# Advanced Analog Technology, Inc.

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 ($V_{DD} - VN$)
- High Accuracy Voltage Detection
  Over Charge Detector…………...$\pm 50mV$
  Over Discharge Detector………. $\pm 3.2\%$
- Over Current and Short Circuit Protection
- Wide Operating Temperature Range $-40°C$ to $85°C$
- Ultra Small Package……..SOT26

PIN CONFIGURATION

TOP VIEW

D_{OUT} 1   6 GND

VN 2   5 V_{DD}

C_{OUT} 3   4 C_{ext}

SOT26
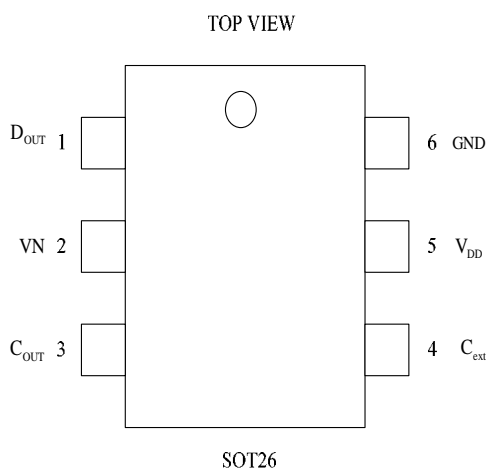
GENERAL DESCRIPTION

