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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 Device Technology Co., Ltd.
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This specification was originally written and established in the Japanese language. This specification has been translated into English for international users. Note that this document is a working document for international users. Any discrepancies found in this document should be verified against the latest Japanese document before any significant decisions are made.

Revision Log

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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

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 that the parts are for space applications.

⁽²⁾ "R" indicates that the parts are radiation hardened for space applications.

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 $T_C=25^\circ\text{C}$ (W)	P_D $T_A=25^\circ\text{C}$ (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 junction 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} (μ A)	I_{GSS} (nA)	$V_{GS(th)}$ (V)	$R_{DS(on)}^{(1)}$ (m Ω)	$gfs^{(1)}$ (S)	E_{AS} (mJ)
	$I_D=1mA$ $V_{GS}=0V$	$V_{DS}=400V$ $V_{GS}=0V$	$V_{GS}=\pm 20V$ $V_{DS}=0V$	$I_D=1mA$ $V_{DS}=V_{GS}$	$I_D=50%$ 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 \leq 1ms, Duty cycle \leq 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 $I_D, V_{GS}=12V, R_G=10\Omega$			
	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)
	$I_F = \text{rated } I_D$ $V_{GS} = 0V$	$I_F = \text{rated } I_D, V_{GS} = 0V,$ $-di/dt = 100A/\mu s,$ $T_{ch} = 25^\circ C$	
	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 $\leq 1ms$, Duty cycle $\leq 2\%$

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 Methods Standard for Semiconductor Devices
MIL-PRF-19500N	Performance Specification Semiconductor Devices, General Specification for

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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 immersion as specified in the paragraph 3.3.7 c) 2) 2.1) of JAXA-QTS-2030. In the case of Pb-Sn solder immersion, unplated lead length shall be less than 2mm from the lead egress on the product's body.

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 1.27 μ m. This finish shall be plated with nickel as an underplating of a thickness between 1.27 μ m and 7.62 μ m.

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.

3.3 Certification

Manufacturers who wish to supply the products specified herein shall be certified by JAXA as specified in 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.

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4.2 Materials Control

The 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

$T_A=+25^{\circ}\text{C}$

Measuring item	$V_{(BR)DSS}$ (V)	I_{DSS} (μA)	I_{GSS} (nA)	$V_{GS(th)}$ (V)	$R_{DS(on)}^{(1)}$ ($\text{m}\Omega$)	$gfs^{(1)}$ (S)	$V_{SD}^{(1)}$ (V)
MIL-STD-750 Test Method No.	3407	3413	3411	3404	3421	3475	---
Test conditions	Bias Condition C $I_D=1\text{mA}$ $V_{GS}=0\text{V}$	Bias Condition C $V_{DS}=400\text{V}$ $V_{GS}=0\text{V}$	Bias Condition C $V_{GS}=\pm 20\text{V}$ $V_{DS}=0\text{V}$	$I_D=1\text{mA}$ $V_{DS}=V_{GS}$	$I_D=50\%$ of rated I_D $V_{GS}=12\text{V}$	$I_D=50\%$ of rated I_D $V_{DS}=25\text{V}$	$I_F=\text{rated } I_D$ $V_{GS}=0\text{V}$
	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 $\leq 1\text{ms}$, Duty cycle $\leq 2\%$

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

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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: $V_{GS}=35V, t=1ms, T_A=25^{\circ}C$

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

Initial $T_C = +25_{+10}^{-5} \text{ }^{\circ}C$

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

Temperature cycling test: Condition G, 20 cycles

Reverse bias burn-in test (GS): $T_A=150^{\circ}C, V_{GS}=16V$

$V_{DS}=0V, 48hr$

Burn-in test (DS): $T_A=150^{\circ}C, V_{DS}=80\% \text{ of rated } V_{DS}$

$V_{GS}=0V, 240hr$

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

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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 Long-term Storage

Delivery 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 Notice for Acquisition Officers

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.

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6.2.2 Beryllium 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 1-a. Group A Inspection ⁽¹⁾

Gr.No	MIL-STD-750		JAXA R	1/1 Die Size		1/2 Die Size		1/4 Die Size	
	Sub	Test Item		Method	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187
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 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					
			Limits	I _D =11.5A max 0.18Ω	I _D =5.0A max 0.48Ω	I _D =2.25A max 1.15Ω			
-1f	Forward Transconductance g _{fs}	3475	Conditions	Pulse Test ⁽²⁾ , V _{DS} =25V					
			Limits	I _D =11.5A min 7.0S	I _D =5.0A min 4.0S	I _D =2.25A min 2.5S			
-1g	Forward Voltage V _{SD}	---	Conditions	Pulse Test ⁽²⁾ , V _{GS} =0V					
			Limits	I _D =23A max 1.6V	I _D =10A max 1.6V	I _D =4.5A max 1.6V			
A -2 Static Characteristics (T_A=125°C)			Sample Size	LTPD 5					
-2a	Gate 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					
			Limits	I _D =11.5A max 0.38Ω	I _D =5.0A max 1.01Ω	I _D =2.25A max 2.43Ω			

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

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

Table 1-b. Group A Inspection (1)

Gr.No	MIL-STD-750		JAXA R	1/1 Die Size		1/2 Die Size		1/4 Die Size	
	Sub	Test Item		Method	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187
A-3	Static Characteristics (T_A=-55°C)		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 g _{fs} (-55°C)	3475	Conditions	Pulse Test (2), V _{DS} =25V					
			Limits	I _D =11.5A	I _D =5.0A	I _D =2.25A			
				min 7.5S	min 4.5S	min 3.0S			
A-4	Dynamic Characteristics (T_A=25°C)		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					
			Limits	I _D =23A	I _D =10A	I _D =4.5A			
				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=25°C) (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					
			Limits	I _D =23A	I _D =10A	I _D =4.5A			
				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 V _{GS} =0V -di/dt=100A/μs					
			Limits	I _F = I _D =10A	I _F = I _D =4.5A				
				max	max	max			
			T _{rr}	950ns	900ns	800ns			
			Q _{rr}	23μC	19μC	11μC			

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 2-a. 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	Dimensions⁽¹⁾		Sample Size	2066	Level I ⁽²⁾ 3p						
			Conditions		Level II ⁽²⁾ 3p						
				See Fig. 1a, 1b, 1c, 1d							
B-2	Resistance to Solvents⁽³⁾ ⁽⁴⁾		Sample Size	1022	Level I 3p						
			Conditions		Level II 3p						
				Solvent a, b, c							
B-3b	Temperature Cycling (Air to Air)		Sample Size	1051	Level I 6p						
			Conditions		Level II 6p						
				-55 ⁺¹⁰ ₋₅ °C ↔ 25 ⁺¹⁰ ₋₅ °C ↔ 150 ⁺⁵ ₋₀ °C							
				100 cycles							
-3c	Surge Test (1) Gate Shock		Sample Size	4066	V _{GS} =35V						
			Conditions								
-3c	(2) Avalanche		Sample Size	4066	I _{D(pulse)} = 23A		I _{D(pulse)} = 10A		I _{D(pulse)} = 4.5A		
			Conditions		V _{DS} =48V						
				L= See paragraph 4.5.2, Equation (1), R _g =10Ω							
-3d	Hermetic Seal (1) Fine		Sample Size	1071	Condition H						
			Limits		max 1×10 ⁻³ Pa·cm ³ /s						
				Condition C							
-3d	(2) Gross		Sample Size	1071	Condition C						
			Conditions								
-3e	End-Point Electrical Measurements		---	---	Same as Gr.A-1						
-3f	Decap-Internal Visual		2075 2071	---	---						
-3g	Bond Strength		Sample Size	2037	Condition A						
			Limits		Gate Wire >90gf						
				Source Wire >90gf							
				>160gf >160gf >90gf							
-3h	SEM⁽¹⁾		2077	---	---						
-3i	Die Shear		Sample Size	2017	Level I 3p						
			Conditions		Level II 3p						

				min 2.5kgf							
B-4	Solderability⁽³⁾ ⁽⁴⁾		Sample Size	2026	Level I ⁽⁵⁾		Level II ⁽⁵⁾				
			Conditions		6 leads 6 terminals		6 leads 6 terminals		6 leads 6 terminals		6 leads 6 terminals
				6 leads 6 terminals		6 leads 6 terminals		6 leads 6 terminals		6 leads 6 terminals	

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 or the quality conformance inspection, respectively. (See paragraphs C.3.2 and C.3.3 of JAXA-QTS-2030)

⁽³⁾ Electrically defective products from the same inspection lot may be used.

