Total Ionizing Dose Test Report

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I. SUMMARY TABLE

Parameter	Tolerance
1. Gross Functionality	Passed 125 krad(SiO_2)
2. Power Supply Current	Passed 125 krad(SiO_2)
3. Input Threshold (VIL/VIH)	Passed 125 krad(SiO_2)
4. Output Drive (VOL/VOH)	Passed 125 krad(SiO_2)
5. Propagation Delay	Passed 125 krad(SiO_2) for 10% degradation criterion
6. Transition Time	Passed 125 krad(SiO_2)

II. TOTAL IONIZING DOSE (TID) TESTING

This testing is designed on the basis of an extensive database of TID testing for Radiation-Tolerant FPGAs including flash-based FPGAs. Microsemi TID reports can be found at http://www.microsemi.com/products/fpga-soc/radtolerant-fpgas/military-aerospace-radiation-reliability-data#tid-reports

Electrical parameters are measured pre-irradiation and post-irradiation using the burn in design and the Automatic Test Equipment (ATE) program. The report summarizes sample pins.

A. Device-Under-Test (DUT) and Irradiation Parameters

Table 1 lists the DUT and irradiation parameters.

Table. 1. DUT and Irradiation Parameters

Part Number	RT4G150
Package	LG1657
Foundry	United Microelectronics Corp.
Technology	65 nm
DUT Design	Burn in design with inverter string
Die Lot Number	KWMTM
Quantity Tested	6
Serial Number (Dose)	1658 (125 krad), 1690 (125 krad), 1703 (125 krad), 1744 (125 krad), 1786 (125 krad), 1793 (125 krad)
Radiation Facility	Defense Microelectronics Activity
Radiation Source	Co-60
Dose Rate	5 krad (SiO_2)/min
Irradiation Temperature	Room
Irradiation and Measurement Bias	Static at 1.2V/2.5V/3.3V/3.3V
IO Configuration	Single ended Differential Pair

B. Test Method

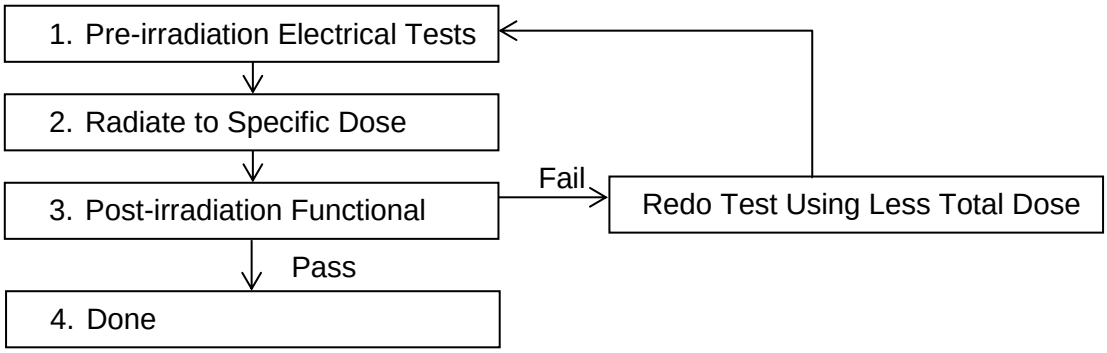

Fig. 1. Parametric test flow chart

The test method generally follows the guidelines in the military standard TM1019. Figure 1 shows the flow chart describing the steps for the functional and parametric tests.

C. Design and Parametric Measurements

RTG4 FPGA devices have different types of I/Os, such as MSIO and MSIOD, double data rate I/Os (DDRIO), and dedicated I/Os based on functional usage. For more information on I/O naming conventions and I/O description, refer to the RTG4 FPGA Pin Description. All I/Os are tested pre and post-irradiation.

Fabric functionality coverage performed by the burn in design is summarized in table 2 below. In addition to the fabric coverage the supplemental test of propagation delay is also used to determine DUT functionality. These tests are performed pre and post-irradiation and recorded as a pass/fail.

Refer to appendix A for a graphical representation of fabric functional coverage blocks used to perform the functional tests.

Table. 2. Fabric Functional Coverage

Block	**Coverage**
Combo Block	combinatorial macros available in the RTG4 library
Register Block	sequential macros available in the RTG4 library
UPROM	Maximum output toggle rate(checker board) compared to reference
Embedded SRAM Blocks	full toggle coverage on 209 fabric LSRAM & 210 µRAM blocks using dual port/ two port configurations (x18 width)
Shift Register Block	core utilization
I/O Block	I/O utilization
Math Block	full toggle coverage on 462 fabric math blocks with maximum width configuration

The core power supply current IDD, the I/Os power supply currents (IDDI_2.5/IDDI_3.3) and the charge pump and PLL power supply current (IPP_PLL) are also monitored during irradiation in real time.

