Cancelled

Title: POWER MOSFET, N-CHANNEL, RADIATION HARDENED, HIGH RELIABILITY, SPACE USE, DETAIL SPECIFICATION FOR (JAXA R 2SK4185, 2SK4186, 2SK4187, 2SK4188, 2SK4189, 2SK4190)

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POWER MOSFET, N-CHANNEL, RADIATION HARDENED, HIGH RELIABILITY, SPACE USE, DETAIL SPECIFICATION FOR

JAXA R
2SK4185, 2SK4186, 2SK4187
2SK4188, 2SK4189, 2SK4190

Prepared and Established by Fuji Electric Co.,Ltd.
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This document is the English version of JAXA QTS/ADS which was originally written and authorized in Japanese and carefully translated into English for international users. If any question arises as to the context or detailed description, it is strongly recommended to verify against the latest official Japanese version.

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Revision Log

Rev.	Date	Description
----	29 Feb. 2008	Original
A	12 Nov. 2012	▪ Table 1b: Corrected errors on the limits of Reverse recovery characteristics 1/1 size: Trr (Max): 950ns → 1400ns Qrr (Max): 23µC → 34.5µC 1/2 size: Trr (Max): 900ns → 1350ns Qrr (Max): 19µC → 28µC 1/4 size: Trr (Max): 800ns → 1200ns Qrr (Max): 11µC → 16.5µC ▪ Table 2b: Changed "Thermal resistance ($R_{th(ch-c)}(\Delta V_{SD})$)" to "Thermal impedance ($Z_{th\ (ch-c)}(\Delta V_{SD})$)" in compliance with the terms in MIL-STD-750. ▪ Table 2b: Added a test condition (Minimum On time: 30 seconds) of Intermittent Operation Life test. ▪ Table 3: Changed "Thermal resistance ($R_{th(ch-c)}(\Delta V_{SD})$)" to "Thermal impedance ($Zth_{(ch-c)}(\Delta VSD)$)" in compliance with the terms in MIL-STD-750. ▪ Table 3: Added a test condition (Minimum On time: 30 seconds) of Intermittent Operation Life test. ▪ Table 3: Added "($^{(5)}$) If the inspection lot is the one used in the Group B test, this test may be exempted" in compliance with General specification. ▪ Table 4a: Reviewed the number of significant figures in the test conditions of D-2a, D-2b and D-2c. ▪ Table 6 Exemption of Quality Conformance Inspection: Deleted test items, for which the quality conformance inspection is not performed. ▪ Added the maximum safe operating area of DC to figures. ▪ Others: Corrected errors to ensure consistency.
B	18 March 2020	▪ Cover: Changed the corporate name. ▪ Paragraph 3.2.1: Added marking for inspection lot identification code and serial number. ▪ Modified the wording in each paragraph in the document. ▪ Table 2a Group B inspection (B-3g), Table 2b Group B inspection (B-6g), and Table 8a Qualification test, Group B inspection (B-3g) and Table 8b Qualification test, Group B inspection (B-6g): Corrected test condition error of Bond strength from "condition A" to "condition D".

Contents

POWER MOSFET, N-CHANNEL, RADIATION HARDENED, HIGH RELIABILITY, SPACE USE, DETAIL SPECIFICATION FOR

JAXA R
2SK4185, 2SK4186, 2SK4187
2SK4188, 2SK4189, 2SK4190

1 GENERAL

This specification establishes the detailed requirements for space use, high reliability, N channel power MOSFET (500V for TO-254 and SMD types) used for electronic equipment installed on spacecrafts. The products specified in this specification are as follows.

1.1 Part Number

The part numbers for the products covered by this specification are as follows:

JAXA(1) R(2) 2SK4185
JAXA(1) R(2) 2SK4186
JAXA(1) R(2) 2SK4187
JAXA(1) R(2) 2SK4188
JAXA(1) R(2) 2SK4189
JAXA(1) R(2) 2SK4190

Notes (1) "JAXA" indicates the common parts for space applications.
(2) "R" indicates the radiation hardness assurance designator.

1.2 Absolute Maximum Ratings

The absolute maximum ratings of the products specified in this specification are as follows. Unless otherwise specified, T_A is +25°C.

Part No.	V_{DS} (V)	I_D (A)	$I_{D(pulse)}$ (A)	V_{GS} (V)	P_D T_C=25°C (W)	P_D T_A=25°C (W)	T_{ch}(1) (°C)	T_{stg} (°C)	$R_{th(ch-c)}$ (°C/W)	$R_{th(ch-a)}$ (°C/W)	SOA
JAXA R 2SK4185	500	23	92	±20	250 Fig.5	2.6 Fig.6	150	-55 to 150	0.5	48.0	Fig.7
JAXA R 2SK4186		10	40		125 Fig.8	2.58 Fig.9			1.0	48.5	Fig.10
JAXA R 2SK4187		4.5	18		60 Fig.11	2.55 Fig.12			2.0	49.0	Fig.13
JAXA R 2SK4188		23	92		250 Fig.14	--- ---			0.5	---	Fig.15
JAXA R 2SK4189		10	40		150 Fig.16	--- ---			0.83	---	Fig.17
JAXA R 2SK4190		4.5	18		70 Fig.18	--- ---			1.67	---	Fig.19

Note(1) The channel temperature T_{ch} is given by the following equations:

$T_{ch}=T_C + R_{th(ch-c)} \times P_D$

$T_{ch}=T_A + R_{th(ch-a)} \times P_D$

Where T_C: Case temperature (°C)

T_A: Ambient temperature (°C)

$R_{th(ch-c)}$: Thermal resistance between channel and case (°C/W)

$R_{th(ch-a)}$: Thermal resistance between channel and ambient (°C/W)

P_D: Power dissipation (W)

1.3 Primary Electrical Characteristics

The primary electrical characteristics of the products specified in this specification are as follows. Unless otherwise specified, T_A is +25°C.

Electrical Characteristics (1/3)

Part No.	$V_{(BR)DSS}$ (V)	I_{DSS} (μA)	I_{GSS} (nA)	$V_{GS(th)}$ (V)	$R_{DS(on)}$(1) (Ω)	gfs(1) (S)	E_{AS} (mJ)
	I_D=1mA V_{GS}=0V	V_{DS}=400V V_{GS}=0V	V_{GS}=±20V V_{DS}=0V	I_D=1mA V_{DS}=V_{GS}	I_D=50% of rated I_D V_{GS}=12V	I_D=50% of rated I_D V_{DS}=25V	Rated I_D V_{DD}=48V, V_{GS}=12V
	Min	Max	Max	Min-Max	Max	Min	Max
JAXA R 2SK4185	500	25	±100	2.5-4.5	0.18	7	521
JAXA R 2SK4186					0.48	4	229
JAXA R 2SK4187					1.15	2.5	226
JAXA R 2SK4188					0.18	7	521
JAXA R 2SK4189					0.48	4	347
JAXA R 2SK4190					1.15	2.5	127

Note(1) Pulse test: Pulse width ≤ 1ms, Duty cycle ≤ 2%

Electrical Characteristics (2/3)

Part No.	Q_{GS} (nC)	Q_{GD} (nC)	Q_G (nC)	$t_{d(on)}$ (ns)	t_r (ns)	$t_{d(off)}$ (ns)	t_f (ns)
	V_{DS}=250V, I_D= rated I_D, V_{GS}=12V			V_{DD}=250V, I_D= rated I_D, V_{GS}=12V, R_G=10Ω			
	Max	Max	Max	Max	Max	Max	Max
JAXA R 2SK4185	85	85	300	85	30	190	30
JAXA R 2SK4186	35	35	120	60	15	90	15
JAXA R 2SK4187	14	14	48	55	10	70	10
JAXA R 2SK4188	85	85	300	85	30	190	30
JAXA R 2SK4189	35	35	120	60	15	90	15
JAXA R 2SK4190	14	14	48	55	10	70	10

Electrical Characteristics (3/3)

(Body Diode Characteristics)

Part No.	V_{SD}(1) (V)	t_{rr} (ns)	Q_{rr} (μC)
	I_F= rated I_D V_{GS}=0V	I_F= rated I_D, V_{GS}=0V, -di/dt=100A/μs, T_{ch}=25°C	
	Max	Typ	Typ
JAXA R 2SK4185	1.6	950	23
JAXA R 2SK4186		900	19
JAXA R 2SK4187		800	11
JAXA R 2SK4188		950	23
JAXA R 2SK4189		900	19
JAXA R 2SK4190		800	11

Note(1) Pulse test: Pulse width ≤ 1ms, Duty cycle ≤ 2%

1.4 Radiation Hardness

The radiation hardness of the products specified in this specification is as follows.

Symbol	Radiation hardness assurance level
R	1000 Gy(Si) {1×10^5 rad(Si)} (Dose Rate 36Gy(Si)/ h to 360Gy(Si)/ h)

2 APPLICABLE DOCUMENTS

The latest issues of documents listed below at the time of contract award or application form a part of this specification the extent specified herein.

JAXA-QTS-2030	Semiconductor Devices, High Reliability, Space Use, General Specification for
MIL-STD-750	Test Method Standard, Test Methods for Semiconductor Devices
MIL-PRF-19500N	Performance Specification Semiconductor Devices, General Specification for

3 REQUIREMENTS

3.1 Design and Construction

The design and construction of the products shall meet the requirements specified in this paragraph and paragraph 3.3 of JAXA-QTS-2030.

3.1.1 Package Configuration and Terminal Connection

The package configuration and terminal connection shall meet the requirements specified in Figures 1a, 1b, 1c and 1d.

3.1.2 Terminal Materials and Finish

a) TO-254 package (JAXA R 2SK4185, 2SK4186 and 2SK4187)

The leads shall be made of Fe-Ni (Ni-Au plating) covered OCF (Oxygen-Free Copper) and plated with Au as specified in the paragraph 3.3.7 c) 2) 2.3) or with Pb-Sn solder dipping as specified in the paragraph 3.3.7 c) 2) 2.1) of JAXA-QTS-2030.

b) SMD package (JAXA R 2SK4188, 2SK4189 and 2SK4190)

The material of terminals shall be Cu-W alloy. The terminals shall be finished with gold plating.

The purity of gold shall be a minimum of 99.7%. The thickness of the plating shall be a minimum of 1.27μm. This finish shall be plated with nickel as an underplating of a thickness between 1.27μm and 7.62μm.

3.1.3 Electrical Characteristics

The electrical characteristics shall meet the requirements specified in Tables 1a and 1b.

3.2 Marking

The marking shall be in accordance with paragraph 3.4 of JAXA-QTS-2030, and Figures 2a, 2b, 2c and 2d.

3.2.1 Marking for Inspection Lot Identification Code and Serial Number

The marking for inspection lot identification code and serial number shall be as follows.

Example:

19 01 001

a) b) c)

Inspection lot identification code: a) b)

Serial number: c)

a) The last two digit number indicating the year the inspection started
b) The two digit number indicating the week of sealing for the first inspection sublot (production lot) of each inspection lot. The week number is counted from the first week of January of the year.
c) Unique three-digit number from 001 to 999 consecutively assigned for each product within the inspection lot

3.3 Certification

The requirements for the products to be certified shall be in accordance with paragraph 3.1 of JAXA-QTS-2030.

4 QUALITY ASSURANCE PROVISIONS

4.1 General Requirements

The general requirements shall be in accordance with paragraph 4.1 of JAXA-QTS-2030.

4.2 Incoming Materials Control

The incoming materials control shall be in accordance with paragraph 4.2 of JAXA-QTS-2030.

4.3 Manufacturing Process Control

The manufacturing process control shall be in accordance with paragraph 4.3 of JAXA-QTS-2030.

4.4 In-process Inspection

The in-process inspection shall be in accordance with paragraph 4.5 of JAXA-QTS-2030.

4.5 Screening

The screening shall be in accordance with paragraph 4.7 of JAXA-QTS-2030. The electrical characteristics to be measured, test conditions and delta limits shall be as follows.

4.5.1 Electrical Characteristics to be Measured

The following parameters shall be measured during the interim and final electrical characteristics tests for screening.

(1) Interim electrical characteristic tests T_A=+25°C

Measuring item	$V_{(BR)DSS}$ (V)	I_{DSS} (μA)	I_{GSS} (nA)	$V_{GS(th)}$ (V)	$R_{DS(on)}$(1) (Ω)	gfs(1) (S)	V_{SD}(1) (V)
MIL-STD-750 Test Method No.	3407	3413	3411	3404	3421	3475	---
Test conditions	Bias Condition C I_D=1mA V_{GS}=0V	Bias Condition C V_{DS}=400V V_{GS}=0V	Bias Condition C V_{GS}=±20V V_{DS}=0V	I_D=1mA V_{DS}=V_{GS}	I_D=50% of rated I_D V_{GS}=12V	I_D=50% of rated I_D V_{DS}=25V	I_F= rated I_D V_{GS}=0V
	Min	Max	Max	Min-Max	Max	Min	Max
JAXA R 2SK4185	500	25	±100	2.5-4.5	0.18	7	1.6
JAXA R 2SK4186					0.48	4	
JAXA R 2SK4187					1.15	2.5	
JAXA R 2SK4188					0.18	7	
JAXA R 2SK4189					0.48	4	
JAXA R 2SK4190					1.15	2.5	

Note(1) Pulse test: Pulse width ≤ 1ms, Duty cycle ≤ 2%

(2) Final electrical characteristics test: As specified in the subgroups 1, 2, and 3 of Tables 1a and 1b.

