Ordering number : ENA1641

SANYO Semiconductors
DATA SHEET

CMOS IC

# LV51142T — 1-Cell Lithium-Ion Battery Protection IC

## Overview

The LV51142T is protection IC for rechargeable Li-ion battery by high withstand voltage CMOS process.
The LV51142T protect single-cell Li-ion battery from over-charge, over-discharge, charge over-current and discharge over-current.

## Features

- High accuracy detection voltage
  - Over-charge detection ±25mV
  - Over-charge hysteresis ±25mV
  - Over-discharge detection ±2.5%
  - Charge over-current detection ±30mV
  - Discharge over-current detection ±20mV
- Delay time (internal adjustment)
- Low current consumption
  - Operation Typ. 3.0μA
  - Over-discharge condition Max. 0.1μA
- 0V cell battery charging function
- The over-discharge detection is released only when the charger is connected.

## Specifications

### Absolute Maximum Ratings/Ta=25℃

| Parameter | Symbol | Conditions | Ratings | Unit |
|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | | $V_{SS}$-0.3 to $V_{SS}$+7 | V |
| Input voltage of $V_M$ | $V_M$ | | $V_{DD}$-28 to $V_{DD}$+0.3 | V |
| Output voltage of $C_O$ | VCO | | $V_M$-0.3 to $V_{DD}$+0.3 | V |
| Output voltage of $D_O$ | VDO | | $V_{SS}$-0.3 to $V_{DD}$+0.3 | V |
| Allowable power dissipation | $P_D$ | | 350 | mW |
| Operating temperature | Topr | | -40 to +85 | °C |
| Storage temperature | Tstg | | -55 to +125 | °C |

**Electrical Characteristics** at Topr = 25°C, unless otherwise specified

| Parameter | Symbol | Conditions | Test circuit | Ratings | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | min | typ | max | |
| **Detection voltage** | | | | | | | |
| Over-charge detection voltage | VC | | 1 | 4.175 | 4.200 | 4.225 | V |
| Over-charge hysteresis voltage | VHc | | 1 | 0.175 | 0.2 | 0.225 | V |
| Over-discharge detection voltage (*2) | Vdc | | 1 | 2.730 | 2.800 | 2.870 | V |
| Charge over-current detection voltage | VIc | | 2 | -0.150 | -0.120 | -0.090 | V |
| Discharge over-current detection voltage | VIdc | | 2 | 0.100 | 0.120 | 0.140 | V |
| Load short-circuiting detection voltage | Vshort | Based on $V_{DD}$, $V_{DD}$ = 3.5V | 2 | -1.7 | -1.3 | -1.0 | V |
| **Input voltage** | | | | | | | |
| Input voltage between $V_{DD}$ and $V_{SS}$ | $V_{DD}$ | Internal circuit operating voltage | - | 1.8 | | 7.0 | V |
| 0V battery charge starting charger voltage | Vcha | Acceptable | 3 | | 0.9 | 1.4 | V |
| **Current consumption** | | | | | | | |
| Current consumption on operation | Iopr | $V_{DD}$ = 3.5V, $V_M$ = 0V | 4 | | 3.0 | 6.0 | μA |
| Current consumption on shutdown | Isdn | $V_{DD}$ = $V_M$ = 1.8V | 4 | | | 0.1 | μA |
| **Output resistance** | | | | | | | |
| $C_O$ : Pch ON resistance | Rcop | $C_O$ = 3.0V, $V_{DD}$ = 3.5V, $V_M$ = 0V | 5 | 1.5 | 3.0 | 4.5 | kΩ |
| $C_O$ : Nch ON resistance | Rcon | $C_O$ = 0.5V, $V_{DD}$ = 4.6V, $V_M$ = 0V | 5 | 0.5 | 1.0 | 1.5 | kΩ |
| $D_O$ : Pch ON resistance | Rdop | $D_O$ = 3.0V, $V_{DD}$ = 3.5V, $V_M$ = 0V | 5 | 1.7 | 3.5 | 5.0 | kΩ |
| $D_O$ : Nch ON resistance | Rdon | $D_O$ = 0.5V, $V_{DD}$ = $V_M$ = 1.8V | 5 | 1.7 | 3.5 | 5.0 | kΩ |
| Discharge over-current release resistance | Rdwn | $V_{DD}$ = 3.5V, $V_M$ = 1.0V | 5 | 15.0 | 30.0 | 60.0 | kΩ |
| **Detection delay time** | | | | | | | |
| Over-charge detection delay time | tc | $V_{DD}$ = VC-0.2V→VC+0.2V, $V_M$ = 0V | 6 | 0.70 | 1.0 | 1.30 | s |
| Over-discharge detection delay time | tdc | $V_{DD}$ = Vdc+0.2V→Vdc-0.2V, $V_M$ = 0V | 6 | 21.7 | 31.0 | 40.3 | ms |
| Charge over-current detection delay time | tic | $V_{DD}$ = 3.0V, $V_M$ = 0V→-1.0V | 6 | 5.6 | 8.0 | 10.4 | ms |
| Discharge over-current detection delay time | tidc | $V_{DD}$ = 3.0V, $V_M$ = 0V→1.0V | 6 | 5.6 | 8.0 | 10.4 | ms |
| Load short-circuiting detection delay time | tshort | $V_{DD}$ = 3.0V, $V_M$ = 0V→3.0V | 6 | 190 | 370 | 550 | μs |
| **Release delay time** | | | | | | | |
| Release delay time 1<br>Over-discharge release<br>Charge over-current release (*1)<br>Discharge over-current release<br>Load short-circuiting release | trel1 | | 6 | 1.0 | 2.0 | 3.0 | ms |
| Release delay time 2<br>Over-charge release | trel2 | $V_{DD}$ = VC+0.2V→VC-0.2V, $V_M$ = 1.0V | 6 | 8.0 | 16.0 | 24.0 | ms |

Note :*1 When the charger is connected under over-discharge , this means the time after the over-discharge detection is released.

