NAVSEA Crane Radiation Test Report

Report No: NSWC C6054-NDS352AP-0001

Program: NASA GODDARD			Report Date: 12/31/2001
Generic Part No.	**Part Description:**	**Manufacturer:**	
NDS352AP	30V, 0.5-Ω P-Channel MOSFET	Fairchild Semiconductor	
Package Type:	**Date Code:**	**Package Markings**	
SuperSOT-3	0053	352A	
Detailed Test Specification:	**General Test Requirement:**	**Performance Specification**	
NDS352AP TID Test Plan	None	Fairchild Specification NDS352AP Rev. D (Feb 1997)	
Serial Number:		**Radiation Test Results**	
1, 2, 3, 4, 5, 6, 7, 8, 9, & 10 (S/N assigned randomly)		See Appendix B, C, D, & E	

1.0 Summary.

NAVSEA Crane was tasked to evaluate the total ionizing dose (TID) performance of a P-channel 30-V, 0.5-Ohm MOSFET, the NDS352AP manufactured by Fairchild Corporation, to conditions specified by NASA under the NDS352AP TID Test Plan drafted by Christian Poivey, NASA-GSFC, Code 561, Greenbelt MD 20771. Specifically, NAVSEA Crane performed these tests:

a.) Electrical Measurements (I_{DSS}, $R_{DS(ON)}$, and $V_{GS(TH)}$); Total Dose Tests at 2.5, 5, 10, 20, 30, and 50 krd(Si) using a dose rate < 1 rd(Si)/s under a bias of $V_D = V_S = 5V$ and $V_G = 0V$; and Post Radiation Anneal Test for 168 hrs @ 25 °C using the same radiation fixture and biases. Electrical Measurements are performed initially and after each radiation step and following the Anneal Test.

Test results indicate the following that IDSS increased to a maximum of 522 pA at 50 krds and to 575 pA after the anneal; RDSON increased to a maximum of 0.98 ohms at 50 krds and to 0.91 ohms after the anneal; and VGSTH increased to a maximum of -2.63 V at 50 krds and to -2.61 after the anneal. Detailed radiation responses are provided in Appendix B, C, D, and E.

2.0 Applicable Documents.

The major applicable documents, used to perform the TID tests, are listed here:

a) NDS352AP TID Test Plan	Specific Test Plan by NASA
b) NDS352AP Specification	Performance Specification by Fairchild Semiconductor (Feb 1997)
c) MIL-STD-750D	Test Methods for Semiconductor Devices
Method 1019.4	Steady State Total Dose Irradiation Procedure
Method 3400	Conditions for Measurement of MOSFET Parameters
3411.1	Gate Reverse Current (I_{G_OFF})
3415.1	Drain Reverse Current (I_{D_OFF})
3421.1	Static Drain to Source On Resistance (R_{DS_ON})
3403.1	Gate to source Voltage (V_{GS_OFF})
e) ASTM Standard E668	Standard Practice for the Application of Thermoluninscensce Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation Hardness Testing of Electronic Devices - Annual Book of ASTM Standards, Vol. 12.02: Nuclear (II), Solar, and Geothermal Energy, American Society for Testing and Materials
f) NAVSEA INST 4734.1	NAVSEA Metrology and Calibration Program
g) DOD-HDBK-263	Handbook - Electrostatic discharge sensitive devices

3.0 Handling Precautions.

Handling precautions were observed to minimize electrostatic discharge (ESD).

4.0 Electrical Test.

Electrical measurements were performed using a Tektronix 370 curve tracer for $V_{GS(TH)}$ and $R_{DS(ON)}$ parameters and using an automated test system consisting of two Keithley 237 SMU's and a controller for the I_{DSS} parameters. Ten samples consisting of two controls and eight test samples were characterized. These electrical test parameters were measured:

PARAMETER	CONDITION	PARAMETER	LIMIT
Zero Gate Voltage Drain Current	V_{DS} = -24 V V_{GS} = 0 V	I_{DSS}	< -1 μA
Static Drain-Source On Resistance	I_{DS} = -0.9 A V_{GS} = -4.5 V	R_{DS_ON}	< 0.5 Ω
Gate Threshold Voltage	I_{DS} = -250 μA V_{DS} = V_{GS}	$V_{GS(TH)}$	> -2.5 V

Note: Appendix A provides a summary of a visual inspection of the test samples.
Appendix B provides a summary of the initial pre-rad electrical test measurements.
Appendix C provides a summary of the post-rad electrical test measurements.
Appendix D provides a summary of the post-anneal electrical test measurements.
Appendix E provides a graphical summary of the electrical test parameters.

4.1 Test Conditions.

Test conditions were performed as specified by the applicable documents of 2.0 (specifically, the NDS352AP TID Test Plan). All electrical measurements were performed at an ambient room temperature of 23 °C ± 5°C and were recorded for each test sequence.

5.0 Total Ionizing Dose (TID) Test.

Total ionizing dose tests were performed at the NAVSEA Crane Co-60 test facility using a J. L. Shepherd and Associates Model 81-22 Irradiator with a Model 484 Radiation Tunnel and Interlock Door Assembly. Test samples were placed inside a Pb/Al container to minimize dose enhancement effects caused by low-energy scattering. The desired dose rate is achieved by selecting different amounts of radioactivity and distance. For this test, the 8,000 curies source was used with the positioning table set at 670 mm.

5.1 Bias Circuit.

A custom bias board was designed and fabricated to perform the TID tests. The bias circuit conformed to the requirements of the test specification (see bias conditions - NASA NDS352AP TID Test Plan). Figure 1 depicts the TID insitu bias circuit used for six of the eight test samples. The other two samples were biased with all leads common ($V_D = V_S = V_G$). Figure 2 shows a pictorial representation of the of the TID bias board. Note that all eight test samples were exposed simultaneously.

