1. Overview

1.1 Description

Family:
µPD166023T1J is part of 2nd Generation Intelligent Power Devices (IPD). This is N-channel high-side switch with charge pump, voltage controlled input, diagnostic feedback with proportional load current sense and embedded protection function. Family includes up to 14 devices depending on on-state resistance, package and channel number combination.

Scalability:
Variety of on-state resistance combined with standardized package on pin-out give user high flexibility for unit design depending on target load.

Robustness:
Because of advanced protection method, 2nd Generation Intelligent Power Devices achieve high robustness against long term and repetitive short circuit condition.

1.2 Features

- Built-in charge pump
- 3.3V compatible logic interface
- Low standby current
- Short circuit protection
  - Shutdown by over current detection
  - Power limitation protection by over load detection (Power limitation: current limitation with delta Tch control)
  - Absolute Tch over temperature protection
- Built-in diagnostic function
  - Proportional load current sensing
  - Defined fault signal in case of abnormal load condition
- Loss of ground protection
- Under voltage lock out
- Active clamp operation at inductive load switch off
- Cross current protection in case of H-bridge high side usage
- AEC Qualified
- RoHS compliant

1.3 Application

- Light bulb switching from 55W to 65W
- Switching of all types of 14V DC grounded loads, such as LED, inductor, resistor and capacitor
- Power supply switch, fail-safe switch of 14V DC grounded system

Note: The information contained in this document is the one that was obtained when the document was issued, and may be subject to change.
2. Ordering Information

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Nick name</th>
<th>Lead plating</th>
<th>Packing</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPD166023T1J-E1-AY</td>
<td>NHS012B</td>
<td>Pure Matte Sn</td>
<td>Tape 1500 p/reel</td>
<td>12-pin Power HSSOP</td>
</tr>
<tr>
<td>UPD166023T1J-E2-AY</td>
<td>NHS012B</td>
<td>Pure Matte Sn</td>
<td>Tape 1500 p/reel</td>
<td>12-pin Power HSSOP</td>
</tr>
</tbody>
</table>

Note: MSL: 1, profile acc. J-STD-20C

2.1 Nick name

![Diagram showing Nick name structure](image)

- A: TO252-7
- B: 12-pin Power HSSOP
- C: 24-pin Power HSSOP

- S: Single channel
- D: Dual channel
- Q: Quad channel

Nch High-side

On-state resistance
3. Specification

3.1 Block Diagram

3.1.1 Nch High-side Single Device

Voltage and Current Definition
3.2 Pin Configuration

3.2.1 12-pin Power HSSOP Pin Configuration

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Terminal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
</tr>
<tr>
<td>2</td>
<td>N.C.</td>
</tr>
<tr>
<td>3</td>
<td>IS</td>
</tr>
<tr>
<td>4</td>
<td>N.C.</td>
</tr>
<tr>
<td>5</td>
<td>IN</td>
</tr>
<tr>
<td>6</td>
<td>VCC</td>
</tr>
<tr>
<td>7</td>
<td>SEN</td>
</tr>
<tr>
<td>8</td>
<td>OUT</td>
</tr>
<tr>
<td>9</td>
<td>OUT</td>
</tr>
<tr>
<td>10</td>
<td>OUT</td>
</tr>
<tr>
<td>11</td>
<td>OUT</td>
</tr>
<tr>
<td>12</td>
<td>VCC</td>
</tr>
<tr>
<td>Tab</td>
<td>VCC</td>
</tr>
</tbody>
</table>

**Pin function**

<table>
<thead>
<tr>
<th>Terminal Name</th>
<th>Pin function</th>
<th>Recommended connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>Ground connection</td>
<td>Connected to GND through a 100 Ohm resistor or a diode for reverse current protection Refer chapter 6.</td>
</tr>
<tr>
<td>IN</td>
<td>Input signal</td>
<td>Connected to MCU port through 2k-50K serial resistor</td>
</tr>
<tr>
<td>IS</td>
<td>Current sense and Diagnosis output signal</td>
<td>Connected to GND through a 0.67K-5K resistor</td>
</tr>
<tr>
<td>SEN</td>
<td>Sense enable input</td>
<td>Connected to MCU port through 2k-50K serial resistor</td>
</tr>
<tr>
<td>OUT</td>
<td>Protected high-side power output</td>
<td>Connected to load with small 50-100nf capacitor in parallel</td>
</tr>
<tr>
<td>VCC</td>
<td>Positive power supply for logic supply as well as output power supply</td>
<td>Connected to battery voltage with small 100nf capacitor in parallel</td>
</tr>
<tr>
<td>N.C.</td>
<td>Non connection</td>
<td>Left open</td>
</tr>
</tbody>
</table>
### 3.3 Absolute Maximum Ratings

