General Description

FS326 is a series of lithium-ion and lithium-polymer rechargeable battery protection ICs with high accurate voltage detection and delay circuits.

These ICs are suitable for protection of single cell lithium-ion or lithium polymer battery packs from over charge, over discharge and over current.

Ordering Information

FS326 **x**

└── Serial code from A to F *

*: Refer to the product name list on next page.

Features

- **Low supply current**
  Normal Operation : 3.0 μA typ. @VDD=3.9V
  Power-down mode : 0.1 μA max. @VDD=2.0V
- **Overcharge detection voltage**
  〔 V_{OCU} 〕 4.2V~4.4V, Accuracy of ±25mV
- **Overcharge release voltage**
  〔 V_{OCR} 〕 3.8V~4.2V, Accuracy of ±50mV
- **Overdischarge detection voltage**
  〔 V_{ODL} 〕 2.2V~2.6V, Accuracy of ±50*mV
- **Overdischarge release voltage**
  〔 V_{ODR} 〕 2.4V~3.2V, Accuracy of ±50*mV
- **Over current detection voltage**
  〔 V_{OI1} 〕 0.05V~0.2V, Accuracy of ±30mV
- **Short circuit detection voltage**
  〔 V_{OI2} 〕 Fixed at 1.35V
- **Delay times are generated by an internal circuit. (External capacitors are unnecessary.)**
- **Charger detection voltage -0.7V**
- **Reset resistance for Over current protection >500kΩ**
- **Wide supply voltage range 1.8 ~ 9.0V**
- **Small package SOT-23-6**

Applications

- **Protection IC for One-Cell Lithium-Ion / Lithium-Polymer Battery Pack**

*: ±50mV for F version, others are ±80mV.

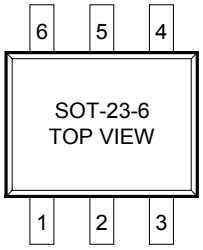
Product Name List

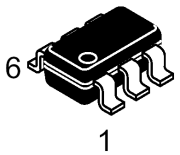
Model	Package	Overcharge detection voltage [V_{OCU}] (V)	Overcharge release voltage [V_{OCR}] (V)	Overdischarge detection voltage [V_{ODL}] (V)	Overdischarge release voltage [V_{ODR}] (V)	Overcurrent detection voltage [V_{OI1}] (mV)
	SOT-23-6					
FS326	A	4.325±0.025	4.075±0.05	2.50±0.08	2.90±0.08	100±30
	B	4.350±0.025	4.150±0.05	2.30±0.08	3.00±0.08	100±30
	C	4.325±0.025	4.075±0.05	2.50±0.08	2.90±0.08	150±30
	D	4.300±0.025	4.080±0.05	2.50±0.08	2.90±0.08	150±30
	E	4.300±0.040	4.080±0.05	2.50±0.08	2.90±0.08	150±30
	F	4.275±0.025	4.175±0.05	2.30±0.05	2.42±0.05	100±30

Overcharge, overdischarge and overcurrent detection voltages can be changed at the customer's request.

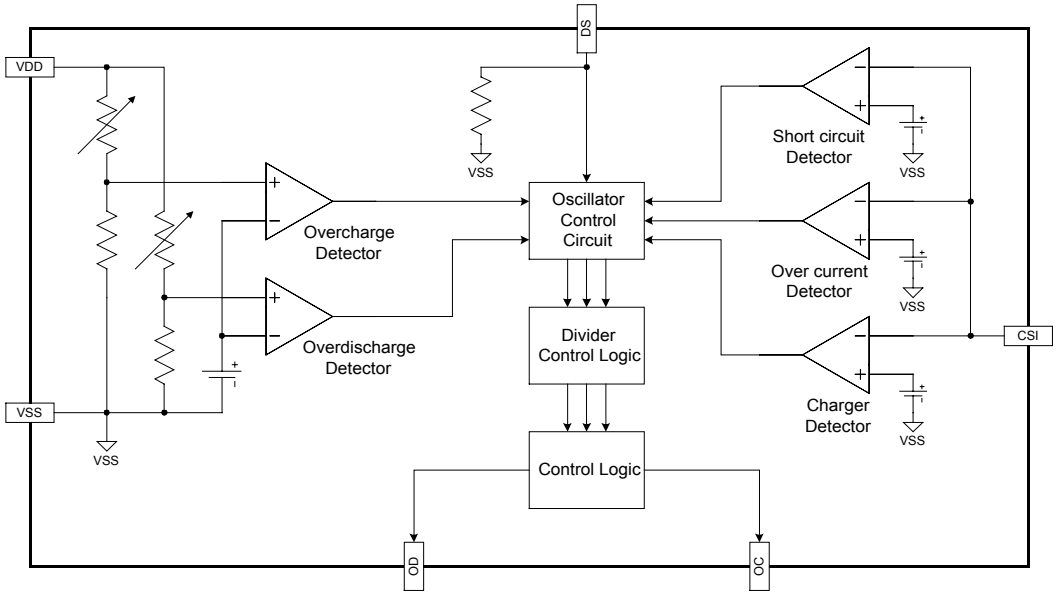
Pin Configuration

Pin No.	Symbol	Description
1	OD	FET gate connection pin for discharge control
2	CSI	Input pin for current sense, charger detect
3	OC	FET gate connection pin for charge control
4	DS	Test pin for reduce delay time
5	VDD	Positive power input pin
6	VSS	Negative power input pin