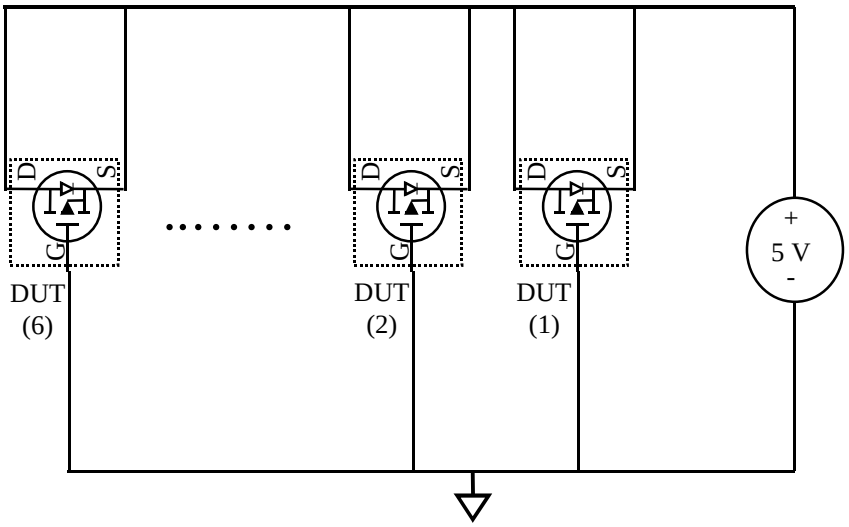

Figure 1. Insitu bias circuit used in TID test.

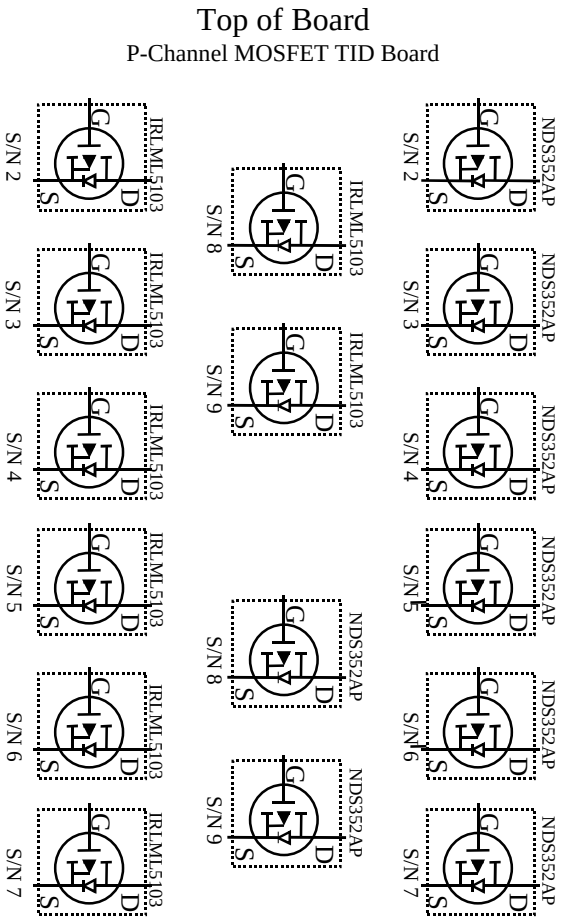

Figure 2. TID board layout of bias circuitry.

5.2 Dosimetry.

Dosimetry standard is described in 2.0(e).
For total dose dosimetry, three ribbons were placed in a TLD holder and wrapped in a thin, (~0.001 inches) aluminum foil. The average reading of these three ribbons is used to determine the dose rate of the Co-60 source. For this test, TLDs were placed upon the top left socket, top right socket, bottom left socket, bottom right socket and the middle of all the sockets as depicted in Figure 3. Note, this dosimetry was used to determine exposure times for all subsequent tests. Table 2 provides a summary of the Co-60 Gamma Cell 220 source dosimetry.

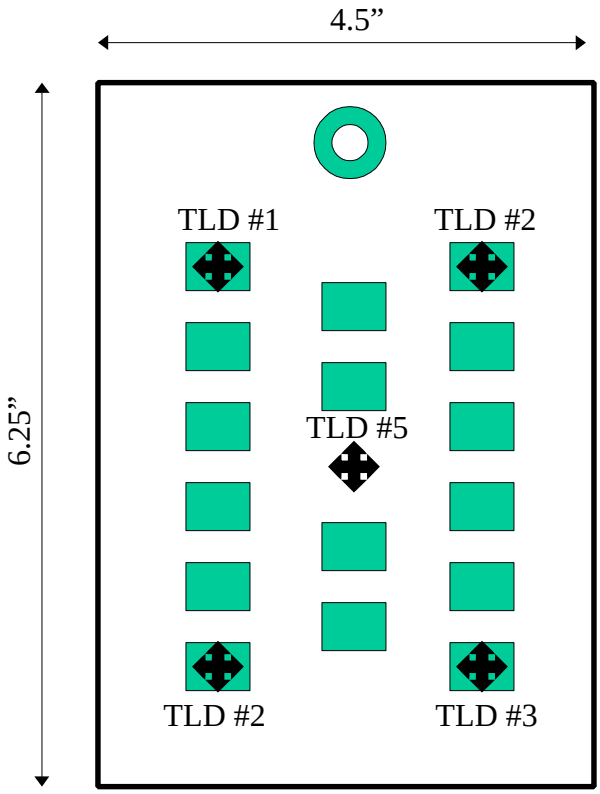

Figure 3. Pictorial Representation Showing TLD Placement.

