



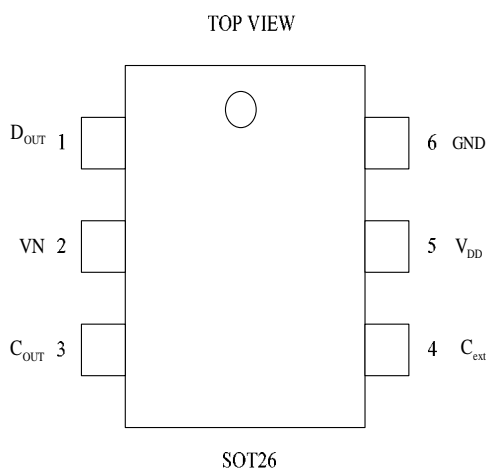
Details are subject to change without notice

### ONE-CELL LI-ION BATTERY PROTECTION IC

#### FEATURES

- Ideal for One-Cell Rechargeable Li-Ion Battery Pack.
- Low Current Consumption  
3.0μA .....Supply Current (Typical)  
0.6μA .....Standby Current
- High Withstand Voltage  
Absolute Maximum Ratings..22V (  $V_{DD} - V_N$  )
- High Accuracy Voltage Detection  
Over Charge Detector..... ± 50mV  
Over Discharge Detector..... ± 3.2%
- Over Current and Short Circuit Protection
- Wide Operating Temperature Range – 40° C to 85° C
- Ultra Small Package.....SOT26

#### PIN CONFIGURATION



#### GENERAL DESCRIPTION

The AAT8635 series are protection ICs designed to safeguard one-cell rechargeable Li-Ion battery pack against over charge, over discharge, over current, and short circuit. The AAT8635 series use advanced high voltage CMOS process to provide high accuracy voltage detection and low current consumption.

The AAT8635 series incorporate a reference unit and three voltage detectors. During the charging process, when the cell voltage ( $V_{DD}$ ) is charged to a value higher than the over charge threshold voltage ( $V_{CI}$ ), the over charge detector (COM1) will switch the output pin ( $C_{OUT}$ ) to a low level within a delay time ( $t_{CI}$ ), and thus turning off the MOSFET connected to the charging path. The  $C_{OUT}$  pin may change to high level again when the  $V_{DD}$  voltage falls below “ $V_{CI} - V_{HYS}$ ”, or when  $V_{DD}$  falls below  $V_{CI}$  while the charger is disconnected from the battery pack.

During the discharging process, when the  $V_{DD}$  drops to a value lower than the over-discharge threshold voltage ( $V_{DI}$ ), the over-discharge detector (COM2) will switch  $D_{OUT}$  to low level within a delay time ( $t_{DI}$ ), and thus turning off the MOSFET connecting to the discharging path. In the mean time, the AAT8635 series will enter a low current standby mode. Once into standby mode, the systems can only be released from



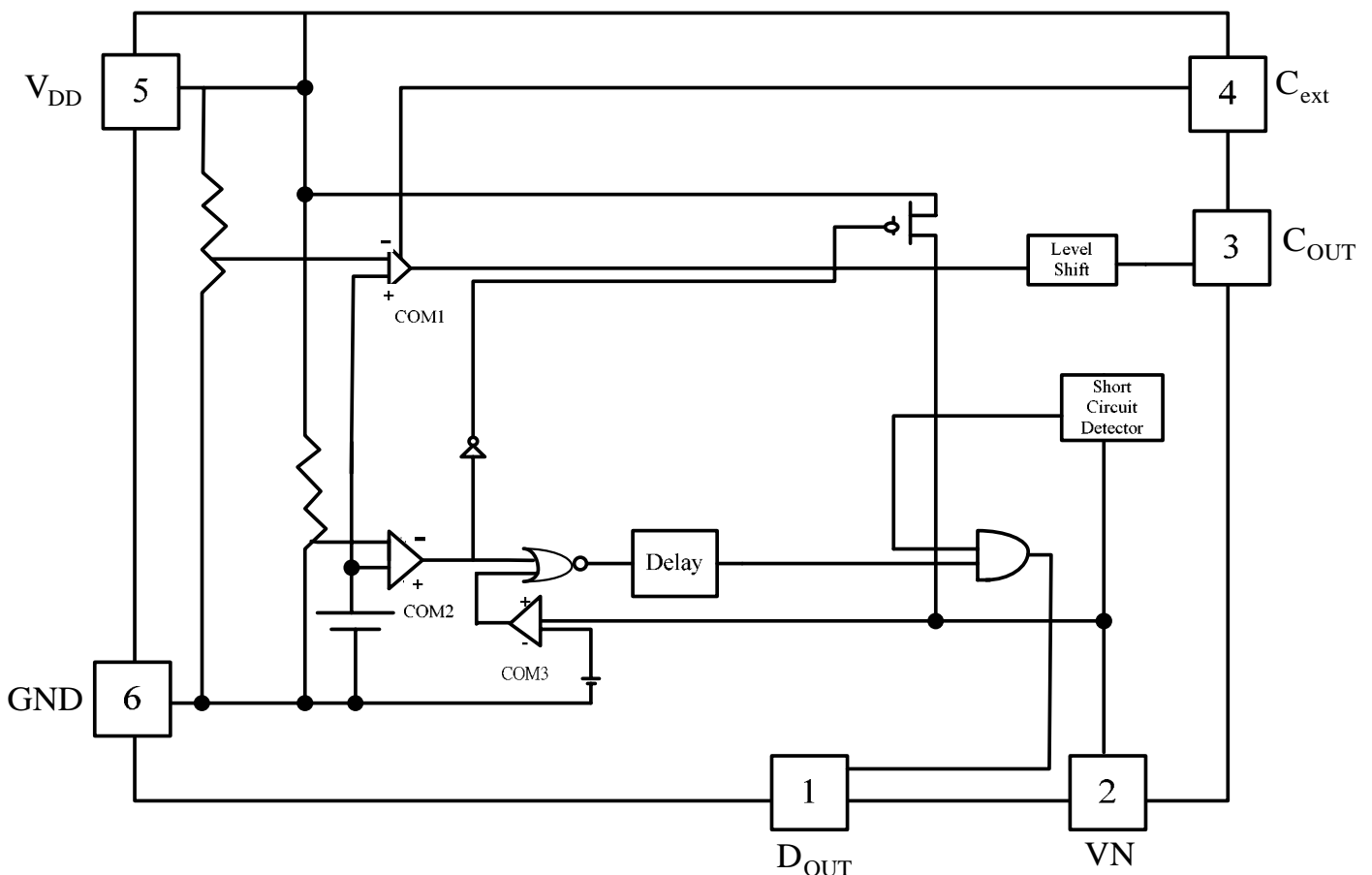
standby mode right after the battery pack is connected to a charger.