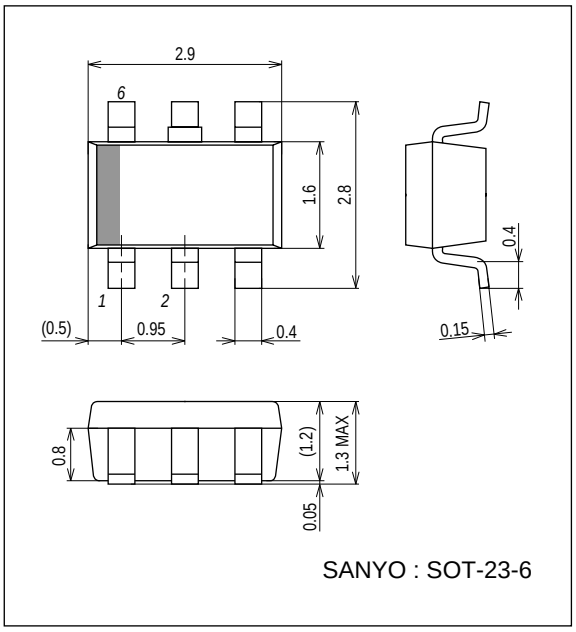
*2 The over-discharge detection is released at this voltage only when the charger is connected.

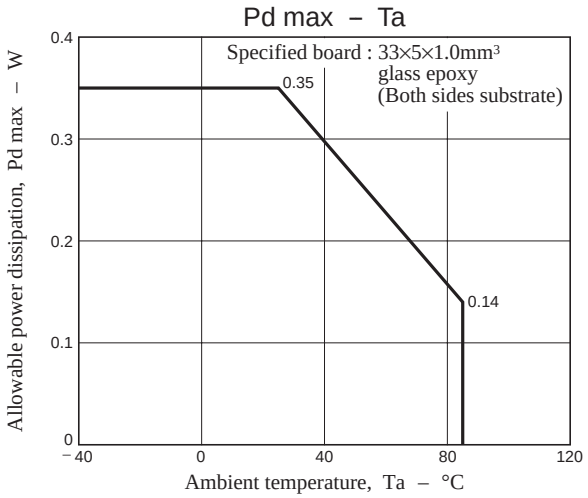
The over-discharge detection isn't released if the charger isn't connected.

## Package Dimensions

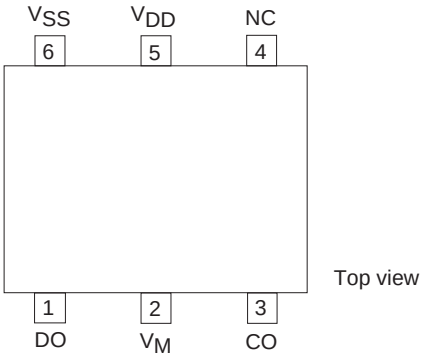
unit : mm (typ)

