



TOTAL DOSE RADIATION TEST REPORT

Part Type : PHP50N06T

Package : TO-220AB

N-Channel Power MOSFET

Philips Semiconductors

Report Reference : ESA_QCA990901T_C

Issue : 01

Date : July 1st 1999

ESA Contract No 13413/98/NL/MV dated 25/01/99

European Space Agency Contract Report

The work described in this report was done under ESA contract.
Responsibility for the contents resides in the author or organization that prepared it

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TOTAL DOSE RADIATION TEST REPORT
on
Philips Semiconductors PHP50N06T N-Channel Power Mosfet.

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Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

1 Abstract

Under ESA/ESTEC contract n° 13413/98/NL/MV covering "Radiation Evaluation of Power MOSFET Devices from Different European Manufacturers", a large number of commercial Power MOSFET device types were radiation assessed. Results from these assessments, primarily focused on the radiation sensitivity of the MOSFETs to Total Ionizing Dose (TID) and Single Event Effects (SEE), are reported in individual TID and SEE reports. Below summary table list manufacturer and evaluated types, and give references to the various reports issued.

Manufacturer	Type	TID Report	SEE Report
Philips	PHP50N06T	ESA_QCA990901T_C	ESA_QCA990901S_C
Philips	BUK456-200A	ESA_QCA990902T_C	ESA_QCA990902S_C
Motorola	MTP50N06VL	ESA_QCA990903T_C	
Motorola	MTW32N20E	ESA_QCA990904T_C	
Motorola	MTP50N06V	ESA_QCA990905T_C	
Siemens	BUZ100S	ESA_QCA990906T_C	ESA_QCA990906S_C
Siemens	BUZ100SL	ESA_QCA990907T_C	ESA_QCA990907S_C
Siemens	BUZ341	ESA_QCA990908T_C	ESA_QCA990908S_C
SGS-Thomson	SP60	ESA_QCA990909T_C	ESA_QCA990909S_C
SGS-Thomson	SP100V	ESA_QCA9909010T_C	ESA_QCA9909010S_C
SGS-Thomson	SP200V	ESA_QCA9909011T_C	ESA_QCA9909011S_C
Siemens	SPP1N60S5	ESA_QCA9909012T_C	ESA_QCA9909012S_C
Philips	BUK7508-55	ESA_QCA9909013T_C	ESA_QCA9909013S_C
Harris	HUF75639P3	ESA_QCA9909014T_C	ESA_QCA9909014S_C

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2 Introduction

A total dose radiation evaluation test of the Philips Semiconductors PHP50N06T N-Channel Power Mosfet has been performed with an accumulated dose of about 37 Krad(Si) at a dose rate of 75 rad(Si)/hour, in response to European Space Agency contract reference : 13413/98/NL/MV.

The purpose of this test was to evaluate total dose withstanding of this component, to investigate its suitability for being used in space applications. This test was conducted on commercial samples provided by ESTEC.

Test has been performed in accordance with Hirex proposal HRX/98.3475 issue 01.

A complete set of electrical measurements together with graphical representation of measured parameters with respect to total dose received, are provided for all samples.

SEE results for this device type can be found in SEE radiation test report: ESA_QCA990901S_C

3 Applicable and Reference Documents

3.1 Applicable Documents

- ESA/SCC Basic specification N° 22900 issue 4
- Philips Semiconductors datasheet (See annex)
- Hirex Engineering proposal: HRX/98.3475 issue 01.

3.2 Reference Documents

- MIL-STD-883: test methods and procedures for microcircuits

4 Test Samples

11 samples of the PHP50N06T device were tested (2 groups of 5 + 1 control sample). The samples were serialized before the radiation test as indicated in the following table.

Serial Number	Allocation
1	Control
2	Bias 1
3	Bias 1
4	Bias 1
5	Bias 1
6	Bias 1
7	Bias 2
8	Bias 2
9	Bias 2
10	Bias 2
11	Bias 2

Identification of the PHP50N06T is given below:

Part Number:	PHP50N06T	Mask Set:	NA
Top Marking:	PHP50N06T PHm9814 D4 Philippines	Chip Marking:	NA
Diffusion Lot:	NA	Wafer #:	NA
Date Code:	9814	Project:	Not defined

Note: NA means not Available

5 Experimental Conditions

5.1 Radiation Source Dose Rate and Annealing

The dose exposures were performed at CERT-ONERA. In this irradiation facility, a Cobalt 60 source is used with the possibility to vary the dose rate by simply adjusting the distance to the source. The irradiation conditions used for this test are provided in the following table:

Irradiation Steps krads	Dose rate krads/h	Annealing steps hours	Temperature °C
0			
3.85	0,075		25
7.35	0,075		25
13.95	0,075		25
19.65	0,075		25
24.65	0,075		25
29.85	0,075		25
36.85	0,075	0	25
		24	25
		192	100

5.2 Bias during Dose Exposures and Measurements conditions

5.2.1 Bias conditions

During exposures dedicated test boards were used mounted on a special board-holder made for irradiation. The test board allowed to bias the devices in accordance with the electrical circuit provided in Figure 1. Two bias conditions were used so called Bias 1 and Bias 2.

Bias 1 corresponds to a gate stress of V_{GS} equals 12 Volts. Bias 2 corresponds to drain to source stress equals 80% of BVDSS.

During annealing steps the same stress conditions were applied at room and 100°C temperatures respectively.

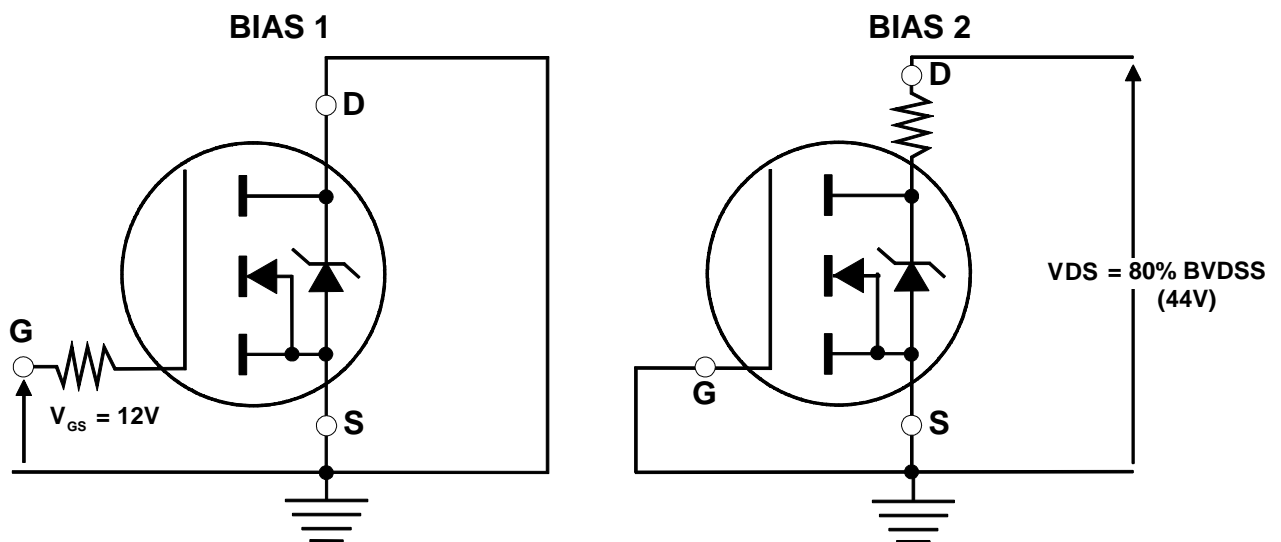


Figure 1 : Bias conditions during radiation exposures and annealing

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Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

5.2.2 Electrical Measurements

Mosfet transistor test program principle is provided in Figure 2. Due to the great number of samples to be measured (test campaign was conducted on 14 part types at the same time) and the time interval constraints required for performing measurements after each exposure and annealing step, It was decided to automate low power and high power measurements.

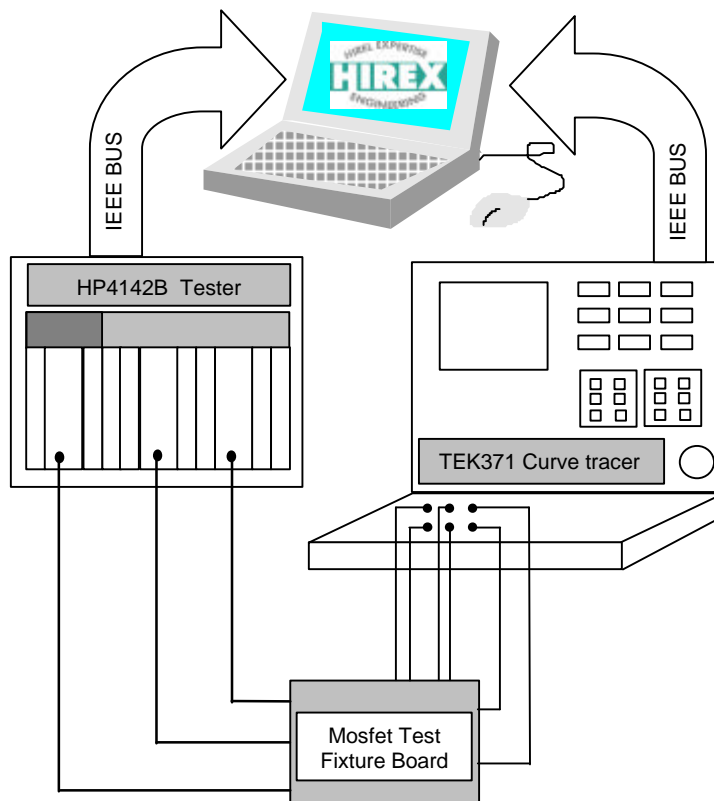
Two instruments were used to cover low power and high power measurements respectively. HP4142B was used for breakdown voltage, gate and drain leakage currents, and threshold voltage measurements.

Tektronix TEK371 high power curve tracer was used for $R_{DS(ON)}$ measurements.

A dedicated test fixture was designed to ensure proper switching of instruments. In addition a faraday cup was used to ensure optimum conditions for low level measurements.

Test program has been written in Visual Basic on a PC computer. GPIB commands were sent to each instrument via IEEE bus, in order to measure a given parameter with specified conditions. Results were automatically loaded in an Excel worksheet and compared in real time to specification limits. This allowed for real time data analysis in particular when failures were recorded.

Figure 2 : Mosfet transistor test program principle



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Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

Electrical parameters test conditions and limits used for performing this test are given in the following table.

Symbol	Test Parameter	Test Conditions	Min limit	Max limit	Unit
BVDSS	Drain to Source breakdown voltage	VGS=0V, ID=0.25mA	55		V
VGSTH	Gate to Source threshold voltage	VDS>=VGS, ID=1mA	2	4	V
+IGSS	Positive Gate Source leakage current	VGS=+10V, VDS=0V		1	μA
-IGSS	Negative Gate Source leakage current	VGS=-10V, VDS=0V		1	μA
IDSS	Drain current	VGS=0V, VDS=55V		10	μA
RDSON	Static drain to source on-state resistance	VGS=10V, ID=25A		0.024	Ohm

Table 1 : Measured electrical parameters

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Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

6 Test Summary

A Total Ionizing Dose assessment was carried out by Hirex Engineering under ESA contract on the Philips Semiconductors PHP50N06T N-Channel Power Mosfet.

