Protection for Lithium-Ion/Lithium Polymer Batteries (1 cell)
Monolithic IC MM3099 Series

April 26, 2004

Outline

This is a protection IC developed for use with 1-serial cell lithium-ion/lithium polymer rechargeable batteries. It provides a function to protect the batteries by detecting overcharge, overdischarge, discharge overcurrent, and other abnormalities and turning off the external Nch MOS FET. The outputs of COUT pin (charge FET control pin) and DOUT pin (discharge FET control pin) are CMOS outputs, so that the external Nch MOS FET can be driven directly. A charge overcurrent detection function is provided for abnormal charge detection. In addition, the IC has a built-in timer circuit(for each detection delay time), so that the protection circuitry can be comprised with fewer external components. Furthermore, by setting the DS pin at V_{DD} level, overcharge, overdischarge, discharge overcurrent can be detected, and the delay time during release can be shortened.

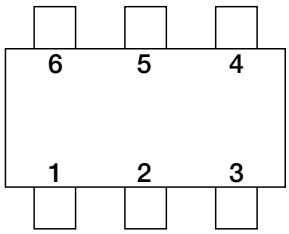
Features

1. Uses high voltage CMOS process — Absolute maximum rating for charger connection 32V
2. Detection voltage precision — Overcharge detection voltage ±20mV (Ta=25°C), ±25mV (Ta=-5~60°C)
   Overdischarge detection voltage ±35mV (Ta=25°C), ±58mV (Ta=-5~60°C)
   Discharge overcurrent detection voltage ±10mV (Ta=25°C), ±15mV (Ta=-5~60°C)
3. Built-in detection delay time (timer circuit) — Overcharge detection delay time 0.25~7.0s (mask option)
   Overdischarge detection delay time 0.25~7.0s (mask option)
   Discharge overcurrent detection delay time 0.25~7.0s (mask option)
   Short detection delay time 400µs
4. Includes a charge overcurrent detection function
5. Overcharge, overdischarge, and discharge overcurrent can be detected, and the delay time during release can be shortened with the DS pin.
6. 0V charging disable function (mask option)

Package

SOT-26A
SON-6A

Pin Assignment



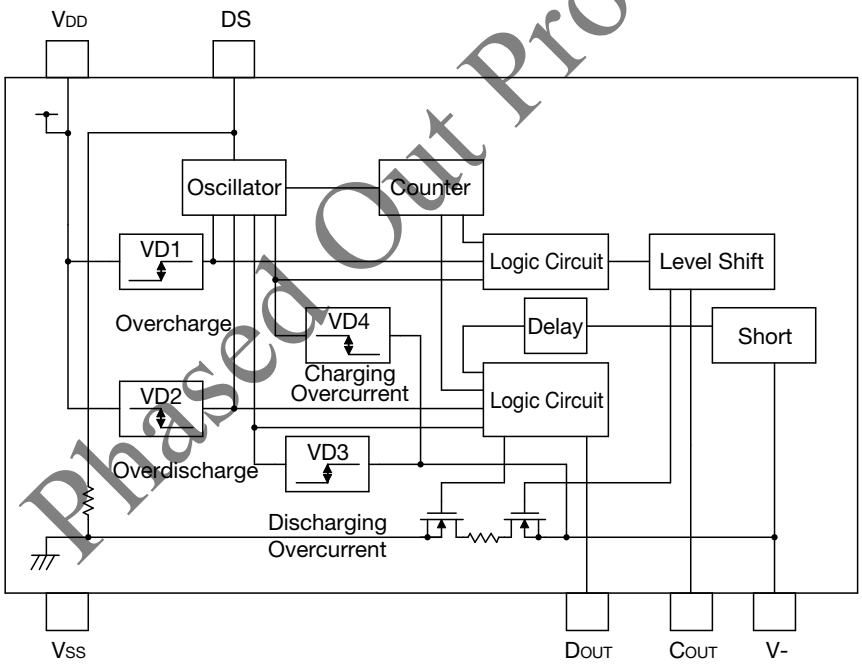
SOT-26A
(TOP VIEW)