Ta=25degreeC, unless other specified

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Rating</th>
<th>Unit</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vcc Voltage</td>
<td>V&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>28</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Vcc Voltage at reverse battery condition</td>
<td>-V&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>-16</td>
<td>V</td>
<td>RL=2ohm, t&lt;2min, RIN=2kohm, RSEN=2kohm, RIS=1kohm, RGND=100ohm</td>
</tr>
<tr>
<td>GND Reverse current at reverse battery condition</td>
<td>I&lt;sub&gt;IGND(Rev)&lt;/sub&gt;</td>
<td>200</td>
<td>mA</td>
<td>RL=2ohm, t&lt;2min</td>
</tr>
<tr>
<td>Vcc voltage under Load Dump condition</td>
<td>V&lt;sub&gt;load dump&lt;/sub&gt;</td>
<td>42</td>
<td>V</td>
<td>RL=1ohm, RL=2ohm, RIS=1kohm, RIN=2kohm, RSEN=2kohm, RGND=100ohm, td=400ms,</td>
</tr>
<tr>
<td>Load Current</td>
<td>I&lt;sub&gt;L&lt;/sub&gt;</td>
<td>Self limited</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Total power dissipation for whole device (DC)</td>
<td>P&lt;sub&gt;D&lt;/sub&gt;</td>
<td>1.85</td>
<td>W</td>
<td>Ta=85degreeC, Device on 50mmx50mmx1.5mm epoxy PCB FR4 with 6 cm² of 70 um copper area</td>
</tr>
<tr>
<td>Voltage at IN pin</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;</td>
<td>-2 ~ 16</td>
<td>V</td>
<td>DC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-16</td>
<td></td>
<td>At reverse battery condition, t&lt;2min, RIN=2kohm</td>
</tr>
<tr>
<td>IN pin current</td>
<td>I&lt;sub&gt;IN&lt;/sub&gt;</td>
<td>10</td>
<td>mA</td>
<td>DC</td>
</tr>
<tr>
<td>Voltage at IS pin</td>
<td>V&lt;sub&gt;IS&lt;/sub&gt;</td>
<td>VCC</td>
<td>V</td>
<td>DC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-16</td>
<td></td>
<td>At reverse battery condition, t&lt;2min, RL=2ohm, RIS=1kohm</td>
</tr>
<tr>
<td>IS Reverse current at reverse battery condition</td>
<td>I&lt;sub&gt;IS(Rev)&lt;/sub&gt;</td>
<td>-30</td>
<td>mA</td>
<td>At reverse battery condition, t&lt;2min, RL=2ohm</td>
</tr>
<tr>
<td>Voltage at SEN pin</td>
<td>V&lt;sub&gt;SEN&lt;/sub&gt;</td>
<td>-2 ~ 16</td>
<td>V</td>
<td>DC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-16</td>
<td></td>
<td>At reverse battery condition, t&lt;2min, RSEN=2kohm</td>
</tr>
<tr>
<td>SEN pin current</td>
<td>I&lt;sub&gt;SEN&lt;/sub&gt;</td>
<td>10</td>
<td>mA</td>
<td>DC</td>
</tr>
<tr>
<td>Channel Temperature</td>
<td>T&lt;sub&gt;CH&lt;/sub&gt;</td>
<td>-40 to +150</td>
<td>degreeC</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>T&lt;sub&gt;STG&lt;/sub&gt;</td>
<td>-55 to +150</td>
<td>degreeC</td>
<td></td>
</tr>
<tr>
<td>ESD susceptibility</td>
<td>V&lt;sub&gt;ESD&lt;/sub&gt;</td>
<td>2000</td>
<td>V HBM</td>
<td>AEC-Q100-002 std., R=1.5kohm, C=100pF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4000</td>
<td></td>
<td>IEC61000-4-2 std., R=330ohm, C=150pF, 100nF at VCC and OUT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td></td>
<td>AEC-Q100-003 std., R=0ohm, C=200pF</td>
</tr>
<tr>
<td>Inductive load switch-off energy dissipation single pulse</td>
<td>EAS</td>
<td>130</td>
<td>mJ</td>
<td>VCC=13.5V, T&lt;sub&gt;CH&lt;/sub&gt;,start&lt;150degreeC, RL=2ohm</td>
</tr>
<tr>
<td>Inductive load switch-off energy dissipation repetitive pulse</td>
<td>EAR</td>
<td>89</td>
<td>mJ</td>
<td>VCC=13.5V, T&lt;sub&gt;CH&lt;/sub&gt;,start=85degreeC, RL=2ohm</td>
</tr>
</tbody>
</table>

Remark) All voltages refer to ground pin of the device
### 3.4 Thermal Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal characteristics</td>
<td>Rth(ch-a)</td>
<td>35</td>
<td></td>
<td></td>
<td>degree C/W</td>
<td>According to JEDEC JESD51-2, -5, -7 on FR4 2s2p board</td>
</tr>
<tr>
<td></td>
<td>Rth(ch-c)</td>
<td>1.3</td>
<td></td>
<td></td>
<td>degree C/W</td>
<td></td>
</tr>
</tbody>
</table>
3.5 Electrical Characteristics