2 groups of 5 samples each plus one control sample were used during testing. The first group was exposed to radiation using Bias 1 conditions corresponding to a gate stress of the devices. The second group of 5 samples was exposed to radiation using Bias 2 conditions corresponding to drain to source stress of the devices, equals 80% of BVDSS (44 Volts).

Based on the analysis of the results, the tolerances of this component and main conclusion are provided below.

Tolerance Level (Parametric : >=Krad): 36.85

Parametric tolerance level represents the last cumulative exposure at which no samples failed any test

Tolerance Level (Functional : >=Krad): 19.65

Functional tolerance level represents the last cumulative exposure at which no samples lost functionality

Main conclusion:

No failures were recorded up to 24.65 Krad(Si) (only marginal) and first failures occurred at 29.85 Krad(Si) for the voltage threshold voltage under Bias 2 conditions. $R_{ds_{on}}$ was also outside specification limit at 19.65 Krad(Si), but drift is considered marginal since the samples are centered initially closed to the maximum limit.

Severe rebound effects are observed on $V_{GS_{th}}$ -Bias 2 and $R_{ds_{on}}$ -Bias 2 after 168 hours annealing step.

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7 Test Results

Test results including tables and graphics are provided in this section for each measured parameter. To allow easy reading of data, each parameter is plotted twice, one for the first bias condition: Bias 1 and one for the second condition: Bias 2.

Parameter: Drain to source breakdown voltage: BVDSS-Bias1 VGS=0V, ID=0.25mA

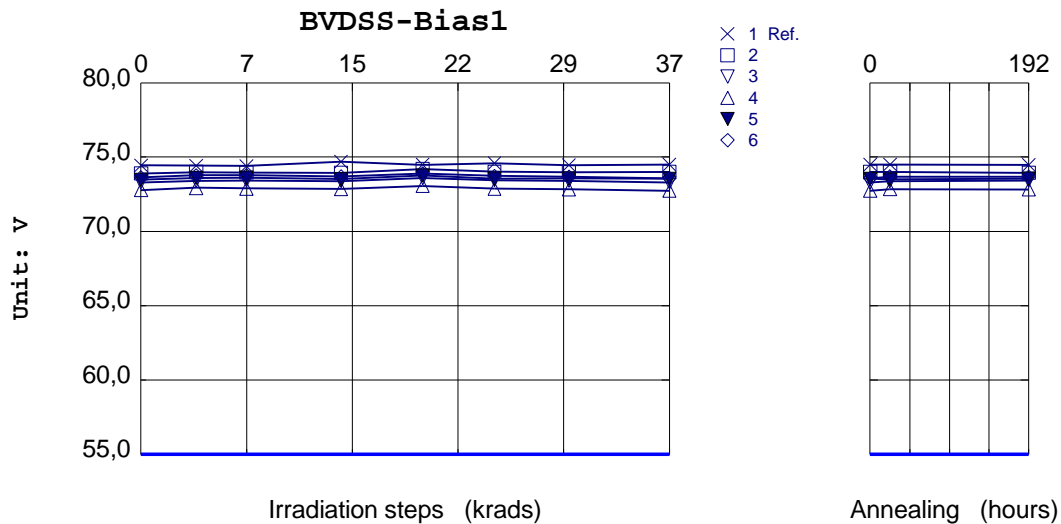
Unit= V

Spec limit min: 55

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	7,444E +01	7,442E +01	7,440E +01	7,469E +01	7,449E +01	7,459E +01	7,446E +01
2	7,390E +01	7,399E +01	7,397E +01	7,394E +01	7,421E +01	7,402E +01	7,398E +01
3	7,331E +01	7,340E +01	7,342E +01	7,339E +01	7,360E +01	7,344E +01	7,340E +01
4	7,279E +01	7,293E +01	7,290E +01	7,285E +01	7,307E +01	7,288E +01	7,284E +01
5	7,349E +01	7,360E +01	7,362E +01	7,351E +01	7,376E +01	7,355E +01	7,356E +01
6	7,364E +01	7,378E +01	7,379E +01	7,370E +01	7,389E +01	7,374E +01	7,368E +01
Statistics							
Min	7,279E +01	7,293E +01	7,290E +01	7,285E +01	7,307E +01	7,288E +01	7,284E +01
Max	7,390E +01	7,399E +01	7,397E +01	7,394E +01	7,421E +01	7,402E +01	7,398E +01
Mean	7,343E +01	7,354E +01	7,354E +01	7,348E +01	7,371E +01	7,352E +01	7,349E +01
Sigma	4,186E -01	4,038E -01	4,121E -01	4,053E -01	4,210E -01	4,213E -01	4,237E -01

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	7,450E +01	7,451E +01	7,448E +01
2	7,399E +01	7,400E +01	7,394E +01
3	7,328E +01	7,337E +01	7,341E +01
4	7,274E +01	7,284E +01	7,283E +01
5	7,354E +01	7,350E +01	7,355E +01
6	7,357E +01	7,369E +01	7,368E +01
Statistics			
Min	7,274E +01	7,284E +01	7,283E +01
Max	7,399E +01	7,400E +01	7,394E +01
Mean	7,342E +01	7,348E +01	7,348E +01
Sigma	4,591E -01	4,304E -01	4,136E -01



HIREX Engineering	Total Dose Test Report			Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors	

Parameter: Drain to source breakdown voltage: BVDSS-Bias2 VGS=0V, ID=0.25mA

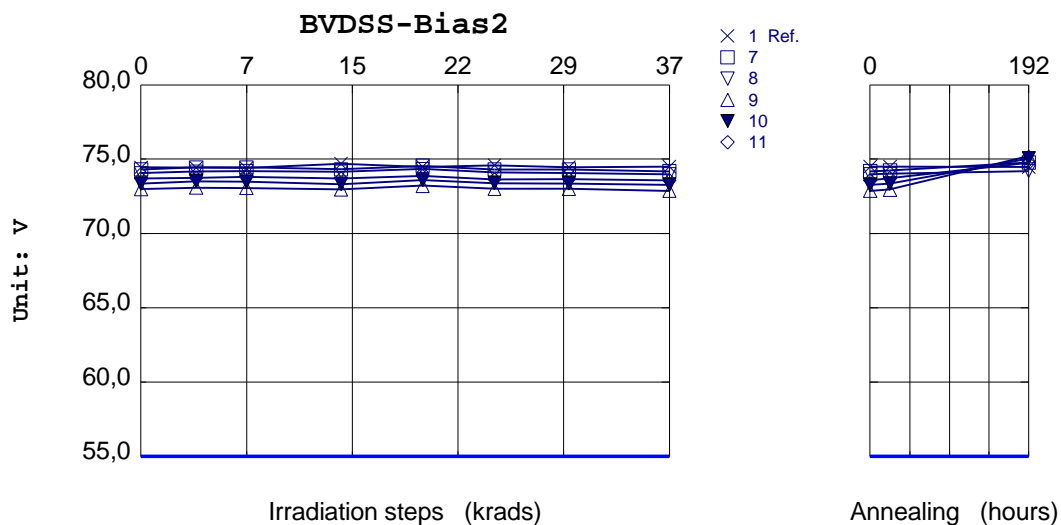
Unit= V

Spec limit min: 55

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	7,444E +01	7,442E +01	7,440E +01	7,469E +01	7,449E +01	7,459E +01	7,446E +01
7	7,431E +01	7,444E +01	7,444E +01	7,432E +01	7,455E +01	7,431E +01	7,431E +01
8	7,405E +01	7,416E +01	7,421E +01	7,415E +01	7,434E +01	7,411E +01	7,406E +01
9	7,299E +01	7,308E +01	7,307E +01	7,297E +01	7,322E +01	7,300E +01	7,300E +01
10	7,335E +01	7,351E +01	7,347E +01	7,333E +01	7,358E +01	7,338E +01	7,337E +01
11	7,370E +01	7,374E +01	7,381E +01	7,370E +01	7,387E +01	7,363E +01	7,366E +01
Statistics							
Min	7,299E +01	7,308E +01	7,307E +01	7,297E +01	7,322E +01	7,300E +01	7,300E +01
Max	7,431E +01	7,444E +01	7,444E +01	7,432E +01	7,455E +01	7,431E +01	7,431E +01
Mean	7,368E +01	7,379E +01	7,380E +01	7,369E +01	7,391E +01	7,369E +01	7,368E +01
Sigma	5,298E -01	5,353E -01	5,527E -01	5,623E -01	5,452E -01	5,330E -01	5,243E -01

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	7,450E +01	7,451E +01	7,448E +01
7	7,419E +01	7,425E +01	7,478E +01
8	7,398E +01	7,403E +01	7,421E +01
9	7,287E +01	7,296E +01	7,520E +01
10	7,327E +01	7,336E +01	7,505E +01
11	7,357E +01	7,372E +01	7,474E +01
Statistics			
Min	7,287E +01	7,296E +01	7,421E +01
Max	7,419E +01	7,425E +01	7,520E +01
Mean	7,358E +01	7,366E +01	7,480E +01
Sigma	5,333E -01	5,178E -01	3,810E -01



HIREX Engineering	Total Dose Test Report		Réf. : HRX/99.4560
			Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

Parameter: Gate to source threshold voltage: VGSTH-Bias1 VDS>=VGS, ID=1mA

Unit= V

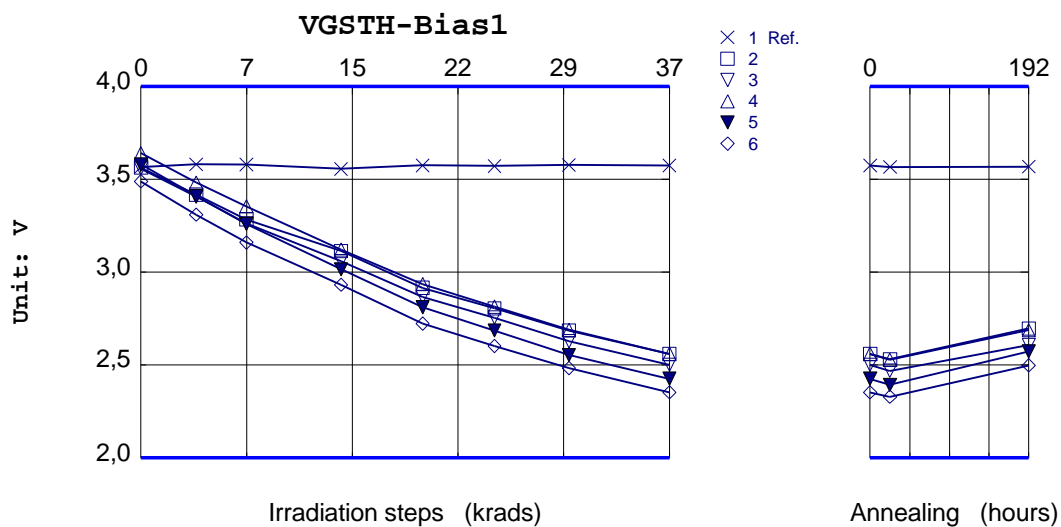
Spec limit max: 4

Spec limit min: 2

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	3,566E +00	3,580E +00	3,579E +00	3,555E +00	3,574E +00	3,571E +00	3,577E +00
2	3,563E +00	3,417E +00	3,284E +00	3,113E +00	2,915E +00	2,805E +00	2,685E +00
3	3,557E +00	3,406E +00	3,262E +00	3,059E +00	2,866E +00	2,754E +00	2,627E +00
4	3,640E +00	3,482E +00	3,353E +00	3,121E +00	2,935E +00	2,814E +00	2,690E +00
5	3,579E +00	3,409E +00	3,259E +00	3,015E +00	2,810E +00	2,685E +00	2,553E +00
6	3,489E +00	3,309E +00	3,159E +00	2,932E +00	2,723E +00	2,602E +00	2,483E +00
Statistics							
Min	3,489E +00	3,309E +00	3,159E +00	2,932E +00	2,723E +00	2,602E +00	2,483E +00
Max	3,640E +00	3,482E +00	3,353E +00	3,121E +00	2,935E +00	2,814E +00	2,690E +00
Mean	3,566E +00	3,405E +00	3,263E +00	3,048E +00	2,850E +00	2,732E +00	2,608E +00
Sigma	5,412E -02	6,192E -02	6,965E -02	7,787E -02	8,568E -02	8,906E -02	8,890E -02