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_{C1}), the over charge detector (COM1) will switch the output pin (C_{OUT}) to a low level within a delay time (t_{C1}), 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 " $V_{C1} - V_{HYS}$ ", or when V_{DD} falls below V_{C1} 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_{D1}), the over-discharge detector (COM2) will switch D_{OUT} to low level within a delay time (t_{D1}), 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 $100\,k\Omega$, 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.
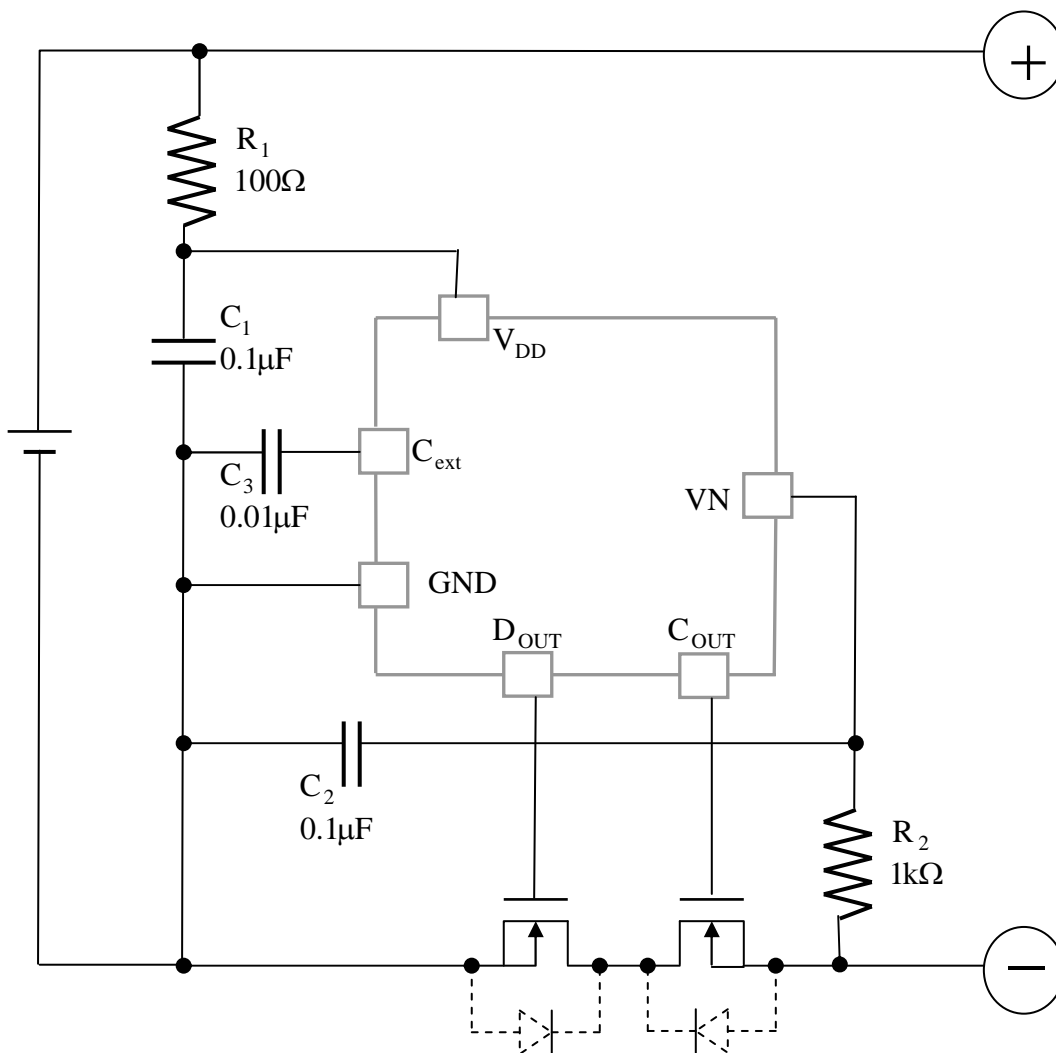
BLOCK DIAGRAM
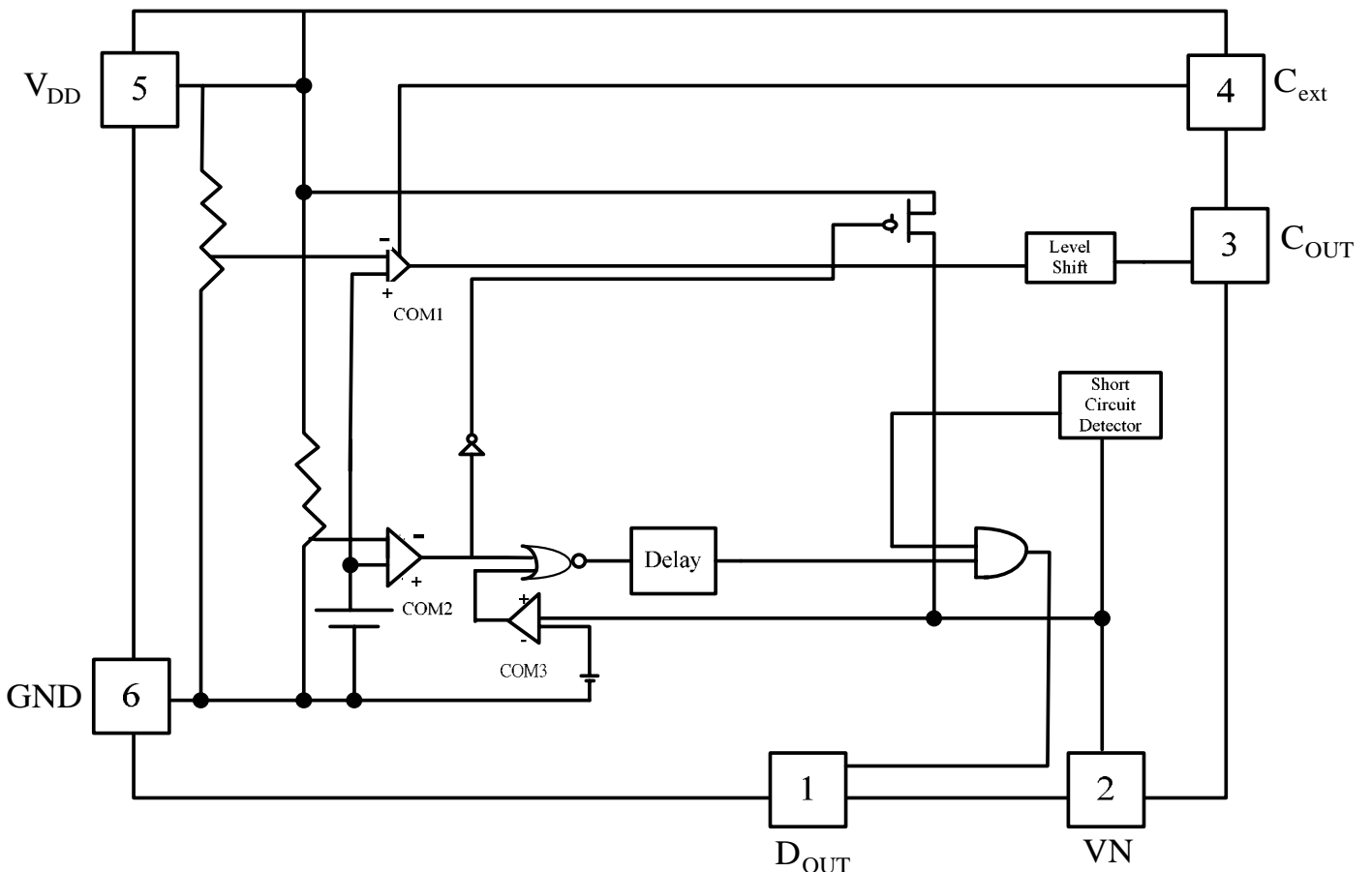
PIN DESCRIPTION