⁽⁴⁾ When electrically defective 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 2-b. Group B Inspection

Gr.No	MIL-STD-750		JAXA R	1/1 Die Size		1/2 Die Size		1/4 Die Size		
	Sub	Test Item		Method	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⁾					
-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 (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 A					
			Limits	Gate Wire >90gf Source Wire >160gf >160gf >90gf						
B -7		Thermal Resistance R _{th(ch-c)} (ΔV _{SD})	Sample Size	Level I LTPD 10 Level II 8p						
			3161	Conditions	T _A =25°C					
			Limits	max	max	max	max	max	max	
				0.5°C/W	0.5°C/W	1.0°C/W	0.83°C/W	2.0°C/W	1.67°C/W	

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

Table 3. Group C Inspection

Gr.No	MIL-STD-750		JAXA R	1/1 Die Size		1/2 Die Size		1/4 Die Size						
	Sub	Test Item		Method	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⁾									
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 Temperature 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		Thermal Shock 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	Conditions	Condition H										
			Limits	max 1×10 ⁻³ Pa-cm ³ /s										
-2c		End-Point Electrical Measurements ⁽³⁾	Conditions	Condition C										
			Limits	Same as Gr.A-1										
C -3		Thermal Resistance ⁽⁴⁾ R _{th(ch-c)} (ΔV _{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	
C -4a		Safe Operating Area Test ⁽⁵⁾	Sample Size	Level I LTPD 10 Level II LTPD 10										
			3474	Conditions	---									
-4b		End-Point Electrical Measurements ⁽⁵⁾	---	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⁾ This test may be exempted if performed in the Group A test.

Table 4-a. Group D Inspection

Gr.No	MIL-STD-750		JAXA R	1/1 Die Size		1/2 Die Size		1/4 Die Size	
	Sub	Test Item		Method	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187
D-1a		Thermal Shock (Glass Strain)	Sample Size	Level I LTPD 15 Level II LTPD 15					
			1056	Conditions	Condition B, 15 cycles				
-1b		Thermal Shock (Temperature Cycling)	1051	Conditions	$-55^{+0}_{-5}^{\circ}\text{C} \leftrightarrow 25^{+10}_{-5}^{\circ}\text{C} \leftrightarrow 150^{+5}_{-0}^{\circ}\text{C}$ 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	Conditions	Condition H					
			Limits	max $1 \times 10^{-3} \text{Pa-cm}^3/\text{s}$					
-1f		Visual Inspection	1051	Conditions	---				
			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, 14710m/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 196.1m/s^2 (20G)				
-2c		Constant Acceleration⁽²⁾	2006	Conditions	98066.5m/s^2 (10000G) X ₁ , Y ₁ , Y ₂ and Z ₁ orientation				
-2d		Hermetic Seal⁽²⁾ (1) Fine	Conditions	Condition H					
			Limits	max $1 \times 10^{-3} \text{Pa-cm}^3/\text{s}$					
-2e		End-Point Electrical Measurements⁽²⁾	1071	Conditions	Condition C				
			---	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 $50 \text{g/m}^2/24\text{hr}$				

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⁾ Electrically defective products from the same inspection lot may be used.

Table 4-b. Group D Inspection

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

Note(1) Electrically defective products from the same inspection lot may be used.

Table 5. Group E Inspection

Gr.No	MIL-STD-750		JAXA R	1/1 Die Size		1/2 Die Size		1/4 Die Size	
	Sub	Test Item		Method	2SK4185	2SK4188	2SK4186	2SK4189	2SK4187
E -1a	Total Dose Irradiation (TID)		Sample Size	Level I 4p ⁽¹⁾ Level II 4p ⁽¹⁾ Total Dose 1×10 ³ Gy(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					
			1019						
-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 ----- min 500V DC					
			Limits						
(2)	Gate Current I _{GSS}	3411	Conditions	Bias Condition C V _{GS} =±20V , V _{DS} =0V ----- max ±100nA DC					
			Limits						
(3)	Drain Current I _{DSS}	3413	Conditions	Bias Condition C V _{DS} =400V , V _{GS} =0V ----- max 25µA DC					
			Limits						
(4)	Gate to Source Voltage (Threshold) V _{GS(th)}	3404	Conditions	Bias Condition C V _{GS} =V _{DS} , I _D =1mA ----- min 1.5V DC ΔV _{GS(th)} max 2.0V					
			Limits						
(5)	Static Drain to Source On-State Resistance R _{DS(on)}	3421	Conditions	Pulse Test ⁽²⁾ , V _{GS} =12V					
			Limits						

Notes⁽¹⁾ This test shall be performed for each single wafer lot. When an inspection lot consists of multiple inspection sublots, one inspection subplot 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	Package Type	TO-254			SMD-2	SMD-1	SMD-0.5
	JAXA-QTS-2030 Appendix C	1/1 Die Size	1/2 Die Size	1/4 Die Size	1/1 Die Size	1/2 Die Size	1/4 Die Size
Sub	Test Item	2SK4185	2SK4186	2SK4187	2SK4188	2SK4189	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.			This test may be exempted when the devices having the same die size or larger die size passed.		
	1-1b End-Point Electrical Measurements						
	-2a Temperature Cycling						
	-2b Hermetic Seal						
	-2c End-Point Electrical Measurements	This test may be exempted when the device passed in the Group B-7 test.					
	-3 Thermal Resistance	This test may be exempted when the device passed in the Group A-6 test.					
	-4a Safe Operating Area Test						
	-4b End-Point Electrical Measurements						
D	-1a Thermal Shock (Glass Strain)	This test may be exempted when any one of the products passed in the Group D test.			<ul style="list-style-type: none"> ▪ This test for the device with SMD-1 and SMD-0.5 Package may be exempted when it passed in 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 in 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.		
	-4 Barometric Pressure						
	-5 Internal Water Vapor						

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

Table 7-a. Qualification Test : Group A Inspection

MIL-PRF -19500N Gr.No	2030C Gr.No. (1)	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	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 _{bss}	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			
				Limits	I _D =11.5A max 0.18Ω	I _D =11.5A max 0.18Ω	I _D =5.0A max 0.48Ω	I _D =2.25A max 1.15Ω
-2f	A-1f	Forward Transconductance g _{fs}	3475	Conditions	Pulse Test ⁽²⁾ , V _{DS} =25V			
				Limits	I _D =11.5A min 7.0S	I _D =11.5A min 7.0S	I _D =5.0A min 4.0S	I _D =2.25A min 2.5S
-2g	A-1g	Forward Voltage V _{SD}	---	Conditions	Pulse Test ⁽²⁾ , V _{GS} =0V			
				Limits	I _D =23A max 1.6V	I _D =23A max 1.6V	I _D =10A max 1.6V	I _D =4.5A max 1.6V
-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 g _{fs} (-55°C)	3475	Conditions	Pulse Test ⁽²⁾ , V _{DS} =25V			
				Limits	I _D =11.5A min 7.5S	I _D =11.5A min 7.5S	I _D =5.0A min 4.5S	I _D =2.25A 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			
				Limits	I _D =11.5A max 0.38Ω	I _D =11.5A max 0.38Ω	I _D =5.0A max 1.01Ω	I _D =2.25A 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 7-b. Qualification Test : Group A Inspection