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	3,574E +00	3,565E +00	3,567E +00
2	2,559E +00	2,530E +00	2,696E +00
3	2,500E +00	2,469E +00	2,608E +00
4	2,560E +00	2,528E +00	2,688E +00
5	2,425E +00	2,393E +00	2,573E +00
6	2,353E +00	2,329E +00	2,497E +00
Statistics			
Min	2,353E +00	2,329E +00	2,497E +00
Max	2,560E +00	2,530E +00	2,696E +00
Mean	2,479E +00	2,450E +00	2,612E +00
Sigma	8,981E -02	8,769E -02	8,303E -02



HIREX Engineering	Total Dose Test Report		Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

Parameter: Gate to source threshold voltage: VGSTH-Bias2 **VDS>=VGS, ID=1mA**

Unit= V

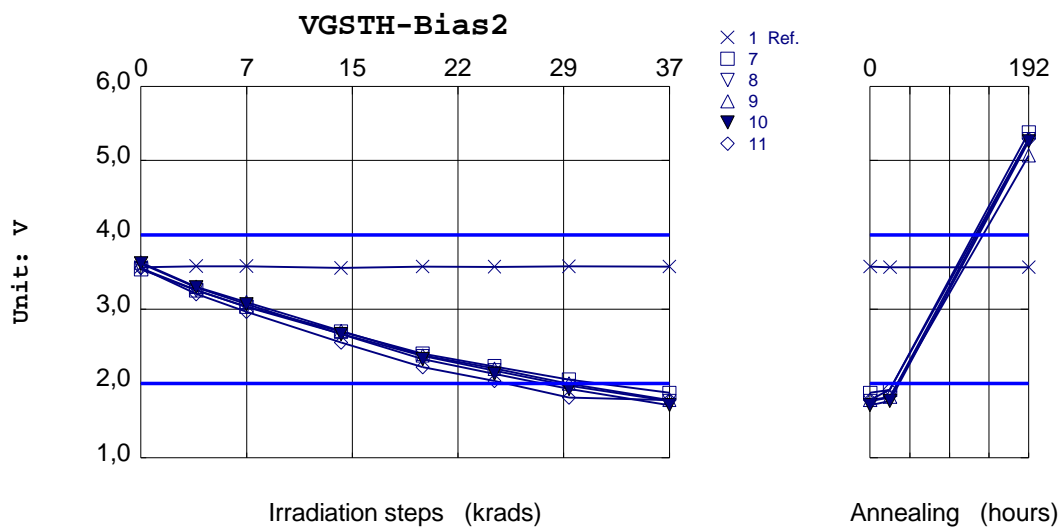
Spec limit max: 4

Spec limit min: 2

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	3,566E +00	3,580E +00	3,579E +00	3,555E +00	3,574E +00	3,571E +00	3,577E +00
7	3,539E +00	3,255E +00	3,034E +00	2,698E +00	2,402E +00	2,232E +00	2,053E +00
8	3,551E +00	3,256E +00	3,026E +00	2,667E +00	2,370E +00	2,176E +00	1,969E +00
9	3,628E +00	3,303E +00	3,096E +00	2,708E +00	2,379E +00	2,200E +00	1,999E +00
10	3,617E +00	3,294E +00	3,067E +00	2,665E +00	2,328E +00	2,128E +00	1,926E +00
11	3,554E +00	3,204E +00	2,965E +00	2,550E +00	2,220E +00	2,035E +00	1,808E +00
Statistics							
Min	3,539E +00	3,204E +00	2,965E +00	2,550E +00	2,220E +00	2,035E +00	1,808E +00
Max	3,628E +00	3,303E +00	3,096E +00	2,708E +00	2,402E +00	2,232E +00	2,053E +00
Mean	3,578E +00	3,262E +00	3,038E +00	2,658E +00	2,340E +00	2,154E +00	1,951E +00
Sigma	4,138E -02	3,947E -02	4,900E -02	6,278E -02	7,219E -02	7,643E -02	9,216E -02

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	3,574E +00	3,565E +00	3,567E +00
7	1,872E +00	1,915E +00	5,379E +00
8	1,765E +00	1,810E +00	5,288E +00
9	1,778E +00	1,823E +00	5,071E +00
10	1,708E +00	1,765E +00	5,258E +00
11	1,778E +00	1,919E +00	5,289E +00
Statistics			
Min	1,708E +00	1,765E +00	5,071E +00
Max	1,872E +00	1,919E +00	5,379E +00
Mean	1,780E +00	1,846E +00	5,257E +00
Sigma	5,877E -02	6,798E -02	1,135E -01



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Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors	

Parameter: Positive Gate source leakage current: +IGSS-Bias1 VGS=+10V, VDS=0V

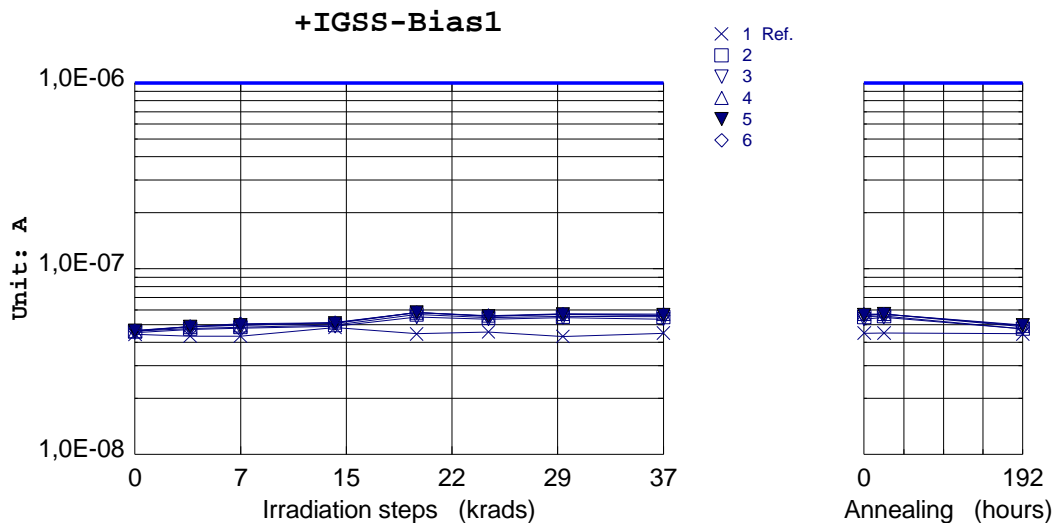
Unit= A

Spec limit max: 1E-6

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	4,433E -08	4,327E -08	4,328E -08	4,821E -08	4,453E -08	4,559E -08	4,314E -08
2	4,614E -08	4,762E -08	4,846E -08	4,973E -08	5,665E -08	5,443E -08	5,519E -08
3	4,518E -08	4,692E -08	4,792E -08	4,895E -08	5,490E -08	5,346E -08	5,447E -08
4	4,589E -08	4,878E -08	4,948E -08	5,132E -08	5,805E -08	5,596E -08	5,716E -08
5	4,632E -08	4,877E -08	4,955E -08	5,073E -08	5,807E -08	5,537E -08	5,661E -08
6	4,644E -08	4,881E -08	5,060E -08	5,116E -08	5,800E -08	5,531E -08	5,685E -08
Statistics							
Min	4,518E -08	4,692E -08	4,792E -08	4,895E -08	5,490E -08	5,346E -08	5,447E -08
Max	4,644E -08	4,881E -08	5,060E -08	5,132E -08	5,807E -08	5,596E -08	5,716E -08
Mean	4,599E -08	4,818E -08	4,920E -08	5,038E -08	5,713E -08	5,491E -08	5,605E -08
Sigma	4,986E -10	8,676E -10	1,042E -09	1,012E -09	1,386E -09	9,761E -10	1,163E -09

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	4,500E -08	4,505E -08	4,454E -08
2	5,498E -08	5,558E -08	4,749E -08
3	5,346E -08	5,461E -08	4,751E -08
4	5,688E -08	5,696E -08	4,926E -08
5	5,617E -08	5,685E -08	4,959E -08
6	5,604E -08	5,683E -08	4,870E -08
Statistics			
Min	5,346E -08	5,461E -08	4,749E -08
Max	5,688E -08	5,696E -08	4,959E -08
Mean	5,551E -08	5,617E -08	4,851E -08
Sigma	1,332E -09	1,041E -09	9,756E -10



HIREX Engineering	Total Dose Test Report		Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

Parameter: Positive Gate source leakage current: +IGSS-Bias2 VGS=+10V, VDS=0V

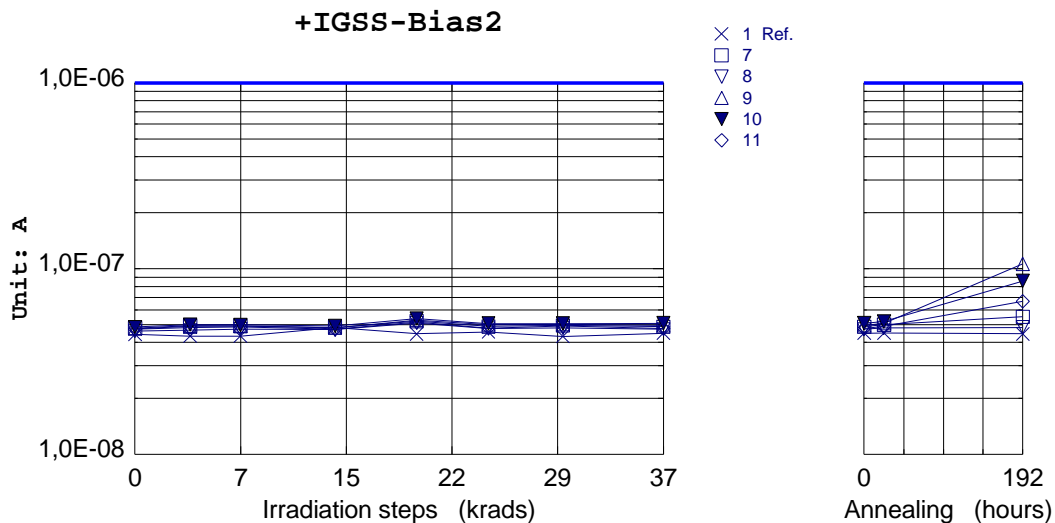
Unit= A

Spec limit max: 1E-6

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	4,433E -08	4,327E -08	4,328E -08	4,821E -08	4,453E -08	4,559E -08	4,314E -08
7	4,785E -08	4,924E -08	4,915E -08	4,824E -08	5,214E -08	4,887E -08	4,944E -08
8	4,606E -08	4,666E -08	4,723E -08	4,691E -08	5,091E -08	4,760E -08	4,794E -08
9	4,745E -08	4,885E -08	4,913E -08	4,811E -08	5,289E -08	4,999E -08	5,017E -08
10	4,856E -08	5,003E -08	4,977E -08	4,914E -08	5,391E -08	5,065E -08	5,061E -08
11	4,740E -08	4,819E -08	4,848E -08	4,711E -08	5,158E -08	4,783E -08	4,912E -08
Statistics							
Min	4,606E -08	4,666E -08	4,723E -08	4,691E -08	5,091E -08	4,760E -08	4,794E -08
Max	4,856E -08	5,003E -08	4,977E -08	4,914E -08	5,391E -08	5,065E -08	5,061E -08
Mean	4,747E -08	4,859E -08	4,875E -08	4,790E -08	5,229E -08	4,899E -08	4,946E -08
Sigma	9,150E -10	1,270E -09	9,675E -10	9,090E -10	1,165E -09	1,327E -09	1,034E -09