Pin No.	Symbol	Description
1	D_{OUT}	Output of Over-Discharge Detection
2	VN	Pin for Charger Negative Input
3	C_{OUT}	Output of Over-Charge Detection
4	C_{ext}	Pin for External Capacitor Setting COM1 Delay Time
5	V_{DD}	Power Supply
6	GND	Ground

TYPICAL APPLICATION

ABSOLUTE MAXIMUM RATINGS

Symbol	Item		Rating	Unit
V_{DD}	Supply Voltage		-0.3 to 12	V
VN	Input Voltage	VN Pin	$V_{DD}-22$ to $V_{DD}+0.3$	V
V_{Cext}		C_{ext} Pin	$GND-0.3$ to $V_{DD}+0.3$	V
V_{Cout}	Output Voltage	C_{OUT} Pin	$V_{DD}-22$ to $V_{DD}+0.3$	V
V_{Dout}		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.

Advanced Analog Technology, Inc.

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_{C1}	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_{C1}	Over Charge Delay Time	$C_3 = 0.01\mu F$, $V_{DD} = 3.6V$ to 4.4V	40	75	145	ms
V_{D1}	Over Discharge Threshold Voltage	Detect Falling Edge of Supply Voltage	2.42	2.50	2.58	V
t_{D1}	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	μs
R_{short}	Reset Resistance for Over Current Protection	$V_{DD} = 3.6V$, VN=1.0V	50	100	150	kΩ
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	$V_{DD} = 3.9V, VN = 0V$		3.0	7.0	μA
$I_{standby}$	Standby Current	$V_{DD} = 2.0V$			0.6	μA

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_{C1}	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_{C1}	Over Charge Delay Time	$C_3 = 0.01\mu F$, $V_{DD} = 3.6V$ to 4.4V	40	75	145	ms
V_{D1}	Over Discharge Threshold Voltage	Detect Falling Edge of Supply Voltage	2.42	2.50	2.58	V
t_{D1}	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	μs
R_{short}	Reset Resistance for Over Current Protection	$V_{DD} = 3.6V$, VN=1.0V	50	100	150	kΩ
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	$V_{DD} = 3.9V, VN = 0V$		3.0	7.0	μA
$I_{standby}$	Standby Current	$V_{DD} = 2.0V$			0.6	μA

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_{C1}	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_{C1}	Over Charge Delay Time	$C_3 = 0.01\mu F$, $V_{DD} = 3.6V$ to 4.4V	40	75	145	ms
V_{D1}	Over Discharge Threshold Voltage	Detect Falling Edge of Supply Voltage	2.42	2.50	2.58	V
t_{D1}	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	μs
R_{short}	Reset Resistance for Over Current Protection	$V_{DD} = 3.6V$, VN=1.0V	50	100	150	kΩ
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	$V_{DD} = 3.9V, VN = 0V$		3.0	7.0	μA
$I_{standby}$	Standby Current	$V_{DD} = 2.0V$			0.6	μA

