

# μPD166020T1F

## MOS INTEGRATED CIRCUIT

R07DS0441EJ0100

Rev.1.00

Aug 15, 2011

### 1. Overview

#### 1.1 Description

The μPD166020T1F is a single N-channel high-side switch with charge pump, diagnostic feedback with load current sense and embedded protection functions.

#### 1.2 Features

- Built-in charge pump
- Low on-state resistance
- Short circuit protection
  - Shutdown by over current detection and over load detection
- Over temperature protection
  - Shutdown with auto-restart on cooling
- Built-in diagnostic function
  - Proportional load current sensing
  - Defined fault signal in case of abnormal load condition
- Under voltage lock out
- Reverse battery protection by self turn on of N-ch MOSFET
- Small multi-chip package: JEDEC 5-pin TO-252 (MSL: 3, profile acc. J-STD-20C)
- AEC Qualified

#### 1.3 Applications

- Light bulb (to 65 W) switching
- Switching of all types of 14 V DC grounded loads, such as LED, inductor, resistor and capacitor
- Replacement for fuse and relay

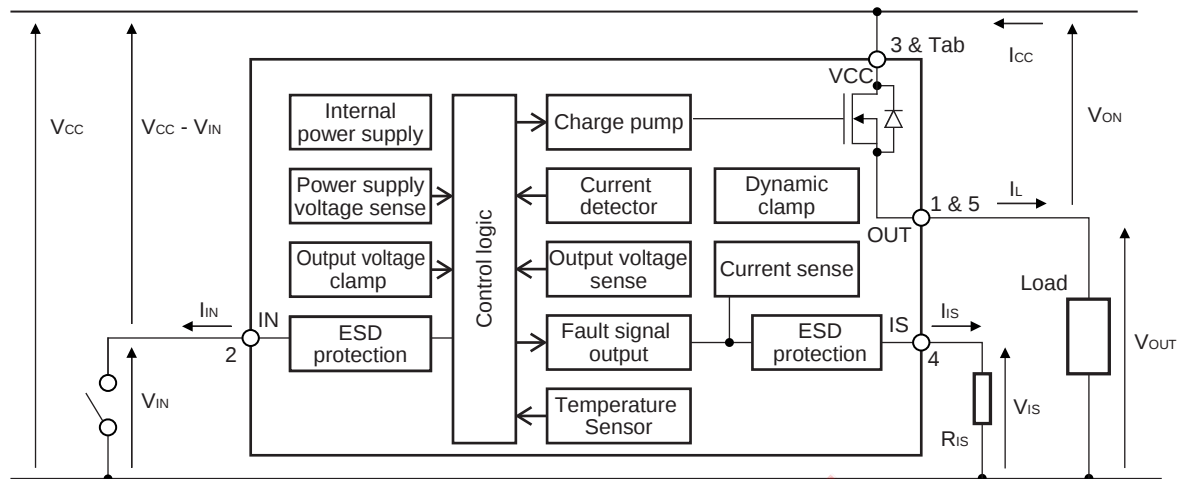
### 2. Ordering Information

| Part No.               | Lead plating | Packing          | Package               |
|------------------------|--------------|------------------|-----------------------|
| μ PD166020T1F-E1-AY *1 | Sn           | Tape 2500 p/reel | 5-pin TO-252 (MP-3ZK) |

Note: \*1. Pb-free (This product does not contain Pb in the external electrode.)

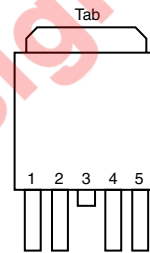
### 3. Specification

#### 3.1 Block Diagram



#### 3.2 Pin Configuration

| Pin No. | Terminal Name |
|---------|---------------|
| 1       | OUT           |
| 2       | IN            |
| 3/Tab   | VCC           |
| 4       | IS            |
| 5       | OUT           |



#### Pin Function

| Terminal Name | Pin function                                         | Recommended connections                                                                                                  |
|---------------|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| OUT           | Output to load                                       | Pin 1 and Pin 5 must be externally shorted                                                                               |
| IN            | Activates the output, if it shorted to ground        | If reverse battery protection feature is used, refer to <b>3.6.3 Power Dissipation Under Reverse Battery Condition</b> . |
| VCC           | Supply Voltage; tab and pin 3 are internally shorted | Connected to battery voltage with small 100 nF capacitor in parallel                                                     |
| IS            | Sense output, diagnostic feedback                    | If current sense and diagnostic feature are not used, connected to GND via resistor                                      |

### 3.3 Absolute Maximum Ratings

$T_A = 25^\circ\text{C}$ , unless otherwise specified

| Parameter                                                  | Symbol          | Rating        | Unit             | Test Conditions                                                                                                                                                                                                |                                                                       |
|------------------------------------------------------------|-----------------|---------------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| $V_{CC}$ Voltage                                           | $V_{CC1}$       | 28            | V                |                                                                                                                                                                                                                |                                                                       |
| $V_{CC}$ voltage under Load Dump condition                 | $V_{CC2}$       | 42            | V                | $R_I = 1\ \Omega$ , $R_L = 1.5\ \Omega$ , $R_{IS} = 1\ \text{k}\Omega$ , $t_d = 400\ \text{ms}$                                                                                                                |                                                                       |
| $V_{CC}$ Voltage at reverse battery condition              | $-V_{CC}$       | -16           | V                | $R_L = 2.2\ \Omega$ , 1 min.                                                                                                                                                                                   |                                                                       |
| Load Current (Short circuit current)                       | $I_{L(SC)}$     | Self limited  | A                |                                                                                                                                                                                                                |                                                                       |
| Power dissipation (DC)                                     | $P_D$           | 1.2           | W                | $T_A = 85^\circ\text{C}$ ,<br>Device on 50 mm x 50 mm x 1.5 mm epoxy PCB FR4 with 6 cm <sup>2</sup> of 70 μm copper area                                                                                       |                                                                       |
| Voltage of IN pin                                          | $V_{IN}$        | $V_{CC} - 28$ | V                | DC                                                                                                                                                                                                             |                                                                       |
|                                                            |                 | $V_{CC} + 14$ |                  | At reverse battery condition, $t < 1\ \text{min}$ .                                                                                                                                                            |                                                                       |
| Voltage of IS pin                                          | $V_{IS}$        | $V_{CC} - 28$ | V                | DC                                                                                                                                                                                                             |                                                                       |
|                                                            |                 | $V_{CC} + 14$ |                  | At reverse battery condition, $t < 1\ \text{min}$ .                                                                                                                                                            |                                                                       |
| Inductive load switch-off energy dissipation single pulse  | $E_{AS1}$       | 50            | mJ               | $V_{CC} = 12\ \text{V}$ , $I_L = 10\ \text{A}$ , $T_{ch, start} \leq 150^\circ\text{C}$<br>refer to <b>3.6.8 Inductive Load Switch Off Energy Dissipation for a Single Pulse</b>                               |                                                                       |
| Maximum allowable energy dissipation at shutdown operation | $E_{AS2}$       | 105           | mJ               | $V_{CC} = 18\ \text{V}$ , $T_{ch, star} \leq 150^\circ\text{C}$ ,<br>$L_{supply} = 5\ \mu\text{H}$ , $L_{short} = 15\ \mu\text{H}$<br>refer to <b>3.6.9 Maximum Allowable Switch off Energy (Single Pulse)</b> |                                                                       |
| Channel Temperature                                        | $T_{ch}$        | -40 to +150   | $^\circ\text{C}$ |                                                                                                                                                                                                                |                                                                       |
| Dynamic temperature increase while switching               | $\Delta T_{ch}$ | 60            | $^\circ\text{C}$ |                                                                                                                                                                                                                |                                                                       |
| Storage Temperature                                        | $T_{stg}$       | -55 to +150   | $^\circ\text{C}$ |                                                                                                                                                                                                                |                                                                       |
| ESD susceptibility                                         | $V_{ESD}$       | 2000          | V                | HBM                                                                                                                                                                                                            | AEC-Q100-002 std.<br>$R = 1.5\ \text{k}\Omega$ , $C = 100\ \text{pF}$ |
|                                                            |                 | 400           | V                | MM                                                                                                                                                                                                             | AEC-Q100-003 std.<br>$R = 0\ \Omega$ , $C = 200\ \text{pF}$           |

### 3.4 Thermal Characteristics

| Parameter               | Symbol         | MIN. | TYP. | MAX. | Unit               | Test Conditions                                                                           |
|-------------------------|----------------|------|------|------|--------------------|-------------------------------------------------------------------------------------------|
| Thermal characteristics | $R_{th(ch-a)}$ |      | 45   |      | $^\circ\text{C/W}$ | Device on 50 mm x 50mm x 1.5 mm epoxy PCB FR4 with 6 cm <sup>2</sup> of 70 μm copper area |
|                         | $R_{th(ch-c)}$ |      |      | 3.17 | $^\circ\text{C/W}$ |                                                                                           |

### 3.5 Electrical Characteristics

#### Operation Function

$T_{ch} = 25^{\circ}\text{C}$ ,  $V_{CC} = 12\text{ V}$ , unless otherwise specified

| Parameter                                            | Symbol        | MIN. | TYP. | MAX. | Unit             | Test Conditions                                                                                                                    |
|------------------------------------------------------|---------------|------|------|------|------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Required current capability of Input switch          | $I_{IH}$      |      | 1.0  | 2.2  | mA               | $T_{ch} = -40$ to $150^{\circ}\text{C}$                                                                                            |
| Input current for turn-off                           | $I_{IL}$      |      |      | 50   | $\mu\text{A}$    |                                                                                                                                    |
| Standby Current                                      | $I_{CC(off)}$ |      | 2.5  | 5.0  | $\mu\text{A}$    | $R_L = 2.2\ \Omega$ , $I_{in} = 0\text{ A}$ , $T_{ch} = 25^{\circ}\text{C}$                                                        |
|                                                      |               |      | 2.5  | 15.0 | $\mu\text{A}$    | $R_L = 2.2\ \Omega$ , $I_{in} = 0\text{ A}$ , $T_{ch} = -40$ to $150^{\circ}\text{C}$                                              |
| On State Resistance                                  | $R_{on}$      |      | 8    | 10   | m $\Omega$       | $I_L = 7.5\text{ A}$ , $T_{ch} = 25^{\circ}\text{C}$                                                                               |
|                                                      |               |      | 14   | 18   |                  | $I_L = 7.5\text{ A}$ , $T_{ch} = 150^{\circ}\text{C}$                                                                              |
| Output voltage drop limitation at small load current | $V_{on(NL)}$  |      | 30   | 65   | mV               | $T_{ch} = -40$ to $150^{\circ}\text{C}$                                                                                            |
| Turn On Time                                         | $t_{on}$      |      | 120  | 360  | $\mu\text{s}$    | $R_L = 2.2\ \Omega$ , $T_{ch} = -40$ to $150^{\circ}\text{C}$ , refer to <b>3.6.6 Measurement Condition</b>                        |
| Turn Off Time                                        | $t_{off}$     |      | 250  | 500  | $\mu\text{s}$    |                                                                                                                                    |
| Slew rate on *1                                      | $dv/dton$     |      | 0.2  | 0.8  | V/ $\mu\text{s}$ | 25 to 50 % $V_{OUT}$ , $R_L = 2.2\ \Omega$ , $T_{ch} = -40$ to $150^{\circ}\text{C}$ , refer to <b>3.6.6 Measurement Condition</b> |
| Slew rate off *1                                     | $-dv/dtoff$   |      | 0.2  | 0.6  | V/ $\mu\text{s}$ | 50 to 25 % $V_{OUT}$ , $R_L = 2.2\ \Omega$ , $T_{ch} = -40$ to $150^{\circ}\text{C}$ , refer to <b>3.6.6 Measurement Condition</b> |