The input logic threshold (VIL/VIH) is measured on all single-ended inputs as well as all differential inputs, and is reported as a pass or fail, as part of the ATE test program. The output-drive voltage (VOL/VOH) is also measured on all pins on the MSIO MSIOD and DDRIO. This report contains the output-drive voltage measurements on selected IO pins used in the burn in design. LVTTL and LVCMOS 2.5V standard at different sourcing and sinking currents are reported.

A 2000 stage inverter string is used to measure the propagation delay. The propagation delay is defined as the time delay from the triggering edge at the Clock input to the switching edge at the output. The propagation delay is monitored real time during irradiation and the time difference between positive switching edges of the clock and output are reported. Additionally, the transition characteristics (rise and fall) at the output of the inverter chain are measured pre and post-irradiation. Oscilloscope screen captures are shown in section III. F.

III. TEST RESULTS

A. Functionality

Every DUT passed the pre-irradiation and post-irradiation functional tests mentioned in section II.C.

B. Power Supply Current

The core power supply current (IDD) is 1.2 V, the I/O bank power supply currents (IDDI) are 2.5 V (IDDI_2.5) and 3.3 V (IDDI_3.3). The charge pump and PLL power supply current (IPP_PLL) is 3.3 V. Figures 2-25 illustrate the plot of in-flux standby IDD, IDDI_2.5, IDDI_3.3 and IPP_PLL versus total dose for every DUT. Tables 3-6 summarize the pre-irradiation and post-irradiation total current (static & dynamic) IDD, IDDI_2.5, IDDI_3.3 and IPP_PLL.

Table. 3. Pre-irradiation and Post-irradiation I_{DD}

DUT	Total Dose	Pre-irradiation (A)	Post-irradiation (A)	Increase (%)
1658	125 krad	0.369	0.388	5.37
1690	125 krad	0.348	0.362	3.86
1703	125 krad	0.337	0.352	4.64
1744	125 krad	0.414	0.428	3.71
1786	125 krad	0.373	0.387	3.56
1793	125 krad	0.356	0.374	5.07

Table. 4. Pre-irradiation and Post-irradiation $I_{DDI\_2.5}$

DUT	Total Dose	Pre-irradiation (A)	Post-irradiation (A)	Increase (%)
1658	125 krad	0.0094	0.0122	28.69
1690	125 krad	0.0084	0.0114	30.45

1703	125 krad	0.0096	0.0125	29.66
1744	125 krad	0.0095	0.0125	30.65
1786	125 krad	0.0088	0.0113	28.68
1793	125 krad	0.0088	0.0113	28.36

Table. 5. Pre-irradiation and Post-irradiation $I_{DDI\_3.3}$

DUT	Total Dose	Pre-irradiation (A)	Post-irradiation (A)	Increase (%)
1658	125 krad	0.0350	0.0379	8.39
1690	125 krad	0.0341	0.0370	8.43
1703	125 krad	0.0353	0.0383	8.34
1744	125 krad	0.0352	0.0381	8.19
1786	125 krad	0.0345	0.0375	8.66
1793	125 krad	0.0344	0.0373	8.54

Table. 6. Pre-irradiation and Post-irradiation I_{PP_PLL}

DUT	Total Dose	Pre-irradiation (A)	Post-irradiation (A)	Increase (%)
1658	125 krad	0.0154	0.0161	4.40
1690	125 krad	0.0154	0.0185	20.50
1703	125 krad	0.0155	0.0174	11.81
1744	125 krad	0.0155	0.0182	17.25
1786	125 krad	0.0155	0.0186	19.94
1793	125 krad	0.0154	0.0208	35.05

The following figures (2-25) show the in-beam monitoring of the currents mentioned above as a function of TID for the available DUTs.