**Operation function**

Tch=−40 to 150degreeC, Vcc=7 to 18V, unless otherwise specified

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>VCC</td>
<td>4.5</td>
<td>28</td>
<td>V</td>
<td>V</td>
<td>VIN=4.5V, RL=2ohm</td>
</tr>
<tr>
<td>Operating current</td>
<td>I_GND</td>
<td>2.2</td>
<td>4</td>
<td>mA</td>
<td></td>
<td>VIN=4.5V</td>
</tr>
<tr>
<td>Output Leakage current</td>
<td>I_L(off)</td>
<td>0.5</td>
<td>µA</td>
<td>3</td>
<td></td>
<td>Tch=25°C, Tch=40~125°C</td>
</tr>
<tr>
<td>Standby current</td>
<td>I_CC(off)</td>
<td>0.5</td>
<td>µA</td>
<td>1.5</td>
<td></td>
<td>Tch=40~85°C</td>
</tr>
<tr>
<td>On-state resistance</td>
<td>Ron</td>
<td>12</td>
<td></td>
<td>24</td>
<td>mohm</td>
<td>Tch=25°C, IL=6.8A, Tch=150°C, IL=6.8A</td>
</tr>
<tr>
<td>Low level IN pin voltage</td>
<td>V_IL</td>
<td>0.8</td>
<td></td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High level IN pin voltage</td>
<td>V_IL</td>
<td>2.5</td>
<td></td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Low level IN pin current</td>
<td>I_IL</td>
<td>2</td>
<td>25</td>
<td>µA</td>
<td>VIN=0.8V</td>
<td></td>
</tr>
<tr>
<td>High level IN pin current</td>
<td>I_IH</td>
<td>2</td>
<td>25</td>
<td>µA</td>
<td>VIN=2.5V</td>
<td></td>
</tr>
<tr>
<td>Clamping IN pin voltage†</td>
<td>V_ZIN</td>
<td>5</td>
<td>6</td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Low level SEN pin voltage</td>
<td>V_SENL</td>
<td>0.8</td>
<td></td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>High level SEN pin voltage</td>
<td>V_SENH</td>
<td>2.5</td>
<td></td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Low level SEN pin current</td>
<td>I_SENL</td>
<td>2</td>
<td>25</td>
<td>µA</td>
<td>VSEN=0.8V</td>
<td></td>
</tr>
<tr>
<td>High level SEN pin current</td>
<td>I_SENH</td>
<td>2</td>
<td>25</td>
<td>µA</td>
<td>VSEN=2.5V</td>
<td></td>
</tr>
<tr>
<td>Clamping SEN pin voltage†</td>
<td>V_ZSEN</td>
<td>5</td>
<td>6</td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Under voltage shutdown</td>
<td>V_CC(Uv)</td>
<td>4.5</td>
<td></td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Under voltage restart</td>
<td>V_CC(Cpr)</td>
<td>5.0</td>
<td></td>
<td>V</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Turn on time</td>
<td>ton</td>
<td>200</td>
<td>µs</td>
<td></td>
<td>VCC=13.5V, RL=2ohm</td>
<td></td>
</tr>
<tr>
<td>Turn on delay time</td>
<td>td(on)</td>
<td>100</td>
<td>µs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn off time</td>
<td>toff</td>
<td>200</td>
<td>µs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn off delay time</td>
<td>td(off)</td>
<td>150</td>
<td>µs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slew rate on</td>
<td>dV/dton</td>
<td>1.0</td>
<td>V/µs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slew rate off</td>
<td>-dV/dtoff</td>
<td>1.0</td>
<td>V/µs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Switching drift†                 | ton-toff| -50 | +50 | µs  | Vcc = 9 to 18V drift from Vcc=13.5V, Tch=40 to 150degreeC drift from Tch=25degreeC;
                                                                |
| Turn on energy loss†             | E_on   | 1.2 | 2.4 | mJ  | VCC=13.5V,Tch=25°C, RL=2ohm                                                   |
| Turn off energy loss†            | E_off  | 1.2 | 2.4 | mJ  |                                                                                  |
| Driving capability†              | Dr(capa)| 118 |     |     | V     |
|                                 |        | 150 |     | mohm| Tch=25°C, VCC=8~16V, Tch=105°C, VCC=8~16V                                    |

Remark) All voltages refer to ground pin of the device

†) not subjected production test, guaranteed by design
## Protection function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over current detection current</td>
<td>IL(SC)</td>
<td>72</td>
<td>121</td>
<td>A</td>
<td>VCC=13.5V, Von=5V, Tch=25°C</td>
<td></td>
</tr>
<tr>
<td>Current limitation under power limitation toggling</td>
<td>IL(CL)</td>
<td>53</td>
<td>A</td>
<td>VCC=13.5V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current limitation under absolute thermal toggling</td>
<td>IL(TT)</td>
<td>21</td>
<td>A</td>
<td>VCC=13.5V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current limitation trigger threshold during turn-on</td>
<td>Von(CL1)</td>
<td>2.0</td>
<td>V</td>
<td>VCC=13.5V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current limitation trigger threshold during on-state</td>
<td>Von(CL2)</td>
<td>0.3</td>
<td>V</td>
<td>VCC=13.5V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current limitation trigger time after input signal</td>
<td>td(CL)</td>
<td>500</td>
<td>µs</td>
<td>VCC=13.5V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute thermal shutdown temperature</td>
<td>aTth</td>
<td>150</td>
<td>°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal hysteresis for absolute thermal toggling</td>
<td>aTth,hys</td>
<td>20</td>
<td>°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power limitation thermal shutdown temperature</td>
<td>dTth</td>
<td>50</td>
<td>°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power limitation restart temperature</td>
<td>dTth,rest</td>
<td>25</td>
<td>°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output clamp at inductive load switch off</td>
<td>Von,clamp</td>
<td>30</td>
<td>40</td>
<td>V</td>
<td>VCC=13.5V, IL=40mA, Tch=25°C</td>
<td></td>
</tr>
<tr>
<td>Output current while GND disconnection</td>
<td>IL(GND)</td>
<td>1</td>
<td>mA</td>
<td>IIN=0A, ISEN=0A, IGND=0A, IIS=0A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage drop at reverse battery condition</td>
<td>Vds(rev)</td>
<td>0.9</td>
<td>V</td>
<td>Tch=25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7</td>
<td>V</td>
<td>VCC=-13.5V, RL=2ohm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remark) All voltages refer to ground pin of the device
### Diagnosis function

