Outline:

This document provides an overview of the surface-mount small-signal diodes, the diode ratings, letter symbols, graphical symbols, and electrical characteristics, the power dissipation, transient thermal resistance, and application circuit examples.

Small signal diodes mainly refer to diodes in small packages with a power dissipation of 1W or less. A wide variety of products are available, including PN-junction diode, Schottky barrier diodes.
Table of Contents

Outline: .................................................................................................................................................. 1

Table of Contents ............................................................................................................................. 2

Description .......................................................................................................................................... 3

1. Diode rating ..................................................................................................................................... 3
   1.1. Definition of maximum rating ............................................................................................... 3
   1.2. Maximum rating of the diode ............................................................................................... 3

2. Character symbol .......................................................................................................................... 5
   2.1. General rectification, detection and switching diodes .............................................................. 5
   2.2. Schottky barrier diode ........................................................................................................... 5
   2.3. Other ....................................................................................................................................... 6

3. Graphical symbol ........................................................................................................................... 7

4. Electrical Characteristics ............................................................................................................... 8
   4.1. General-Purpose Rectifiers, Detectors and switching Diodes ................................................ 8
   4.2. Schottky barrier diode ........................................................................................................... 13

5. Power Dissipation ......................................................................................................................... 15
   5.1. ESC ........................................................................................................................................ 15
   5.2. SSM ....................................................................................................................................... 15
   5.3. USC ....................................................................................................................................... 16
   5.4. USM ....................................................................................................................................... 16
   5.5. S-Mini ................................................................................................................................... 17

6. Transient Thermal Resistance ($r_{th}$) ............................................................................................ 18

7. Typical Circuit Diagram ............................................................................................................... 19
   7.1. Switching diode .................................................................................................................... 19
   7.2. Switching circuit diagram .................................................................................................... 20

8. Related Links ............................................................................................................................... 21

RESTRICTIONS ON PRODUCT USE .............................................................................................. 22
Description

1. Diode rating
1.1. Definition of maximum rating
For semiconductor devices, applied voltage, current, temperature, power loss, and other factors are major factors limiting the operation function.

The maximum rating is the maximum allowable value that must not be exceeded in order to operate the semiconductor element effectively and ensure sufficient reliability, and is specified as the absolute maximum rating.

The absolute maximum rating (hereinafter referred to as the maximum rating) is defined as "the limit value that must not be exceeded either instantaneously or simultaneously, and that must not be reached for any two items at the same time." Operation exceeding the maximum rating may cause breakage, damage or deterioration, and may cause explosion or burn-in hazards.

1.2. Maximum rating of the diode

Table 1.1 Voltage ratings

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Content of the maximum rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Reverse Voltage</td>
<td>$V_{RM}$</td>
<td>Peak value of the alternating current voltage that can be applied in the opposite direction within the range where the mean voltage does not exceed $V_{R}$ given in the following paragraph</td>
</tr>
<tr>
<td>DC Reverse Voltage</td>
<td>$V_{R}$</td>
<td>Maximum value of the DC voltage that can be applied in the reverse direction</td>
</tr>
</tbody>
</table>

Table 1.2 Current ratings

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Content of the maximum rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Forward Current</td>
<td>$I_{FM}$</td>
<td>The peak of an alternating forward current that can flow within $I_{O}$ of the following term</td>
</tr>
<tr>
<td>Average Rectification</td>
<td>$I_{O}$</td>
<td>Maximum value of the average rectified current or direct current that can flow in the forward direction</td>
</tr>
<tr>
<td>Surge Current</td>
<td>$I_{FSM}$</td>
<td>Maximum surge current that can flow only once with a specified pulse width</td>
</tr>
</tbody>
</table>