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	4,500E -08	4,505E -08	4,454E -08
7	4,873E -08	4,993E -08	5,505E -08
8	4,718E -08	4,794E -08	4,824E -08
9	4,942E -08	5,077E -08	1,061E -07
10	5,084E -08	5,198E -08	8,585E -08
11	4,772E -08	4,887E -08	6,658E -08
Statistics			
Min	4,718E -08	4,794E -08	4,824E -08
Max	5,084E -08	5,198E -08	1,061E -07
Mean	4,878E -08	4,990E -08	7,236E -08
Sigma	1,443E -09	1,582E -09	2,362E -08



HIREX Engineering	Total Dose Test Report			Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors	

Parameter: Negative Gate source leakage current: -IGSS-Bias1 VGS=-10V, VDS=0V

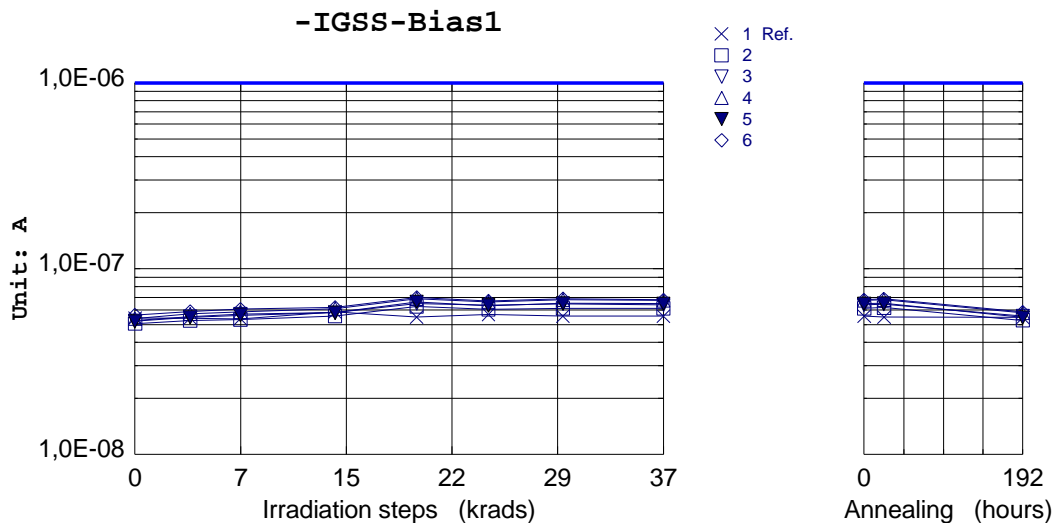
Unit= A

Spec limit max: 1E-6

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	5,425E -08	5,409E -08	5,373E -08	5,847E -08	5,485E -08	5,664E -08	5,542E -08
2	5,060E -08	5,252E -08	5,317E -08	5,551E -08	6,257E -08	6,048E -08	6,112E -08
3	5,247E -08	5,511E -08	5,682E -08	5,792E -08	6,487E -08	6,350E -08	6,458E -08
4	5,379E -08	5,710E -08	5,848E -08	6,092E -08	6,881E -08	6,618E -08	6,797E -08
5	5,203E -08	5,462E -08	5,613E -08	5,790E -08	6,619E -08	6,320E -08	6,498E -08
6	5,628E -08	5,874E -08	6,065E -08	6,189E -08	7,000E -08	6,703E -08	6,899E -08
Statistics							
Min	5,060E -08	5,252E -08	5,317E -08	5,551E -08	6,257E -08	6,048E -08	6,112E -08
Max	5,628E -08	5,874E -08	6,065E -08	6,189E -08	7,000E -08	6,703E -08	6,899E -08
Mean	5,303E -08	5,562E -08	5,705E -08	5,883E -08	6,649E -08	6,408E -08	6,553E -08
Sigma	2,143E -09	2,389E -09	2,782E -09	2,572E -09	2,993E -09	2,608E -09	3,104E -09

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	5,547E -08	5,488E -08	5,463E -08
2	6,113E -08	6,162E -08	5,275E -08
3	6,377E -08	6,425E -08	5,561E -08
4	6,750E -08	6,795E -08	5,783E -08
5	6,473E -08	6,489E -08	5,460E -08
6	6,786E -08	6,860E -08	5,837E -08
Statistics			
Min	6,113E -08	6,162E -08	5,275E -08
Max	6,786E -08	6,860E -08	5,837E -08
Mean	6,500E -08	6,546E -08	5,583E -08
Sigma	2,782E -09	2,855E -09	2,318E -09



HIREX Engineering	Total Dose Test Report			Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors	

Parameter: Negative Gate source leakage current: -IGSS-Bias2 VGS=-10V, VDS=0V

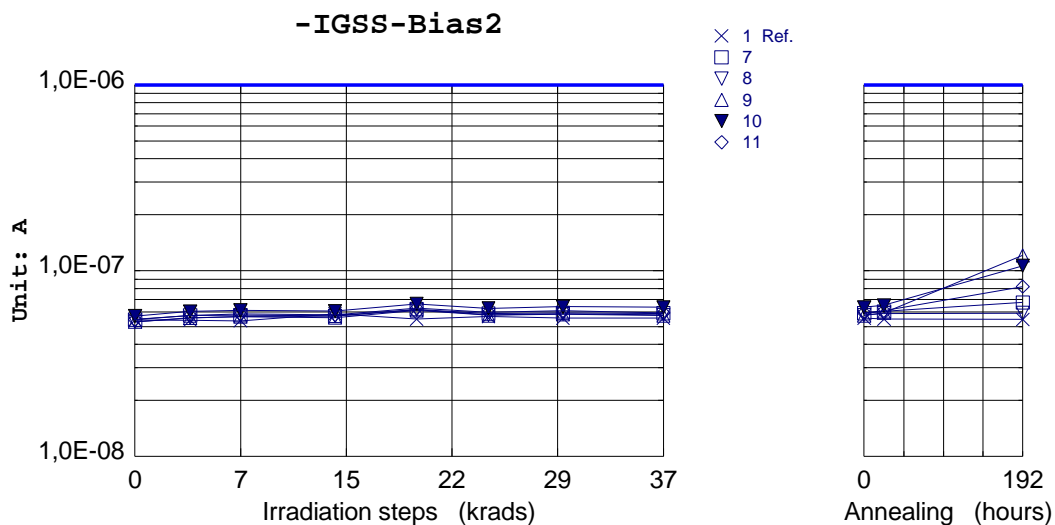
Unit= A

Spec limit max: 1E-6

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	5,425E -08	5,409E -08	5,373E -08	5,847E -08	5,485E -08	5,664E -08	5,542E -08
7	5,455E -08	5,741E -08	5,765E -08	5,706E -08	6,203E -08	5,877E -08	5,925E -08
8	5,309E -08	5,574E -08	5,680E -08	5,682E -08	6,147E -08	5,777E -08	5,838E -08
9	5,302E -08	5,577E -08	5,649E -08	5,595E -08	6,106E -08	5,746E -08	5,815E -08
10	5,693E -08	6,027E -08	6,114E -08	6,057E -08	6,616E -08	6,266E -08	6,397E -08
11	5,453E -08	5,728E -08	5,842E -08	5,784E -08	6,287E -08	5,973E -08	6,083E -08
Statistics							
Min	5,302E -08	5,574E -08	5,649E -08	5,595E -08	6,106E -08	5,746E -08	5,815E -08
Max	5,693E -08	6,027E -08	6,114E -08	6,057E -08	6,616E -08	6,266E -08	6,397E -08
Mean	5,442E -08	5,730E -08	5,810E -08	5,765E -08	6,272E -08	5,928E -08	6,012E -08
Sigma	1,584E -09	1,845E -09	1,857E -09	1,765E -09	2,041E -09	2,091E -09	2,398E -09

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	5,547E -08	5,488E -08	5,463E -08
7	5,893E -08	6,038E -08	6,742E -08
8	5,771E -08	5,892E -08	5,913E -08
9	5,742E -08	5,930E -08	1,208E -07
10	6,353E -08	6,490E -08	1,063E -07
11	5,934E -08	6,081E -08	8,206E -08
Statistics			
Min	5,742E -08	5,892E -08	5,913E -08
Max	6,353E -08	6,490E -08	1,208E -07
Mean	5,938E -08	6,086E -08	8,715E -08
Sigma	2,451E -09	2,386E -09	2,598E -08



HIREX Engineering	Total Dose Test Report		Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

Parameter: Drain current: IDSS-Bias1 VGS=0V, VDS=55V

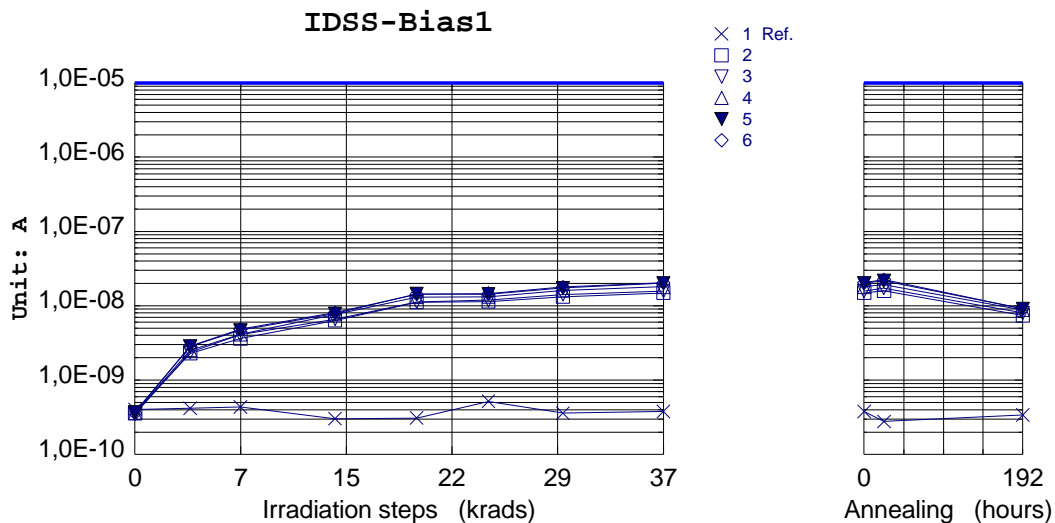
Unit= A

Spec limit max: 1E-5

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	4,031E -10	4,188E -10	4,353E -10	3,020E -10	3,094E -10	5,184E -10	3,593E -10
2	3,593E -10	2,291E -09	3,639E -09	6,355E -09	1,117E -08	1,141E -08	1,318E -08
3	3,486E -10	2,368E -09	4,080E -09	6,614E -09	1,131E -08	1,188E -08	1,426E -08
4	3,566E -10	2,535E -09	4,134E -09	7,640E -09	1,313E -08	1,318E -08	1,607E -08
5	3,709E -10	2,836E -09	4,687E -09	7,846E -09	1,447E -08	1,429E -08	1,739E -08
6	3,594E -10	2,874E -09	4,843E -09	8,081E -09	1,438E -08	1,466E -08	1,791E -08
Statistics							
Min	3,486E -10	2,291E -09	3,639E -09	6,355E -09	1,117E -08	1,141E -08	1,318E -08
Max	3,709E -10	2,874E -09	4,843E -09	8,081E -09	1,447E -08	1,466E -08	1,791E -08
Mean	3,589E -10	2,581E -09	4,277E -09	7,307E -09	1,289E -08	1,308E -08	1,576E -08
Sigma	7,995E -12	2,654E -10	4,886E -10	7,725E -10	1,600E -09	1,431E -09	2,017E -09

