FH01

High-precision lithium battery protection circuit with integrated RC

FEATURES

- Ideal protection circuit for one-cell Li-ion or Li-polymer battery
- High precision protection voltage threshold (over-charge/over-discharge)
- Allow or inhibit low power consumption mode
- High precision over-discharge protection current threshold
- Protection for battery short
- Multi-type of detector voltage and time delay option
- inhibit variable 0V battery charge
- Internal integrate RC caused to only one external elements—Dual MOSFETs
- Small SOT23-6 Package

APPLICATIONS

- Protection circuit for charge and discharge of Li-ion or Li-polymer battery
- High precision protector for cell phone battery and any other protector of Li-ion or Li-polymer battery

DESCRIPTION

FH01 series are high precision protection ICs for over-charge and over-discharge of rechargeable one-cell Li-ion or Li-polymer battery. It integrates the high precision protection capability for over-charge, over-discharge, excess-current discharge, and battery short.

Under normal conditions，when V_{DD} is between the protection thresholds of over-charge (V_{OC}) and over-discharge (V_{OD}), and the detection voltage of V_M is between the charger detect voltage (V_{CHG}) and excess-current discharge (V_{EDI}), the outputs of C_{OUT} and D_{OUT} are high conducting the N-MOSFET charge controller, Q1, and the N-MOSFET discharge controller, Q2. Thus, the battery can be charged through a charger and can be discharged through a load.

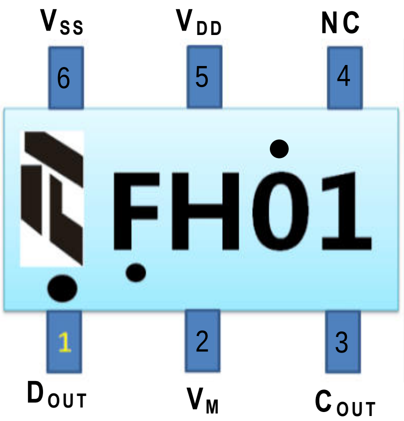
FH01 series realizes the over-charge and over-discharge protection through detecting the voltages of V_{DD} and V_M. When abnormal conditions occur during charging or discharging, the outputs of C_{OUT} and D_{OUT} both change from a high level to a low level, stopping charging or discharging by turning Q1/Q2 off.

All protections can be released at corresponding conditions. When the recovery condition is met, the outputs of C_{OUT}/D_{OUT} change from a low level to a high level, turning on Q1/Q2 to enable charge/discharge.

FH01 sets internal delay time for each protection and release. It does not enter into the protection or release state until its corresponding condition reaches its delay time. If the protection or release condition disappears in less than the corresponding delay time, it will not enter to either the protection or release state.

PIN CONFIGURATIONS

top view



SOT23-6

Figure 1 FH01 Pin Configurations (Not to scale)

Silk screen remarks: The upper and lower dots of the model may change! !

ORDERING INFORMATION

[Table 1] Product Name

TYPE	PACKAGE	PIN NUMBER	PRINT MARK
FH01	SOT23-6	6	FH01

[Table 2] Detector Voltage Threshold and Delay Time

PARAMETER NAME	VALUE	ACCURACY RANGE
Protection threshold of over-charge V_{OCTYP}	4.300V	±50mV
Release threshold of over-charge V_{OCRTYP}	4.100V	±50mV
Protection threshold of over-discharge V_{ODTYP}	2.500V	±75mV
Release threshold of over-discharge V_{ODRTYP}	2.900V	±75mV
Protection threshold of excess-current discharge V_{EDITYP}	0.150V	±20mV
Protection delay time of over-charge t_{OCTYP}	100ms	±50%
Protection delay time of over-discharge t_{ODTYP}	50ms	±50%
Protection delay time of excess-current discharge t_{EDITYP}	7.0ms	±50%
0V-charge allow/inhibit	Inhibit	
Over-discharge self-recovery allow/inhibit	Allow	