1	DOUT
2	V–
3	COUT
4	DS
5	VDD
6	VSS

SON-6A
(TOP VIEW)

1	DOUT
2	VDD
3	VSS
4	DS
5	COUT
6	V–

Block Diagram



Pin Description

SOT-26A

Pin no.	Pin name	Functions
1	D_{OUT}	Output of overdischarge detection. Output type is CMOS.
2	V–	Input terminal connected to charger negative voltage.
3	C_{OUT}	Output of overcharge detection. Output type is CMOS.
4	DS	Delay shorten terminal.
5	V_{DD}	V_{DD} terminal. Connected to IC substrate.
6	V_{SS}	V_{SS} terminal. Connected to ground.

SON-6A

Pin no.	Pin name	Functions
1	D_{OUT}	Output of overdischarge detection. Output type is CMOS.
2	V_{DD}	V_{DD} terminal. Connected to IC substrate.
3	V_{SS}	V_{SS} terminal. Connected to ground.
4	DS	Delay shorten terminal.
5	C_{OUT}	Output of overcharge detection. Output type is CMOS.
6	V–	Input terminal connected to charger negative voltage.

Absolute Maximum Ratings (T_{OPR}=25°C, V_{SS}=0V)

Item	Symbol	Ratings	Units
Supply voltage	V_{DD}	–0.3~12	V
V- terminal input voltage	V–	V_{DD}–32~V_{DD}+0.3	V
DS terminal input voltage	V_{DS}	V_{SS}–0.3~V_{DD}+0.3	V
C_{OUT} terminal output voltage	V_{COUT}	V_{DD}–32~V_{DD}+0.3	V
D_{OUT} terminal output voltage	V_{DOUT}	V_{SS}–0.3~V_{DD}+0.3	V
Operation temperature	T_{OPR}	–40~+85	°C
Storage temperature	T_{STG}	–55~+125	°C

Electrical Characteristics Written Model : MM3099E

T_{OPR}=25°C

Item	Symbol	Measurement conditions	Min.	Typ.	Max.	Units	*1
Operating input voltage	$V_{DD}1$	V_{DD}–V_{SS}	1.5		10.0	V	A
Minimum operating voltage for 0V charging	V_{ST}	V_{DD}–V–, V_{DD}–V_{SS}=0V			1.2	V	A
Discharging overcurrent release resistance	R_{SHORT}	V_{DD}=3.6V, V–=1V	30	50	100	kΩ	F
DS pin pull-down resistance	R_{DS}	V_{DD}=3.6V	6.5	13.0	26.0	kΩ	H
C_{OUT} pin Nch ON voltage	$V_{OL}1$	I_{OL}=30μA, V_{DD}=4.5V		0.4	0.5	V	I
C_{OUT} pin Pch ON voltage	$V_{OH}1$	I_{OL}=–30μA, V_{DD}=3.9V	3.4	3.7		V	J
D_{OUT} pin Nch ON voltage	$V_{OL}2$	I_{OL}=30μA, V_{DD}=2.0V		0.2	0.5	V	K
D_{OUT} pin Pch ON voltage	$V_{OH}2$	I_{OL}=–30μA, V_{DD}=3.9V	3.4	3.7		V	L
Current consumption	I_{DD}	V_{DD}=3.9V, V–=0V		3.0	6.0	μA	M
Current consumption at stand-by	I_S	V_{DD}=2.0V			0.1	μA	M

Note: *1 The test circuit symbols.