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	3,787E -10	2,773E -10	3,398E -10
2	1,495E -08	1,592E -08	7,429E -09
3	1,578E -08	1,728E -08	7,998E -09
4	1,801E -08	1,925E -08	8,782E -09
5	2,021E -08	2,165E -08	9,118E -09
6	2,041E -08	2,253E -08	9,156E -09
Statistics			
Min	1,495E -08	1,592E -08	7,429E -09
Max	2,041E -08	2,253E -08	9,156E -09
Mean	1,787E -08	1,933E -08	8,497E -09
Sigma	2,493E -09	2,808E -09	7,567E -10



HIREX Engineering	Total Dose Test Report		Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

Parameter: Drain current: IDSS-Bias2 VGS=0V, VDS=55V

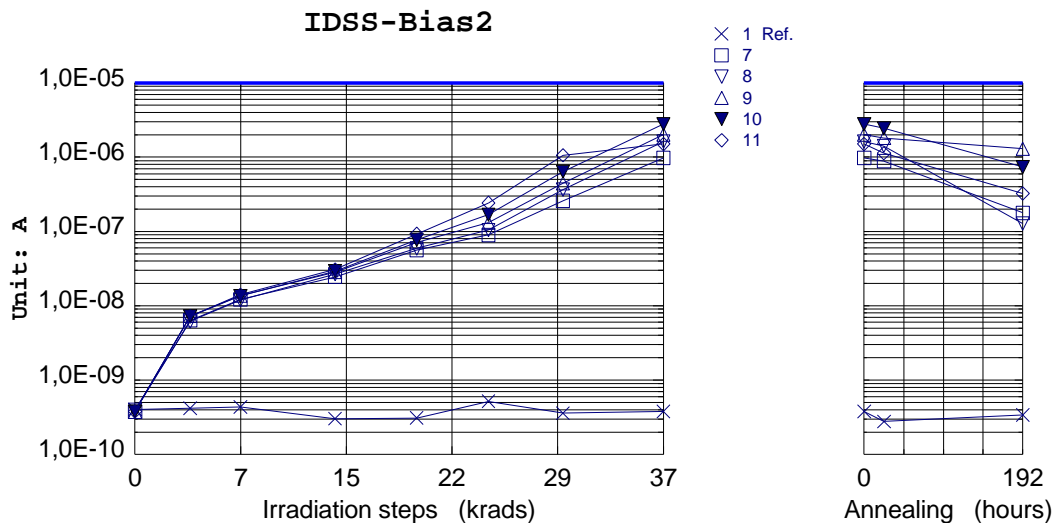
Unit= A

Spec limit max: 1E-5

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	4,031E -10	4,188E -10	4,353E -10	3,020E -10	3,094E -10	5,184E -10	3,593E -10
7	3,758E -10	6,380E -09	1,218E -08	2,457E -08	5,609E -08	8,974E -08	2,591E -07
8	3,964E -10	6,176E -09	1,191E -08	2,662E -08	5,926E -08	1,045E -07	3,656E -07
9	3,733E -10	7,298E -09	1,373E -08	2,846E -08	7,160E -08	1,320E -07	4,470E -07
10	3,769E -10	7,207E -09	1,353E -08	2,927E -08	7,718E -08	1,681E -07	6,385E -07
11	3,784E -10	7,197E -09	1,410E -08	3,076E -08	9,289E -08	2,427E -07	1,060E -06
Statistics							
Min	3,733E -10	6,176E -09	1,191E -08	2,457E -08	5,609E -08	8,974E -08	2,591E -07
Max	3,964E -10	7,298E -09	1,410E -08	3,076E -08	9,289E -08	2,427E -07	1,060E -06
Mean	3,801E -10	6,852E -09	1,309E -08	2,794E -08	7,140E -08	1,474E -07	5,539E -07
Sigma	9,301E -12	5,302E -10	9,777E -10	2,405E -09	1,481E -08	6,106E -08	3,149E -07

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	3,787E -10	2,773E -10	3,398E -10
7	9,786E -07	8,836E -07	1,780E -07
8	1,617E -06	1,412E -06	1,276E -07
9	2,016E -06	1,812E -06	1,298E -06
10	2,789E -06	2,456E -06	7,368E -07
11	1,500E -06	1,133E -06	3,237E -07
Statistics			
Min	9,786E -07	8,836E -07	1,276E -07
Max	2,789E -06	2,456E -06	1,298E -06
Mean	1,780E -06	1,539E -06	5,328E -07
Sigma	6,749E -07	6,175E -07	4,901E -07



HIREX Engineering	Total Dose Test Report			Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors	

Parameter: Static drain to source on-state resistance : RDSON-Bias1 VGS=10V, ID=25A

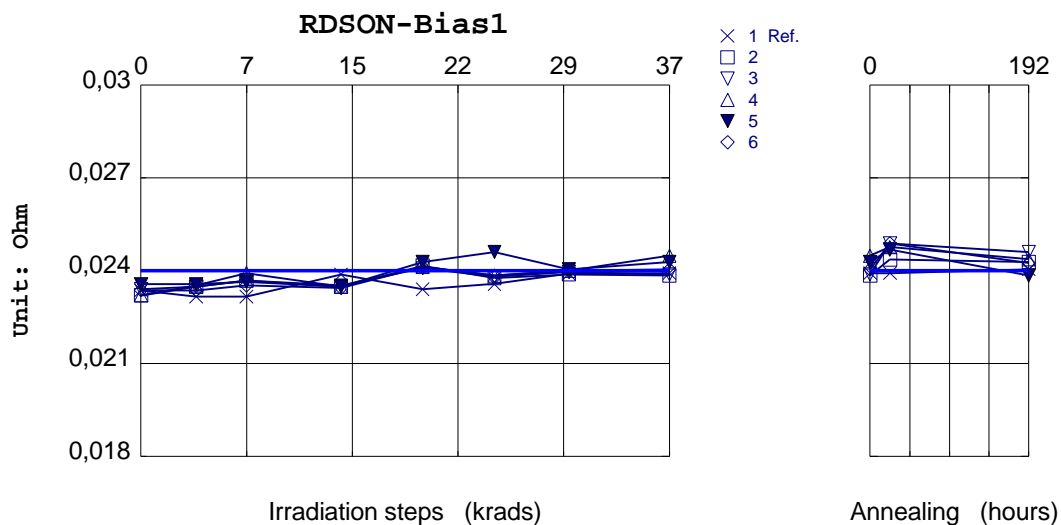
Unit= Ohm

Spec limit max: 0.024

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	2,336E -02	2,316E -02	2,316E -02	2,388E -02	2,340E -02	2,357E -02	2,390E -02
2	2,320E -02	2,348E -02	2,368E -02	2,349E -02	2,416E -02	2,376E -02	2,388E -02
3	2,340E -02	2,348E -02	2,368E -02	2,352E -02	2,408E -02	2,380E -02	2,396E -02
4	2,321E -02	2,352E -02	2,392E -02	2,348E -02	2,412E -02	2,384E -02	2,400E -02
5	2,356E -02	2,356E -02	2,364E -02	2,348E -02	2,428E -02	2,460E -02	2,404E -02
6	2,337E -02	2,336E -02	2,352E -02	2,344E -02	2,412E -02	2,384E -02	2,400E -02
Statistics							
Min	2,320E -02	2,336E -02	2,352E -02	2,344E -02	2,408E -02	2,376E -02	2,388E -02
Max	2,356E -02	2,356E -02	2,392E -02	2,352E -02	2,428E -02	2,460E -02	2,404E -02
Mean	2,335E -02	2,348E -02	2,369E -02	2,348E -02	2,415E -02	2,397E -02	2,398E -02
Sigma	1,499E -04	7,483E -05	1,453E -04	2,846E -05	7,694E -05	3,549E -04	6,066E -05

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	2,392E -02	2,392E -02	2,404E -02
2	2,384E -02	2,436E -02	2,428E -02
3	2,388E -02	2,488E -02	2,460E -02
4	2,448E -02	2,476E -02	2,437E -02
5	2,428E -02	2,468E -02	2,384E -02
6	2,404E -02	2,488E -02	2,424E -02
Statistics			
Min	2,384E -02	2,436E -02	2,384E -02
Max	2,448E -02	2,488E -02	2,460E -02
Mean	2,410E -02	2,471E -02	2,427E -02
Sigma	2,722E -04	2,143E -04	2,759E -04



HIREX Engineering	Total Dose Test Report		Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

Parameter: Static drain to source on-state resistance : RDSON-Bias2 VGS=10V, ID=25A

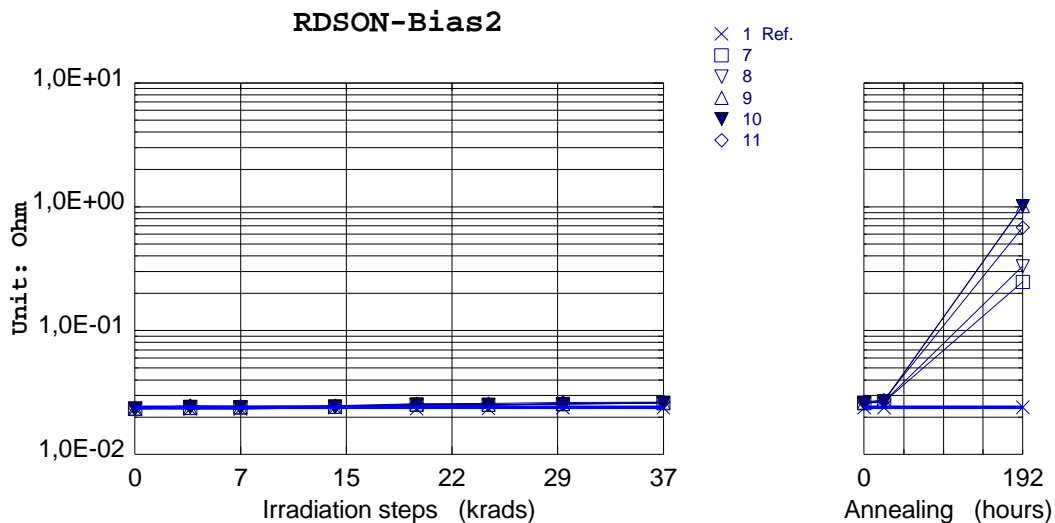
Unit= Ohm

Spec limit max: 0.024

Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krad	7,35 krad	13,95 krad	19,65 krad	24,65 krad	29,85 krad
Serial #							
1 Ref.	2,336E -02	2,316E -02	2,316E -02	2,388E -02	2,340E -02	2,357E -02	2,390E -02
7	2,324E -02	2,384E -02	2,404E -02	2,424E -02	2,516E -02	2,508E -02	2,548E -02
8	2,360E -02	2,424E -02	2,400E -02	2,436E -02	2,516E -02	2,504E -02	2,548E -02
9	2,356E -02	2,380E -02	2,396E -02	2,424E -02	2,520E -02	2,516E -02	2,564E -02
10	2,336E -02	2,412E -02	2,388E -02	2,416E -02	2,508E -02	2,508E -02	2,556E -02
11	2,376E -02	2,472E -02	2,449E -02	2,472E -02	2,568E -02	2,573E -02	2,624E -02
Statistics							
Min	2,324E -02	2,380E -02	2,388E -02	2,416E -02	2,508E -02	2,504E -02	2,548E -02
Max	2,376E -02	2,472E -02	2,449E -02	2,472E -02	2,568E -02	2,573E -02	2,624E -02
Mean	2,350E -02	2,414E -02	2,407E -02	2,434E -02	2,526E -02	2,522E -02	2,568E -02
Sigma	2,051E -04	3,716E -04	2,395E -04	2,220E -04	2,410E -04	2,902E -04	3,200E -04

