Surface Mount Small Signal MOSFET Precautions for use

Outline:

This document provides an overview of the compact surface-mount MOSFET, as well as a description of its construction, features, ratings, and electrical characteristics.

It also compares the characteristics (operating voltage/switching characteristics) between MOSFET and a bipolar transistor with built-in resistor.

Small package MOSFET are used for on/off switches such as 7002 series and load switches of several A or less.

This is for reference only. Do not design the final equipment in this document.

Table of Contents

1. Structure and Features

1.1. Outline of MOSFET

Compared to bipolar transistors, MOSFET,

(1) Because it is a majority carrier device, there is no accumulation effect of minority carriers switching speed is fast.

(2) Since the temperature coefficient is negative, problems such as thermal runaway and secondary yield are reduced.

(3) Since it is not necessary to consider the drive current almost, power saving can be achieved.

With the above features, this is a device widely used for communications equipment, audio visual equipment, etc.

1.2. Construction of MOSFET

MOSFET can be broadly divided into three types, as shown in Figure below.

Figure 1.1 Horizontal D-MOS construction.

This structure makes it possible to reduce the feedback capacitance because the current flows parallel to the surface of the element and the drain contact becomes the surface. It is mainly used for high-frequency MOSFET and is suitable for high-speed switching in the MHz band.

Figure 1.2 Vertical D-MOS construction (planar).

In this structure, the same diffusion window is used for the drain substrate with high resistance, and the gate region to be the channel and the source region to be heavily doped are diffused, and the channel is constructed by utilizing the diffusion difference between the two.

Figure1.3 Trench construction (U-MOS).

The gate is a U-groove, and the channel is formed vertically to achieve high integration and reduce on-resistance. The on-resistance per unit area of this structure is smaller than that of the planar structure, so the on-resistance can be reduced.

In all the above three types of structures, parasitic diodes enter between the drain and source, so care must be taken in actual design.

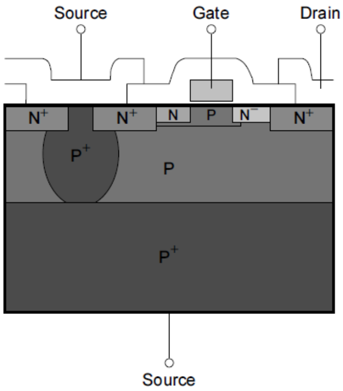


Figure. 1.1 Horizontal D-MOS construction

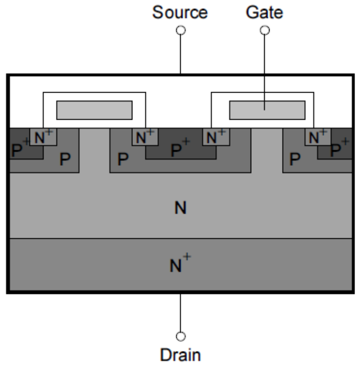


Fig. 1.2 Vertical D-MOS construction (planar)

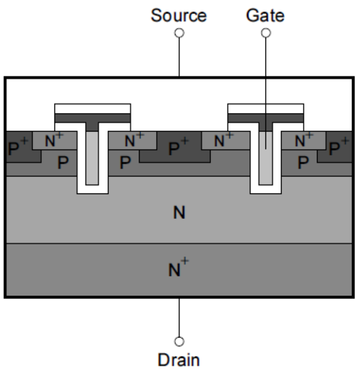


Figure. 1.3 Trench construction (U-MOS)

1.3. Features of TOSHIBA CORPORATION Small Size Surface Mount MOSFET

(1) Drive current not required

Because it is a voltage control element, almost no gate drive current flows, resulting in very low power consumption.

(2) Reduced number of parts

Compared to a transistor with a built-in resistor (digital transistor), there is no selection of a type for each drive voltage, so the number of product types is reduced, which simplifies circuit design and component management.

(3) Driving at low voltage is possible

The lineup is centered on low-voltage drive type, so it is suitable for battery-powered equipment.

(4) Extensive product lineup

Available from general-purpose products with an on-resistance of 20 Ω to ultra-low on-resistance products with an on-resistance of 10 m Ω or less. Drain-source withstand voltage up to 100 V is available for a wide range of circuits.