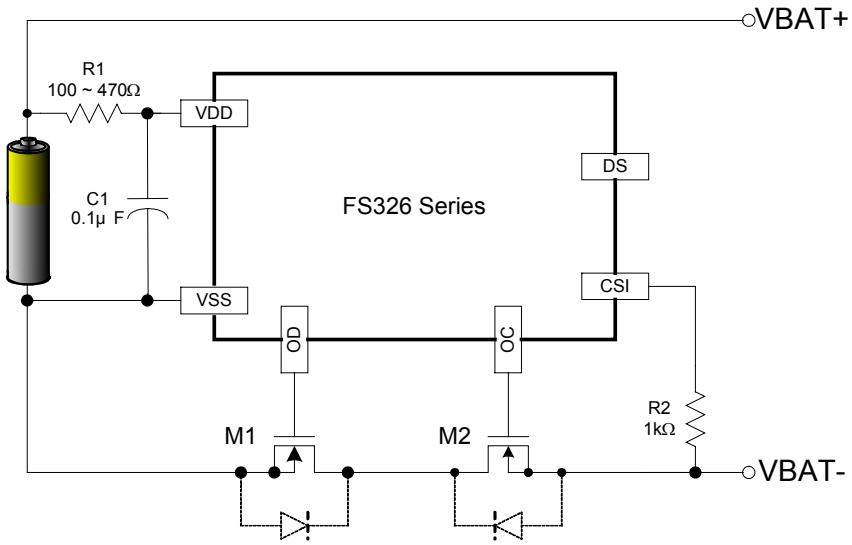




Functional Block Diagram



Typical Application Circuit



Absolute Maximum Ratings

(VSS=0V, Ta=25°C unless otherwise specified)

Item	Symbol	Rating	Unit
Input voltage between VDD and VSS *	V_{DD}	V_{SS} -0.3 to V_{SS} +12	V
OC output pin voltage	V_{OC}	V_{DD} -26 to V_{DD} +0.3	V
OD output pin voltage	V_{OD}	V_{SS} -0.3 to V_{DD} +0.3	V
CSI input pin voltage	V_{CSI}	V_{DD} -26 to V_{DD} +0.3	V
DS input pin voltage	V_{DS}	V_{SS} -0.3 to V_{DD} +0.3	V
Operating Temperature Range	T_{OP}	-40 to +85	°C
Storage Temperature Range	T_{ST}	-40 to +125	°C

Note: FS326 contains a circuit that will protect it from static discharge; but please take special care that no excessive static electricity or voltage which exceeds the limit of the protection circuit will be applied to it.

* Pulse (μ sec) noise exceeding the above input voltage (V_{SS}+12V) may cause damage to the IC.

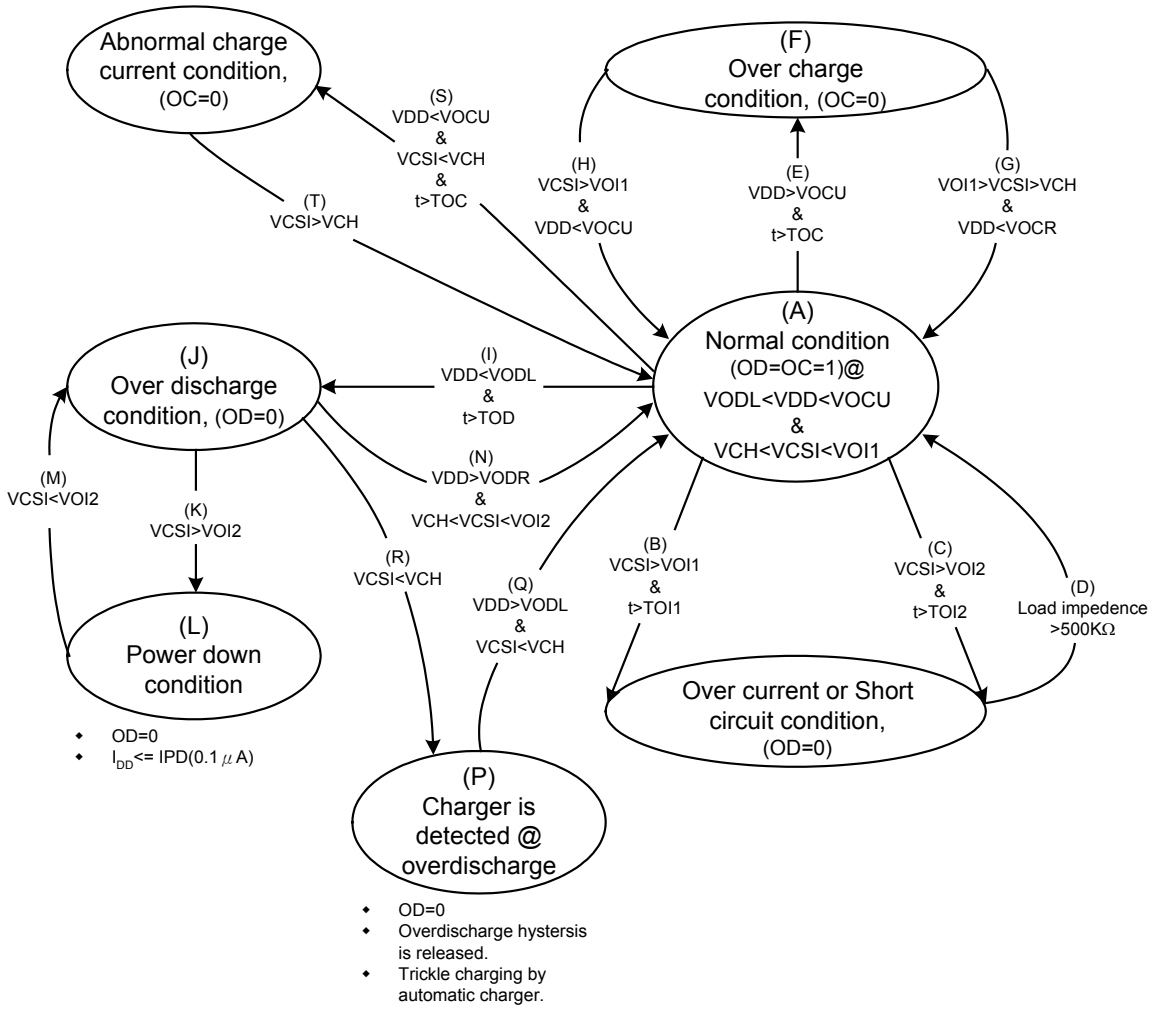
Electrical Characteristics

(VSS=0V, DS=Floating, Ta=25°C unless otherwise specified)