Test Step	36,85 krad	24 hours	192 hours
Serial #			
1 Ref.	2,392E -02	2,392E -02	2,404E -02
7	2,592E -02	2,648E -02	2,470E -01
8	2,588E -02	2,668E -02	3,310E -01
9	2,616E -02	2,700E -02	1,013E +00
10	2,612E -02	2,672E -02	1,013E +00
11	2,652E -02	2,756E -02	6,806E -01
Statistics			
Min	2,588E -02	2,648E -02	2,470E -01
Max	2,652E -02	2,756E -02	1,013E +00
Mean	2,612E -02	2,689E -02	6,570E -01
Sigma	2,546E -04	4,190E -04	3,636E -01



HIREX Engineering	Total Dose Test Report		Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

8 Conclusion

A total dose radiation verification test has been performed on PHP50N06T N-Channel Power Mosfet from Philips Semiconductors up to 36.85 Krad(Si) accumulated dose.

No failures were recorded up to 24.65 Krad(Si) (only marginal), and first failures occurred at 29.85 Krad(Si) for the voltage threshold voltage under Bias 2 conditions.

$R_{ds_{on}}$ was also outside specification limit at 19.65 Krad(Si), but drift is considered marginal since the samples are centered initially closed to the maximum limit.

Severe rebound effects are observed on $V_{GS_{th}}$ -Bias 2 and $R_{ds_{on}}$ -Bias 2 after 168 hours annealing step.

A significant increase (about 3 orders of magnitude) of Drain-to-Source leakage current is recorded under Bias 2 conditions with a slight recovery (one order of magnitude) after annealing.

It is finally observed that for this device, Bias 2 conditions corresponding to drain to source stress equals 80% of BVDSS induced the most severe degradation.

HIREX Engineering	Total Dose Test Report		Réf. : HRX/99.4560 Issue : 01
Part Type :	PHP50N06T	Manufacturer :	Philips Semiconductors

ANNEX 1 : PHP50N06T DATA SHEET

TrenchMOS™ transistor Standard level FET

PHP50N06T

GENERAL DESCRIPTION

N-channel enhancement mode standard level field-effect power transistor in a plastic envelope using 'trench' technology. The device features very low on-state resistance and has integral zener diodes giving ESD protection up to 2kV. It is intended for use in DC-DC converters and general purpose switching applications.

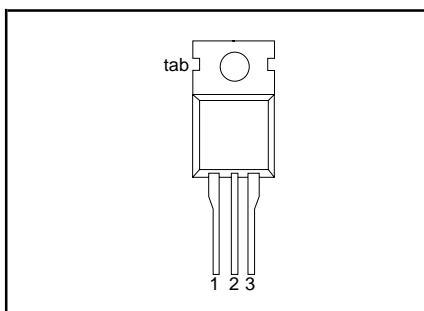
QUICK REFERENCE DATA

SYMBOL	PARAMETER	MAX.	UNIT
V_{DS}	Drain-source voltage	55	V
I_D	Drain current (DC)	50	A
P_{tot}	Total power dissipation	125	W
T_j	Junction temperature	175	°C
$R_{DS(ON)}$	Drain-source on-state resistance $V_{GS} = 10\text{ V}$	24	mΩ

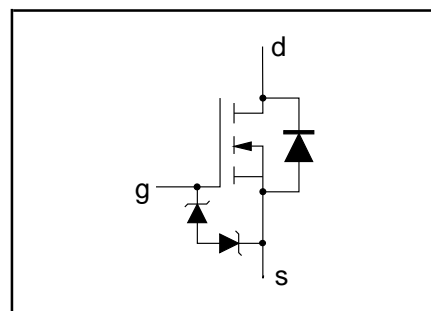
PINNING - TO220AB

PIN	DESCRIPTION
1	gate
2	drain
3	source
tab	drain

PIN CONFIGURATION



SYMBOL



LIMITING VALUES

Limiting values in accordance with the Absolute Maximum System (IEC 134)

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{DS}	Drain-source voltage	-	-	55	V
V_{DGR}	Drain-gate voltage	$R_{GS} = 20\text{ k}\Omega$	-	55	V
$\pm V_{GS}$	Gate-source voltage	-	-	20	V
I_D	Drain current (DC)	$T_{mb} = 25\text{ }^\circ\text{C}$	-	50	A
I_D	Drain current (DC)	$T_{mb} = 100\text{ }^\circ\text{C}$	-	35	A
I_{DM}	Drain current (pulse peak value)	$T_{mb} = 25\text{ }^\circ\text{C}$	-	200	A
P_{tot}	Total power dissipation	$T_{mb} = 25\text{ }^\circ\text{C}$	-	125	W
T_{stg}, T_j	Storage & operating temperature	-	-55	175	°C

ESD LIMITING VALUE

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_C	Electrostatic discharge capacitor voltage, all pins	Human body model (100 pF, 1.5 kΩ)	-	2	kV

THERMAL RESISTANCES

SYMBOL	PARAMETER	CONDITIONS	TYP.	MAX.	UNIT
$R_{th\ j-mb}$	Thermal resistance junction to mounting base	-	-	1.2	K/W
$R_{th\ j-a}$	Thermal resistance junction to ambient	in free air	60	-	K/W

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STATIC CHARACTERISTICS

T_j = 25 °C unless otherwise specified

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
V _{(BR)DSS}	Drain-source breakdown voltage	V _{GS} = 0 V; I _D = 0.25 mA; T _j = -55 °C	55 50	- -	- -	V V
V _{GS(TO)}	Gate threshold voltage	V _{DS} = V _{GS} ; I _D = 1 mA T _j = 175 °C T _j = -55 °C	2.0 1.0	3.0 -	4.0 -	V V
I _{DSS}	Zero gate voltage drain current	V _{DS} = 55 V; V _{GS} = 0 V; T _j = 175 °C	-	0.05	10	μA
I _{GSS}	Gate source leakage current	V _{GS} = ±10 V; V _{DS} = 0 V T _j = 175 °C	-	0.02	1	μA
±V _{(BR)GSS}	Gate source breakdown voltage	I _G = ±1 mA; T _j = 175 °C	16	-	20	V
R _{DS(ON)}	Drain-source on-state resistance	V _{GS} = 10 V; I _D = 25 A T _j = 175 °C	-	19	24	mΩ
			-	-	50	mΩ

DYNAMIC CHARACTERISTICS

T_{mb} = 25 °C unless otherwise specified

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
g _{fs}	Forward transconductance	V _{DS} = 25 V; I _D = 25 A	4	11	-	S
Q _{g(tot)}	Total gate charge	I _D = 50 A; V _{DD} = 44 V; V _{GS} = 10 V	-	30	-	nC
Q _{gs}	Gate-source charge		-	6	-	nC
Q _{gd}	Gate-drain (Miller) charge		-	12	-	nC
C _{iss}	Input capacitance	V _{GS} = 0 V; V _{DS} = 25 V; f = 1 MHz	-	1100	1500	pF
C _{oss}	Output capacitance		-	280	340	pF
C _{rss}	Feedback capacitance		-	130	180	pF
t _{d on}	Turn-on delay time	V _{DD} = 30 V; I _D = 25 A;	-	12	18	ns
t _r	Turn-on rise time	V _{GS} = 10 V; R _G = 10 Ω	-	19	35	ns
t _{d off}	Turn-off delay time	Resistive load	-	25	35	ns
t _f	Turn-off fall time		-	18	25	ns
L _d	Internal drain inductance	Measured from contact screw on tab to centre of die	-	3.5	-	nH
L _d	Internal drain inductance	Measured from drain lead 6 mm from package to centre of die	-	4.5	-	nH
L _s	Internal source inductance	Measured from source lead 6 mm from package to source bond pad	-	7.5	-	nH

REVERSE DIODE LIMITING VALUES AND CHARACTERISTICS

T_j = 25 °C unless otherwise specified

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I _{DR}	Continuous reverse drain current		-	-	50	A
I _{DRM}	Pulsed reverse drain current		-	-	200	A
V _{SD}	Diode forward voltage	I _F = 25 A; V _{GS} = 0 V I _F = 40 A; V _{GS} = 0 V	-	0.95 1.0	1.2 -	V
t _{rr}	Reverse recovery time	I _F = 40 A; -dI _F /dt = 100 A/μs; V _{GS} = -10 V; V _R = 30 V	-	40	-	ns
Q _{rr}	Reverse recovery charge		-	0.07	-	μC