FUNCTIONAL DIAGRAM

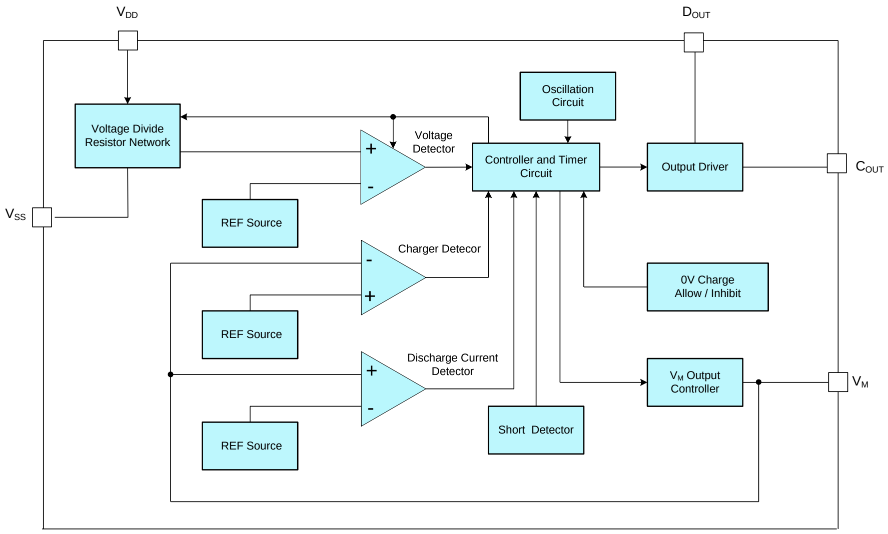


Figure 2 FH01 Functional Diagram

PIN DESCRIPTION

[Table 3] PIN Description

NAME	ORDER	I/O	FUNCTION
D_{OUT}	1	O	**Discharge Control Output** Connect to the Gate of the external discharge controller N-MOSFET Q2.
V_M	2	I	**Charge/Discharge Current Sense Input** Connect this to the Source of external charge controller N-MOSFET Q1, and then the voltage drop on Q1 and Q2, which cause by the charge current or discharge current can be sensed.
C_{OUT}	3	O	**Charge Control Output** Connect to the Gate of the external charge controller N-MOSFET Q1.
NC	4		**Not Connected**
V_{DD}	5	POW	**Power Supply Input** Connect to the positive of power supply (battery normally).
V_{SS}	6	POW	**Ground** Connect to the negative of power supply.

ABSOLUTE MAXIMUM RATINGS

Power supply V_{DD}............................ -0.3V~+10V

V_M, C_{OUT} acceptable voltage. V_{DD}-26V~V_{DD}+0.3V

D_{OUT} acceptable voltage............-0.3V~V_{DD}+0.3V

Operation temperature T_A ....-40℃~+85℃

Junction temperature ....150℃

Storage temperature .... -65℃~150℃

Power consumption P_D (T_A=25℃)

SOT23-6 package (θ_{JA}=200℃/W)............ 625mW

Solder Temperature (Tin soldering, 10s)............260℃

Note: Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond the recommended operating condition are not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

ELECTRICAL SPECIFICATION

(V_{DD} = 3.6V, T_A = 25℃, unless otherwise specified. The operation temperature with Mark "♦" is: -40℃≤T_A≤85℃)