PARAMETER	CONDITIONS	SYMBOL	Min	Typ	Max	UNIT
CURRENT CONSUMPTION						
Supply Current	VDD=3.9V	IDD		3.0	6.0	μA
Power-Down Current	VDD=2.0V	IPD			0.1	μA
OPERATING VOLTAGE						
Operating input voltage	VDD-VSS	VDS1	1.8		9.0	V
DETECTION VOLTAGE						
Overcharge detection voltage		VOCU	VOCU -0.025	VOCU	VOCU +0.025	V
Overcharge release voltage		VOCR	VOCR -0.050	VOCR	VOCR +0.050	V
Overdischarge detection voltage		VODL	VODL -0.080*	VODL	VODL +0.080*	V
Overdischarge release voltage		VODR	VODR -0.080*	VODR	VODR +0.080*	V
Over current detection voltage		VOI1	VOI1 -0.030	VOI1	VOI1 +0.030	V
Short circuit detection voltage	VDD=3.0V	VOI2	1.0	1.35	1.7	V
Reset resistance for Over current protection	VDD=3.6V	Rshort	400	500	600	kΩ
Charger detection voltage		VCH	-1.2	-0.7	-0.2	V
DELAY TIME						
Overcharge detection delay time	VDD=3.6V to 4.4V	TOC		1.3	1.9	s
Overdischarge detection delay time	VDD=3.6V to 2.0V	TOD		180	260	ms
Over current detection delay time	VDD=3.0V	TOI1	5	10	15	ms
Short circuit detection delay time	VDD=3.0V	TOI2		10	50	μs
OTHER						
OC pin output “H” voltage	VDD=3.9V, Ioh=-50μA	Voh1	3.4	3.7		V
OC pin output “L” voltage	VDD=4.5V, CSI=0V	Vol1		0.1	0.5	V
OD pin output “H” voltage	VDD=3.9V, Ioh=-50μA	Voh2	3.4	3.7		V
OD pin output “L” voltage	VDD=2.0V, Iol=50μA	Vol2		0.1	0.5	V

*: For FS326F, the accuracy is ±0.05V.

State Diagram of Operation



Description of Operation

1. Normal Condition

The FS326 monitors the voltage of the battery connected between V_{DD} and V_{SS}. The charge and discharge scheme will be sensed by the voltage difference between CSI and V_{SS}. When $V_{ODL}<V_{DD}<V_{OCU}$ and $V_{CH}<V_{CSI}<V_{OI1}$, FS326 will turn on the charging (M2) and discharging (M1) control MOSFETs. The charging and discharging processes can be operated normally. This is called the normal condition.

Note: When a battery is connected to FS326 for the first time, it may not enter the normal condition (dischargeable may not be enabled). In this case, short the CSI and V_{SS} pins or connect a charger to restore to the normal condition.

2. Overcharge Condition

When the battery voltage becomes higher than the overcharge detection voltage (V_{OCU}) during normal charging condition through a delay time longer than T_{OC} (the overcharge detection delay time), FS326 will turn M2 off to stop charging. This condition is called the overcharge condition.

3. Release of Overcharge Condition

There are two ways to return to normal condition from overcharge condition.

1) When the battery is self discharging, and if $V_{DD}<V_{OCR}$ and $V_{OI1}>V_{CSI}>V_{CH}$ occurs, M2 will be turned on and back to normal condition.

2) Remove the charger and connect FS326 to a load, the discharging current will flow through the parasitic diode of M2. At this moment, V_{CSI} increases a voltage (V_F) of the parasitic diode from the V_{SS} level momentarily. While $V_{CSI}>V_{OI1}$ and $V_{DD}<V_{OCU}$ occurs, M2 will be turned on and back to normal condition.

Note 1: After entering the overcharge condition, if the charger remains connected and $V_{OI1}>V_{CSI}>V_{CH}$, then M2 will be turned on when the voltage of the battery is lower than V_{OCR} (because the self-discharge of the battery). The system can enter the charging status again as **1)**.

Note 2: After entering the overcharge condition, if the charger remains connected and $V_{CSI}<V_{CH}$, then M2 will be kept off even though the voltage of the battery is lower than V_{OCR} (because the self-discharge of the battery), and the system will not be allowed to enter the charging status.

4. Overdischarge Condition

When the battery voltage falls below the overdischarge detection voltage (V_{ODL}) during discharging condition and through a delay time longer than T_{OD} (the overdischarge detection delay time), FS326 will turn M1 off to stop discharging. This is called the overdischarge condition. In the meanwhile, CSI will be pulled up to V_{DD} through an internal resistance. If $V_{CSI}>V_{OI2}$, FS326 will enter into power-down mode. While in this mode, the current consumption is lower than 0.1 μA.

5. Release of Power-down mode

After entering power-down mode, when the system is connected to a charger, the charging current will flow through the parasitic diode of M1. If $V_{CSI}<V_{OI2}$ occurs, then FS326 will release power-down mode. While keeping charging status, there are two ways back to normal condition:

1) If V_{CSI}<V_{CH} (Charger detection), then when V_{DD}>V_{ODL}, M1 will be turned on and the system will back to normal condition.

2) If V_{CH}<V_{CSI}<V_{OI2}, the condition V_{DD}>V_{ODR} must be satisfied for M1 to be turned on, and then the system will back to the normal condition.

6. Charger Detection

While connecting to a charger after entering into power-down mode, then if V_{CSI}<V_{CH}, M1 will be turned on when V_{DD}>V_{ODL}. The system will back to normal condition as described in 1) of previous section since the charger has been detected. This action is called charger detection.