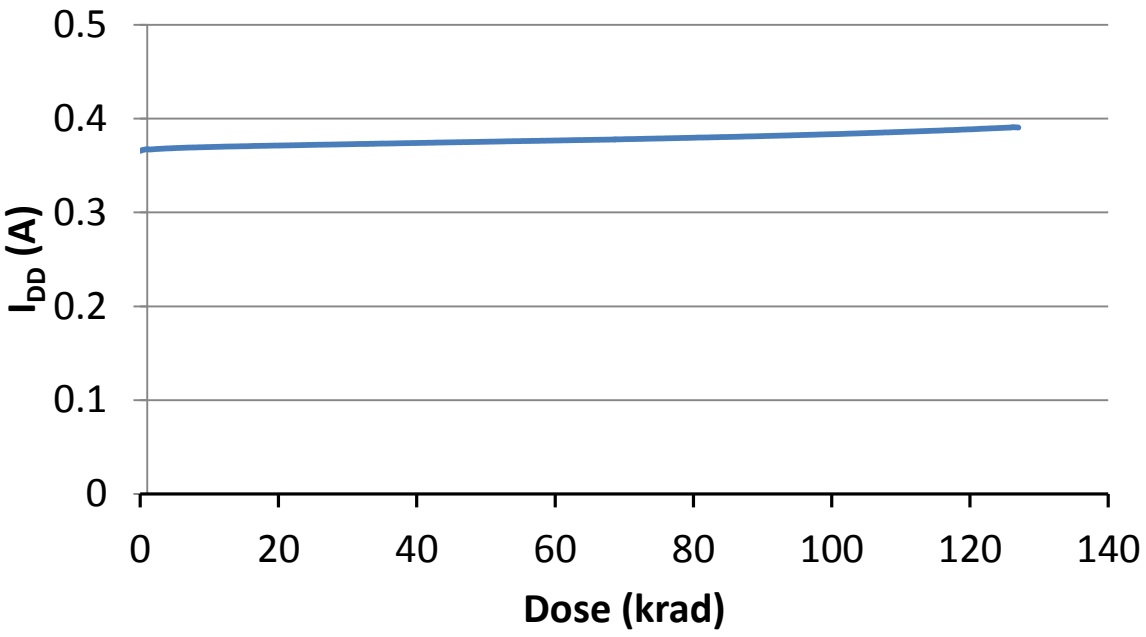

Fig. 2. DUT 1658 core power supply current (I_{DD}) versus TID

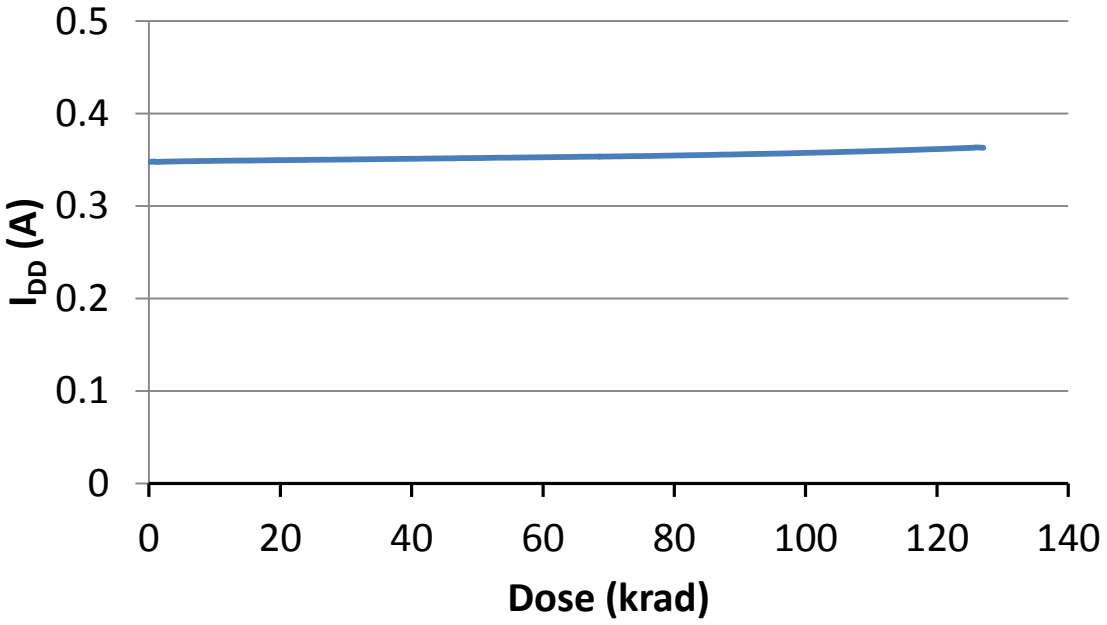

Fig. 3. DUT 1690 core power supply current (I_{DD}) versus TID

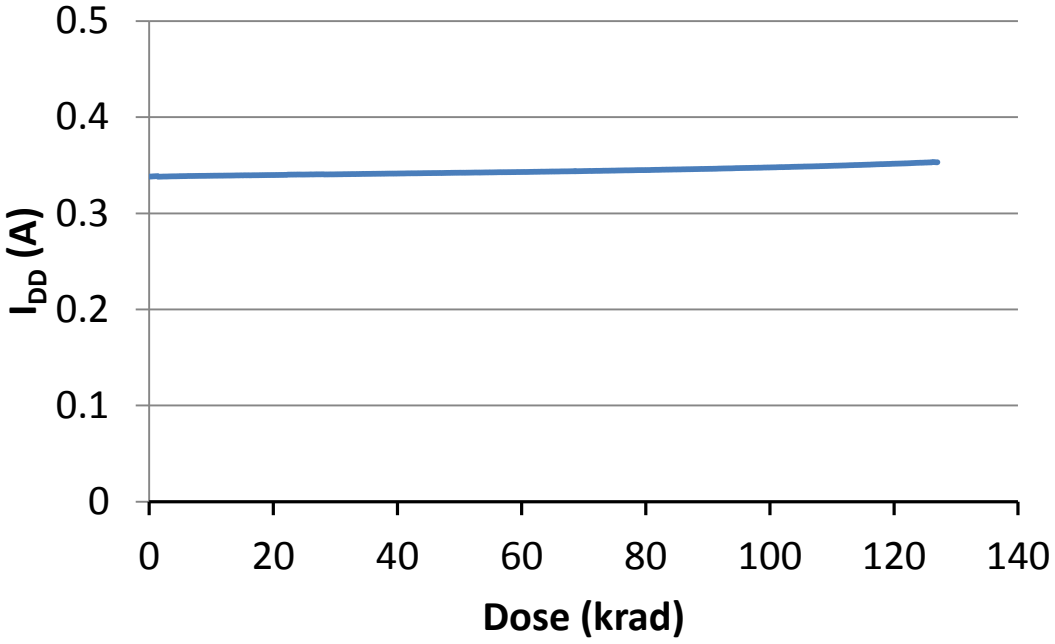