[Table 4] Electrical Specification

PARAMETER	SYMBOL	CONDITIOIN		MIN	TYP	MAX	UNIT
Power supply	V_{DD}		♦	1.5		10	V
Over-charge protection threshold (rising)	V_{OC}			V_{OCTYP}-0.050	V_{OCTYP}	V_{OCTYP}+0.050	V
			♦	V_{OCTYP}-0.080	V_{OCTYP}	V_{OCTYP}+0.080	V
Over-charge release Threshold(falling)	V_{OCR}			V_{OCRTYP}-0.050	V_{OCRTYP}	V_{OCRTYP}+0.050	V
			♦	V_{OCRTYP}-0.080	V_{OCRTYP}	V_{OCRTYP}+0.080	V
Over-charge protection delay time	t_{OC}	V_{DD}=3.6V→4.4V		0.5×t_{OCTYP}	t_{OCTYP}	1.5×t_{OCTYP}	ms
Over-discharge protection Threshold(falling)	V_{OD}			V_{ODTYP}-0.075	V_{ODTYP}	V_{ODTYP}+0.075	V
			♦	V_{ODTYP}-0.105	V_{ODTYP}	V_{ODTYP}+0.105	V
Over-discharge release Threshold(rising)	V_{ODR}			V_{ODRTYP}-0.075	V_{ODRTYP}	V_{ODRTYP}+0.075	V
			♦	V_{ODRTYP}-0.105	V_{ODRTYP}	V_{ODRTYP}+0.105	V
Over-discharge protection delay time	t_{OD}	V_{DD}=3.6V→2.4V		0.5×t_{ODTYP}	t_{ODTYP}	1.5×t_{ODTYP}	ms
Excess-current discharge protection threshold	V_{EDI}			V_{EDITYP}-0.020	V_{EDITYP}	V_{EDITYP}+0.020	V
Excess-current discharge protection delay time	t_{EDI}			0.5×t_{EDITYP}	T_{EDITYP}	1.5×t_{EDITYP}	ms
Excess-current discharge release delay time	t_{EDIR}			0.85	1.70	2.55	ms
Battery short protection threshold	V_{SHORT}	Voltage of V_M		0.75	1.25	1.75	V
Battery short protection delay time	t_{SHORT}			8.5	17	25.5	μs
Charger detect voltage	V_{CHG}	V_{DD}=3.0V		-0.27	-0.5	-0.86	V
Resistance of V_M to V_{DD}	R_{VMD}	V_{DD}=1.8V, V_M=0V		100	300	900	kΩ
Resistance of V_M to V_{SS}	R_{VMS}			15	30	45	kΩ
C_{OUT} output low level pull-low resistor					4		MΩ
C_{OUT} output high level		V_{DD}=3.9V, I_{COUT}=10μA		V_{DD}-0.4	V_{DD}-0.2		V
D_{OUT} output low level		V_{DD}=2.0V, I_{DOUT}=10μA			0.2	0.4	V
D_{OUT} output high level		V_{DD}=3.9V, I_{DOUT}=10μA		V_{DD}-0.4	V_{DD}-0.2		V
Power current	I_{DD}	V_{DD} =3.9V			2.0	6.0	μA
Current under low power consumption mode	I_{PDWN}	V_{DD}=2.0V			0.7	1.0	μA
0V charge allow threshold （If 0V charge allow）	V_{0V_CHG}	Charger Voltage		-1.5		0	V
0V charge inhibit threshold （If 0V charge inhibit）	V_{0V_INH}	Battery Voltage, V_M=-2.0V		0.5		1.2	V

Note: 1. All the voltages are referred to V_{SS}, unless otherwise specified.

2. Shown in Figure 3.

FUNCTION DESCRIPTION

FH01 is a high precision protection circuit for the one-cell Li-ion or Li-polymer battery. Under normal conditions, during the battery charging, FH01 may get into the over-charge protection. It resets to the normal condition when it reaches the release condition. During the battery discharging, FH01 may get into the over-discharge or excess-current discharge protection. It can also reset to the normal state when it reaches the release condition. Figure 3 shows the typical application schematic. The state conversion diagram is shown in Figure 4. The detailed description of each condition is followed.

Normal Condition

Under normal conditions, FH01 is powered by the battery. When V_{DD} is between the protection thresholds of over-charge (V_{OC}) and over-discharge (V_{OD}), V_M is between the charger detect voltage (V_{CHG}) and excess-current discharge (V_{EDI}), the outputs of C_{OUT} and D_{OUT} become high and turn on the charge controller N-MOSFET Q1 and the discharge controller N-MOSFET Q2. Thus, the battery can be charged through a charger or discharged through a load.

Over-charge Protection

- **Protection condition**

During the battery charging and under the normal condition, if the voltage of V_{DD} exceeds the over-charge protection threshold (V_{OC}) and this state lasts more than the over-charge protection delay time (t_{OC}), the voltage of C_{OUT} pin is equal to the voltage of V_M pin. The N-MOSFET's charge controller Q1 is turned off. The charge current is "shut off". FH01 gets into over-charge protection.