7. Abnormal Charge Current Condition

When a charger is connected to the battery system in normal condition, then if V_{DD}<V_{OCU} and V_{CSI}<V_{CH} occurs through a delay time longer than T_{OC} (delay time of overcharge detection), M2 will be turned off to stop this charging status. It is called the abnormal charge current condition.

Abnormal charge current condition is released when the voltage of CSI pin becomes higher than charger detection voltage (V_{CH}), or the charger is removed.

8. Over Current / Short Circuit Condition

When the current is too large during discharging under normal condition as a result of the voltage detected by CSI is greater than V_{OI1} (or V_{OI2}) through a delay time T_{OI1} (or T_{OI2}), it satisfies the over current (or short circuit) condition. Then M1 will be turned off and CSI will be pulled down to V_{SS} through an internal resistance. It is called the over current (or short circuit) condition.

- If the over current / short circuit is detected and it keeps longer than the overdischarge detection delay time with the same circumstance, the condition will be changed to the power-down mode when the battery voltage falls below the overdischarge detection voltage.
- If the battery voltage falls below the overdischarge detection voltage (V_{ODL}) due to the over current / short circuit, the discharging control FET (M1) will be turned off when this condition occurs. After overdischarge detection delay time (T_{OD}) expired, if the battery voltage is still equal to or lower than the overdischarge detection voltage, the condition will then be changed to power-down mode.

9. Release of Over Current / Short Circuit Condition

While the protection IC remains in Over current/Short circuit condition, then if the load is removed or the impedance between V_{BAT+} and V_{BAT-} is larger than 500kΩ as well as V_{CSI}<V_{OI1}, M1 will be turned on and then back to normal condition.

10. DS Pin

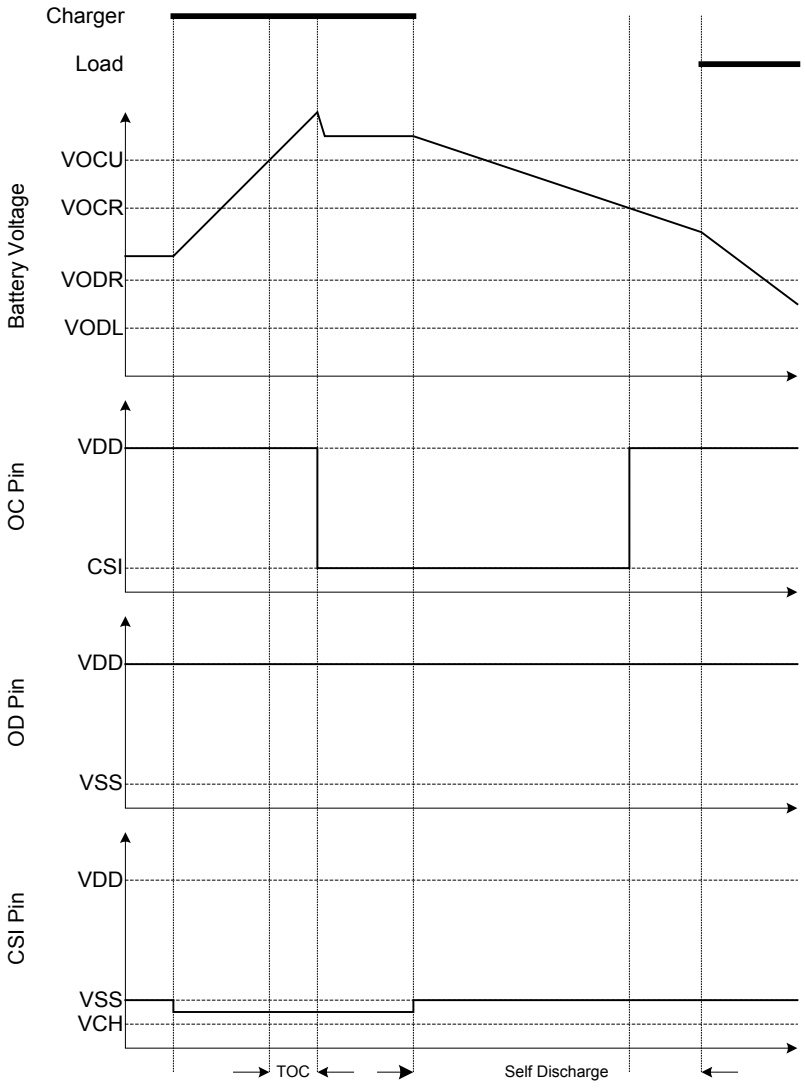
By forcing DS to V_{DD}, the delay time of the overcharge and overdischarge can be reduced to within 50ms; therefore, testing time of protector circuit board can be reduced.

1.6MΩ pull down resistor is connected between DS pin and V_{SS} internally.