(5) Excellent switching characteristics

Because it is a majority carrier element, there is no accumulation effect of minority carriers, and excellent switching characteristics are realized.

(6) Compact, high power dissipation surface mount package ideal for high density design

Compact, high power dissipation surface mount package ideal for high density design

In order to accommodate high-density surface-mount with the downsizing and weight reduction of equipment, the lineup is centered on SMDs (Surface Mount Device). LGA(Land Grid

Array), WCSP(Wafer level Chip Scale Package) and flat lead packages can be selected from a compact, high-power dissipation product lineup to suit your application.

2. Maximum rating

2.1. 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.

2.2. Drain-source voltage VDS

2.2.1. Maximum allowable value of the voltage that can be applied between the drain and source

Drain-source breakdown voltage specifications can be classified into V_{DSS}, V_{DSX}, V_{DSR}, V_{DSO} four categories, for example, according to bias conditions between gate-sources.

There is little difference in the size of V_{DSS}, V_{DSX}, V_{DSR}, and the relation of V_{DSS}=V_{DSX}=V_{DSR} holds.

If you specify V_{DSS} in this section, it will be the highest draining-source VDS rating. However, that the above relationship does not hold for the trench-structured element.

Suppose that a voltage lower than V_{DS} max. rating is applied between the drain and source in V_{DSO} mode (gate open). In such cases, MOSFET itself has an extremely high-impedance input. Therefore, the gate/source is biased due to the induction of static electricity, etc., and this may cause the gate/source to become "on" and damage the device. Therefore ,don't use this mode.

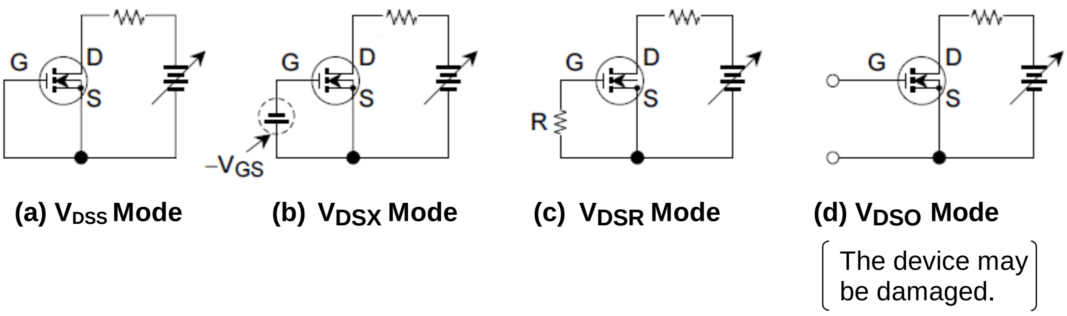


Figure 2.1 Drain-Source Breakdown Voltage

2.3. Gated-source voltage V_{GSS}

2.3.1. Maximum allowable value of the voltage that can be applied between the gate and source

There are two types of V_{GSS} items, one with both positive and negative signs and one with positive and negative signs. Elements with both positive and negative signs may have a bi-directional protection diode inserted between the gate and source to prevent gate breakdown or may not have a protection diode. A protection diode in one direction is inserted in the element with either sign of positive or negative.

2.4. Drain current I_D

2.4.1. Maximum allowable value of the drain current that can be supplied by direct current

Many elements describe the maximum drain current rating in terms of DC rating and pulse rating. For an element whose pulse rating is not stated, consider that nearly twice the DC rating is the pulse rating.

2.5. Power Dissipation (drain dissipation: P_{Dmax})

The power dissipation of a single MOSFET element depends on the packaging. Please refer to the individual specifications for the power dissipation of each package.

Figures 2.2 and 2.3 show examples of power dissipation characteristics for each package.

In the mounted state, the power dissipation from the lead to the board is increased, which means that the power dissipation is greater than that of a single unit.

The heat dissipation during mounting varies greatly depending on the board material, board area, Pad area, ambient temperature, and other operating environments. Design the product with sufficient heat dissipation in mind when using it.