Tch=-40 to 150°C, Vcc=7 to 18V, VIN=4.5V, VSEN=4.5V, unless otherwise specified

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current sense ratio</td>
<td>KILIS</td>
<td>5000</td>
<td>6250</td>
<td>7500</td>
<td></td>
<td>IL=4.6A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4375</td>
<td>6250</td>
<td>8125</td>
<td></td>
<td>IL=0.9A</td>
</tr>
<tr>
<td>Current sense drift depend on temperature</td>
<td>dKILIS</td>
<td>-15</td>
<td></td>
<td>15</td>
<td>%</td>
<td>VCC=13.5V, Tch,start=25°C, RL=2ohm</td>
</tr>
<tr>
<td>Sense current offset current</td>
<td>Iis,offset</td>
<td>2</td>
<td></td>
<td></td>
<td>µA</td>
<td>IL&lt;10mA</td>
</tr>
<tr>
<td>Sense current leakage current</td>
<td>Iis,dis</td>
<td></td>
<td></td>
<td>1</td>
<td>µA</td>
<td>VIN=0V, VSEN=0V</td>
</tr>
<tr>
<td>Sense current under fault condition</td>
<td>Iis,fault</td>
<td>3</td>
<td>9.5</td>
<td></td>
<td>mA</td>
<td>VCC=13.5V, RIS=0.67kohm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.5</td>
<td>9</td>
<td></td>
<td></td>
<td>VCC=13.5V, RIS=1kohm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.5</td>
<td>5.5</td>
<td></td>
<td></td>
<td>VCC=13.5V, RIS=2kohm</td>
</tr>
<tr>
<td>Minimum output current for current sense output</td>
<td>IL(CSE)</td>
<td>10</td>
<td></td>
<td>100</td>
<td>mA</td>
<td>IIS&gt;5µA</td>
</tr>
<tr>
<td>Open load detection threshold at off-state</td>
<td>VOUT(OL)</td>
<td>2.0</td>
<td>5.0</td>
<td></td>
<td>V</td>
<td>VIN=0V, Tch=-40~105°C</td>
</tr>
<tr>
<td>OUT terminal current at Open load condition</td>
<td>IOUT(OL)</td>
<td>-1.0</td>
<td></td>
<td></td>
<td>µA</td>
<td>VIN =0V</td>
</tr>
<tr>
<td>Open load detection delay after input negative slope</td>
<td>tdop</td>
<td>300</td>
<td></td>
<td></td>
<td>µs</td>
<td>VIN=4.5V to 0V, VOUT&gt;VOUT(OL)</td>
</tr>
</tbody>
</table>

Remark) All voltages refer to ground pin of the device
3. Specification

Diagnosis function

Tch=-40 to 150degreeC, Vcc=7 to 18V, VIN=4.5V, VSEN=4.5V, unless otherwise specified

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sense current settling time after input signal positive slope</td>
<td>tsis(on)</td>
<td>250</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>VCC=13.5V, VIN=0V to 4.5V, IL/IIS=KILIS, RL=2ohm</td>
</tr>
<tr>
<td>Sense current settling time after input signal negative slope</td>
<td>tsis(off)</td>
<td>10</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>VIN=4.5V to 0V</td>
</tr>
<tr>
<td>Sense current settling time after sense enable during on-state (^1)</td>
<td>tssen(on)</td>
<td>20</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>VSEN=0V to 4.5V, RL=2ohm</td>
</tr>
<tr>
<td>Sense current settling time after sense disable during on-state (^1)</td>
<td>tssen(off)</td>
<td>20</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>VSEN=4.5V to 0V, RL=2ohm</td>
</tr>
<tr>
<td>Sense current settling time during on-state (^1)</td>
<td>tsis(LC)</td>
<td>20</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>RL=2ohm to 1ohm</td>
</tr>
<tr>
<td>Fault signal delay after over current detection (^1)</td>
<td>tdsc(fault)</td>
<td>10</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>VIN=0V to 4.5V, IL=IL(SC)</td>
</tr>
<tr>
<td>Fault signal delay after power limitation valid (^1)</td>
<td>tdpl(fault)</td>
<td>10</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>Von&gt;Von(CL1)</td>
</tr>
<tr>
<td>Fault signal delay after power limitation invalid (^1)</td>
<td>tdpl(off)</td>
<td>30</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>Von&lt;Von(CL1)</td>
</tr>
<tr>
<td>Fault signal delay after absolute thermal shutdown (^1)</td>
<td>tdot(fault)</td>
<td>10</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>IIS→IIS,fault</td>
</tr>
<tr>
<td>Fault signal delay after open load detection at off-state (^1)</td>
<td>tdop(fault)</td>
<td>10</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>VIN=0V, VOUT&gt;VOUT(OL)</td>
</tr>
<tr>
<td>Fault signal delay after input negative slope (^1)</td>
<td>tdoff(fault)</td>
<td>10</td>
<td>µs</td>
<td></td>
<td>µs</td>
<td>VIN=4.5V to 0V</td>
</tr>
</tbody>
</table>

Remark) All voltages refer to ground pin of the device

1) not subjected production test, guaranteed by design
3.6 Feature Description

3.6.1 Driving Circuit

The high-side output is turned on, if the input pin is over VIH. The high-side output is turned off, if the input pin is open or the input pin is below VIL. Threshold is designed between VIH min and VIL max with hysteresis. IN terminal is pulled down with constant current source.