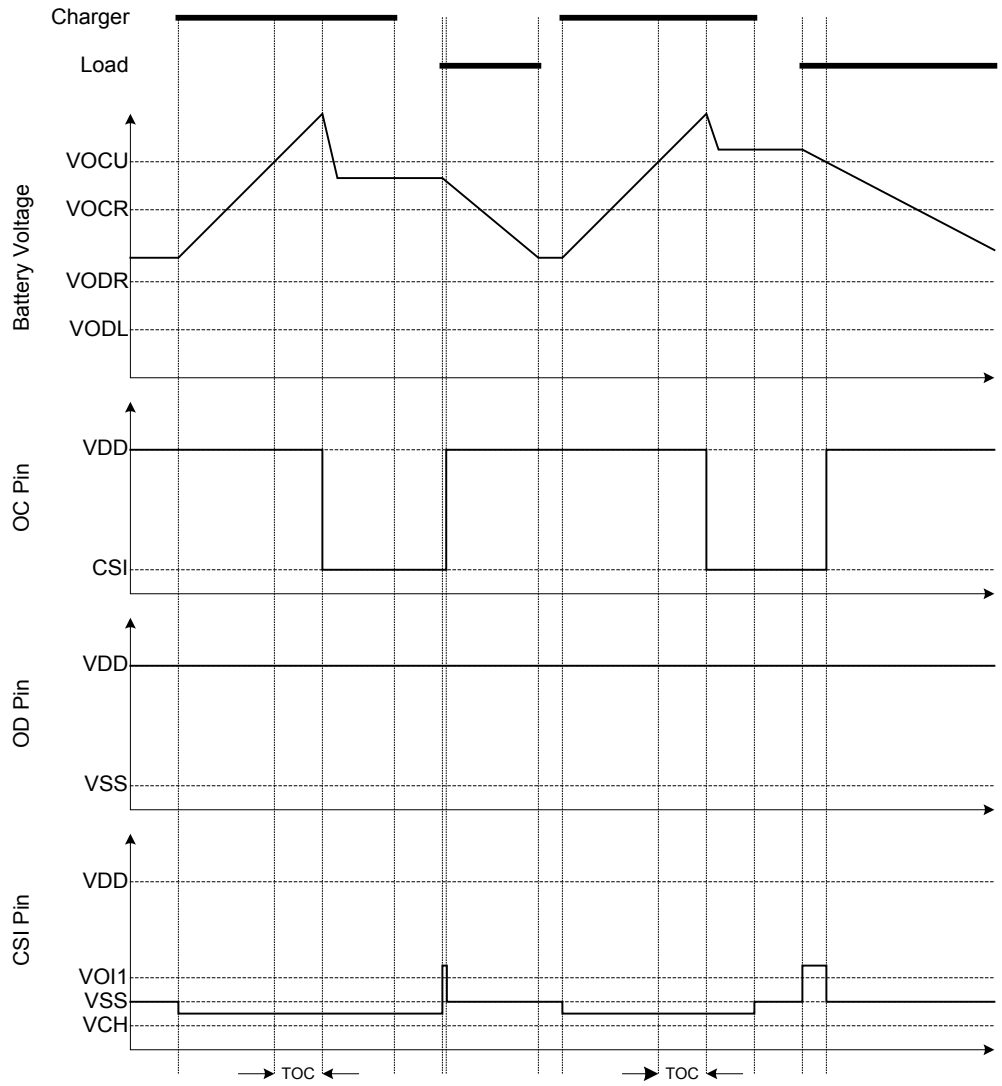
DS pin should be left open or connected to V_{SS} in the actual application.

Timing Diagram

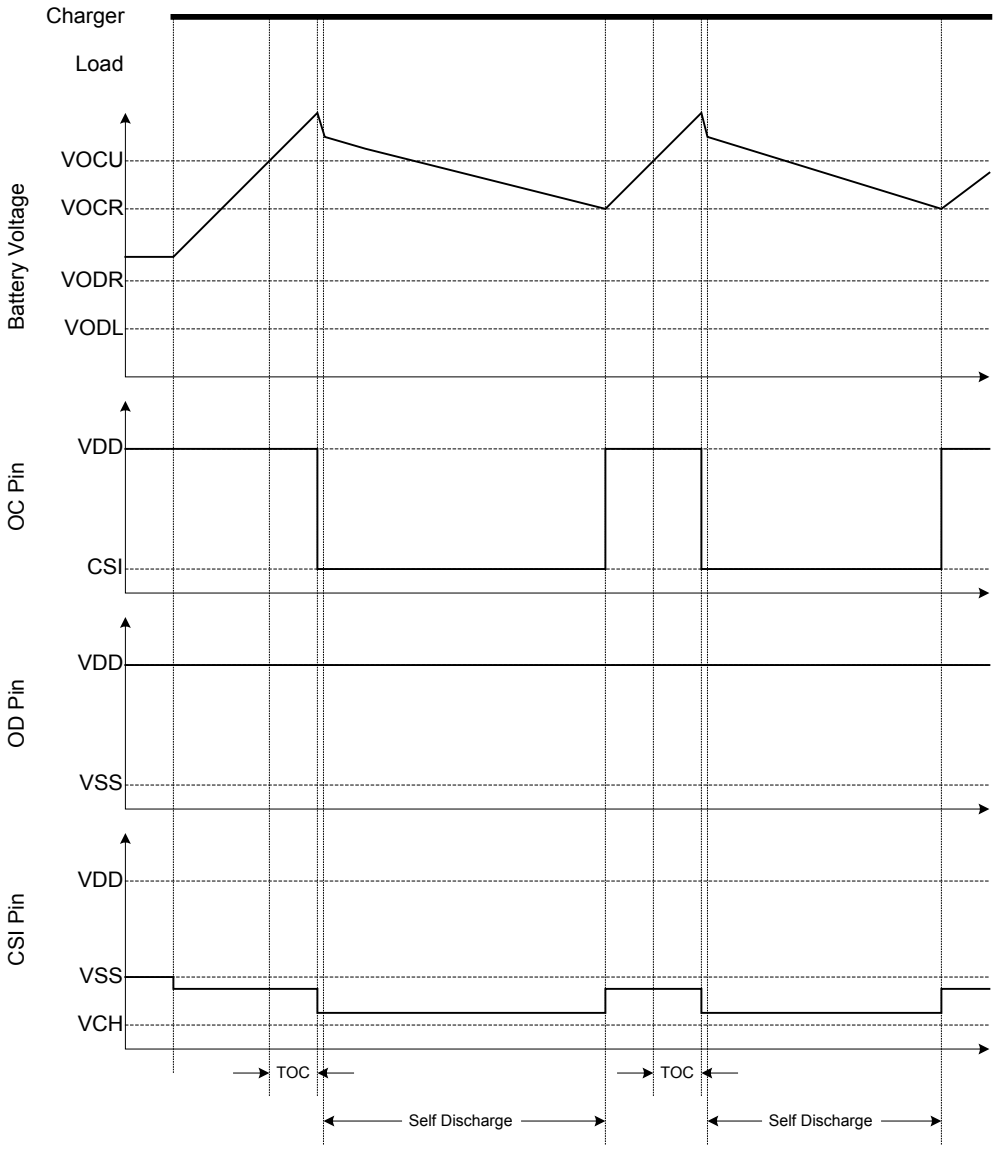
1. Overcharge Condition → Self Discharge → Normal Condition