■ T_{OPR}=25°C

Item	Symbol	Measurement conditions	Min.	Typ.	Max.	Units	*1
Overcharge detection voltage	V_{DET1}	R1=330Ω	4.255	4.275	4.295	V	B
Overdischarge detection voltage	V_{DET2}	V−=0V, R1=330Ω	2.265	2.3	2.335	V	D
Discharging overcurrent detection voltage	V_{DET3}	V_{DD}=3V, R2=2.2kΩ	0.090	0.100	0.110	V	F
Charging overcurrent detection voltage	V_{DET4}	V_{DD}=3V, R2=2.2kΩ	−0.120	−0.100	−0.080	V	G
Short detection voltage	V_{SHORT}	V_{DD}=3V	V_{DD}−1.2	V_{DD}−0.9	V_{DD}−0.6	V	F
Overcharge detection delay time	tV_{DET1}	V_{DD}=3.6V→4.4V	0.80	1.00	1.20	s	B
Overcharge release delay time	tV_{REL1}	V_{DD}=4.4V→3.6V	12.8	16.0	19.2	ms	B
Overdischarge detection delay time	tV_{DET2}	V_{DD}=3.6V→2.2V	16.0	20.0	24.0	ms	D
Overdischarge release delay time	tV_{REL2}	V_{DD}=3V, V−=3V→0V	0.8	1.0	1.2	ms	E
Discharging overcurrent detection delay time	tV_{DET3}	V_{DD}=3V, V−=0V→1V	4.8	6.0	7.2	ms	F
Discharging overcurrent release delay time	tV_{REL3}	V_{DD}=3V, V−=3V→0V	0.8	1.0	1.2	ms	G
Charging overcurrent detection delay time	tV_{DET4}	V_{DD}=3V, V−=0V→−1V	6.4	8.0	9.6	ms	G
Charging overcurrent release delay time	tV_{REL4}	V_{DD}=3V, V−=−1V→0V	0.8	1.0	1.2	ms	F
Short detection delay time	t_{SHORT}	V_{DD}=3V, V−=0V→3V	280	400	560	µs	F

Note: *1 The test circuit symbols.

T_{OPR}=-5~60°C *2

Item	Symbol	Measurement conditions	Min.	Typ.	Max.	Units	*1
Overcharge detection voltage	V_{DET1}	R1=330Ω	4.250	4.275	4.300	V	B
Overdischarge detection voltage	V_{DET2}	V-=0V, R1=330Ω	2.242	2.300	2.358	V	D
Discharging overcurrent detection voltage	V_{DET3}	V_{DD}=3V, R2=2.2kΩ	0.085	0.100	0.115	V	F
Charging overcurrent detection voltage	V_{DET4}	V_{DD}=3V, R2=2.2kΩ	-0.130	-0.100	-0.070	V	G
Short detection voltage	V_{SHORT}	V_{DD}=3V	V_{DD}-1.2	V_{DD}-0.9	V_{DD}-0.6	V	F
Overcharge detection delay time	tV_{DET1}	V_{DD}=3.6V→4.4V	0.70	1.00	1.30	s	B
Recharge release delay time	tV_{REL1}	V_{DD}=4.4V→3.6V	11.2	16.0	20.8	ms	B
Overdischarge detection delay time	tV_{DET2}	V_{DD}=3.6V→2.2V	14.0	20.0	26.0	ms	D
Overdischarge release delay time	tV_{REL2}	V_{DD}=3V, V-=3V→0V	0.7	1.0	1.3	ms	E
Discharging overcurrent detection delay time	tV_{DET3}	V_{DD}=3V, V-=0V→1V	4.2	6.0	7.8	ms	F
Discharging overcurrent release delay time	tV_{REL3}	V_{DD}=3V, V-=3V→0V	0.7	1.0	1.3	ms	F
Charging overcurrent detection delay time	tV_{DET4}	V_{DD}=3V, V-=0V→-1V	5.6	8.0	10.4	ms	G
Charging overcurrent release delay time	tV_{REL3}	V_{DD}=3V, V-=-1V→0V	0.7	1.0	1.3	ms	G
Short detection delay time	t_{SHORT}	V_{DD}=3V, V-=0V→3V	250	400	600	µs	F

Note: *1 The test circuit symbols.
*2 The all parameters on this page is guaranteed by design.