Switching a resistive load

Switching lamps
Switching an inductive load

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 0V. The gate voltage of SW1 is then nearly equal to GND. 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 VCC, 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 Device behavior at over voltage condition

In case of supply voltage greater than $V_{load\, dump}$, logic part is clamped by $ZD_{AZ}$ (35V min). And current through of logic part is limited by external ground resistor. In addition, the power transistor switches off in order to protect the load from over voltage. Permanent supply voltage than $V_{load\, dump}$ must not be applied to VCC.

3.6.3 Device behavior at low voltage condition

If the voltage supply ($V_{CC}$) goes down under $V_{CC}(Uv)$, the device outputs shuts down. If voltage supply ($V_{CC}$) increase over $V_{CC}(Cpr)$, the device outputs turns back on automatically. The device keeps off state after under voltage shutdown. The IS output is cleared during off-state.

3.6.4 Loss of Ground protection

In case of complete loss of the device ground connection, but connected load ground, the device securely changes to off if $V_{IN}$ was initially greater than $VIH$ state or keeps off state if $V_{IN}$ was initially lower than $VIL$ state.

In case of device loss of ground, IN and SEN terminal will/ could/ might be at VCC voltage.
3.6.5 Short circuit protection

**Turn-on in an over load condition including short circuit condition**

The device shuts down automatically when condition (a) is detected. The sense pin output Iis,fault. Shutdown is latched until the next reset via input pin. The device shuts down automatically when condition (b) is detected. The device restarts automatically in power limitation mode. The device shuts down automatically when condition (c) is detected and restarts automatically in absolute thermal toggling mode. The device starts current limitation when (d) is detected. The sense pin output Iis,fault during power limitation mode or thermal toggling mode.

(a) \( IL > IL(SC) \)
(b) \( \Delta Tch > dTth \)
(c) \( Tch > aTth \)
(d) \( Von > Von(CL1) \) after \( td(CL) \)

**Over load condition including short circuit condition during on-state**

The device runs automatically into power limitation mode when condition (a) is detected once after \( Von < Von(CL2) \). The device shuts down automatically when condition (b) is detected. The device restarts automatically in power limitation mode. The device shuts down automatically when condition (c) is detected and restarts automatically in absolute thermal toggling mode. The sense pin output Iis,fault during power limitation mode or thermal toggling mode.

(a) \( Von > Von(CL2) \)
(b) \( \Delta Tch > dTth \)
(c) \( Tch > aTth \)

**Power limitation control**

Current limitation control with \( IL(CL) \) when auto restart from \( \Delta Tch \) protection.

During the current limitation operation and \( Von>Von(CL1) \), the sense pin outputs Iis,fault. Even auto restart from \( \Delta Tch \) protection, if \( Von<Von(CL1) \) depends on short circuit impedance condition, the device does not operate as current limitation with \( IL(CL) \). In this case, the sense pin output sense current at on-state, Iis,fault at off-state during toggling operation with power limitation mode.

**Absolute thermal toggling**

Current limitation control with \( IL(TT) \) when auto restart from absolute \( Tch \) protection.

During the current limitation operation and \( Von>Von(CL1) \), the sense pin outputs Iis,fault. Even auto restart from absolute \( Tch \) protection, if \( Von<Von(CL1) \) depends on short circuit impedance condition, the device does not operate as current limitation with \( IL(TT) \). In this case, the sense pin output sense current at on-state, Iis,fault at off-state during toggling operation with thermal toggling mode.

**\( \Delta Tch \)**

Junction temperature differences between thermal sensor of power area and thermal sensor of control area.
State transition diagram

Turn-on
IN -> High

Thermal

Von < Von(CL1)
Yes

Over current

IL > IL(lim)
No

Current limitation

IL > IL(SC)
Yes

Shutdown by latch

IN = Low
No

Return

Von = Von(CL2)
No

Thermal

Von < Von(CL1)
Yes

Over current

IL > IL(lim)
No

Thermal

IL > IL(NL)
Yes

Von = Von(NL)

Input

IN = Low
Yes

Turn-off

No

C

C

C

Input

IN = Low
Yes

Return

C

C

C

Input

IN = Low
Yes

Return

C

C

C

Input

IL > IL(NL)
No

Von = Von(NL)

IN = Low
No

Turn-off

Over current

IL > IL(lim)
Yes

Shutdown by latch

IN = Low
No

Return

IL > IL(lim)
Yes

Over current

IL > IL(lim)
No

Thermal

Tch > Tth
No

Shutdown

IL(lim) = IL(TT)

Input

dTch > dTth
No

Current limitation

ID(CL) unexpired
Yes

Input

dTch > dTth
No

Over current

IL > IL(lim)
Yes

Input

dTch > dTth
No

Thermal

Input

IL > IL(lim)
Yes

Shutting down

Turn-on

Yes

Return

B

C

B

C

B

Return
Turn-on in an over load condition including short circuit condition

(a) $IL > IL(SC)$

[Diagram of the process flow]

- **Turn-on**
  - $IN \rightarrow High$
  - **Thermal**
  - $Von < Von(CL_1)$
    - No
    - **Current limitation**
    - $IL > IL(lim)$
      - No
      - **Thermal**
      - $IL > IL(NL)$
        - No
        - $Von = Von(NL)$
          - Yes
          - **Turn-off**
          - No
          - $IN = Low$
            - Yes
            - Before over current detection
            - After over current detection
            - Exit from off-latch

