



SANYO Semiconductors

# DATA SHEET

## CMOS IC LV51140T — 1-Cell Lithium-Ion Battery Protection IC

### Overview

The LV51140T is protection IC for rechargeable Li-ion battery by high withstand voltage CMOS process.

The LV51140T 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	±25%
Charge over-current detection	±0.3V
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

### Specifications

**Absolute Maximum Ratings** at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	V <sub>DD</sub>		V <sub>SS</sub> -0.3 to V <sub>SS</sub> +7	V
Input voltage of V <sub>M</sub>	V <sub>M</sub>		V <sub>DD</sub> -28 to V <sub>DD</sub> +0.3	V
Output voltage of C <sub>O</sub>	V <sub>CO</sub>		V <sub>M</sub> -0.3 to V <sub>DD</sub> +0.3	V
Output voltage of D <sub>O</sub>	V <sub>DO</sub>		V <sub>SS</sub> -0.3 to V <sub>DD</sub> +0.3	V
Power dissipation	P <sub>D</sub>		350	mW
Operating temperature	T <sub>opr</sub>		-40 to +85	°C
Storage temperature	T <sub>stg</sub>		-55 to +125	°C

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**SANYO Semiconductor Co., Ltd.**

TOKYO OFFICE Tokyo Bldg., 1-10, 1 Chome, Ueno, Taito-ku, TOKYO, 110-8534 JAPAN

# LV51140T

**Electrical Characteristics** at  $T_{opr} = 25^{\circ}\text{C}$ , unless otherwise specified

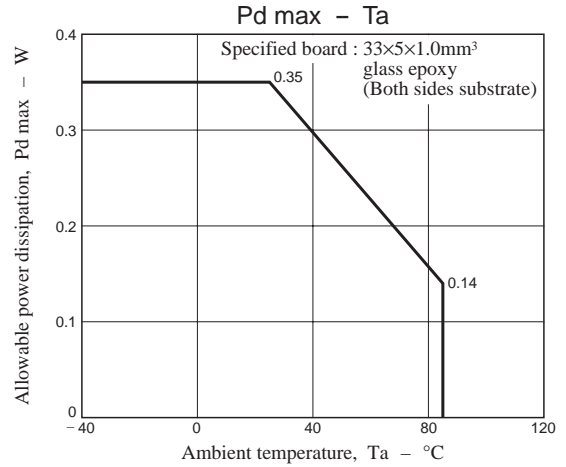
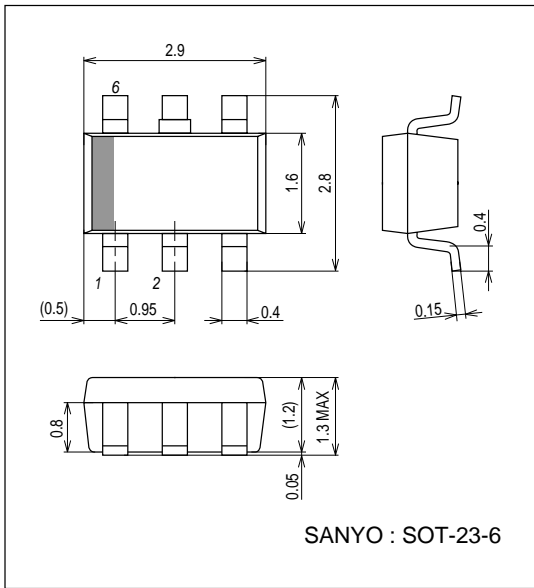
Parameter	Symbol	Conditions	Test circuit	Ratings			Unit
				min	typ	max	
<b>Detection voltage</b>							
Over-charge detection voltage	VC		1	4.225	4.250	4.275	V
Over-charge hysteresis voltage	VHc		1	0.175	0.2	0.225	V
Over-discharge detection voltage	Vdc		1	2.438	2.500	2.563	V
Over-discharge reset voltage	VRdc		1	2.633	2.700	2.768	V
Charge over-current detection voltage	Vlc		2	-1.000	-0.700	-0.400	V
Discharge over-current detection voltage	Vldc		2	0.180	0.200	0.220	V
Load short-circuiting detection voltage	Vshort	Based on $V_{DD}$ , $V_{DD} = 3.5\text{V}$	2	-1.7	-1.3	-1.0	V
<b>Input voltage</b>							
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
<b>Current consumption</b>							
Current consumption on operation	Iopr	$V_{DD} = 3.5\text{V}$ , $V_M = 0\text{V}$	4		3.0	6.0	$\mu\text{A}$
Current consumption on shutdown	Istdn	$V_{DD} = V_M = 1.8\text{V}$	4			0.1	$\mu\text{A}$
<b>Output resistance</b>							
$C_O$ : Pch ON resistance	Rcop	$C_O = 3.0\text{V}$ , $V_{DD} = 3.5\text{V}$ , $V_M = 0\text{V}$	5	1.5	3.0	4.5	$\text{k}\Omega$
$C_O$ : Nch ON resistance	Rcon	$C_O = 0.5\text{V}$ , $V_{DD} = 4.6\text{V}$ , $V_M = 0\text{V}$	5	0.5	1.0	1.5	$\text{k}\Omega$
$D_O$ : Pch ON resistance	Rdop	$D_O = 3.0\text{V}$ , $V_{DD} = 3.5\text{V}$ , $V_M = 0\text{V}$	5	1.7	3.5	5.0	$\text{k}\Omega$
$D_O$ : Nch ON resistance	Rdon	$D_O = 0.5\text{V}$ , $V_{DD} = V_M = 1.8\text{V}$	5	1.7	3.5	5.0	$\text{k}\Omega$
Discharge over-current release resistance	Rdwn	$V_{DD} = 3.5\text{V}$ , $V_M = 1.0\text{V}$	5	15.0	30.0	60.0	$\text{k}\Omega$
<b>Detection delay time</b>							
Over-charge detection delay time	tc	$V_{DD} = \text{VC}-0.2\text{V} \rightarrow \text{VC}+0.2\text{V}$ , $V_M = 0\text{V}$	6	0.70	1.0	1.30	s
Over-discharge detection delay time	tdc	$V_{DD} = \text{Vdc}+0.2\text{V} \rightarrow \text{Vdc}-0.2\text{V}$ , $V_M = 0\text{V}$	6	21.7	31.0	40.3	ms
Charge over-current detection delay time	tic	$V_{DD} = 3.5\text{V}$ , $V_M = 0\text{V} \rightarrow -1.0\text{V}$	6	5.6	8.0	10.4	ms
Discharge over-current detection delay time	tidc	$V_{DD} = 3.5\text{V}$ , $V_M = 0\text{V} \rightarrow 1.0\text{V}$	6	5.6	8.0	10.4	ms
Load short-circuiting detection delay time	tshort	$V_{DD} = 3.5\text{V}$ , $V_M = 0\text{V} \rightarrow 3.5\text{V}$	6	190	370	550	$\mu\text{s}$
<b>Release delay time</b>							
Release delay time 1 Over-discharge release Charge over-current release (*1) Discharge over-current release Load short-circuiting release	trel1		6	1.0	2.0	3.0	ms
Release delay time 2 Over-charge release	trel2	$V_{DD} = \text{VC}+0.2\text{V} \rightarrow \text{VC}-0.2\text{V}$ , $V_M = 1.0\text{V}$	6	8.0	16.0	24.0	ms