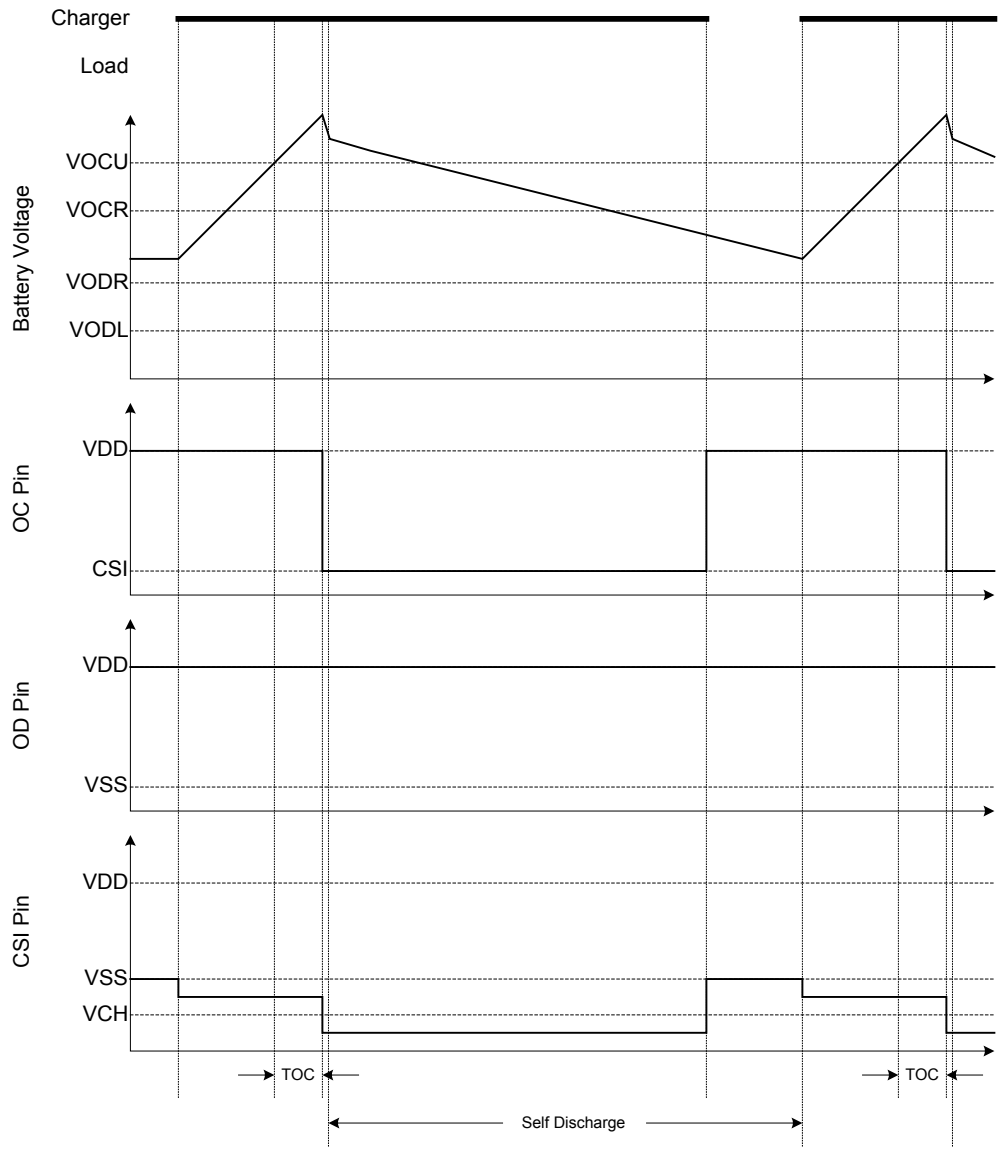
2. Overcharge Condition → Load Discharge → Normal Condition



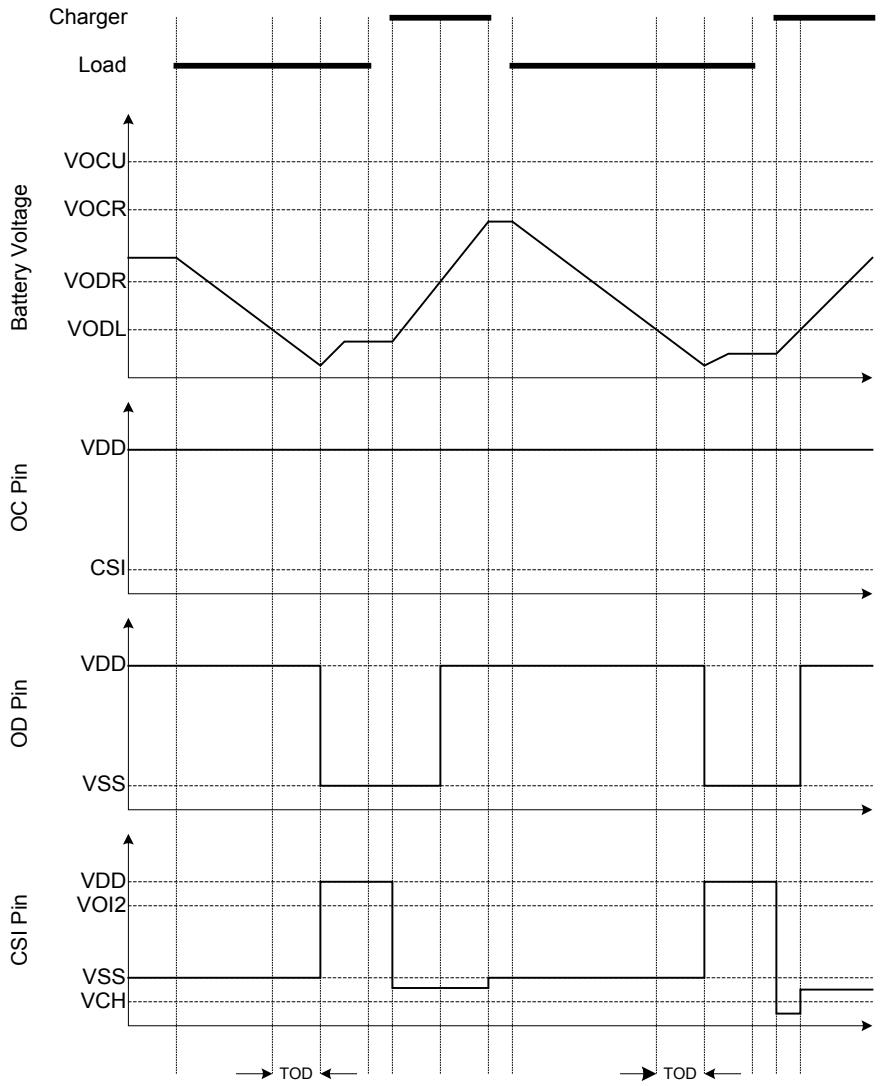
3. Overcharge Condition → Charger remains connected and VCSI >VCH → Self Discharge



