# Battery Protection IC, OTP Function, 1-Cell Lithium-Ion Battery

# LC06511FMX

#### Overview

LC06511FMX is a protection IC for 1 cell lithium-ion or lithium-polymer battery. It provides highly accurate over-charge, over-discharge, over-current protection. Current is detected by high precision external chip resistor. Which realizes accurate current detection over temperature.

#### Function

- Highly Accurate Detection Voltage/Current at Ta = 25°C, VCC = 3.8 V
- Over Charge Detection Voltage
  - ◆ 4.276 V, 4.426 V, 4.476 V
- Over Charge Release Hysteresis
   0.2 V
- Over Discharge Detection Voltage
  2.3 V, 2.5 V, 2.8 V
- Over Discharge Release Hysteresis2
   0.2 V
- Discharge Over Current Detection Voltage1
  6.3 mV, 7.5 mV
- Short Current Detection Voltage
  30 mV
- Charge Over Current Detection Voltage
  5.0 mV, 6.0 mV
- Over-discharge Detection Delay Time
  - 32 ms
- Discharge Over-current Detection Delay Time1
   16 ms
- 0 V Battery Charging
  - "Permit"
- Auto Wake-up Function
  - "Permit"
- This is a Pb–Free Device

#### **Typical Applications**

- Smart Phone
- Tablet
- Wearable Device



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X2DFN6 1.4x1.4, 0.5P CASE 716AF

#### MARKING DIAGRAM



XX = Specific Device Code

- M = Month Code
- = Pb-Free Package

(Note: Microdot may be in either location)

#### **ORDERING INFORMATION**

Device	Package	Shipping <sup>†</sup>
LC06511FXXMXTBG	X2DFN6 (Pb-Free)	4000 / Tape & Reel

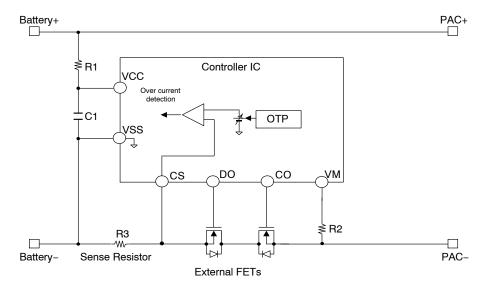
XX = 1A–9A, 1B–9B

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

#### Table 1. ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	VCC		-0.3 to 12.0	V
CS terminal Input voltage	VCS		-0.3 to 7	V
VM terminal Input voltage	rminal Input voltage VVM VCC - 24.0 to VCC + 0		VCC - 24.0 to VCC + 0.3	V
CO terminal voltage	rminal voltage VCO VCC - 24.0 to VCC +		VCC - 24.0 to VCC + 0.3	V
DO terminal voltage	VDO		VCC - 0.3 to VCC + 0.3	
Storage temperature	Tstg		–55 to +125	°C
Operating ambient temperature	perating ambient temperature Topr -40 to +85		°C	
Junction temperature	Tj		125	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.



#### **EXAMPLE OF APPLICATION CIRCUIT**

#### Figure 1. Example of Application Circuit

#### Table 2.

Components	Min	Recommended Value	Max	Unit Description	
R1	0.1	0.33	1	kΩ	Battery+ is filtered to VCC by R1 and C1
R2	0.1	1	2	kΩ	Protection from reverse connection of charger
C1	0.01	0.1	1.0	μF	Battery+ is filtered to VCC by R1 and C1
R3	1		20	mΩ	Sence resistor for over-current detection