The conditions of over current and short circuit protection are both determined by the voltage at the VN pin. As the voltage of VN pin reaches a value higher than  $V_{oc}$ , which indicates an undesirable large current is flowing through the path,  $D_{OUT}$  will be switched to low and the path is cut-off right after an internally pre-set delay time ( $t_{oc}$ ) elapses. In the case of short circuit, i.e.

VN rises above  $V_{short}$ , the path will also be cut-off but with almost no delay time. Once the over current or factors contributing to short circuit is removed, the built-in resistor at the VN pin, typically  $100\text{ k}\Omega$ , will pull VN down to GND and bring the IC back to standard operation.

Together with the application circuit, the AAT8635 series will function as a consummate protector, which promotes safe usage and the sustainability of Li-Ion battery packs.

### BLOCK DIAGRAM

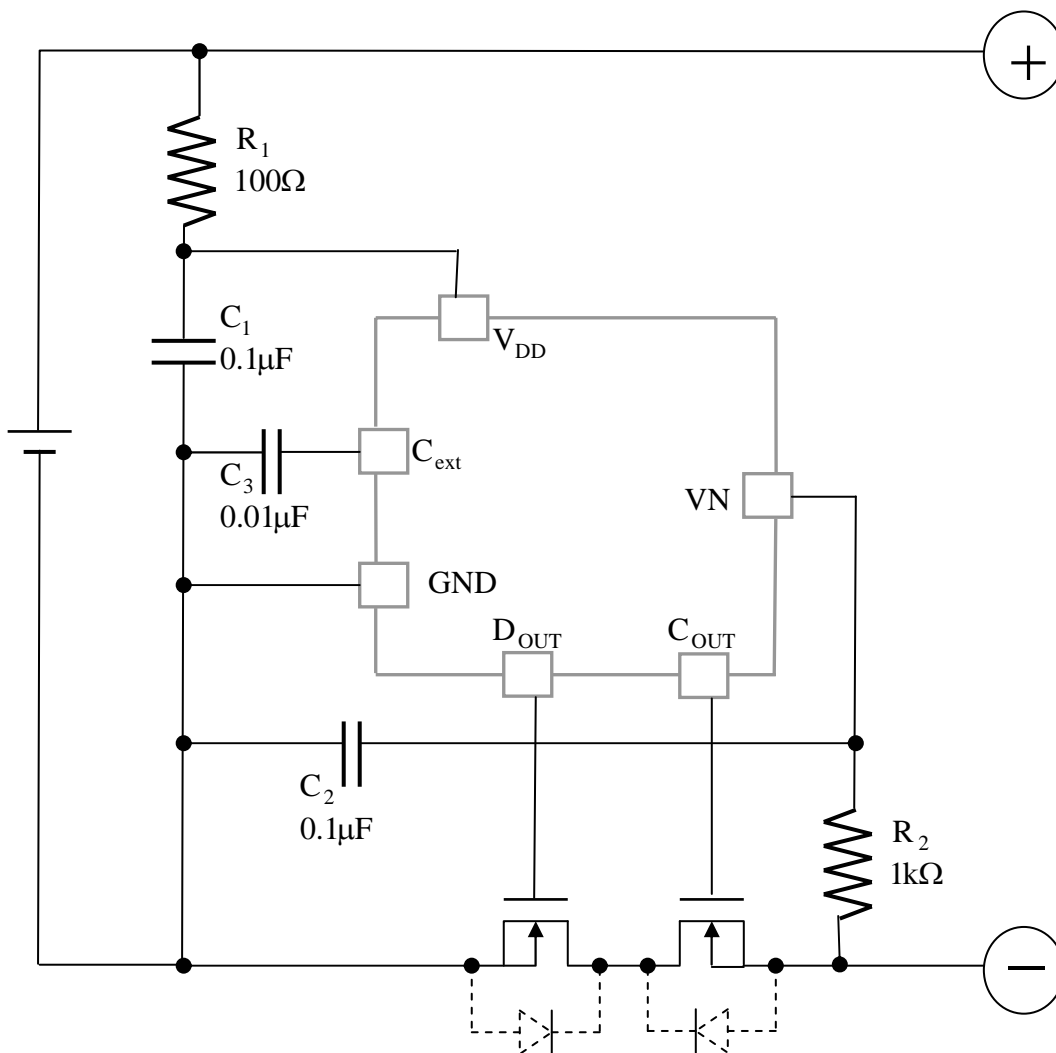




**PIN DESCRIPTION**

Pin No.	Symbol	Description
1	D <sub>OUT</sub>	Output of Over-Discharge Detection
2	VN	Pin for Charger Negative Input
3	C <sub>OUT</sub>	Output of Over-Charge Detection
4	C <sub>ext</sub>	Pin for External Capacitor Setting COM1 Delay Time
5	V <sub>DD</sub>	Power Supply
6	GND	Ground

**TYPICAL APPLICATION**



**ABSOLUTE MAXIMUM RATINGS**

Symbol	Item		Rating	Unit
$V_{DD}$	Supply Voltage		- 0.3 to 12	V
$V_N$	Input Voltage	VN Pin	$V_{DD} - 22$ to $V_{DD} + 0.3$	V
$V_{C_{ext}}$		$C_{ext}$ Pin	GND - 0.3 to $V_{DD} + 0.3$	V
$V_{C_{out}}$	Output Voltage	$C_{OUT}$ Pin	$V_{DD} - 22$ to $V_{DD} + 0.3$	V
$V_{D_{out}}$		$D_{OUT}$ Pin	GND - 0.3 to $V_{DD} + 0.3$	V
$P_d$	Power Dissipation		160	mW
$T_C$	Operating Temperature Range		- 40 to +85	