Table 1.3 Power Dissipation Ratings

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Content of the maximum rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Dissipation</td>
<td>$P$</td>
<td>Continuously acceptable power loss under certain ambient and cooling conditions, determined by junction temperature ($T_j$), ambient temperature ($T_a$), and thermal resistance from the junction of the device to the atmosphere ($R_{th (j-a)}$). $P = \frac{T_j-T_a}{R_{th (j-a)}}$</td>
</tr>
<tr>
<td>Peak Reverse Power</td>
<td>$P_{RM}$, $P_{ZM}$</td>
<td>Maximum allowable power loss when intermittent power is applied to a constant voltage diode</td>
</tr>
<tr>
<td>Dissipation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse Surge Power</td>
<td>$P_{RSM}$, $P_{ZSM}$</td>
<td>Maximum surge power that can be applied only once to a constant voltage diode with a specified pulse width</td>
</tr>
</tbody>
</table>
Table 1.4 Temperature ratings

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Content of the maximum rating</th>
</tr>
</thead>
</table>
| Junction Temperature        | T<sub>j</sub> | The maximum junction temperature T<sub>max</sub> must not only operate as defined by the material and reliability of the element, but also be considered to be reliable in terms of degradation, life, etc. Generally, the degradation of the element is accelerated as the junction temperature rises, and the following relation is recognized between the average life L<sub>m</sub> (hours) and junction temperature T<sub>j</sub> (K) with A and B as element-specific constants.  
  \[
  \log L_m = A + \frac{B}{T_j}
  \]

  Therefore, the maximum junction temperature of the element that requires long life guarantee is determined. In addition, the temperature dependence of the reverse current (off-current) is expressed by the following equation.

  \[
  I_R \propto A \cdot \exp\left(-\frac{qV}{kT_j}\right)
  \]

  A: Constant with element, q: Electron charge, K: Boltzmann constant, T<sub>j</sub>: Junction temperature (absolute temperature), V: Applied voltage

  As can be seen in the above equation, the reverse current at high temperatures is large, and the power loss of the reverse current at high temperatures is also large. This power loss can cause thermal runaway due to repetition of increasing junction temperature and increasing reverse current. In order to suppress this thermal runaway, the junction temperature and heat dissipation conditions, etc., must be sufficiently considered.

| Storage Temperature Range  | T<sub>stg</sub> | The storage temperature T<sub>stg</sub> is defined by the nature and reliability of the materials that make up the components other than the silicon chip, and is defined by the ambient temperature at which the components can be stored without operating the device. When storing, be careful about oxidation of the terminals and take the conservation method into consideration.

  Figure 1 shows an example of the relationship between diode life and storage temperature.

  \[
  T_n = \frac{T_{stg} - T_a}{T_{jmax} - T_a} \quad (T_a: \text{normally } 25^\circ\text{C})
  \]

  Figure 1.1 Diode Failure Rate (MIL-HDBK-217A)
2. Character symbol

2.1. General rectification, detection and switching diodes

Table 2.1 Symbols for Diode Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Definition or description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_F$</td>
<td>Forward Voltage</td>
<td>DC value of the voltage drop caused by the forward current flowing through the element ($I_F$ specification)</td>
</tr>
<tr>
<td>$V_R$</td>
<td>Reverse Voltage</td>
<td>Voltage applied in the reverse direction of the element</td>
</tr>
<tr>
<td>$V_{(BR)}$</td>
<td>Breakdown Voltage</td>
<td>Voltage ($I_R$ specification) at the specified reverse current value in the breakdown region</td>
</tr>
<tr>
<td>$I_F$</td>
<td>Forward Current</td>
<td>DC current value ($V_F$ specification) flowing in the forward direction of the element under specified voltage conditions</td>
</tr>
<tr>
<td>$I_R$</td>
<td>Reverse Current</td>
<td>DC current value ($V_R$ specification) flowing in the reverse direction of the element according to the specified voltage condition</td>
</tr>
<tr>
<td>$C_T$</td>
<td>Terminal Capacitance</td>
<td>Capacitance value between pins under specified voltage conditions ($V_R$ specification)</td>
</tr>
<tr>
<td>$t_{TR}$</td>
<td>Reverse Recovery Time</td>
<td>When the PN junction is conducted in the forward direction, even if a reverse voltage is applied to the PN junction to cut it off, the reverse current flows in the reverse direction with low impedance while the minority carriers accumulated in the junction remain. Time required to recover to 10% of reverse current $I_R$ from this shut-off ($I_F$, $I_R$ operation circuit specified)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Rectifying Efficiency</td>
<td>AC voltage $V_i$ (rms) is applied to the element, and is expressed by the following equation according to the DC voltage $V_O$ value after rectification $\eta = \frac{V_O(DC)}{\sqrt{2V_i(rms)}}$ ($V_i$, operation circuit specification)</td>
</tr>
</tbody>
</table>