## Table 3. ELECTRICAL CHARACTERISTICS (R1 = $0.33 \text{ k}\Omega$ , R2 = 1 k $\Omega$ , VCC = 3.8 V (Note 1))

Parameter	Symbol	Cond	itions	Min.	Тур.	Max.	Unit	Test Circui
DETECTION VOLTAGE								
Over-charge Detection	Vov	R1 = 0.33 kΩ	Ta = 25°C	Vov_set - 10	Vov_set	Vov_set + 10	mV	В
Voltage			Ta = –20 to 60°C	Vov_set - 15	Vov_set	Vov_set + 15	1	
Over-charge Release	Vovr1	R1 = 0.33 kΩ	Ta = 25°C	Vovr_set - 30	Vovr_set	Vovr_set + 30	mV	В
Voltage		VM < Vcocr& CS = 0 V	Ta = –20 to 60°C	Vovr_set - 55	Vovr_set	Vovr_set + 40		
	Vovr2	$R1 = 0.33 k\Omega$	Ta = 25°C	Vov_set - 15	Vov_set	Vov_set + 10	mV	I
		VM > Vcocr& CS = 0 V	Ta = –20 to 60°C	Vov_set - 20	Vov_set	Vov_set + 15		
Over-discharge Detection	Vuv	R1 = 0.33 kΩ	Ta = 25°C	Vuv_set - 35	Vuv_set	Vuv_set + 35	mV	В
Voltage			Ta = –20 to 60°C	Vuv_set - 55	Vuv_set	Vuv_set + 55		
Over-discharge Release	Vuvr1	$R1 = 0.33 k\Omega$	Ta = 25°C	Vuv_set – 35	Vuv_set	Vuv_set + 50	mV	В
Voltage1		VM = 0 V	Ta = –20 to 60°C	Vuv_set - 55	Vuv_set	Vuv_set + 80		
Over-discharge Release	Vuvr2	R1 = 0.33 kΩ	Ta = 25°C	Vuvr_set - 100	Vuvr_set	Vuvr_set + 100	mV	D
Voltage2		VM = OPEN	Ta = –20 to 60°C	Vuvr_set - 110	Vuvr_set	Vuvr_set + 110		
Discharge Over-current Detection Voltage (Primary Protection)	Vdoc	R2 = 1 kΩ VCC = 3.8 V	Ta = 25°C	Vdoc_set - 1.0	Vdoc_set	Vdoc_set + 1.0	mV	F
			Ta = −20 to 60°C	Vdoc_set - 1.8	Vdoc_set	Vdoc_set + 1.8		
Discharge Over-current	Vshrt		Ta = 25°C	Vshrt_set – 10	Vshrt_set	Vshrt_set + 10	mV	F
Detection Voltage (Short Circuit)		VCC = 3.8 V	Ta = −20 to 60°C	Vshrt_set – 12	Vshrt_set	Vshrt_set + 12		
Discharge Over-current (Short Circuit) Release	Vdocr	R2 = 1 kΩ VCC = 3.8 V	Ta = 25°C	VCC - 1.1	VCC-0.65	VCC - 0.2	V	Α
Voltage		CS = 0 V	Ta = –20 to 60°C	VCC - 1.2	VCC-0.65	VCC - 0.1		
Charge Over-current Detection Voltage	Vcoc	R2 = 1 kΩ VCC = 3.8 V	Ta = 25°C	Vcoc_set - 1.0	Vcoc_set	Vcoc_set + 1.0	mV	F
Detection voltage		V00 - 0.0 V	Ta = –20 to 60°C	Vcoc_set - 1.8	Vcoc_set	Vcoc_set + 1.8		
Charge Over-current Release Voltage	Vcocr	R2 = 1 kΩ VCC = 3.8 V	Ta = 25°C	0.08	0.2	0.32	V	A
Tielease voltage		CS = 0 V	Ta = –20 to 60°C	0.05	0.2	0.35		
INPUT VOLTAGE								
0 V Battery Charge Permission Charger Voltage	Vchg	VCC – VM VCC = VSS = 0 V	Ta = 25°C			1.4	V	A
CURRENT CONSUMPTION	•			-	•			
Operating Current	lcc	At normal state	Ta = 25°C VCC = 3.8 V		3	6	μA	J
Stand-by Current	Istb	At stand-by state	Ta = 25°C VCC = 2.0 V			0.95	μΑ	J
				1	1	1	1	1