3356



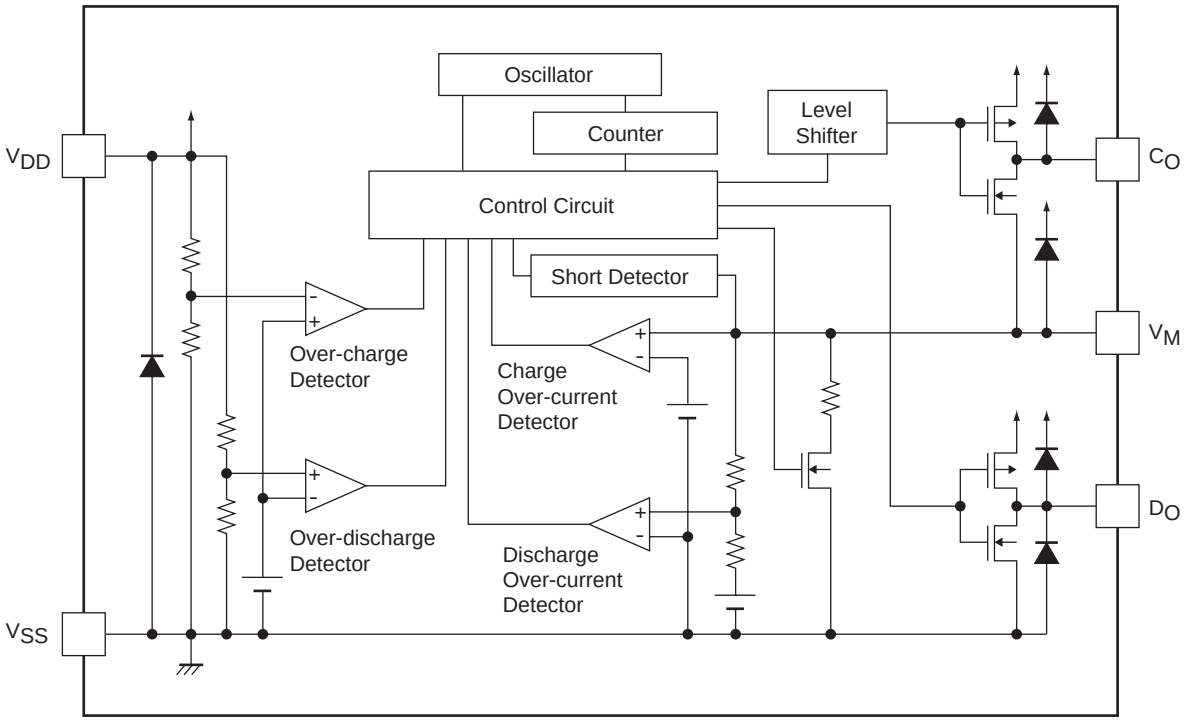

## Pin Assignment




## Pin Function

| Pin No. | Pin Name | Description |
|---|---|---|
| 1 | $D_O$ | FET gate connection for discharge control (CMOS output) |
| 2 | $V_M$ | Voltage monitoring for charger negative |
| 3 | $C_O$ | FET gate connection for charge control (CMOS output) |
| 4 | NC | N/C |
| 5 | $V_{DD}$ | Positive power input |
| 6 | $V_{SS}$ | Negative power input |

## Block Diagram




## Measurement Conditions

- Over-charge detection voltage, Over-charge hysteresis voltage --- [Circuit 1]
  Set V1 = 3.0V and V2 = 0V. Over-charge detection voltage VC is V1 at which VCO goes "Low" from "High" when V1 is gradually increased from 3.0V. Then IC is released from the over-charge state and VCO goes "High" from "Low" at the voltage "Measured VC-VHc" when V1 is gradually decreased.
  If V2 is set to the greater value than discharge over-current detection voltage VIdc in the over-charge state, VHc is canceled and then IC is released from the over-charge state at VC.

- Over-discharge detection voltage --- [Circuit 1]
  Set V1 = 3.0V and V2 = 0V. Over-discharge detection voltage Vdc is V1 at which VDO goes "Low" from "High" when V1 is gradually decreased from 3.0V. Next, set V2 under to charge over-current detection voltage VIc. Then IC is released from the over-discharge state at Vdc and VDO goes "High" from "Low".

- Charge over-current detection voltage --- [Circuit 2]
  Set V1 = 3.0V and V2 = 0V. Charge over-current detection voltage VIc is V2 at which VCO goes "Low" from "High" when V2 is gradually decreased from 0V.

- Discharge over-current detection voltage --- [Circuit 2]
  Set V1 = 3.0V and V2 = 0V. Discharge over-current detection voltage VIdc is V2 at which VDO goes "Low" from "High" when V2 is gradually increased from 0V.

- Load short-circuiting detection voltage --- [Circuit 2]
  Set V1 = 3.0V and V2 = 0V. Load short-circuiting detection voltage Vshort is V2 at which VDO goes "Low" from "High" within a time between the minimum and the maximum value of load short-circuiting detection delay time tshort, when V2 is increased rapidly within 10μs.

- 0V battery charge starting charger voltage --- [Circuit 3]
  Set V1 = V2 = 0V and decrease V2 gradually. 0V battery charge starting charger voltage Vcha is V2 when VCO goes "High" (V1-0.1V or higher).

Continued on next page.

Continued from preceding page.

- Current consumption on operation and shutdown --- [Circuit 4]
  Set V1 = 3.5V and V2 = 0V on normal condition. $I_{DD}$ shows current consumption on operation Iopr.
  Set V1 = V2 = 1.8V on over-discharge condition. $I_{DD}$ shows current consumption on shutdown Isdn.

- Co : Pch ON resistance, Co : Nch ON resistance --- [Circuit 5]
  Set V1 = 3.5V, V2 = 0V and V3 = 3.0V. (V1-V3)/|ICo| is Pch ON resistance Rcop.
  Set V1 = 4.6V, V2 = 0V and V3 = 0.5V. V3/|ICo| is Nch ON resistance Rcon.

- Do : Pch ON resistance, Do : Nch ON resistance --- [Circuit 5]
  Set V1 = 3.5V, V2 = 0V and V4 = 3.0V. (V1-V4)/|IDo| is Pch ON resistance Rdop.
  Set V1 = V2 = 1.8V and V4 = 0.5V. V4/|IDo| is Nch ON resistance Rdon.

- Discharge over-current release resistance --- [Circuit 5]
  Set V1 = 3.5V, V2 = 0V at first. And then, set V2 = 1.0V. V2/|$IV_M$| is discharge over-current release resistance Rdwn.

- Over-charge detection delay time, Release delay time 2 --- [Circuit 6]
  Set V2 = 0V. Increase V1 from the voltage VC-0.2V to VC+0.2V rapidly within 10μs. Over-charge detection delay time tc is the time needed for VCO to go "Low" just after the change of V1.
  Next, set V2 = 1V and decrease V1 from VC+0.2V to VC-0.2V rapidly within 10μs. Over-charge release delay time trel 2 is the time needed for VCO to go "High" just after the change of V1.

