# DIO7111
# True Monolithic Li-Ion/Polymer Battery Protector in Tiny Thin Package

## Features

- Ultra Compact Protection Solution
- 56mΩ Pass Resistance
- 1.3μA Operation Current
- Factory Programmable OVP Threshold Options
  4.2V to 4.55V with 0.05V per Step
- Over-Charge/Discharge Current Protection
  4 Threshold Combination Options
- Battery Under-Voltage Protection
  2.4V/2.5V/2.8V/3.0V Options
- 100nA Deep Discharging Shutdown
- 0V Battery Charge Function
- With High Efficiency Charging Mode
- Input Surge Clamping
- Input Over-Voltage Safe
- Load Short-Circuit Safe
- Reverse Polarity Battery Safe
- Input Reversed-Attaching Safe
- Available in Green DFN2*2-6 Package

## Applications

- Wireless Chargers
- Portable Equipment
- Communication Systems

## Descriptions

The DIO7111 is designed for primary protection of Li-Ion/Polymer rechargeable cells. The product integrates all the protections required for safe operation of polymer rechargeable cells. The device is packaged in a tiny and thin package. Its small solution size leaves more space for fitting the battery cell into a given cavity for small size wearable devices.

The DIO7111 integrates all the protections and the required low on-resistance disconnect switch on one die. The protection features include charging and discharging protection, detection and protection of a cell in over-charging, over-discharging, over-current, and battery under-voltage. The low standby current drains little current from cell while in storage.

The DIO7111 operates in -40°C to 85°C temperature range, and is in a thin and low profile DFN2*2-6 package. This package is convenient for small cell packing design.

## Typical Applications

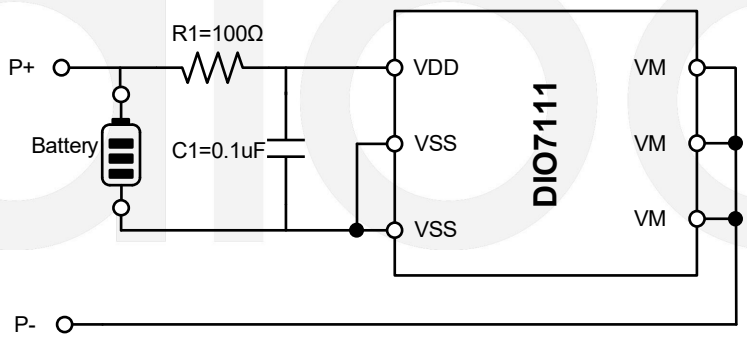



**Figure 1. Typical Application Circuit**

# Ordering Information

| Order Part Number | Top Marking | | $T_A$ | Package | |
|---|---|---|---|---|---|
| DIO7111aaabcDN6 | LXbc | Green | -40 to 85°C | DFN2*2-6 | Tape & Reel, 3000 |

| **Order Part Number: DIO7111aaabcDN6** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Over Voltage Threshold Options** | | | | | | | | |
| Option Code "**aaa**" | **420** | **425** | **430** | **435** | **440** | **445** | **450** | **455** |
| Over Voltage Threshold $V_{OV}$ (V) | 4.20 | 4.25 | 4.30 | 4.35 | 4.40 | 4.45 | 4.50 | 4.55 |
| **Under Voltage Threshold Options** | | | | | | | | |
| Option Code "**b**" | **A** | | **B** | | **C** | | **D** | |
| Under Voltage Threshold $V_{UV}$ (V) | 2.4 | | 2.5 | | 2.8 | | 3.0 | |
| **Current Threshold Combination Options** | | | | | | | | |
| Option Code "**c**" | **A** | | **B** | | **C** | | **D** | |
| Over Charge Current $I_{OC}$ (A) | 1.20 | | 0.59 | | 1.20 | | 0.59 | |
| Over Discharge Current $I_{OD}$ (A) | 1.33 | | 1.33 | | 0.66 | | 0.66 | |
| Short Circuit Current (A) | 2.68 | | 2.68 | | 1.96 | | 1.96 | |