Auto wake-up = enable

#### Table 3. ELECTRICAL CHARACTERISTICS (R1 = 0.33 kΩ, R2 = 1 kΩ, VCC = 3.8 V (Note 1)) (continued)

Parameter	Symbol	Conditions		Min.	Тур.	Max.	Unit	Test Circuit
RESISTANCE								
Internal Resistance (VCC–VM)	Rvmu	VCC = 2.0 V VM = 0 V	Ta = 25°C	150	300	600	kΩ	E
Internal Resistance (VSS-VM)	Rvmd	VCC = 3.8 V VM = 0.1 V	Ta = 25°C	5	10	20	kΩ	E
CO Output Resistance (High)	Rcoh	VCC = 3.8 V CO = 3.3 V CS = 0 V	Ta = 25°C	6	12	24	kΩ	Н
CO Output Resistance (Low)	Rcol	VCC = 4.5 V CO = 0.5 V CS = 0 V	Ta = 25°C	0.5	0.7	2.0	kΩ	Н
DO Output Resistance (High)	Rdoh	VCC = 3.8 V DO = 3.3 V CS = 0 V	Ta = 25°C	0.5	1.0	2.0	kΩ	G
DO Output Resistance (Low)	Rdol	VCC = 2.0 V CS = 0 V DO = 0.5 V	Ta = 25°C	0.2	0.3	0.8	kΩ	G
DETECTION AND RELEASE	DELAY TIME	E						
Over-charge Detection	Tov	VCC = 3 V to	Ta = 25°C	819	1024	1229	ms	В
Delay Time		4.6 V VM = CS = 0 V	Ta = −20 to 60°C	717	1024	1331		
Over-charge Release Delay	Tovr	VCC = 4.6 V to 3 V VM = CS = 0 V	Ta = 25°C	12.8	16	19.2	ms	В
Time			Ta = −20 to 60°C	11.2	16	20.8		
Over-discharge Detection	Tuv		Ta = 25°C	Tuv_set * 0.8	Tuv_set	Tuv_set * 1.2	ms	В
Delay Time		to 1.8 V VM = CS = 0 V	Ta = –20 to 60°C	Tuv_set * 0.65	Tuv_set	Tuv_set * 1.35		
Over-discharge Release	Tuvr \		Ta = 25°C	0.84	1.05	1.26	ms	В
Delay Time		to 3.5 V VM = CS = 0 V	Ta = –20 to 60°C	0.68	1.05	1.42		
Discharge Over-current	Tdoc1	CS = 0 V to	Ta = 25°C	Tdoc1_set * 0.8	Tdoc1_set	Tdoc1_set * 1.2	ms	F
Detection Delay Time 1		VdocMAX VM = 0 V	Ta = –20 to 60°C	Tdoc1_set * 0.7	Tdoc1_set	Tdoc1_set * 1.3		
Discharge Over-current Release Delay Time	Tdocr	VM = 3.8 V to 2.65 V	Ta = 25°C	3.2	4	4.8	ms	А
Nelease Delay Time		CS = 0 V	Ta = −20 to 60°C	2.8	4	5.2		
Short-current	Tshrt	CS = 0 V to VshrtMAX	Ta = 25°C	175	250	325	μs	F
Detection Delay Time		VM = 0	Ta = –20 to 60°C	150	250	350		
Charge Over-current Detection Delay Time	Тсос	CS = 0 V to	Ta = 25°C	12.8	16	19.2	ms	F
Detection Delay Time		VcocMIN VM = 0	Ta = –20 to 60°C	11.2	16	20.8		
Charge Over-current	Tcocr	VM = 0 V to VcocrMAX	Ta = 25°C	3.2	4	4.8	ms	F
Release Delay Time		CS = 0 V	Ta = –20 to 60°C	2.8	4	5.2		

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions. 1. The specifications in high temperature and low temperature are guaranteed by design.