- Over-discharge detection delay time, Release delay time 1 --- [Circuit 6]
  Set V2 = 0V. Decrease V1 from the voltage Vdc+0.2V to Vdc-0.2V rapidly within 10μs. Over-discharge detection delay time tdc is the time needed for VDO to go "Low" just after the change of V1.
  Next, set V2 = -1V and increase V1 from Vdc-0.2V to Vdc+0.2V rapidly within 10μs. Release delay time 1 trel1 in case of over-discharge is the time needed for VDO to go "High" just after the change of V1.

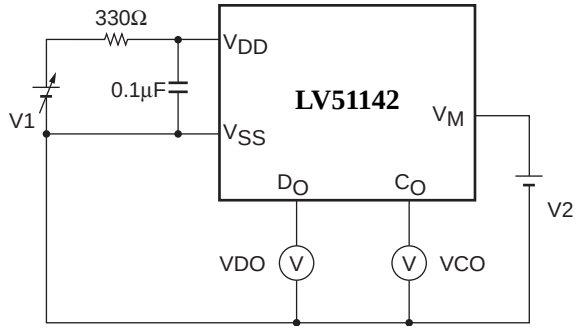
- Charge over-current detection delay time, Release delay time 1 --- [Circuit 6]
  Set V1 = 3.0V and V2 = 0V. Decrease V2 from 0V to -1V rapidly within 10μs. Charge over-current delay time tic is the time needed for VCO to go "Low" just after the change of V2.
  Next, increase V2 from -1V to 0V rapidly within 10μs. Release delay time 1 trel1 in case of charge over-current is the time needed for VCO to go "High" just after the change of V2.

- Discharge over-current detection delay time, Release delay time 1 --- [Circuit 6]
  Set V1 = 3.0V and V2 = 0V. Increase V2 from 0V to 1V rapidly within 10μs. Discharge over-current delay time tidc is the time needed for VDO to go "Low" just after the change of V2.
  Next, decrease V2 from 1V to 0V rapidly within 10μs. Release delay time 1 trel1 in case of discharge over-current is the time needed for VDO to go "High" just after the change of V2.

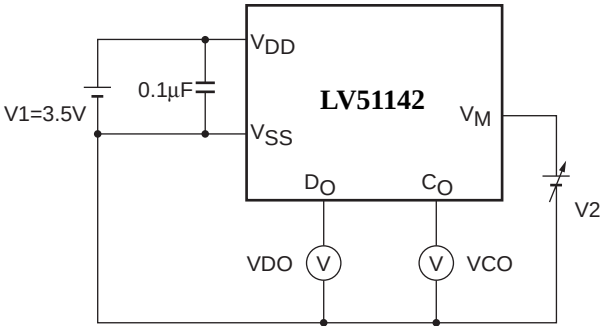
- Load short-circuiting detection delay time, Release delay time 1 --- [Circuit 6]
  Set V1 = 3.0V and V2 = 0V. Increase V2 from 0V to 3.0V rapidly within 10μs. Load short-circuiting detection delay time tshort is the time needed for VDO to go "Low" just after the change of V2.
  Next, decrease V2 from 3.0V to 0V rapidly within 10μs. Release delay time 1 trel1 in case of load short-circuiting is the time needed for VDO to go "High" just after the change of V2.

