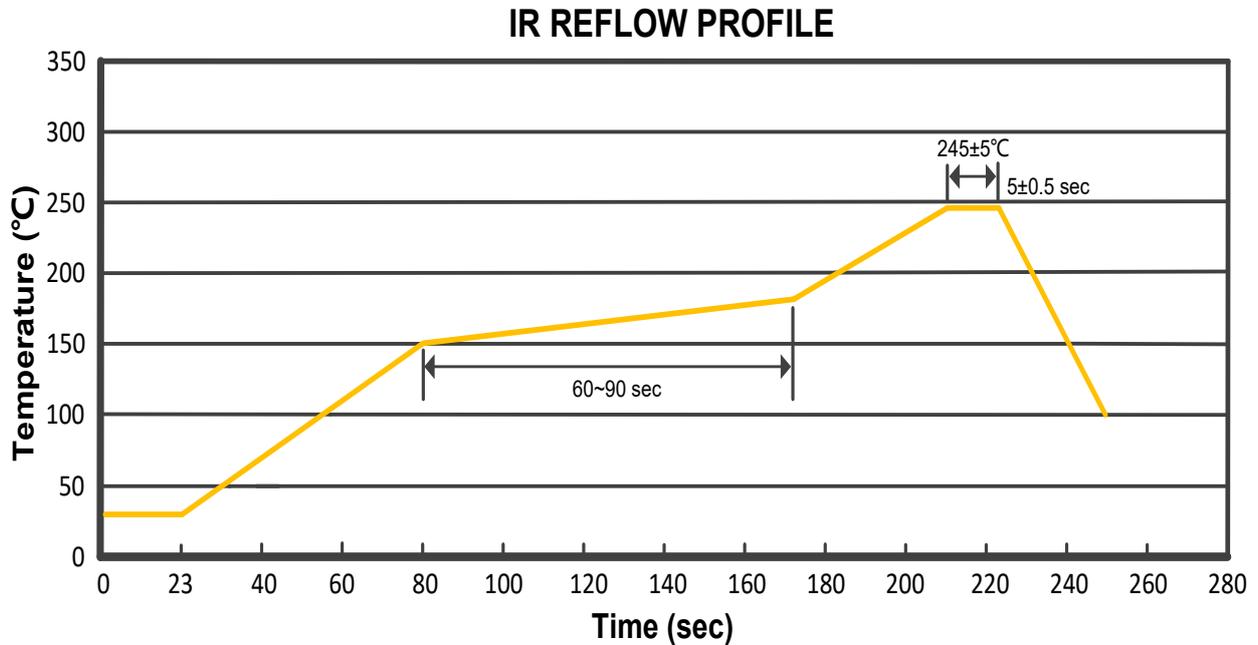


Figure6-6

## Solderability Curve of Lead-Free Reflow Soldering (applicable to SMT tube)



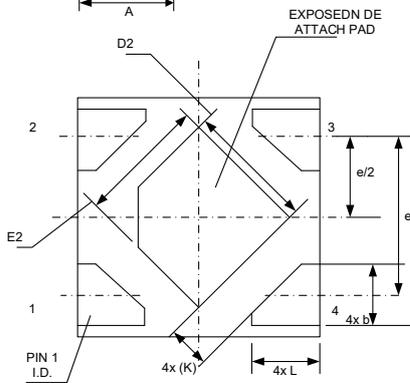
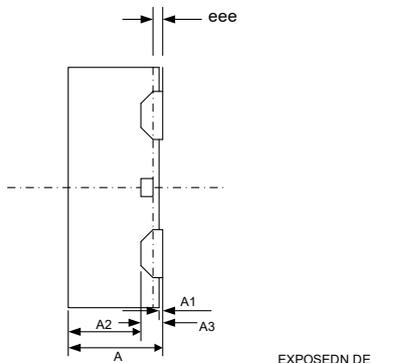
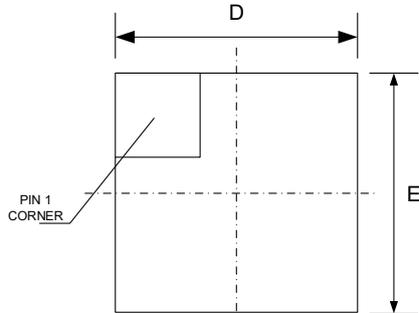
Explain:

1. Preheating temperature 25~150°C, duration 60~90sec;
2. Peak temperature  $245 \pm 5$  °C, duration  $5 \pm 0.5$ sec;
3. Cooling rate of welding process is 2~10°C/sec.

### Resistance to welding heat conditions

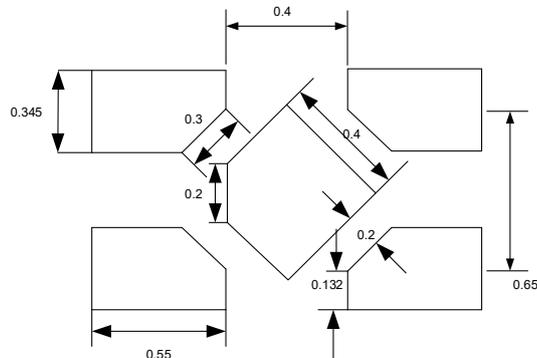
Temperature:  $270 \pm 5$ °C; Time:  $10 \pm 1$ sec

## PACKAGE OUTLINE(DFN1x1-4)



	SYMBOL	MIN	NOM	MAX
TOTAL THICKNESS	A	0.32	0.37	0.4
STAND OFF	A1	0	0.02	0.05
MOLD THICKNESS	A2	---	0.27	---
L/F THICKNESS	A3	0.102REF		
LEAD WIDTH	b	0.18	0.23	0.28
BODY SIZE	D	1BSC		
	E	1BSC		
LEAD PITCH	e	0.65BSC		
EP SIZE	D2	0.43	0.48	0.53
	E2	0.43	0.48	0.53
LEAD LENGTH	L	0.2	0.25	0.3
Lead TIP TO EXPOSED PAD EDGE	K	0.21REF		
COPLANARITY	eee	0.05		

### RECOMMENDED LAND PATTERN unit (mm)



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