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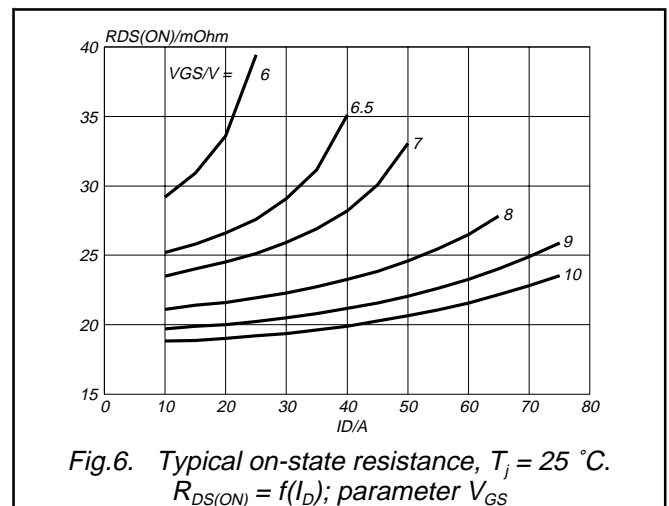
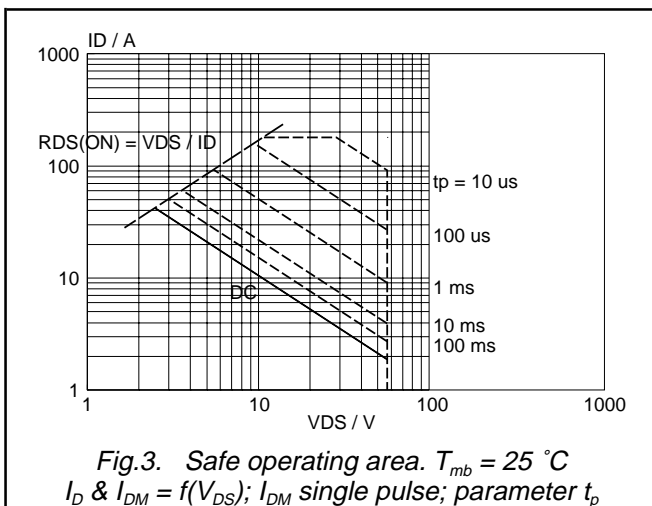
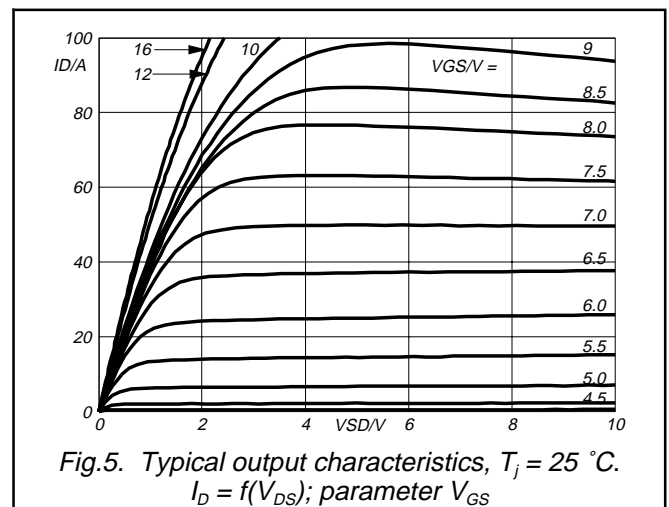
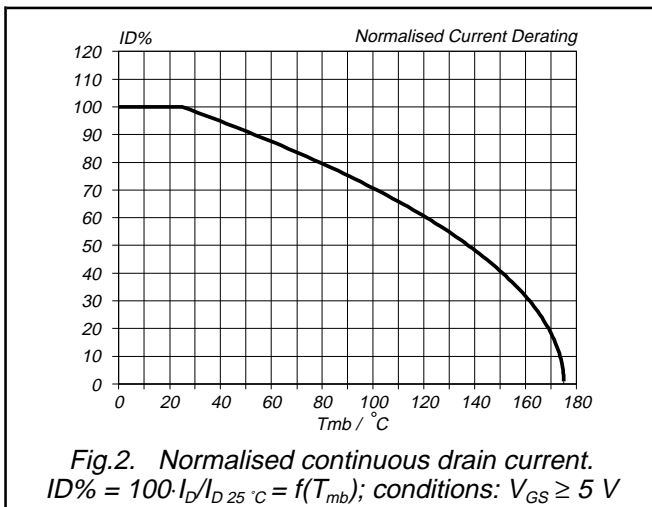
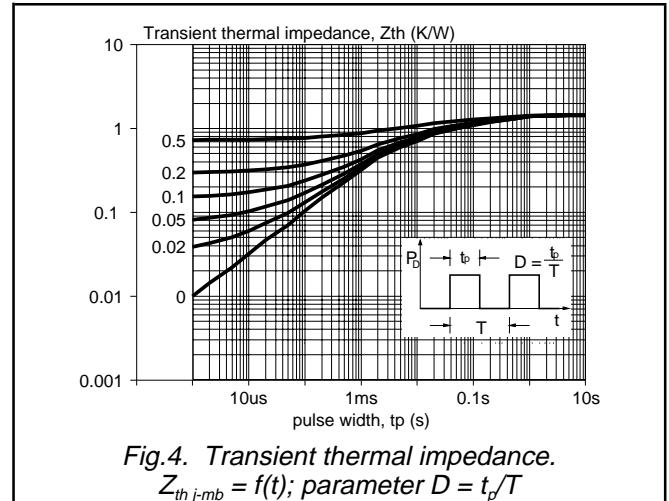
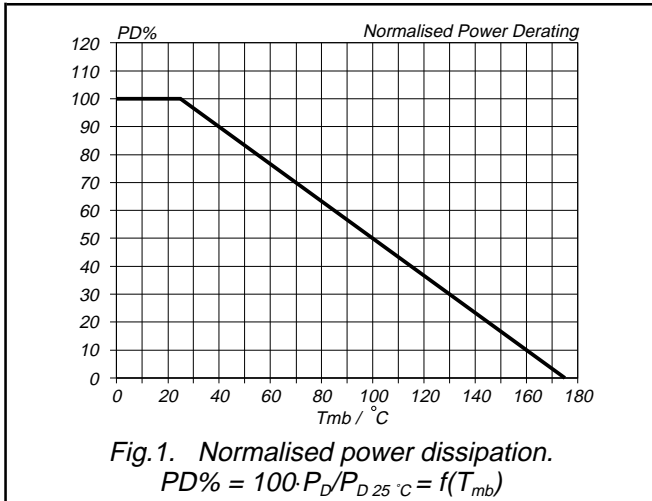
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AVALANCHE LIMITING VALUE

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
W_{DSS}	Drain-source non-repetitive unclamped inductive turn-off energy	$I_D = 40 \text{ A}$; $V_{DD} \leq 25 \text{ V}$; $V_{GS} = 10 \text{ V}$; $R_{GS} = 50 \text{ } \Omega$; $T_{mb} = 25 \text{ } ^\circ\text{C}$	-	-	80	mJ

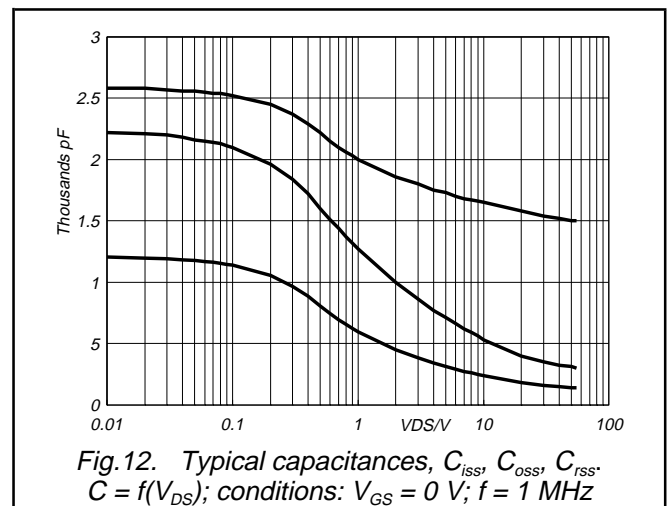
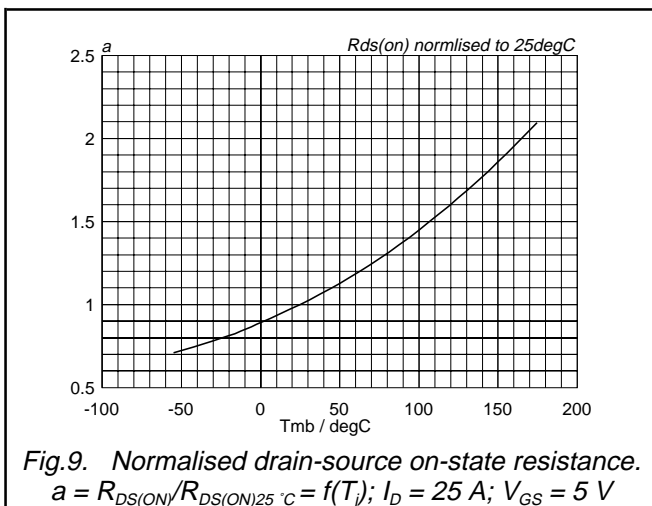
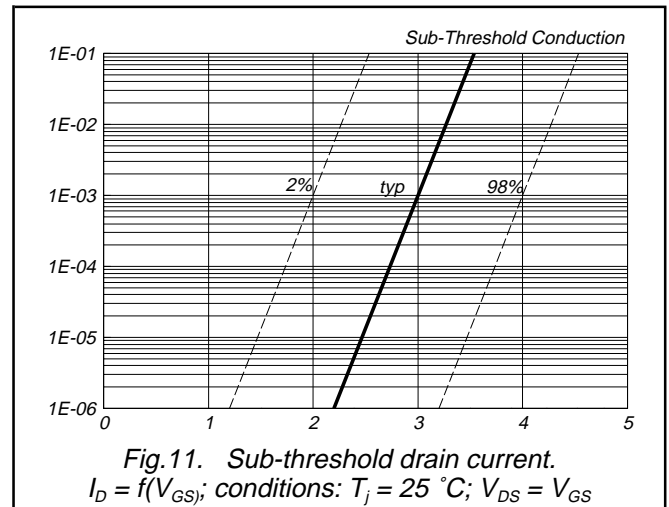
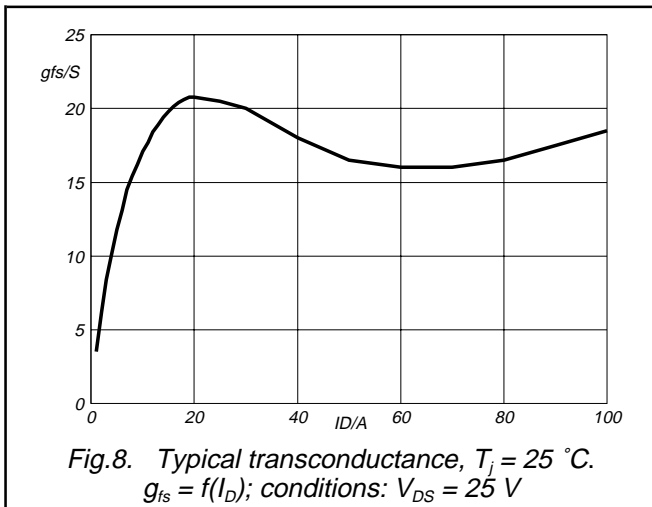
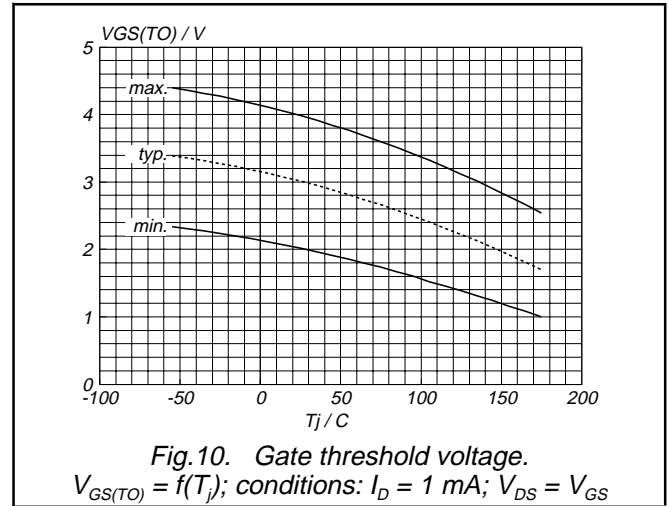
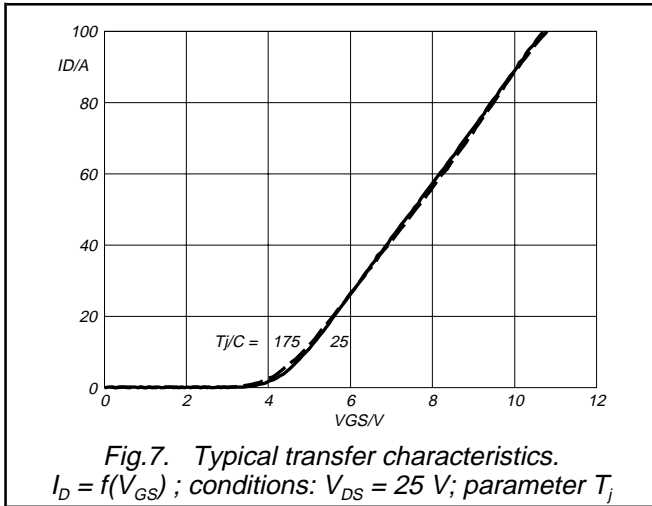
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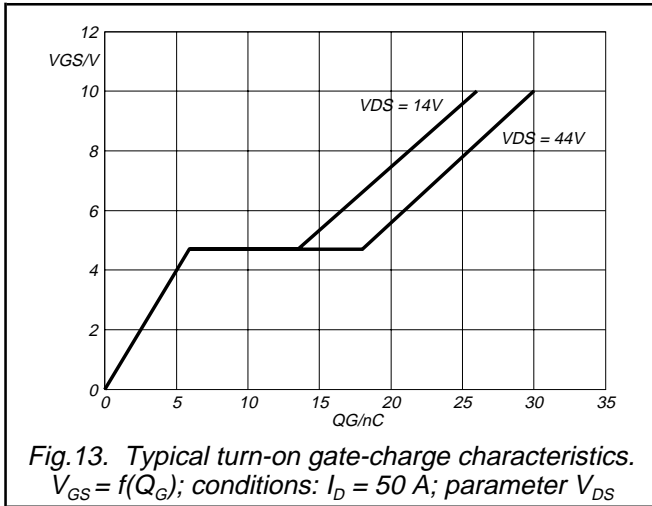