- **Release condition**

FH01 can recover from over-charge protection when it meets one of the following two conditions. 1) The battery discharges itself to make V_{DD} lower than the over-charge release threshold (V_{OCR}); 2) The battery is discharged through an extra load (Note: Even though Q1 is turned off, discharge loop is still available due to its body diode), V_{DD} is lower than the over-charge protection threshold (V_{OC}), and the voltage of V_M pin is higher than the excess-current discharge protection threshold (V_{EDI}). (Before Q1 is turned on, the voltage of V_M is one diode voltage higher than the voltage of V_{SS}).

After FH01 recovers to normal condition, the output of C_{OUT} pin goes to a high level. The charge controller N-MOSFET, Q1, is turned on again.

Once FH01 enter into over-charge protection, it will never release to normal condition if a charger is always connected, even if its V_{DD} is below V_{ODR}. It only can be released by disconnecting the charger.

Over-discharge Protection/Low Power Consumption Mode

- **Protection condition**

Under normal conditions, if the voltage of V_{DD} pin is lower than the over-discharge protection threshold (V_{OD}) and this state lasts more than the over-discharge protection delay time (t_{OD}), the voltage of D_{OUT} pin goes to low(V_{SS}) from a high level. The discharge controller N-MOSFET, Q2, is turned off, shutting off the discharging loop. FH01 gets into the over-discharge protection. The voltage of V_M pin is pulled up to V_{DD} through the internal resistor, R_{VMD}.

During over-charge protection, the voltage of V_M pin （equal to V_{DD}） is always higher than the battery short protection threshold (V_{SHORT}). Thus, the circuit gets into a low power consumption or "Power saving" mode. In this mode, the current of V_{DD} pin is less than 0.7μA.

- **Release condition**

In the low power consumption mode, the battery should be charged to make the voltage of V_M pin lower than the battery short protection threshold (V_{SHORT}), and then FH01 can recover to the over-voltage discharge protection.(The charging circuit is still available due to the diode in Q2). Under this condition, the output level of D_{OUT} is held low, and Q_2 is still turned off. If stopped from charging, FH01 returns to the low power consumption mode, because the voltage of V_M pin is still pulled up to V_{DD} by the R_{VMD} resistor and the voltage is higher than the battery short protection threshold (V_{SHORT}). Only when the battery is charged continually until the voltage of V_{DD} pin rises above the over-discharge protection threshold (V_{OD}), FH01 can recover to the normal condition from the over-discharge protection.

FH01 also can release to the normal condition from the over-discharge protection, if the battery's self-voltage lifting feature makes the voltage of V_{DD} higher than the over-discharge release threshold (V_{ODR}).

After FH01 recovers to the normal condition, the output of D_{OUT} pin goes to a high level. The charge controller N-MOSFET, Q2, is turned on again.

Excess-current Discharge/Battery Short Protection

- **Protection condition**

FH01 supplies two-step excess-current protection. Under normal conditions, during the battery discharging through a load, the voltage of V_M pin rises with the discharge current increasing. If the discharge current increases to make the voltage of V_M pin exceed the excess-current discharge protection threshold (V_{EDI}) for more than the excess-current discharge protection delay time (t_{EDI}), FH01 gets into the excess-current discharge protection. If the discharge current increases continuously to make the voltage of V_M pin exceed the protection battery short threshold (V_{SHORT})，FH01 gets into the battery short protection.

When FH01 is in the excess-current discharge protection or battery short protection, the output of

D_{OUT} pin changes from a high level to a low level (V_{SS}). The external discharge controller N-MOSFET Q2 is turned off, shutting off the discharge loop. V_M is connected to the V_{SS} through the internal resistor R_{VMS}. Once the discharge load is removed, the level of V_M pin changes to the level of V_{SS} pin.

• Release condition

In the excess-current discharge protection or the battery short protection, when the voltage of V_M pin drops lower than the excess-current discharge protection threshold V_{EDI} for more than the excess-current discharge release delay time (t_{EDIR}), FH01 recovers to the normal condition. FH01 self-releases under the excess-current discharge protection or the battery short protection when removing all of the discharge loads.

After FH01 recovers to the normal condition, the output of D_{OUT} pin goes to a high level. The charge controller N-MOSFET, Q2, is turned on again.