Note : \*1 Upon connecting to charger upon over-discharge, the delay time after recovery from over-discharge.

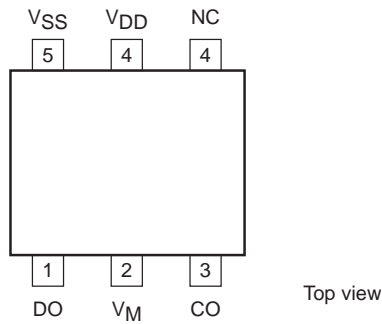
**Package Dimensions**

unit : mm (typ)

3356



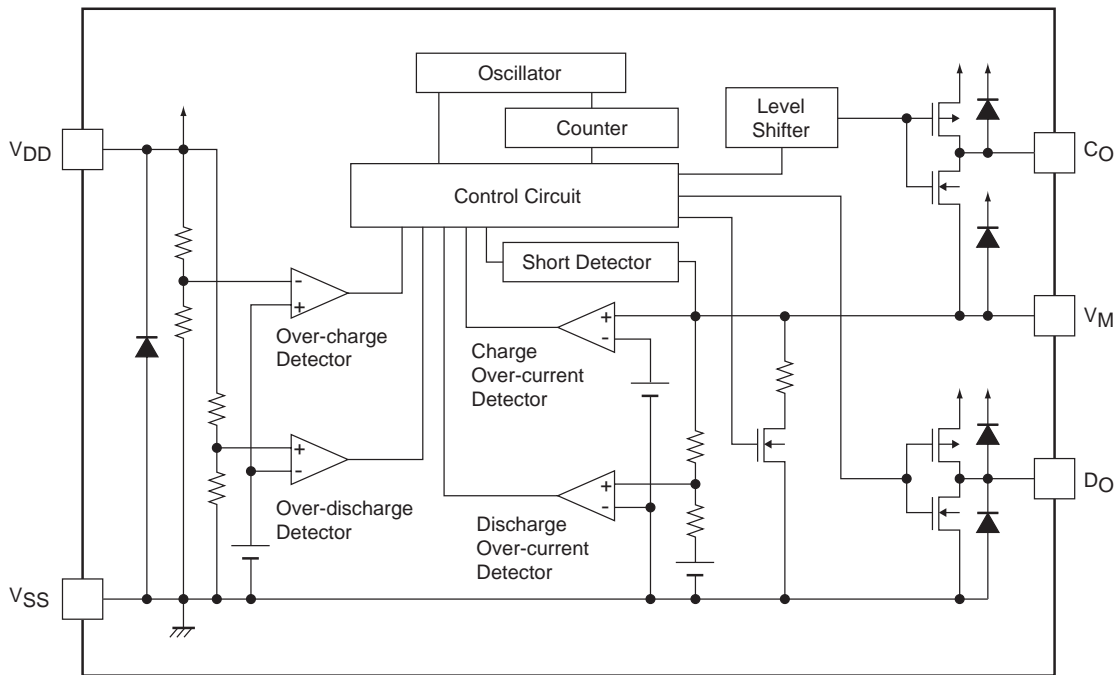
**Pin Assignment**



**Pin Function**

Pin No.	Pin Name	Description
1	D <sub>O</sub>	FET gate connection for discharge control (CMOS output)
2	V <sub>M</sub>	Voltage monitoring for charger negative
3	C <sub>O</sub>	FET gate connection for charge control (CMOS output)
4	NC	N/C
5	V <sub>DD</sub>	Positive power input
6	V <sub>SS</sub>	Negative power input