| **Marking Definition: LXbc** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Product code** | | | | | | | | |
| Option Code "**L**" | Product code | | | | | | | |
| **Over Voltage Threshold Options** | | | | | | | | |
| Option Code "**X**" | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| Over Voltage Threshold $V_{OV}$ (V) | 4.20 | 4.25 | 4.30 | 4.35 | 4.40 | 4.45 | 4.50 | 4.55 |
| **Under Voltage Threshold Options** | | | | | | | | |
| Option Code "**b**" | **A** | | **B** | | **C** | | **D** | |
| Under Voltage Threshold $V_{UV}$ (V) | 2.4 | | 2.5 | | 2.8 | | 3.0 | |

| Current Threshold Combination Options | | | | |
|---|---|---|---|---|
| Option Code "**c**" | **A** | **B** | **C** | **D** |
| Over Charge Current $I_{OC}$ (A) | 1.20 | 0.59 | 1.20 | 0.59 |
| Over Discharge Current $I_{OD}$ (A) | 1.33 | 1.33 | 0.66 | 0.66 |
| Short Circuit Current (A) | 2.68 | 2.68 | 1.96 | 1.96 |

## Pin Assignment

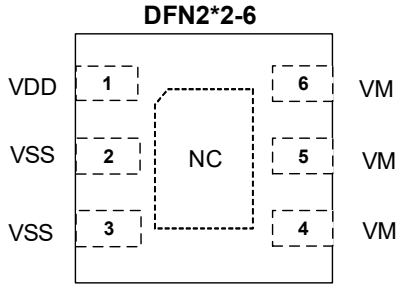



**Figure 2. Pin Assignment (Top View)**

## Pin Descriptions

| Pin | Name | Type | Description |
|---|---|---|---|
| 1 | VDD | P | Power input and output, the battery pack positive connection. The default sate after battery attached is Closed or locked-off, dependent on the external circuitry. |
| 2,3 | VSS | G | Ground of internal circuit. Connect to battery cathode end. |
| 4,5,6 | VM | P | Power input and output, the battery pack cathode. Short this pin to the VSS pin to release off the lock-open state, and make the output path closed. |
| Thermal Pad | NC | NC | Not connected internally. Can be connected to VSS. |

## Absolute Maximum Ratings

Stresses beyond those listed under “Absolute Maximum Rating” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| Supply Voltage | $V_{DD}$ | -0.3 to 8 | V |
| $V_M$ Pin Input Voltage | $V_M$ | $V_{DD}$−10 to $V_{DD}$+0.3 | V |
| Supply Voltage to VM Pin Voltage | $V_{DD}$-$V_M$ | -0.3 to 10 | V |
| Power Consumption at $T_A$=25℃ | $P_d$ | 400 | mW |
| Operating Temperature Range | $T_A$ | -40 to 85 | ℃ |
| Storage Temperature Range | $T_{STG}$ | -55 to 125 | ℃ |
| Maximum Junction Temperature | $T_J$ | 125 | ℃ |
| Lead temperature （Soldering, 10 sec） | $T_L$ | 260 | ℃ |
| Package thermal resistance (junction to ambient) | $\Theta_{JA}$ | 240 | ℃/W |
| ESD Susceptibility | HBM | 6000 | V |

## Recommend Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended Operating conditions are specified to ensure optimal performance to the datasheet specifications. DIOO does not Recommend exceeding them or designing to Absolute Maximum Ratings.