$T_{storage}, T_j$	Storage and Junction Temperature		- 50 to +120	

**ABSOLUTE MAXIMUM RATINGS**

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended period of time may affect device reliability.



**ELECTRICAL CHARACTERISTICS**

•AAT8635A

$T_{oper} = 25$

Symbol	Item	Conditions	Min	Typ	Max	Unit
$V_{DD1}$	Operating Input Voltage	Voltage Defined as $V_{DD} - GND$	1.5		10.0	V
$V_{CI}$	Over Charge Threshold Voltage	Detect Rising Edge of Supply Voltage	4.30	4.35	4.40	V
$V_{HYS}$	Over Charge Threshold Hysteresis Range		0.15	0.20	0.25	V
$t_{CI}$	Over Charge Delay Time	$C_3 = 0.01\mu F$ , $V_{DD} = 3.6V$ to $4.4V$	40	75	145	ms
$V_{DI}$	Over Discharge Threshold Voltage	Detect Falling Edge of Supply Voltage	2.42	2.50	2.58	V
$t_{DI}$	Over Discharge Delay Time	$V_{DD} = 3.6V$ to $2.4V$	4	10	20	ms
$V_{OC}$	Over Current Detection Voltage	Detect Rising Edge of VN Pin Voltage	0.17	0.20	0.23	V
$t_{OC}$	Over Current Detection Delay Time	$V_{DD} = 3.0V$	6	13	35	ms
$V_{short}$	Short Circuit Detection Voltage	$V_{DD} = 3.0V$	$V_{DD} - 1.2$	$V_{DD} - 0.9$	$V_{DD} - 0.6$	V
$t_{short}$	Short Circuit Detection Delay Time	$V_{DD} = 3.0V$		5	50	$\mu s$
$R_{short}$	Reset Resistance for Over Current Protection	$V_{DD} = 3.6V$ , $V_N = 1.0V$	50	100	150	k $\Omega$
$V_{OL1}$	Nch ON Voltage of $C_{OUT}$	$I_{OL} = 50\mu A$ , $V_{DD} = 4.4V$		0.35	0.50	V
$V_{OH1}$	Pch ON Voltage of $C_{OUT}$	$I_{OH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
$V_{OL2}$	Nch ON Voltage of $D_{OUT}$	$I_{OL} = 50\mu A$ , $V_{DD} = 2.4V$		0.2	0.5	V
$V_{OH2}$	Pch ON Voltage of $D_{OUT}$	$I_{OH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
$I_{DD}$	Supply Current	$V_{DD} = 3.9V$ , $V_N = 0V$		3.0	7.0	$\mu A$
$I_{s\ tan\ dby}$	Standby Current	$V_{DD} = 2.0V$			0.6	$\mu A$