**Note:** \*1. Not tested, specified by design

# Protection Function

$T_{ch} = 25^{\circ}\text{C}$ ,  $V_{CC} = 12\text{ V}$ , unless otherwise specified

| Parameter                                                 | Symbol                              | MIN. | TYP. | MAX. | Unit | Test Conditions                                           |                                                                                |
|-----------------------------------------------------------|-------------------------------------|------|------|------|------|-----------------------------------------------------------|--------------------------------------------------------------------------------|
| On-state resistance at reverse battery conditon *1        | R <sub>on(rev)</sub>                |      | 9.5  | 13   | mΩ   | T <sub>ch</sub> = 25°C                                    | V <sub>CC</sub> = -12 V,<br>I <sub>L</sub> = -7.5 A,<br>R <sub>IS</sub> = 1 kΩ |
|                                                           |                                     |      | 16   | 22   | mΩ   | T <sub>ch</sub> = 150°C                                   |                                                                                |
| Short circuit detection current                           | I <sub>L6,3(SC)</sub> *1            |      | 50   | 120  | A    | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 6 V,<br>V <sub>on</sub> = 3 V              |
|                                                           |                                     |      | 50   |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 20   | 45   |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
|                                                           | I <sub>L6,6(SC)</sub> *1            |      | 35   | 110  |      | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 6 V,<br>V <sub>on</sub> = 6 V              |
|                                                           |                                     |      | 35   |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 10   | 35   |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
|                                                           | I <sub>L12,3(SC)</sub>              |      | 110  | 180  |      | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 12 V,<br>V <sub>on</sub> = 3 V             |
|                                                           |                                     | 76   | 105  |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 50   | 95   |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
|                                                           | I <sub>L12,6(SC)</sub> *1           |      | 90   | 160  |      | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 12 V,<br>V <sub>on</sub> = 6 V             |
|                                                           |                                     |      | 85   |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 40   | 80   |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
|                                                           | I <sub>L12,12(SC)</sub> *1          |      | 55   | 120  |      | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 12 V,<br>V <sub>on</sub> = 12 V            |
|                                                           |                                     |      | 50   |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 10   | 45   |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
|                                                           | I <sub>L18,3(SC)</sub> *1           |      | 130  | 200  |      | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 18 V,<br>V <sub>on</sub> = 3 V             |
|                                                           |                                     |      | 125  |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 60   | 110  |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
|                                                           | I <sub>L18,6(SC)</sub> *1           |      | 110  | 170  |      | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 18 V,<br>V <sub>on</sub> = 6 V             |
|                                                           |                                     |      | 110  |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 50   | 110  |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
|                                                           | I <sub>L18,12(SC)</sub> *1          |      | 75   | 120  |      | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 18 V,<br>V <sub>on</sub> = 12 V            |
|                                                           |                                     |      | 70   |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 30   | 65   |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
|                                                           | I <sub>L18,18(SC)</sub> *1          |      | 50   | 90   |      | T <sub>ch</sub> = -40°C                                   | V <sub>CC</sub> - V <sub>IN</sub> = 18 V,<br>V <sub>on</sub> = 18 V            |
|                                                           |                                     |      | 50   |      |      | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 5    | 45   |      |      | T <sub>ch</sub> = 150°C                                   |                                                                                |
| Turn-on check delay after input current positive slope *1 | t <sub>d(OC)</sub>                  | 0.9  | 2.1  | 3.8  | ms   | T <sub>ch</sub> = -40 to 150°C                            |                                                                                |
| Remaining Turn-on check delay after turn-on time *1       | t <sub>d(OC)</sub> -t <sub>on</sub> | 0.65 | 1.6  |      | ms   | R <sub>L</sub> = 2.2 Ω,<br>T <sub>ch</sub> = -40 to 150°C |                                                                                |
| Over load detection voltage                               | V <sub>on(OvL)</sub>                | 0.65 | 1    | 1.45 | V    | T <sub>ch</sub> = -40 to 150°C                            |                                                                                |
| Under voltage shutdown                                    | V <sub>CIN(Uv)</sub>                |      |      | 5.5  | V    | T <sub>ch</sub> = -40°C                                   |                                                                                |
|                                                           |                                     | 3.2  | 4.0  | 5.35 | V    | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 2.7  |      |      | V    | T <sub>ch</sub> = 150°C                                   |                                                                                |
| Under voltage restart of charge pump                      | V <sub>CIN(CPr)</sub>               |      |      | 6.3  | V    | T <sub>ch</sub> = -40°C                                   |                                                                                |
|                                                           |                                     | 3.6  | 4.5  | 6.2  | V    | T <sub>ch</sub> = 25°C                                    |                                                                                |
|                                                           |                                     | 3.2  |      |      | V    | T <sub>ch</sub> = 150°C                                   |                                                                                |
| Output clamp voltage (inductive load switch off)          | V <sub>on(CL)</sub>                 | 30   | 34   | 40   | V    | I <sub>L</sub> = 40 mA, T <sub>ch</sub> = -40 to 150°C    |                                                                                |
| Thermal shutdown temperature *1                           | T <sub>th</sub>                     | 150  | 175  |      | °C   |                                                           |                                                                                |
| Thermal hysteresis *1                                     | ΔT <sub>th</sub>                    |      | 10   |      | °C   |                                                           |                                                                                |

**Note:** \*1. Not tested, specified by design

# Diagnosis Function

$T_{ch} = 25^{\circ}\text{C}$ ,  $V_{CC} = 12\text{ V}$ , unless otherwise specified

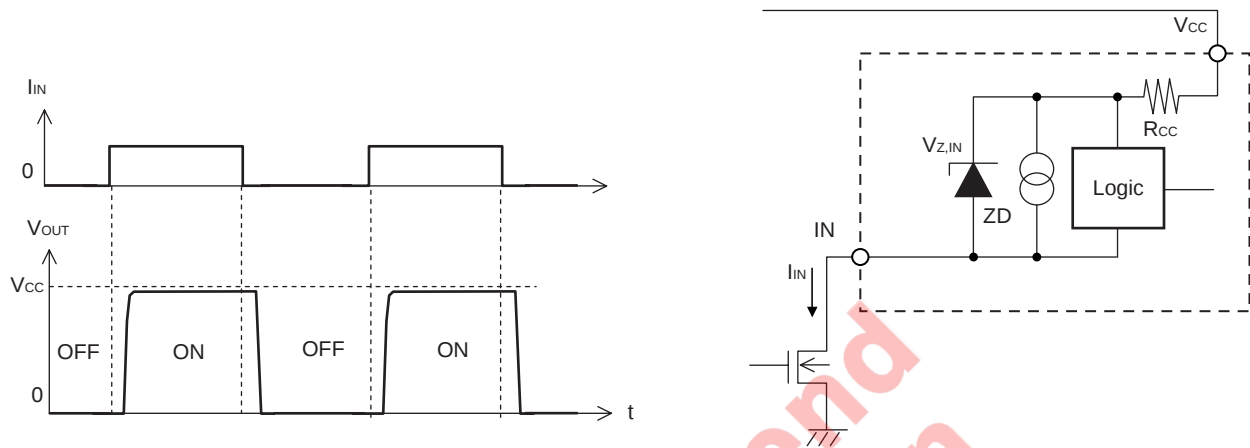
| Parameter                                                                                    | Symbol              | MIN. | TYP.  | MAX.  | Unit | Test Conditions                                                                                                          |
|----------------------------------------------------------------------------------------------|---------------------|------|-------|-------|------|--------------------------------------------------------------------------------------------------------------------------|
| Current sense ratio                                                                          | $K_{ILIS}$          |      |       |       |      | $K_{ILIS} = I_L/I_{IS}$ , $I_{IS} < I_{IS,lim}$                                                                          |
|                                                                                              |                     | 8300 | 9200  | 11000 |      | $T_{ch} = -40^{\circ}\text{C}$                                                                                           |
|                                                                                              |                     | 8300 | 9200  | 10600 |      | $T_{ch} = 25^{\circ}\text{C}$                                                                                            |
|                                                                                              |                     | 8400 | 9300  | 10200 |      | $T_{ch} = 150^{\circ}\text{C}$                                                                                           |
|                                                                                              |                     | 7500 | 9200  | 11400 |      | $T_{ch} = -40^{\circ}\text{C}$                                                                                           |
|                                                                                              |                     | 8000 | 9300  | 10800 |      | $T_{ch} = 25^{\circ}\text{C}$                                                                                            |
|                                                                                              |                     | 8300 | 9300  | 10400 |      | $T_{ch} = 150^{\circ}\text{C}$                                                                                           |
|                                                                                              |                     | 7100 | 10200 | 13400 |      | $T_{ch} = -40^{\circ}\text{C}$                                                                                           |
|                                                                                              |                     | 7700 | 10000 | 12500 |      | $T_{ch} = 25^{\circ}\text{C}$                                                                                            |
|                                                                                              |                     | 8000 | 9800  | 12000 |      | $T_{ch} = 150^{\circ}\text{C}$                                                                                           |
|                                                                                              |                     | 5000 | 12000 | 21000 |      | $T_{ch} = -40^{\circ}\text{C}$                                                                                           |
|                                                                                              |                     | 5500 | 11500 | 17000 |      | $T_{ch} = 25^{\circ}\text{C}$                                                                                            |
|                                                                                              |                     | 6000 | 11500 | 16000 |      | $T_{ch} = 150^{\circ}\text{C}$                                                                                           |
| Sense current offset current                                                                 | $I_{IS,offset}$     |      | 0.1   | 1     | μA   | $V_{IN} = 0\text{ V}$ , $I_L = 0\text{ A}$                                                                               |
| Sense current under fault condition                                                          | $I_{IS,fault}$      | 3.5  | 6.0   | 12.0  | mA   | Under fault conditions<br>$8\text{ V} < V_{CC} - V_{IS} < 12\text{ V}$ ,<br>$T_{ch} = -40\text{ to }150^{\circ}\text{C}$ |
| Sense current saturation current                                                             | $I_{IS,lim}$        | 3.5  | 7.0   | 12.0  | mA   | $V_{IS} < V_{OUT} - 6\text{ V}$ ,<br>$T_{ch} = -40\text{ to }150^{\circ}\text{C}$                                        |
| Fault Sense Signal delay after short circuit detection *1                                    | $t_{sdelay(fault)}$ |      | 2     | 6     | μs   | $T_{ch} = -40\text{ to }150^{\circ}\text{C}$                                                                             |
| Sense current leakage current                                                                | $I_{IS(LL)}$        |      | 0.1   | 0.5   | μA   | $I_{IN} = 0\text{ A}$                                                                                                    |
| Current sense settling time to $I_{IS}(\text{static})$ after input current positive slope *1 | $t_{son(IS)}$       |      |       | 700   | μs   | $T_{ch} = -40\text{ to }150^{\circ}\text{C}$ ,<br>$I_{IN} = 0\text{ A}$ $\square$ $I_{IH}$ ,<br>$R_L = 2.2\ \Omega$      |
| Current sense settling time during on condition *1                                           | $T_{sic(IS)}$       |      | 50    | 100   | μs   | $T_{ch} = -40\text{ to }150^{\circ}\text{C}$ ,<br>$I_L = 10\text{ A}$ $\square$ $20\text{ A}$                            |