2.2. Schottky barrier diode

Table 2.2 Characteristic Symbols for Shot Chibaria Diodes

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Definition or description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF</td>
<td>Noise Figure</td>
<td>It mainly represents the noise level of the Schottky barrier diode in the high frequency band.</td>
</tr>
<tr>
<td>BO</td>
<td>Reverse Burning</td>
<td>Energy tolerance when energy is applied in the opposite direction of the Schottky Junction</td>
</tr>
<tr>
<td>$\Delta V_F$</td>
<td>Forward Voltage Difference</td>
<td>When used for DBM, $V_F$ is ranked and this $V_F$ variation width</td>
</tr>
<tr>
<td>$\Delta C_T$</td>
<td>Terminal Capacitance Difference</td>
<td>$C_T$ difference within the same $\Delta V_F$ rank</td>
</tr>
</tbody>
</table>
## 2.3. Other

### Table 2.3 Other Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Definition or description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_a$</td>
<td>Ambient Temperature</td>
<td>The temperature of air measured in a sufficiently uniform environment that is cooled by natural convection of air alone and is not substantially affected by reflection and radiation</td>
</tr>
<tr>
<td>$R_{th}$</td>
<td>Thermal Resistance</td>
<td>A value representing how many times the junction temperature rises per unit power over an external specified point when the heat flow due to junction power consumption is in equilibrium</td>
</tr>
<tr>
<td>$R_{th(j-a)}$</td>
<td>Thermal Resistance (between junction and ambient atmosphere)</td>
<td>Thermal Resistance Generally Without Heat Dissipator</td>
</tr>
<tr>
<td>$R_{th(j-c)}$</td>
<td>Thermal Resistance (between junction and case)</td>
<td>Thermal resistance from junction to package surface</td>
</tr>
<tr>
<td>$r_{th}$</td>
<td>Transient Thermal Resistance</td>
<td>A value representing how many times the junction temperature rises per unit power over an external specified point when the case temperature or ambient temperature is constant and the junction power loss is pulsed</td>
</tr>
</tbody>
</table>
3. Graphical symbol

The letters and numbers in the graphic symbols are for illustrative purposes only and are not part of the symbols. These characters are shown below.

- A: Anode
- C: Cathode

<table>
<thead>
<tr>
<th>Type</th>
<th>Graphical symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diode</td>
<td>![Diode Symbol]</td>
</tr>
<tr>
<td>Zener diode</td>
<td>![Zener Diode Symbol]</td>
</tr>
</tbody>
</table>

Figure 3.1 Schematic Symbols
4. Electrical Characteristics

4.1. General-Purpose Rectifiers, Detectors and switching Diodes

(1) PN junction

Consider the contact between a P-type semiconductor and an N-type semiconductor. In this case, we assume that the P-shaped region and the N-shaped region exist adjacent to each other in a single crystal. Such a structure is called a PN junction, and the band structure is shown in Figure 4.1.

![PN junction diagram]

The P-type and the N-type part originally differ in the height of the Fermi level. The Fermi levels are located near the upper edge of the filling band in the P-type region and near the lower edge of the conduction band in the N-type region. If they are in contact with each other, electrons in the N-type region near the contact move to the P-shaped region, where they recombine with free holes. This electron transfer lowers the level of the conduction band in the N-type region and reaches a new equilibrium state where the Fermi level matches both the N-type and P-type regions. At this time, the reduction of the conduction band level is equal to the work-function difference in both regions, and a diffusive potential called \( V_d \) appears between the two regions.