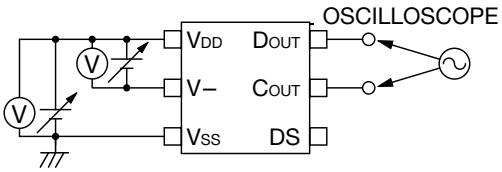
T_{OPR}=-30~70°C ⋆2

Item	Symbol	Measurement conditions	Min.	Typ.	Max.	Units	*1
Overcharge detection voltage	V_{DET1}	R1=330Ω	4.230	4.275	4.320	V	B
Overdischarge detection voltage	V_{DET2}	V−=0V, R1=330Ω	2.225	2.300	2.375	V	D
Discharging overcurrent detection voltage	V_{DET3}	V_{DD}=3V, R2=2.2kΩ	0.080	0.100	0.120	V	F
Charging overcurrent detection voltage	V_{DET4}	V_{DD}=3V, R2=2.2kΩ	−0.140	−0.100	−0.060	V	G
Short detection voltage	V_{SHORT}	V_{DD}=3V	V_{DD}−1.2	V_{DD}−0.9	V_{DD}−0.6	V	F
Overcharge detection delay time	tV_{DET1}	V_{DD}=3.6V→4.4V	0.60	1.00	1.50	s	B
Overcharge release delay time	tV_{REL1}	V_{DD}=4.4V→3.6V	9.6	16.0	24.0	ms	B
Overdischarge detection delay time	tV_{DET2}	V_{DD}=3.6V→2.2V	12.0	20.0	30.0	ms	D
Overdischarge release delay time	tV_{REL2}	V_{DD}=3V, V−=3V→0V	0.6	1.0	1.5	ms	E
Discharging overcurrent detection delay time	tV_{DET3}	V_{DD}=3V, V−=0V→1V	3.6	6.0	9.0	ms	F
Discharging overcurrent release delay time	tV_{REL3}	V_{DD}=3V, V−=3V→0V	0.6	1.0	1.5	ms	F
Charging overcurrent detection delay time	tV_{DET4}	V_{DD}=3V, V−=0V→−1V	4.8	8.0	12.0	ms	G
Charging overcurrent release delay time	tV_{REL4}	V_{DD}=3V, V−=−1V→0V	0.6	1.0	1.5	ms	G
Short detection delay time	t_{SHORT}	V_{DD}=3V, V−=0V→3V	200	400	800	µs	F

Note: ⋆1 The test circuit symbols.
⋆2 The all parameters on this page is guaranteed by design.

Measuring Circuit

A



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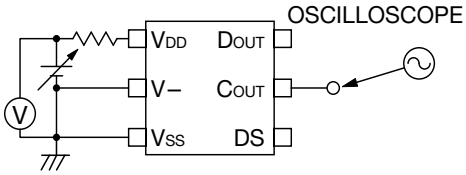

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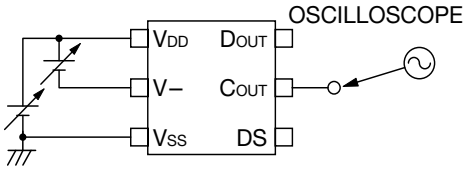

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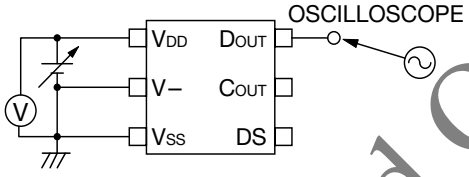

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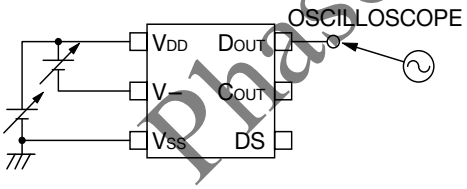