4.5.2 Test Conditions

The conditions of gate stress test, avalanche energy test, temperature cycling test, reverse bias burn-in test and burn-in test for screening test shall be as follows.
(Gate stress test is performed as part of In-process inspection.)

Gate stress test: V_{GS}=35V, t=1ms, T_A=25°C

Single pulse avalanche energy (E_{AS}) test: $I_{D(pulse)}$ = rated I_D, V_{DD}=48V, V_{GS}=12V, single pulse,

Initial $T_C = +25^{-5}_{+10}$ °C

$$L(mH) = \left[\frac{2E_{AS}}{(I_D)^2}\right]\left[\frac{BV_{DSS} - V_{DD}}{BV_{DSS}}\right] \quad \text{▪▪ Equation (1)}$$

Temperature cycling test: Condition G, 20 cycles

Reverse bias burn-in test (GS): T_A=150°C, V_{GS}=16V
V_{DS}=0V, 48hr

Burn-in test (DS): T_A=150°C, V_{DS}=400V
V_{GS}=0V, 240hr

4.5.3 Delta Limits

The delta limits for reverse bias burn-in test and burn-in test shall be as follows.

$\Delta I_{GSS} \leq |20nA|$

$\Delta I_{DSS} \leq |10\mu A|$

$\Delta R_{DS(on)} \leq |20\%|$

$\Delta V_{GS(th)} \leq |20\%|$

4.6 Qualification Test and Quality Conformance Inspection

The qualification test and the quality conformance inspection shall be in accordance with paragraphs 4.6 and 4.8 of JAXA-QTS-2030. External dimensions, electrical characteristics, test conditions and limits shall be as specified in Figure 1, and Tables 1, 2, 3 and 4.

Group C inspection and Group D inspection may be exempted when the qualification test or quality conformance inspection for the Groups C and D inspections was performed and the device passed the test within a year. Detailed requirements are specified in Table 6.

Group E inspection may be exempted in spite of chip size, when the semiconductor devices manufactured from the die of the same wafer lot have passed the Group E inspection in the qualification test or the quality conformance inspection.

4.6.1 Electrostatic Discharge Sensitivity Test

Electrostatic discharge sensitivity test in the qualification test shall be performed with the following lead combination:

Gate and Source

4.6.2 Radiation Hardness Test

Radiation test (TID: Total Dose Irradiation) level, electrical characteristics, test conditions and limits in the qualification tests and the quality conformance inspections shall be as specified in Table 5. The bias shall be maintained during the irradiation and post-irradiation electrical characteristics test. The post-irradiation electrical characteristics test shall be performed within 24 hours after the completion of irradiation.

4.7 Change of Tests and Inspections

No change has been made to any test or inspection specified in appendixes A, B or C of JAXA-QTS -2030.

4.8 Shipment after Long-term Storage

Shipment of the products stored at the manufacturer’s site for 24 months or longer shall be in accordance with paragraph 4.9.1 of JAXA-QTS-2030.

5 PREPARATION FOR DELIVERY

Preparation for delivery shall be in accordance with Section 5 of JAXA-QTS-2030.

6 NOTES

6.1 Terms and Definitions

The terms and definitions used herein shall be in accordance with paragraph 1.2 of JAXA-QTS-2030 and as follows.

(1) SEB (Single Event Burnout);
Burnout of the device caused by the incidence of a proton or a heavy ion, when the device is applied to an off-state voltage between drain and source.

(2) SEGR (Single Event Gate Rupture);
Breakdown of MOSFET Gate Oxide film caused by the incidence of a proton or a heavy ion, when the device is applied to a gate bias voltage between gate and source.

6.2 Notes for Purchasers

The precautions to be taken by the purchaser shall be in accordance with paragraph 6.2 of JAXA-QTS-2030 and as follows.

6.2.1 Handling Instructions

The products specified in this specification contain thin oxide films and can be damaged due to electrostatic discharge (ESD). ESD protection measures shall be implemented to avoid ESD between the gate and source and between the gate and drain during transportation and other handling environments.

6.2.2 Beryllia Warning

The products of TO-254 package contain beryllium. Disintegration or chemical processing of the products that may produce dusts or fumes shall be prohibited. Disposition of the products shall be performed in accordance with applicable regulations.

6.3 Coordination with MIL-PRF-19500N

The comparison of qualification test items between MIL-PRF-19500N and JAXA-QTS-2030/103 is shown in Tables 7 through 11.

Table 1a. Group A Inspection ([1])

Gr.No	Sub	MIL-STD-750 Test Item	Method	JAXA R	1/1 Die Size 2SK4185	1/1 Die Size 2SK4188	1/2 Die Size 2SK4186	1/2 Die Size 2SK4189	1/4 Die Size 2SK4187	1/4 Die Size 2SK4190
A-1		**Static Characteristics (T_A=25°C)**		Sample Size	LTPD 3					
	-1a	Breakdown Voltage Drain to Source V_{DSS}	3407	Conditions	Bias Condition C I_D=1mA , V_{GS}=0V					
				Limits	min 500V DC					
	-1b	Gate-to-Source Leakage Current I_{GSS}	3411	Conditions	Bias Condition C V_{GS}=±20V , V_{DS}=0V					
				Limits	max ±100nA DC					
	-1c	Drain Current I_{DSS}	3413	Conditions	Bias Condition C V_{DS}=400V , V_{GS}=0V					
				Limits	max 25μA DC					
	-1d	Gate to Source Voltage (Threshold) $V_{GS(th)}$	3404	Conditions	Bias Condition C V_{GS}=V_{DS} , I_D=1mA					
				Limits	2.5 - 4.5V DC					
	-1e	Static Drain to Source On-State Resistance $R_{DS(on)}$	3421	Conditions	Pulse Test([2]) , V_{GS}=12V					
					I_D=11.5A		I_D=5.0A		I_D=2.25A	
				Limits	max 0.18Ω		max 0.48Ω		max 1.15Ω	
	-1f	Forward Transconductance gfs	3475	Conditions	Pulse Test([2]) , V_{DS}=25V					
					I_D=11.5A		I_D=5.0A		I_D=2.25A	
				Limits	min 7.0S		min 4.0S		min 2.5S	
	-1g	Forward Voltage V_{SD}	---	Conditions	Pulse Test([2]) , V_{GS}=0V					
					I_F=23A		I_F=10A		I_F=4.5A	
				Limits	max 1.6V					
A-2		**Static Characteristics (T_A=125°C)**		Sample Size	LTPD 5					
	-2a	Gate-to-Source Leakage Current I_{GSS} (125°C)	3411	Conditions	Bias Condition C V_{GS}=±20V , V_{DS}=0V					
				Limits	max ±100nA DC					
	-2b	Drain Current I_{DSS} (125°C)	3413	Conditions	Bias Condition C V_{DS}=400V , V_{GS}=0V					
				Limits	max 50μA DC					
	-2c	Gate to Source Voltage (Threshold) $V_{GS(th)}$ (125°C)	3404	Conditions	Bias Condition C V_{GS}=V_{DS} , I_D=1mA					
				Limits	min 1.5V DC					
	-2d	Static Drain to Source On-State Resistance $R_{DS(on)}$ (125°C)	3421	Conditions	Pulse Test([2]) , V_{GS}=12V					
					I_D=11.5A		I_D=5.0A		I_D=2.25A	
				Limits	max 0.38Ω		max 1.01Ω		max 2.43Ω	

Notes ([1]) The same sample may be used for all subgroups.

([2]) Pulse test: Pulse width ≤ 1ms, Duty cycle ≤ 2%

Table 1b. Group A Inspection ([1])

Gr.No	MIL-STD-750			1/1 Die Size		1/2 Die Size		1/4 Die Size	
Sub	Test Item	Method	JAXA R	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187	2SK4190
A -3	**Static Characteristics (T_A=-55ºC)**		Sample Size	LTPD 5					
-3a	Gate to Source Voltage (Threshold) $V_{GS(th)}$ (-55°C)	3404	Conditions	Bias Condition C V_{GS}=V_{DS} , I_D=1mA					
			Limits	max 5.0V DC					
-3b	Forward Transconductance gfs (-55°C)	3475	Conditions	Pulse Test ([2]) , V_{DS}=25V					
				I_D=11.5A		I_D=5.0A		I_D=2.25A	
			Limits	min 7.5S		min 4.5S		min 3.0S	
A -4	**Dynamic Characteristics (T_A=25ºC)**		Sample Size	LTPD 3					
	Switching Time Test (1) Turn-on delay time $t_{d(on)}$ Rise time: t_r (2) Turn-off delay time $t_{d(off)}$ Fall time: t_f	3472	Conditions	V_{DD}=250V V_{GS}=12V , R_g=10Ω					
				I_D=23A		I_D=10A		I_D=4.5A	
			Limits	max		max		max	
			$t_{d(on)}$	85ns		60ns		55ns	
			t_r	30ns		15ns		10ns	
			$t_{d(off)}$	190ns		90ns		70ns	
			t_f	30ns		15ns		10ns	
A -6a	**Safe Operating Area Test**([3])		Sample Size	LTPD 5					
		3474	Conditions	---					
-6b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
A -7	**Other Characteristics (T_A=25ºC)**([4])		Sample Size	LTPD 10					
-7a	Gate Charge (1) Gate Charge: Q_g (2) Gate to Drain Charge: Q_{gd} (3) Gate to Source Charge: Q_{gs}	3471	Conditions	V_{GS}=12V V_{DS}=250V					
				I_D=23A		I_D=10A		I_D=4.5A	
			Limits	max		max		max	
			Q_g	300nC		120nC		48nC	
			Q_{gd}	85nC		35nC		14nC	
			Q_{gs}	85nC		35nC		14nC	
-7b	Reverse Recovery Characteristics (1) T_{rr} (2) Q_{rr}	3473	Conditions	I_F= I_D=23A		I_F= I_D=10A		I_F= I_D=4.5A	
				V_{GS}=0V -di/dt=100A/μs					
			Limits	max		max		max	
			T_{rr}	1400ns		1350ns		1200ns	
			Q_{rr}	34.5μC		28μC		16.5μC	

Notes ([1]) The same sample may be used for all subgroups.

([2]) Pulse test: Pulse width ≤ 1ms, Duty cycle ≤ 2%

([3]) The samples used for subgroups A-1, A-2, and A-3 tests shall be used.

([4]) The samples used for subgroups A-6 tests shall be used.

Table 2a. Group B Inspection

Gr.No	MIL-STD-750			1/1 Die Size		1/2 Die Size		1/4 Die Size	
Sub	Test Item	Method	JAXA R	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187	2SK4190
B-1	**External Dimensions**(1)		Sample Size	Level I (2) 3p Level II (2) 3p					
		2066	Conditions	See Fig. 1a, 1b, 1c, 1d					
B-2	**Resistance to Solvents**(3) (4)		Sample Size	Level I 3p Level II 3p					
		1022	Conditions	Solvent a, b, c					
B-3b	**Temperature Cycling (Air to Air)**		Sample Size	Level I 6p Level II 6p					
		1051	Conditions	-55^{+0}_{-5}°C↔25^{+10}_{-5}°C↔150^{+5}_{-0}°C 100 cycles					
-3c	**Surge Test** (1) Gate Shock	4066	Conditions	V_{GS}=35V					
	(2) Avalanche	3470	Conditions	$I_{D(pulse)}$= 23A		$I_{D(pulse)}$= 10A		$I_{D(pulse)}$= 4.5A	
				V_{DS}=48V L= See paragraph 4.5.2, Equation (1)					
-3d	**Hermetic Seal** (1) Fine	1071	Conditions	Condition H					
			Limits	max 1×10^{-3}Pa-cm^3/s					
	(2) Gross	1071	Conditions	Condition C					
-3e	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
-3f	**Decap-Internal** **Visual and mechanical** inspection	2075 2071	Conditions	---					
-3g	**Bond Strength**	2037	Conditions	Condition D					
			Limits	Gate Wire >90gf					
				Source Wire					
				>160gf		>160gf		>90gf	
-3h	**SEM**(1)	2077	Conditions	---					
-3i	**Die Shear**		Sample Size	Level I 3p Level II 3p					
		2017	Conditions	---					
			Limits	min 2.5kgf					
B-4	**Solderability**(3) (4)		Sample Size	Level I (5)					
				6 leads	6 terminals	6 leads	6 terminals	6 leads	6 terminals
				Level II (5)					
				6 leads	6 terminals	6 leads	6 terminals	6 leads	6 terminals
		2026	Conditions	---					

Notes (1) The test may be performed using the samples prior to inspection lot formation.