In the vicinity of the boundary layer, free electrons in the N-type region recombine with free holes in the P-type region, and free carriers are depleted, and later distributed donor ions (positive) and acceptor ions (negative) exist, and this distributed space charge exists, even at the diffusion potential. This distributed space-charge layer generates an electric field from the N-type to the P-type, which acts to move electrons to the N-type and holes to the P-type, respectively.

When electrodes are attached to each region of such a structure, current flows well when a voltage is applied in a direction where the P type is positive and the N type is negative. When a voltage is applied in the opposite direction, the current hardly flows and strong rectification appears.

**Figure 4.1 Energy Level Diagram of PN Junctions**
(2) Characteristics of the diode

Figure 4.2 shows the static characteristics of the diode. Rectifier detection and switching diodes utilize forward characteristics, where the forward current \( I_F \) is expressed by the following equation.

\[
I_F = I_S \exp \left( \frac{qV_F}{KT} - 1 \right)
\]  

(1)

\( I_S \) : Reverse saturation current  
\( T \) : Absolute temperature  
\( V_F \) : Forward voltage  
\( K \) : Boltzmann constant  
\( q \) : Total charge of electrons

The above equation is for the small current region. In the large current region, a voltage drop occurs due to the internal resistance, and the value of \( V_F \) is changed, so it cannot be applied.

The forward characteristics of the diode depend on the semiconductor material and structure used. A typical example is the difference between Ge and Si materials.

Ge diodes have rising voltages of 0.1 to 0.2 V and Si diodes of 0.6 to 0.7 V, which are essential to the difference in energy gap between the two type.

The forward characteristics vary with temperature. In the small current region, both Si and Ge vary with \( dV/dT = -2.3 \) mV/°C.

![Figure 4.2 Static Characteristics of Diodes](image_url)
However, in the large current range, the temperature coefficient of the voltage drop due to the internal resistance becomes positive, so the temperature coefficient of \( \frac{dV}{dT} \) becomes small.

Figure 4.3 shows the \( I_F-V_F \) temperature characteristics of a Si diode.

When a voltage is applied in the reverse direction of the diode, the current flowing is called the reverse current \( I_R \) or saturation current \( I_S \).

Generally, Ge-Diodes are several \( \mu \)A (\( 10^{-6} \) A) and SiDiodes are several nA (\( 10^{-9} \) A). Figure 4.4 shows the \( I_R-V_R \) temperature characteristics of a Si diode. The \( I_R \) changes approximately twice as much as the temperature change of 8 to 10°C. Therefore, the inverse current \( I_R \) is approximated.

\[
I_R = I_{R0} \exp \left( k(T - T_0) \right) \quad \ldots \ldots \quad (2)
\]

\( I_{R0} \): Reverse current at standard temperature \( T_0 \)
\( k \): Constant determined by the semiconductor material

It can be expressed as about 0.1/°C for Si and about 0.08/°C for Ge.
Figure 4.5 shows the operating principle of the diode detection circuit. The characteristics required for these detection and switching diodes are as follows. For detection diodes, a higher detection efficiency $\eta$ is required first. This requires a small $V_F$, a small $I_R$, and a small junction capacitance $C_j$. In the case of switching diodes, a fast switching time is required. For this purpose, the reverse recovery time $t_{rr}$ must be small and $C_j$ must be small. Naturally, it is also important that the $I_R$ is small.

**Figure 4.5 Diode Detection Operation**
When forward current $I_F$ is applied to the diode, even if the reverse voltage $V_R$ is applied to the diode to cut it off, the reverse direction also becomes low-impedance while the minority carriers accumulated in the P junction remain, and a large reverse current $I_R$ flows. The time from the cutoff to the recovery of 10% of the reverse current $I_R$ is called the reverse recovery time $t_{rr}$, which represents the switching time of the diodes. The measurement circuit is shown in Figure 4.6.

\[
t_{rr} = \tau \ln \left(1 + \frac{I_F}{I_R}\right)
\]

\[\tau: \text{Minority carrier lifetime}\]

Therefore, the shorter the minority carrier lifetime, the smaller the $I_F$, and the larger the $I_R$, the shorter the $t_{rr}$. 