Fig. 4. DUT 1703 core power supply current (I_{DD}) versus TID

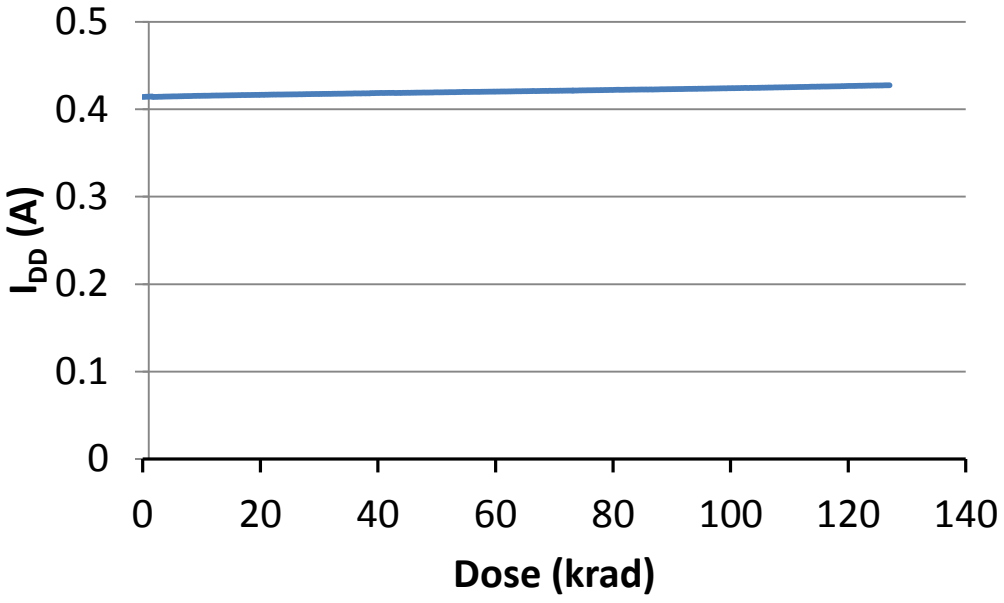

Fig. 5. DUT 1744 core power supply current (I_{DD}) versus TID

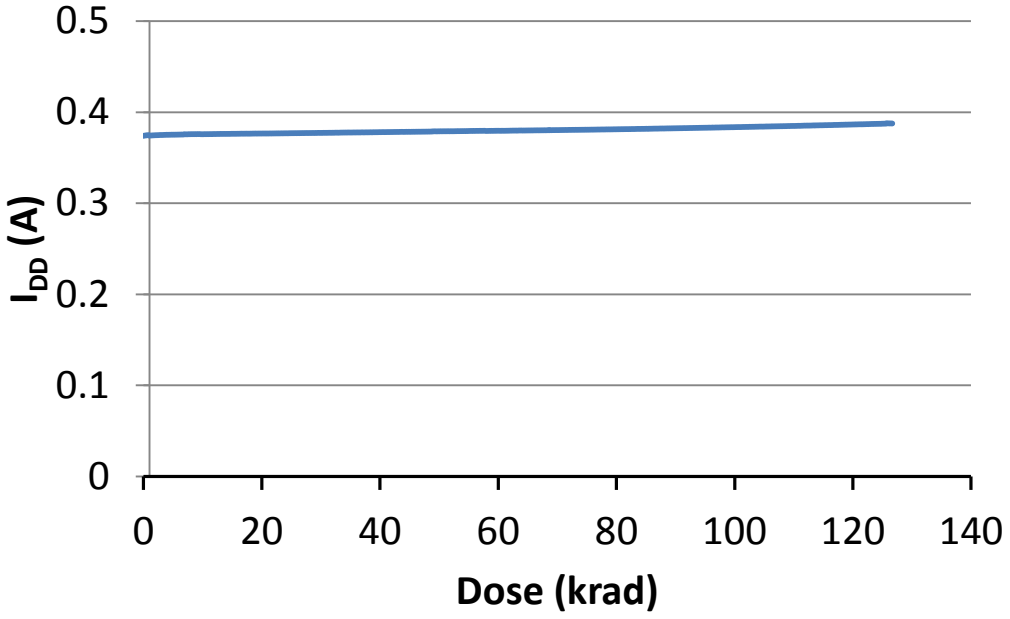

Fig. 6. DUT 1786 core power supply current (I_{DD}) versus TID