(2) Level I and Level II shall be applicable to the qualification test and the quality conformance inspection, respectively. (See paragraphs C.3.2 and C.3.3 of JAXA-QTS-2030)

(3) Electrical reject products from the same inspection lot may be used.

(4) When electrical reject products are used, the samples shall be exposed to the same thermal environments as the certified samples experience in all thermal tests required as part of the screening test.

(5) This test shall be performed for each 3 leads or terminals from 2 devices.

Table 2b. Group B Inspection

Gr.No	MIL-STD-750			1/1 Die Size		1/2 Die Size		1/4 Die Size	
Sub	Test Item	Method	JAXA R	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187	2SK4190
B -5a	**Intermittent Operation Life**		Sample Size	Level I LTPD 10 Level II 12p					
		1042	Conditions	Condition D, 2000 cycles([1]) Minimum On time: 30 seconds					
-5b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
B -6c	**Accelerated Steady-state Gate Stress (High Temp. GS)**		Sample Size	Level I LTPD 10 Level II 12p					
		1042	Conditions	V_{GS}=20V, T_A=150°C, 48hr or V_{GS}=20V, T_A =175°C, 24hr					
-6d	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
-6e	**Accelerated Steady-state Reverse Bias (High temp. DS)**	1042	Conditions	V_{DS}=500V, T_A =150°C, 240hr or V_{DS}=500V, T_A =175°C, 120hr					
-6f	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
-6g	**Bond Strength**		Sample Size	20 wires					
		2037	Conditions	Condition D					
			Limits	Gate Wire >90gf					
				Source Wire >160gf		>160gf		>90gf	
B -7	**Thermal Impedance** $Z_{th(ch-c)}(\Delta V_{SD})$		Sample Size	Level I LTPD 10 Level II 8p					
		3161	Conditions	T_A=25°C					
			Limits	max 0.5°C/W	max 0.5°C/W	max 1.0°C/W	max 0.83°C/W	max 2.0°C/W	max 1.67°C/W

Note([1]) If the samples are also used for “Intermittent operating life test” of C1-1 in the Group C inspection, the test shall be performed up to 6000 cycles.

Table 3. Group C Inspection

Gr.No	MIL-STD-750			1/1 Die Size		1/2 Die Size		1/4 Die Size	
Sub	Test Item	Method	JAXA R	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187	2SK4190
C 1-1a	**Intermittent Operation Life**		Sample Size	Level I LTPD 10 Level II LTPD 10					
		1042	Conditions	Condition D, 6000 cycles ([1]) Minimum On time: 30 seconds					
1-1b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
C 1-2a	**Steady-state Bias Life Test (High Temperature GS Applied)** ([2])		Sample Size	Level I LTPD 5 Level II NA					
		1042	Conditions	V_{GS}=16V T_A=150°C, 1000hr					
1-2b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
1-2c	**Steady-state Bias Life Test (High Temp. DS Applied)** ([2])	1042	Conditions	V_{DS}=400V T_A=150°C, 1000hr					
1-2d	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
C -2a	**Temperature Cycling**		Sample Size	Level I 12p Level II NA					
		1051	Conditions	-55^{+0}_{-5}°C↔25^{+10}_{-5}°C↔150^{+5}_{-0}°C 100 cycles					
-2b	**Hermetic Seal** (1) Fine	1071	Conditions	Condition H					
			Limits	max 1×10^{-3}Pa-cm^3/s					
	(2) Gross	1071	Conditions	Condition C					
-2c	**End-Point Electrical Measurements**([3])	---	Conditions	Same as Gr.A-1					
C -3	**Thermal Impedance** ([4]) ([5])		Sample Size	Level I LTPD 10 Level II 8p					
	$Z_{th(ch-c)}(\Delta V_{SD})$	3161	Conditions	T_A=25°C					
			Limits	max 0.5°C/W	max 0.5°C/W	max 1.0°C/W	max 0.83°C/W	max 2.0°C/W	max 1.67°C/W
C -4a	**Safe Operating Area Test**([6])		Sample Size	Level I LTPD 10 Level II LTPD 10					
		3474	Conditions	---					
-4b	**End-Point Electrical Measurements**([6])	---	Conditions	Same as Gr.A-1					
C -6a	**Electric Discharge Sensitivity Classification**		Sample Size	Level I 3p Level II NA					
		1020	Conditions	V_{GS}=±2750V V_{DS}=0V		V_{GS}=±1000V V_{DS}=0V		V_{GS}=±500V V_{DS}=0V	
-6b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					

Notes([1]) For the quality conformance inspection, the cycles may be reduced to 2000 cycles as a minimum.
([2]) The legibility of the marking shall not apply.
([3]) This test may be conducted prior to the hermetic seal.
([4]) Thermal impedance curve shall be obtained during the qualification test.
([5]) If the inspection lot is the one used in the Group B inspection, this test may be exempted.
([6]) This test may be exempted if performed in the Group A inspection.

Table 4a. Group D Inspection

Gr.No	MIL-STD-750			1/1 Die Size		1/2 Die Size		1/4 Die Size	
Sub	Test Item	Method	JAXA R	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187	2SK4190
D -1a	**Thermal Shock (Glass Strain)**		Sample Size	Level I LTPD 15 Level II LTPD 15					
		1056	Conditions	Condition B, 15 cycles					
-1b	**Temperature Cycling**	1051	Conditions	-55^{+0}_{-5}°C↔25^{+10}_{-5}°C↔150^{+5}_{-0}°C 45 cycles					
-1c	**Terminal Strength** (1)	2036	Conditions	Condition A 1.5kg, 30s					
-1d	**Moisture Resistance**	1021	Conditions	(MIL-STD-202, Method 106)					
-1e	**Hermetic Seal** (1) Fine	1071	Conditions	Condition H					
			Limits	max 1×10^{-3}Pa-cm^3/s					
	(2) Gross	1071	Conditions	Condition C					
-1f	**Visual Inspection**	1051 1021	Conditions	---					
-1g	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					
D -2a	**Shock**(2)		Sample Size	Level I LTPD 15 Level II LTPD 15					
		2016	Conditions	No Operating, 14700m/s^2 (1500G) 5 blows in each orientation, X_1, Y_1, Y_2 and Z_1					
-2b	**Vibration, Variable Frequency**(2)	2056	Conditions	100 to 2000 Hz, 4min 196 m/s^2 (20G) 4 blows in each orientation X,Y,Z					
-2c	**Constant Acceleration**(2)	2006	Conditions	98100m/s^2 (10000G) X_1, Y_1, Y_2 and Z_1 orientation					
-2d	**Hermetic Seal**(2) (1) Fine	1071	Conditions	Condition H					
			Limits	max 1×10^{-3}Pa-cm^3/s					
	(2) Gross	1071	Conditions	Condition C					
-2e	**End-Point Electrical Measurements**(2)	---	Conditions	Same as Gr.A-1					
D -3a	**Salt Atmosphere**(3)		Sample Size	Level I LTPD 15 Level II LTPD 15					
		1041	Conditions	35°C, 24hr Rate of salt deposit=10 to 50g/m^2/24hr					

Notes(1) This test shall be applicable to TO-254 package type (2SK4185, 2SK4186, 2SK4187).

(2) Samples used for subgroup 1 may be used.

(3) Electrical reject products from the same inspection lot may be used.

Table 4b. Group D Inspection

Gr.No	MIL-STD-750			1/1 Die Size		1/2 Die Size		1/4 Die Size	
Sub	Test Item	Method	JAXA R	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187	2SK4190
D-4	**Barometric Pressure (reduced)**		Sample Size	Level I 3p Level II NA					
		1001	Conditions	8mmHg, 60sec (minimum) V_{DS}=500V , V_{GS}=0V					
D-5	**Internal Water Vapor** (1)		Sample Size	Level I 3p Level II 3p					
		1018	Conditions	---					
D-6a	**Resistance to Soldering Heat**		Sample Size	Level I 3p Level II NA					
		2031	Conditions	250°C 10s	240°C 10s	250°C 10s	240°C 10s	250°C 10s	240°C 10s
-6b	**Visual Inspection**	---	Conditions	---					
-6c	**Hermetic Seal** (1) Fine	1071	Conditions	Condition H					
			Limits	max 1×10^{-3}Pa-cm^3/s					
	(2) Gross	1071	Conditions	Condition C					
-6d	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-1					

Note(1) Electrical reject products from the same inspection lot may be used.

Table 5. Group E Inspection

Gr.No	Sub	MIL-STD-750 Test Item	Method	JAXA R	1/1 Die Size 2SK4185	1/1 Die Size 2SK4188	1/2 Die Size 2SK4186	1/2 Die Size 2SK4189	1/4 Die Size 2SK4187	1/4 Die Size 2SK4190
E	**-1a**	**Total Dose Irradiation (TID)**		Sample Size	Level I 4p([1]) Level II 4p([1])					
			1019	Conditions	Total Dose 1×10^3Gy(Si) Dose Rate 36Gy(Si)/h to 360Gy(Si)/h Bias Condition (during irradiation, after irradiation) (a)V_{DS}=0V , V_{GS}=20V (b)V_{DS}=0V , V_{GS}=-20V (c)V_{DS}=400V , V_{GS}=0V					
	-1b	**End-Point Electrical Measurements**			Within 24hr after irradiation					
	(1)	Breakdown Voltage Drain to Source V_{DSS}	3407	Conditions	Bias Condition C I_D=1mA , V_{GS}=0V					
				Limits	min 500V DC					
	(2)	Gate to Source Leakage Current I_{GSS}	3411	Conditions	Bias Condition C V_{GS}=±20V , V_{DS}=0V					
				Limits	max ±100nA DC					
	(3)	Drain Current I_{DSS}	3413	Conditions	Bias Condition C V_{DS}=400V , V_{GS}=0V					
				Limits	max 25μA DC					
	(4)	Gate to Source Voltage (Threshold) $V_{GS(th)}$	3404	Conditions	Bias Condition C V_{GS}=V_{DS} , I_D=1mA					
				Limits	min 1.5V DC $\Delta V_{GS(th)}$ max 2.0V					
	(5)	Static Drain to Source On-State Resistance $R_{DS(on)}$	3421	Conditions	Pulse Test ([2]) , V_{GS}=12V					
					I_D=11.5A		I_D=5.0A		I_D=2.25A	
				Limits	max 0.18Ω		max 0.48Ω		max 1.15Ω	

Notes([1]) This test shall be performed for each single wafer lot. When an inspection lot consists of multiple inspection sublots, one inspection sublot may be performed this test.

([2]) Pulse test: Pulse width ≤ 1ms, Duty cycle ≤ 2%

Table 6. Exemption of Quality Conformance Inspection

When the qualification test or the quality conformance inspection for products specified as following table was initiated within a year from the completion date of the screening test for the inspection lot, and the device passed the test or inspection, the corresponding tests may be exempted.

Gr.No	Sub	Package Type / JAXA-QTS-2030 Appendix C / Test Item	TO-254 1/1 Die Size 2SK4185	TO-254 1/2 Die Size 2SK4186	TO-254 1/4 Die Size 2SK4187	SMD-2 1/1 Die Size 2SK4188	SMD-1 1/2 Die Size 2SK4189	SMD-0.5 1/4 Die Size 2SK4190
C	1-1a	Intermittent Operation Life	This test may be exempted when the devices having the same die size or larger die size passed the test.			This test may be exempted when the devices having the same die size or larger die size passed the test.		
	1-1b	End-Point Electrical Measurements						
	-3	Thermal Impedance	This test may be exempted when the device passed in the subgroup B-7 of Group B inspection.					
	-4a	Safe Operating Area Test	This test may be exempted when the device passed in the subgroup A-6 of Group A inspection.					
	-4b	End-Point Electrical Measurements						
D	-1a	Thermal Shock (Glass Strain)	This test may be exempted when any one of the products passed the test in the Group D inspection.			▪ This test for the device with SMD-1 and SMD-0.5 Package may be exempted when it passed this test for the device with SMD-2 Package. ▪ This test for the device with SMD-0.5 Package may be exempted when it passed this test for the device with SMD-1 Package.		
	-1b	Thermal Shock (Temperature Cycling)						
	-1c	Terminal Strength ([1])						
	-1d	Moisture Resistance						
	-1e	Hermetic Seal						
	-1f	Visual Inspection						
	-1g	End-Point Electrical Measurements						
	-2a	Shock						
	-2b	Vibration, Variable Frequency						
	-2c	Constant Acceleration						
	-2d	Hermetic Seal						
	-2e	End-Point Electrical Measurements						
	-3a	Salt Atmosphere				This test may be exempted when any one of the products passed the test.		
	-5	Internal Water Vapor						

Note([1]) This test shall be applicable to TO-254 package type.