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_{C1}	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_{C1}	Over Charge Delay Time	$C_3 = 0.01\mu F$, $V_{DD} = 3.6V$ to 4.4V	40	75	145	ms
V_{D1}	Over Discharge Threshold Voltage	Detect Falling Edge of Supply Voltage	2.42	2.50	2.58	V
t_{D1}	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	μs
R_{short}	Reset Resistance for Over Current Protection	$V_{DD} = 3.6V$, VN=1.0V	50	100	150	kΩ
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	$V_{DD} = 3.9V, VN = 0V$		3.0	7.0	μA
$I_{standby}$	Standby Current	$V_{DD} = 2.0V$			0.6	μA

TIMING DIAGRAM

•AAT8635 SERIES
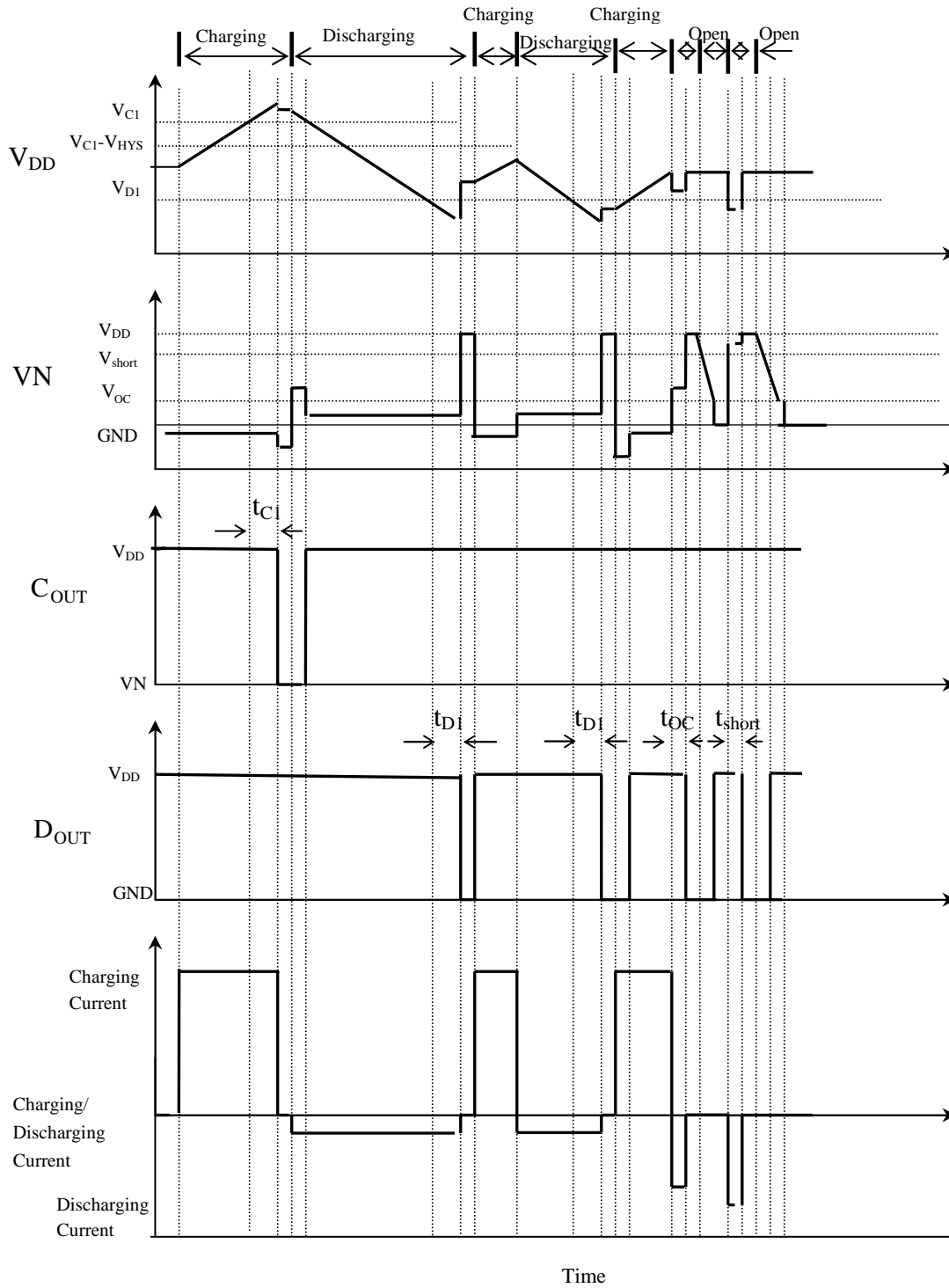
OPERATION

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_{C1}), when the voltage at V_{DD} exceeds the over charge detector threshold V_{C1}. 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_{C1} of over charging is determined by the external capacitor C_3 connected between the GND and C_{ext} pin. The delay time t_{C1} can be estimated as the following:

$$t_{C1} = \frac{C_3 \times (V_{DD} - 0.7)}{0.48 \times 10^{-6}}$$

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 "$V_{C1} - V_{HYS}$" 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 ($V_{C1} - V_{HYS} \leq V_{DD} < V_{C1}$).