MIL-PRF -19500N Gr.No	2030C Gr.No.	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190	
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	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				
				Limits	I _D =23A	I _D =23A	I _D =10A	I _D =4.5A	
				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			
					Limits	I _D =23A	I _D =23A	I _D =10A	I _D =4.5A
					Q _g	300nC	300nC	120nC	48nC
					Q _{gd}	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
					Limits	V _{GS} =0V -di/dt=100A/μs			
T _{rr}	950ns				950ns	900ns	800ns		
Q _{rr}	23μC	23μC	19μC	11μC					

Table 8-a. Qualification Test : Group B Inspection

MIL-PRF-19500N Gr.No	2030C Gr.No	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	SMD-0.5 1/4 Die Size
B-1	B-1	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	Thermal shock (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⁾
			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 A	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⁾ Electrically defective products from the same inspection lot may be used.

⁽²⁾ When electrically defective 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 8-b. Qualification Test : Group B Inspection

MIL-PRF -19500N Gr.No	2030C Gr.No.	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	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	Steady-state Gate Stress		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	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 A	Condition A	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 Resistance R _{th(ch-c)} (ΔV _{SD})	3161	Sample Size	22p	22p	22p	22p
				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 9-a. Qualification Test : Group C Inspection

MIL-PRF-19500N Gr.No	2030C Gr.No	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	SMD-0.5 1/4 Die Size
C-1	B-1	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	Thermal Shock (Temperature Cycling)	1051	Conditions	-55 ⁺¹⁰ °C ↔ 25 ⁺¹⁰ °C ↔ 150 ⁺⁵ °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⁾
-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⁾ Electrically defective products from the same inspection lot may be used.

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

Table 9-b. Qualification Test : Group C Inspection

MIL-PRF -19500N Gr.No	2030C Gr.No.	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	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 Resistance $R_{th(ch-c)}(\Delta V_{SD})$		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⁾ Electrically defective 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	2030C Gr.No	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190	
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	SMD-0.5 1/4 Die Size	
D-2	E-1a	Total Dose Irradiation (TID)	1019	Sample Size	---	---	4/4/4p	---	
				Conditions	Tested in 2SK4189	Tested in 2SK4189	Total Dose 1×10^3 Gy(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	---	Sample Size			Within 24hr after irradiation	
					Conditions	Tested in 2SK4189	Tested in 2SK4189	Bias Condition C $I_D=1mA, V_{GS}=0V$ min	Tested in 2SK4189
					Limits			500V DC	
					Conditions	Tested in 2SK4189	Tested in 2SK4189	Bias Condition C $V_{GS}=\pm 20V, V_{DS}=0V$ max	Tested in 2SK4189
					Limits			$\pm 100nA$ DC	
Conditions	Tested in 2SK4189	Tested in 2SK4189	Bias Condition C $V_{DS}=400V, V_{GS}=0V$ max	Tested in 2SK4189					
Limits			25 μA DC						
Conditions	Tested in 2SK4189	Tested in 2SK4189	Bias Condition C $V_{GS}=V_{DS}, I_D=1mA$ min	Tested in 2SK4189					
Limits			1.5V DC $\Delta V_{GS(th)}$ max 2.0V						
Conditions	Tested in 2SK4189	Tested in 2SK4189	Pulse Test ⁽¹⁾ $V_{GS}=12V, I_D=5A$ max	Tested in 2SK4189					
Limits			0.48 Ω						

Note ⁽¹⁾ Pulse width $\leq 1ms$, Duty cycle $\leq 2\%$

Table 11-a. Qualification Test : Group E Inspection

MIL-PRF -19500N Gr.No	2030C Gr.No.	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	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 Resistance⁽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.

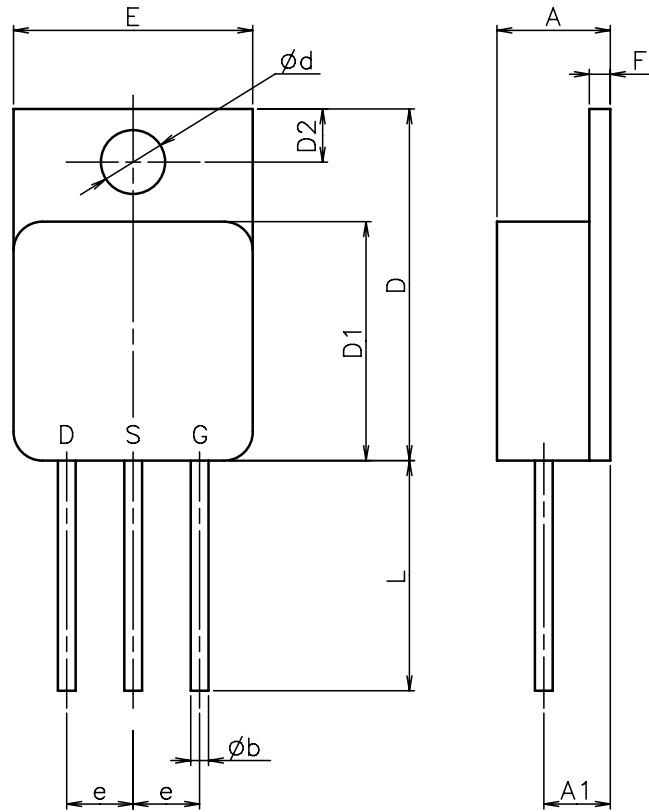
Table 11-b. Qualification Test : Group E Inspection

MIL-PRF -19500N Gr.No	2030C Gr.No.	MIL-STD-750		Type	JAXA R 2SK4185	JAXA R 2SK4188	JAXA R 2SK4189	JAXA R 2SK4190
		Test Item	Method		TO-254 1/1 Die Size	SMD-2 1/1 Die Size	SMD-1 1/2 Die Size	SMD-0.5 1/4 Die Size
E-7a	D-6a	Resistance to Soldering Heat	2031	Sample Size	3p	---	---	---
				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)	1080	Sample Size	3p			
				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.