## Measurement Circuits

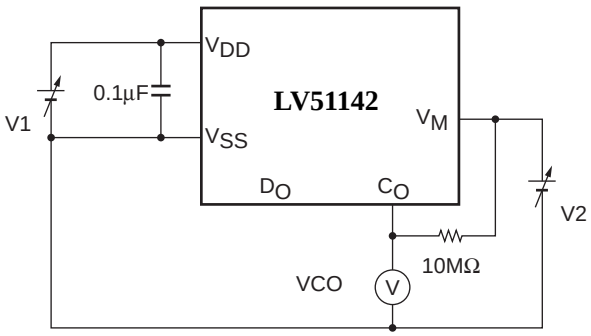
• Circuit 1



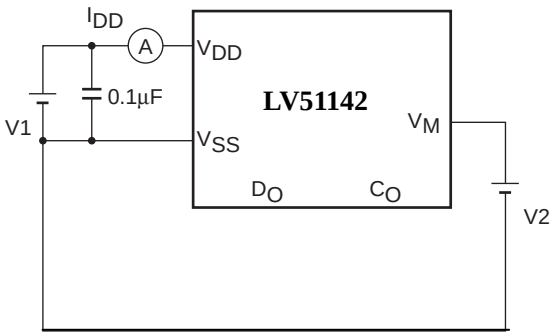

• Circuit 2



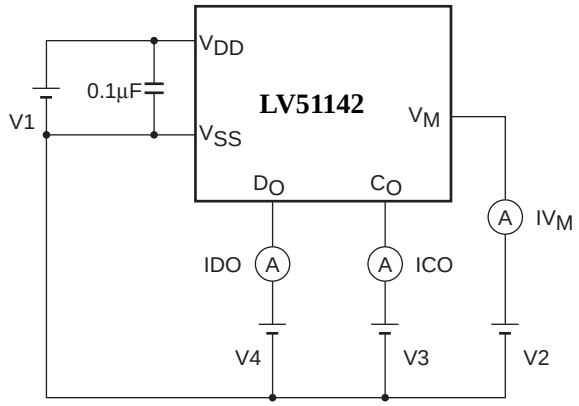

• Circuit 3



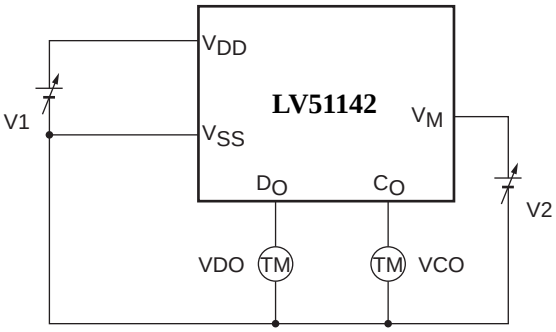

• Circuit 4




• Circuit 5

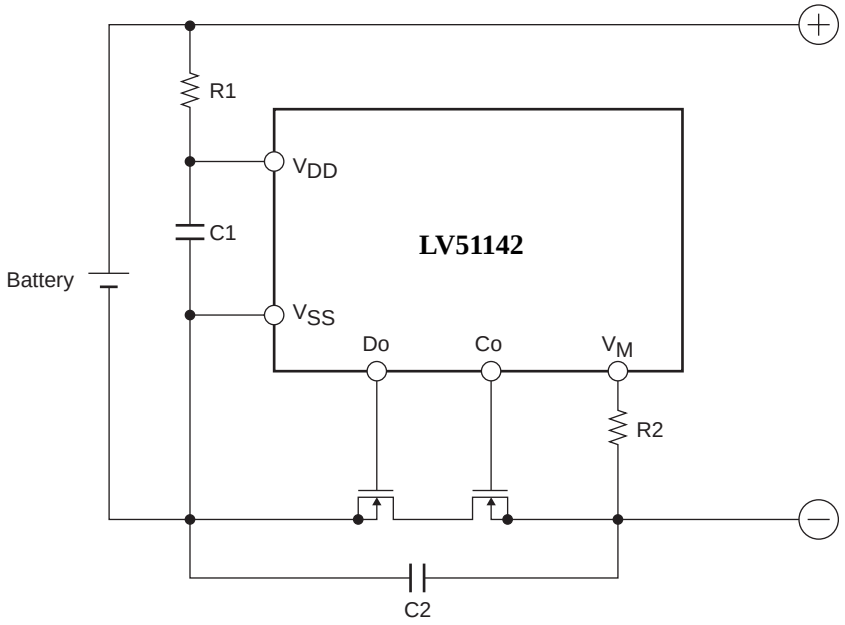



• Circuit 6




TM = Time Measurement

## Application Circuit Example




## External Components

| Items | Symbol | Recommended value |
|---|---|---|
| Resistor 1 | R1 | 330Ω |
| Capacitor 1 | C1, 2 | 0.1μF |
| Resistor 2 | R2 | 3.9kΩ |

- The supply voltage ($V_{DD}$) to this IC is stabilized by R1 and C1. Moreover, R1 and R2 act as the current restriction resistances at the time of reverse-connecting a charger, or at the time of connecting a charger which outputs the voltage exceeding the absolute maximum rating of this IC. Be sure to connect these components.

- If the value of R1 is too large, the over-charge detection voltage will become high due to the current consumption of this IC. 330Ω is recommended.

- If the value of C1 is too small, this IC may be in a shutdown state at the time of the discharge over-current or the load short-circuiting. 0.1μF is recommended.

- Use the value within the limits shown in the table about the value of R2. In order to reduce the current at the time of reverse-connecting a charger, we recommend to choose R1 and R2 so that the sum total of resistance values is more than 4kΩ. The recommended value of R2 is 3.9kΩ.

Note 1 : The connection diagram and each value of external components shown above are just recommendation. Including a battery and FETs, determine the circuit after sufficient evaluation about your actual application.
These numbers don't mean to guarantee the characteristic of the IC

Note 2 : The IC is susceptible to static electricity and some pins are easily damaged by it. Handle the IC carefully.

## Description of Operation

- Normal condition

  This IC monitors the battery voltage ($V_{DD}$) and the voltage of $V_M$ terminal, and controls charge and discharge.
  If the battery voltage ($V_{DD}$) is in the range from the over-discharge detection voltage (Vdc) to the over-charge detection voltage (VC) and the $V_M$ terminal voltage is in the range from the charge over-current detection voltage (VIc) to the discharge over-current detection voltage (VIdc), this IC turns on both the charge and discharge control FETs. This state is called the normal condition, and charge and discharge are possible together.

- Discharge over-current detection, Load short-circuiting detection

  When the discharge current becomes equal to or higher than the specified value under the normal condition, and if the $V_M$ terminal voltage is in the range from the discharge over current detection voltage (VIdc) to the short-circuiting detection voltage (Vshort) and that state is maintained during more than the discharge over-current detection delay time (tidc), this IC turns off the discharge control FET to stop discharge. This state is called the discharge over-current condition.
  At that time, if the $V_M$ terminal voltage is equal to or higher than Vshort and that state is maintained during more than the load short-circuiting detection delay time (tshort), this IC turns off the discharge control FET to stop discharge. This state is called the load short-circuiting detection condition.
  While load is connected, in both conditions, the $V_M$ terminal voltage equals to $V_{DD}$ potential due to the load, but it falls by the discharge over-current release resistance (Rdwn) when the load is removed and the resistance between (+) and (-) terminals of battery pack (refer to “Application Circuit Example”) becomes larger than the value which enables the automatic return.
  Then the $V_M$ terminal voltage becomes less than VIdc, and if that state is maintained during more than the release delay time 1 (trel1), this IC returns to normal condition.