**Figure 4.6 Reverse Recovery Time $t_{rr}$ Measuring Circuit**
4.2. Schottky barrier diode

Because this diode utilizes the rectifying property of metal-semiconductor contacts, which was proposed by Schottky, this is called a Schottky barrier diode.

It is characterized by creating a shotky barrier between the deposited metal and the N-shaped epitaxial layer.

Typical metals that create a Schottky barrier are molybdenum (Mo), titanium (Ti), and so on. The Schottky barrier diode has a small rising voltage, similar to a Ge diode, and has no complicated factors such as needle pressure, such as a point contact diode, making it easy to handle in manufacturing.

This diode is mainly used for mixed circuits and detection circuits above the UHF band, and has the reliability advantage of a noise figure of 2 dB or more lower than that of the point contact type, and also strong mechanically and electrically. Figure 4.7 shows the structure of the Schottky barrier diode.

![Figure 4.7 Structural Diagram of Shotky Barrier Diode](image)
Reliability Test Example (Switching Diode)
The following shows a test example of the Super Mini Type (S-Mini) switching diode.

Table 4.1 Switching Diode Reliability Test Example

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Test Condition</th>
<th>Failure Size / Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Thermal tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat resistance (Reflow)</td>
<td>Peak : 260 deg.C (a moment) Preheat : 180 to 180 deg.C, 60 to 120 s 4 times</td>
<td>0 / 32</td>
</tr>
<tr>
<td>Heat resistance (Flow)</td>
<td>Peak : 260 deg.C Immersion time : 10 s Once</td>
<td>0 / 32</td>
</tr>
<tr>
<td>Heat resistance (Iron)</td>
<td>Temperature of the iron tip : 400 deg.C Time : 3 s Once</td>
<td>0 / 32</td>
</tr>
<tr>
<td>Temperature cycling</td>
<td>-55 deg.C (30 min) to 125 deg.C (30 min), 100 cycles</td>
<td>0 / 50</td>
</tr>
<tr>
<td>2. Mechanical tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solderability</td>
<td>Solder bath : Sn-Ag-Cu 245 deg.C, 5 s, once (using Flux) Solder bath : Sn-Pb 230 deg.C, 5 s, once (using Flux)</td>
<td>0 / 11</td>
</tr>
<tr>
<td>3. Life tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steady state operation</td>
<td>Ta = 25 deg.C, 10 = 100mA, 1000 h</td>
<td>0 / 30</td>
</tr>
<tr>
<td>High temp. reverse bias</td>
<td>Ta = 125 deg.C, VR = 80V, 1000 h</td>
<td>0 / 30</td>
</tr>
<tr>
<td>High temp. storage</td>
<td>Ta = 125 deg.C, 1000 h</td>
<td>0 / 30</td>
</tr>
<tr>
<td>High temp. high humidity storage</td>
<td>Ta = 85 deg.C, RH = 85%, 1000 h</td>
<td>0 / 30</td>
</tr>
<tr>
<td>High temp. high humidity bias</td>
<td>Ta = 85 deg.C, RH = 85%, VR = 80V, 1000 h</td>
<td>0 / 30</td>
</tr>
<tr>
<td>Pressure cooker test</td>
<td>Ta = 121 deg.C (200kPa) (Unsaturated), 96 h</td>
<td>0 / 20</td>
</tr>
</tbody>
</table>
5. Power Dissipation

Note that the power dissipation varies greatly depending on the mounting method of the element and the ambient temperature. The following shows examples of power dissipation changes by package.