Table 2. Verification of Co-60 Source

TLD Package	Slide Number	Avg. Dose Rd(CaF2)	Standard Deviation	Dose Rate [Rd(Si)/s]	Board Position
1	101	123.5	2.9%	0.8948	Top Left
2	102	124.2	0.6%	0.9000	Top Right
3	103	127.4	3.8%	0.9228	Bottom Left
4	104	119.7	1.4%	0.8677	Bottom Right
5	105	123.4	2.6%	0.8942	Middle

6	106	2489	1.6%	0.8861	Top Right

Based upon the dosimetry, the dose rate was determined to be 0.89 rd(Si)/s. To validate the first radiation level (and to verify the dose rate), another TLD (top right corner) was placed upon the TID board above the top right socket. The exposure time was set for 2809 seconds (0.89 x 2,809 = 2,500), resulting in an average TLD reading of 2,489 rd(Si).

Table 3 is a summary of the required exposure times to achieve radiation levels of 2.5, 5, 10, 20, 30, and 50 krd(Si) as required by the NDS352AP TID Test Plan. Table 3 also provides the times to perform the electrical measurements between each exposure.

Table 3. Summary of Exposure and Electrical Test Times of TID Test

Total Dose Test Date	Exposure Start Time	Exposure Stop Time	Total Dose Rd(Si)	Electrical Test Start Time	Electrical Test Stop Time
12/18/2001	11:12 AM	11:59 AM	2,500	12:00 PM	12:38 PM
12/18/2001	12:40 PM	1:26 PM	5,000	1:28 PM	2:00 PM
12/18/2001	2:03 PM	3:38 PM	10,000	3:39 PM	4:11 PM
12/18/2001	4:15 PM	7:23 PM	20,000	7:25 PM	8:04 PM
12/18/2001	8:07 PM	11:16 PM	30,000	11:17 PM	11:53 PM
12/19/2001	12:08 AM	6:28 AM	50,000	6:37 AM	7:25 AM

5.3 Post-Radiation Anneal Test.

Upon completion of the last exposure (50 krd(Si)) and electrical characterization, samples were annealed for 168 hours at 25 °C under similar bias conditions. After annealing, the samples were electrically characterized again. This was specified in the NDS352AP TID Test Plan.

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APPENDIX A. Visual Inspection Summary

Tagged S/N	Package Markings	Marking Verified	Comments
001	352A	Yes	
002	352A	Yes	
003	352A	Yes	
004	352A	Yes	
005	352A	Yes	
006	352A	Yes	
007	352A	Yes	
008	352A	Yes	
009	352A	Yes	
010	352A	Yes	

Note: Samples were mounted on a custom designed Device under test (DUT) card to facilitate handling and testing protocols. Serial numbers were randomly assigned and marked on each DUT card using a permanent marker.

Appendix B. Summary of Initial Electrical Test Data

Radiation Level - 0 krd(Si)				
S/N	I_{DSS} V_{DS} = -24V V_{GS} = 0 V (A)	$R_{DS(ON)}$ I_{DS} = -0.9 A V_{GS} = -4.5 V (Ohms)	$V_{GS(TH)}$ V_{DS} = V_{GS} I_{DS} = -250 mA (Volts)	Radiation Sample Description
001	1.03E-10	0.46	-1.61	Control
002	4.25E-11	0.46	-1.62	Biased
003	5.87E-11	0.46	-1.61	Biased
004	9.43E-11	0.46	-1.606	Biased
005	1.30E-10	0.45	-1.6	Biased
006	3.12E-11	0.45	-1.6	Biased
007	4.73E-10	0.46	-1.61	Biased
008	3.20E-11	0.45	-1.59	PINS COMMON
009	4.40E-11	0.47	-1.64	PINS COMMON
010	3.50E-11	0.46	-1.606	Control

Appendix C. Summary of Electrical Parameters After each Radiation Level

Radiation Level 2,500 rd(Si)				
S/N	**I_{DSS} (A)**	**$R_{DS(ON)}$ (Ohms)**	**$V_{GS(TH)}$ (Volts)**	**Radiation Sample Description**
001	9.00E-11	0.46	1.61	Control
002	3.70E-11	0.47	1.67	Biased
003	5.10E-11	0.47	1.66	Biased
004	8.30E-11	0.47	1.66	Biased
005	1.16E-10	0.46	1.65	Biased
006	2.60E-11	0.46	1.65	Biased
007	4.30E-10	0.47	1.67	Biased
008	2.70E-11	0.46	1.63	PINS COMMON
009	3.70E-11	0.47	1.67	PINS COMMON
010	2.90E-11	0.46	1.604	Control
Radiation Level 5,000 rd(Si)				
S/N	**I_{DSS} (A)**	**$R_{DS(ON)}$ (Ohms)**	**$V_{GS(TH)}$ (Volts)**	**Radiation Sample Description**
001	9.90E-11	0.46	-1.61	Control
002	4.70E-11	0.47	-1.72	Biased
003	5.96E-11	0.48	-1.71	Biased
004	9.48E-11	0.48	-1.71	Biased
005	1.30E-10	0.47	-1.71	Biased
006	3.30E-11	0.47	-1.7	Biased
007	4.55E-10	0.48	-1.72	Biased
008	3.60E-11	0.46	-1.66	PINS COMMON
009	4.40E-11	0.47	-1.7	PINS COMMON
010	3.20E-11	0.46	-1.604	Control
Radiation Level 10,000 rd(Si)				
S/N	**I_{DSS} (A)**	**$R_{DS(ON)}$ (Ohms)**	**$V_{GS(TH)}$ (Volts)**	**Radiation Sample Description**
001	9.60E-11	0.46	-1.608	Control
002	6.20E-11	0.49	-1.822	Biased
003	7.20E-11	0.49	-1.816	Biased
004	1.12E-10	0.50	-1.816	Biased
005	1.47E-10	0.49	-1.81	Biased
006	4.30E-11	0.49	-1.804	Biased
007	4.74E-10	0.49	-1.828	Biased
008	5.10E-11	0.47	-1.718	PINS COMMON
009	5.30E-11	0.48	-1.766	PINS COMMON
010	3.30E-11	0.46	-1.604	Control