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| Battery Voltage Range | $V_{DD}$-$V_{SS}$ | 0 to 5.5 | V |
| VM Voltage Range | $V_{DD}$-$V_M$ | $V_{DD}$-5 to $V_{DD}$+0.3 | V |
| Operating Temperature Range | $T_A$ | -40 to 85 | ℃ |

## Electrical Characteristics

$T_A$ = 25°C, $V_{BAT}$ = 3.6V, unless otherwise noted. Specifications subject to change without notice.

| Parameter | Symbol | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Over-Charge Voltage Threshold | $V_{OV}$ | DIO7111-420_ _ | $T_A$=25°C | 4.165 | 4.200 | 4.235 | V |
| | | | $T_A$=-20°C to 55°C | 4.152 | | 4.248 | |
| | | | $T_A$=-40°C to 85°C | 4.100 | | 4.300 | |
| | | DIO7111-425_ _ | $T_A$=25°C | 4.215 | 4.250 | 4.285 | |
| | | | $T_A$=-20°C to 55°C | 4.202 | | 4.298 | |
| | | | $T_A$=-40°C to 85°C | 4.150 | | 4.350 | |
| | | DIO7111-430_ _ | $T_A$=25°C | 4.265 | 4.300 | 4.335 | |
| | | | $T_A$=-20°C to 55°C | 4.252 | | 4.348 | |
| | | | $T_A$=-40°C to 85°C | 4.200 | | 4.400 | |
| | | DIO7111-435_ _ | $T_A$=25°C | 4.315 | 4.350 | 4.385 | |
| | | | $T_A$=-20°C to 55°C | 4.302 | | 4.398 | |
| | | | $T_A$=-40°C to 85°C | 4.250 | | 4.450 | |
| | | DIO7111-440_ _ | $T_A$=25°C | 4.365 | 4.400 | 4.435 | |
| | | | $T_A$=-20°C to 55°C | 4.352 | | 4.448 | |
| | | | $T_A$=-40°C to 85°C | 4.300 | | 4.500 | |
| | | DIO7111-445_ _ | $T_A$=25°C | 4.415 | 4.450 | 4.485 | |
| | | | $T_A$=-20°C to 55°C | 4.402 | | 4.498 | |
| | | | $T_A$=-40°C to 85°C | 4.350 | | 4.550 | |
| | | DIO7111-450_ _ | $T_A$=25°C | 4.465 | 4.500 | 4.535 | |
| | | | $T_A$=-20°C to 55°C | 5.452 | | 4.548 | |
| | | | $T_A$=-40°C to 85°C | 4.400 | | 4.600 | |
| | | DIO7111-455_ _ | $T_A$=25°C | 4.515 | 4.550 | 4.585 | |
| | | | $T_A$=-20°C to 55°C | 4.502 | | 4.598 | |
| | | | $T_A$=-40°C to 85°C | 4.450 | | 4.650 | |
| OV Release Hysteresis | $V_{OVHYS}$ | Voltage lower than the battery voltage | | | 200 | | mV |
| Battery Under Voltage Threshold | $V_{UV}$ | DIO7111-_ _ _A_ | $T_A$=25°C | 2.362 | 2.400 | 2.438 | V |
| | | | $T_A$=-20°C to 55°C | 2.350 | | 2.450 | |
| | | | $T_A$=-40°C to 85°C | 2.290 | | 2.510 | |
| | | DIO7111-_ _ _B_ | $T_A$=25°C | 2.462 | 2.500 | 2.538 | |
| | | | $T_A$=-20°C to 55°C | 2.450 | | 2.550 | |
| | | | $T_A$=-40°C to 85°C | 2.390 | | 2.610 | |
| | | DIO7111-_ _ _C_ | $T_A$=25°C | 2.762 | 2.800 | 2.838 | |
| | | | $T_A$=-20°C to 55°C | 2.750 | | 2.850 | |
| | | | $T_A$=-40°C to 85°C | 2.690 | | 2.910 | |
| | | DIO7111-_ _ _D_ | $T_A$=25°C | 2.962 | 3.000 | 3.038 | |
| | | | $T_A$=-20°C to 55°C | 2.950 | | 3.050 | |
| | | | $T_A$=-40°C to 85°C | 2.890 | | 3.110 | |
| UV Release Hysteresis | $V_{UVHYS}$ | | | | 100 | | mV |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Over-Discharge Current | $I_{OD}$ | DIO7111-_ _ _ _ C | $T_A$=25°C | 0.50 | 0.66 | 0.82 | A |
| | | -_ _ _ _ D | $T_A$=-20°C to 55°C | 0.43 | | 0.94 | |
| | | DIO7111-_ _ _ _ A | $T_A$=25°C | 1.00 | 1.33 | 1.66 | |
| | | -_ _ _ _ B | $T_A$=-20°C to 55°C | 0.85 | | 1.91 | |
| Over-Charge Current | $I_{OC}$ | DIO7111-_ _ _ _ B | $T_A$=25°C | 0.36 | 0.59 | 0.82 | A |
| | | -_ _ _ _ D | $T_A$=-20°C to 55°C | 0.27 | | 1.02 | |
| | | DIO7111-_ _ _ _ A | $T_A$=25°C | 0.74 | 1.20 | 1.66 | |
| | | -_ _ _ _ C | $T_A$=-20°C to 55°C | 0.56 | | 2.08 | |
| Pass Resistance | $R_P$ | $T_A$=25°C | | | 56 | 64 | mΩ |
| | | $T_A$=-20°C to 55°C | | | | 78 | |
| Operating Current | $I_{OP}$ | $T_A$=25°C | | | 1.3 | 1.8 | uA |
| | | $T_A$=-20°C to 55°C | | | | 2.8 | |
| Shutdown Current | $I_{SHDN}$ | | | | | 0.1 | uA |
| Over-Voltage Detection Delay | $t_{OVPD}$ | | | | 160 | | ms |
| Under-Voltage Detection Delay | $t_{UVPD}$ | | | | 40 | | ms |
| Over-Discharge Current Detection Delay | $t_{ODD}$ | | | | 10 | | ms |
| Over-Charge Current Detection Delay | $t_{OCD}$ | | | | 10 | | ms |
| Discharge Short-Circuit Detection Delay | $t_{OCSD}$ | | | | 0.2 | | ms |
| Discharge Short-Circuit Current | $I_{SC}$ | DIO7111-_ _ _ _ A | | | 2x $I_{OD}$ | | A |
| | | -_ _ _ _ B | | | | | |
| | | DIO7111-_ _ _ _ C | | | 3x $I_{OD}$ | | |
| | | -_ _ _ _ D | | | | | |
| Over Temperature Pretection | $T_{OTP}$ | | | | 140 | | °C |
| Over Temperature Pretection Hysteresis | $T_{OTPHYS}$ | | | | 20 | | °C |