Block Diagram



Measurement Conditions

- Over-charge detection voltage, Over-charge hysteresis voltage --- [Circuit 1]  
 Set  $V_1 = 3.5V$  and  $V_2 = 0V$ . Over-charge detection voltage  $V_C$  is  $V_1$  at which  $V_{CO}$  goes "Low" from "High" when  $V_1$  is gradually increased from  $3.5V$ . Then IC is released from the over-charge state and  $V_{CO}$  goes "High" from "Low" at the voltage "Measured  $V_C - V_{Hc}$ " when  $V_1$  is gradually decreased.  
 If  $V_2$  is set to the greater value than discharge over-current detection voltage  $V_{Idc}$  in the over-charge state,  $V_{Hc}$  is canceled and then IC is released from the over-charge state at  $V_C$ .
- Over-discharge detection voltage --- [Circuit 1]  
 Set  $V_1 = 3.5V$  and  $V_2 = 0V$ . Over-discharge detection voltage  $V_{dc}$  is  $V_1$  at which  $V_{DO}$  goes "Low" from "High" when  $V_1$  is gradually decreased from  $3.5V$ . Next, set  $V_2$  under to charge over-current detection voltage  $V_{Ic}$ . Then IC is released from the over-discharge state at  $V_{dc}$  and  $V_{DO}$  goes "High" from "Low".
- Charge over-current detection voltage --- [Circuit 2]  
 Set  $V_1 = 3.5V$  and  $V_2 = 0V$ . Charge over-current detection voltage  $V_{Ic}$  is  $V_2$  at which  $V_{CO}$  goes "Low" from "High" when  $V_2$  is gradually decreased from  $0V$ .
- Discharge over-current detection voltage --- [Circuit 2]  
 Set  $V_1 = 3.5V$  and  $V_2 = 0V$ . Discharge over-current detection voltage  $V_{Idc}$  is  $V_2$  at which  $V_{DO}$  goes "Low" from "High" when  $V_2$  is gradually increased from  $0V$ .
- Load short-circuiting detection voltage --- [Circuit 2]  
 Set  $V_1 = 3.5V$  and  $V_2 = 0V$ . Load short-circuiting detection voltage  $V_{short}$  is  $V_2$  at which  $V_{DO}$  goes "Low" from "High" within a time between the minimum and the maximum value of load short-circuiting detection delay time  $t_{short}$ , when  $V_2$  is increased rapidly within  $10\mu s$ .
- 0V battery charge starting charger voltage --- [Circuit 3]  
 Set  $V_1 = V_2 = 0V$  and decrease  $V_2$  gradually. 0V battery charge starting charger voltage  $V_{cha}$  is  $V_2$  when  $V_{CO}$  goes "High" ( $V_1 - 0.1V$  or higher).