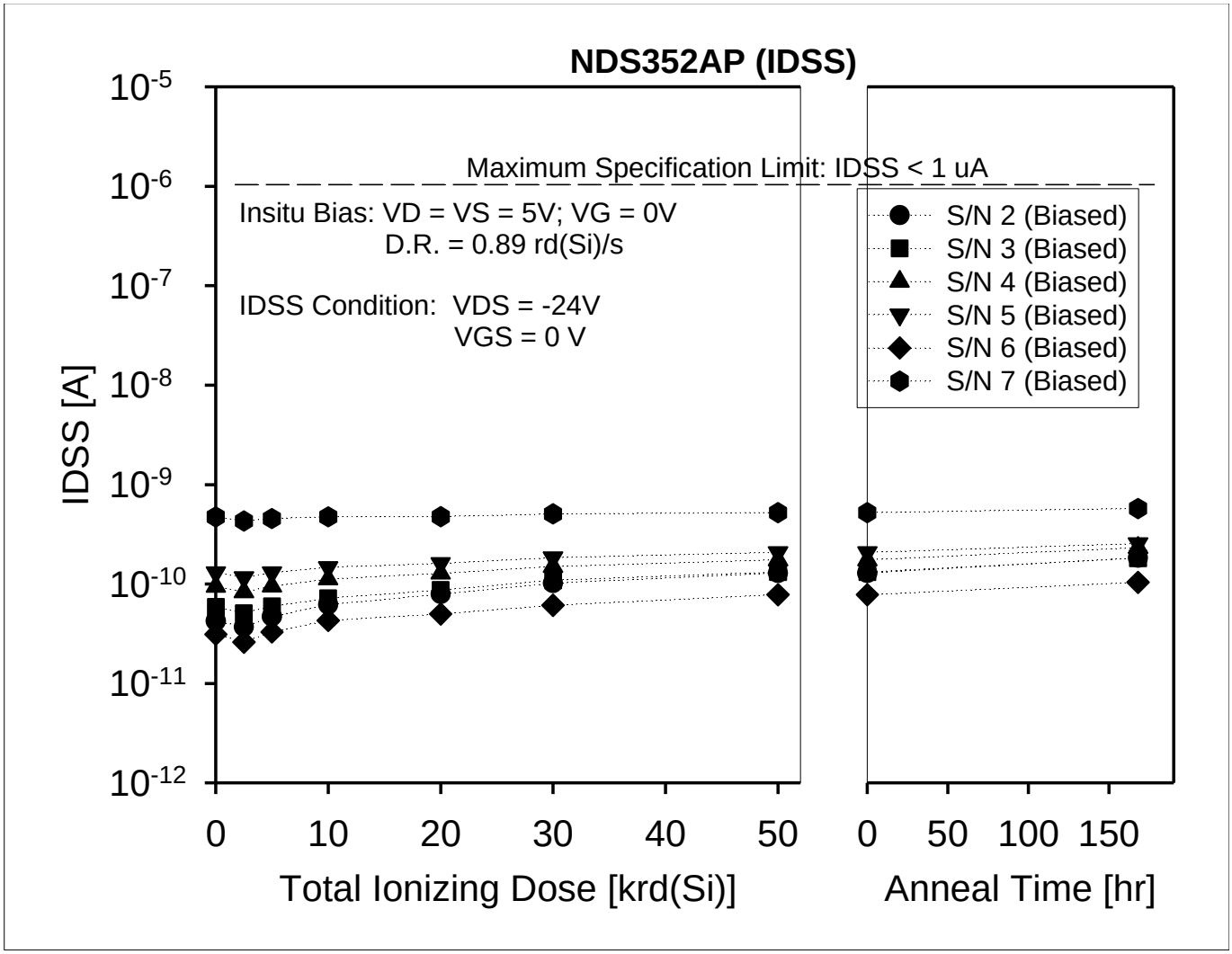
Appendix C. Summary of Electrical Parameters After each Radiation Level (CONT.)