Table 7a. Qualification Test : Group A Inspection

MIL-PRF -19500N Gr.No / Sub	2030C Gr.No. (1)	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
A -2	A-1	**Static Characteristics (T_A=25°C)**		Sample Size	116p	116p	116p	116p
-2a	A-1a	Breakdown Voltage Drain to Source V_{DSS}	3407	Conditions	Bias Condition C I_D=1mA , V_{GS}=0V			
				Limits	min 500V DC			
-2b	A-1b	Gate Current I_{GSS}	3411	Conditions	Bias Condition C V_{GS}=±20V , V_{DS}=0V			
				Limits	Max ±100nA DC			
-2c	A-1c	Drain Current I_{DSS}	3413	Conditions	Bias Condition C V_{DS}=400V , V_{GS}=0V			
				Limits	max 25μA DC			
-2d	A-1d	Gate to Source Voltage (Threshold) $V_{GS(th)}$	3404	Conditions	Bias Condition C V_{GS}=V_{DS} , I_D=1mA			
				Limits	2.5 - 4.5V DC			
-2e	A-1e	Static Drain to Source On-State Resistance $R_{DS(on)}$	3421	Conditions	Pulse Test(2) , V_{GS}=12V			
					I_D=11.5A	I_D=11.5A	I_D=5.0A	I_D=2.25A
				Limits	max 0.18Ω	max 0.18Ω	max 0.48Ω	max 1.15Ω
-2f	A-1f	Forward Transconductance gfs	3475	Conditions	Pulse Test(2) , V_{DS}=25V			
					I_D=11.5A	I_D=11.5A	I_D=5.0A	I_D=2.25A
				Limits	min 7.0S	min 7.0S	min 4.0S	min 2.5S
-2g	A-1g	Forward Voltage V_{SD}	---	Conditions	Pulse Test(2) , V_{GS}=0V			
					I_D=23A	I_D=23A	I_D=10A	I_D=4.5A
				Limits	max 1.6V DC			
-3	A-2 A-3	**Static Characteristics (T_A=-55, 125°C)**		Sample Size	116p	116p	116p	116p
-3a	A-3a	Gate to Source Voltage (Threshold) $V_{GS(th)}$ (-55°C)	3404	Conditions	Bias Condition C V_{GS}=V_{DS} , I_D=1mA			
				Limits	max 5.0V DC			
-3b	A-3b	Forward Transconductance gfs (-55°C)	3475	Conditions	Pulse Test(2) , V_{DS}=25V			
					I_D=11.5A	I_D=11.5A	I_D=5.0A	I_D=2.25A
				Limits	min 7.5S	min 7.5S	min 4.5S	min 3.0S
-3c	A-2a	Gate Current I_{GSS} (125°C)	3411	Conditions	Bias Condition C V_{GS}=±20V , V_{DS}=0V			
				Limits	max ±100nA DC			
-3d	A-2b	Drain Current I_{DSS} (125°C)	3413	Conditions	Bias Condition C V_{DS}=400V , V_{GS}=0V			
				Limits	max 50μA DC			
-3e	A-2c	Gate to Source Voltage (Threshold) $V_{GS(th)}$ (125°C)	3404	Conditions	Bias Condition C V_{GS}=V_{DS} , I_D=1mA			
				Limits	min 1.5V DC			
-3f	A-2d	Static Drain to Source On-State Resistance $R_{DS(on)}$ (125°C)	3421	Conditions	Pulse Test(2) , V_{GS}=12V			
					I_D=11.5A	I_D=11.5A	I_D=5.0A	I_D=2.25A
				Limits	max 0.38Ω	max 0.38Ω	max 1.01Ω	max 2.43Ω

Notes(1) The symbols refer to the test method number in JAXA-QTS-2030C.

(2) Pulse width ≤ 1ms, Duty cycle ≤ 2%

Table 7b. Qualification Test : Group A Inspection

MIL-PRF -19500N Gr.No / Sub	2030C Gr.No.	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
A -4	A-4	**Dynamic Characteristics (T_A=25°C)**		Sample Size	116p	116p	116p	116p
		Switching Time Test (1) Turn-on delay time $t_{d(on)}$ Rise time: t_r (2) Turn-off delay time $t_{d(off)}$ Fall time: t_f	3427	Conditions	V_{DD}=250V V_{GS}=12V , R_g=10Ω			
					I_D=23A	I_D=23A	I_D=10A	I_D=4.5A
				Limits	max	max	max	max
				$t_{d(on)}$	85ns	85ns	60ns	55ns
				t_r	30ns	30ns	15ns	10ns
				$t_{d(off)}$	190ns	190ns	90ns	70ns
				t_f	30ns	30ns	15ns	10ns
A -5a	A-6a	**Safe Operating Area test**		Sample Size	45p	15p	15p	15p
			3474	Conditions	---			
-5b	A-6b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2			
A -7	**---**	**Other Characteristics (T_A=25°C)**		Sample Size	45p	45p	45p	45p
-7a		Gate Charge (1) Gate Charge: Q_g (2) Gate to Drain Charge: Q_{gd} (3) Gate to Source Charge: Q_{gs}	3471	Conditions	V_{GS}=12V V_{DS}=250V			
					I_D=23A	I_D=23A	I_D=10A	I_D=4.5A
				Limits	max	max	max	max
				Q_g	300nC	300nC	120nC	48nC
				Q_{gd}	85nC	85nC	35nC	14nC
				Q_{gs}	85nC	85nC	35nC	14nC
-7b		Reverse Recovery Characteristics (1) t_{rr} (2) Q_{rr}	3473	Conditions	I_F= I_D=23A	I_F= I_D=23A	I_F= I_D=10A	I_F= I_D=4.5A
					V_{GS}=0V -di/dt=100A/μs			
				Limits	max	max	max	max
				t_{rr}	950ns	950ns	900ns	800ns
				Q_{rr}	23μC	23μC	19μC	11μC

Table 8a. Qualification Test : Group B Inspection

MIL-PRF-19500N Gr.No / Sub	2030C Gr.No.	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
B-1	B-1	**External Dimensions**(1)		Sample Size	22p	---	---	---
			2066	Conditions	---	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
B-2a	B-4	**Solderability** (1) (2)		Sample Size	15p	---	---	---
			2026	Conditions	---	Tested in 2SK4152(3)	Tested in 2SK4153(3)	Tested in 2SK4154(3)
-2b	B-2	**Resistance to Solvents**(1) (2)	1022	Conditions	---	Tested in 2SK4152(3)	Tested in 2SK4153(3)	Tested in 2SK4154(3)
B-3b	B-3b	**Temperature Cycling (Air to Air)**		Sample Size	22p	---	---	---
			1051	Conditions	-55^{+0}_{-5}°C↔25^{+10}_{-5}°C ↔150^{+5}_{-0}°C 100 cycles	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
-3c	B-3c	**Surge Test** (1) Gate Shock	4066	Conditions	V_{GS}=35V	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
		(2) Avalanche	4066	Conditions	V_{DS}=48V $I_{D(pulse)}$=23A L=100μH, R_g=10Ω	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
-3d	B-3d	**Hermetic Seal** (1) Fine	1071	Conditions	Condition H	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
				Limits	max 1×10^{-3}Pa-cm^3/s			
		(2) Gross	1071	Conditions	Condition C	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
-3e	B-3e	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
-3f	B-3f	**Decap-Internal Visual**	2075 2071	Conditions	---	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
-3g	B-3g	**Bond Strength**	2037	Conditions	Condition D	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
				Limits	G-Wire>90gf S-Wire>160gf			
-3h	B-3h	**SEM**	2077	Conditions	After Bond Strength test	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
-3i	B-3i	**Die Shear**	2017	Conditions	---	Tested in 2SK4155(3)	Tested in 2SK4156(3)	Tested in 2SK4157(3)
				Limits	min 2.5kgf			

Notes(1) Electrical reject products from the same inspection lot may be used.

(2) When electrical reject products are used, the samples shall be exposed to the same thermal environments as the experience in all thermal tests required in the screening test.

(3) As specified in the detail specification JAXA-QTS-2030/102.

Table 8b. Qualification Test : Group B Inspection

MIL-PRF -19500N Gr.No / Sub	2030C Gr.No.	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
B-4a	B-5a	**Intermittent Operation Life**		Sample Size	---	---	---	---
			1042	Conditions	Condition D, 2000 cycles Refer to the result of Gr.C-6.			
-4b	B-5b	**End-Point Electrical Measurements**	---	Conditions	Refer to the result of Gr.C-6.			
B-5a	B-6c	**Accelerated Steady -state Gate Stress (High Temp. GS)**		Sample Size	22p	22p	---	---
			1042	Conditions	V_{GS}=20V T_A=150°C 48hr	V_{GS}=20V T_A=150°C 48hr	Tested in 2SK4188	Tested in 2SK4188
-5b	B-6d	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2	Same as Gr.A-2	Tested in 2SK4188	Tested in 2SK4188
-5c	B-6e	**Accelerated Steady-State Reverse Bias (High Temp. DS)**	1042	Conditions	V_{DS}=500V T_A=150°C 240hr	V_{DS}=500V T_A=150°C 240hr	Tested in 2SK4188	Tested in 2SK4188
-5d	B-6f	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2	Same as Gr.A-2	Tested in 2SK4188	Tested in 2SK4188
-5e	B-6g	**Bond Strength**	2037	Conditions	Condition D	Condition D	Tested in 2SK4159([1])	Tested in 2SK4160([1])
				Limits	G-Wire>90gf S-Wire>160gf	G-Wire>90gf S-Wire>160gf	---	---
B-6	B-7	**Thermal Impedance** $Z_{th(ch-c)}(\Delta V_{SD})$		Sample Size	22p	22p	22p	22p
			3161	Conditions	T_A=25°C			
				Limits	max 0.5°C/W	max 0.5°C/W	max 0.83°C/W	max 1.67°C/W

Note([1]) As specified in the detail specification JAXA-QTS-2030/102.

Table 9a. Qualification Test : Group C Inspection

MIL-PRF -19500N Gr.No / Sub	2030C Gr.No.	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
C-1	B-1	**External Dimensions**([1])		Sample Size	---	---	---	---
			2066	Conditions	Performed in Gr.B-1 test.	Tested in 2SK4155([2])	Tested in 2SK4156([2])	Tested in 2SK4157([2])
C-2a	D-1a	**Thermal Shock (Glass Strain)**		Sample Size	22p	---	---	---
			1056	Conditions	Condition B 25 cycles	Tested in 2SK4158([2])	Tested in 2SK4159([2])	Tested in 2SK4160([2])
-2b	D-1b	**Temperature Cycling**	1051	Conditions	-55^{+0}_{-5}°C↔25^{+10}_{-5}°C ↔150^{+5}_{-0}°C 45 cycles	Tested in 2SK4158([2])	Tested in 2SK4159([2])	Tested in 2SK4160([2])
-2c	D-1c	**Terminal Strength**	2036	Conditions	Condition A 1.5kg, 30s	Not applicable for SMD package	Not applicable for SMD package	Not applicable for SMD package
-2d	D-1d	**Moisture Resistance**	1021	Conditions	(MIL-STD-202 Method 106)	Tested in 2SK4158([2])	Tested in 2SK4159([2])	Tested in 2SK4160([2])
-2e	D-1e	**Hermetic Seal** (1) Fine	1071	Conditions	Condition H	Tested in 2SK4158([2])	Tested in 2SK4159([2])	Tested in 2SK4160([2])
				Limits	max 1×10^{-3}Pa-cm^3/s			
		(2) Gross	1071	Conditions	Condition C	Tested in 2SK4158([2])	Tested in 2SK4159([2])	Tested in 2SK4160([2])
-2f	D-1g	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2	Tested in 2SK4158([2])	Tested in 2SK4159([2])	Tested in 2SK4160([2])
C-3a	D-2a	**Shock**		Sample Size	22p	---	---	---
			2016	Conditions	No Operating 14710m/s^2 (1500G) X_1, Y_1, Y_2, Z_1 5 blows	Tested in 2SK4152([2])	Tested in 2SK4153([2])	Tested in 2SK4154([2])
-3b	D-2b	**Vibration Variable Frequency**	2056	Conditions	100～2000Hz 196.1m/ s^2(20G)	Tested in 2SK4152([2])	Tested in 2SK4153([2])	Tested in 2SK4154([2])
-3c	D-2c	**Constant Acceleration**	2006	Conditions	98066.5m/s^2 (10000G) X_1, Y_1, Y_2, Z_1	Tested in 2SK4152([2])	Tested in 2SK4153([2])	Tested in 2SK4154([2])
-3d	D-2f	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2	Tested in 2SK4152([2])	Tested in 2SK4153([2])	Tested in 2SK4154([2])

Notes ([1]) Electrical reject products from the same inspection lot may be used.