Note : The resistance value between (+) and (-) terminals of battery pack for automatic return changes with battery voltage ($V_{DD}$) or VIdc. The standard is expressed with the following equation.

$$\text{Resistance value for automatic return} = Rdwn \times (V_{DD} / VIdc - 1)$$

- Charge over-current detection

  When the charge current becomes equal to or higher than the specified value under the normal condition, if the $V_M$ terminal voltage becomes less than the charge over-current detection voltage (VIc) and that state is maintained during more than the charge over-current detection delay time (tic), this IC turns off the charge control FET to stop charge. This state is called the charge over-current detection condition.
  Then the $V_M$ terminal voltage becomes equals to or higher than VIc and that state is maintained during more than the release delay time 1 (trel1) when the charger is removed and the load is connected, this IC returns to the normal condition.

- Over-charge detection

  When the battery voltage ($V_{DD}$) under the normal condition becomes equal to or higher than the over-charge detection voltage (VC) and that state is maintained during more than the over-charge detection delay time (tc), this IC turns off the charge control FET and stops charge. This state is called the over-charge detection condition. Release from the over-charge detection condition includes following three cases.

  (1) When $V_{DD}$ falls to Vc-VHc without load and that state is maintained during more than the delay time 2 (trel2), this IC turns on the charge control FET and returns to the normal condition.
  * VHc : Over-charge hysteresis voltage

  (2) When the load is installed and discharge starts, the discharge current flows through the internal parasitic diode of the charge control FET. Then the $V_M$ terminal voltage rises to only the Vf voltage of the internal parasitic diode from $V_{SS}$ potential. At this time, if the $V_M$ terminal voltage is higher than the discharge over-current detection voltage (VIdc) and $V_{DD}$ is equal to or less than VC, this IC returns to the normal condition when this state continues more than the delay time 2 (trel2).

  (3) In case (2), if the $V_M$ terminal voltage is higher than the discharge over-current detection voltage (VIdc) and $V_{DD}$ is equal to or higher than VC, battery is discharged until $V_{DD}$ becomes less than VC, and then this IC returns to the normal condition when this state continues more than the delay time 2 (trel2).

- Over-discharge detection

  When the battery voltage ($V_{DD}$) under the normal condition becomes equal to or less than the over-discharge detection voltage (Vdc) and that state continues for more than the over-discharge detection time (tdc), this IC turns off the discharge control FET and stops discharging. This state is called the over-discharge detection condition. Recovery from the over-discharge detection condition is achieved only by connecting the charger.

- Return from over-discharge

  When the charger is connected and charging starts, the charge current flows through the internal parasitic diode of the discharge control FET. When $V_{DD}$ becomes higher than Vdc and that state continues for more than the delay time 1(trel1), this IC is released from the over-discharge detection condition automatically and returns to the normal condition.

  If $V_{DD}$ is less than Vdc, this IC returns to the normal condition when $V_{DD}$ becomes equal to or higher than Vdc, and this state continues more than delay time 1 (trel1).

  This IC stops all internal circuits (Shutdown condition) after detecting the over-discharge and reduces current consumption. (Max 0.1μA, at $V_{DD}$ = 1.8V)