**Note:** \*1. Not tested, specified by design

### 3.6 Feature Description

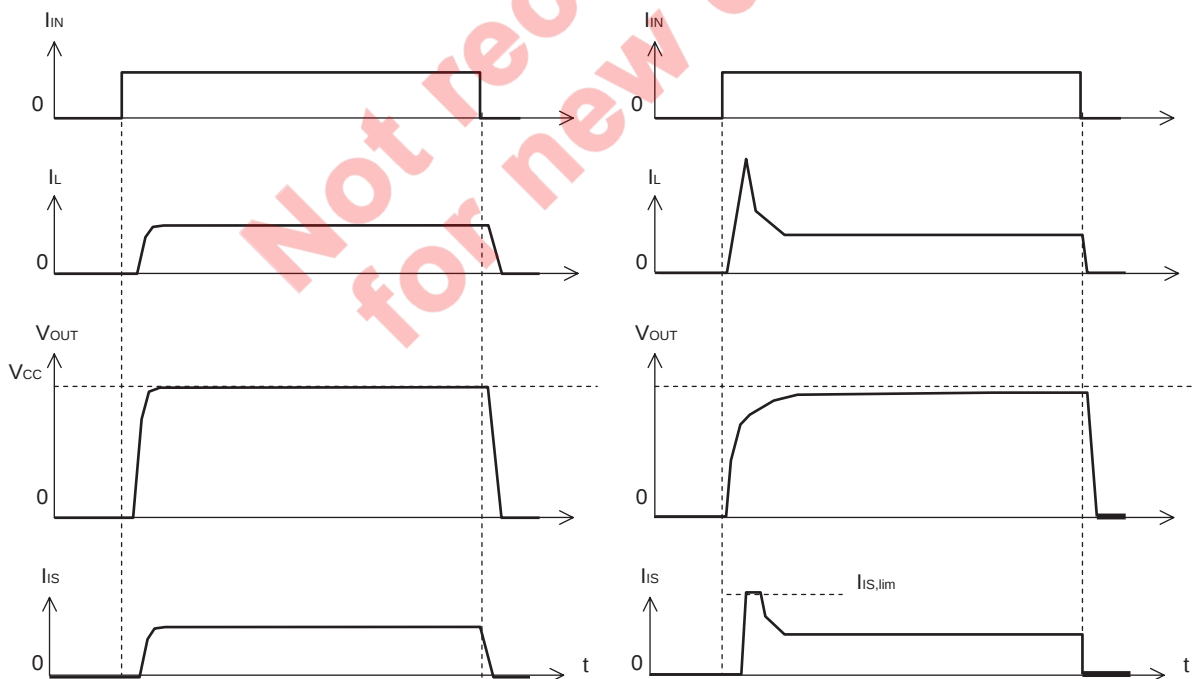
#### 3.6.1 Driving Circuit

The high-side output is turned on, if the input pin is shorted to ground. The input current is below  $I_{IH}$ . The high-side output is turned off, if the input pin is open or the input current is below  $I_{IL}$ .  $R_{CC}$  is 100  $\Omega$  TYP. ESD protection diode: 46 V TYP.

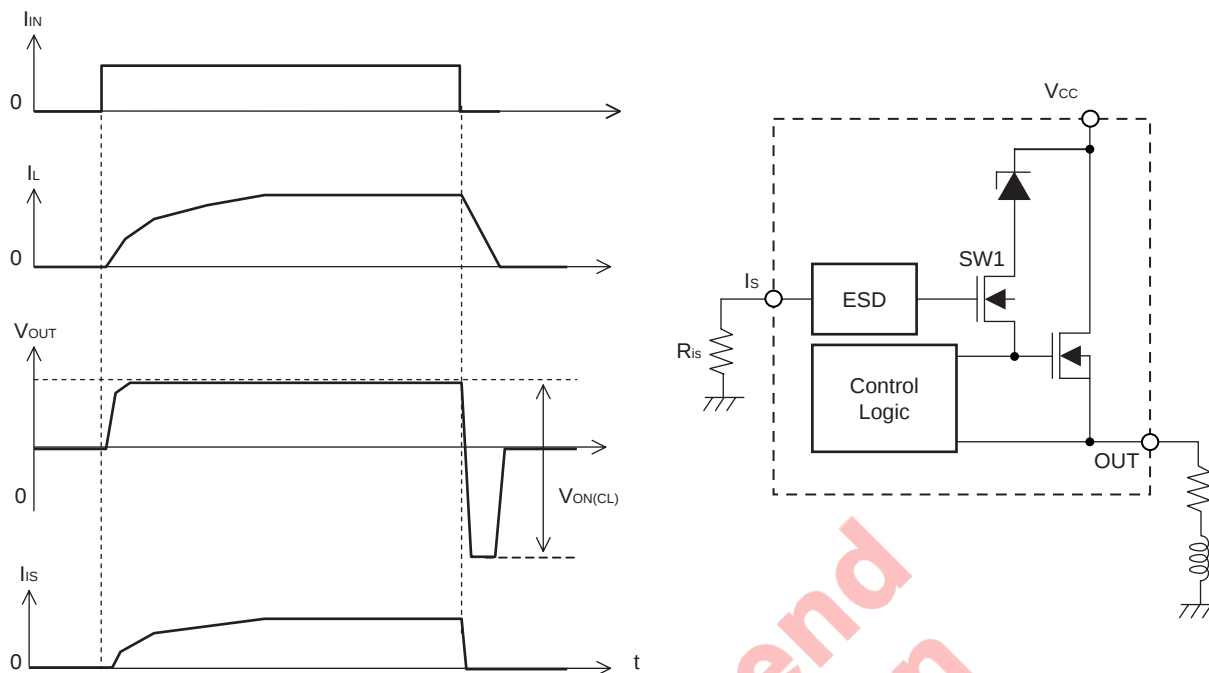


Switching a resistive load

Switching lamps



## Switching an inductive load

**Dynamic clamp operation at inductive load switch off**

The dynamic clamp circuit works only when the inductive load is switched off. When the inductive load is switched off, the voltage of  $OUT$  falls below 0 V. The gate voltage of  $SW1$  is then nearly equal to GND because the  $IS$  terminal is connected to GND via an external resistor. Next, the voltage at the source of  $SW1$  (= gate of output MOS) falls below the GND voltage.  $SW1$  is turned on, and the clamp diode is connected to the gate of the output MOS, activating the dynamic clamp circuit.

When the over-voltage is applied to  $V_{CC}$ , the gate voltage and source voltage of  $SW1$  are both nearly equal to GND.  $SW1$  is not turned on, the clamp diode is not connected to the gate of the output MOS, and the dynamic clamp circuit is not activated.

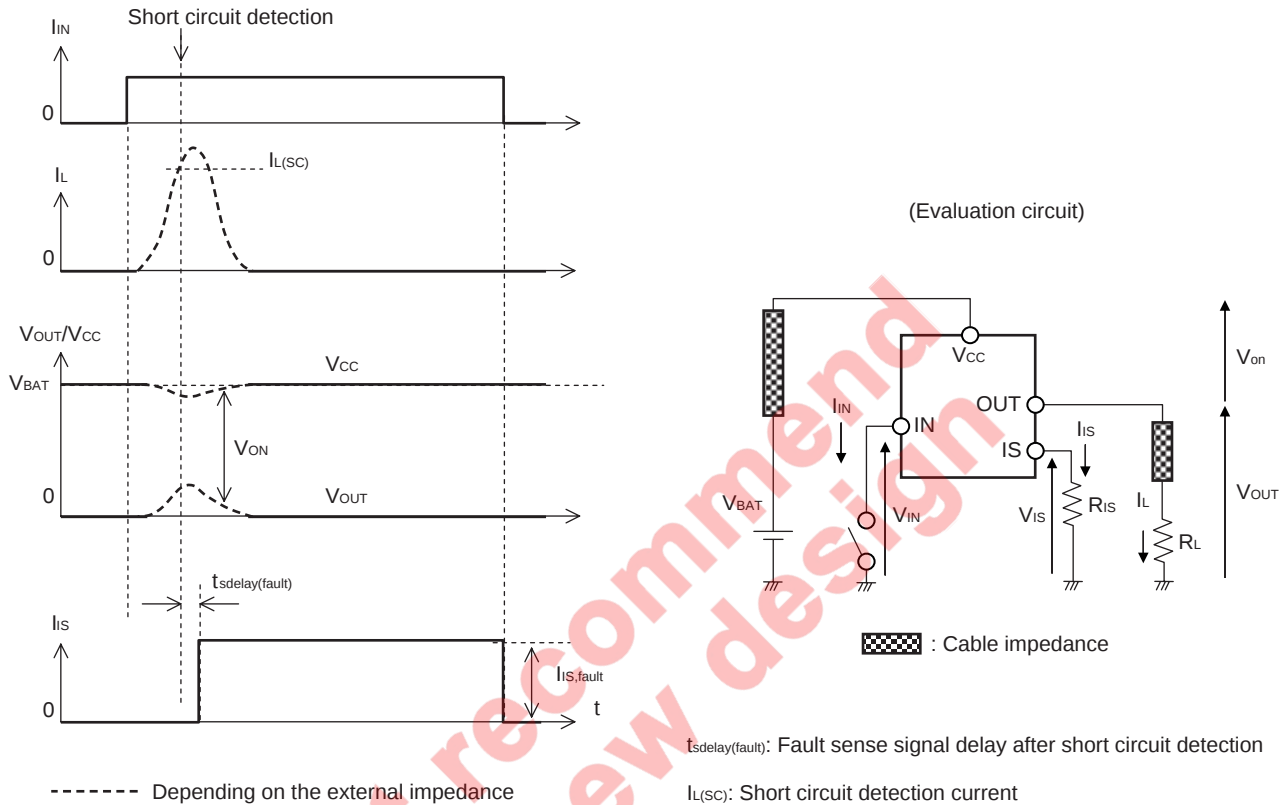
### 3.6.2 Short Circuit Protection

Case 1:  $I_{IN}$  pin is shorted to ground in an overload condition, which includes a short circuit condition.