## Application Information

The DIO7111 monitors voltage and current applied on battery cell connected between VDD and VSS, and opens the connection between battery and pack terminal with its internal switches when a fault condition is detected.

**Normal Condition**

Battery voltage is between the over discharge voltage threshold and over charge voltage threshold, and no overcharge current and over discharge current is detected, charging and discharging can be carried out freely, this condition is called the normal operating condition.

**Over Charge Condition**

When battery voltage reaches over-voltage threshold ($V_{OV}$) and keeps for over-charge detection delay time ($T_{OVPD}$), the charging path is open circuited. The path closes again in the following two cases:

(1) If VM pin's voltage is less than 0.35V (typical), when battery voltage falls back about $V_{OVHYS}$ below the battery voltage, then over charge condition is released.

(2) If VM pin's voltage is above 0.35V (typical), when battery voltage falls back about $V_{OV}$, then over charge condition is released.

**Over Discharge Condition**

In order to protect the battery from over discharging when battery voltage falls below $V_{UV}$, the discharge path is open circuited and the DIO7111 enters into shutdown sleeping mode in order to further reduce the current consumption, which helps to keep the battery from harmful exhausted conditions as long as possible. The path closes again when a charging supply is applied or the battery voltage rises to about 100mV above the $V_{UV}$ threshold.