Charger Detection

When a battery in the over-discharge condition is connected to a charger and provided that the V_M pin voltage is lower than the charger detect voltage (V_{CHG}), the FH01 releases the over-discharge condition and turns the discharge controller N-MOSFET, Q1 on when the battery voltage becomes equal to or higher than the over-discharge threshold voltage (V_{OD}) since the charger detect function works. This action is called charger detection.

When a battery in the over-discharge condition is connected to a charger and provided that the V_M pin voltage is not lower than the charger detect voltage (V_{CHG}), the FH01 releases the over-discharge condition when the battery voltage reaches the over-discharge release threshold voltage (V_{ODR}).

0V Battery Charging

• 0V battery charge

This function is used to recharge the battery whose voltage is 0V due to self-discharging. If the battery is charged until V_{DD} is higher than V_M about 0V charge threshold (V_{0V_CHG}), the C_{OUT} pin is connected to the V_{DD}. If the voltage of the C_{OUT} pin is high enough to turn on the charge controller N-MOS, Q1, a charging circuit is formed through the diode built in the discharge controller N-MOS, Q2. The battery voltage rises. When V_{DD} is higher than over-voltage discharge protection threshold (V_{OD}), FH01 enters the normal condition. The output of discharge control pin (D_{OUT}) is high. The discharge controller N-MOS is turned on.

• 0V battery charge inhibition

If 0V battery charge is inhibited, the charge control pin (C_{OUT}) is connected to the V_M pin, when V_{DD} is lower than the 0V charge inhibition threshold (V_{NOCHG}). The charge controller N-MOS is turned off.

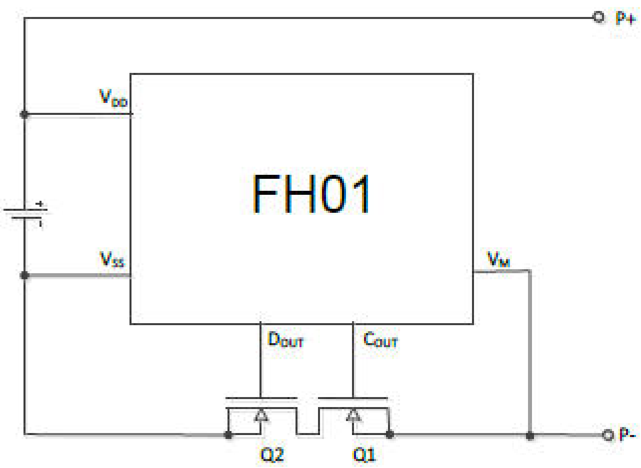


Figure3-1 FH01 Typical Application Schematic 1

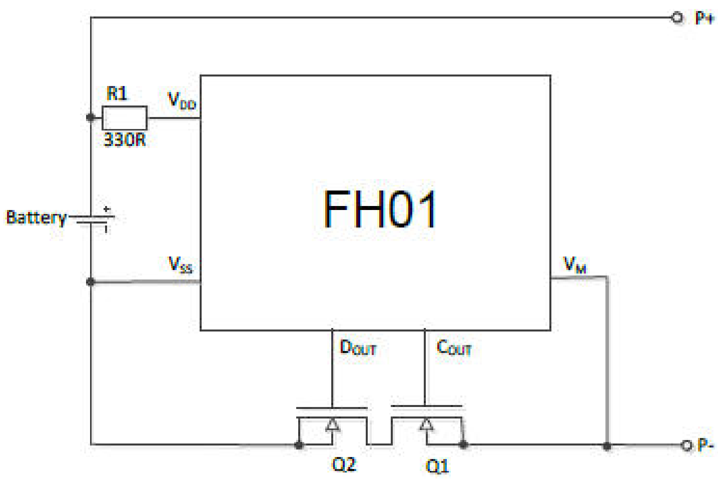


Figure3-2 FH01 Typical Application Schematic 2
(R1 can improve the protection ability in the production process)