The device shuts down automatically when either or both of following conditions (a, b) is detected. The sense current is fixed at  $I_{IS, fault}$ . Shutdown is latched until the next reset via input.

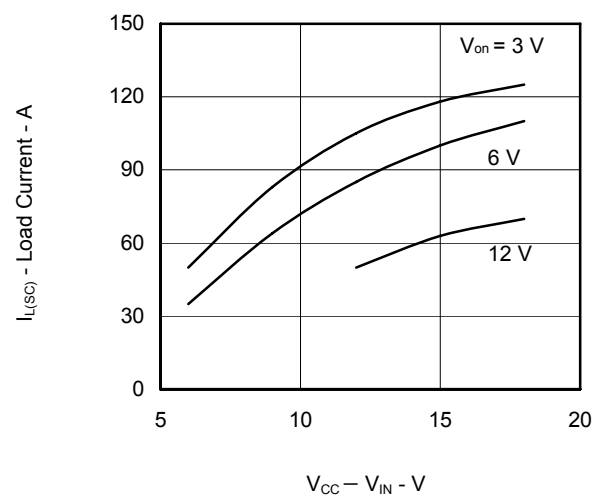
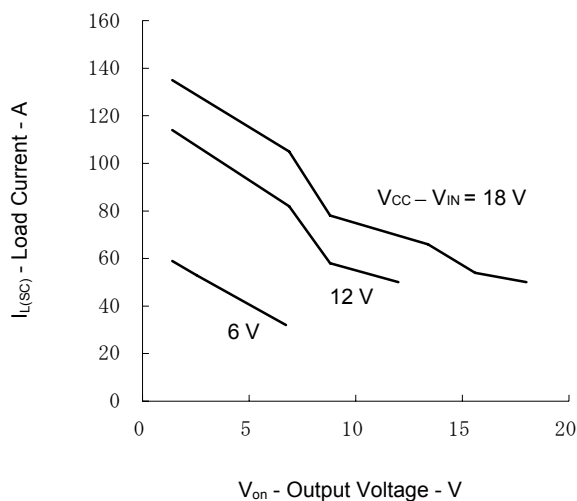
- (a)  $I_L > I_{L(SC)}$
- (b)  $V_{on} > V_{on(OVL)}$  after  $t_{d(OC)}$

#### Case 1-(a) $I_L > I_{L(SC)}$

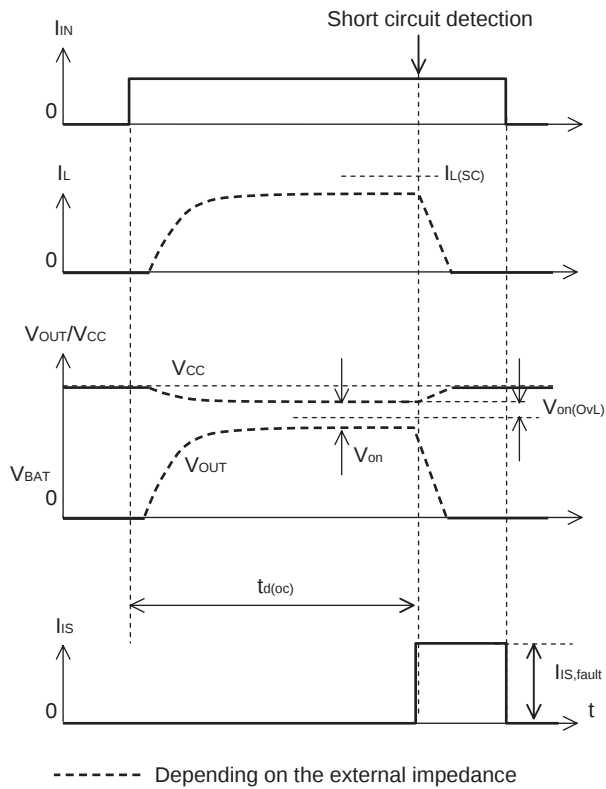


#### Typical Short circuit detection current characteristics

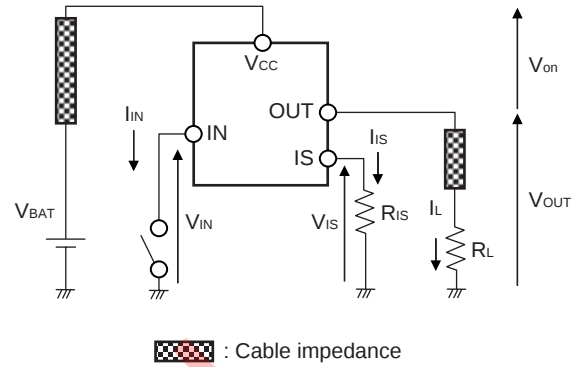
The short circuit detection current changes according  $V_{CC}$  voltage and  $V_{on}$  voltage for the purpose of to be strength of the robustness under short circuit condition.



Case 1-(b)  $V_{on} > V_{on(OvL)}$  after  $t_{d(OC)}$



(Evaluation circuit)



$t_{d(OC)}$ : Turn-on check delay after input current positive slope

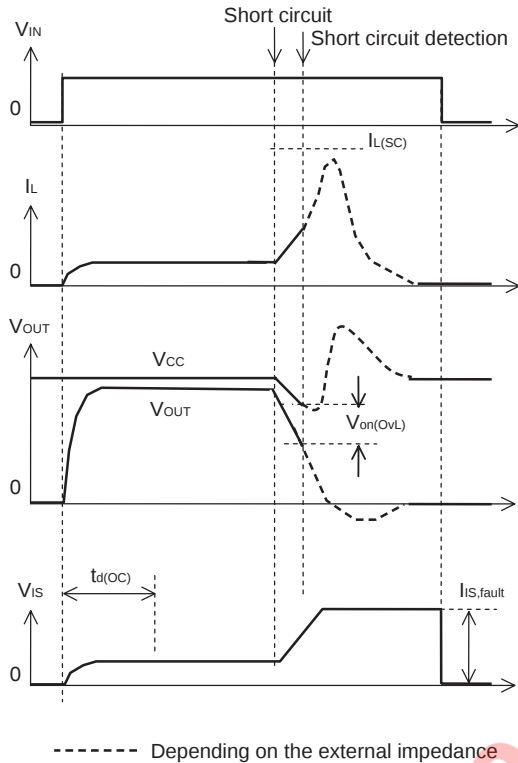
Not recommended for new design

## Case 2: Short circuit during on-condition

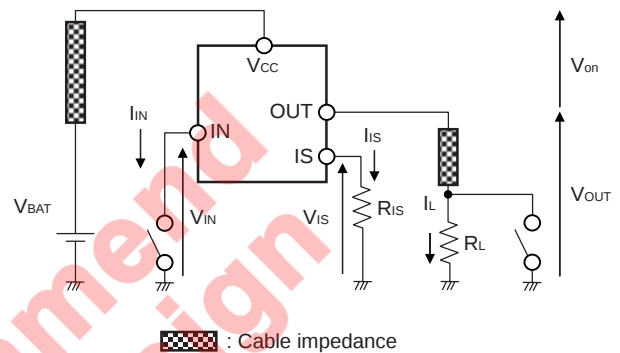
The device shuts down automatically when following conditions (a) is detected. The sense current is fixed at  $I_{S, fault}$ . Shutdown is latched until the next reset via input. In the case of  $V_{on(NL)}$  works such open load condition at on-state,  $t_{d(OC)}$  is expired.

(a)  $V_{on} > V_{on(OvL)}$  after  $t_{d(OC)}$

### Case 2-(a) $V_{on} > V_{on(OvL)}$ after $t_{d(OC)}$



(Evaluation circuit)

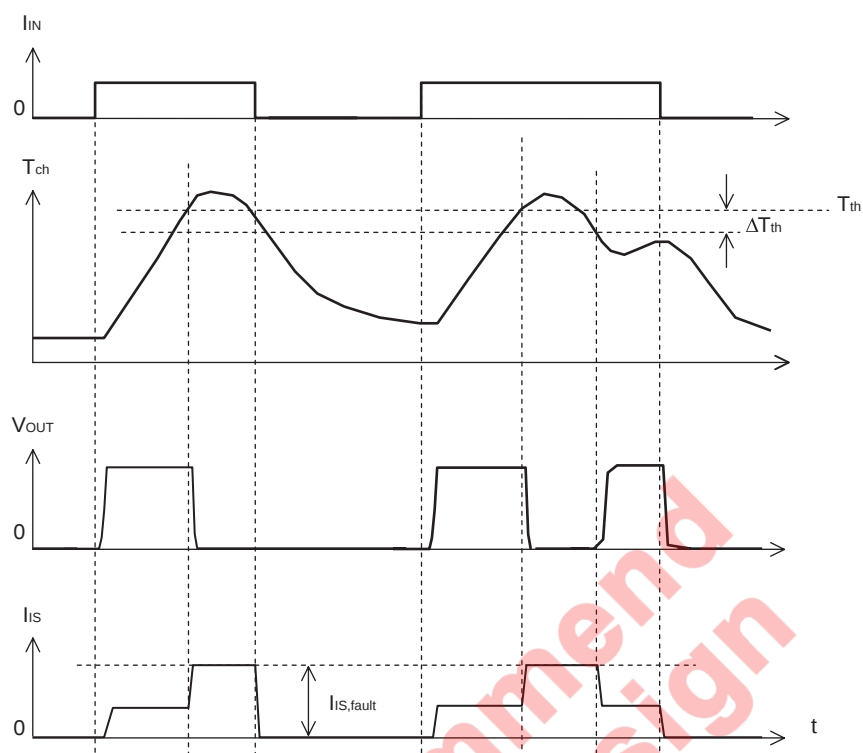


$t_{d(OC)}$ : Turn-on check delay after input current positive slope

$I_{L(SC)}$ : Short circuit detection current

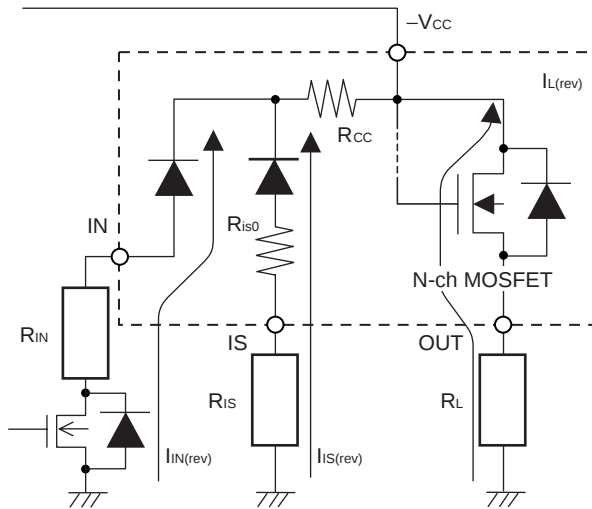
## Over-temperature protection

The output is switched off if over-temperature is detected. The device switches on again after it cools down.