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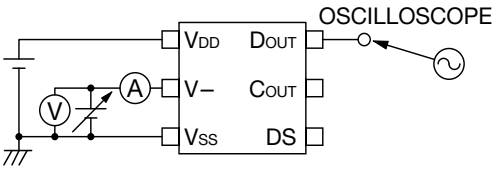

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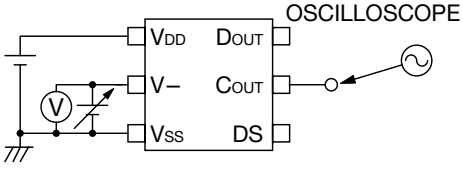

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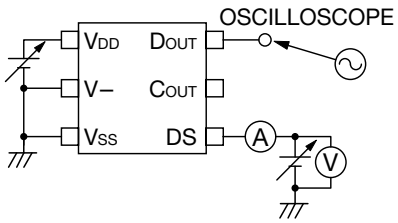

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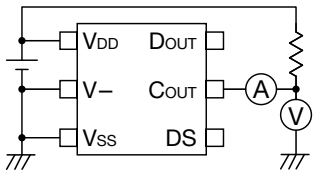

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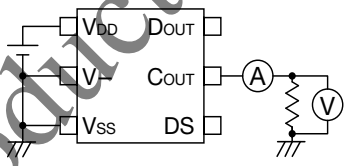

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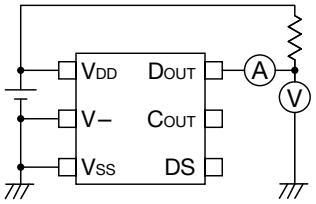

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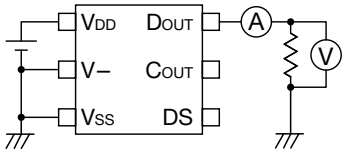

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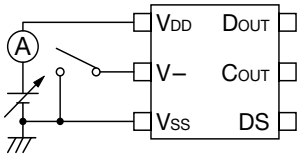


Description

1. Over charge detector (VD1)

In the state of charging the battery, it will detect the overcharge state of the battery if the V_{DD} terminal voltage becomes higher than the overcharge detection voltage (4.275V typ.). And then the C_{OUT} terminal turns to low level, so the external charging control Nch MOS FET turns OFF and it forbids to charge the battery.

When the V_{DD} terminal voltage is higher than the overcharge detection voltage, to disconnect the charger and connect the load, leave the C_{OUT} terminal low level, but it accepts to conduct load current via the paracitical body diode of the external Nch MOS FET. And then if the V_{DD} terminal voltage becomes lower than the overcharge voltage, the C_{OUT} terminal turns to high level, so the external Nch MOS FET turn ON, and it accepts to charge the battery.

The overcharge detection and release have delay time decided internally. When the V_{DD} terminal voltage becomes higher than the overcharge detection voltage, it will not detect overcharge, if the V_{DD} terminal voltage becomes lower than the overcharge detection Voltage again within the overcharge detection delay time (1.00s typ.). And in the state of overcharge and disconnecting the charger and connecting the loads, when the V_{DD} terminal voltage becomes lower than the overcharge detection voltage, it will not release overcharge, if the V_{DD} terminal voltage backs higher than the overcharge detection voltage again within the overcharge release delay time (16ms typ.)

The output driver stage of the C_{OUT} terminal includes a Level shifter, so it will output the V- terminal voltage as Low level. The output type of the C_{OUT} terminal is CMOS output between V_{DD} and V- terminal voltage.

2. Over discharge detector (VD2)

In the state of discharging the battery, it will detect the overdischarge state of the battery if the V_{DD} terminal becomes lower than the overdischarge detection voltage (2.300V typ.). And then the D_{OUT} terminal turns to low level, so the external discharging control Nch MOS FET turn OFF and it forbids to discharge the battery.