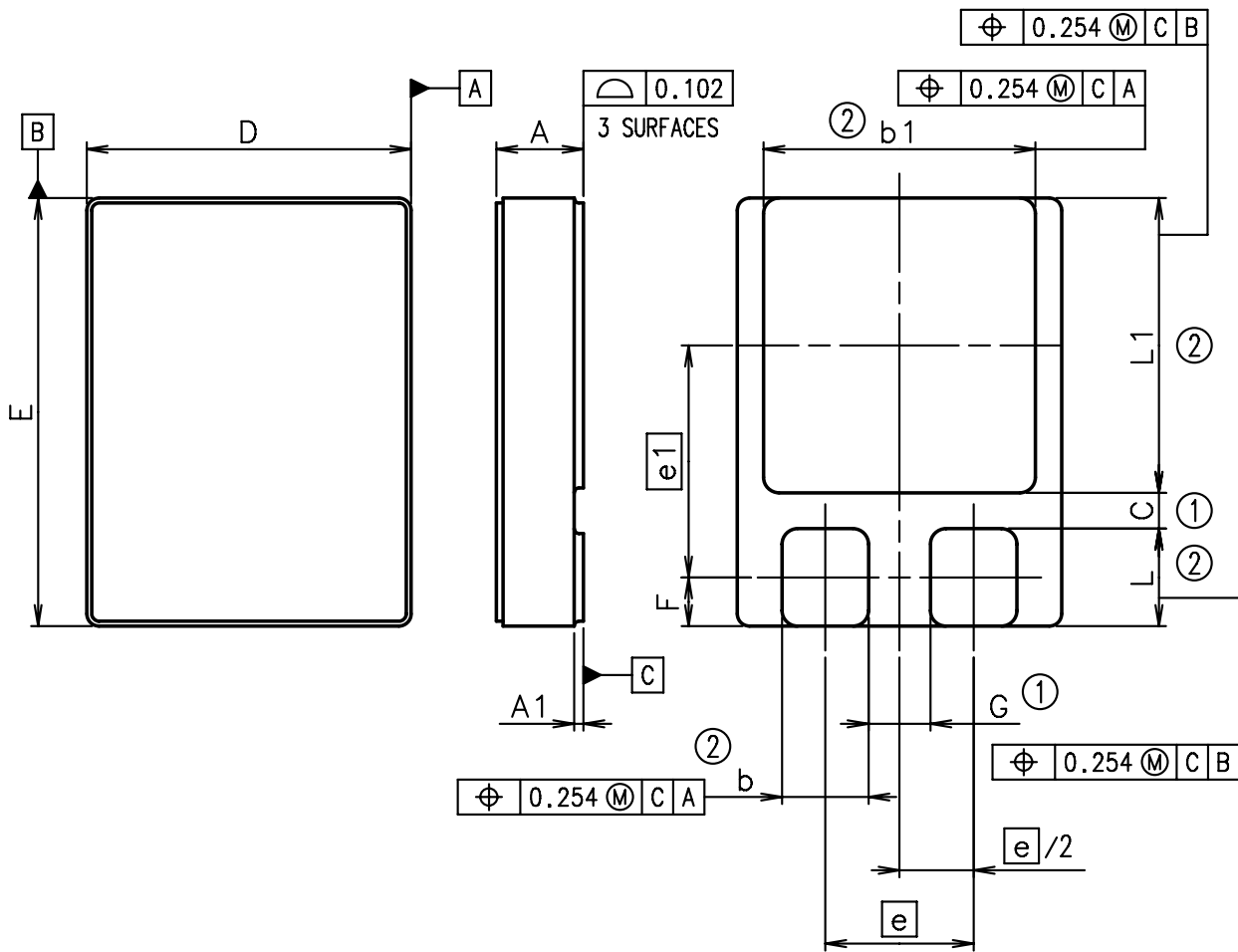


Symbol	Dimension (mm)	
	Min	Max
A	6.35	6.65
A1	3.61	4.01
ϕb	0.90	1.14
D	20.07	20.31
D1	13.59	13.85
D2	2.93	3.17

Symbol	Dimension (mm)	
	Min	Max
ϕd	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 1-a. Package Configuration and Lead Connection of TO-254 type package (JAXA R 2SK4185, 2SK4186, 2SK4187)



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

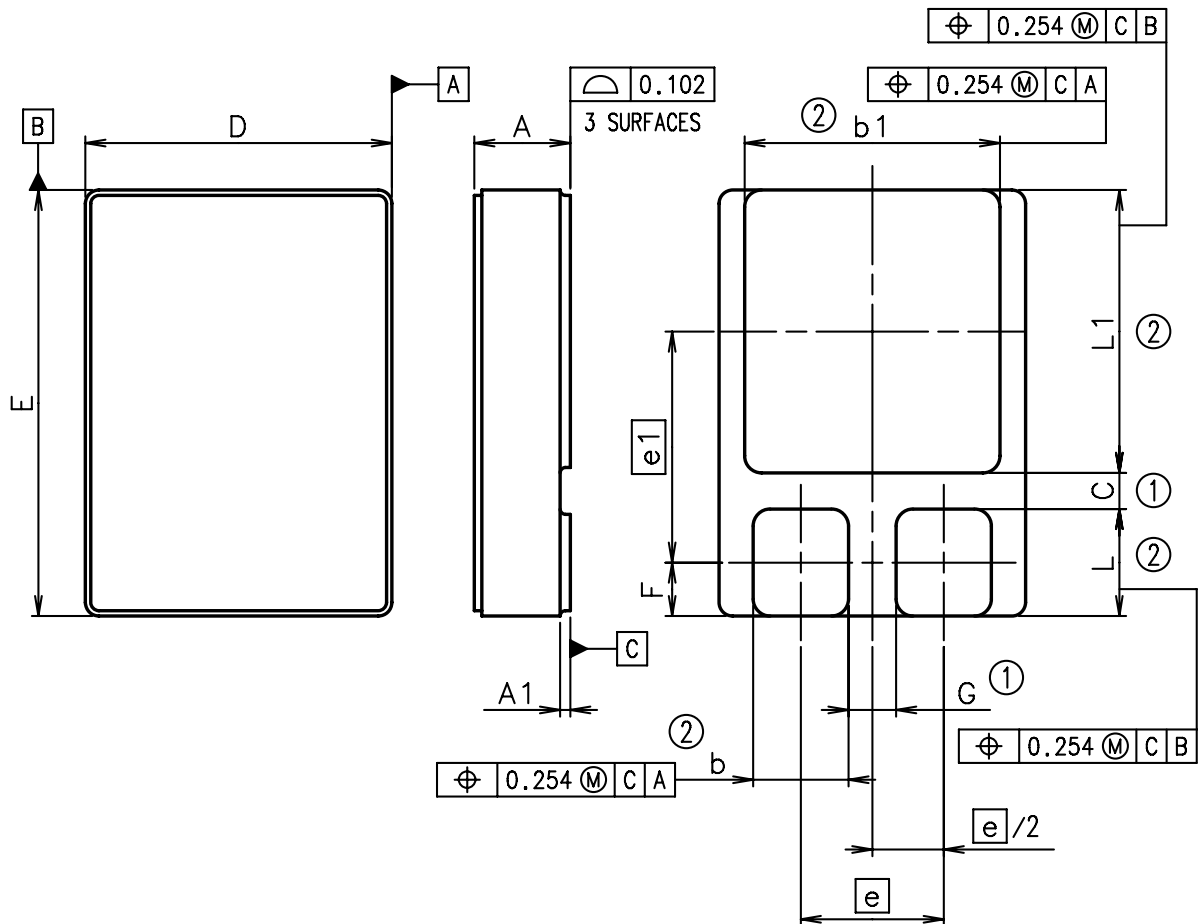
Symbol	Dimension (mm)		
	Min	Typ	Max
$e/2$	—	3.05	—
e	—	6.10	—
e1	—	9.50	—
F	—	1.99	—
G	1.27	—	—
L	3.87	3.99	4.11
L1	11.94	12.065	12.19

Notes: ① Dimension includes metallization flash.

② Dimension does not include metallization flash.

Note: All terminals are isolated from the case.