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_{C1}, 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
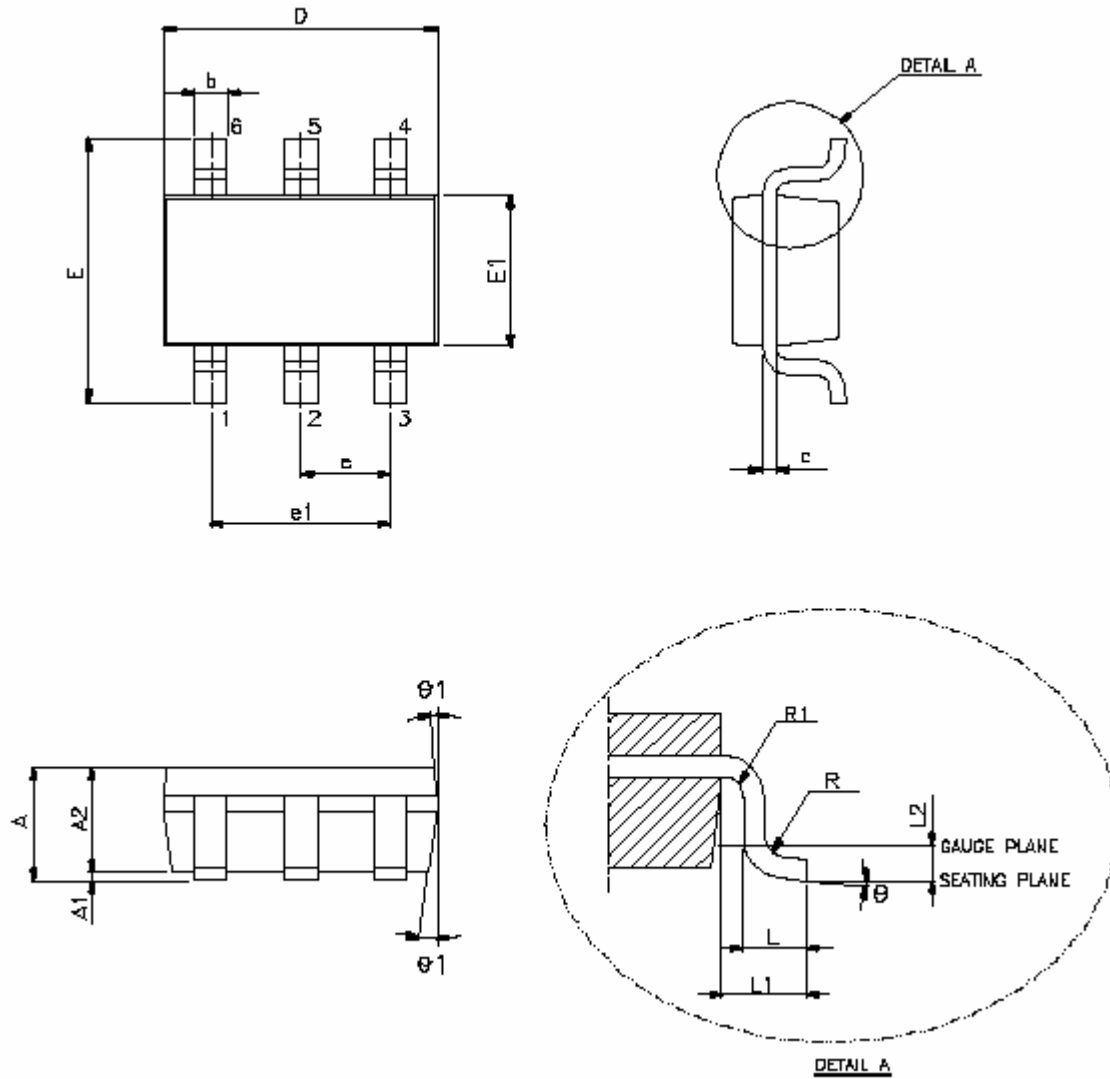
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