**ELECTRICAL CHARACTERISTICS**

•AAT8635B

$T_{oper} = 25$

Symbol	Item	Conditions	Min	Typ	Max	Unit
$V_{DD1}$	Operating Input Voltage	Voltage Defined as $V_{DD} - GND$	1.5		10.0	V
$V_{CI}$	Over Charge Threshold Voltage	Detect Rising Edge of Supply Voltage	4.23	4.28	4.33	V
$V_{HYS}$	Over Charge Threshold Hysteresis Range		0.15	0.20	0.25	V
$t_{CI}$	Over Charge Delay Time	$C_3 = 0.01\mu F$ , $V_{DD} = 3.6V$ to $4.4V$	40	75	145	ms
$V_{DI}$	Over Discharge Threshold Voltage	Detect Falling Edge of Supply Voltage	2.42	2.50	2.58	V
$t_{DI}$	Over Discharge Delay Time	$V_{DD} = 3.6V$ to $2.4V$	4	10	20	ms
$V_{OC}$	Over Current Detection Voltage	Detect Rising Edge of VN Pin Voltage	0.17	0.20	0.23	V
$t_{OC}$	Over Current Detection Delay Time	$V_{DD} = 3.0V$	6	13	35	ms
$V_{short}$	Short Circuit Detection Voltage	$V_{DD} = 3.0V$	$V_{DD} - 1.2$	$V_{DD} - 0.9$	$V_{DD} - 0.6$	V
$t_{short}$	Short Circuit Detection Delay Time	$V_{DD} = 3.0V$		5	50	$\mu s$
$R_{short}$	Reset Resistance for Over Current Protection	$V_{DD} = 3.6V$ , $V_N = 1.0V$	50	100	150	k $\Omega$
$V_{OL1}$	Nch ON Voltage of $C_{OUT}$	$I_{OL} = 50\mu A$ , $V_{DD} = 4.4V$		0.35	0.50	V
$V_{OH1}$	Pch ON Voltage of $C_{OUT}$	$I_{OH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
$V_{OL2}$	Nch ON Voltage of $D_{OUT}$	$I_{OL} = 50\mu A$ , $V_{DD} = 2.4V$		0.2	0.5	V
$V_{OH2}$	Pch ON Voltage of $D_{OUT}$	$I_{OH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
$I_{DD}$	Supply Current	$V_{DD} = 3.9V$ , $V_N = 0V$		3.0	7.0	$\mu A$
$I_{s\ tan\ dby}$	Standby Current	$V_{DD} = 2.0V$			0.6	$\mu A$



**ELECTRICAL CHARACTERISTICS**

•AAT8635C

$T_{oper} = 25$

Symbol	Item	Conditions	Min	Typ	Max	Unit
$V_{DD1}$	Operating Input Voltage	Voltage Defined as $V_{DD} - GND$	1.5		10.0	V
$V_{CI}$	Over Charge Threshold Voltage	Detect Rising Edge of Supply Voltage	4.27	4.32	4.37	V
$V_{HYS}$	Over Charge Threshold Hysteresis Range		0.15	0.20	0.25	V
$t_{CI}$	Over Charge Delay Time	$C_3 = 0.01\mu F$ , $V_{DD} = 3.6V$ to $4.4V$	40	75	145	ms
$V_{DI}$	Over Discharge Threshold Voltage	Detect Falling Edge of Supply Voltage	2.42	2.50	2.58	V
$t_{DI}$	Over Discharge Delay Time	$V_{DD} = 3.6V$ to $2.4V$	4	10	20	ms
$V_{OC}$	Over Current Detection Voltage	Detect Rising Edge of VN Pin Voltage	0.17	0.20	0.23	V
$t_{OC}$	Over Current Detection Delay Time	$V_{DD} = 3.0V$	6	13	35	ms
$V_{short}$	Short Circuit Detection Voltage	$V_{DD} = 3.0V$	$V_{DD} - 1.2$	$V_{DD} - 0.9$	$V_{DD} - 0.6$	V
$t_{short}$	Short Circuit Detection Delay Time	$V_{DD} = 3.0V$		5	50	$\mu s$
$R_{short}$	Reset Resistance for Over Current Protection	$V_{DD} = 3.6V$ , $V_N = 1.0V$	50	100	150	k $\Omega$
$V_{OL1}$	Nch ON Voltage of $C_{OUT}$	$I_{OL} = 50\mu A$ , $V_{DD} = 4.4V$		0.35	0.50	V
$V_{OH1}$	Pch ON Voltage of $C_{OUT}$	$I_{OH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
$V_{OL2}$	Nch ON Voltage of $D_{OUT}$	$I_{OL} = 50\mu A$ , $V_{DD} = 2.4V$		0.2	0.5	V
$V_{OH2}$	Pch ON Voltage of $D_{OUT}$	$I_{OH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
$I_{DD}$	Supply Current	$V_{DD} = 3.9V$ , $V_N = 0V$		3.0	7.0	$\mu A$
$I_{s\ tan\ dby}$	Standby Current	$V_{DD} = 2.0V$			0.6	$\mu A$