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



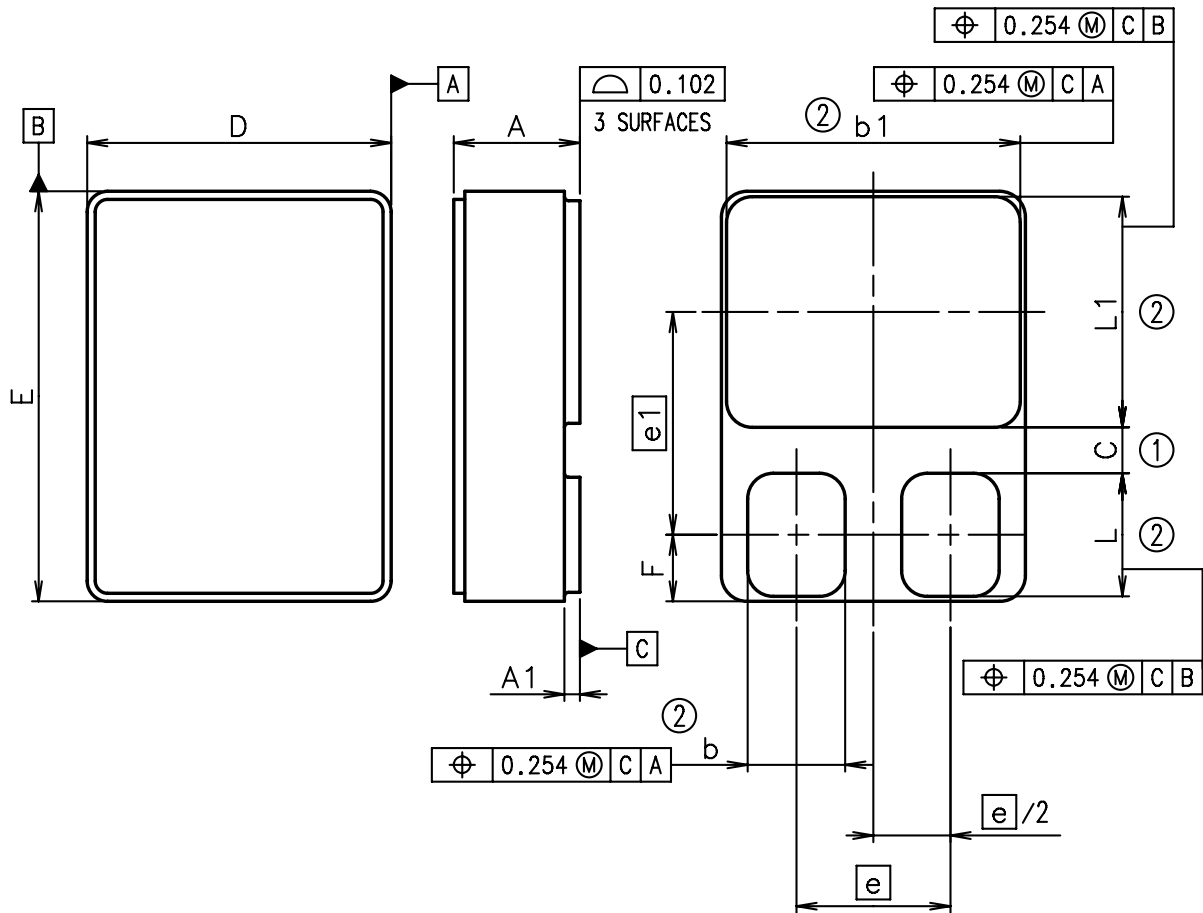
Symbol	Dimension (mm)		
	Min	Typ	Max
A	—	—	3.58
A1	0.254	0.381	0.508
b	3.43	3.555	3.68
b1	9.40	9.525	9.65
C	0.76	—	—
D	11.31	11.43	11.55
E	15.75	15.875	16.00

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



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

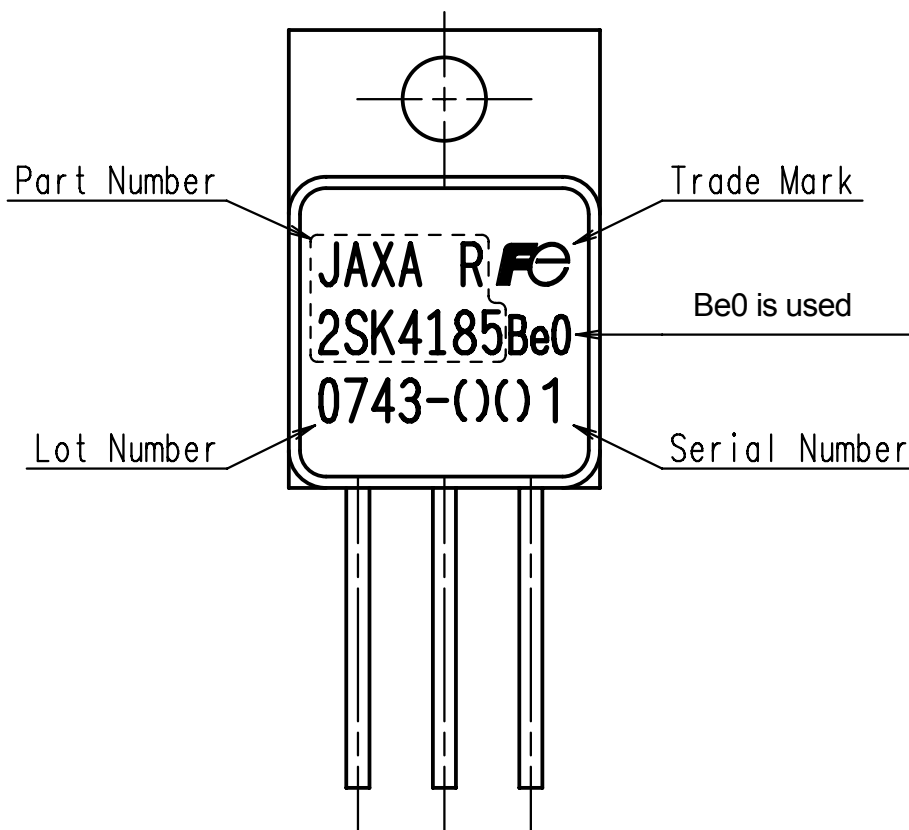


Figure 2-a. Marking (TO-254)
(JAXA R 2SK4185, 2SK4186, 2SK4187)

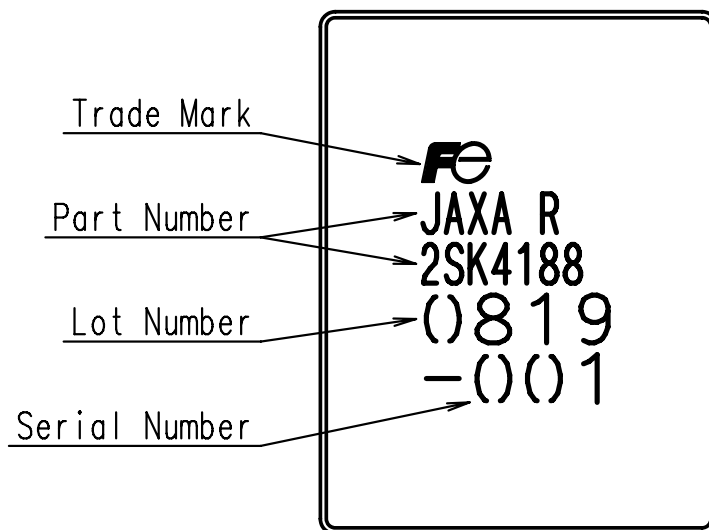


Figure 2-b. Marking (SMD-2)
(JAXA R 2SK4188)