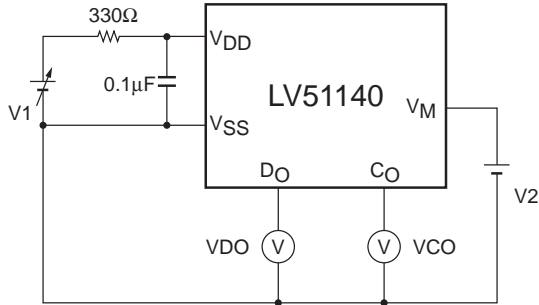
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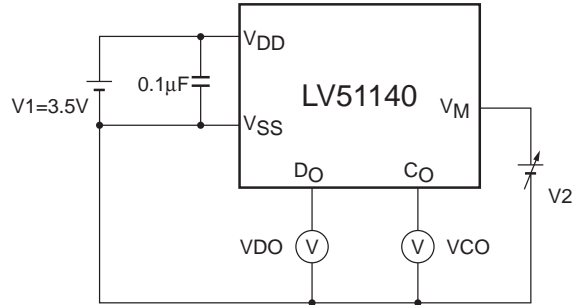
- Current consumption on operation and shutdown --- [Circuit 4]  
Set  $V_1 = 3.5V$  and  $V_2 = 0V$  on normal condition.  $I_{DD}$  shows current consumption on operation  $I_{opr}$ .  
Set  $V_1 = V_2 = 1.8V$  on over-discharge condition.  $I_{DD}$  shows current consumption on shutdown  $I_{sdn}$ .
- $C_o$  : Pch ON resistance,  $C_o$  : Nch ON resistance --- [Circuit 5]  
Set  $V_1 = 3.5V$ ,  $V_2 = 0V$  and  $V_3 = 3.0V$ .  $(V_1 - V_3)/|I_{Co}|$  is Pch ON resistance  $R_{cop}$ .  
Set  $V_1 = 4.6V$ ,  $V_2 = 0V$  and  $V_3 = 0.5V$ .  $V_3/|I_{Co}|$  is Nch ON resistance  $R_{con}$ .
- $D_o$  : Pch ON resistance,  $D_o$  : Nch ON resistance --- [Circuit 5]  
Set  $V_1 = 3.5V$ ,  $V_2 = 0V$  and  $V_4 = 3.0V$ .  $(V_1 - V_4)/|I_{Do}|$  is Pch ON resistance  $R_{dop}$ .  
Set  $V_1 = V_2 = 1.8V$  and  $V_4 = 0.5V$ .  $V_4/|I_{Do}|$  is Nch ON resistance  $R_{don}$ .
- Discharge over-current release resistance --- [Circuit 5]  
Set  $V_1 = 3.5V$ ,  $V_2 = 0V$  at first. And then, set  $V_2 = 1.0V$ .  $V_2/|I_{VM}|$  is discharge over-current release resistance  $R_{dwn}$ .
- Over-charge detection delay time, Release delay time 2 --- [Circuit 6]  
Set  $V_2 = 0V$ . Increase  $V_1$  from the voltage  $V_C - 0.2V$  to  $V_C + 0.2V$  rapidly within  $10\mu s$ . Over-charge detection delay time  $t_c$  is the time needed for  $V_{CO}$  to go "Low" just after the change of  $V_1$ .  
Next, set  $V_2 = 1V$  and decrease  $V_1$  from  $V_C + 0.2V$  to  $V_C - 0.2V$  rapidly within  $10\mu s$ . Over-charge release delay time  $t_{rel2}$  is the time needed for  $V_{CO}$  to go "High" just after the change of  $V_1$ .
- Over-discharge detection delay time, Release delay time 1 --- [Circuit 6]  
Set  $V_2 = 0V$ . Decrease  $V_1$  from the voltage  $V_{dc} + 0.2V$  to  $V_{dc} - 0.2V$  rapidly within  $10\mu s$ . Over-discharge detection delay time  $t_{dc}$  is the time needed for  $V_{DO}$  to go "Low" just after the change of  $V_1$ .  
Next, set  $V_2 = -1V$  and increase  $V_1$  from  $V_{dc} - 0.2V$  to  $V_{dc} + 0.2V$  rapidly within  $10\mu s$ . Release delay time 1  $t_{rel1}$  in case of over-discharge is the time needed for  $V_{DO}$  to go "High" just after the change of  $V_1$ .
- Charge over-current detection delay time, Release delay time 1 --- [Circuit 6]  
Set  $V_1 = 3.5V$  and  $V_2 = 0V$ . Decrease  $V_2$  from  $0V$  to  $-1V$  rapidly within  $10\mu s$ . Charge over-current delay time  $t_{ic}$  is the time needed for  $V_{CO}$  to go "Low" just after the change of  $V_2$ .  
Next, increase  $V_2$  from  $-1V$  to  $0V$  rapidly within  $10\mu s$ . Release delay time 1  $t_{rel1}$  in case of charge over-current is the time needed for  $V_{CO}$  to go "High" just after the change of  $V_2$ .
- Discharge over-current detection delay time, Release delay time 1 --- [Circuit 6]  
Set  $V_1 = 3.5V$  and  $V_2 = 0V$ . Increase  $V_2$  from  $0V$  to  $1V$  rapidly within  $10\mu s$ . Discharge over-current delay time  $t_{idc}$  is the time needed for  $V_{DO}$  to go "Low" just after the change of  $V_2$ .  
Next, decrease  $V_2$  from  $1V$  to  $0V$  rapidly within  $10\mu s$ . Release delay time 1  $t_{rel1}$  in case of discharge over-current is the time needed for  $V_{DO}$  to go "High" just after the change of  $V_2$ .
- Load short-circuiting detection delay time, Release delay time 1 --- [Circuit 6]  
Set  $V_1 = 3.5V$  and  $V_2 = 0V$ . Increase  $V_2$  from  $0V$  to  $3.5V$  rapidly within  $10\mu s$ . Load short-circuiting detection delay time  $t_{short}$  is the time needed for  $V_{DO}$  to go "Low" just after the change of  $V_2$ .  
Next, decrease  $V_2$  from  $3.5V$  to  $0V$  rapidly within  $10\mu s$ . Release delay time 1  $t_{rel1}$  in case of load short-circuiting is the time needed for  $V_{DO}$  to go "High" just after the change of  $V_2$ .