**ELECTRICAL CHARACTERISTICS**

•AAT8635D

$T_{oper} = 25$

Symbol	Item	Conditions	Min	Typ	Max	Unit
$V_{DD1}$	Operating Input Voltage	Voltage Defined as $V_{DD} - GND$	1.5		10.0	V
$V_{CI}$	Over Charge Threshold Voltage	Detect Rising Edge of Supply Voltage	4.25	4.30	4.35	V
$V_{HYS}$	Over Charge Threshold Hysteresis Range		0.15	0.20	0.25	V
$t_{CI}$	Over Charge Delay Time	$C_3 = 0.01\mu F$ , $V_{DD} = 3.6V$ to $4.4V$	40	75	145	ms
$V_{DI}$	Over Discharge Threshold Voltage	Detect Falling Edge of Supply Voltage	2.42	2.50	2.58	V
$t_{DI}$	Over Discharge Delay Time	$V_{DD} = 3.6V$ to $2.4V$	4	10	20	ms
$V_{OC}$	Over Current Detection Voltage	Detect Rising Edge of VN Pin Voltage	0.17	0.20	0.23	V
$t_{OC}$	Over Current Detection Delay Time	$V_{DD} = 3.0V$	6	13	35	ms
$V_{short}$	Short Circuit Detection Voltage	$V_{DD} = 3.0V$	$V_{DD} - 1.2$	$V_{DD} - 0.9$	$V_{DD} - 0.6$	V
$t_{short}$	Short Circuit Detection Delay Time	$V_{DD} = 3.0V$		5	50	$\mu s$
$R_{short}$	Reset Resistance for Over Current Protection	$V_{DD} = 3.6V$ , $V_N = 1.0V$	50	100	150	$k\Omega$
$V_{OL1}$	Nch ON Voltage of $C_{OUT}$	$I_{OL} = 50\mu A$ , $V_{DD} = 4.4V$		0.35	0.50	V
$V_{OH1}$	Pch ON Voltage of $C_{OUT}$	$I_{OH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
$V_{OL2}$	Nch ON Voltage of $D_{OUT}$	$I_{OL} = 50\mu A$ , $V_{DD} = 2.4V$		0.2	0.5	V
$V_{OH2}$	Pch ON Voltage of $D_{OUT}$	$I_{OH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
$I_{DD}$	Supply Current	$V_{DD} = 3.9V$ , $V_N = 0V$		3.0	7.0	$\mu A$
$I_{s\ tan\ dby}$	Standby Current	$V_{DD} = 2.0V$			0.6	$\mu A$