The release from the overdischarge state is done by connecting the charger. If the charger is connected and the V_{DD} terminal voltage is lower than the overdischarge detection voltage, it accepts to conduct charge current via the paracitical body diode of the external Nch MOS FET. And then if the V_{DD} terminal voltage becomes higher than the overdischarge detection voltage, the D_{OUT} terminal turns to high level, so the external Nch MOS PET turns ON, and it accepts to discharge the battery. If the charger is connected and the V_{DD} terminal voltage is higher than the overdischarge detection voltage, the D_{OUT} terminal will turn to high level with the delay time.

When the battery voltage is about 0V, the C_{OUT} terminal outputs high level and it accepts to conduct charging current, if the charger voltage is higher than the minimum operating voltage for 0V charging (1.2V max.).

The overdischarge detection have delay time decided internally. When the V_{DD} terminal voltage becomes lower than the overdischarge detection voltage, it will not detect overdischarge, if the V_{DD} terminal voltage becomes higher than the overdischarge detection voltage again within the overdischarge detection delay time (20ms typ.). Moreover, the overdischarge release delay time (1ms typ.) exists, too.

All the circuits are stopped, and after the overdischarge is detected, it is assumed the state of the standby, and decreases the current (standby current) which IC consumes as much as possible (When V_{DD}=2V, 0.1μA max.).

The output type of the D_{OUT} terminal is CMOS output between V_{DD} and V_{SS} terminal voltage.

3. Discharging overcurrent detector, Short detector (VD3, Short Detector)

In the state of chargeable and dischargeable, if the V- terminal voltage becomes higher than the discharging overcurrent detection voltage (0.100V typ.) by short of loads, etc., it will detect discharging overcurrent state. If the V- terminal voltage becomes higher than short detection voltage (V_{DD}-0.9V typ.), it will detect discharging overcurrent state, too. And then the D_{OUT} terminal outputs low lewd, so the external discharging control Nch MOS FET turns OFF, and it protects from large current discharging.

The discharging overcurrent detection has delay time decided internally. When the V- terminal voltage becomes higher than the discharging overcurrent detection voltage, it will not detect discharging overcurrent, if the V- terminal voltage becomes lower than the discharging overcurrent detection voltage within the discharging overcurrent detection delay time (6ms typ.). Moreover, the discharging overcurrent release delay time (1ms typ.) exists, too.

The short detection delay time (400μs typ.) decided internally exists, too.

The discharging overcurrent release resistance(50kΩ typ.) is built into between V- terminal and V_{SS} terminal. In the state of discharging overcurrent or short, if the load is opened, V- terminal is pulled down to the V_{SS} via the discharging overcurrent release resistance. And when the V- terminal voltage becomes Bower than the discharging overcurrent detection voltage, it will automatically release discharging overcurrent or short state. The discharging overcurrent release resistance turns ON, if discharging overcurrent or short is detected. On the normal state (chargeable state), the discharging overCurgent release resistance is OFFed.

4. Charging overcurrent detector (VD4)

In the state of chargeable and dischargeable, if the V- terminal voltage becomes lower than charging overcurrent detection voltage (-0.100V typ.) by abnormal voltage or current charger, etc., it will detect charging overcurrent state. And then the C_{OUT} terminal outputs low level, so the external charging control Nch MOS FET turn OFF, and it protects from large current charging.

It release charging overcurrent state, if the abnormal charger is disconnected, and the Load is connected.

The charging overcurrent detection has delay time decided internally. When the V- terminal voltage becomes lower than the charging overcurrent detection voltage, it will not detect charging overcurrent, if the V- terminal voltage becomes higher than the charging overcurrent detection voltage within the charging overcurrent detection delay time (8ms typ.). Moreover, the charging overcurrent release delay time (1ms typ.) exists, too.