In the over discharge condition, the battery charges through the internal power MOSFET body diode. All internal circuitry is OFF. Discharge is not allowed. When battery voltage rises above under-voltage threshold, the chip enters normal operation and charge and discharge modes are allowed.

**Over-discharge Current Condition**

When over-discharging current condition occurs and keeps for over-discharge current detection delay ($T_{OD}$), the discharging path opens, and the VM pin is shorted to VSS through internal resistance. The path closes again by load removed or connecting a charger.

**Over-charge Current Condition**

During a charging condition, if charging current is above 400mA and keeps for 10ms (typical) delay, DIO7111 enters into High Efficiency Charging Mode, and when the charging current increase further, an over-charging current is identified, the DIO7111 enters into the locked-off state. This state can be reset by charger removal (pack removal).

**Short-circuit protection**

When discharge current exceeds 3 times (DIO7111_ _ _ _ C/D) or 2 times (DIO7111_ _ _ _A/B) of the over-current threshold, discharging path disconnects instantly in $t_{OCSD}$ , in order to protect the battery from

potential over current stress. After this disconnection, the DIO7111 stays in the locked-off non-conducting state until being reactivated.

**0V Battery Charge Function**

This function is used to recharge the connected battery whose voltage is 0V due to the self-discharge. When the 0V battery charge starting charger voltage or higher is applied between VDD and VM Pins by connecting a charger, In this state the battery charges through the internal power MOSFET body diode. When the battery voltage rises to about 100mV above the Over-discharge Detection Voltage ($V_{UV}$), the IC enters the normal condition.

**Pack activation**

In order to release the pack from lock-off state and to place it into a conducting state, apply a charging input or connect VM to VSS momentarily.