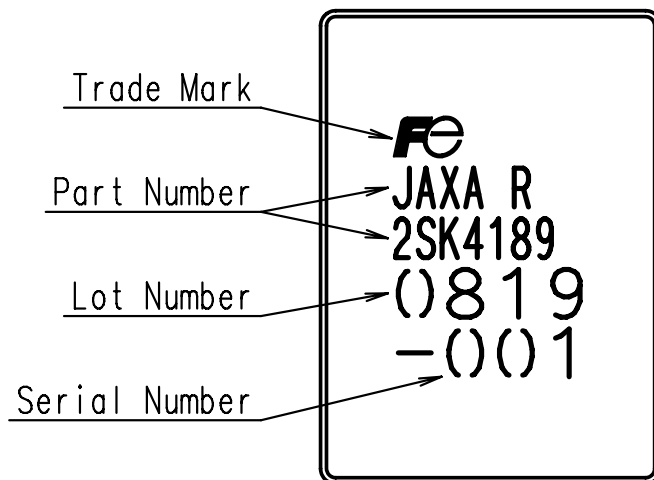


Figure 2-c. Marking (SMD-1)
(JAXA R 2SK4189)

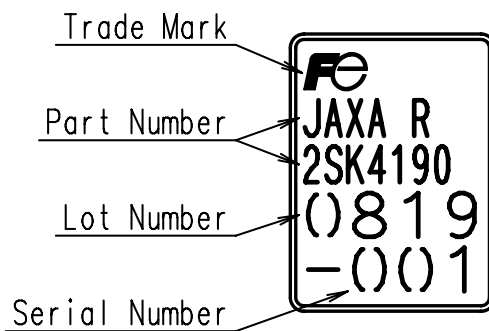


Figure 2-d. Marking (SMD-0.5)
(JAXA R 2SK4190)