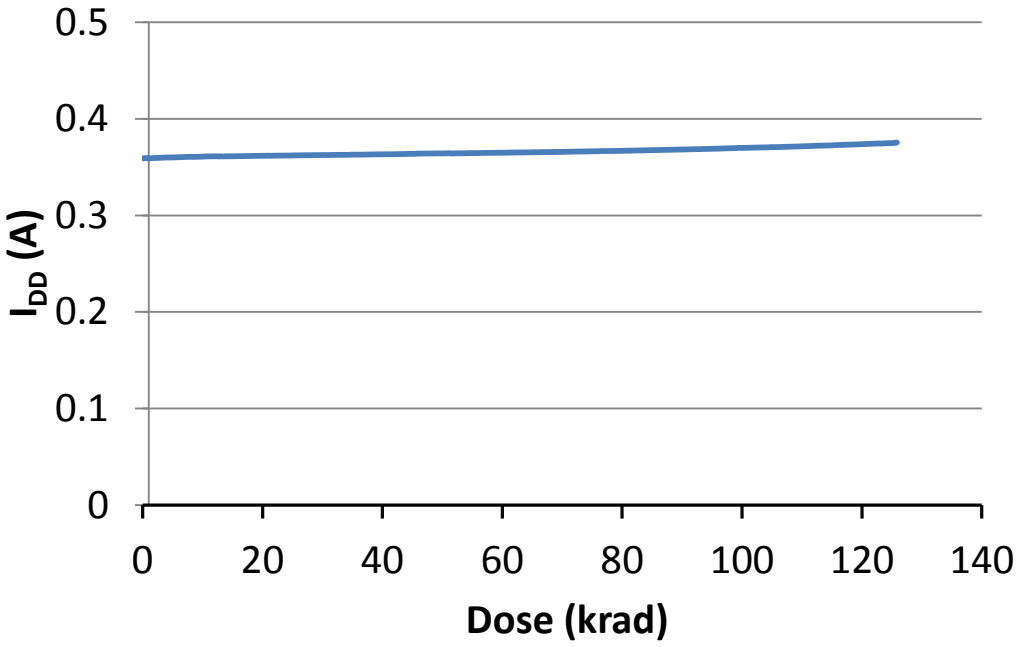

Fig. 7. DUT 1793 core power supply current (I_{DD}) versus TID

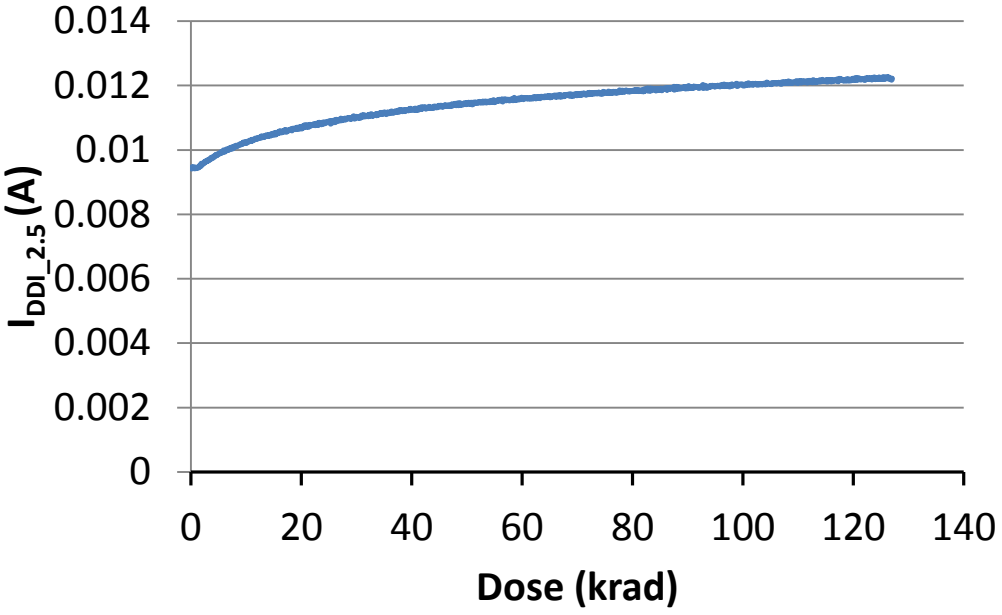

Fig. 8. DUT 1658 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

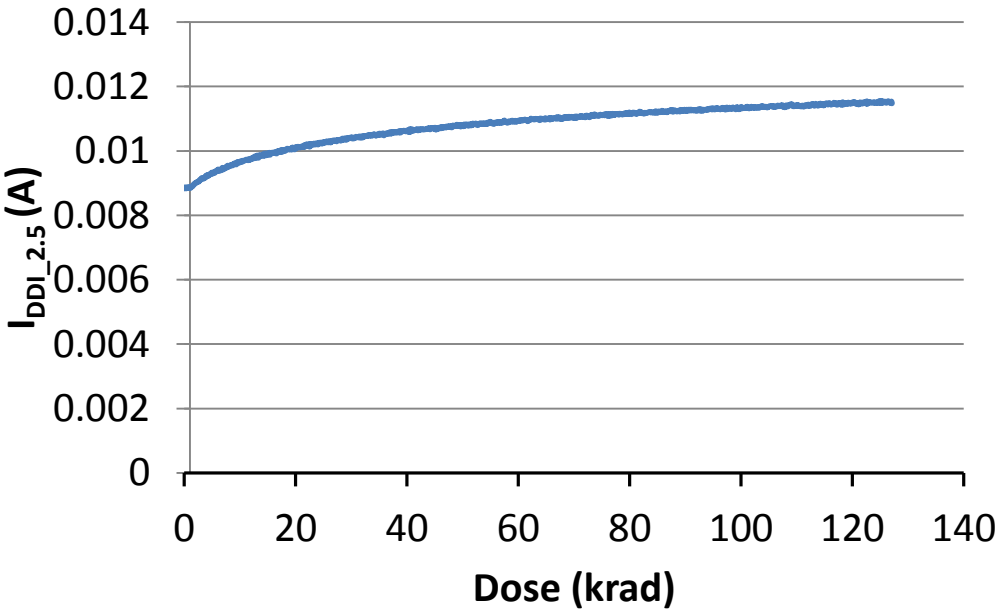