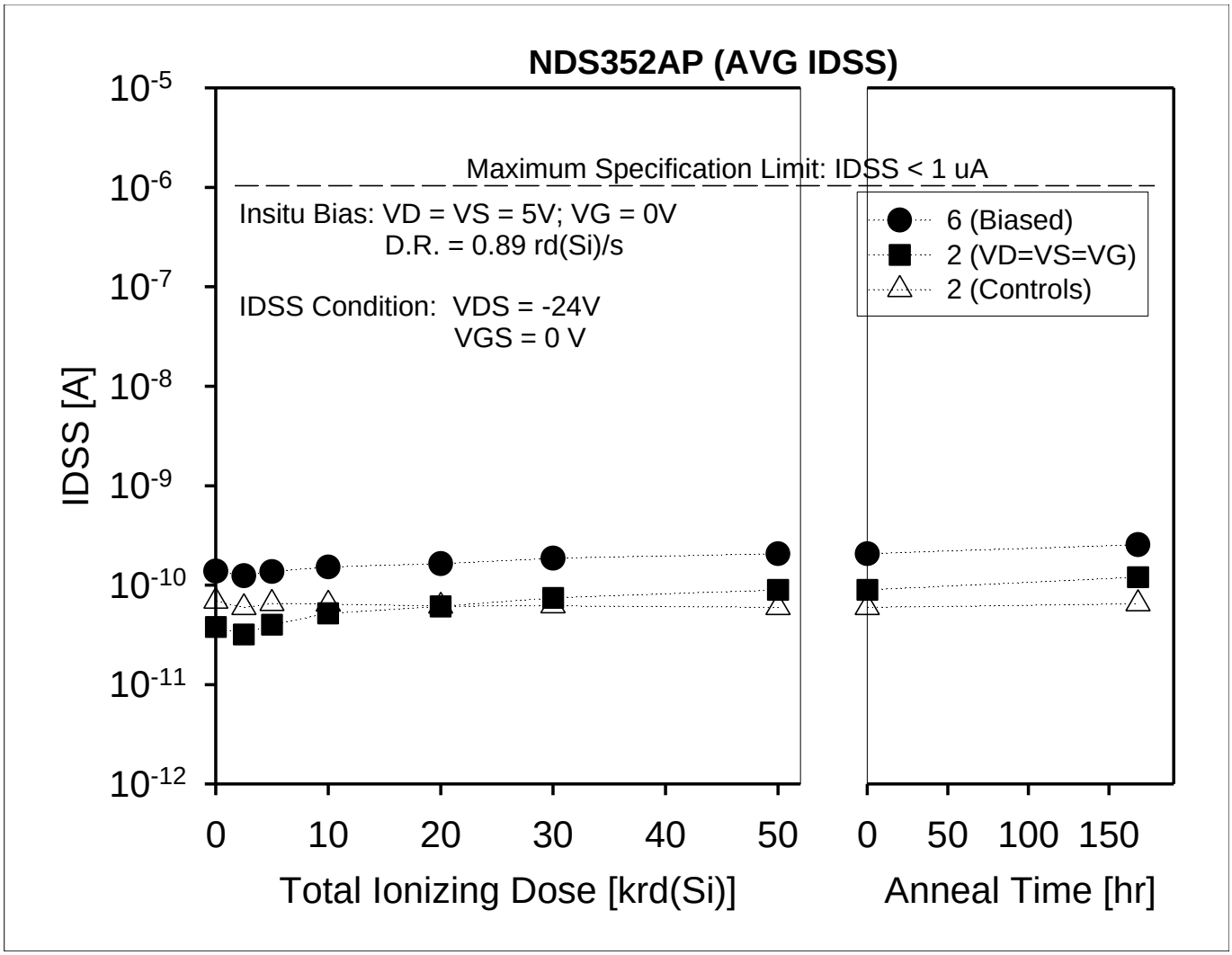
Radiation Level 20,00 rd(Si)				
S/N	**I_{DSS} (A)**	**$R_{DS(ON)}$ (Ohms)**	**$V_{GS(TH)}$ (Volts)**	**Radiation Sample Description**
001	9.30E-11	0.45	-1.61	Control
002	7.90E-11	0.54	-2.03	Biased
003	8.70E-11	0.54	-2.03	Biased
004	1.28E-10	0.54	-2.03	Biased
005	1.61E-10	0.53	-2.02	Biased
006	5.00E-11	0.53	-2.01	Biased
007	4.76E-10	0.54	-2.04	Biased
008	6.20E-11	0.49	-1.83	PINS COMMON
009	6.00E-11	0.50	-1.89	PINS COMMON
010	3.00E-11	0.46	-1.605	Control
Radiation Level 30,00 rd(Si)				
S/N	**I_{DSS} (A)**	**$R_{DS(ON)}$ (Ohms)**	**$V_{GS(TH)}$ (Volts)**	**Radiation Sample Description**
001	9.40E-11	0.45	-1.61	Control
002	1.02E-10	0.61	-2.235	Biased
003	1.09E-10	0.61	-2.225	Biased
004	1.50E-10	0.62	-2.225	Biased
005	1.84E-10	0.62	-2.22	Biased
006	6.10E-11	0.60	-2.22	Biased
007	5.08E-10	0.61	-2.24	Biased
008	7.80E-11	0.50	-1.935	PINS COMMON
009	7.10E-11	0.52	-1.98	PINS COMMON
010	3.00E-11	0.46	-1.605	Control
Radiation Level 50,00 rd(Si)				
S/N	**I_{DSS} (A)**	**$R_{DS(ON)}$ (Ohms)**	**$V_{GS(TH)}$ (Volts)**	**Radiation Sample Description**
001	9.10E-11	0.46	-1.61	Control
002	1.29E-10	0.95	-2.63	Biased
003	1.32E-10	0.95	-2.61	Biased
004	1.75E-10	0.96	-2.62	Biased
005	2.08E-10	0.94	-2.61	Biased
006	7.80E-11	0.92	-2.6	Biased
007	5.22E-10	0.98	-2.63	Biased
008	9.50E-11	0.54	-2.1	PINS COMMON
009	8.40E-11	0.55	-2.15	PINS COMMON
010	2.80E-11	0.46	-1.605	Control