### 3.6.3 Power Dissipation under Reverse Battery Condition

In case of reverse battery condition, internal N-ch MOSFET is turned on to reduce the power dissipation by body diode. Additional power is dissipated by the internal resistor. Following is the formula for estimation of total power dissipation  $P_{D(rev)}$  in reverse battery condition.



$$P_{D(rev)} = R_{on(rev)} \times I_{L(rev)}^2 + (V_{CC} - V_f - I_{in(rev)} \times R_{IN}) \times I_{in(rev)} + (V_{CC} - I_{is(rev)} \times R_{IS}) \times I_{is(rev)}$$

$$I_{in(rev)} = (V_{CC} - 2 \times V_f) / (R_{CC} + R_{IN})$$

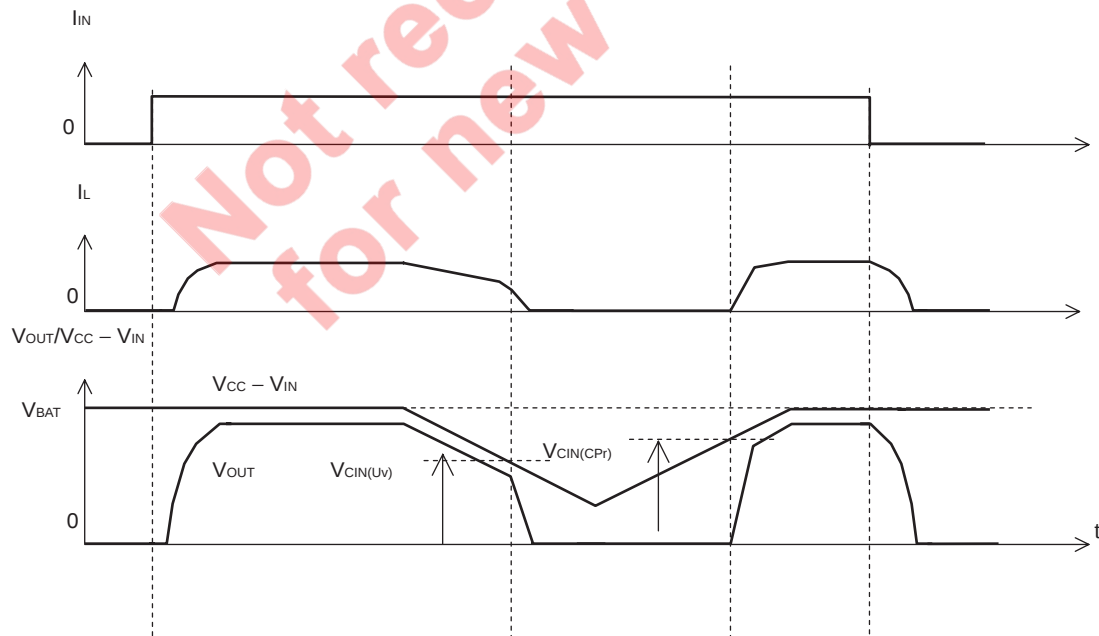
$$I_{is(rev)} = (V_{CC} - V_f) / (R_{CC} + R_{IS0} + R_{IS})$$

The reverse current through the N-ch MOSFET has to be limited by the connected load.

$$R_{IN} < (|V_{CC} - 8 V|) / 0.08 A$$

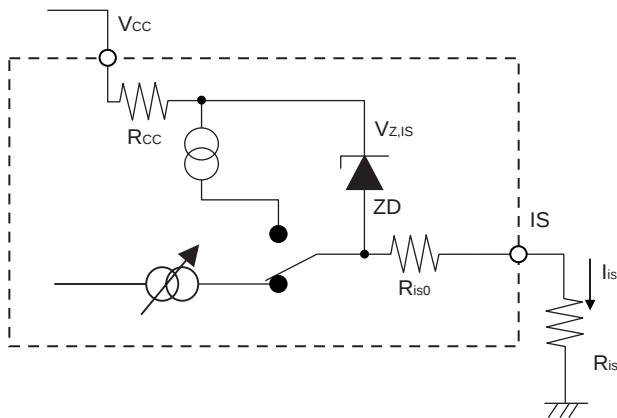
### 3.6.4 Device Behavior at Low Voltage Condition

If the supply voltage ( $V_{CC} - V_{IN}$ ) goes down under  $V_{CIN(UV)}$ , the device shuts down the output. If supply voltage ( $V_{CC} - V_{IN}$ ) increase over  $V_{CIN(CPr)}$ , the device turns on the output automatically. The device keeps off state if supply voltage ( $V_{CC} - V_{IN}$ ) does not increase over  $V_{CIN(CPr)}$  after under voltage shutdown. It is assumed that  $V_{IN} = 0 V$  when  $I_{IN}$  is activated.

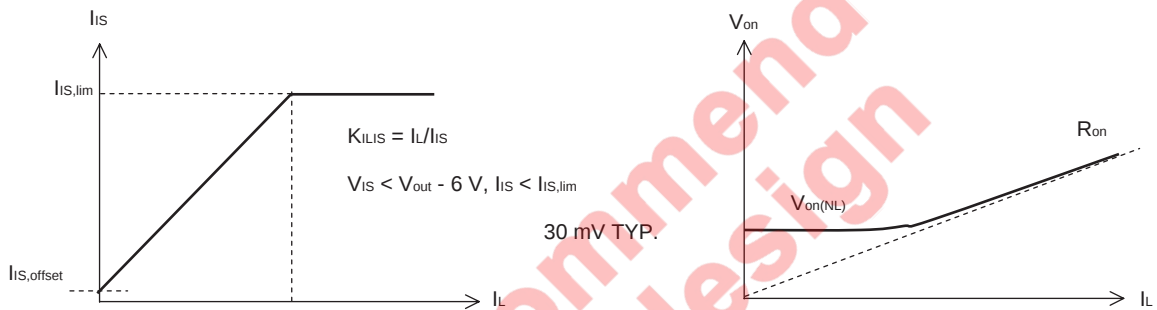


**Remark** It is assumed that  $V_{IN} = 0 V$  when  $I_{IN}$  is activated.

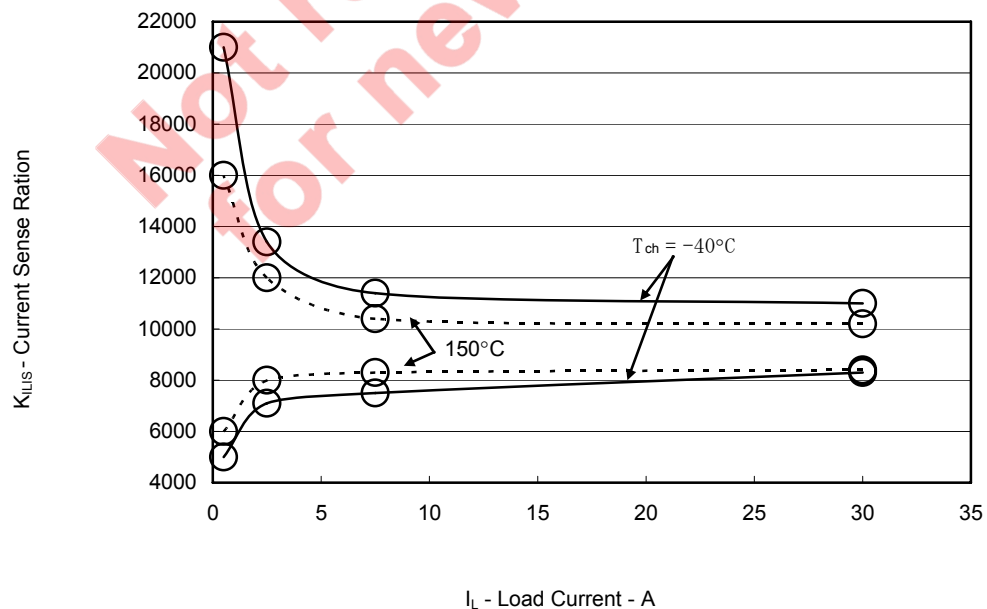
### 3.6.5 Current Sense Output



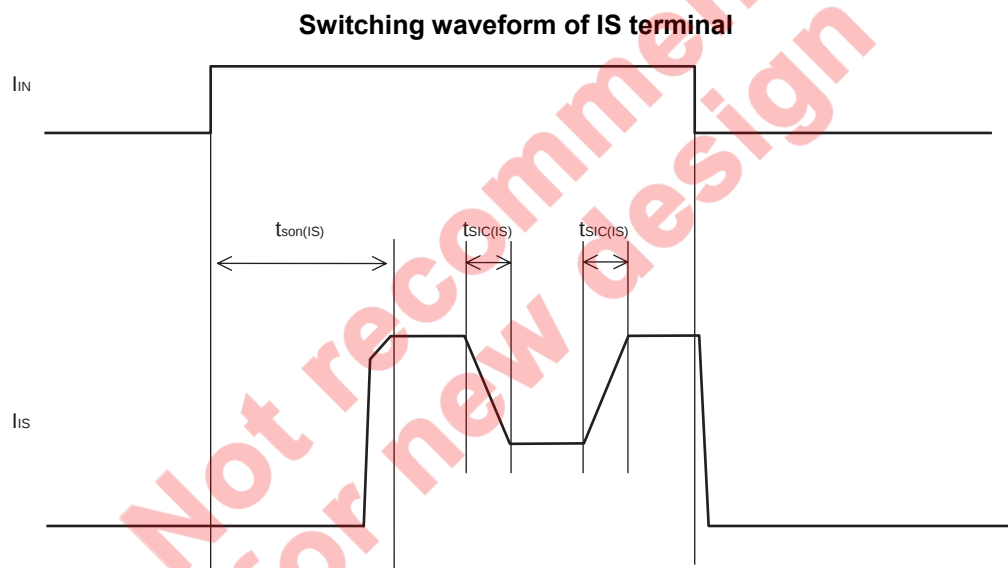
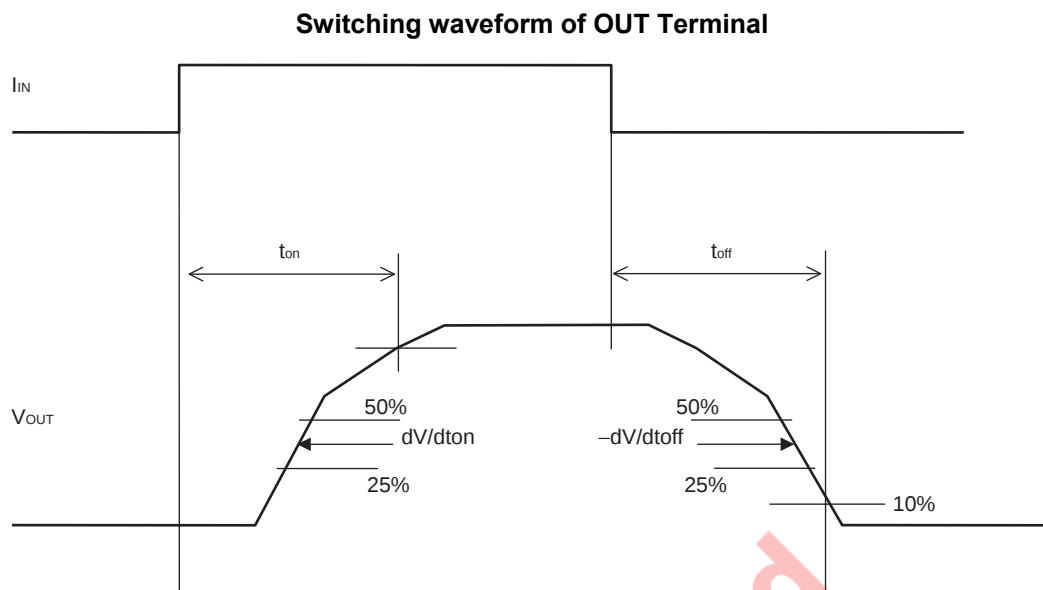
$R_{cc}$  and  $R_{iso}$  are 100  $\Omega$  (TYP.).  $V_{Z,IS}$  = 46 V (TYP.),  $R_{IS}$  = 1 k $\Omega$  nominal.