Fig. 9. DUT 1690 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

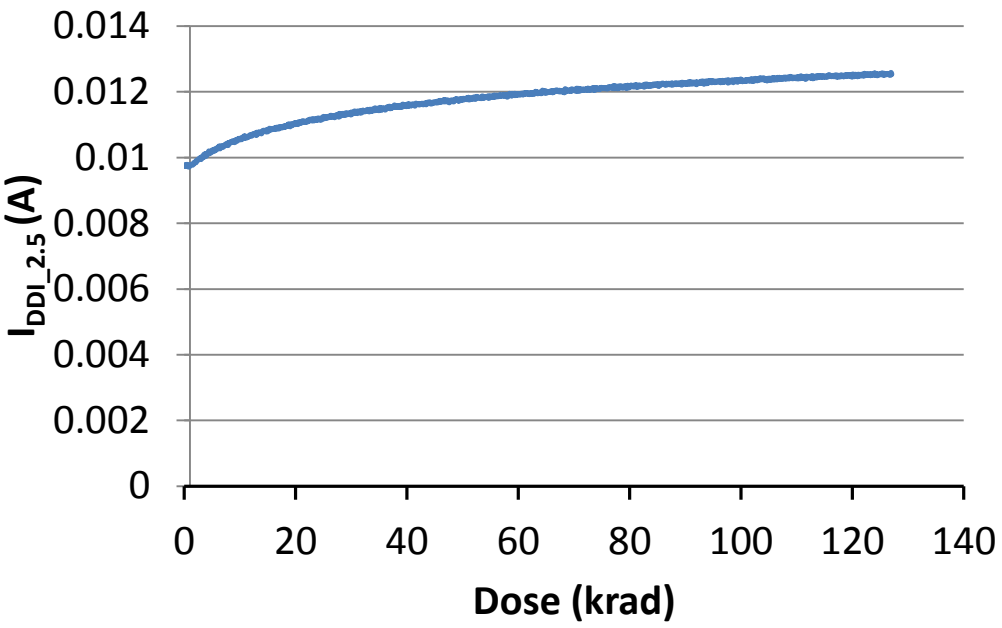

Fig. 10. DUT 1703 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

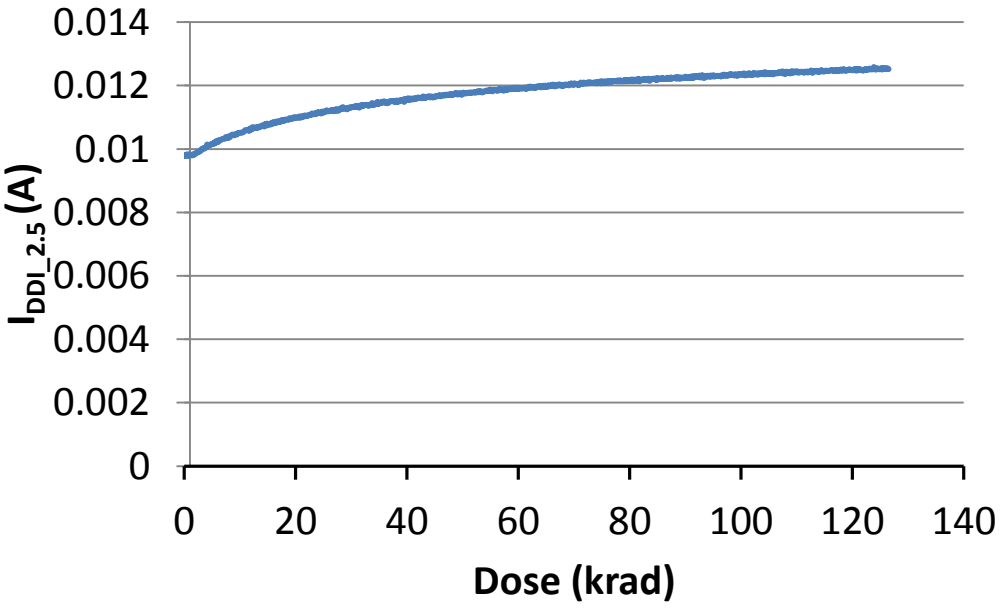