5.1. ESC

![ESC Power Dissipation PD – Ta characteristic](image)

Figure 5.1 ESC Power Dissipation $P_D$ – $T_a$ characteristic example

5.2. SSM

![SSM Power Dissipation PD – Ta characteristic](image)

Figure 5.2 SSM Power Dissipation $P_D$ – $T_a$ characteristic example
5.3. USC

Figure 5.3 USC Power Dissipation PD – Ta characteristic example

5.4. USM

Figure 5.4 USM Power Dissipation PD – Ta characteristic example
5.5. S-Mini

![Figure 5.5 S-Mini Power Dissipation $P_D$ – $T_a$ characteristic example-](image)

Figure 5.5 S-Mini Power Dissipation $P_D$ – $T_a$ characteristic example-
6. Transient Thermal Resistance ($r_{th}$)

The power dissipation when pulsed rather than continuous power is applied to the diode is determined by the transient thermal resistance $r_{th}$ and the following table. Fig. 6.1 shows the transient thermal resistance $r_{th}$-t.

Table 6.1 Allowable Power Calculation Formula for Pulsed Power Applications

<table>
<thead>
<tr>
<th>Type of load</th>
<th>Power waveform</th>
<th>Permissible power (crest value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single pulse loading</td>
<td>$P_M$</td>
<td>$P_M = \frac{T_j-T_a}{r_{th}}$</td>
</tr>
<tr>
<td>Load where a single pulse load is superimposed on a continuous DC load</td>
<td>$P_Z$</td>
<td>$P_M = \frac{T_j-T_a-P_Z \cdot R_{th}}{r_{th}} + P_Z$</td>
</tr>
<tr>
<td>Continuous repetitive pulse loading</td>
<td>$P_M$</td>
<td>$P_M = \frac{T_j-T_a}{\frac{R_{th}}{t} + (\frac{1}{t})r_{(t+T)<em>h} - r</em>{Th} + r_{th}}$</td>
</tr>
</tbody>
</table>

Note: $R_{th}$ : Thermal resistance when steady

$r_{th}$ : Transient thermal resistance at $t$

$r_{Th}$ : Transient thermal resistance at $T$

$r_{(t+T)_h}$ : Transient thermal resistance at $t + T$

![Image of transient thermal resistance graph](image_url)

**Figure 6.1 $r_{th}$ by Diode Package-t**
Typical Circuit Diagram

7. Typical Circuit Diagram

7.1. Switching diode

(a) 8 Inputs NAND gate

(b) 6 Inputs NOR gate

(c) 4 Inputs NAND gate

(d) 4 Inputs NOR gate

(e) Input protection circuit

(f) Output protection circuit

(g) Delay time control circuit

(h) Square wave generator

(i) MOS IC output protection circuit
7.2. Switching circuit diagram

(a) (b) Level shift circuit

(c) (d) (e) (f) Clipping circuit

(g) Slicer circuit

(h) Limiter circuit
8. Related Links

- Product Lineup (Catalogue) [Click]
- TVS diode (parametric search) [Click]
- Schottky barrier diode (parametric search) [Click]
- Switching diode (parametric search) [Click]
- Zener diode (parametric search) [Click]
- High Frequency Diode (Details) [Click]
- Online distributor purchase, inventory search [Click]
- FAQ of small-signal diodes [Click]
- FAQ of the TVS diode [Click]
- Application notes [Click]
- Reference Design Center [Click]
RESTRICTIONS ON PRODUCT USE

Toshiba Corporation and its subsidiaries and affiliates are collectively referred to as “TOSHIBA”.

Hardware, software and systems described in this document are collectively referred to as “Product”.

- TOSHIBA reserves the right to make changes to the information in this document and related Product without notice.

- This document and any information herein may not be reproduced without prior written permission from TOSHIBA. Even with TOSHIBA’s written permission, reproduction is permissible only if reproduction is without alteration/omission.