## **TEST CIRCUITS**

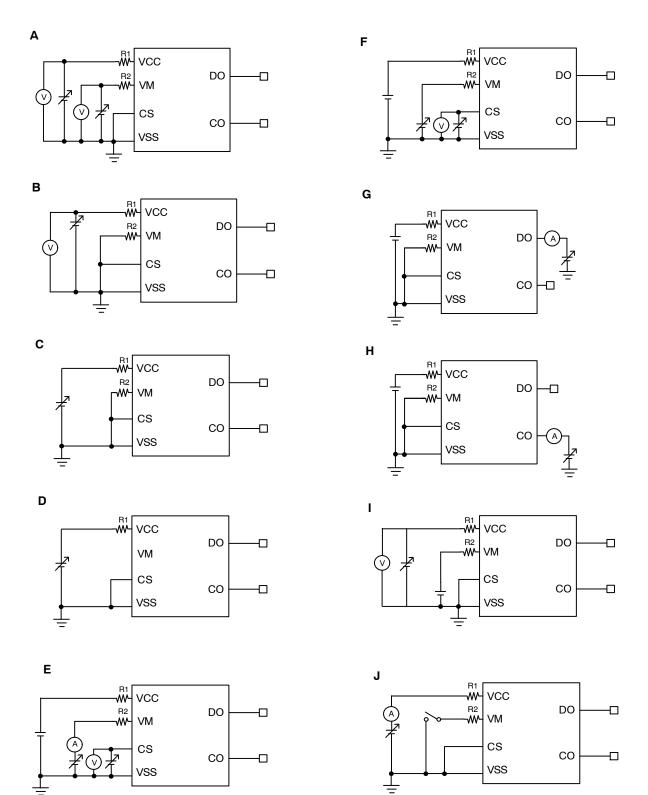


Figure 2. Test Circuits

#### Table 4. SELECTION GUIDE

Device	Vov (mV)	Vovr (mV)	Vuv (mV)	Vuvr2 (mV)	Vdoc (mV)	Vshrt (mV)	Vcoc (mV)	Tuv (ms)	Tdoc1 (ms)	Specific Device Code
LC06511F1AMX	4276	4076	2300	2500	6.3	30	-5	32	16	LL
LC06511F1BMX	4276	4076	2300	2500	7.5	30	-6	32	16	LW
LC06511F2AMX	4426	4226	2300	2500	6.3	30	-5	32	16	LM
LC06511F2BMX	4426	4226	2300	2500	7.5	30	-6	32	16	LX
LC06511F3AMX	4476	4276	2300	2500	6.3	30	-5	32	16	LN
LC06511F3BMX	4476	4276	2300	2500	7.5	30	-6	32	16	LY
LC06511F4AMX	4276	4076	2500	2700	6.3	30	-5	32	16	LP
LC06511F4BMX	4276	4076	2500	2700	7.5	30	-6	32	16	LZ
LC06511F5AMX	4426	4226	2500	2700	6.3	30	-5	32	16	LQ
LC06511F5BMX	4426	4226	2500	2700	7.5	30	-6	32	16	L2
LC06511F6AMX	4476	4276	2500	2700	6.3	30	-5	32	16	LR
LC06511F6BMX	4476	4276	2500	2700	7.5	30	-6	32	16	L3
LC06511F7AMX	4276	4076	2800	3000	6.3	30	-5	32	16	LT
LC06511F7BMX	4276	4076	2800	3000	7.5	30	-6	32	16	L4
LC06511F8AMX	4426	4226	2800	3000	6.3	30	-5	32	16	LU
LC06511F8BMX	4426	4226	2800	3000	7.5	30	-6	32	16	L5
LC06511F9AMX	4476	4276	2800	3000	6.3	30	-5	32	16	LV
LC06511F9BMX	4476	4276	2800	3000	7.5	30	-6	32	16	L6

#### Table 5. SENSE RESISTOR SELECTION GUIDE

		L	.C06511F 1A-9A M	x	L	.C06511F 1B-9B M	x
		Vcoc –5.0 mV	Vdoc 6.3 mV	Vshrt 30 mV	Vcoc –6.0 mV	Vdoc 7.5 mV	Vshrt 30 mV
		Charge Over Current [A]	Discharge Over Current [A]	Short Current [A]	Charge Over Current [A]	Discharge Over Current [A]	Short Current [A]
Sense	2	2.5	3.2	15	3	3.8	15
Resistor [mΩ]	3	1.7	2.1	10	2	2.5	10
[]	4	1.3	1.6	7.5	1.5	1.9	7.5
	5	1	1.3	6	1.2	1.5	6
	6	0.8	1.1	5	1	1.3	5
	7	0.7	0.9	4.3	0.9	1.1	4.3
	8	0.6	0.8	3.8	0.8	0.9	3.8
	9	0.6	0.7	3.3	0.7	0.8	3.3
	10	0.5	0.6	3	0.6	0.8	3