Current sense ratio



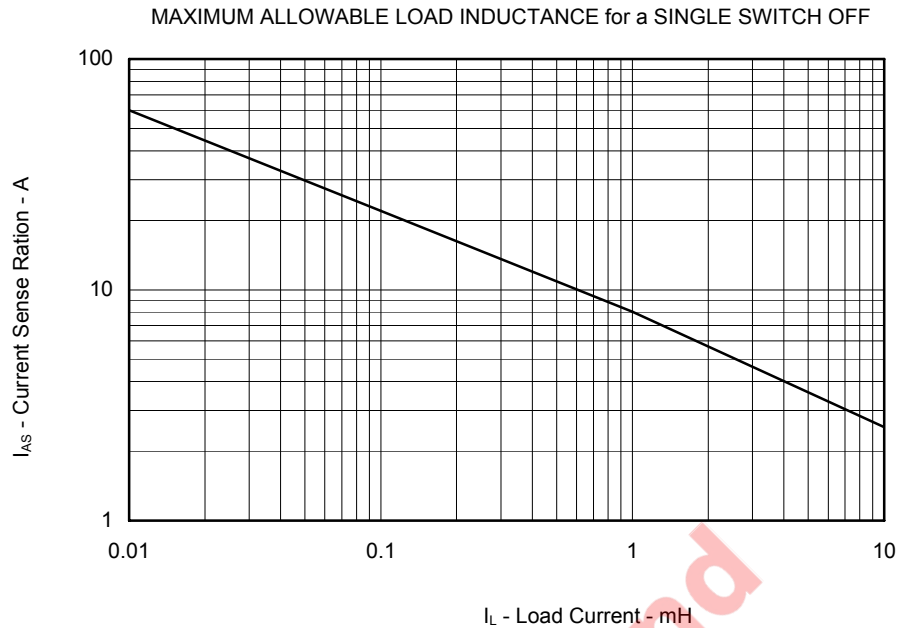
### 3.6.6 Measurement Condition



### 3.6.7 Truth Table

| Input Current | State                             | Output | Sense Current   |
|---------------|-----------------------------------|--------|-----------------|
| L             | —                                 | OFF    | $I_{IS(LL)}$    |
| H             | Normal Operation                  | ON     | $I_L/K_{IIS}$   |
|               | Over-temperature or Short circuit | OFF    | $I_{IS,fault}$  |
|               | Open Load                         | ON     | $I_{IS,offset}$ |

### 3.6.8 Inductive Load Switch Off Energy Dissipation for a Single Pulse

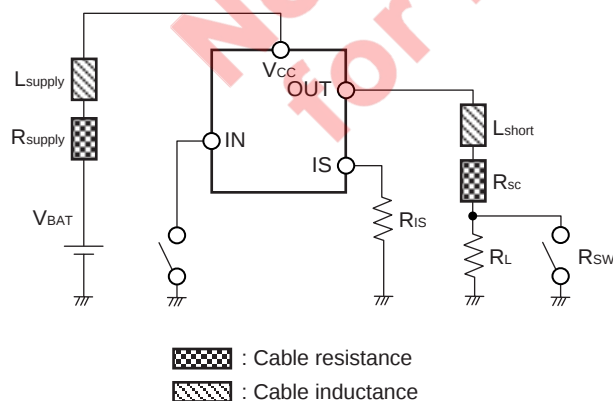


The energy dissipation for an inductive load switch-off single pulse in device ( $E_{AS1}$ ) is estimated by the following formula as  $R_L = 0 \Omega$ .

$$E_{AS1} = \frac{1}{2} I^2 L \left( \frac{V_{on(CL)}}{V_{on(CL)} - V_{CC}} \right)$$

### 3.6.9 Maximum Allowable Switch off Energy (Single Pulse)

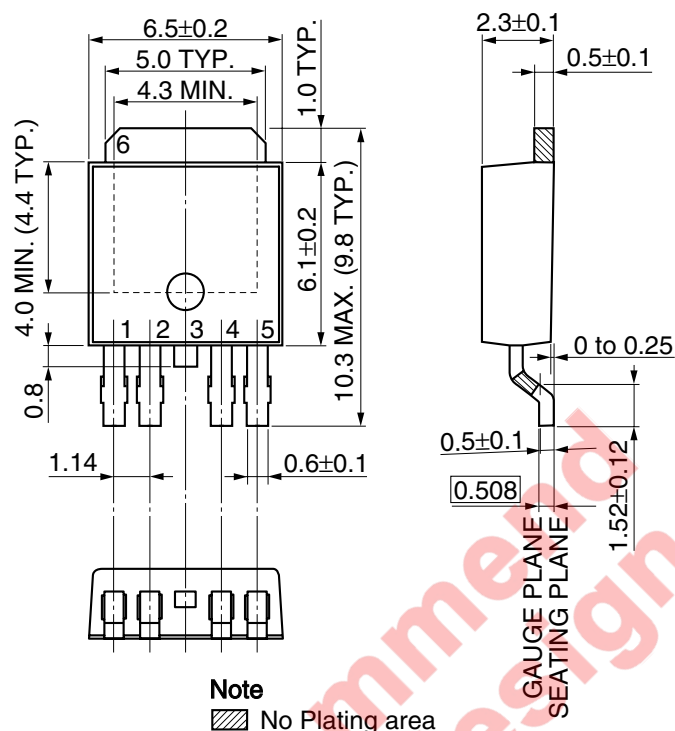
The harness connecting the power supply, the load and the device has a small inductance and resistance. When the device turns off, the energy stored in the harness inductance is dissipated by the device, the harness resistance and the internal resistance of power supply. If the current is abnormally high due to a load short, the energy stored in the harness can be large. This energy has to be taken into consideration for the safe operation. The following figure shows the condition for  $E_{AS2}$ , the maximum switch-off energy (single pulse) for abnormally high current.



$V_{BAT} = 18 \text{ V}$ ,  
 $R_{supply} = 10 \text{ m}\Omega$ ,  $R_{short} = R_{sc} + R_{SW(on)} = 50 \text{ m}\Omega$ ,  
 $L_{supply} = 5 \text{ }\mu\text{H}$ ,  $L_{short} = 15 \text{ }\mu\text{H}$ ,  
 $T_{ch,start} \leq 150^\circ\text{C}$

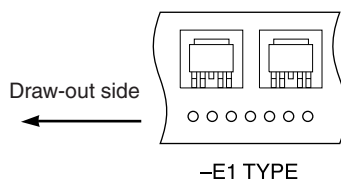
### 3.7 Package Drawing (unit: mm)

#### 5-pin TO-252 (MP-3ZK)



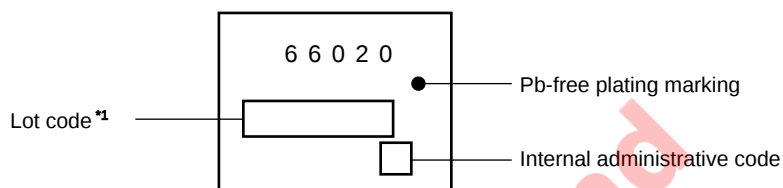
### 3.8 Taping Information

This is one type (E1) of direction of the device in the carrier tape.

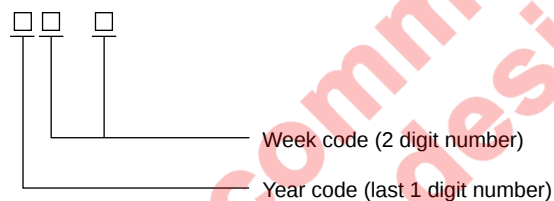


### 3.9 Marking Information

This figure indicates the marking items and arrangement. However, details of the letterform, the size and the position aren't indicated.