Please note that the published power dissipation values for each individual product type may differ in some cases.

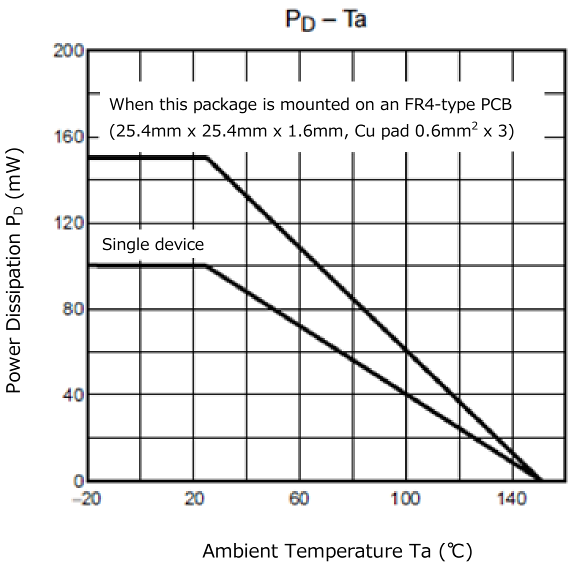


Figure 2.2 Power Dissipation Example for USM Package

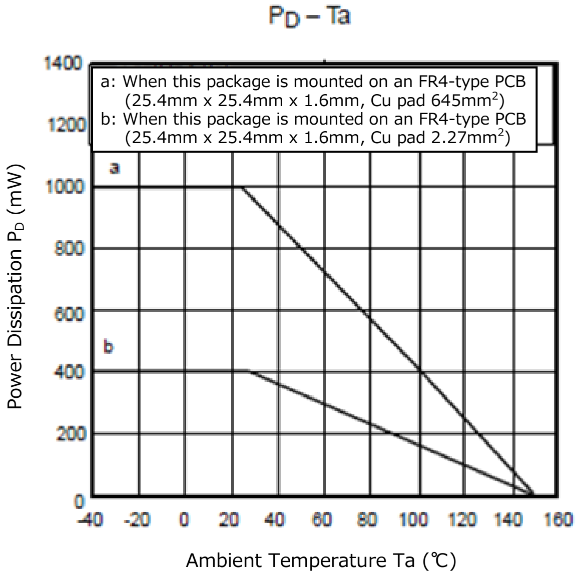


Figure 2.3 Power Dissipation Example for UDFN6B Packag

3. Electrical Characteristics

3.1. Terms used with MOSFET

(1) $|Y_{fs}|$: Forward transfer admittance

$$|Y_{fs}| = \Delta I_D / \Delta V_{GS}$$

$|Y_{fs}|$ expresses MOSFET's sensitivity or amplifying power.

(2)Vth : Gate threshold voltage

The gate-source voltage when the drain current begins to flow (in the threshold region) when the gate-source voltage is gradually increased with a voltage applied between the drain and source.

(3)$R_{DS\ (ON)}$: Drain-source ON-resistance

It corresponds to the collector-emitter saturation-voltage $V_{CE(sat)}$ of the bipolar transistor, and is a guideline for determining the self-loss (dissipation) in the ON state.

(4)$V_{DS\ (ON)}$: Drain-source ON-voltage

This is the dissipation in the ON state, which is the same as for $R_{DS(ON)}$ and is expressed as a voltage.

(5)C_{iss}, C_{rss}, C_{oss} : Capacitances

C_{iss}, C_{rss} and C_{oss} the are input capacitance, feedback capacitance and output capacitance respectively.

When MOSFET is used in switching operation, this capacitance constrains the available frequency or switching speed.