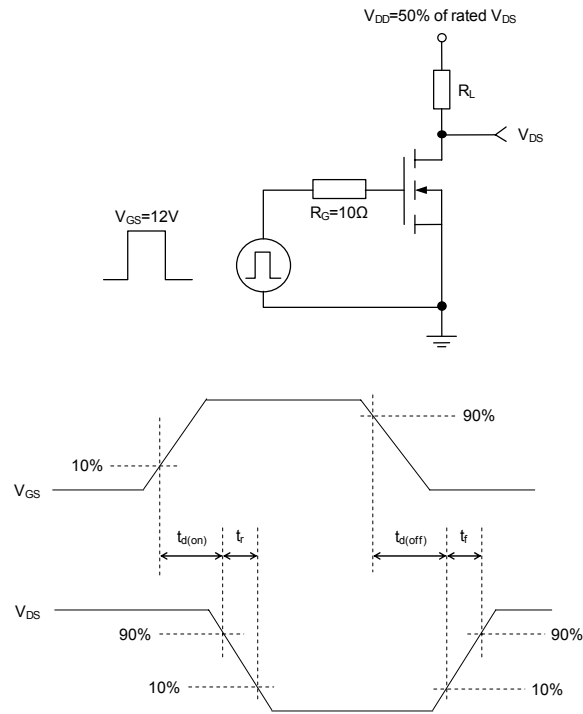


Figure 3. Switching time test circuit and waveforms

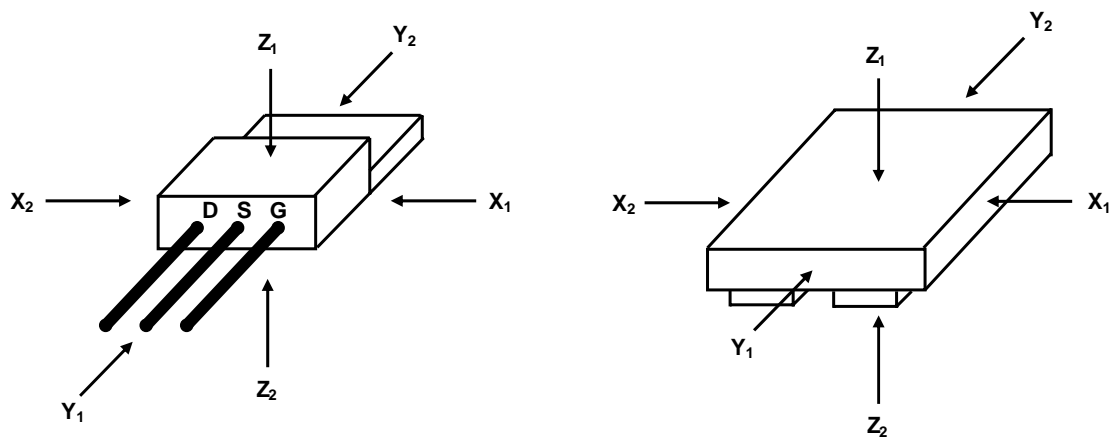


Figure 4. Orientation

JAXA R 2SK4185

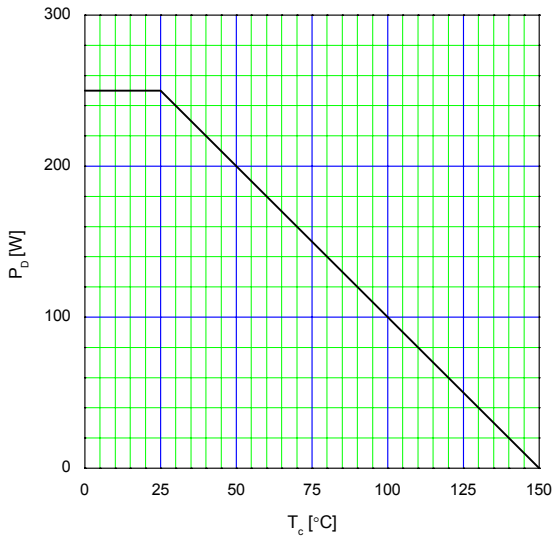


Fig. 5 Allowable Power Dissipation
 $P_D=f(T_c)$

JAXA R 2SK4185

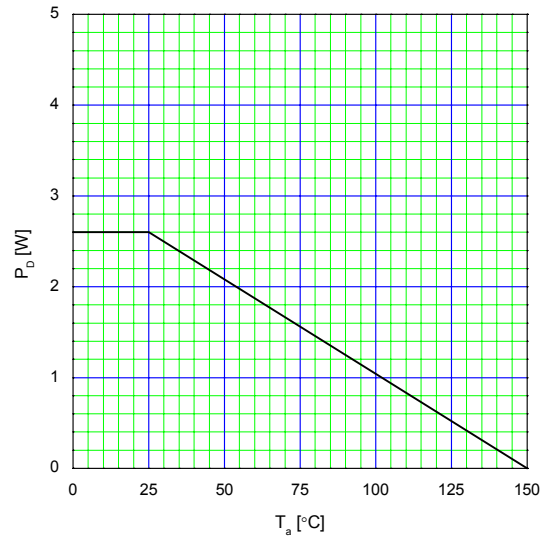


Fig. 6 Allowable Power Dissipation
 $P_D=f(T_a)$

JAXA R 2SK4185

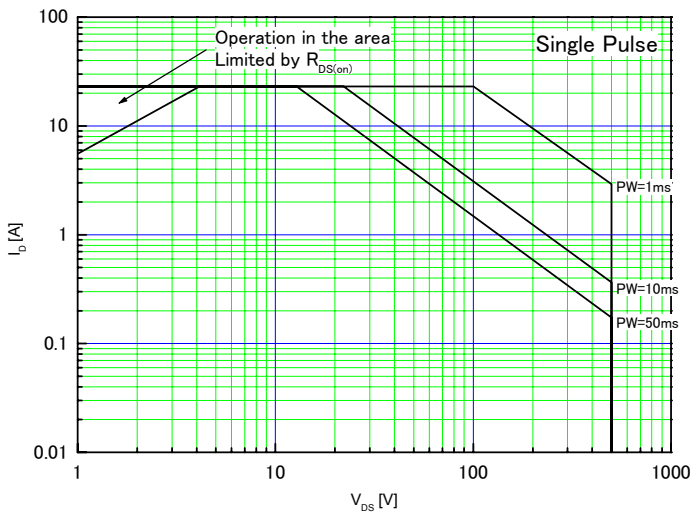


Fig. 7 Maximum Safe Operating Area
 $I_D=f(V_{DS})$

JAXA R 2SK4186

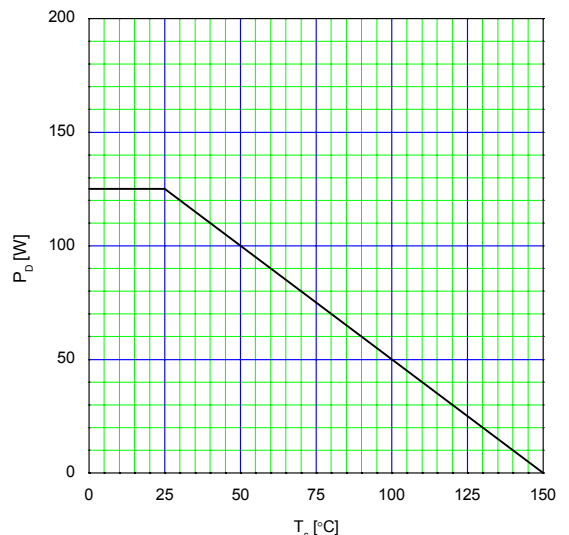


Fig. 8 Allowable Power Dissipation
 $P_D=f(T_c)$

JAXA R 2SK4186

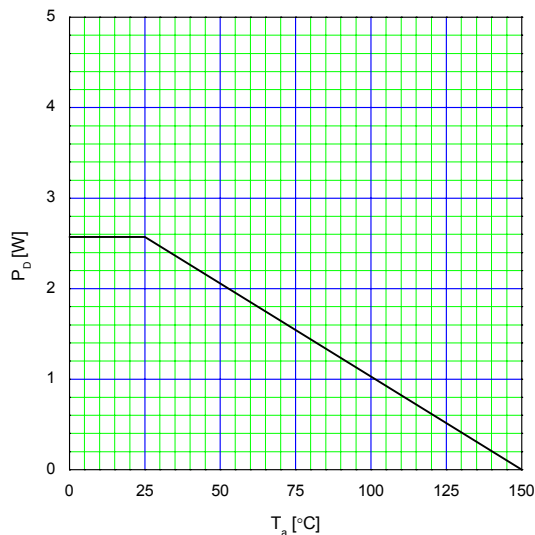


Fig. 9 Allowable Power Dissipation
 $P_D=f(T_a)$

JAXA R 2SK4186

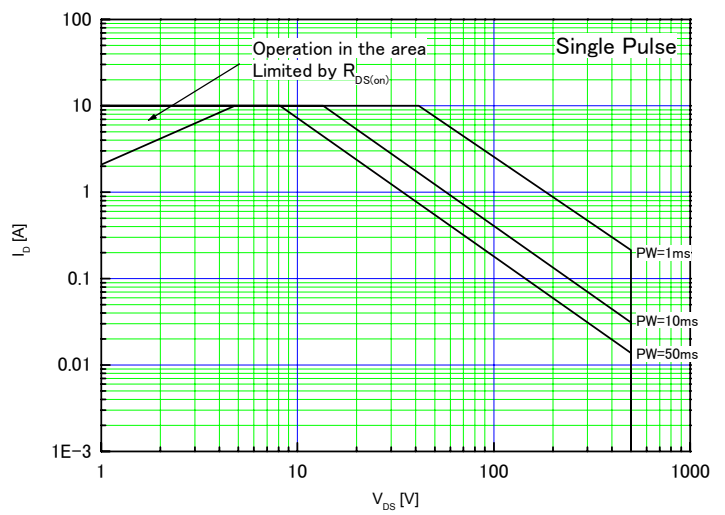


Fig. 10 Maximum Safe Operating Area
 $I_D=f(V_{DS})$

JAXA R 2SK4187

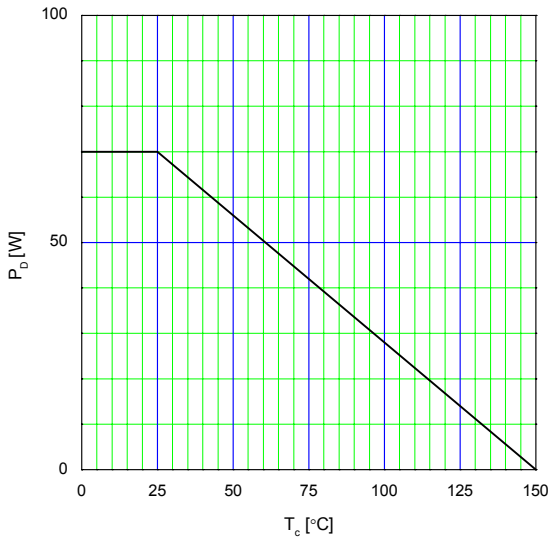


Fig. 11 Allowable Power Dissipation