([2]) As specified in the detail specification JAXA-QTS-2030/102.

Table 9b. Qualification Test : Group C Inspection

MIL-PRF-19500N Gr.No / Sub	2030C Gr.No.	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
C-4	D-3a	**Salt Atmosphere**(1)		Sample Size	15p	---	---	---
			1041	Conditions	35°C, 24hr Rate of salt deposit = 10 to 50g/m^2/24hr	Tested in 2SK4152(2)	Tested in 2SK4153(2)	Tested in 2SK4154(2)
C-5	C-3	**Thermal Impedance** $Z_{th(ch-c)}(\Delta V_{SD})$		Sample Size	---	---	---	---
			3161	Conditions	Performed in Gr.B-6 test.	Performed in Gr.B-6 test.	Performed in Gr.B-6 test.	Performed in Gr.B-6 test.
C-6a	C1-1a	**Intermittent Operation Life**		Sample Size	22p	22p	22p	22p
			1042	Conditions	Condition D, 6000 cycles			
-6b	C1-1b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2			
C-7	D-5	**Internal Water Vapor**		Sample Size	3p	---	---	---
			1018	Conditions	---	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)

Notes (1) Electrical reject products from the same inspection lot may be used.

(2) As specified in the detail specification JAXA-QTS-2030/102.

Table 10. Qualification Test : Group D Inspection

MIL-PRF-19500N Gr.No / Sub	2030C Gr.No.	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
D-2	E-1a	**Total Dose Irradiation (TID)**		Sample Size	---	---	4/4/4p	---
			1019	Conditions	Tested in 2SK4189	Tested in 2SK4189	Total Dose 1×10^3Gy(Si) Dose Rate 42Gy(Si)/h Bias Condition (during irradiation, after irradiation) (a)V_{DS}=0V, V_{GS}=20V (b)V_{DS}=0V, V_{GS}=-20V (c)V_{DS}=400V, V_{GS}=0V	Tested in 2SK4189
-2a	E-1b	**End-Point Electrical Measurements**	---				Within 24hr after irradiation	
(1)		Breakdown Voltage Drain to Source V_{DSS}	3407	Conditions	Tested in 2SK4189	Tested in 2SK4189	Bias Condition C I_D=1mA , V_{GS}=0V	Tested in 2SK4189
				Limits			min 500V DC	
(2)		Gate Current I_{GSS}	3411	Conditions	Tested in 2SK4189	Tested in 2SK4189	Bias Condition C V_{GS}=±20V , V_{DS}=0V	Tested in 2SK4189
				Limits			max ±100nA DC	
(3)		Drain Current I_{DSS}	3413	Conditions	Tested in 2SK4189	Tested in 2SK4189	Bias Condition C V_{DS}=400V , V_{GS}=0V	Tested in 2SK4189
				Limits			max 25μA DC	
(4)		Gate to Source Voltage (Threshold) $V_{GS(th)}$	3404	Conditions	Tested in 2SK4189	Tested in 2SK4189	Bias Condition C V_{GS}=V_{DS} , I_D=1mA	Tested in 2SK4189
				Limits			min 1.5V DC $\Delta V_{GS(th)}$ max 2.0V	
(5)		Static Drain to Source On-State Resistance $R_{DS(on)}$	3421	Conditions	Tested in 2SK4189	Tested in 2SK4189	Pulse Test([1]) V_{GS}=12V , I_D=5A	Tested in 2SK4189
				Limits			max 0.48Ω	

Note ([1]) Pulse width ≤ 1ms, Duty cycle ≤ 2%

Table 11a. Qualification Test : Group E Inspection

MIL-PRF-19500N Gr.No / Sub	2030C Gr.No.	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
E-1a	C-2a	**Temperature Cycling**		Sample Size	45p	---	---	---
			1051	Conditions	-55^{+0}_{-5}°C↔25^{+10}_{-5}°C ↔150^{+5}_{-0}°C 500 cycles	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)
-1b	C-2b	**Hermetic Seal** (1) Fine	1071	Conditions	Condition H	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)
				Limits	max 1×10^{-3}Pa-cm^3/s			
		(2) Gross	1071	Conditions	Condition C	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)
-1c	C-2c	**End-Point Electrical Measurements (1)**	---	Conditions	Same as Gr.A-2	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)
E-2a	C1-2a	**Steady-state Bias Life test (High Temperature GS Applied)** (3)		Sample Size	45p	45p	---	45p
			1042	Conditions	V_{GS}=16V, T_A=150°C 1000hr	V_{GS}=16V, T_A=150°C 1000hr	Tested in 2SK4188	Tested in 2SK4188
-2b	C1-2b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2	Same as Gr.A-2	Tested in 2SK4188	Tested in 2SK4188
-2c	C1-2c	**Steady-state Bias Life test (High Temperature DS Applied)** (3)	1042	Conditions	V_{DS}=400V T_A=150°C 1000hr	Tested in 2SK4190	Tested in 2SK4190	V_{DS}=400V ,T_A=150°C 1000hr
-2d	C1-2d	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2	Tested in 2SK4190	Tested in 2SK4190	Same as Gr.A-2
E-4	C-3	**Thermal Impedance**(4)		Sample Size	3p	3p	3p	3p
			3161	Conditions	T_A=25°C			
				Limits	max 0.5°C/W	max 0.5°C/W	max 0.83°C/W	max 1.67°C/W
E-5	D-4	**Barometric Pressure**		Sample Size	3p	3p	3p	3p
			1001	Conditions	8mmHg, 60sec (minimum) V_{DS}=500V , V_{GS}=0V			
E-6a	C-6a	**Electric Discharge Sensitivity Classification**		Sample Size	3p	3p	3p	3p
			1020	Conditions	V_{GS}=±2750V V_{DS}=0V	V_{GS}=±2750V V_{DS}=0V	V_{GS}=±1000V V_{DS}=0V	V_{GS}=±500V V_{DS}=0V
-6b	C-6b	**End-Point Electrical Measurements**	---	Conditions	Same as Gr.A-2			

Notes (1) This test may be conducted prior to the hermetic seal.

(2) As specified in the detail specification JAXA-QTS-2030/102.

(3) The legibility of the marking shall not apply.

(4) Thermal impedance curve shall be obtained during the qualification test.

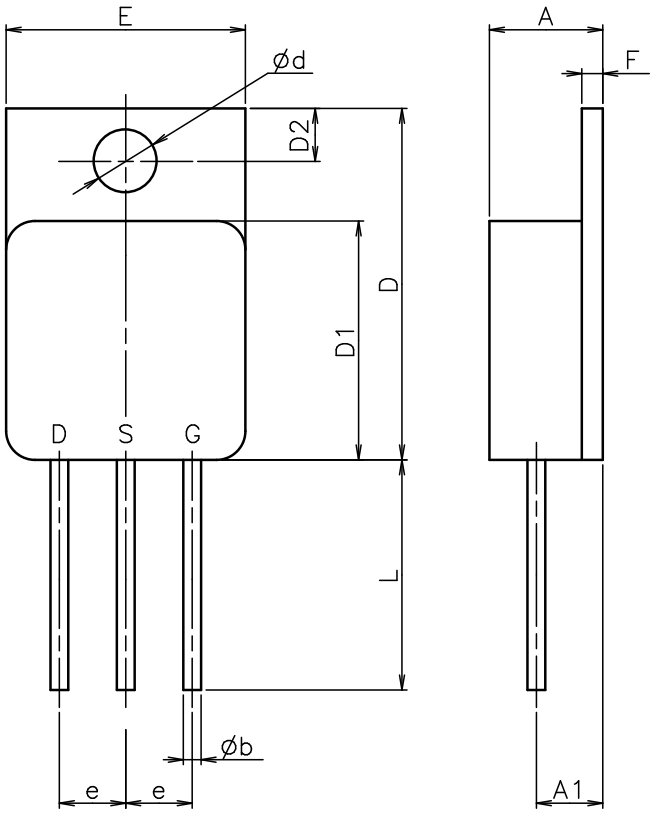
Table 11b. Qualification Test : Group E Inspection

MIL-PRF -19500N Gr.No / Sub	2030C Gr.No.	MIL-STD-750 Test Item	MIL-STD-750 Method	Type	JAXA R 2SK4185 TO-254 1/1 Die Size	JAXA R 2SK4188 SMD-2 1/1 Die Size	JAXA R 2SK4189 SMD-1 1/2 Die Size	JAXA R 2SK4190 SMD-0.5 1/4 Die Size
E-7a	D-6a	**Resistance to Soldering Heat**		Sample Size	3p	---	---	---
			2031	Conditions	250°C, 10s	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)
-7b	D-6c	**Hermetic Seal** (1) Fine	1071	Conditions	Condition H	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)
				Limits	max 1×10^{-3}Pa-cm^3/s			
		(2) Gross	1071	Conditions	Condition C	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)
-7c	D-6d	**End-Point Electrical Measurements**(1)	---	Conditions	Same as Gr.A-2	Tested in 2SK4158(2)	Tested in 2SK4159(2)	Tested in 2SK4160(2)
E-8	E-2, 3	**Radiation Hardness (SEB/SEGR Test)**		Sample Size	3p			
			1080	Conditions	Ion: ^{89}Y Energy: 928MeV LET: 40.5MeV/(mg/cm^2) (3) Range (Si): 102µm T_A =25+/-5°C Fluence: 3E5+/-5% ions/cm^2 V_{DS}=500V and V_{GS}= -7.5V			
				Limits	I_{GSS}≤10µA and shall not be destroyed			

Notes (1) This test may be conducted prior to the hermetic seal.

(2) As specified in the detail specification JAXA-QTS-2030/102.

(3) Average LET in the device.

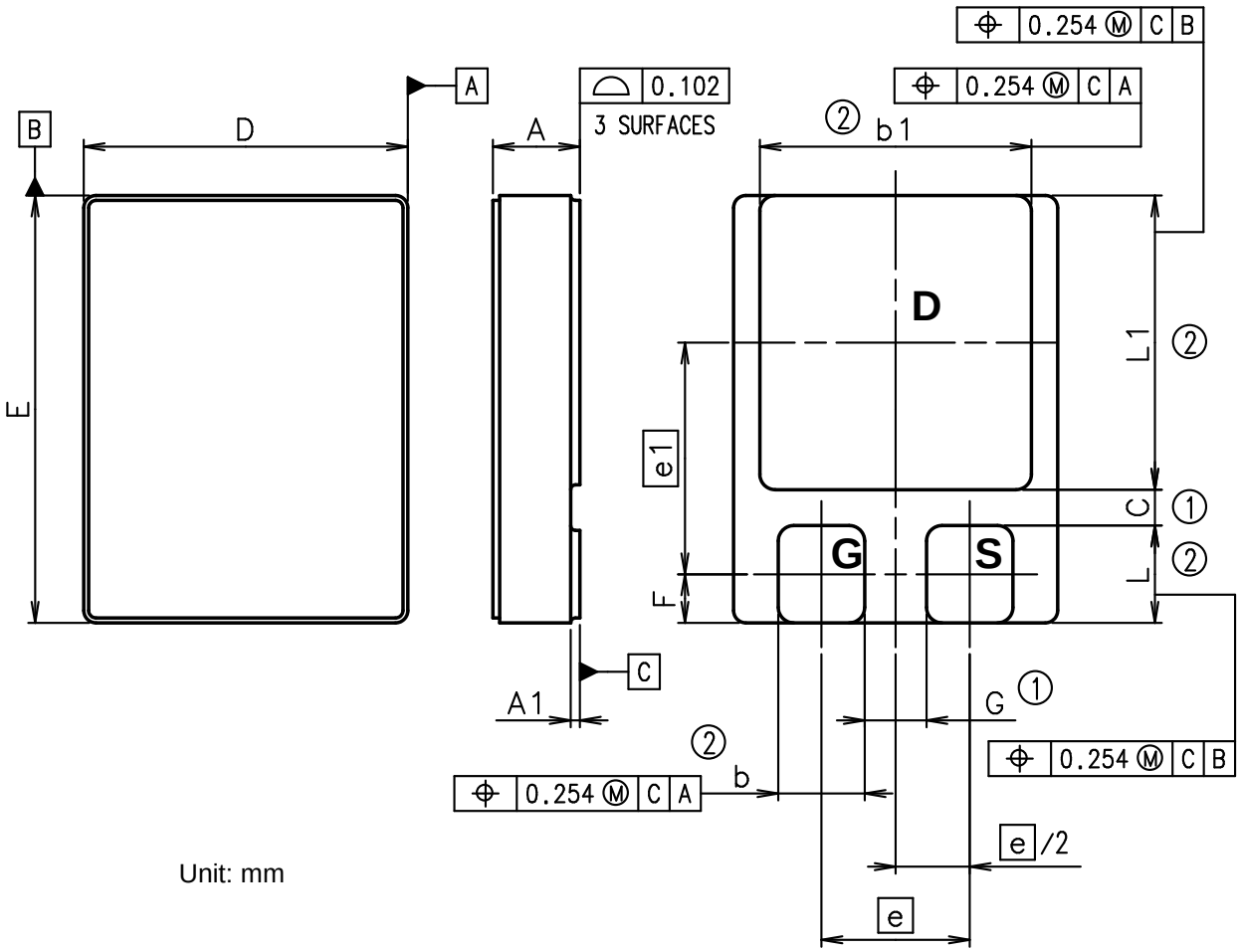


Symbol	Dimension (mm)	
	Min	Max
A	6.35	6.65
A1	3.61	4.01
øb	0.90	1.14
D	20.07	20.31
D1	13.59	13.85
D2	2.93	3.17

Symbol	Dimension (mm)	
	Min	Max
ød	3.56	3.80
E	13.60	13.84
e	3.51	4.11
F	1.10	1.30
L	12.84	13.60

Note: All leads are isolated from the case.