Measurement Circuits

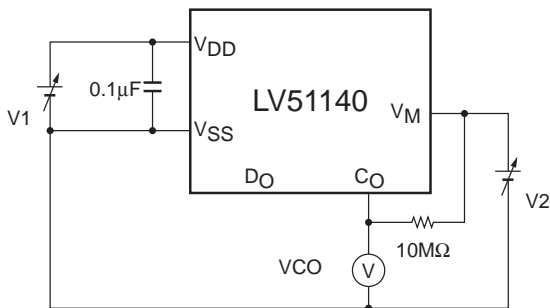
• Circuit 1



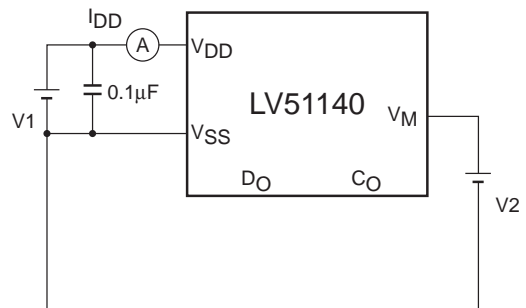
• Circuit 2



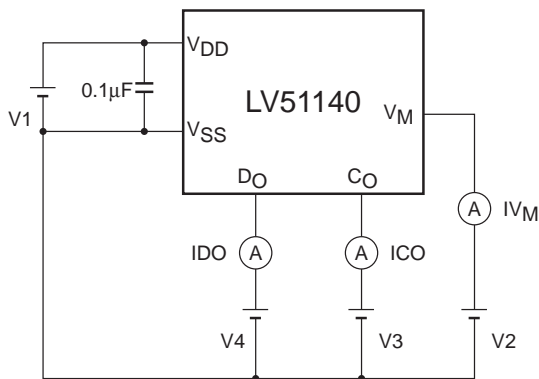
• Circuit 3



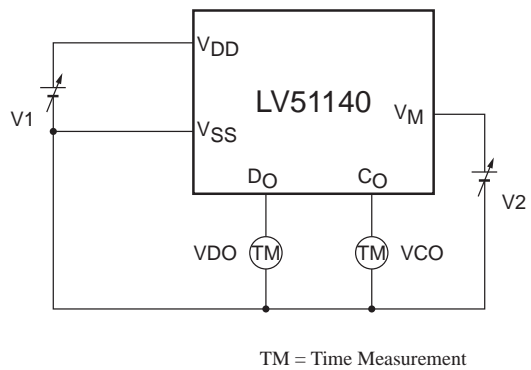
• Circuit 4



• Circuit 5

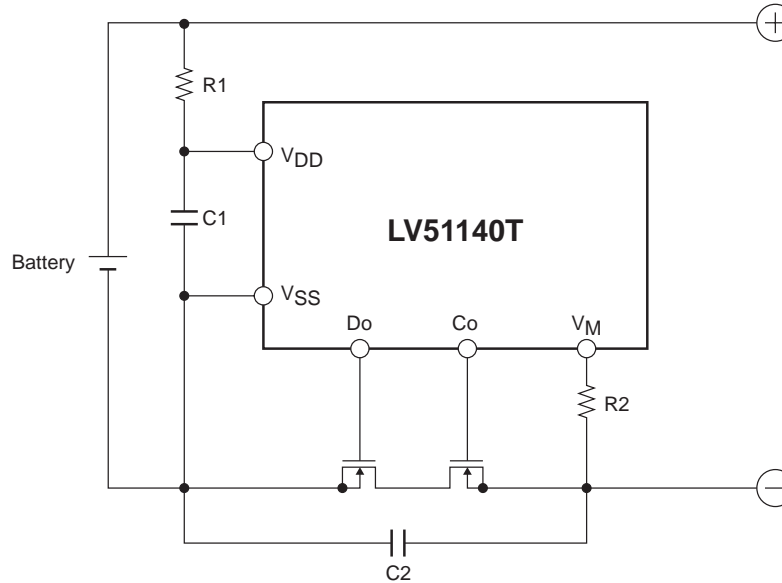


• Circuit 6



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.

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 ( $V_{dc}$ ) to the over-charge detection voltage ( $V_C$ ) and the  $V_M$  terminal voltage is in the range from the charge over-current detection voltage ( $V_{Ic}$ ) to the discharge over-current detection voltage ( $V_{Idc}$ ), 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 ( $V_{Idc}$ ) to the short-circuiting detection voltage ( $V_{short}$ ) and that state is maintained during more than the discharge over-current detection delay time ( $t_{idc}$ ), 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  $V_{short}$  and that state is maintained during more than the load short-circuiting detection delay time ( $t_{short}$ ), 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 ( $R_{dwn}$ ) 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  $V_{Idc}$ , and if that state is maintained during more than the release delay time 1 ( $t_{rel1}$ ), 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  $V_{Idc}$ . The standard is expressed with the following equation.

$$\text{Resistance value for automatic return} = R_{dwn} \times (V_{DD} / V_{Idc} - 1)$$

- 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 ( $V_{Ic}$ ) and that state is maintained during more than the charge over-current detection delay time ( $t_{ic}$ ), 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 equal to or higher than  $V_{Ic}$  and that state is maintained during more than the release delay time 1 ( $t_{rel1}$ ) when the charger is removed and the load is connected, this IC returns to the normal condition.

Note : If the  $V_M$  terminal voltage becomes equal to or less than  $V_{SS}-7V$  (typical), the charge over-current detection delay time ( $t_{ic}$ ) changes as below.