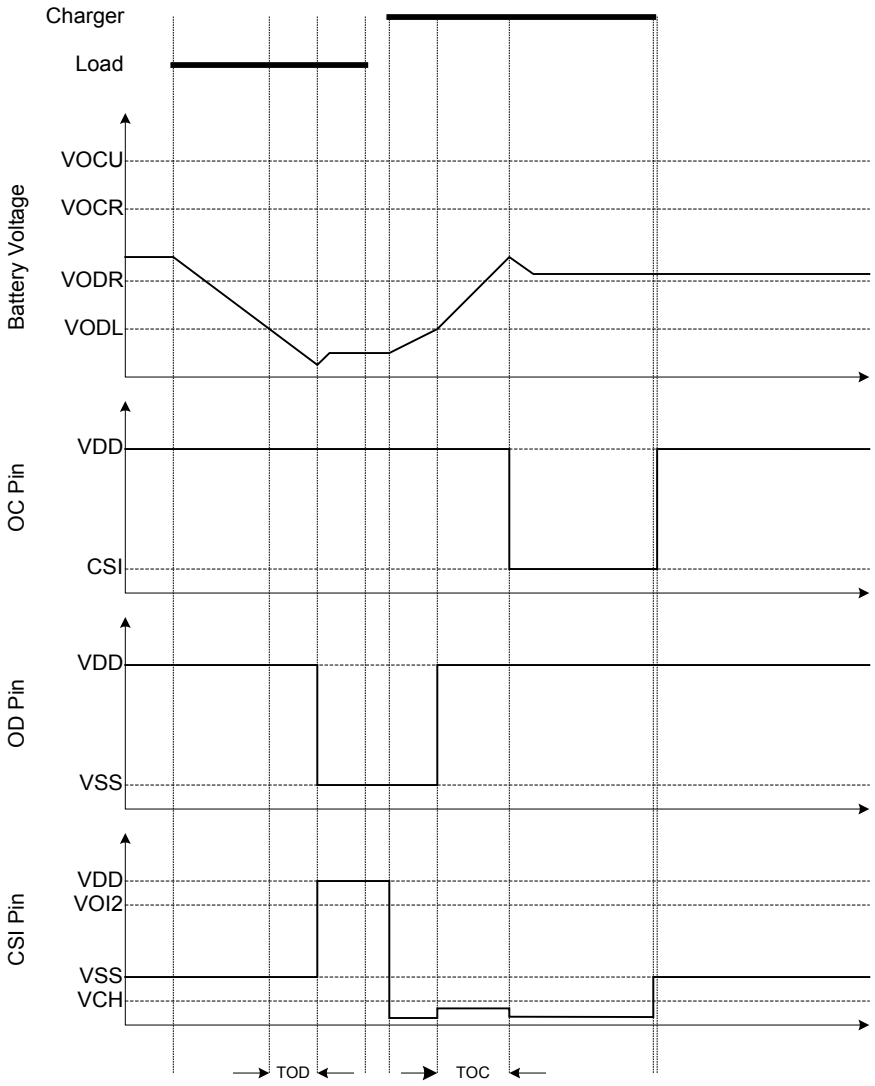
4. Overcharge Condition → Charger remains connected and VCSI <VCH → Self Discharge