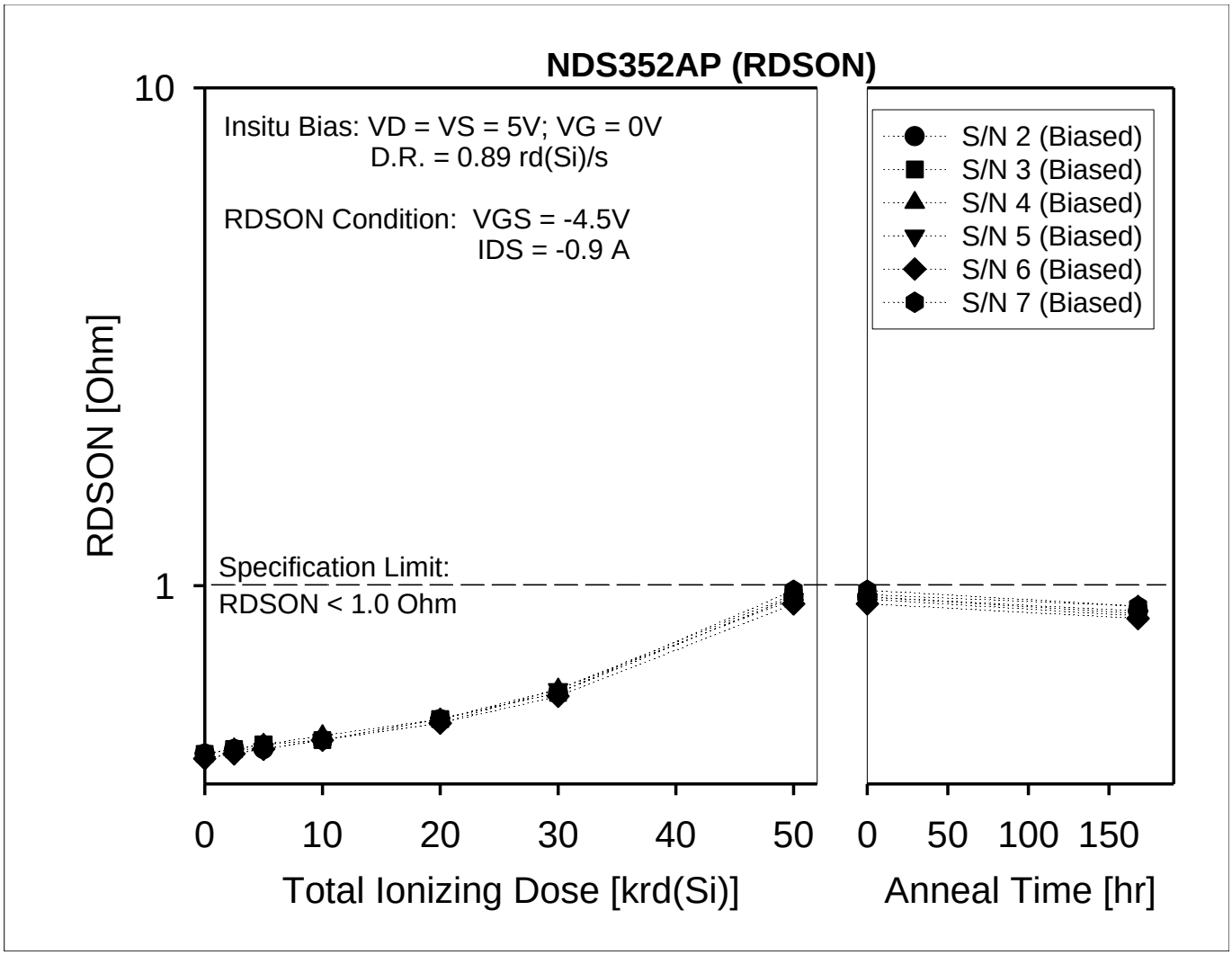
Appendix D. Summary of Electrical Tests After 168 hr Anneal

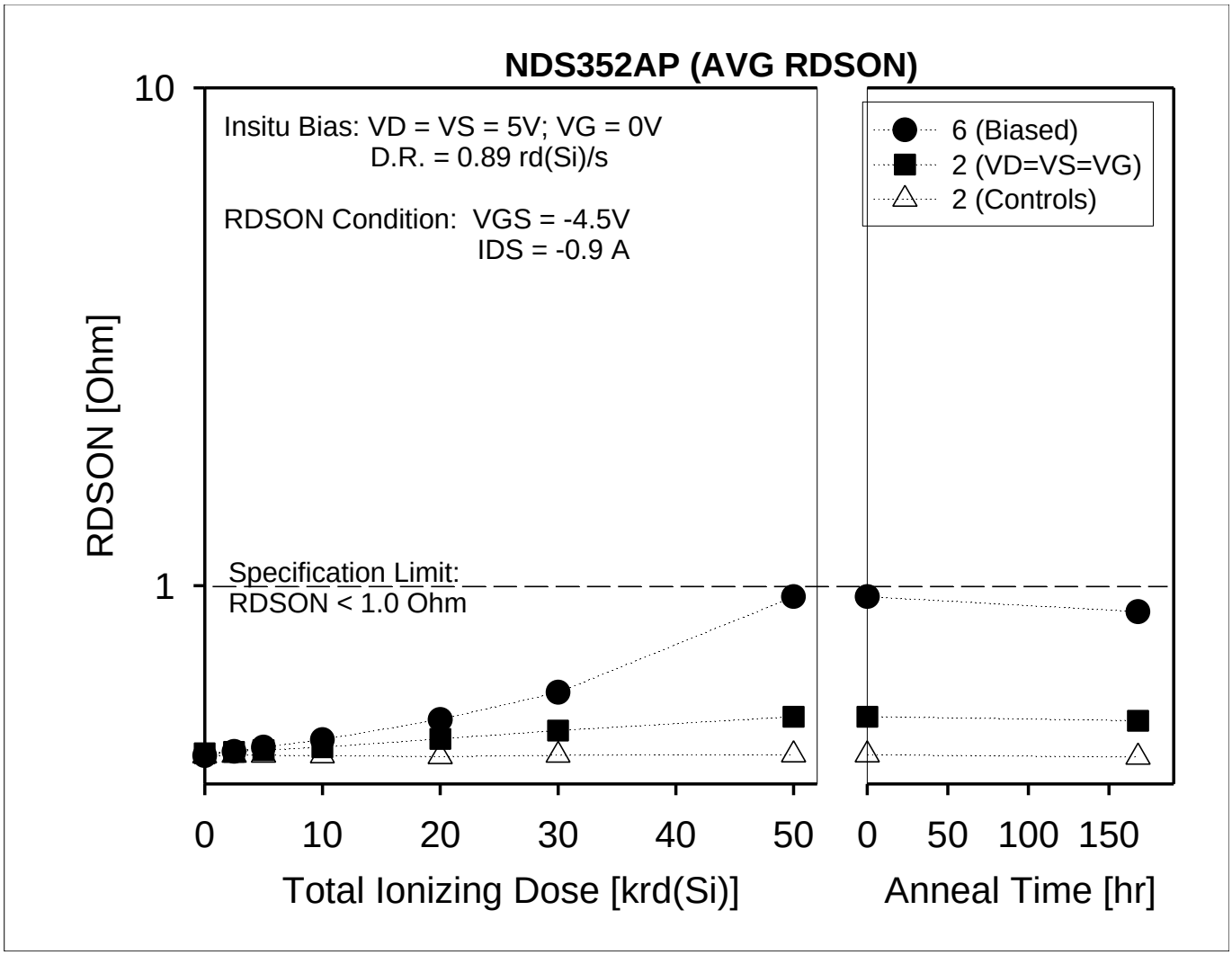
Anneal: 168 hours at 25 °C(Si) after 50,000 rd(Si) TID				
S/N	**I_{DSS}** **V_{DS} = -24V** **V_{GS} = 0 V** **(A)**	**$R_{DS(ON)}$** **I_{DS} = -0.9 A** **V_{GS} = -4.5 V** **(Ohms)**	**$V_{GS(TH)}$** **V_{DS} = V_{GS}** **I_{DS} = -250 mA** **(Volts)**	**Radiation Sample Description**
001	9.80E-11	0.45	-1.62	Control
002	1.83E-10	0.89	-2.6	Biased
003	1.82E-10	0.88	-2.6	Biased
004	2.32E-10	0.91	-2.6	Biased
005	2.55E-10	0.87	-2.6	Biased
006	1.04E-10	0.86	-2.59	Biased
007	5.75E-10	0.91	-2.61	Biased
008	1.26E-10	0.53	-2.1	PINS COMMON
009	1.13E-10	0.54	-2.14	PINS COMMON
010	3.20E-11	0.45	-1.61	Control