STATE CONVERSION DIAGRAM

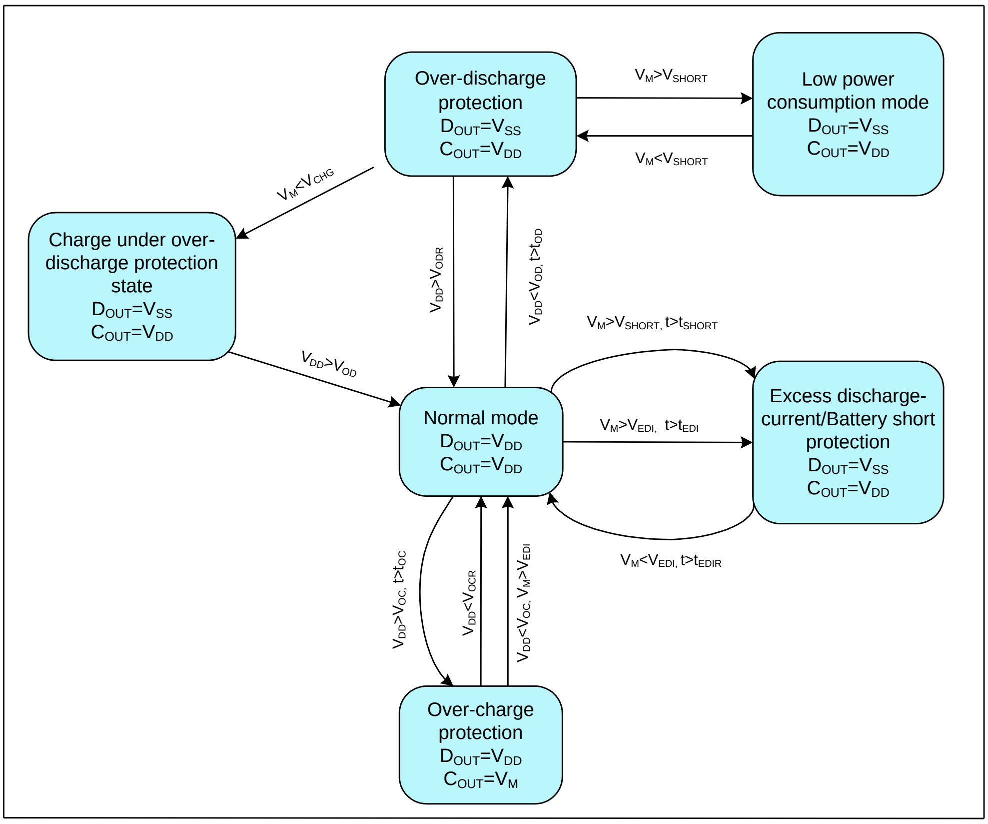


Figure 4 FH01 State Conversion Diagram

STATE CONVERSION AND TIMING DIAGRAM

Over-charge/Over-discharge Protection

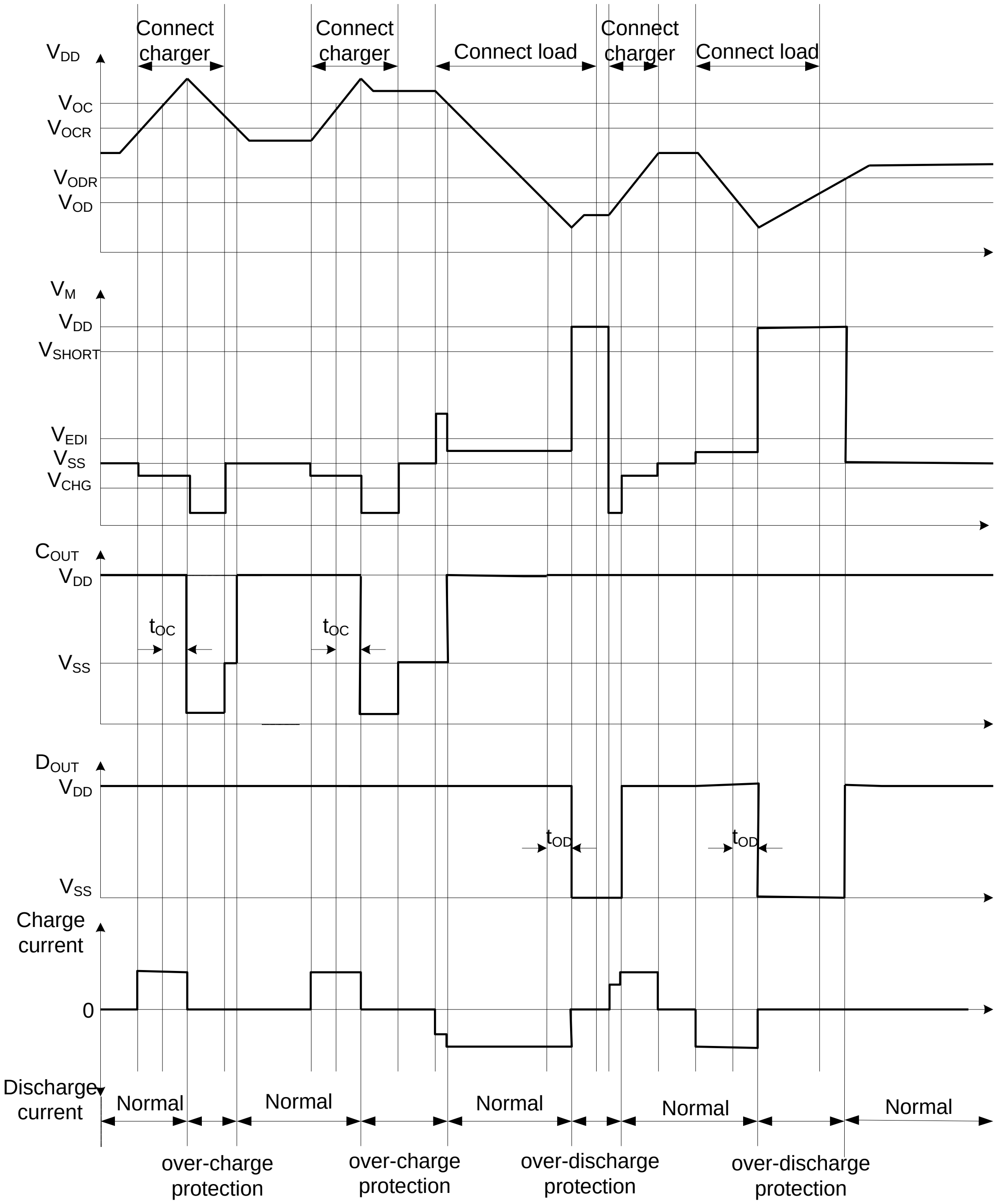


Figure 5 Timing Diagram of Over-charge/Over-discharge Protection

Excess-current Discharge/Battery Short Protection

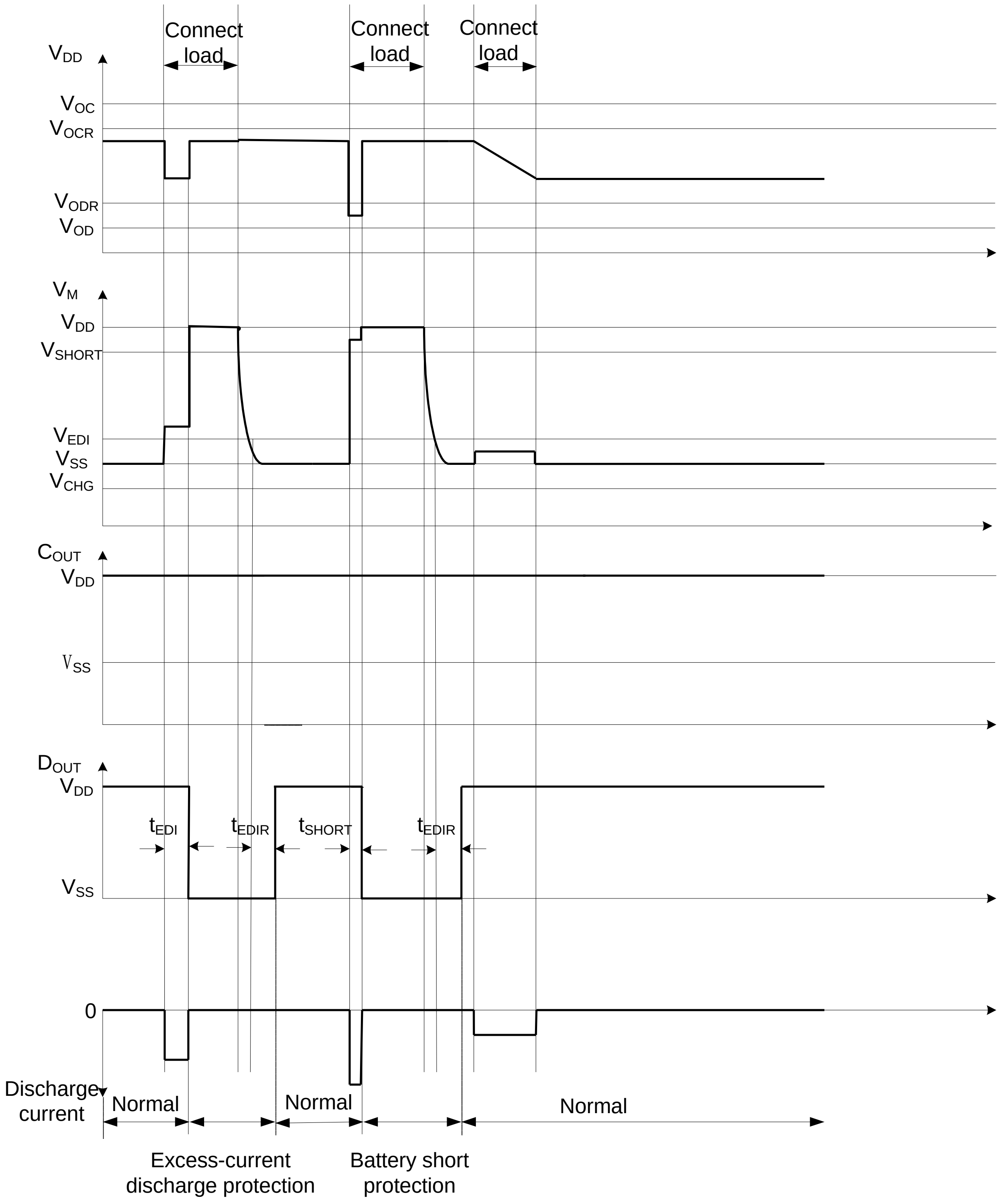


Figure 6 Timing Diagram of Excess-current Discharge/Battery Short Protection