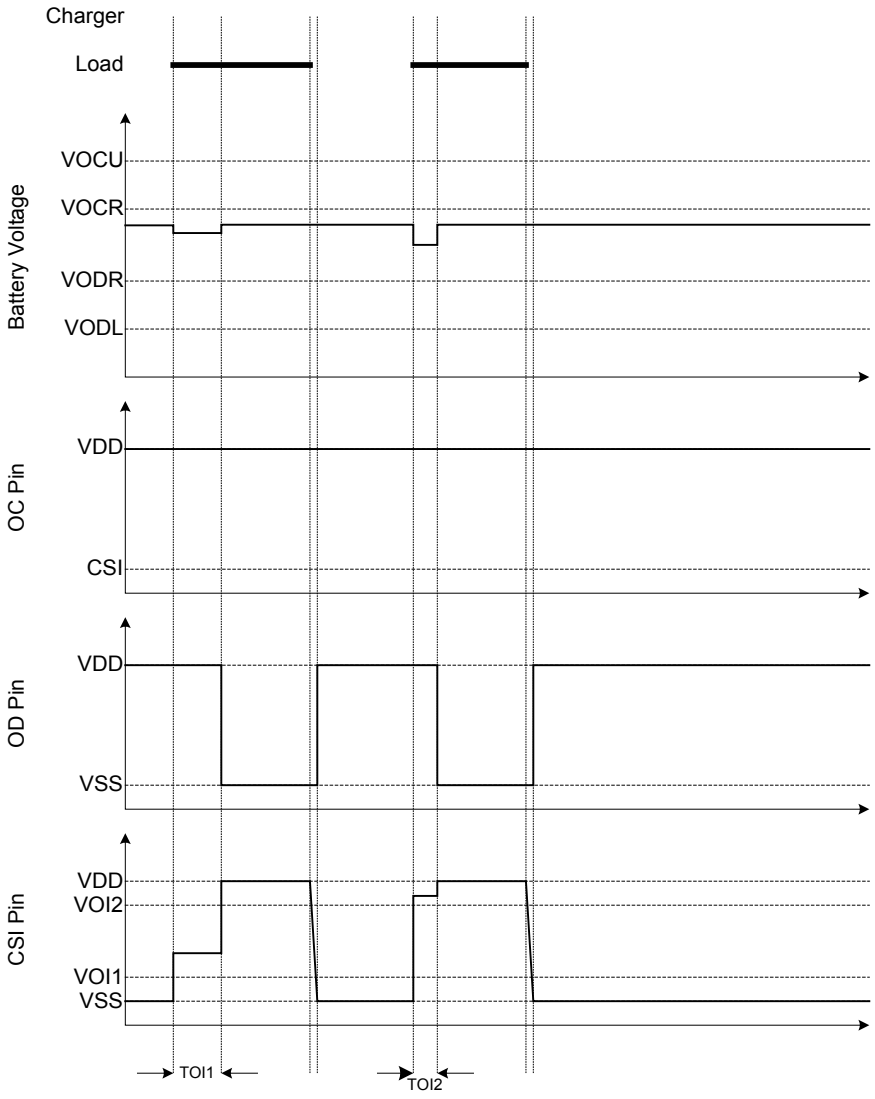
5. Overdischarge Condition → Charging by a Charger → Normal Condition



6. Overdischarge Condition → Abnormal Charge Current Condition → Normal Condition

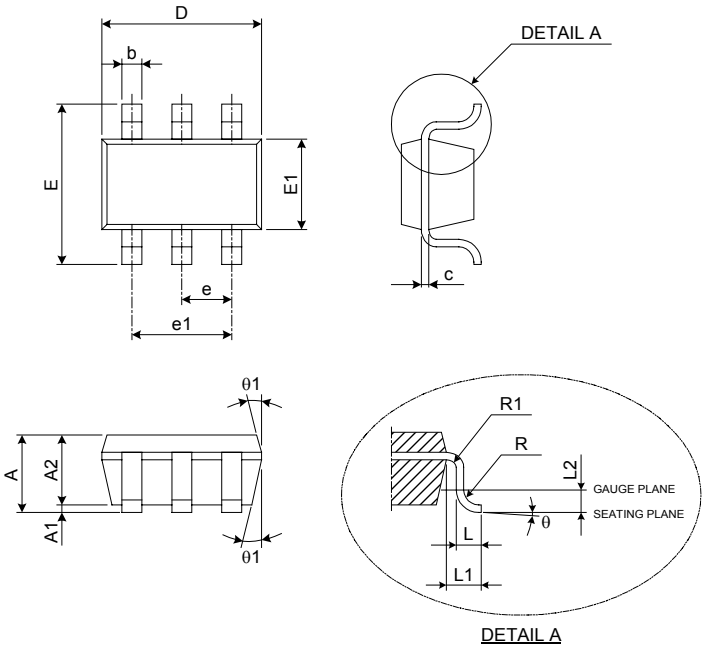


7. Over Current / Short Circuit Condition → Normal Condition



Package Outline

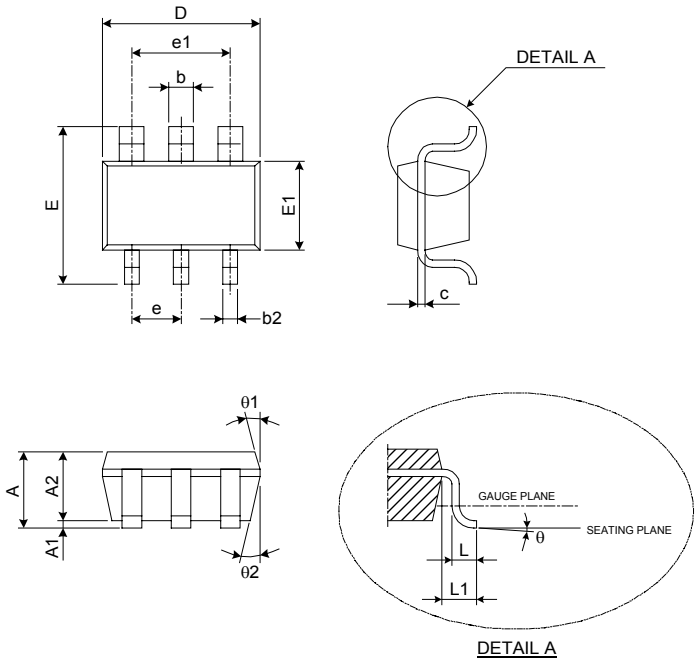
Dimension (Package A)



Unit : mm

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°

Dimension (Package B)



Unit : mm

SYMBOL	MIN.	TYP.	MAX.
A	1.05	-	1.35
A1	0.05	-	0.15
A2	1.00	1.10	1.20
b	0.40	-	0.55
b2	0.25	-	0.40
c	0.08	-	0.20
D	2.70	2.90	3.00
E	2.60	2.80	3.00
E1	1.50	1.60	1.70
L	0.35	0.45	0.55
L1		0.60 REF.	
e		0.95 BSC.	
e1		1.90 BSC.	
θ	0°	5°	10°
θ1	3°	5°	7°
θ2	6°	8°	10°