8ms model	→	8ms (not changed)
125ms model	→	7ms (typical)
1.0s model	→	56ms (typical)

- Over-charge detection

When the battery voltage ( $V_{DD}$ ) under the normal condition becomes equal to or higher than the over-charge detection voltage ( $V_C$ ) and that state is maintained during more than the over-charge detection delay time ( $t_c$ ), 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  $V_C-V_{Hc}$  without load and that state is maintained during more than the delay time 2 ( $t_{rel2}$ ), this IC turns on the charge control FET and returns to the normal condition.

\*  $V_{Hc}$  : 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  $V_f$  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 ( $V_{Idc}$ ) and  $V_{DD}$  is equal to or less than  $V_C$ , this IC returns to the normal condition when this state continues more than the delay time 2 ( $t_{rel2}$ ).

(3) In case (2), if the  $V_M$  terminal voltage is higher than the discharge over-current detection voltage ( $V_{Idc}$ ) and  $V_{DD}$  is equal to or higher than  $V_C$ , battery is discharged until  $V_{DD}$  becomes less than  $V_C$ , and then this IC returns to the normal condition when this state continues more than the delay time 2 ( $t_{rel2}$ ).



- Over-discharge detection

When the battery voltage ( $V_{DD}$ ) under the normal condition becomes equal to or less than the over-discharge detection voltage ( $V_{dc}$ ) and that state continues for more than the over-discharge detection time ( $t_{dc}$ ), 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. If the  $V_M$  terminal voltage is higher than the charge over-current detection voltage ( $V_{Ic}$ ), the IC returns to the normal condition when  $V_{DD}$  becomes equal to or higher than  $V_{Rdc}$  and this state continues more than the delay time1 ( $t_{rel1}$ ).

If the  $V_M$  terminal voltage is lower than the charge over-current detection voltage ( $V_{Ic}$ ), same as the above-mentioned case, the IC returns to the normal condition when  $V_{DD}$  becomes equal to or higher than  $V_{dc}$  and this state continues more than the delay time1 ( $t_{rel1}$ ).

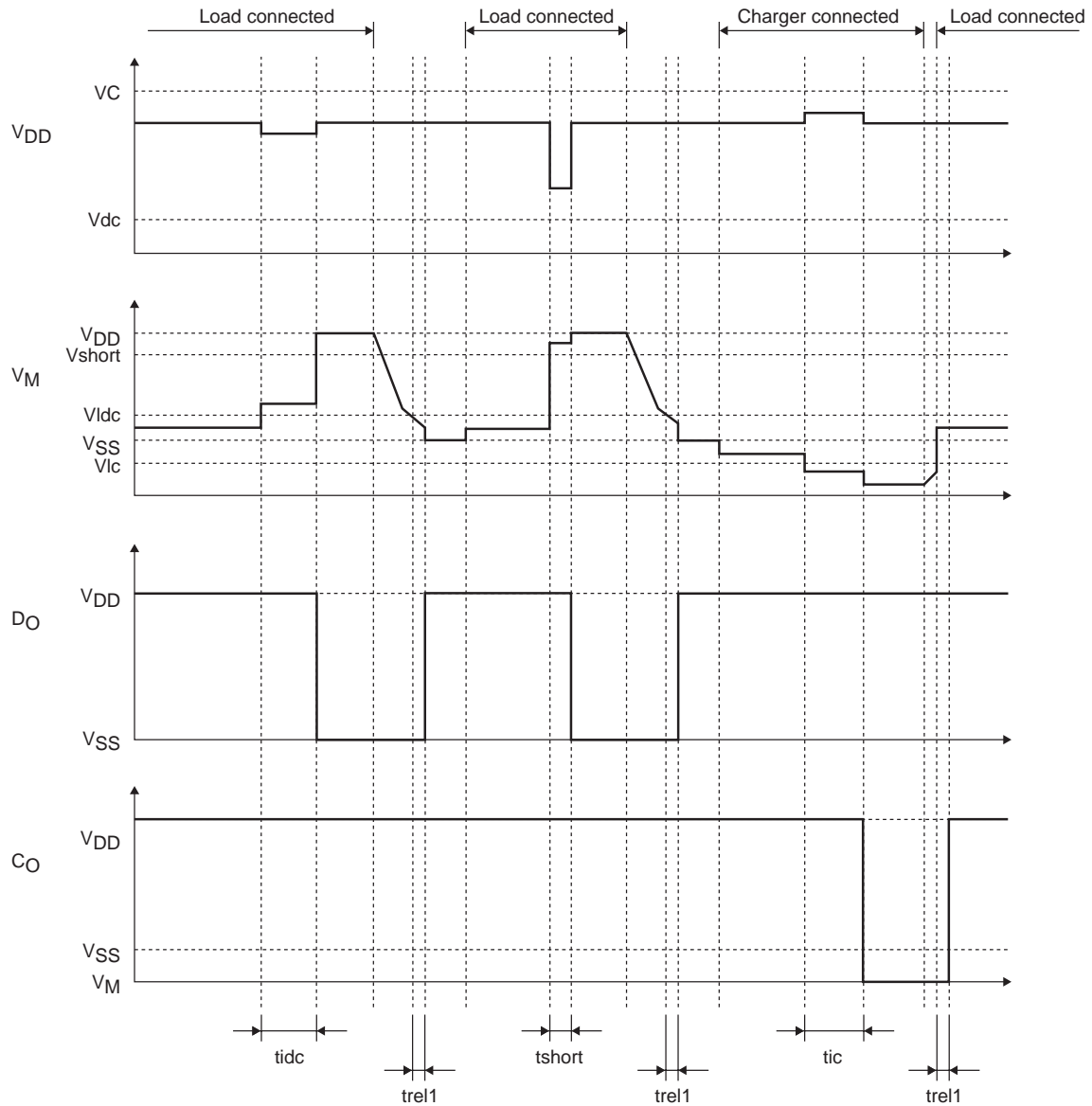
This IC stops all internal circuits (Shutdown condition) after detecting the over-discharge and reduces current consumption. (Max 0.1 $\mu$ A, at  $V_{DD} = 1.8V$ )