- **Over current**
  - $IL > IL(SC)$
    - Yes
    - **Shutdown by latch**
    - $IN = Low$
      - Yes
      - **Shutdown**
      - No
      - **Return**

- **Thermal**
  - $Tch > Thh$
    - Yes
    - **Shutdown**
    - $IL(lim) = IL(TT)$
      - Yes
      - **Return**
      - No
      - $dTch > dThh$
        - Yes
        - **Return**
        - No
        - $dTh > dThh$
          - Yes
          - **Shutdown**
          - No
          - $IL(lim) = IL(CL)$
            - Yes
            - **Return**
            - No
            - $Input$
              - **Shutting down?**
                - Yes
                - **Turn-on**
                - No

- **Input**
  - **Before over current detection**
  - **After over current detection**
  - **Exit from off-latch**
Turn-on in an over load condition including short circuit condition

(b) \( \Delta T_{ch} > \Delta T_{th} \)
Turn-on in an over load condition including short circuit condition

(c) $T_{ch} > aT_{th}$

- **Turn-on**
  - $IN \rightarrow \text{High}$

- **Thermal**
  - $V_{on} < V_{on}(CL1)$
    - **Yes**
      - **Over current**
    - **No**
      - **Current limitation**

- **Thermal**
  - $V_{on} < V_{on}(CL2)$
    - **Yes**
      - **Current limitation**
    - **No**
      - **Thermal**

- **Thermal**
  - $IL > IL(lim)$
    - **No**
      - **Over current**
    - **Yes**
      - **Return**

- **Thermal**
  - $IL > IL(NL)$
    - **No**
      - $V_{on} = V_{on}(NL)$
    - **Yes**
      - $IN = \text{Low}$

- **Thermal**
  - $V_{on} < V_{on}(CL1)$
    - **Yes**
      - **Over current**
    - **No**
      - **Over current**

- **Thermal**
  - $dT_{ch} > dT_{th}$
    - **No**
      - **Thermal toggling**
    - **Yes**
      - **Shutdown by latch**

- **Thermal**
  - $IL > IL(SC)$
    - **Yes**
      - **Shutdown**
    - **No**
      - **Return**

- **Thermal**
  - $IL > IL(lim)$
    - **No**
      - $V_{on} = V_{on}(CL1)$
    - **Yes**
      - $IN = \text{Low}$

- **Thermal**
  - $V_{on} < V_{on}(CL2)$
    - **Yes**
      - **Current limitation**
    - **No**
      - **Thermal**

- **Thermal**
  - $IN = \text{Low}$
    - **Yes**
      - **Turn-off**
    - **No**
      - **Turn-on**

**Thermal toggling**

- Before $aT_{ch}$ detection
- During shutdowning by $aT_{th}$ detection
- During current limitation control
- Exit from power limitation control
An over load condition which is include a short circuit condition during on-state

(a) Von > Von(CL) with weak short condition

- **Turn-on**
  - IN -> High
- **Thermal**
  - Von < Von(CL1)
    - Yes
    - Over current
  - Yes
  - Thermal
- **Over current**
  - IL > IL(SC)
    - Yes
    - Shutdown by latch
  - No
    - IN = Low
      - Yes
      - thermal
  - No
    - IL(lim)=IL(CL)
      - Yes
      - thermal
      - No
      - IL(lim)=IL(TT)
        - Yes
        - thermal
        - No
        - thermal
- **Turn-off**
  - IN = Low
    - Yes
    - thermal
    - No
    - thermal

- **Current limitation**
  - IL > IL(lim)
    - Yes
    - Input
    - No
    - thermal

- **Power limitation control**
  - Before Von(CL) detection after turn on
  - After Von(CL) detection
  - During shut downing by dTth detection
  - During current limitation control
  - Exit from power limitation control

- **Thermal**
  - Tch > Tth
    - Yes
    - thermal
    - No
    - thermal

- **Shutdown**
  - thermal

- **Return**
An over load condition including short circuit condition during on-state

(a) Von > Von(CL) with dead condition
An over load condition including short circuit condition during on-state

(b) $\delta T_{ch} > dT_{th}$

- **Turn-on**
  - $IN \rightarrow High$
  - **Thermal**
  - $V_{on} < V_{on}(CL1)$
    - No
    - **Thermal**
  - $V_{on} = V_{on}(NL)$
    - Yes
    - **Turn-off**
  - $IL > IL(NL)$
    - No
    - $V_{on} = V_{on}(NL)$
    - Yes
    - **Turn-off**

- **Over current**
  - $IL > IL(SC)$
    - Yes
    - **Shutdown by latch**
  - $IN = Low$
    - Yes
    - **Input**
    - $IL(lim) = IL(TT)$
      - Yes
      - **Return**
  - $dT_{ch} > dT_{th}$
    - Yes
    - **Thermal**
    - **Return**
  - $IL > IL(lim)$
    - No
    - **Current limitation**
    - **Thermal**
    - $V_{on} < V_{on}(CL2)$
      - Yes
      - **Current limitation**
      - **Thermal**
      - $IL > IL(lim)$
        - Yes
        - **Over current**
      - $V_{on} < V_{on}(CL1)$
        - No
        - **Over current**
      - $IN = Low$
        - Yes
        - **Input**
  - $IN = Low$
    - No
    - **Return**