APPLICATION NOTES

Selection of Q1 and Q2

Same type of N-MOSFET can be chosen for Q1 and Q2. The threshold voltage, V_{th} should be between 0.4V and the over-discharge protection threshold voltage (V_{OD}). If V_{th} is less than 0.4V, Q1 might not be turned off. If V_{th} is higher than V_{OD}, Q2 might be turned off before the over-discharge is detected.

The breakdown voltages between the gate and the source (BV_{GS}) of Q1 and Q2 should be higher than the charger voltage, V_{DD}. Otherwise, Q1 and Q2 can be destroyed during charging.

PACKAGE DIMENSION

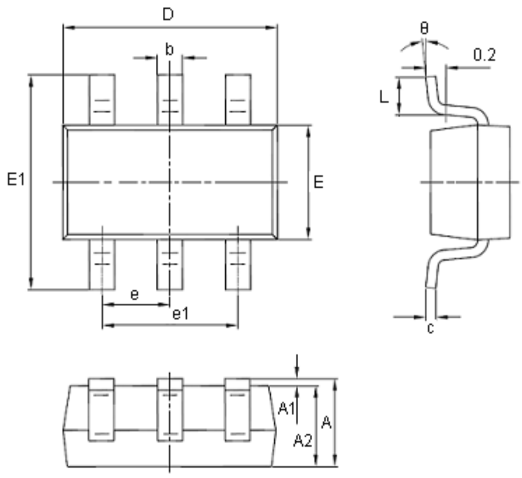


Figure 7 SOT23-6 Package

[Table 5] Physical Dimensions in figure 9 (Unit:mm)

符号	最小值	最大值
A	1.050	1.250
A1	0.000	0.100
A2	1.050	1.150
b	0.300	0.500
c	0.100	0.200
D	2.280	3.020
E	1.500	1.700
E1	2.650	2.950
e	0.950 (BSC)	
e1	1.800	2.000
L	0.300	0.600
θ	0º	8º