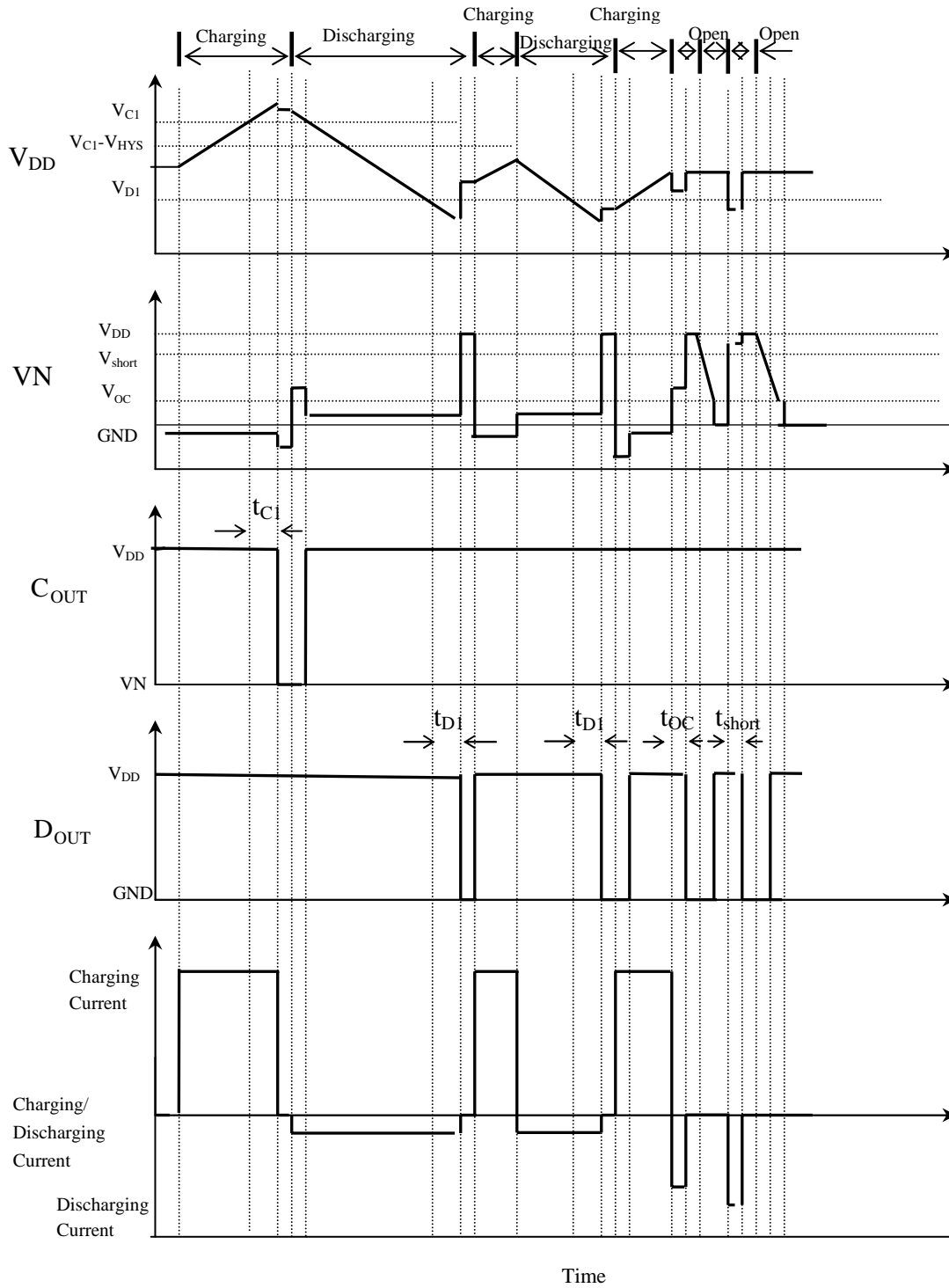




**TIMING DIAGRAM**

**•AAT8635 SERIES**

Over Short  
Current Circuit





## OPERATION

### 1. COM1 (Over-Charge Detector)

COM1 is the monitor of the voltage at the  $V_{DD}$  pin. COM1 senses an over charging condition and if this condition continues longer than the delay time ( $t_{Cl}$ ), when the voltage at  $V_{DD}$  exceeds the over charge detector threshold  $V_{Cl}$ . Under this condition,  $C_{OUT}$  pin falls to a low level and thus turns off the external charge control N-channel MOSFET. An internal level shifter is incorporated in the buffer driver at the  $C_{OUT}$  pin to drive the low level of  $C_{OUT}$  to be equal to the VN pin voltage. Furthermore, the high level of  $C_{OUT}$  is set to be equivalent to  $V_{DD}$ .

The over charge delay time  $t_{Cl}$  of over charging is determined by the external capacitor  $C_3$  connected between the GND and  $C_{ext}$  pin. The delay time  $t_{Cl}$  can be estimated as the following:

$$t_{Cl} = \frac{C_3 \times (V_{DD} - 0.7)}{0.48 \times 10^{-6}}$$

However, if the duration of the over charge condition is not long enough to cover the time delay window,  $C_{OUT}$  will not change to the low level and the charging process continues.

### 2. Required Conditions to Reset COM1 from Over Charging

After the MOSFET, the charge control, is turned off, COM1 can be reset under two conditions. As resetting COM1 means  $C_{OUT}$  returns to high level again and the charging path is reconnected to restart charging process, one of the conditions to reset COM1 is when  $V_{DD}$  falls to lower than " $V_{Cl} - V_{HYS}$ " as a result of battery cell internal discharge. Disconnecting the battery pack from the charger can also reset COM1 even when  $V_{DD}$  is still within the hysteresis window ( $V_{Cl} - V_{HYS} \leq V_{DD} < V_{Cl}$ ).

After the battery pack is disconnected from the charger, connecting a system load to the battery pack allows current to flow through the parasitic diode of external charge control MOSFET. This discharging current will bring  $V_{DD}$  down eventually and once  $V_{DD}$  drops below  $V_{Cl}$ ,  $C_{OUT}$  will change to high level.



## OPERATION (CONT.)

### 3. COM2 (Over Discharge Detector)

COM2 monitors the cell voltage at the  $V_{DD}$  pin. When  $V_{DD}$  drops below the over discharge threshold  $V_{D1}$  during the discharging process, COM1 detects an over charging condition and after delay time ( $t_{D1}$ ) elapses, the  $D_{OUT}$  pin falls to a low level and thus turning off the external discharge control N-channel MOSFET. As soon as this happens, the VN pin will be changed to high level by an internal PMOS and the AAT8635 series will enter the standby mode.

Connecting the battery pack to a charger is the required condition for AAT8635 series to recover from standby mode. With the charger connected, the charge current can flow through the parasitic diode of the external discharge control N-channel MOSFET while  $V_{DD}$  is still lower than the over-discharge threshold. Once  $V_{DD}$  is charged up to a value higher than  $V_{D1}$ , the  $D_{OUT}$  pin goes to a high level. This leads to the “ON” state of both the charge and discharge control MOSFETs, and the charging process proceeds on as long as the charger is connected. Connecting a charger to the battery pack when  $V_{DD}$  is already higher than  $V_{D1}$  will make  $D_{OUT}$  instantaneously high.

### 4. COM3 (Over Current Detector, Short Circuit Protector)

The over current detector and short circuit protector function normally when both the charge and discharge control N-channel MOSFETs are “ON”.

In standard operation, voltage on VN pin will be either slightly higher or lower than GND, depending on the impedance of the two MOSFETs. However, when the VN pin voltage rises to a value between the short circuit detection voltage  $V_{short}$  and over current detection voltage  $V_{OC}$ , the AAT8635 series detect an over current condition. As a result, the external discharge control N-channel MOSFET goes to “OFF” with  $D_{OUT}$  pin at the low state. An output delay time for the over current detection is internally fixed. A quick recovery of VN from a value between  $V_{short}$  and  $V_{OC}$  to the normal value within the delay time keeps the discharge control FET staying at the “ON” state.