Fig. 11. DUT 1744 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

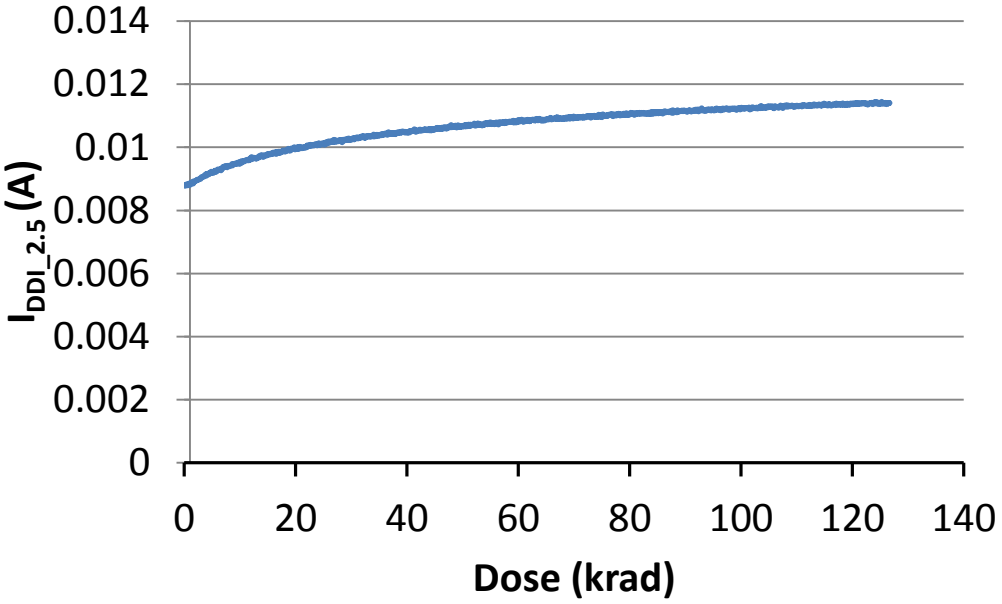

Fig. 12. DUT 1786 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

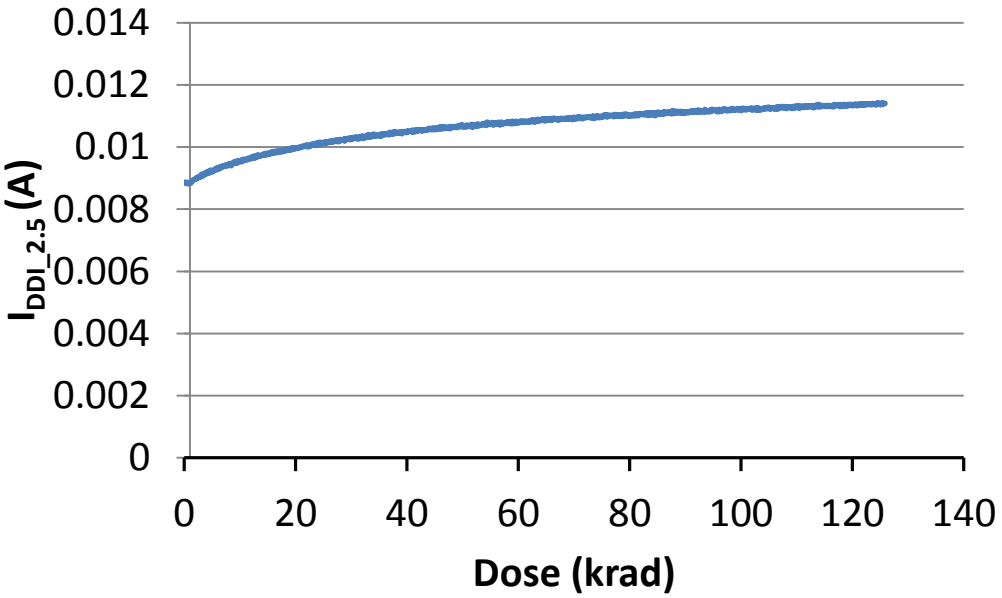

Fig. 13. DUT 1793 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