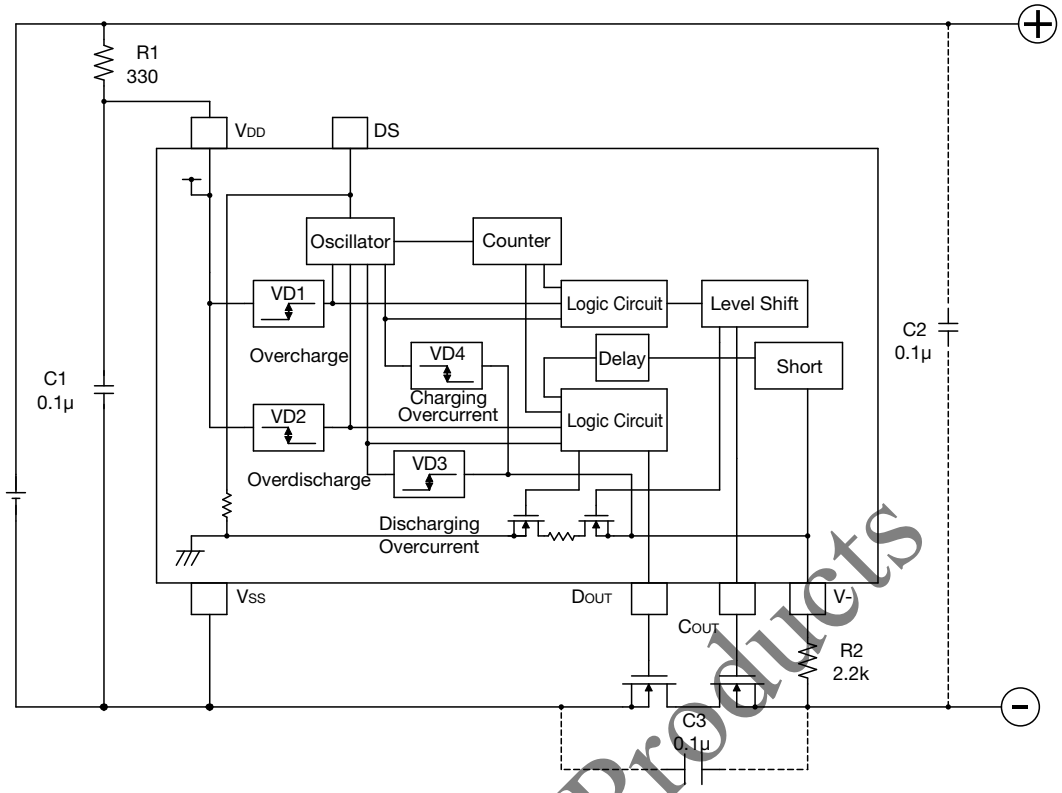
5. DS (Delay Shortening) function

The delay time of overcharge, overdischarge, discharging overcurrent, and charging overcurrent detection and release can be shortened by making the DS terminal to V_{DD} level voltage. The overcharge detection delay time can be adjusted to several 100μs by making the DS terminal to middle level voltage, so test time of protection module can be shortened.

In the DS terminal, the pull-down resistance of 13kΩ is connected between V_{SS}.

Please open the DS terminal when using usually.