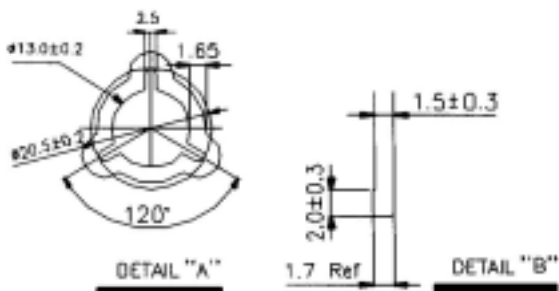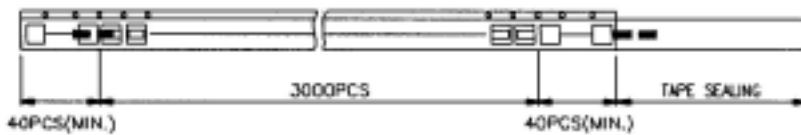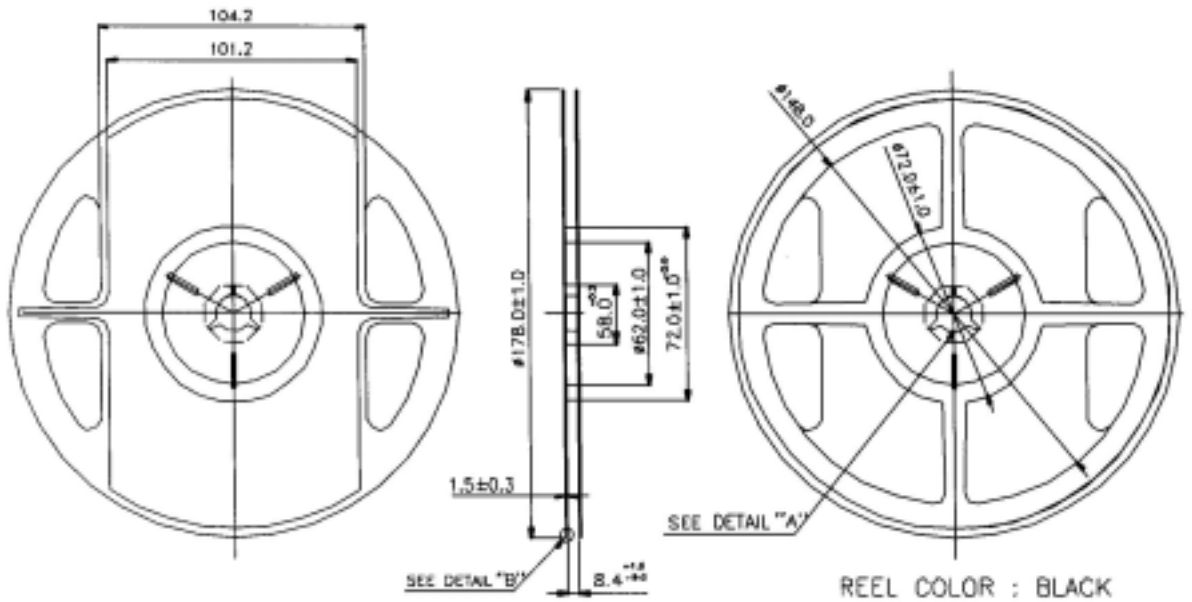
VARIATION (ALL DIMENSIONS SHOWN IN MILLIMETERS)