- 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 ( $V_{cha}$ ), 0V battery charge becomes possible when CO terminal outputs  $V_{DD}$  terminal potential and turns on the charge control FET.

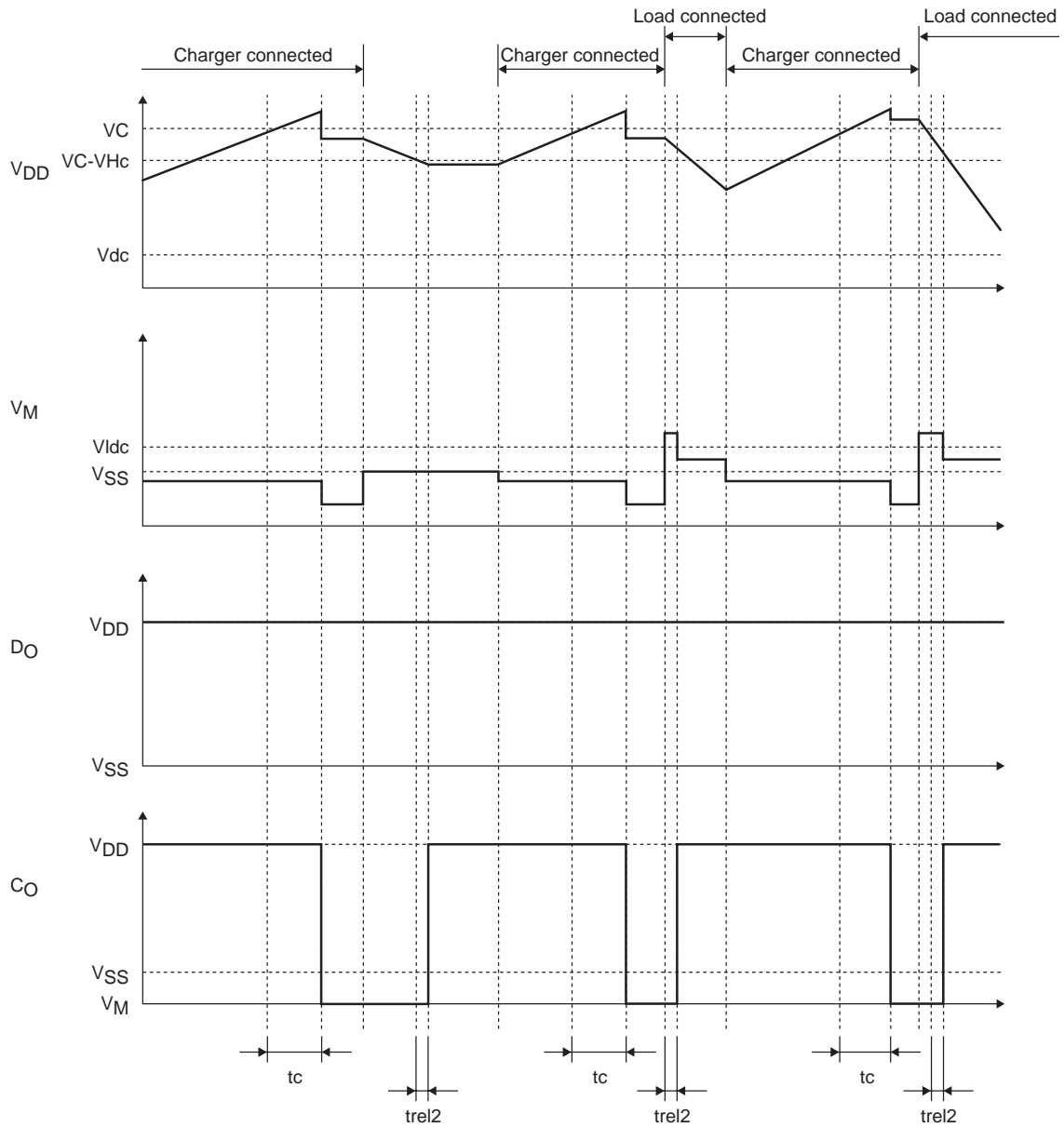
**Timing Chart**

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



- |  |   |
|--|---|
| VC : Over-charge detection voltage               | t <sub>ic</sub> : Charge over-current detection delay time      |
| Vdc : Over-discharge detection voltage           | t <sub>idc</sub> : Discharge over-current detection delay time  |
| Vlc : Charge over-current detection voltage      | t <sub>short</sub> : Load short-circuiting detection delay time |
| Vldc : Discharge over-current detection voltage  | t <sub>rel1</sub> : Release delay time 1                        |
| Vshort : Load short-circuiting detection voltage |   |