Figure 1a. Package Configuration and Lead Connection of TO-254 type package (JAXA R 2SK4185, 2SK4186, 2SK4187)



Unit: mm

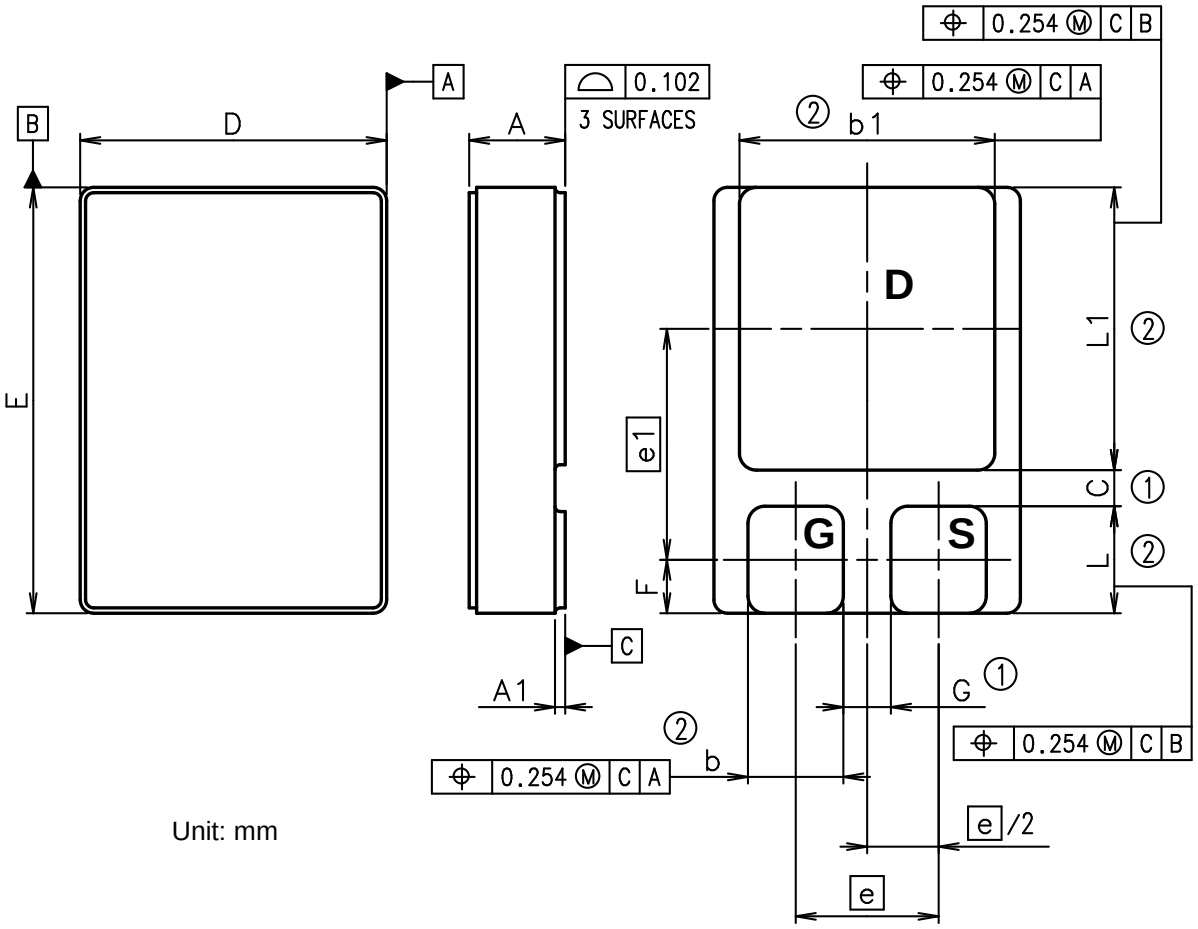
Symbol	Dimension (mm)		
	Min	Typ	Max
A	———	———	3.58
A1	0.254	0.381	0.508
b	3.43	3.555	3.68
b1	11.05	11.175	11.30
C	0.89	———	———
D	13.21	13.335	13.46
E	17.40	17.525	17.65

Symbol	Dimension (mm)		
	Min	Typ	Max
e/2	———	3.05	———
e	———	6.10	———
e1	———	9.50	———
F	———	1.99	———
G	1.27	———	———
L	3.87	3.99	4.11
L1	11.94	12.065	12.19

Notes: ① Dimension includes metallization flash.
② Dimension does not include metallization flash.

Note: All terminals are isolated from the case.

Figure 1b. Package Configuration and Terminal Connection of SMD-2 type package (JAXA R 2SK4188)



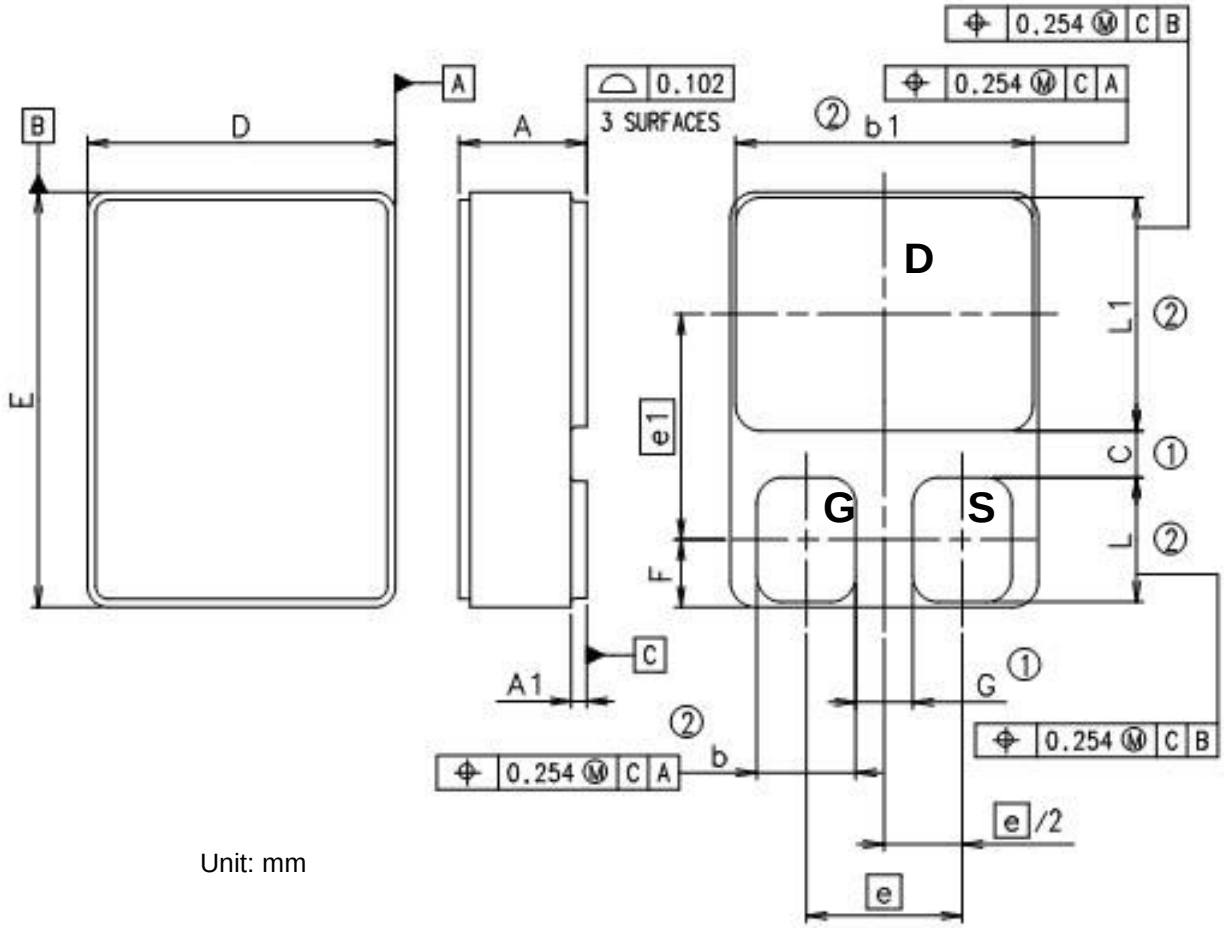
Symbol	Dimension (mm)		
	Min	Typ	Max
A	———	———	3.58
A1	0.254	0.381	0.508
b	3.43	3.555	3.68
b1	9.40	9.525	9.65
C	0.76	———	———
D	11.31	11.43	11.55
E	15.75	15.875	16.00

Symbol	Dimension (mm)		
	Min	Typ	Max
e/2	———	2.67	———
e	———	5.33	———
e1	———	8.61	———
F	———	1.99	———
G	0.89	———	———
L	3.87	3.99	4.11
L1	10.42	10.54	10.66

Notes: ① Dimension includes metallization flash.
② Dimension does not include metallization flash.

Note: All terminals are isolated from the case.

Figure 1c. Package Configuration and Terminal Connection of SMD-1 type package (JAXA R 2SK4189)



Unit: mm

Symbol	Dimension (mm)		
	Min	Typ	Max
A	——	——	3.12
A1	0.254	0.381	0.508
b	2.29	2.415	2.54
b1	7.14	7.265	7.39
C	0.76	——	——
D	7.40	7.52	7.64
E	10.04	10.16	10.28

Symbol	Dimension (mm)		
	Min	Typ	Max
e/2	——	1.905	——
e	——	3.81	——
e1	——	5.52	——
F	——	1.65	——
G	0.762	——	——
L	2.93	3.05	3.17
L1	5.59	5.715	5.84

Notes: ① Dimension includes metallization flash.
② Dimension does not include metallization flash.

Note: All terminals are isolated from the case.