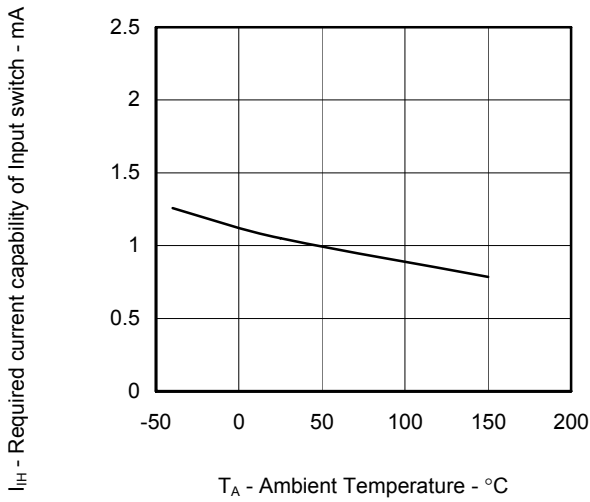


**Note: \*1.** Composition of the lot code

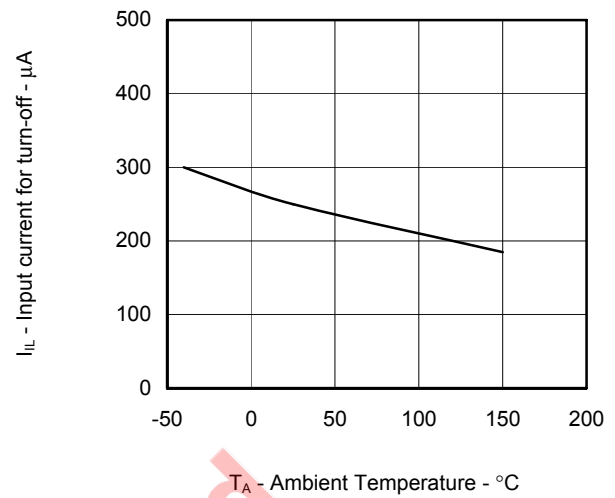


## 4. Typical Characteristics

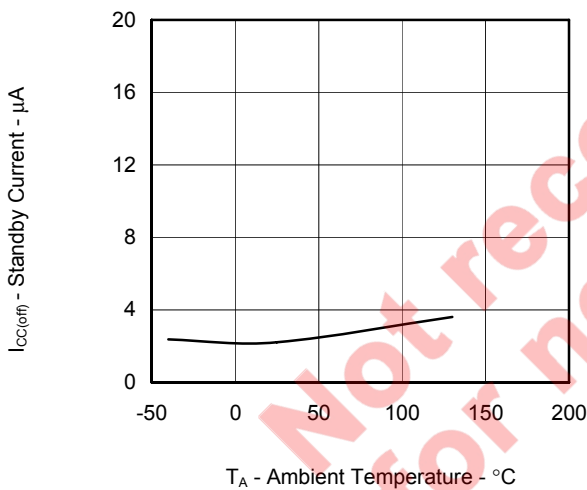
REQUIRED CURRENT CAPABILITY OF INPUT SWITCH vs. AMBIENT TEMPERATURE



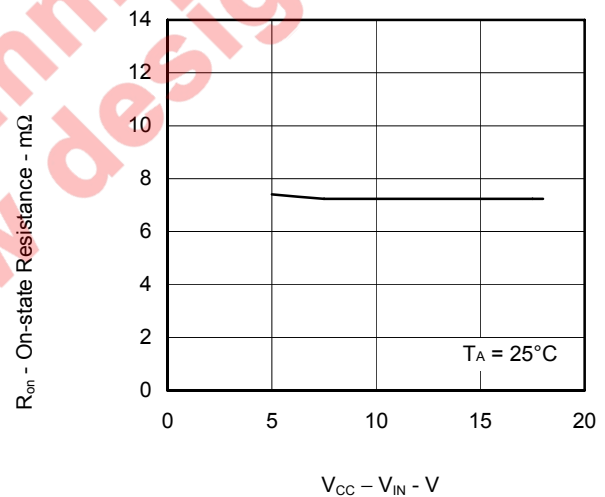
INPUT CURRENT FOR TURN OFF vs. AMBIENT TEMPERATURE



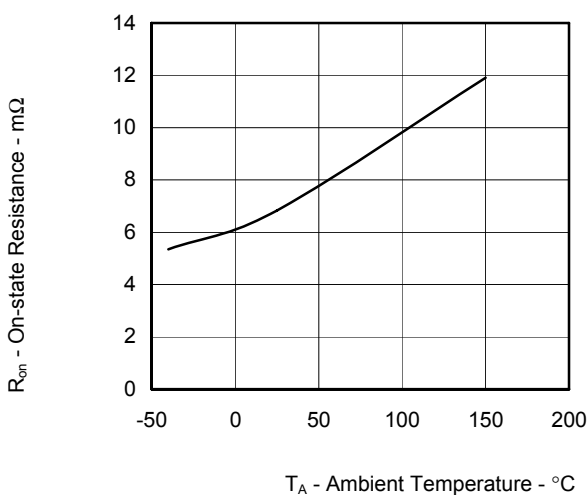
STANDBY CURRENT vs. AMBIENT TEMPERATURE



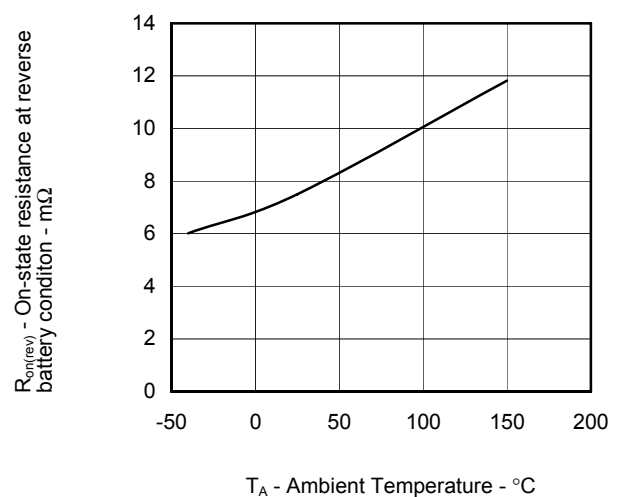
ON STATE RESISTANCE vs.  $V_{CC} - V_{IN}$  voltage



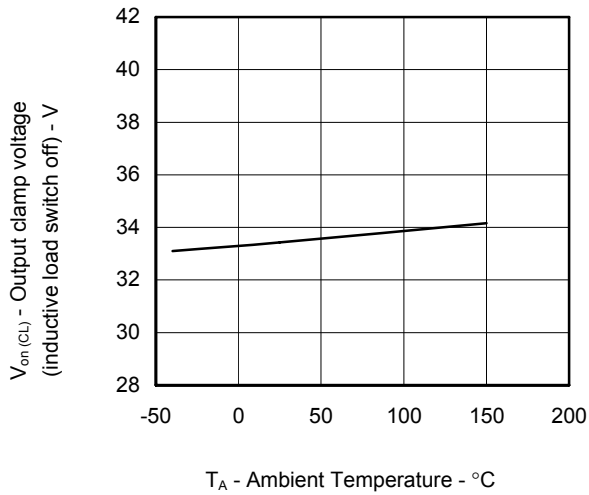
ON STATE RESISTANCE vs. AMBIENT TEMPERATURE