#### Table 6. PIN FUNCTION

Pin No.	Symbol	Pin Function			
1	VM	Charger negative voltage input terminal			
2	CO	Charge FET control terminal			
3	DO	Discharge FET control terminal			
4	VSS	VSS terminal			
5	VCC	VCC terminal			
6	CS	Over-current detection input terminal			

#### **BLOCK DIAGRAM**

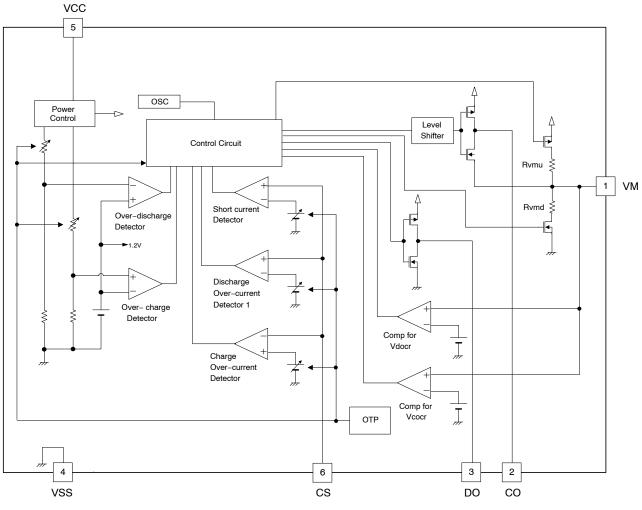


Figure 3. Block Diagram

## **DESCRIPTION OF OPERATION**

• The battery voltage is detected between VCC pin and VSS pin and the battery current is detected between VSS pin and CS pin.

## 1. Normal State

• "VCC voltage" is between "over-discharge detection voltage (Vuv)", "over-charge detection voltage (Vov)", and "CS voltage" is between "charge over-current detection voltage (Vcoc)", "discharge over-current detection voltage (Vdoc)", and "VM voltage" is lower than "dicharge over-current (short) release voltage (Vdocr)".

This is the normal state. Both CO and DO are high level output. Charge and discharge is allowed.

## 2. Over-charging State

• "VCC voltage" is higher than or equal to "over-charge detection voltage (Vov)" for longer than "over-charge detection delay time (Tov)".

This is the over-charging state, CO is low level output. Charge is prohibited.

• Release from Over-charging State 1

"VM voltage" is lower than "charge over-current (short) release voltage (Vcocr)". Then "VCC voltage" is lower than "over-charge release voltage (Vovr)" for longer than "over-charging release delay time (Tovr)".

• Release from Over-charging State 2 "VM voltage" is higher than "charge over-current (short) release voltage (Vcocr)". Then "VCC voltage" is lower than "over-charge detection voltage (Vov) for longer than "over-charge release delay time (Tovr)".

#### 3. Over-discharging State

• "VCC voltage" is lower than "over-discharge detection voltage (Vuv)" for longer than "over-discharge delay time (Tuv)".

This is the over-discharging state, DO is low level output. Discharge is prohibited.

During over-discharging state, VM pin is pulled up to Vcc by internal resistor (Rvmu) and circuits are shut down. The low power consumption is kept.

• Release from Over-discharging State 1

Charger is connected, then "VCC voltage" goes higher than "over-discharge release voltage1 (Vuvr1)" for longer than "over-charge release delay time (Tuvr)".

• Release from Over-discharging State (with Auto Wake-up Feature) 2

"VCC voltage" is higher than "over-discharge release voltage2 (Vuvr1)" without charger for longer than "over-charge release delay time (Tovr)".