**Before $dT_{th}$ detection after turn on**

- **During shutdowning by $dT_{th}$ detection**
- **Exit from thermal protection control**
An over load condition including short circuit condition during on-state

(c) $T_{ch} > aT_{th}$
3.6.6 Device behavior at small load current conduction

The device has a function which controls Ron in order to improve KILIS accuracy at small load current conduction. Von (VCC-OUT) is proportionate to IL under normal conditions. Under IL<IL(NL) condition, Ron is controlled to increase to be Von=Von(NL)=30mV(typ).
### 3.6.7 Diagnostic signal

#### Truth table

<table>
<thead>
<tr>
<th>SEN</th>
<th>Input</th>
<th>Output</th>
<th>Diagnostic output 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal Operation</td>
<td>H</td>
<td>H</td>
<td>VCC</td>
</tr>
<tr>
<td>L</td>
<td>L 1)</td>
<td>&lt; 1uA (Iis,dis)</td>
<td></td>
</tr>
<tr>
<td>Shutdown by over current detection</td>
<td>H</td>
<td>L 1)</td>
<td>&lt; 1uA (Iis,dis)</td>
</tr>
<tr>
<td>L</td>
<td>L 1)</td>
<td>&lt; 1uA (Iis,dis)</td>
<td></td>
</tr>
<tr>
<td>Power limitation</td>
<td>H</td>
<td>VOUT 6)</td>
<td>IIS = IL/KILIS in case of Von&lt;Von(CL1)</td>
</tr>
<tr>
<td>L 1)</td>
<td>Iis,fault 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>L 1)</td>
<td>&lt; 1uA (Iis,dis)</td>
</tr>
<tr>
<td>Thermal toggling</td>
<td>H</td>
<td>VOUT 6)</td>
<td>IIS = IL/KILIS in case of Von&lt;Von(CL1)</td>
</tr>
<tr>
<td>L 1)</td>
<td>Iis,fault 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>L 1)</td>
<td>&lt; 1uA (Iis,dis)</td>
</tr>
<tr>
<td>Short circuit to VCC</td>
<td>H</td>
<td>VCC</td>
<td>&lt; 2uA (Iis,offset)</td>
</tr>
<tr>
<td>L</td>
<td>VOUT 7)</td>
<td>Iis,fault in case of VOUT&gt;VOUT(OL)</td>
<td></td>
</tr>
<tr>
<td>Open Load</td>
<td>H</td>
<td>VCC</td>
<td>&lt; 2uA (Iis,offset)</td>
</tr>
<tr>
<td>L</td>
<td>VOUT 7)</td>
<td>Iis,fault in case of VOUT&gt;VOUT(OL)</td>
<td></td>
</tr>
<tr>
<td>X 8)</td>
<td>L</td>
<td>X 8)</td>
<td>X 8)</td>
</tr>
</tbody>
</table>

1) In case of OUT terminal is connected to GND via load.
2) In case of IS terminal is connected to GND via resistor.
3) IS terminal keeps Iis,fault as long as input signal activate after the over current detection.
4) IS terminal keeps Iis,fault during power limitation if Von>Von(CL1).
5) IS terminal keeps Iis,fault during thermal toggling if Von>Von(CL1).
6) VOUT depends on the short circuit condition
7) VOUT depends on the ratio of VCC-OUT-GND resistive component.
8) Don’t care
Current sense output

The device output analog feedback current proportional to output current from IS pin. In the case of much higher current than nominal load current, current sense output is saturated. In the case of much lower current than nominal load current, current sense output is above 5uA if output current is above IL(CSE) max, current sense output is below 2uA, IIS,offset max, if output current is below IL(CSE) min.

Sense current under fault condition

The device output IIS,fault, constant current, from IS pin under fault condition such as after over current detection, during power limitation and during thermal toggling. IIS,fault is specified with RIS=1kohm condition. IIS,fault is attenuated depends on VCC-VIS voltage. Operation point as IIS,fault output is also depends on RIS condition. For example, In the case of RIS=1kohm, IIS,fault could be 3.5mA to 9mA, VCC-VIS could be 4.5V to 10V, VIS could be 9V to 3.5V if VCC=13.5V. In the case of RIS is higher than 1kohm, Operation point as IIS,fault is lower than specified value but VIS should be higher than RIS=1kohm condition.
Sense current settling time

Fault signal delay time at over current detection
Fault signal delay time at power limitation

Fault signal delay time at Thermal toggling
Fault signal delay time at open load detection

- $V_{IN}$
- $V_{SEN}$
- $V_{OUT}$
- $I_{IS}$

Open load condition appears at $I_{IS,offset}$ and open load detection occurs at $t_{dop}$. The fault signal delay time is $t_{dop(fault)}$. The current $I_{IS,fault}$ appears at this time.
3.6.8 Nominal load

<table>
<thead>
<tr>
<th>Product</th>
<th>Nominal load</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHS012B</td>
<td>2.0ohm</td>
</tr>
</tbody>
</table>

3.6.9 Driving Capability

Driving Capability is specified as load impedance. Over current detection characteristics is designed below Driving Capability characteristics. If estimated load impedance which comes from peak inrush current is higher than Driving Capability characteristics, this means, the device does not detect inrush current as over current and does not shutdown the output. Depend on the conditions, Power Limitation function may work during inrush current. If estimated load impedance which comes from peak inrush current is higher than Driving Capability characteristics, Power limitation disappear within 30ms. This parameter does not mean that the device can drive the resistive load up to Driving Capability characteristics.