 $P_D=f(T_c)$

JAXA R 2SK4187

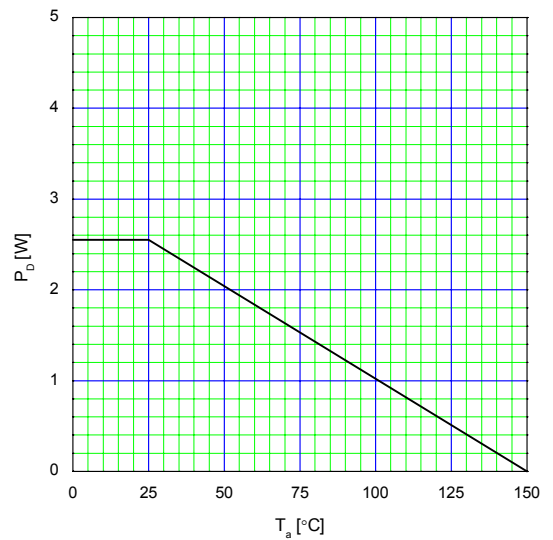


Fig. 12 Allowable Power Dissipation
 $P_D=f(T_a)$

JAXA R 2SK4187

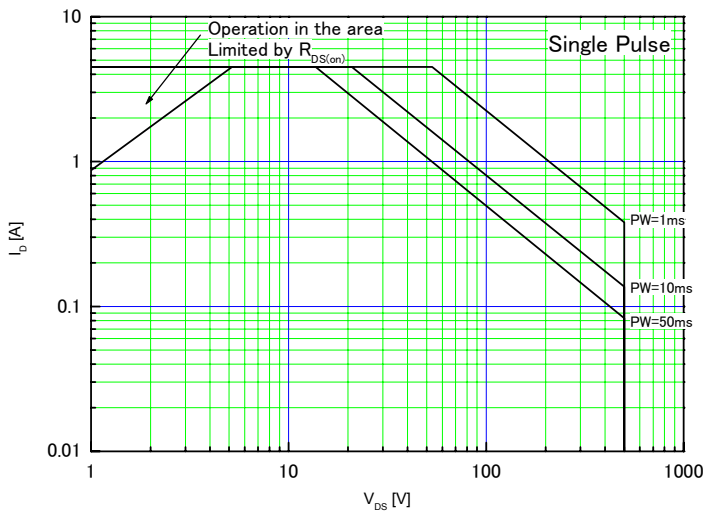


Fig. 13 Maximum Safe Operating Area
 $I_D=f(V_{DS})$

JAXA R 2SK4188

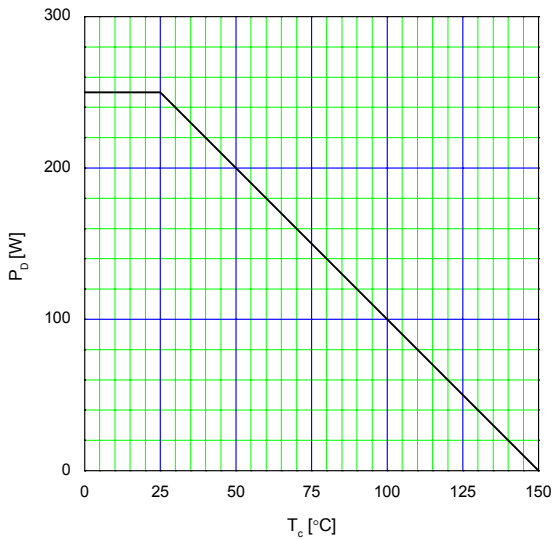


Fig. 14 Allowable Power Dissipation
 $P_D = f(T_c)$

JAXA R 2SK4188

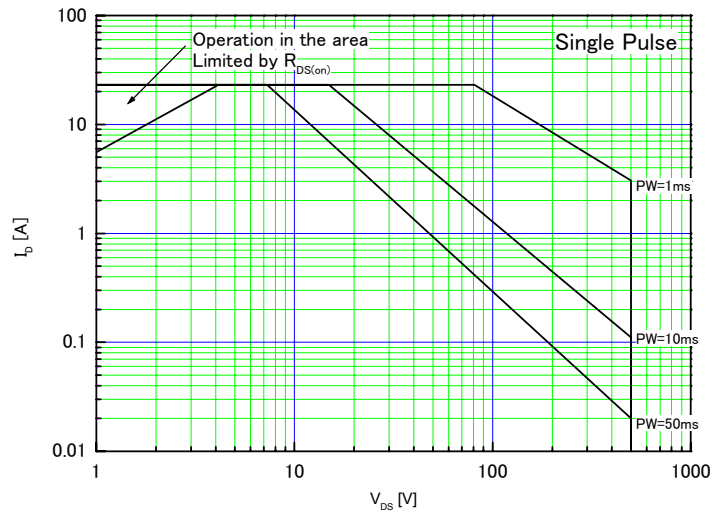


Fig. 15 Maximum Safe Operating Area
 $I_D = f(V_{DS})$

JAXA R 2SK4189

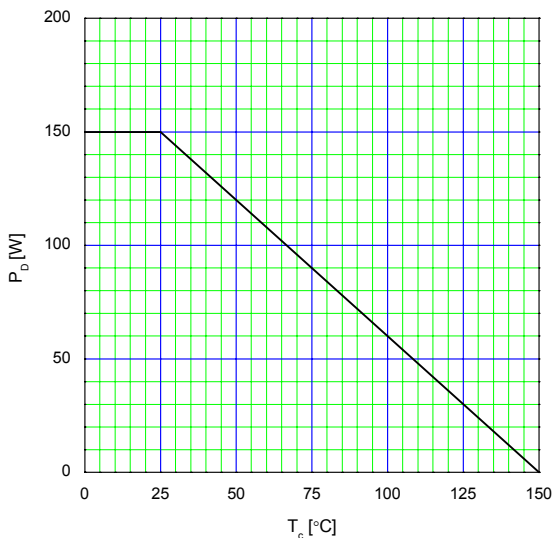


Fig. 16 Allowable Power Dissipation
 $P_D = f(T_c)$

JAXA R 2SK4189

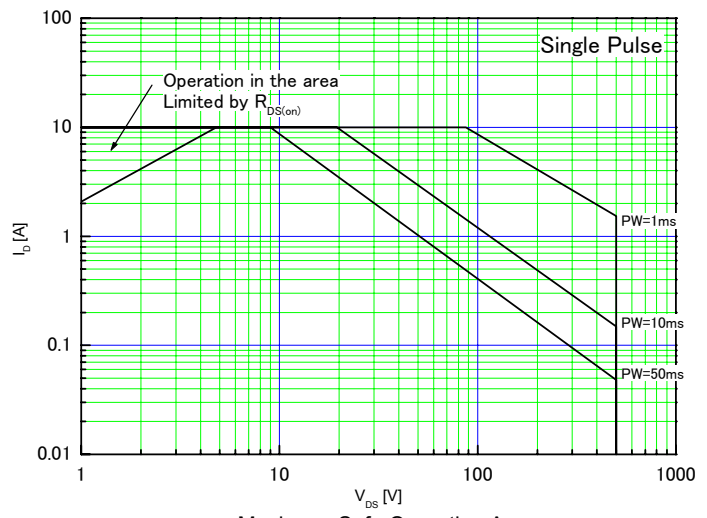


Fig. 17 Maximum Safe Operating Area
 $I_D = f(V_{DS})$

JAXA R 2SK4190

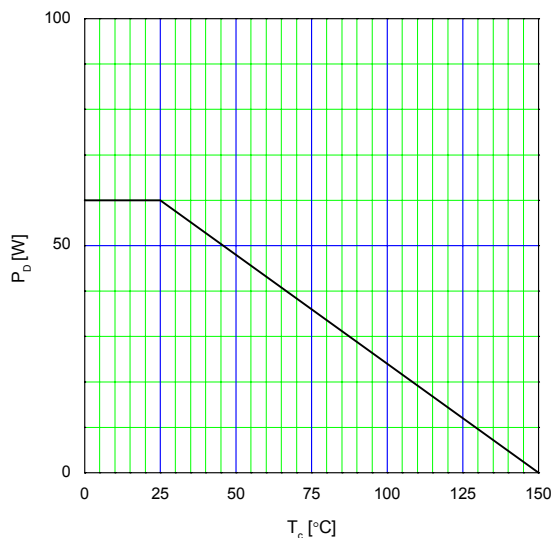


Fig. 18 Allowable Power Dissipation
 $P_D = f(T_c)$

JAXA R 2SK4190

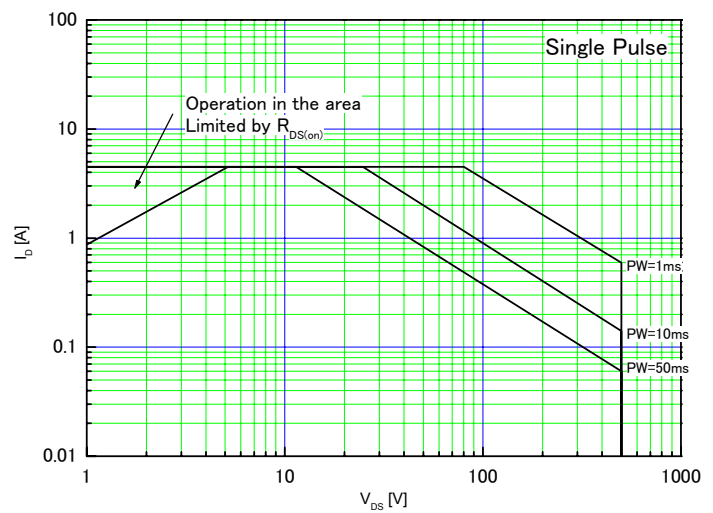


Fig. 19 Maximum Safe Operating Area
 $I_D = f(V_{DS})$