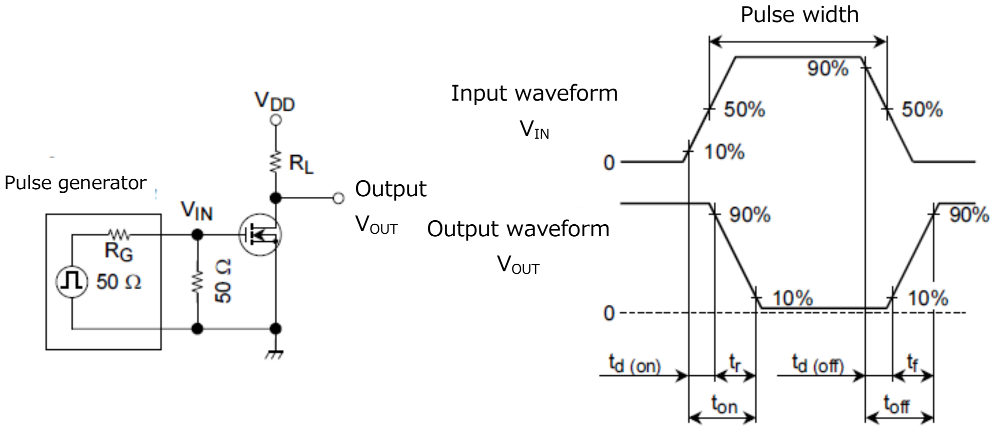
(6)t_{on}, t_{off}, t_r, t_f : Switching time

Because MOSFET is a majority carrier device, its switching properties are much faster than bipolar transistors, and it is superior in high-speed operation and high-frequency operation.

Since this device has no accumulation time due to the accumulation effect of carriers and no temperature dependence of capacitance, the switching characteristics are hardly affected by temperature.

Figure 3.1 shows an example of a switching time measurement circuit and input/output waveforms.

© 2022
Toshiba Electronic Devices & Storage Corporation



(a) Measurement Circuit (b) Input/Output Waveforms

Figure 3.1 Switching Time Measurement Circuit and Input/Output Waveforms

3.2. Symbols and definitions of switching time in Input/Output waveforms

(1)$t_{d\ (on)}$: Turn-ON delay time

Charge time required to raise the input capacitance C_{iss} to the gate threshold voltage V_{th}.

(2)t_r : Rise time

Charge duration required to pull the charge-based gate-to-source voltage to be charged to the input capacitance from the gate threshold voltage V_{th} to a specified V_{GS} level between the linear and saturated regions.

(3)$t_{d\ (off)}$: Turn-OFF delay time

Discharge duration required to pull the charge-based potential on the input capacitance down to a specified V_{GS} level in the linear region by the drive voltage in the saturation region.

(4)t_f : Fall time

Time required for the voltage based on the charge charged in the input capacitance to be lowered from the driving voltage in the saturation region to the gate threshold voltage V_{th} level and the output voltage to be raised to the supply voltage.

The switching time can be divided into four times as described above. The sum of the turn-ON delay time $t_{d(on)}$ and the rise time t_r is expressed as a turn-ON time t_{on}, and the sum of the turn-OFF delay time $t_{d(off)}$ and the fall time t_f is expressed as a turn-off time t_{off}.

$$t_{d(on)} + t_r = t_{on}$$
$$t_{d(off)} + t_f = t_{off}$$

Figure. 3.2 shows the switching characteristics (switching time versus drain current I_D)