Figure 1d. Package Configuration and Terminal Connection of SMD-0.5 type package (JAXA R 2SK4190)

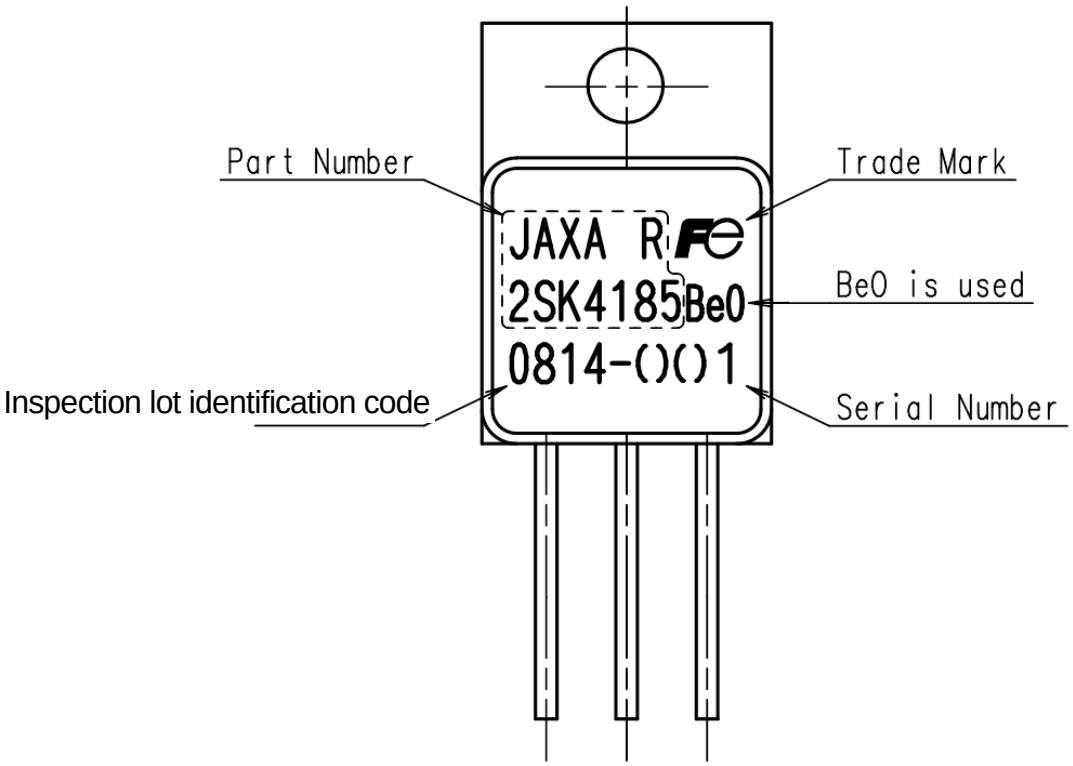


Figure 2a. Marking (TO-254)
(JAXA R 2SK4185, 2SK4186, 2SK4187)

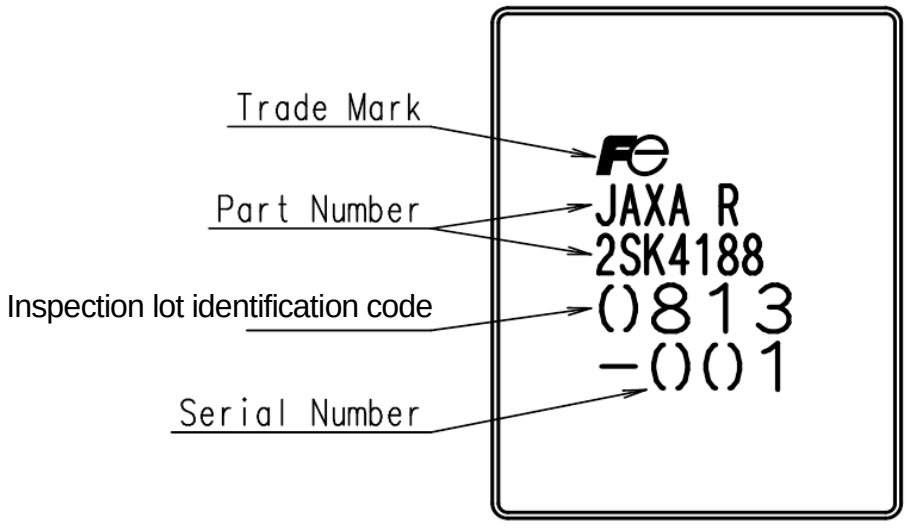


Figure 2b. Marking (SMD-2)
(JAXA R 2SK4188)

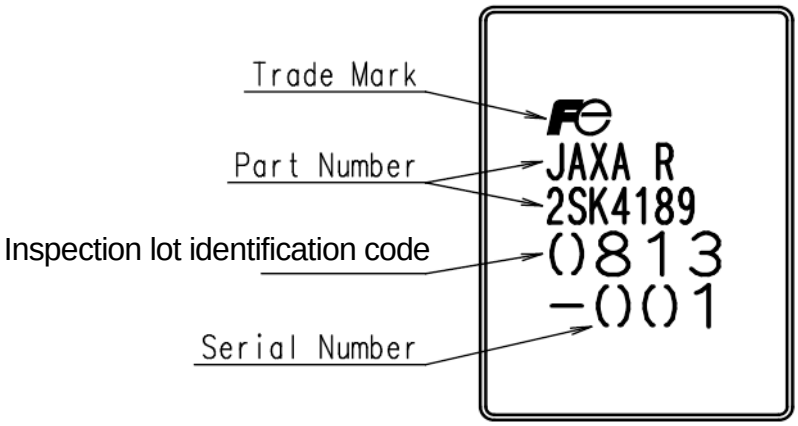


Figure 2c. Marking (SMD-1)
(JAXA R 2SK4189)

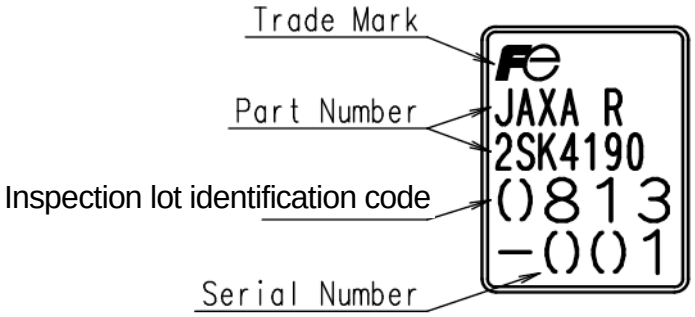


Figure 2d. Marking (SMD-0.5)
(JAXA R 2SK4190)