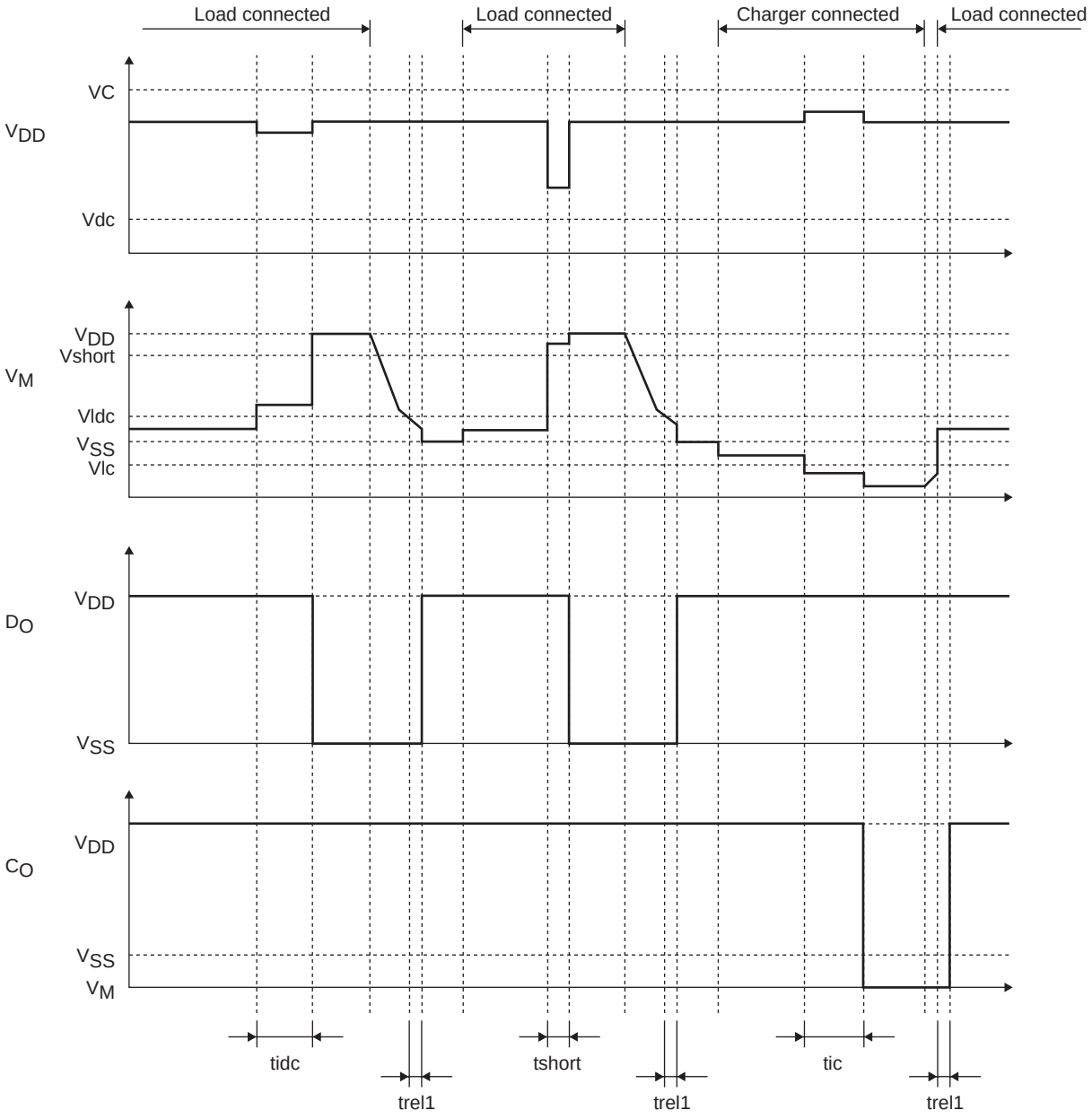
- Charge to 0V battery

  0V battery charge function

  If the voltage of charger (the voltage between $V_{DD}$ and $V_M$) is larger than the 0V battery charge starting charger voltage (Vcha), 0V battery charge becomes possible when CO terminal outputs $V_{DD}$ terminal potential and turns on the charge control FET.

## Timing Chart

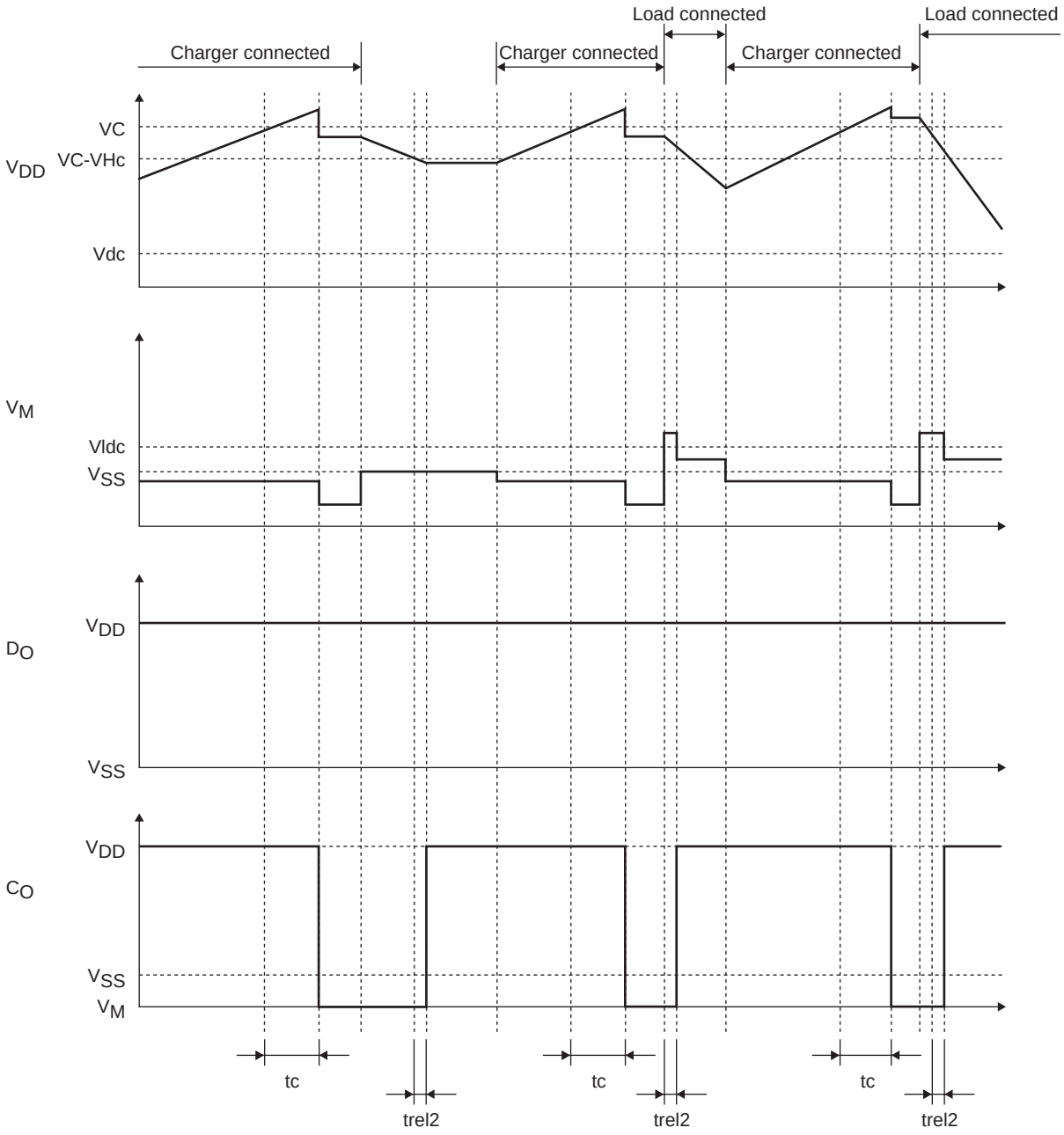
• Discharge over-current detection, Load short-circuiting detection, Charge over-current detection