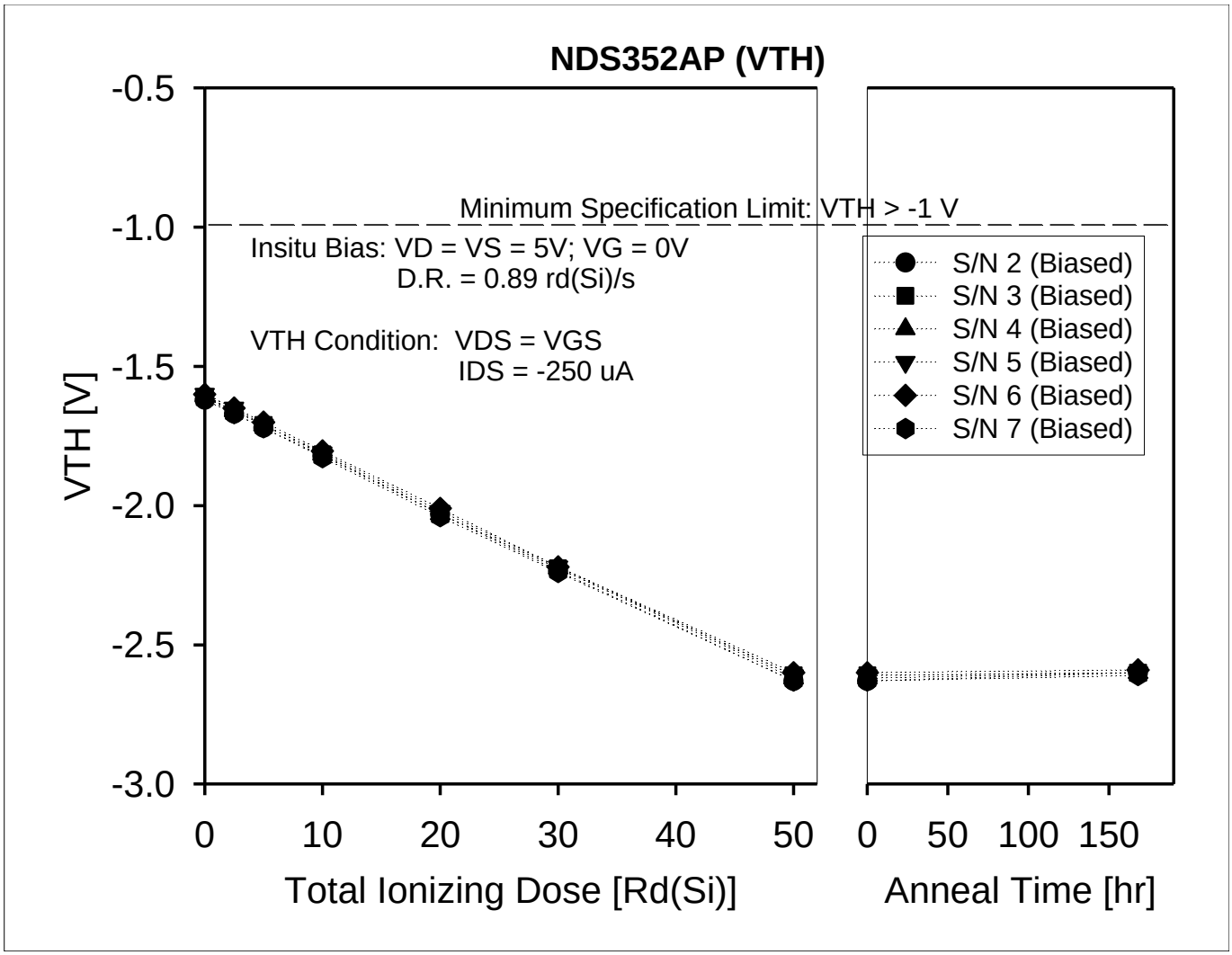
Appendix E. Graphical Summary of Electrical Tests Results




NDS352AP (AVG IDSS)
Maximum Specification Limit: IDSS < 1 uA
Insitu Bias: VD = VS = 5V; VG = 0V
D.R. = 0.89 rd(Si)/s
IDSS Condition: VDS = -24V
VGS = 0 V
6 (Biased)
2 (VD=VS=VG)
2 (Controls)
IDSS [A]
10-5
10-6
10-7
10-8
10-9
10-10
10-11
10-12
0 10 20 30 40 50
0 50 100 150
Total Ionizing Dose [krd(Si)]
Anneal Time [hr]