**Select Protection Parameters**

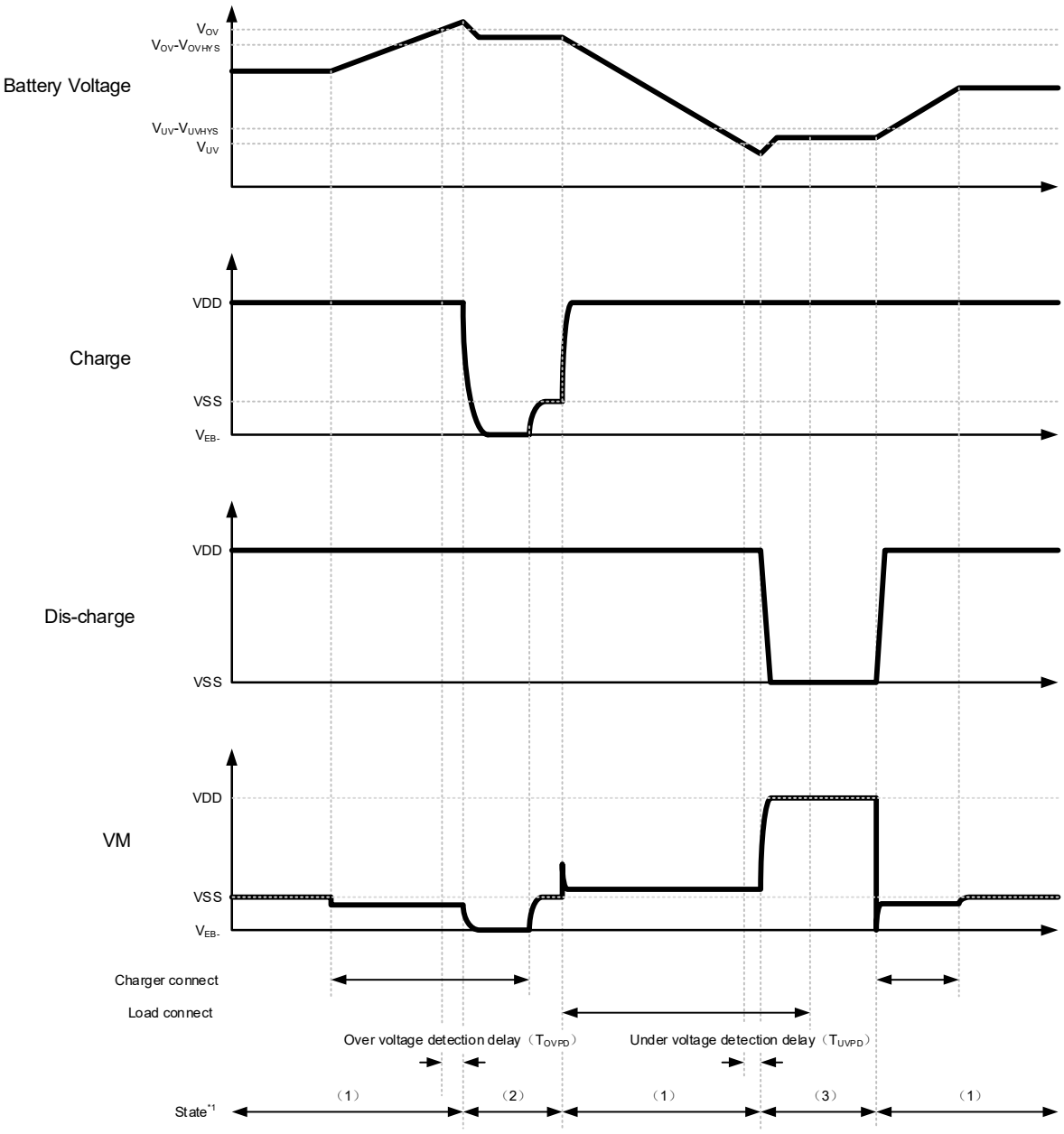
Battery models from different vendors may be customized for different applications. Consult the battery vendor for protection limits for specific battery model. Parameters for the protection circuit and of the charger circuit affecting same variables should be set for proper charge or discharge protection sequence. For example, the over-voltage threshold of the battery should be 50mV~100mV higher than constant voltage threshold of the charger.

**Cautions on parameter misalignment**

If the $V_{OV}$ is lower than the battery charger's full of charge voltage, the protection circuit cuts off the battery charge path before the battery is fully charged, and turns into the non-conductive lock-off state; if the $I_{OC}$ is lower than the charger's charge current, the protection circuit also turns itself into the lock-off state. In either $V_{OV}$ or $I_{OC}$, the charger input should be removed and then re-applied for activating the protection circuit from the lock-off state to the conducting state. If the charger is not removed after a $V_{OV}$ or $I_{OV}$ event, the battery will not be charged even if the battery voltage depletes.