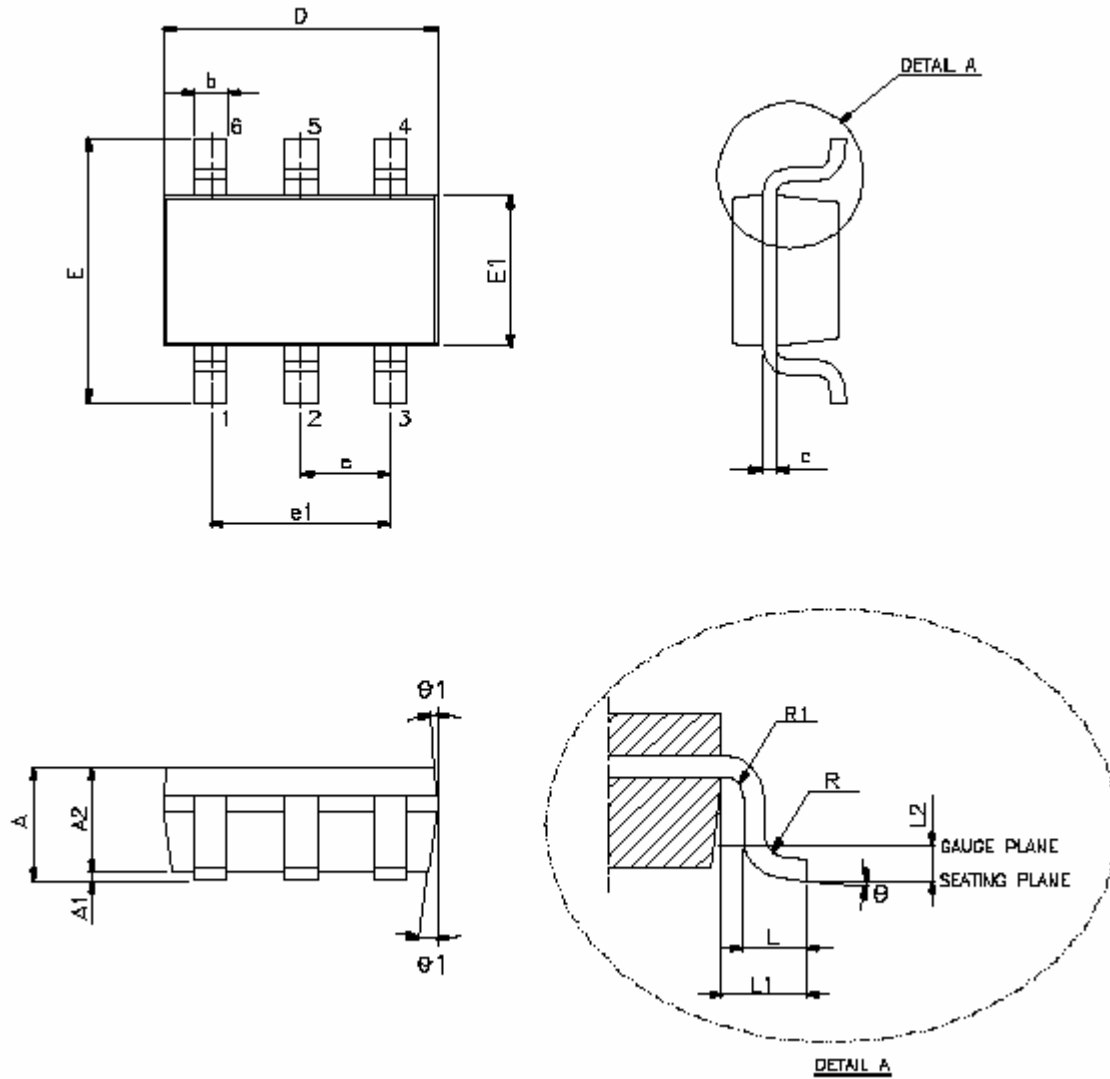
Short circuit may as well be explained as a “serious” over current condition. When the VN pin voltage rises to a value not only higher than  $V_{OC}$  but also higher than  $V_{short}$ , the short circuit protector will shut down the discharge MOSFET immediately to protect battery pack from being damaged or exploding.

The VN pin has a built-in pull down resistor. Thus once the factors that cause over current or short circuit is removed, the VN pin will be pulled down to ground level through the internal resistor. Therefore, with VN lower than the over current and short circuit protection threshold,  $D_{OUT}$  will be turned back on and the AAT8635 series can continue normal charge or discharge operation.

When over current or short circuit occurs, the AAT8635 series will not enter a standby mode.