VC : Over-charge detection voltage
Vdc : Over-discharge detection voltage
VIc : Charge over-current detection voltage
VIdc : Discharge over-current detection voltage
Vshort : Load short-circuiting detection voltage

tic : Charge over-current detection delay time
tidc : Discharge over-current detection delay time
tshort : Load short-circuiting detection delay time
trel1 : Release delay time 1

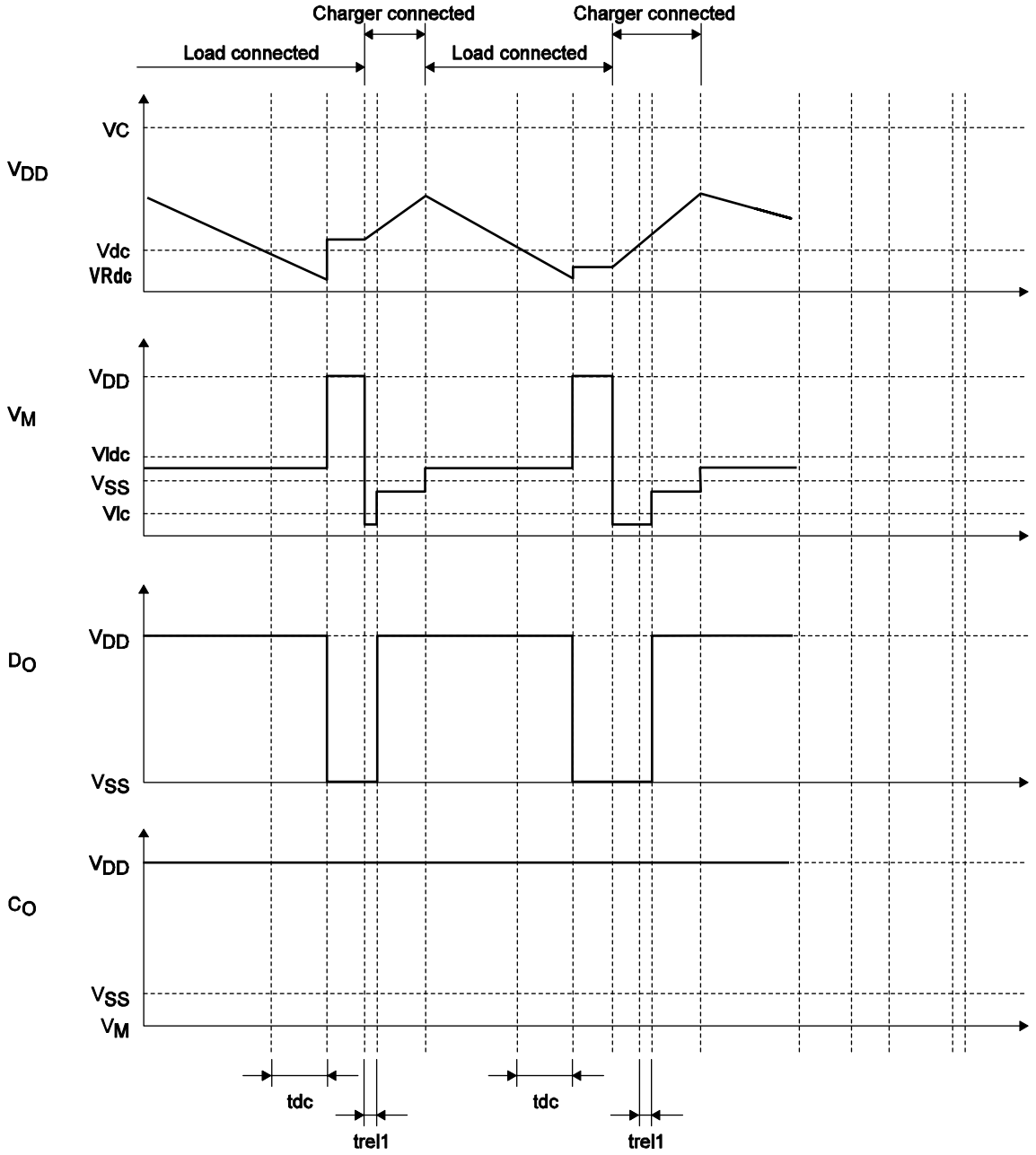
• Over-charge detection




VC : Over-charge detection voltage
Vdc : Over-discharge detection voltage
VHc : Over-charge hysteresis voltage
Vidc : Discharge over-current detection voltage

tc : Over-charge detection delay time
trel2 : Release delay time 2

• Over-discharge detection




VC : Over-charge detection voltage
Vdc : Over-discharge detection voltage
VRdc : Over-discharge return voltage
Vic : Charge over-current detection voltage
Vidc : Discharge over-current detection voltage

tdc : Over-discharge detection delay time
trel1 : Release delay time 1