- Though TOSHIBA works continually to improve Product’s quality and reliability, Product can malfunction or fail. Customers are responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of Product could cause loss of human life, bodily injury or damage to property, including data loss or corruption. Before customers use the Product, create designs including the Product, or incorporate the Product into their own applications, customers must also refer to and comply with (a) the latest versions of all relevant TOSHIBA information, including without limitation, this document, the specifications, the data sheets and application notes for Product, and the procedures and conditions set forth in the “TOSHIBA Semiconductor Reliability Handbook” and (b) the instructions for the application with which the Product will be used with or for. Customers are solely responsible for all aspects of their own product design or applications, including but not limited to (a) determining the appropriateness of the use of this Product in such design or applications; (b) evaluating and determining the applicability of any information contained in this document, or in charts, diagrams, programs, algorithms, sample application circuits, or any other referenced documents; and (c) validating all operating parameters for such designs and applications. TOSHIBA ASSUMES NO LIABILITY FOR CUSTOMERS’ PRODUCT DESIGN OR APPLICATIONS.

- PRODUCT IS NEITHER INTENDED NOR WARRANTED FOR USE IN EQUIPMENTS OR SYSTEMS THAT REQUIRE EXTRAORDINARILY HIGH LEVELS OF QUALITY AND/OR RELIABILITY, AND/OR A MALFUNCTION OR FAILURE OF WHICH MAY CAUSE LOSS OF HUMAN LIFE, BODILY INJURY, SERIOUS PROPERTY DAMAGE AND/OR SERIOUS PUBLIC IMPACT (“UNINTENDED USE”). Except for specific applications as expressly stated in this document, Unintended Use includes, without limitation, equipment used in nuclear facilities, equipment used in the aerospace industry, lifesaving and/or life supporting medical equipment, equipment used for automobiles, trains, ships and other transportation, traffic signaling equipment, equipment used to control combustions or explosions, safety devices, elevators and escalators, and devices related to power plant. IF YOU USE PRODUCT FOR UNINTENDED USE, TOSHIBA ASSUMES NO LIABILITY FOR PRODUCT. For details, please contact your TOSHIBA sales representative or contact us via our website.

- Do not disassemble, analyze, reverse-engineer, alter, modify, translate or copy Product, whether in whole or in part.

- Product shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable laws or regulations.

- The information contained herein is presented only as guidance for Product use. No responsibility is assumed by TOSHIBA for any infringement of patents or any other intellectual property rights of third parties that may result from the use of Product. No license to any intellectual property right is granted by this document, whether express or implied, by estoppel or otherwise.

- ABSENT A WRITTEN SIGNED AGREEMENT, EXCEPT AS PROVIDED IN THE RELEVANT TERMS AND CONDITIONS OF SALE FOR PRODUCT, AND TO THE MAXIMUM EXTENT ALLOWABLE BY LAW, TOSHIBA (1) ASSUMES NO LIABILITY WHATSOEVER, INCLUDING WITHOUT LIMITATION, INDIRECT, CONSEQUENTIAL, SPECIAL, OR INCIDENTAL DAMAGES OR LOSS, INCLUDING WITHOUT LIMITATION, LOSS OF PROFITS, LOSS OF OPPORTUNITIES, BUSINESS INTERRUPTION AND LOSS OF DATA, AND (2) DISCLAIMS ANY AND ALL EXPRESS OR IMPLIED WARRANTIES AND CONDITIONS RELATED TO SALE, USE OF PRODUCT, OR INFORMATION, INCLUDING WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.

- Do not use or otherwise make available Product or related software or technology for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). Product and related software and technology may be controlled under the applicable export laws and regulations including, without limitation, the Japanese Foreign Exchange and Foreign Trade Law and the U.S. Export Administration Regulations. Export and re-export of Product or related software or technology are strictly prohibited except in compliance with all applicable export laws and regulations.

- Please contact your TOSHIBA sales representative for details as to environmental matters such as the RoHS compatibility of Product. Please use Product in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. TOSHIBA ASSUMES NO LIABILITY FOR DAMAGES OR LOSSES OCCURRING AS A RESULT OF NONCOMPLIANCE WITH APPLICABLE LAWS AND REGULATIONS.