© 2022
Toshiba Electronic Devices & Storage Corporation

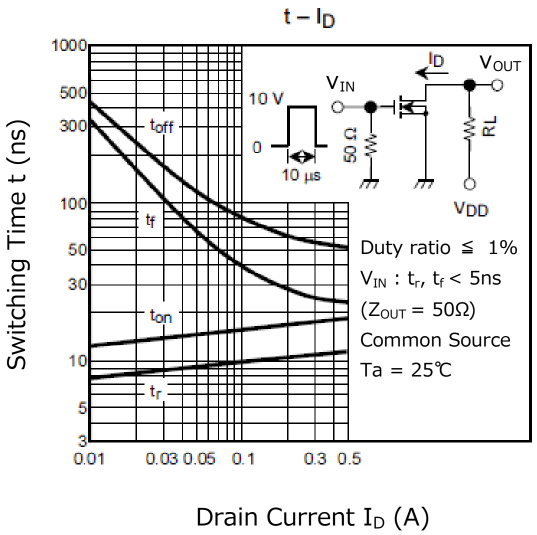
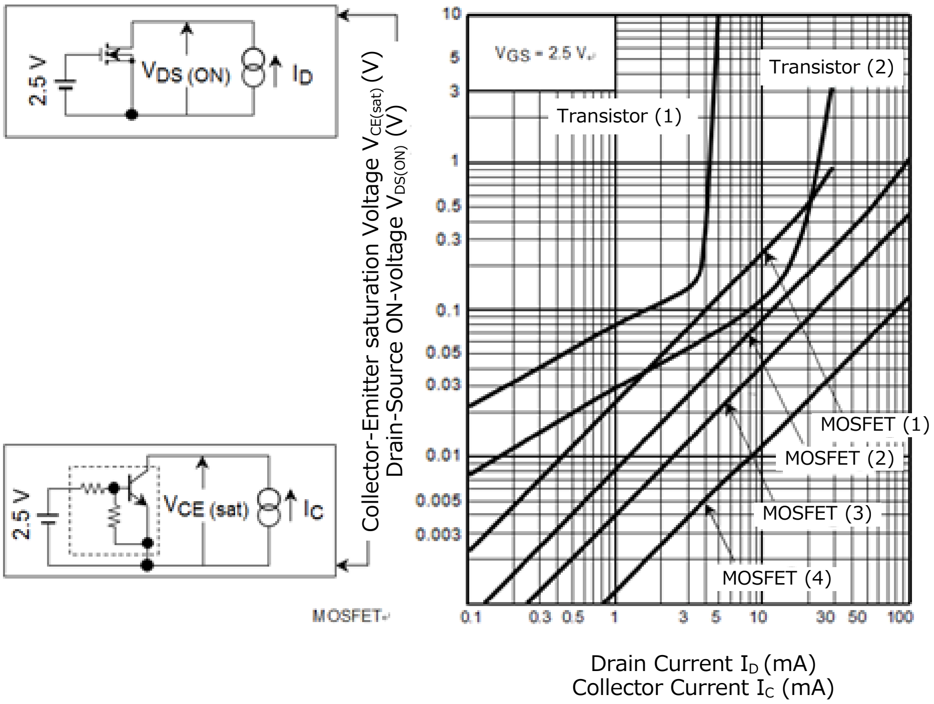


Figure 3.2 Switching Characteristics

4. Comparison with Built-in Resistor Bipolar Transistor (Digital Transistor)

4.1. Comparison of operating voltages

The Drain-Source ON resistance of MOSFET shows a nearly constant value independent of the current value. Therefore, in the low-current region, $V_{DS(ON)}$ of a MOSFET is smaller than $V_{CE(sat)}$ of Built-in Resistor Bipolar Transistor (Digital Transistor).



Transistor (1): Built-in Resistor Bipolar Transistor $R_1 = R_2 = 47k\Omega$
Transistor (2): Built-in Resistor Bipolar Transistor $R_1 = R_2 = 4.7k\Omega$
MOSFET(1), (2), (3), (4): No external resister needed

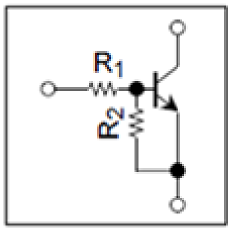


Figure 4.1 Comparing the operating voltages of MOSFET and transistors

4.2. Comparison of switching characteristics

Because MOSFETs are not subject the same charge storage effect as bipolar transistors, they are capable high-speed switching.