Fig. 13. Typical turn-on gate-charge characteristics.
 $V_{GS} = f(Q_G)$; conditions: $I_D = 50 A$; parameter V_{DS}

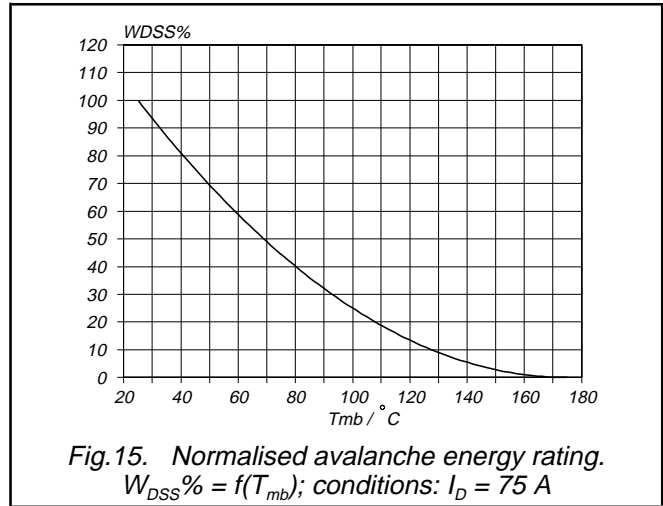


Fig. 15. Normalised avalanche energy rating.
 $W_{DSS}\% = f(T_{mb})$; conditions: $I_D = 75 A$

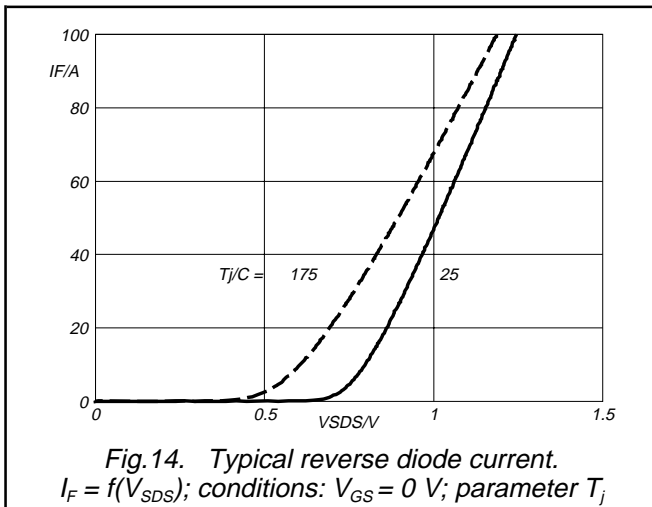


Fig. 14. Typical reverse diode current.
 $I_F = f(V_{SDS})$; conditions: $V_{GS} = 0 V$; parameter T_j

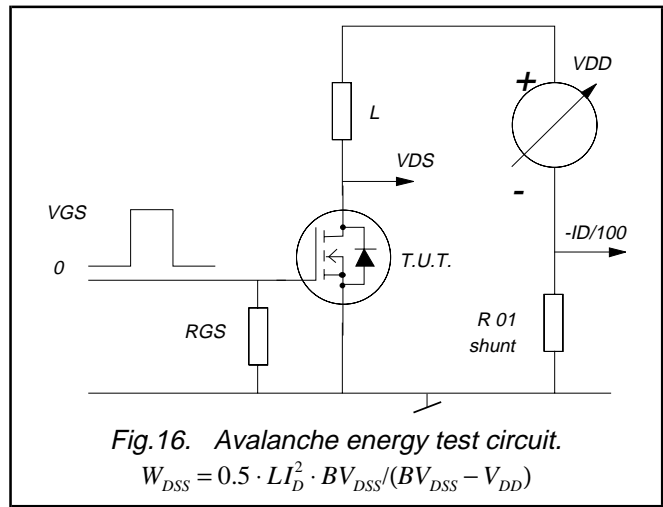


Fig. 16. Avalanche energy test circuit.
 $W_{DSS} = 0.5 \cdot L I_D^2 \cdot BV_{DSS} / (BV_{DSS} - V_{DD})$

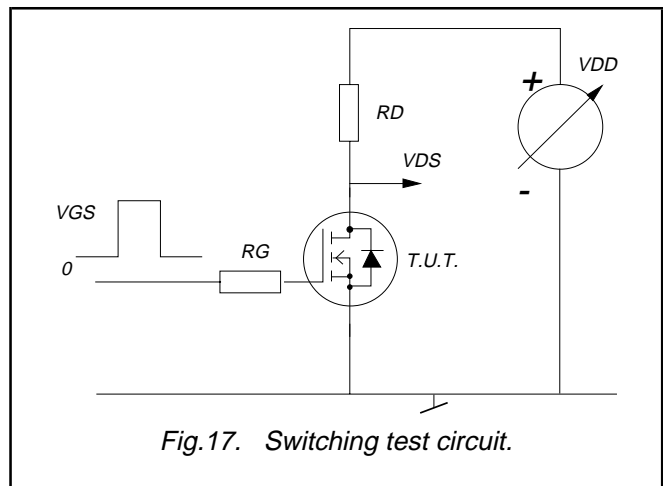


Fig. 17. Switching test circuit.

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MECHANICAL DATA

Dimensions in mm

Net Mass: 2 g

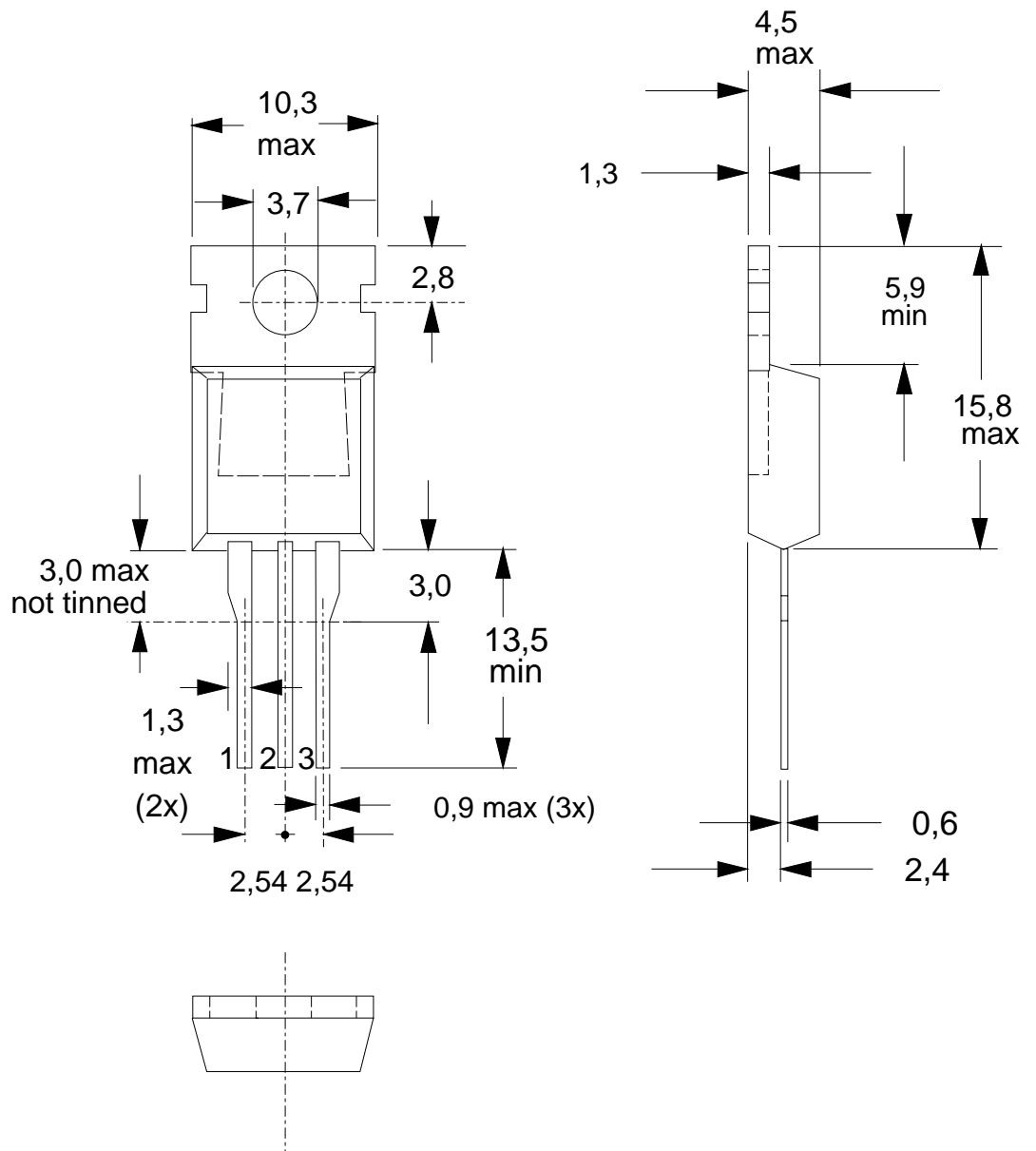


Fig.18. SOT78 (TO220AB); pin 2 connected to mounting base.

Notes

1. Observe the general handling precautions for electrostatic-discharge sensitive devices (ESDs) to prevent damage to MOS gate oxide.
2. Refer to mounting instructions for SOT78 (TO220) envelopes.
3. Epoxy meets UL94 V0 at 1/8".

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DEFINITIONS

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values are given in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of this specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	
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