• Over-charge detection

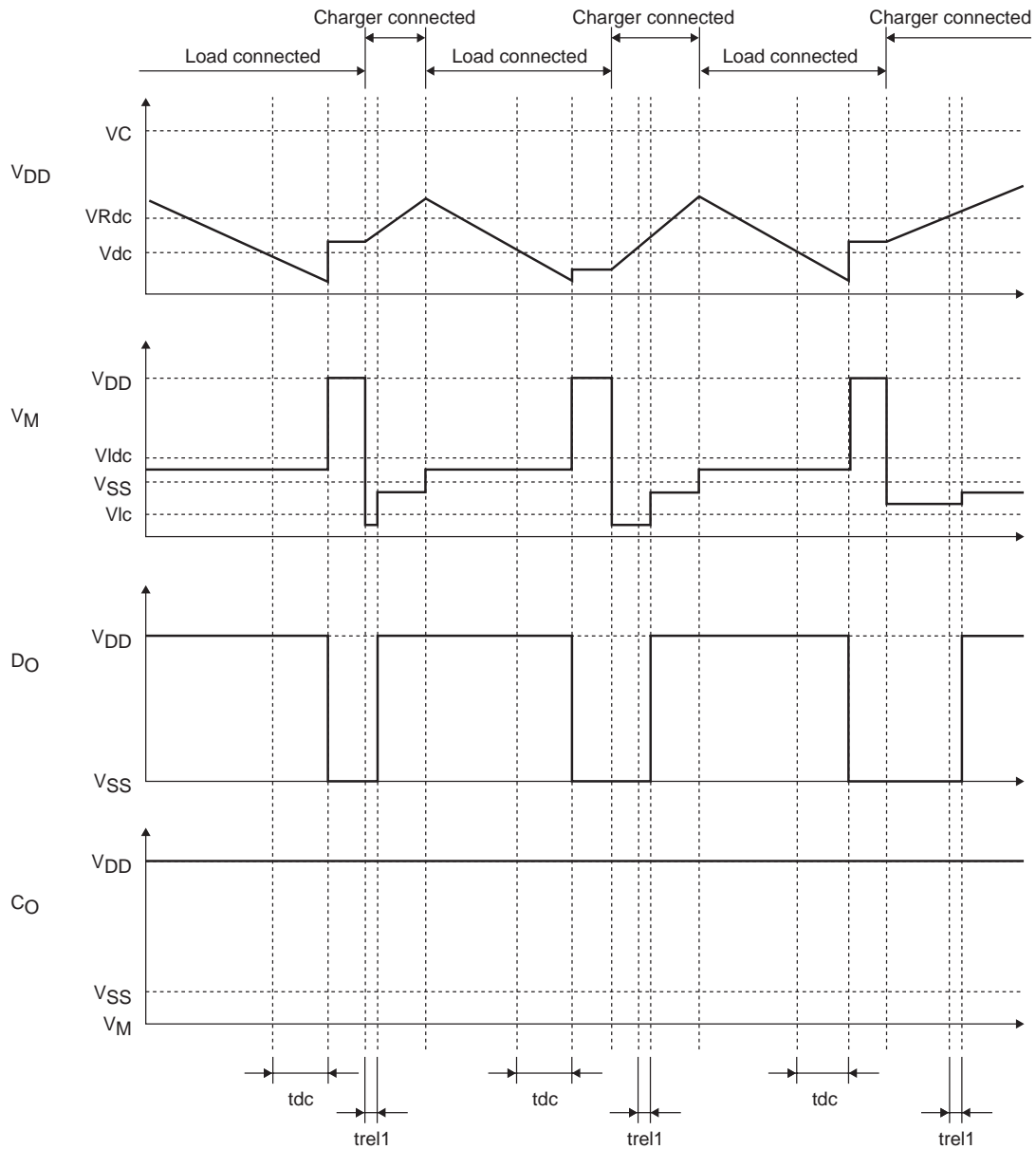


$V_C$  : Over-charge detection voltage  
 $V_{dc}$  : Over-discharge detection voltage  
 $V_{Hc}$  : Over-charge hysteresis voltage  
 $V_{dc}$  : Discharge over-current detection voltage

$t_c$  : Over-charge detection delay time  
 $t_{rel2}$  : Release delay time 2

# LV51140T

## • Over-discharge detection



VC : Over-charge detection voltage  
 VdC : Over-discharge detection voltage  
 VRdc : Return from over-discharge voltage  
 Vic : Charge over-current detection voltage  
 Vidc : Discharge over-current detection voltage

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

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