Application Circuit



ApplicAtion hints

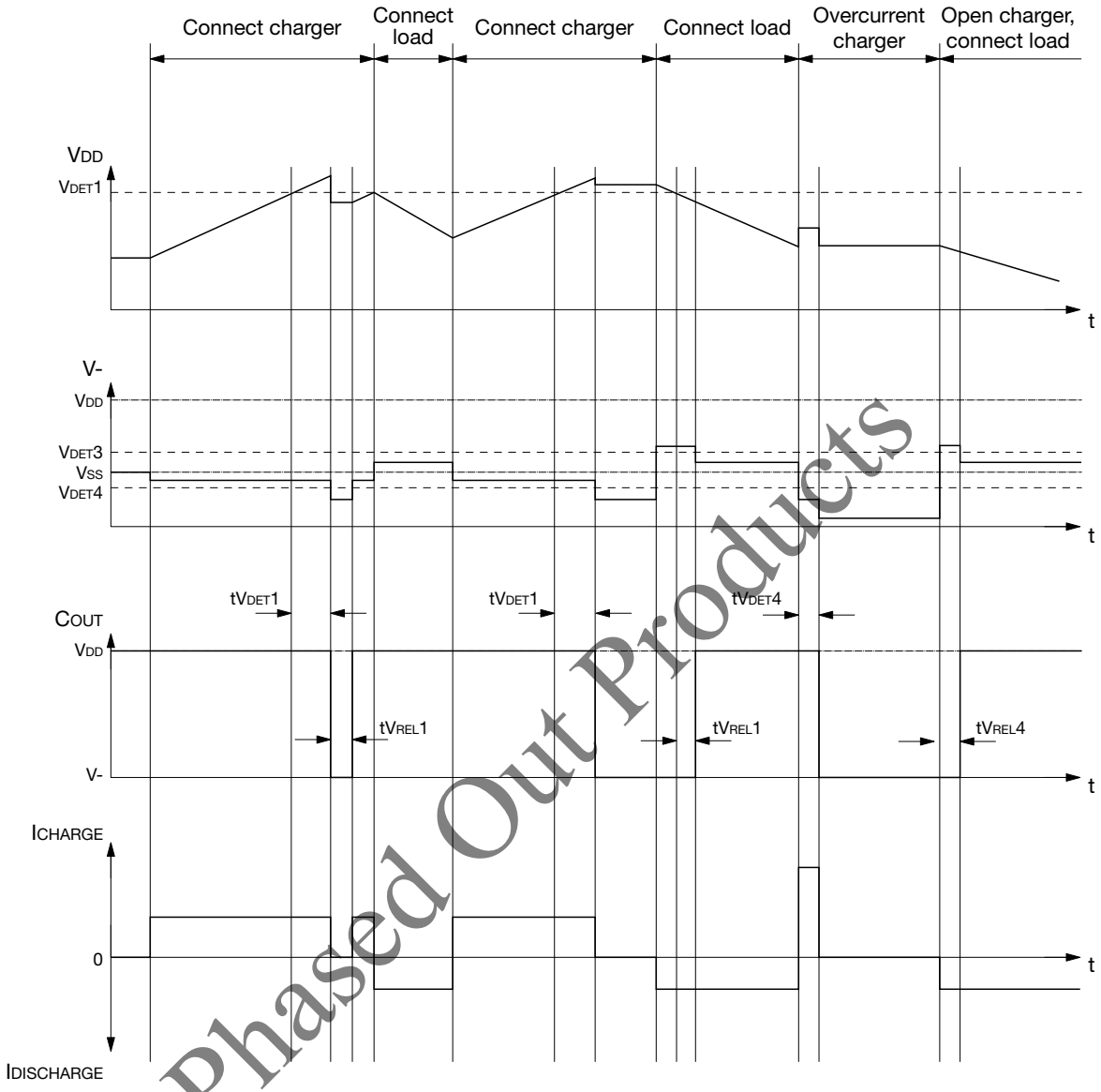
R1 and C1 stabilize a supply voltage ripple. However, the detection voltage rises by the current of penetration in IC of the voltage detection when R1 is enlarged, and the value of R1 is adjusted to 1kohm or less. Moreover, adjust the value of C1 to 0.01µF or more to do the stability operation, please.

R1 and R2 resistors are current limit resistance if a charger is connected reversibly or a high- voltage charger that exceeds the absolute maximum rating is connected. R1 and R2 may cause a power consumption will be over rating of power dissipation, therefore the 'R1+R2' should be more than 1kΩ. Moreover, if R2 is too enlarged, the charger connection release cannot be occasionally done after the overdischarge is detected, so adjust the value of R2 to 10kΩ or less, please.

C2 and C3 capacitors have effect that the system stability about voltage ripple or imported noise. After check characteristics, decide that these capacitors should be inserted or not, where should be inserted, and capacitance value, please.

Timing Chart

Overcharge, charging, overcurrent operation



Overdischarge, discharging, overcurrent, and short operation