NDS352AP (RDSON)
Insitu Bias: VD = VS = 5V; VG = 0V
D.R. = 0.89 rd(Si)/s
RDSON Condition: VGS = -4.5V
IDS = -0.9 A
S/N 2 (Biased)
S/N 3 (Biased)
S/N 4 (Biased)
S/N 5 (Biased)
S/N 6 (Biased)
S/N 7 (Biased)
RDSON [Ohm]
10
1
Specification Limit:
RDSON < 1.0 Ohm
0
10
20
30
40
50
0
50
100
150
Total Ionizing Dose [krd(Si)]
Anneal Time [hr]


NDS352AP (AVG RDSON)
Insitu Bias: VD = VS = 5V; VG = 0V
D.R. = 0.89 rd(Si)/s
RDSON Condition: VGS = -4.5V
IDS = -0.9 A
6 (Biased)
2 (VD=VS=VG)
2 (Controls)
Specification Limit:
RDSON < 1.0 Ohm
RDSON [Ohm]
10
1
0
10
20
30
40
50
0
50
100
150
Total Ionizing Dose [krd(Si)]
Anneal Time [hr]


NDS352AP (VTH)
Minimum Specification Limit: VTH > -1 V
Insitu Bias: VD = VS = 5V; VG = 0V
D.R. = 0.89 rd(Si)/s
VTH Condition: VDS = VGS
IDS = -250 uA
S/N 2 (Biased)
S/N 3 (Biased)
S/N 4 (Biased)
S/N 5 (Biased)
S/N 6 (Biased)
S/N 7 (Biased)
VTH [V]
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
0
10
20
30
40
50
0
50
100
150
Total Ionizing Dose [Rd(Si)]
Anneal Time [hr]

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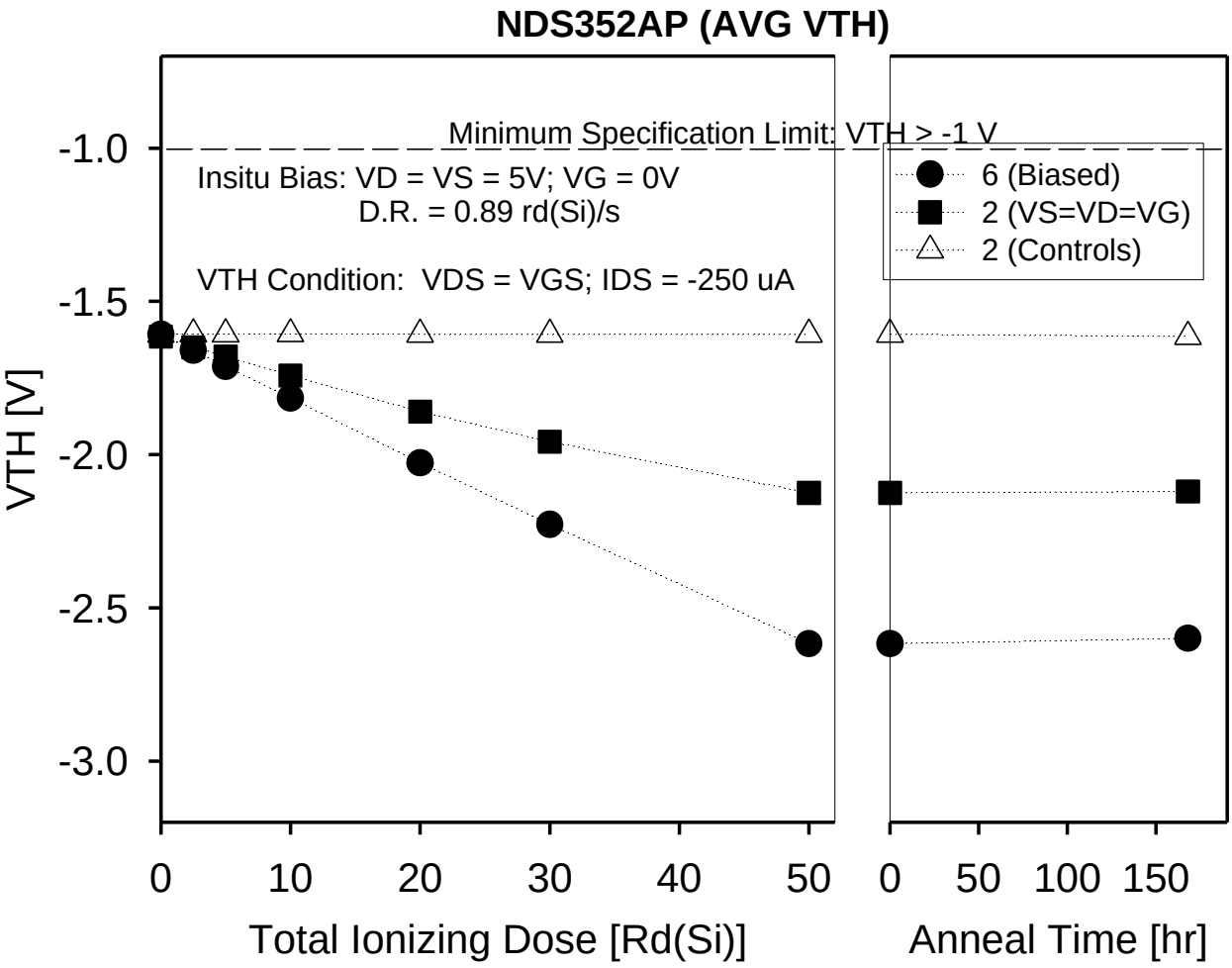

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