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

REEL COLOR : BLACK

DETAIL "A"

DETAIL "B"

TAPE AND REEL (CONT.)
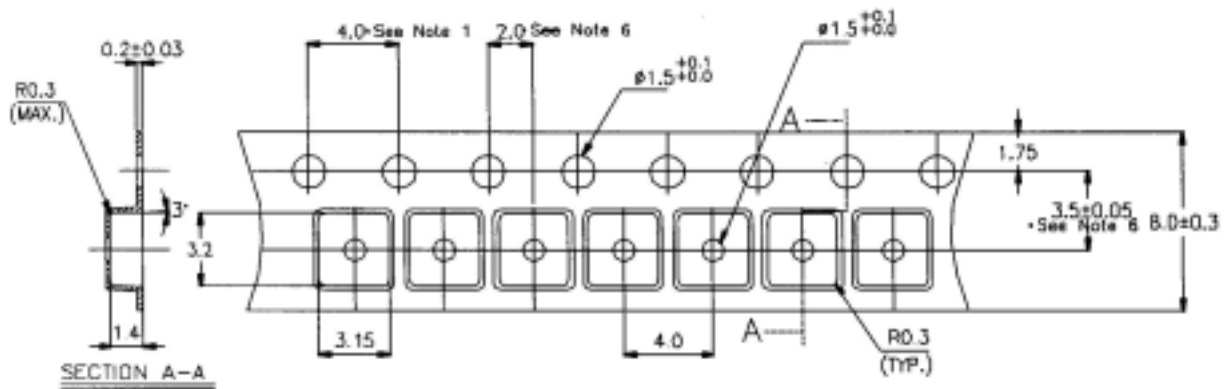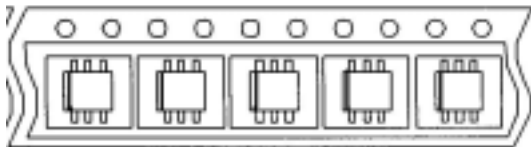
X.XXX X	± 0.0025
X.XXX	± 0.006
X.XX	± 0.025
X.X	± 0.10
X	± 0.25

UNIT: MILLIMETERS

AAT8635 Versions						
Description	8635A	8635 B	8635 C	8635D		
Over Charge Threshold Voltage (V_{C1})	4.35V	4.28V	4.32V	4.30V		
Over Discharge Threshold Voltage (V_{D1})	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 MAKING

AXXX

AXX

NEW TOP MARKING

BXX
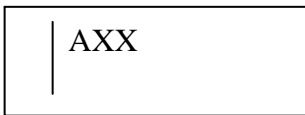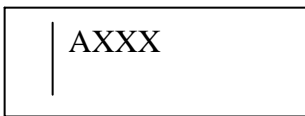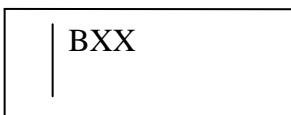
Note:

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

AAT xxxxx-xx-x

AAT Part Number

Package Code 1
Sot26: S3

Package Code 2
T=Taping Reel
Blank=Tube or Tray

Remark:
T=Taping Reel
PS.
Sot26→3,000pcs/reel

Blank=Tube