# Operation Timing Chart

## 1. Over-charge and over-discharge detection:

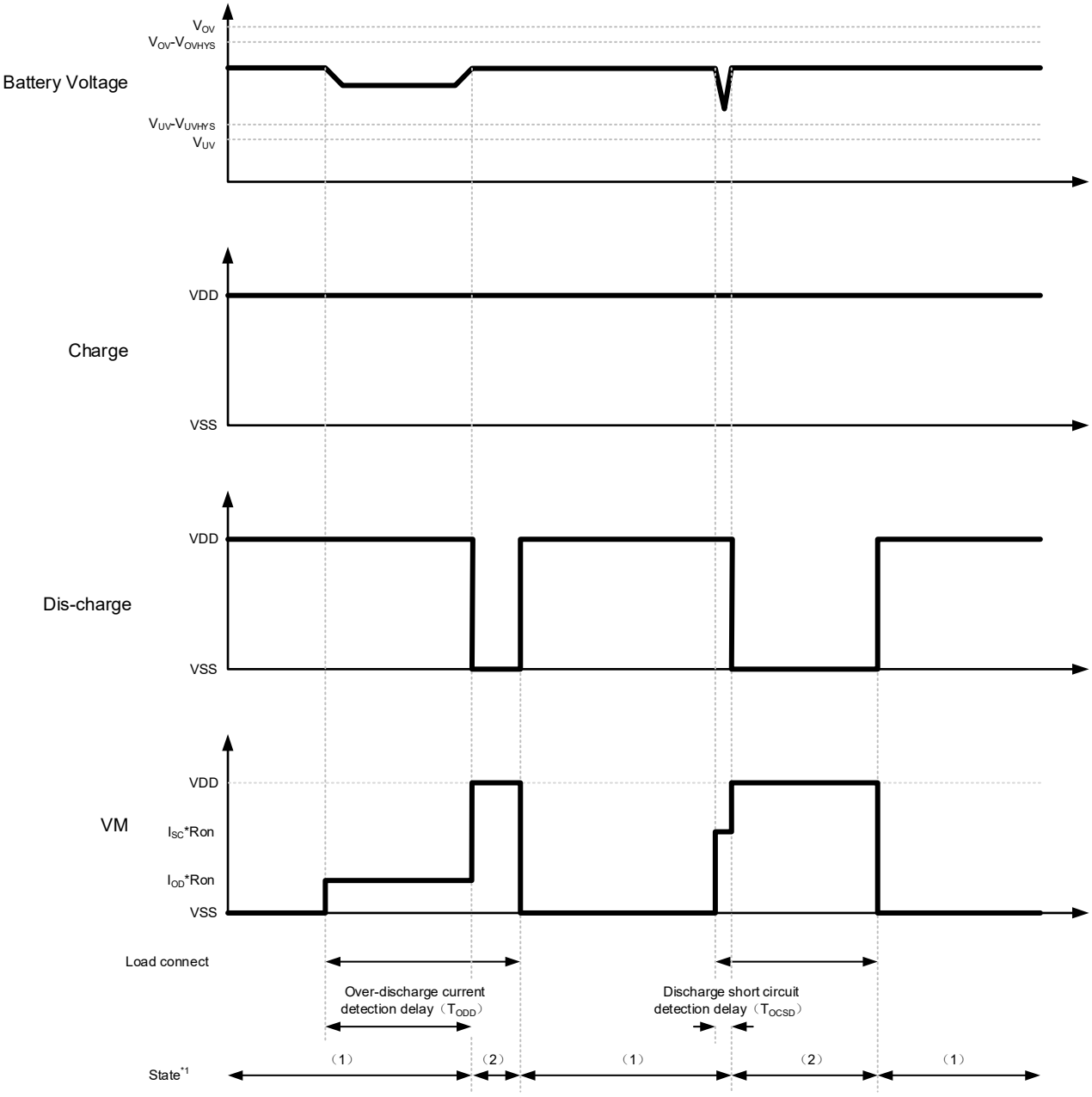



*1. （1）normal condition
（2）over voltage condition
（3）under voltage condition

Note：assume charging with constant current

**Figure 3**

**2. Over-discharge current detection:**

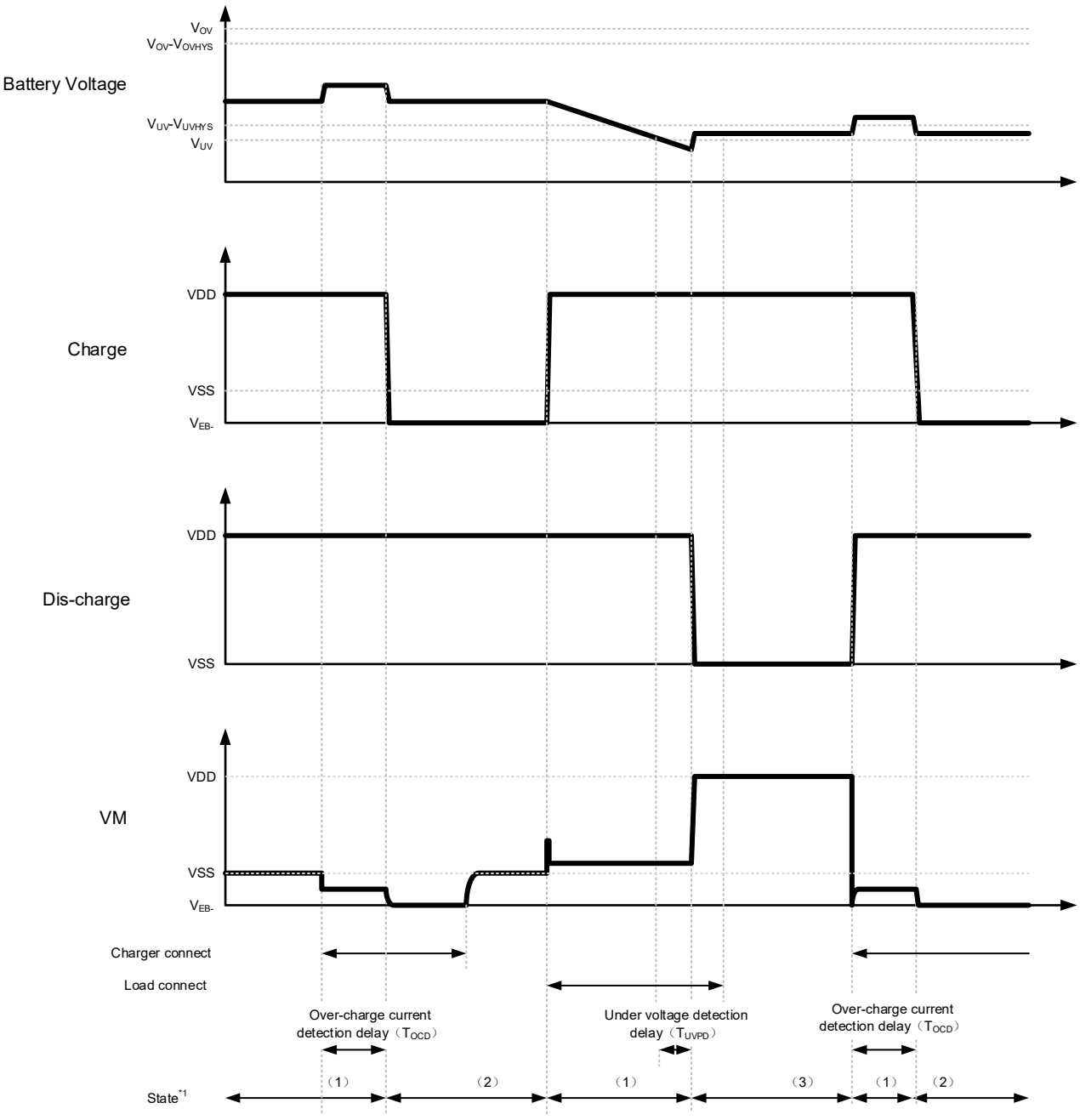



*1.（1）normal condition
（2）over-discharge current condition

Note：assume charging with constant current

**Figure 4**

### 3. Over-charge current detection:




*1. (1) normal condition
(2) over-charge current condition
(3) under voltage condition

Note: assume charging with constant current

**Figure 5**

## CONTACT US

Dioo is a professional design and sales corporation for high-quality and performance analog semiconductors. The company focuses on industry markets, such as, cell phone, handheld products, laptop, and medical equipment and so on. Dioo's product families include analog signal processing and amplifying, LED drivers and charger IC. Go to http://www.dioo.com for a complete list of Dioo product families.

For additional product information, or full datasheet, please contact with our Sales Department or Representatives.