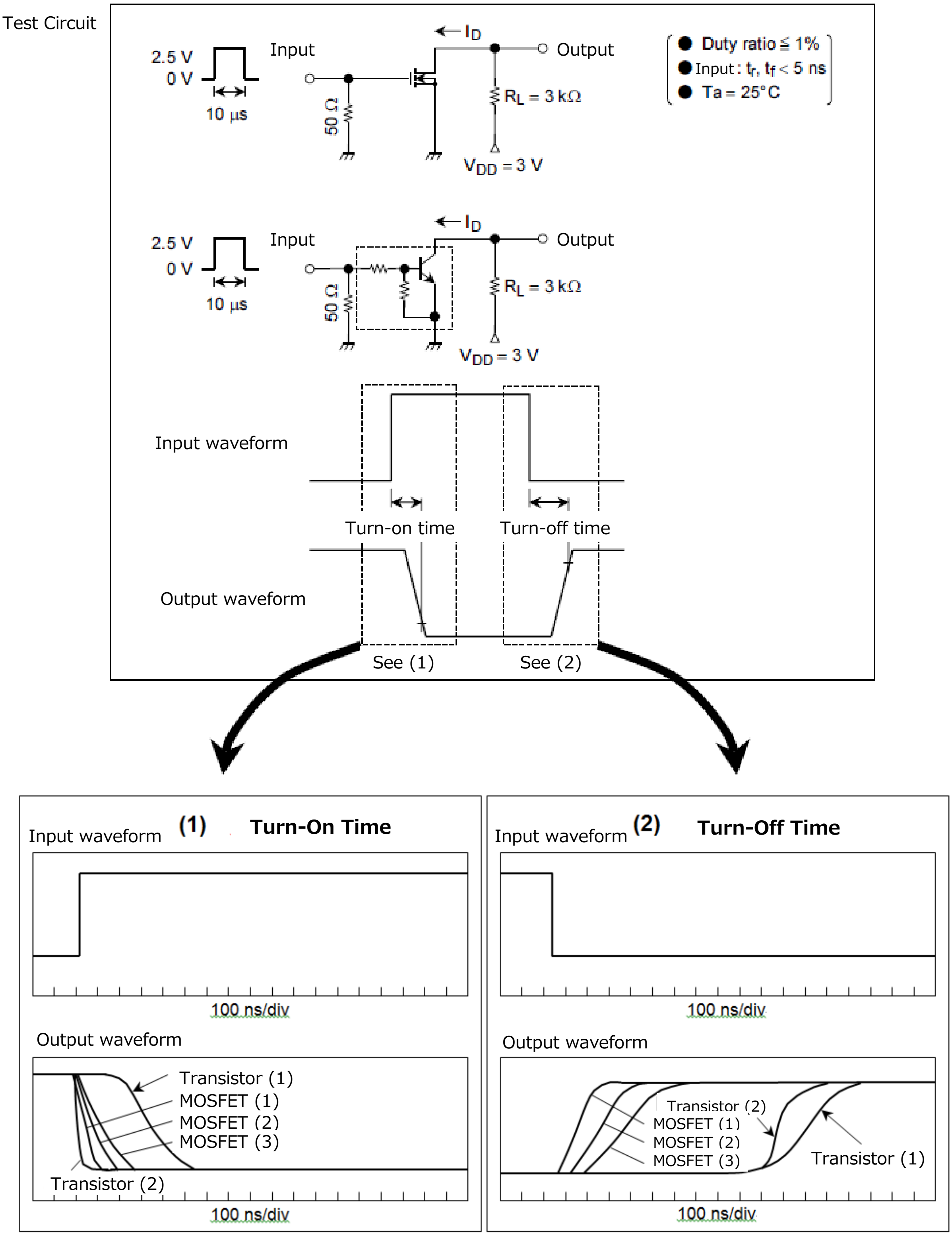


Figure 4.2 MOSFET Turn-On and Turn-Off times

5. Reference data

5.1. On-Resistor $R_{DS\ (ON)}$ and Gate-Source Voltage V_{GS}

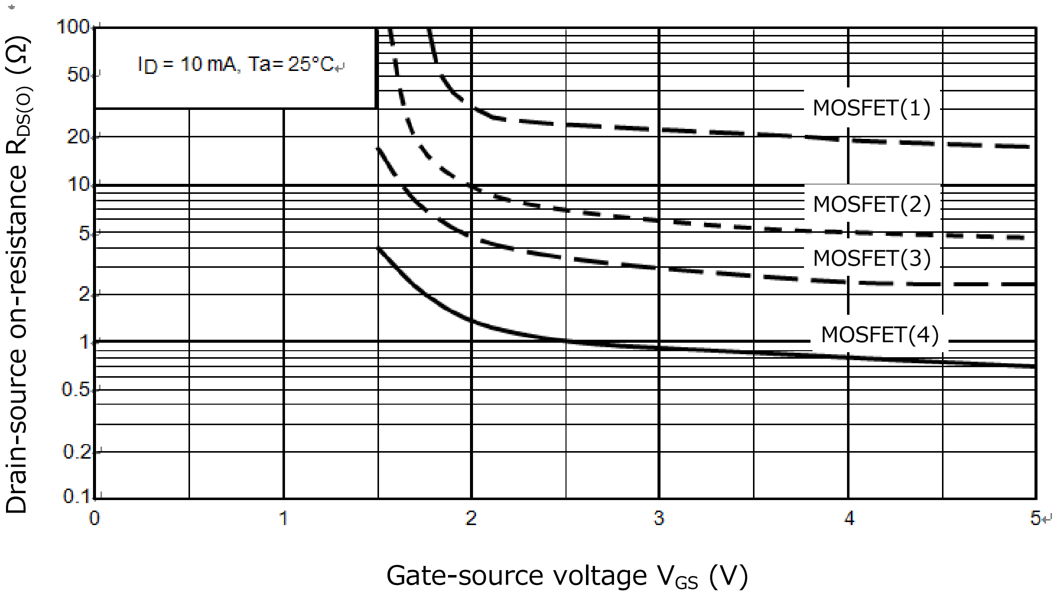


Figure 5.1 $R_{DS\ (ON)}$ - V_{GS}

5.2. Temperature Characteristics of On-Resistor $R_{DS\ (ON)}$

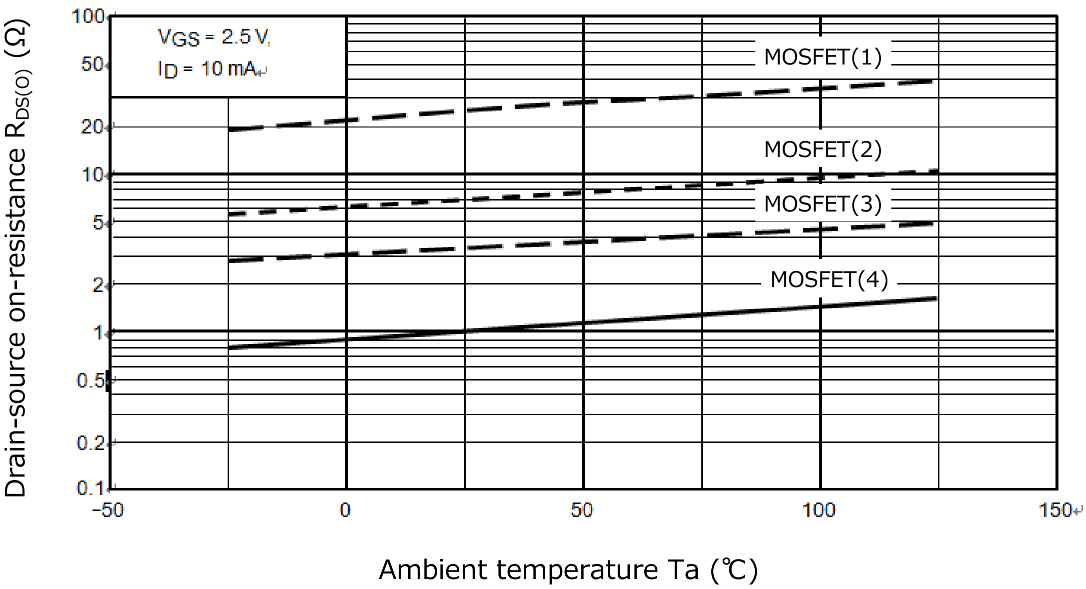


Figure 5.2 $R_{DS\ (ON)}$ - T_a

© 2022
Toshiba Electronic Devices & Storage Corporation

6. Related Links

■MOSFETs Lineup	Click
■MOSFET (Parametric Search)	Click
■Stock Check & Purchase	Buy Online
■FAQ	Click
■Application Notes	Click
■Reference Design Center	Click

© 2022
Toshiba Electronic Devices & Storage Corporation

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 precautions 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.**

Toshiba Electronic Devices & Storage Corporation

https://toshiba.semicon-storage.com/

© 2022
Toshiba Electronic Devices & Storage Corporation