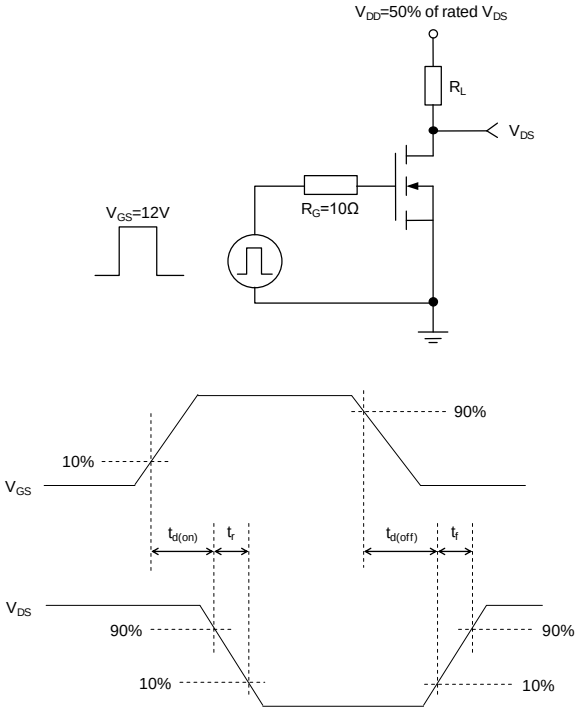


Figure 3. Switching time test circuit and waveforms

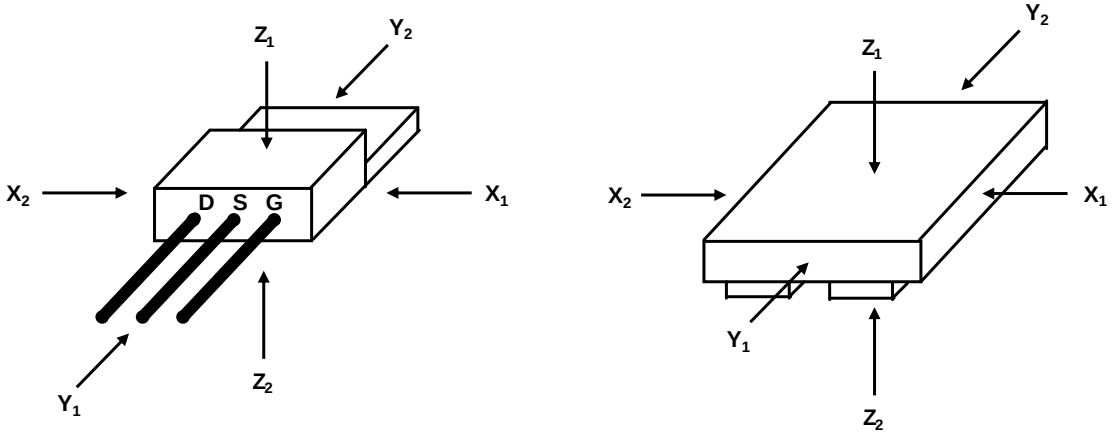


Figure 4. Orientation

JAXA R 2SK4185

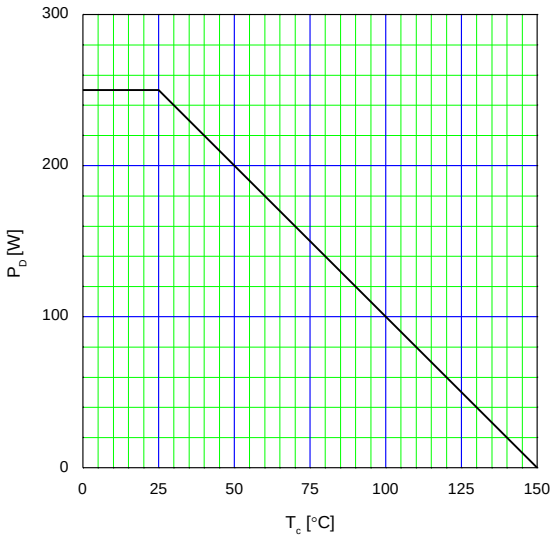


Fig. 5 Allowable Power Dissipation
$P_D=f(T_c)$

JAXA R 2SK4185

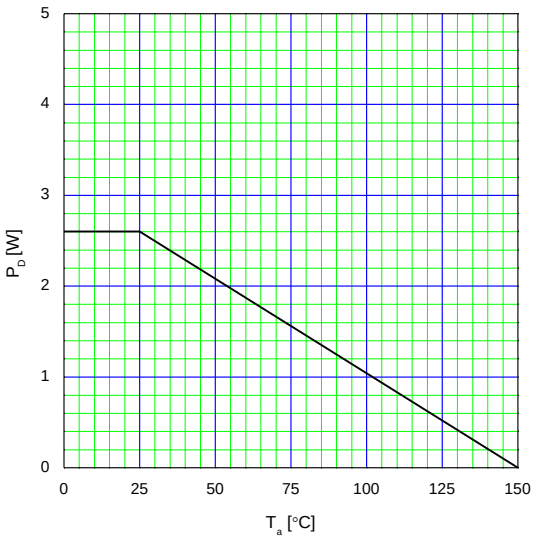


Fig. 6 Allowable Power Dissipation
$P_D=f(T_a)$

JAXA R 2SK4185

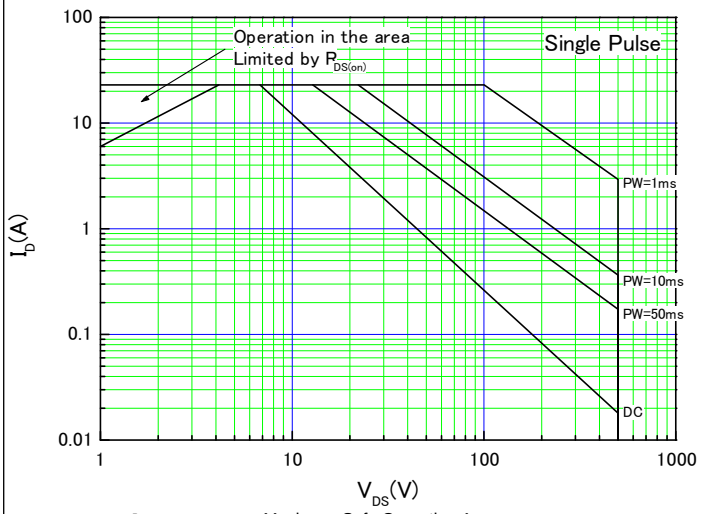


Fig. 7 Maximum Safe Operating Area
$I_D=f(V_{DS})$

JAXA R 2SK4186

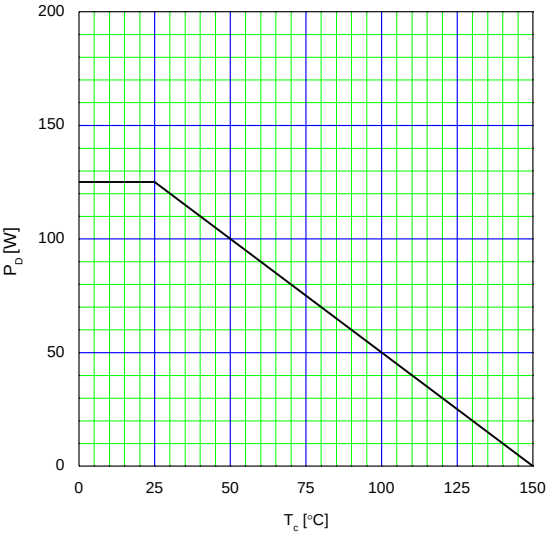


Fig. 8 Allowable Power Dissipation
$P_D=f(T_c)$

JAXA R 2SK4186

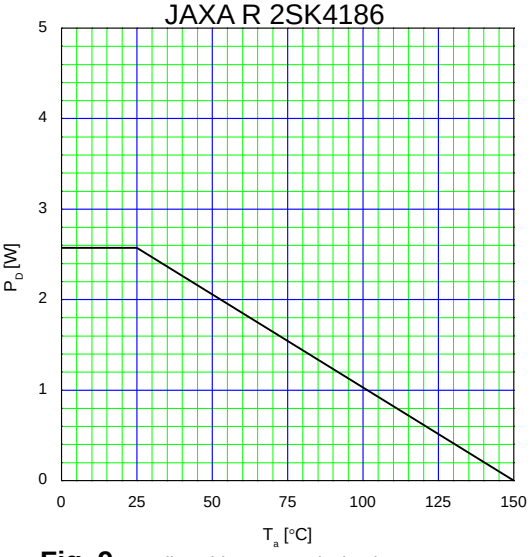


Fig. 9 Allowable Power Dissipation
$P_D=f(T_a)$

JAXA R 2SK4186

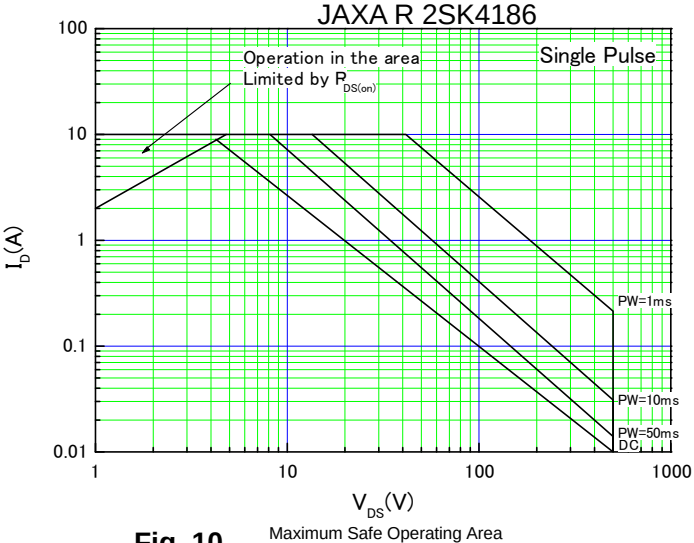


Fig. 10 Maximum Safe Operating Area
$I_D=f(V_{DS})$

JAXA R 2SK4187

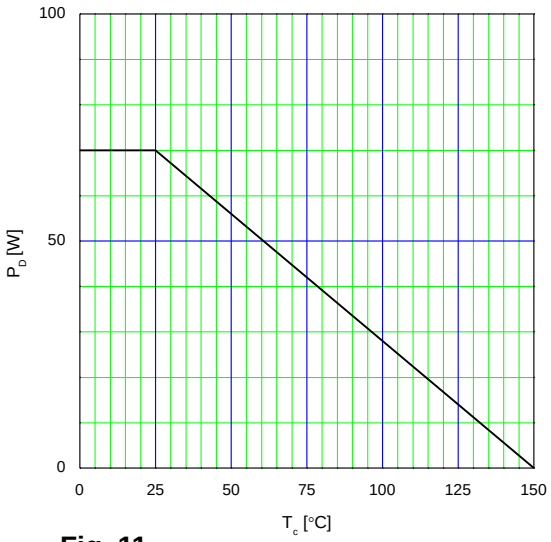


Fig. 11 Allowable Power Dissipation
$P_D=f(T_c)$

JAXA R 2SK4187

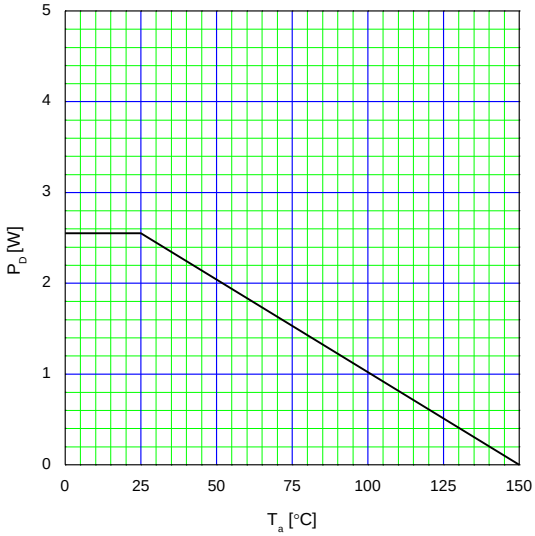


Fig. 12 Allowable Power Dissipation
$P_D=f(T_a)$

JAXA R 2SK4187

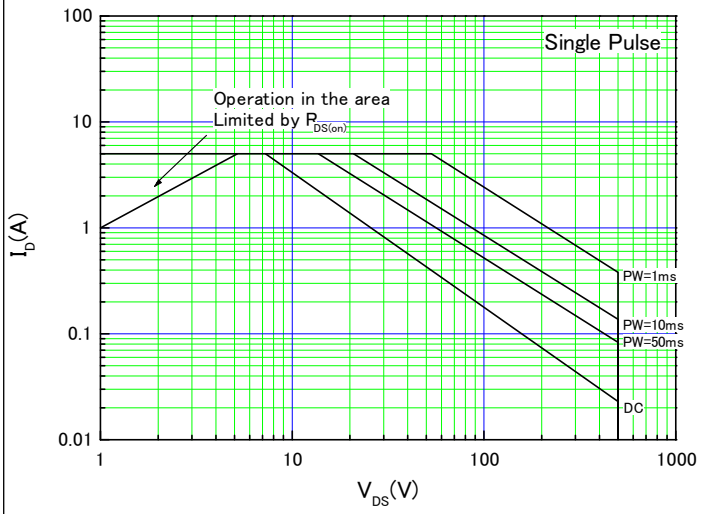


Fig. 13 Maximum Safe Operating Area
$I_D=f(V_{DS})$

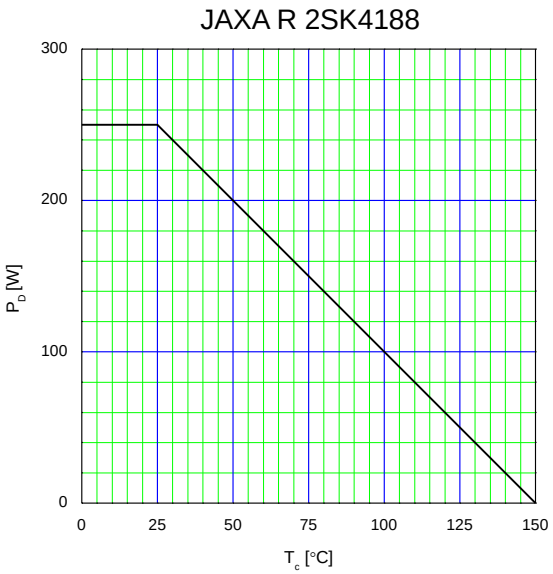


Fig. 14 Allowable Power Dissipation
$P_D=f(T_c)$

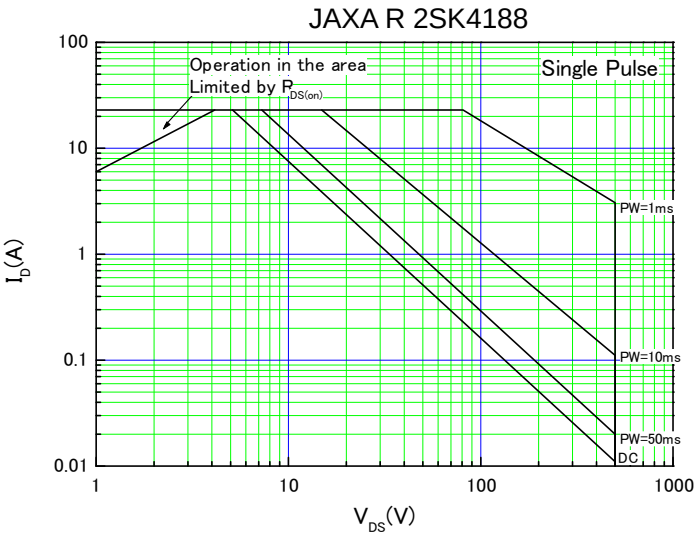


Fig. 15 Maximum Safe Operating Area
$I_D=f(V_{DS})$

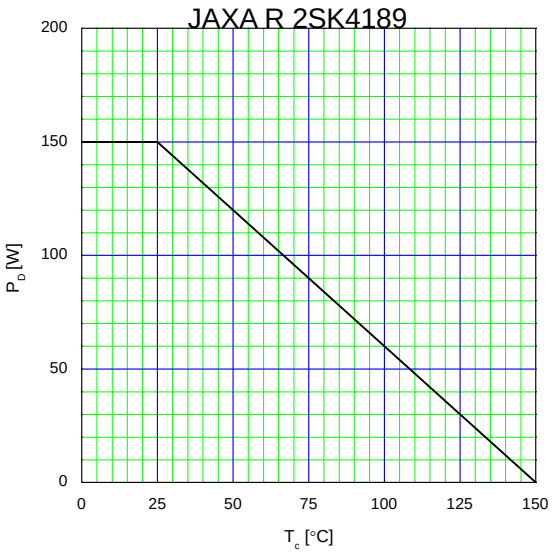


Fig. 16 Allowable Power Dissipation
$P_D=f(T_c)$

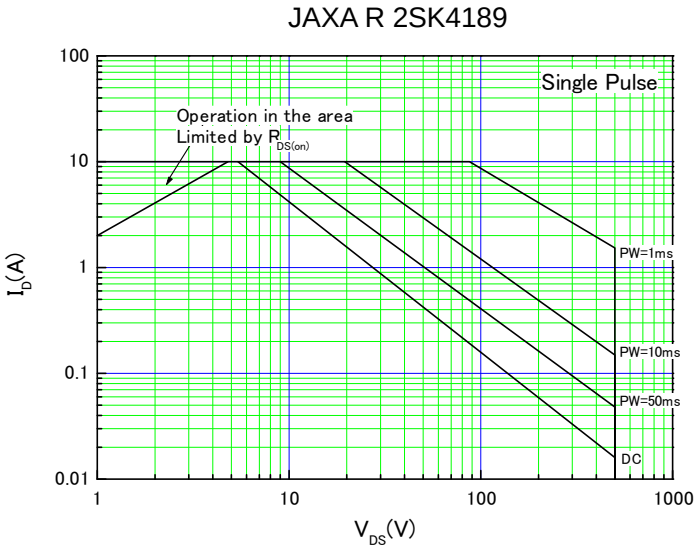


Fig. 17 Maximum Safe Operating Area
$I_D=f(V_{DS})$

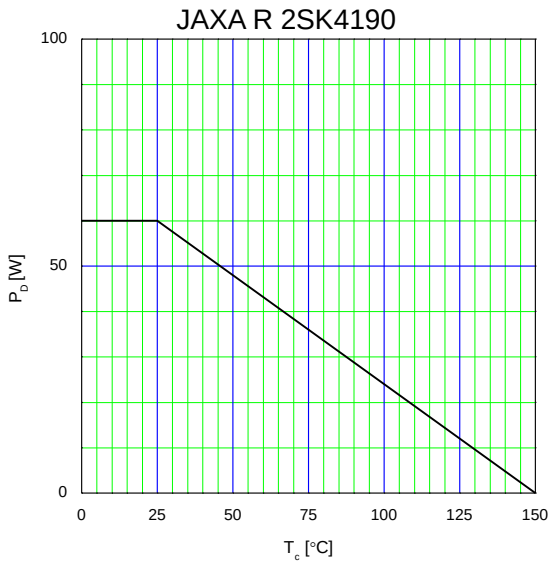


Fig. 18 Allowable Power Dissipation
$P_D=f(T_c)$

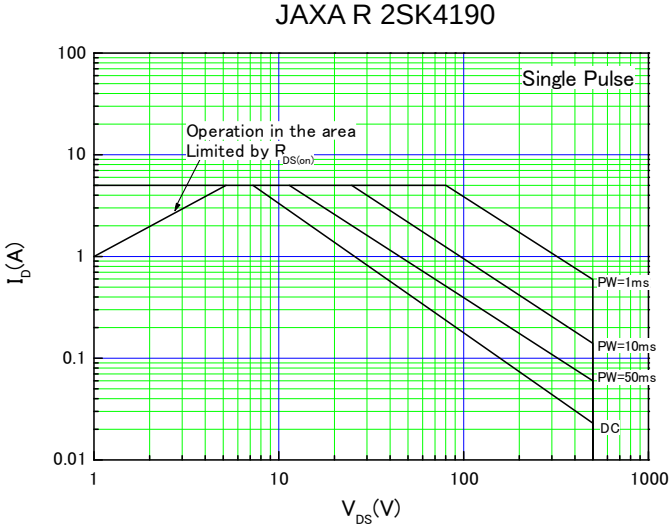


Fig. 19 Maximum Safe Operating Area
$I_D=f(V_{DS})$