- 4. Discharging Over-current State
- Discharge Over-current Detection

CS terminal is higher than or equal to "discharge over-current detection voltage (Vdoc)" for longer than "discharge over-current detection delay time (Tdoc1)". DO is low level output. Discharge is prohibited.

- Discharge Over-current Detection (Short Circuit)
  - CS terminal is higher than or equal to "discharge over-current detection voltage (Short circuit) (Vshrt)" for longer than "short-current detection delay time (Tshrt)".

DO is low level output. Dischaege is prohibited. During discharging over-current state, VM pin is pulled down to Vss by internal resistor (Rvmd).

## • Release from Discharging Over-current State

"CS voltage" goes lower than "discharge over-current detection voltage (Vdoc)" and VM voltage goes lower than "discharge over-current (short) release voltage (Vdocr)" for longer than "discharge over-current release delay time (Tdocr)".

#### 5. Charging Over-current State

• "CS voltage" goes lower than or equal to "charge over-current detection voltage (Vcoc) for longer than "charge over-current detection delay time (Tcoc)". This is the charging over-current state, CO is low level output. Charge is prohibited.

#### • Release from charging over-current state

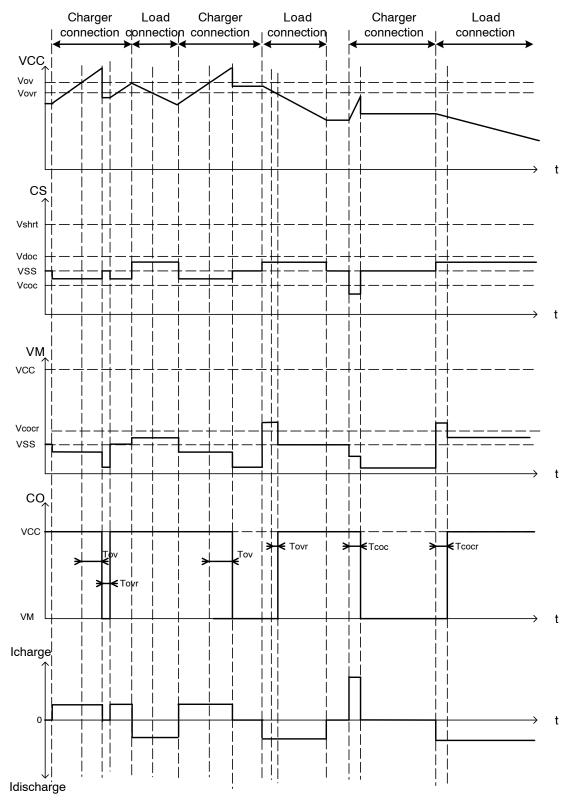
"CS voltage" goes higher than "charge over-current detection voltage (Vcoc)" and "VM voltage" goes higher than "charge over-current release voltage (Vcocr)" for longer than "charge over-current release delay time (Tcocr)".

#### 6. 0 V Battery Charging

• When the Battery voltage is lower than or equal to "0 V battery charge permission voltage (Vchg)", charge is allowed if charger voltage is higher than or equal "0 V battery charge permission voltage (Vchg)". CO is fixed by the "VCC voltage".