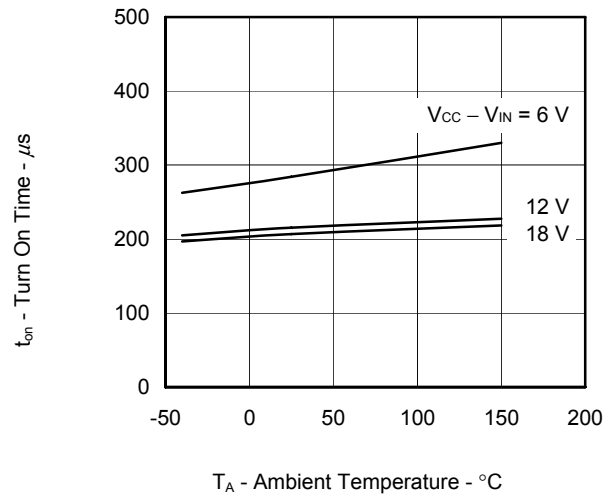
ON STATE RESISTANCE AT REVERSE BATTERY CONDITION vs. AMBIENT TEMPERATURE



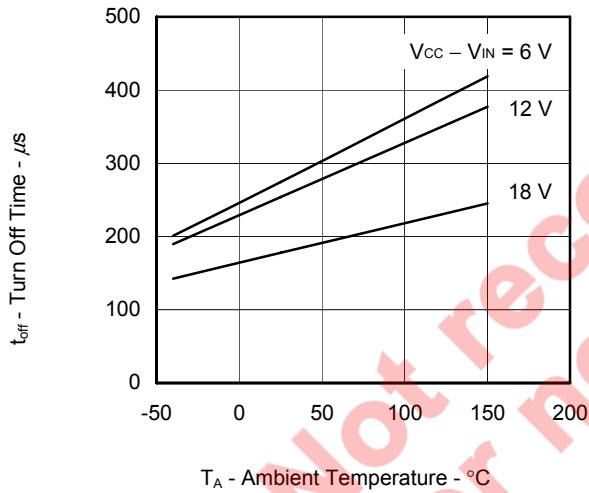
OUTPUT CLAMP VOLTAGE (INDUCTIVE LOAD SWITCH OFF) vs. AMBIENT TEMPERATURE



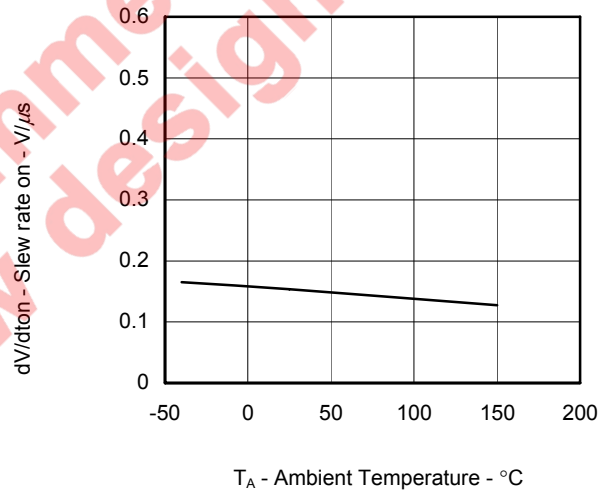
TURN ON TIME vs. AMBIENT TEMPERATURE



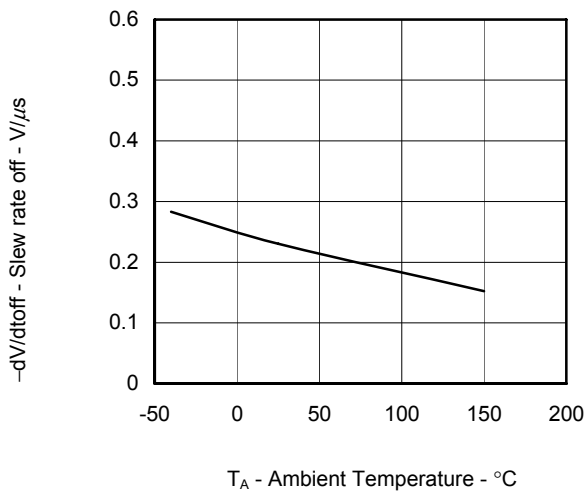
TURN OFF TIME vs. AMBIENT TEMPERATURE



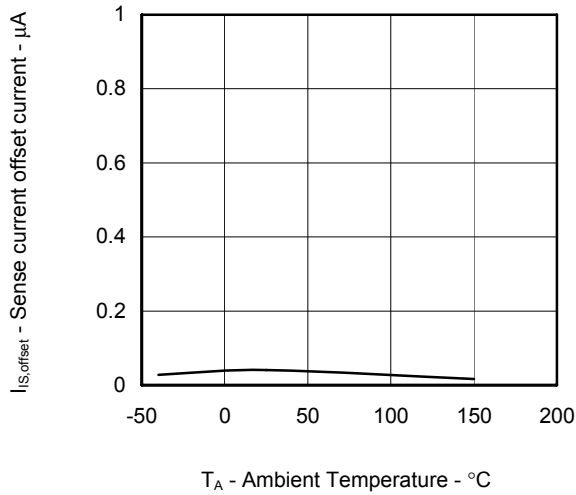
SLEW RATE ON vs. AMBIENT TEMPERATURE



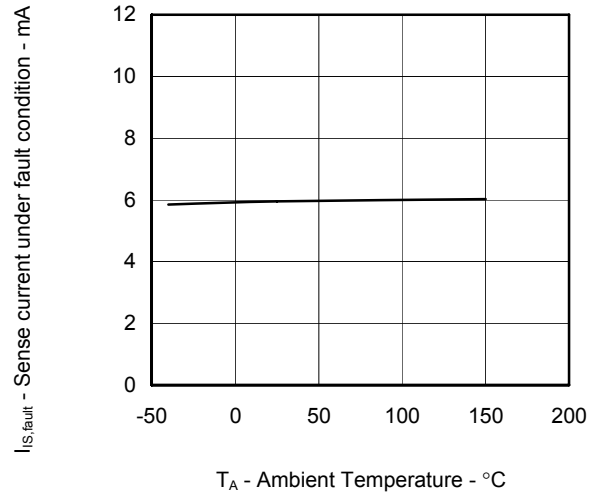
SLEW RATE OFF vs. AMBIENT TEMPERATURE



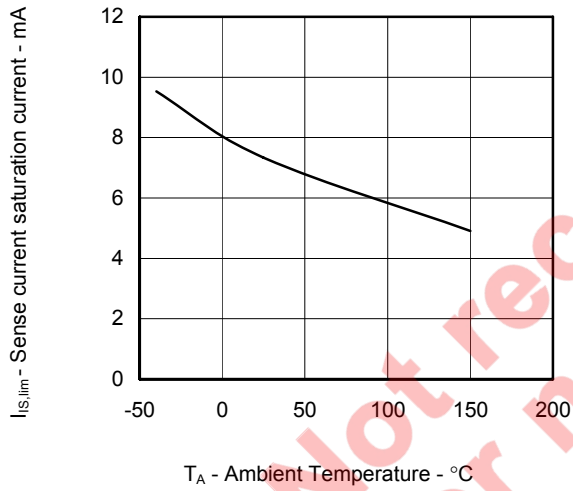
SENSE CURRENT OFFSET CURRENT  
vs. AMBIENT TEMPERATURE



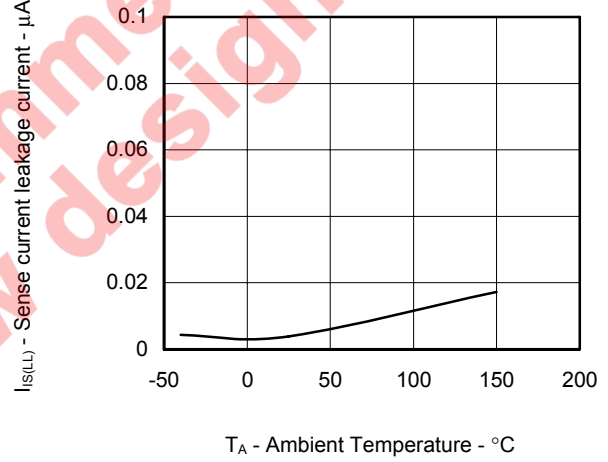
SENSE CURRENT UNDER FAULT CONDITION  
vs. AMBIENT TEMPERATURE



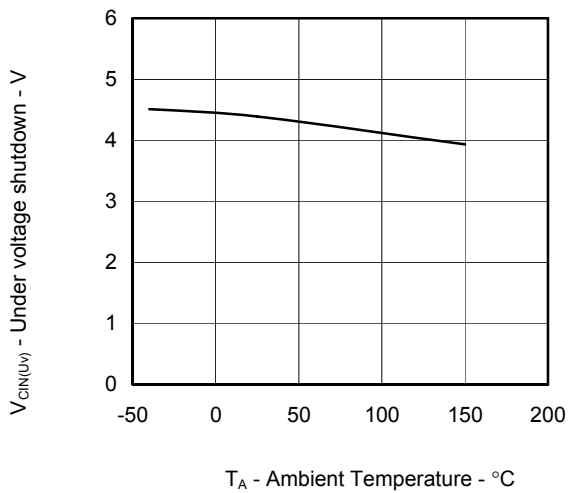
SENSE CURRENT SATURATION CURRENT  
vs. AMBIENT TEMPERATURE



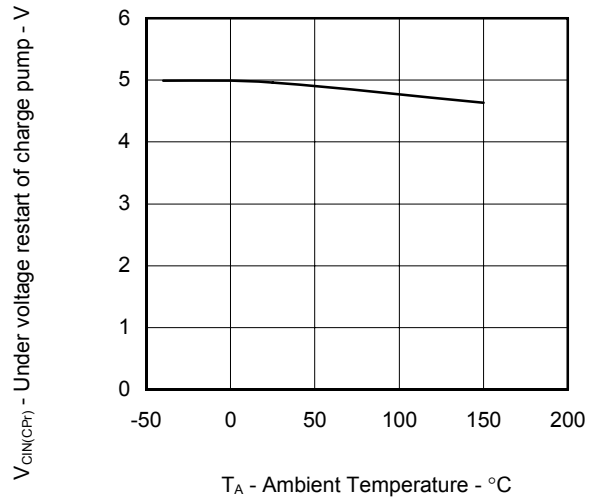
SENSE CURRENT LEAKAGE CURRENT  
vs. AMBIENT TEMPERATURE



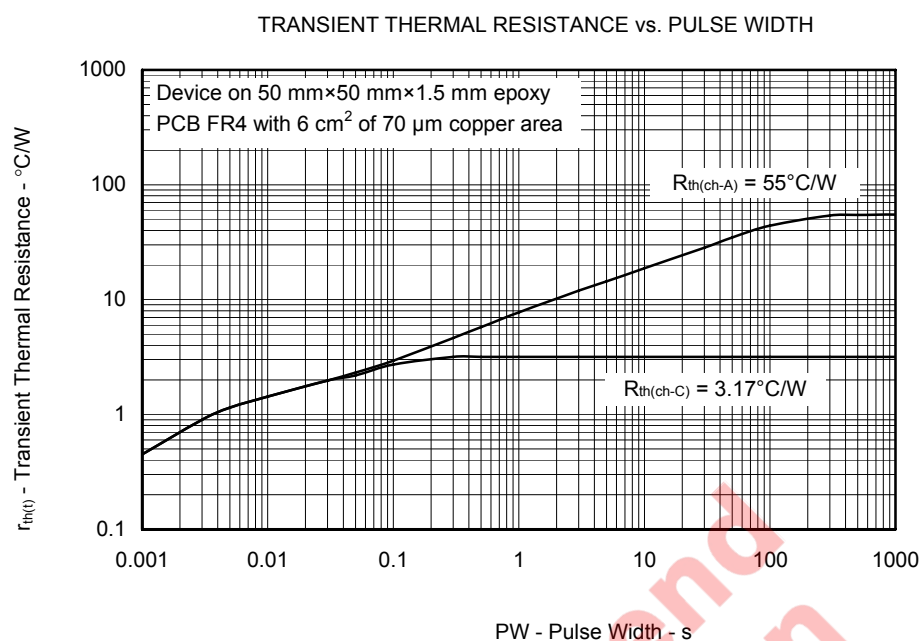
UNDER VOLTAGE SHUTDOWN  
vs. AMBIENT TEMPERATURE



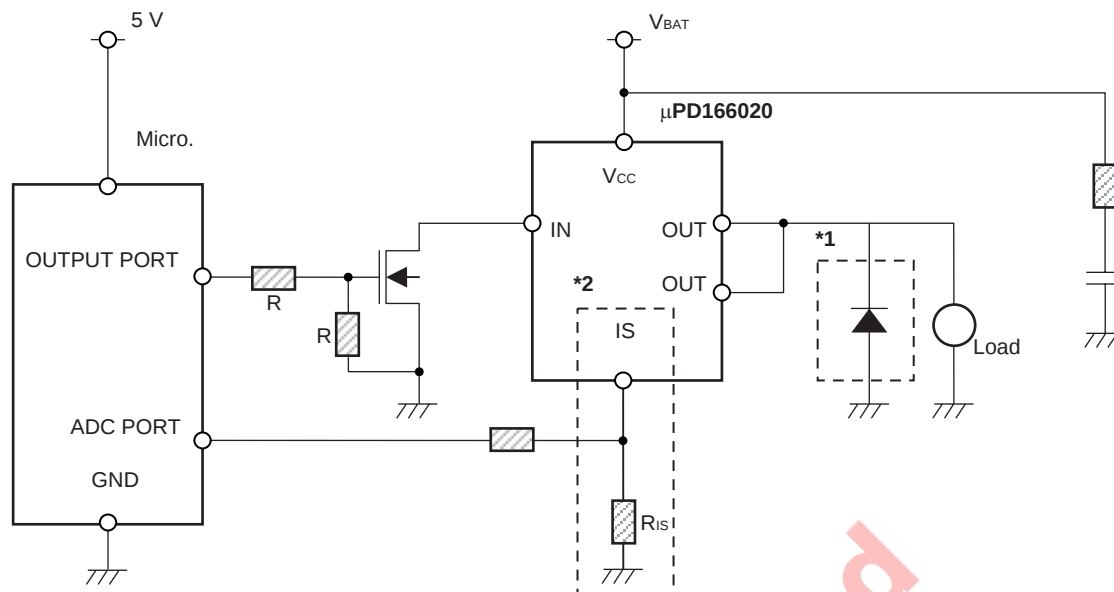
UNDER VOLTAGE RESTART OF CHARGE PUMP  
vs. AMBIENT TEMPERATURE



## 5. Thermal Characteristics



## 6. Application Example in Principle



Notes: \*1. If output current is over the maximum allowable current for inductive load at a single switch off, or if energy at a single switch off is over  $E_{AS1}/E_{AS2}$ , then a free wheeling diode must be connected in parallel the load.

\*2. If current sense and diagnostic features are not used, IS terminal has to be connected to GND via resistor.

|                         |                                |
|-------------------------|--------------------------------|
| <b>Revision History</b> | <b>μPD166020T1F Data Sheet</b> |
|-------------------------|--------------------------------|

| Rev. | Date         | Description |                      |
|------|--------------|-------------|----------------------|
|      |              | Page        | Summary              |
| 1.00 | Aug 15, 2011 | –           | First Edition Issued |

Not recommend  
for new design

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