PACKAGE DIMENSION





**PACKAGE DIMENSION (CONT.)**

**VARIATION (ALL DIMENSIONS SHOWN IN MILLIMETERS)**

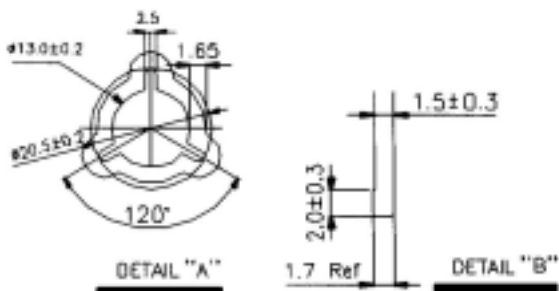
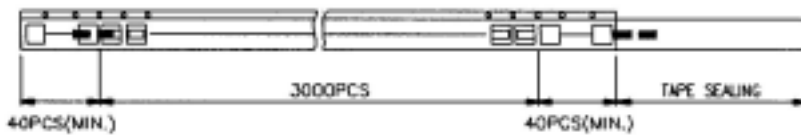
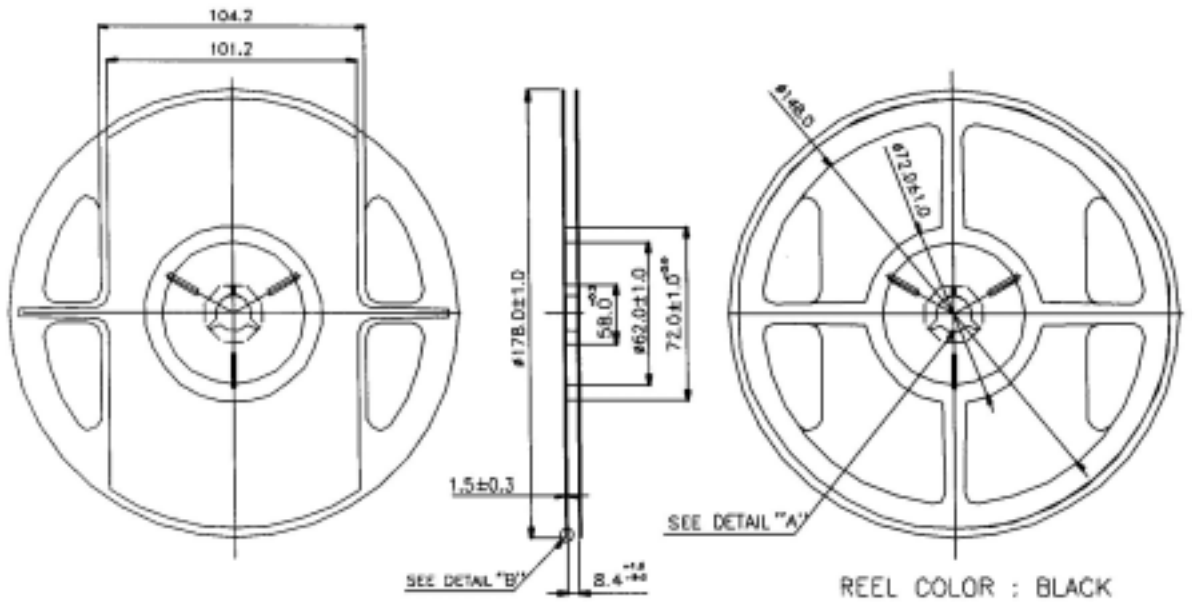
SYMBOL	MIN	TYP	MAX
A	-----	-----	1.45
A1	-----	-----	0.15
A2	0.90	1.15	1.30
b	0.30	-----	0.50
c	0.08	-----	0.22
D	2.90 BSC		
E	2.80 BSC		
E1	1.60 BSC		
e	0.95 BSC		
e1	1.90 BSC		
L	0.30	0.45	0.60
L1	0.60 REF		
L2	0.25 BSC		
R	0.10	-----	-----
R1	0.10	-----	0.25
θ	0°	4°	8°
θ1	5°	10°	15°

NOTE:

1 JEDEC OUTLINE: MO-178 AB

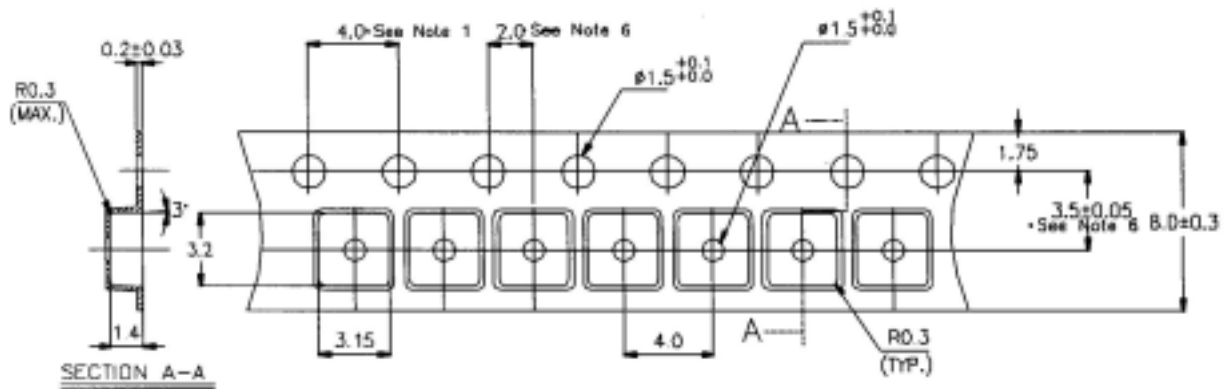
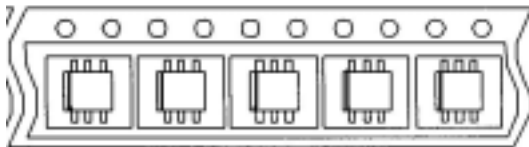


**TAPE AND REEL**





TAPE AND REEL (CONT.)



X.XXX X	± 0.0025
X.XXX	± 0.006
X.XX	± 0.025
X.X	± 0.10
X	± 0.25

UNIT: MILLIMETERS

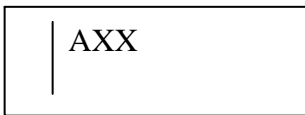
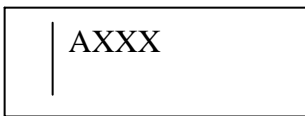


AAT8635 Versions

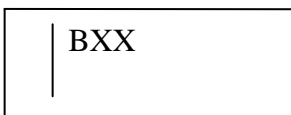
Description	8635A	8635 B	8635 C	8635D		
Over Charge Threshold Voltage ( $V_{CI}$ )	4.35V	4.28V	4.32V	4.30V		
Over Discharge Threshold Voltage ( $V_{DI}$ )	2.50V	2.50V	2.50V	2.50V		
Over Current Detection Voltage ( $V_{OC}$ )	0.20V	0.20V	0.20V	0.20V		

PART MARKING

PREVIOUS TOP MARKING



NEW TOP MARKING



Note:

1. Starting from January 2004, mass production products bear the new top marking presented above.
2. SOT-23-6 has no back marking.





**ORDERING INFORMATION**