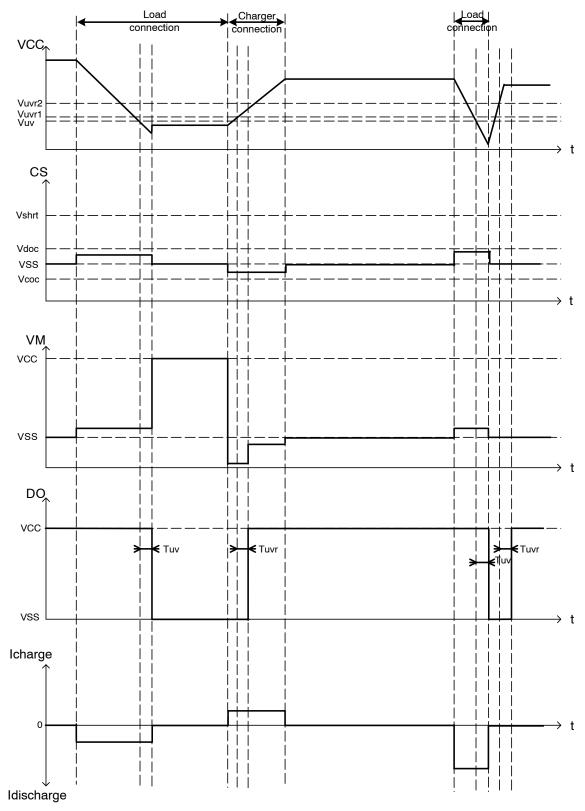
#### **TIMING CHARTS**

#### **Over Charge Voltage and Charge Over Current**





#### Over Discharge Detection and Release (with/without Charger)





#### Discharge Over Current and Short Current Detection and Release

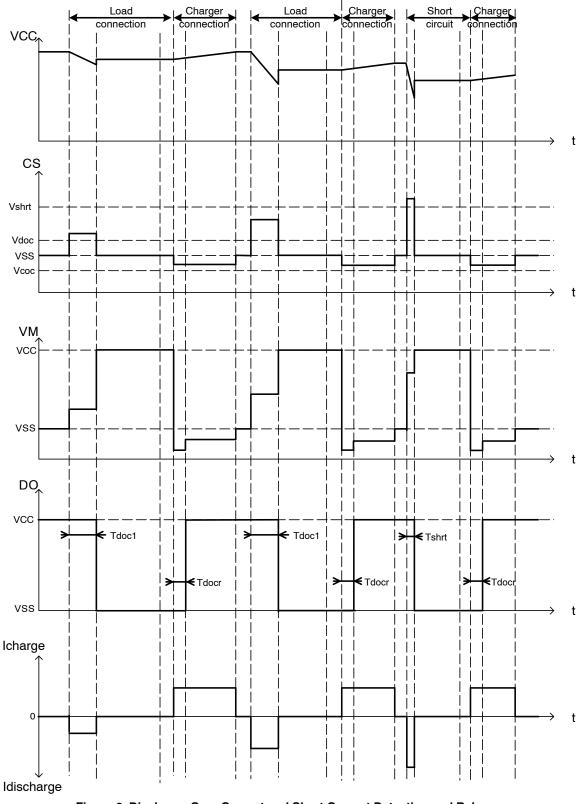
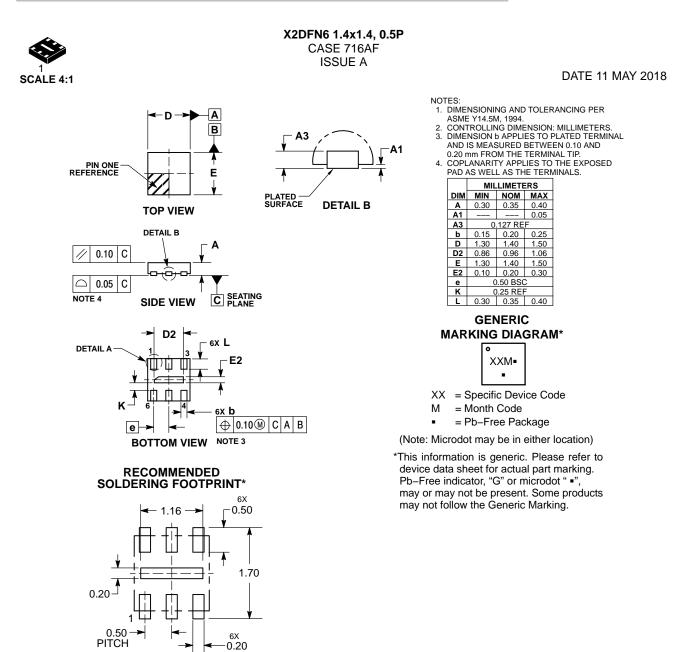


Figure 6. Discharge Over Current and Short Current Detection and Release





\*For additional information on our Pb–Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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