![Diagram showing IL vs. VIN and IL vs. t with IL(SC) specified point and IL(SC) characteristics with NHS012B: 72A and Driving Capability: NHS012B: 118mohm]
3.6.10 Cross current protection in case of H-bridge high side usage

In case of using High side driver in H-bridge circuit, High side driver protects High side driver itself and also low side driver from high power dissipation by cross current when low side driver switching on.

3.6.11 Measurement condition

Switching waveform of OUT terminal
3.7 Package drawing

12-pin Power HSSOP

Note
1) Excluding resin burr
2) Stand off
3.8 Taping information
uPD166023T1J

3.9 Marking information
uPD166023T1J

Note: *1. Composition of the lot code

- Week code (2 digit number)
- Year code (last 2 digit number)
4. Typical characteristics

- Operating current per channel VS. Channel TEMPERATURE
- Output Leakage current per channel VS. Channel TEMPERATURE
- Standby current VS. Channel TEMPERATURE
- On-state resistance per channel VS. Channel TEMPERATURE
- Low level IN pin voltage VS. Channel TEMPERATURE
- High level IN pin voltage VS. Channel TEMPERATURE
### Typical characteristics

**Under voltage shutdown**

**VS. Channel TEMPERATURE**

- Voltage range: 0 to 10 V
- Temperature range: -50 to 200 °C

**Under voltage restart**

**VS. Channel TEMPERATURE**

- Voltage range: 0 to 10 V
- Temperature range: -50 to 200 °C

**Turn on time**

**VS. Channel TEMPERATURE**

- Time range: 0 to 200 ms
- Temperature range: -50 to 200 °C

**Turn on delay time**

**VS. Channel TEMPERATURE**

- Time range: 0 to 100 ms
- Temperature range: -50 to 200 °C

**Turn off time**

**VS. Channel TEMPERATURE**

- Time range: 0 to 200 ms
- Temperature range: -50 to 200 °C

**Turn off delay time**

**VS. Channel TEMPERATURE**

- Time range: 0 to 100 ms
- Temperature range: -50 to 200 °C
4. Typical characteristics

- Slew rate on vs. Channel TEMPERATURE
- Slew rate off vs. Channel TEMPERATURE
- Turn on energy loss vs. Channel TEMPERATURE
- Turn off energy loss vs. Channel TEMPERATURE
- Over current detection current vs. Channel TEMPERATURE
- Output clamp at inductive load switch off vs. Channel TEMPERATURE
4. Typical characteristics

Sense current offset current
VS. Channel TEMPERATURE

Sense current under fault condition
VS. Channel TEMPERATURE

Open load detection threshold at off-state
VS. Channel TEMPERATURE
5. Thermal characteristics

TRANSIENT THERMAL RESISTANCE vs. PULSE WIDTH

$R_{th(c-a)} = 35 \text{ degree } C/W$

Pulse width (s)

Transient Thermal Resistance, $R_{th}$ (degreeC/W)
6. Application example in principle

RIN, RSEN, RAN values are in range of 2k to 50kohm depending microcontroller while R_L value is typically 4kohm. If necessary to raise HBM tolerated dose, adding resister between OUT terminal and Ground is effective. Resister’s value is typically 100kohm.

GND Network recommendation

In case of V_loaddump < 35V

External diode is recommended in order to prevent reverse current toward control logic part at reverse battery condition.

In case of 35V < V_loaddump < 42V

External diode and resistor are recommended in order to prevent reverse current toward control logic part at reverse battery condition and limit the current through ZDAZ at load dump condition. 100ohm is recommended as RGND.

Note: If other component is installed to prevent reverse current at reverse battery condition, diode is not required in GND Network.

Note: Approx. 10kohm additional resistor in parallel with diode is recommended depends on Vf. If performance of the diode.
## Revision History

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Page</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>Sep. 17, 2013</td>
<td>1-38</td>
<td>1st issue</td>
</tr>
<tr>
<td>2.00</td>
<td>May 22, 2015</td>
<td>23</td>
<td>&quot;Device behavior at small load current conduction&quot; is added.</td>
</tr>
</tbody>
</table>
Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.

2. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.

3. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.

4. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from such alteration, modification, copy or otherwise misappropriation of Renesas Electronics product.

5. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality”. The recommended applications for each Renesas Electronics product depend on the product’s quality grade, as indicated below. “Standard”: Computer; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots etc. “High Quality”: Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; and safety equipment etc. Renesas Electronics products are neither intended nor authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems, surgical implantations etc.) or may cause serious property damages (nuclear reactor control systems, military equipment etc.). You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application for which it is not intended. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for which the product is not intended by Renesas Electronics.

6. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.

7. Always use Renesas Electronics products to improve the quality and reliability of its products. Semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, the control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or systems manufactured by you.

8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including but not limited to the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.

9. Renesas Electronics products and technology may not be used or incorporated into any products or systems whose manufacturer, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You should not use Renesas Electronics products or technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. When exporting the Renesas Electronics product or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations.

10. It is the responsibility of the buyer or distributor of Renesas Electronics products, who distributes, disposes of, or otherwise places the product with a third party, to notify such third party in advance of the contents and conditions set forth in this document. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties as a result of unauthorized use of Renesas Electronics products.

11. This document may not be reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.

12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.

(Note 1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.

(Note 2) “Renesas Electronics products” means any product developed or manufactured by or for Renesas Electronics.