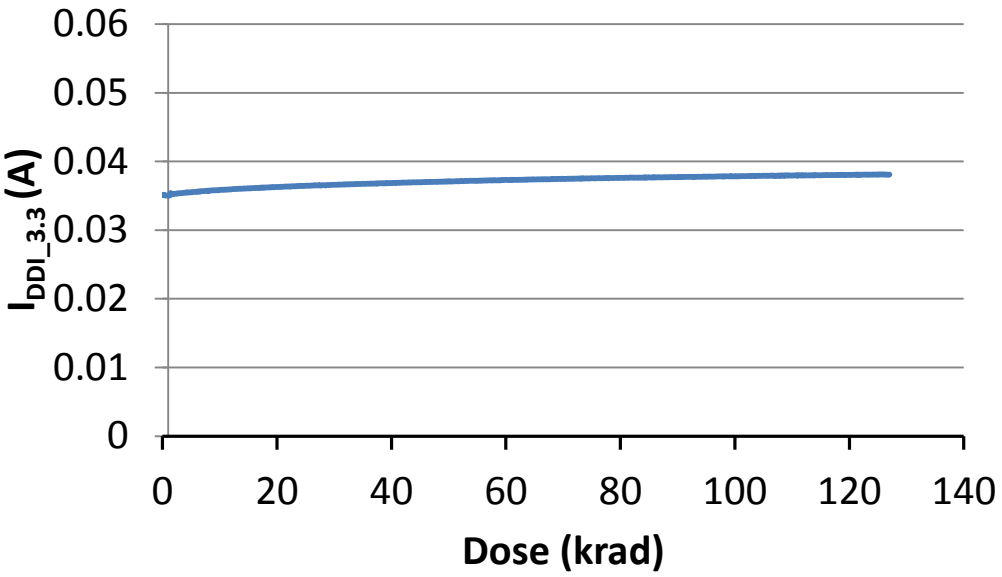

Fig. 14. DUT 1658 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

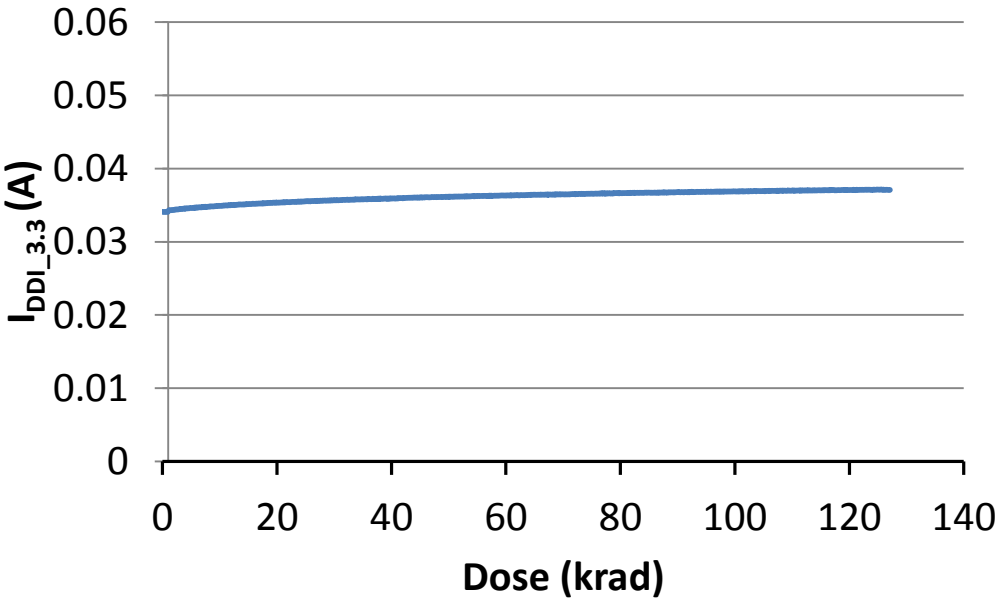

Fig. 15. DUT 1690 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

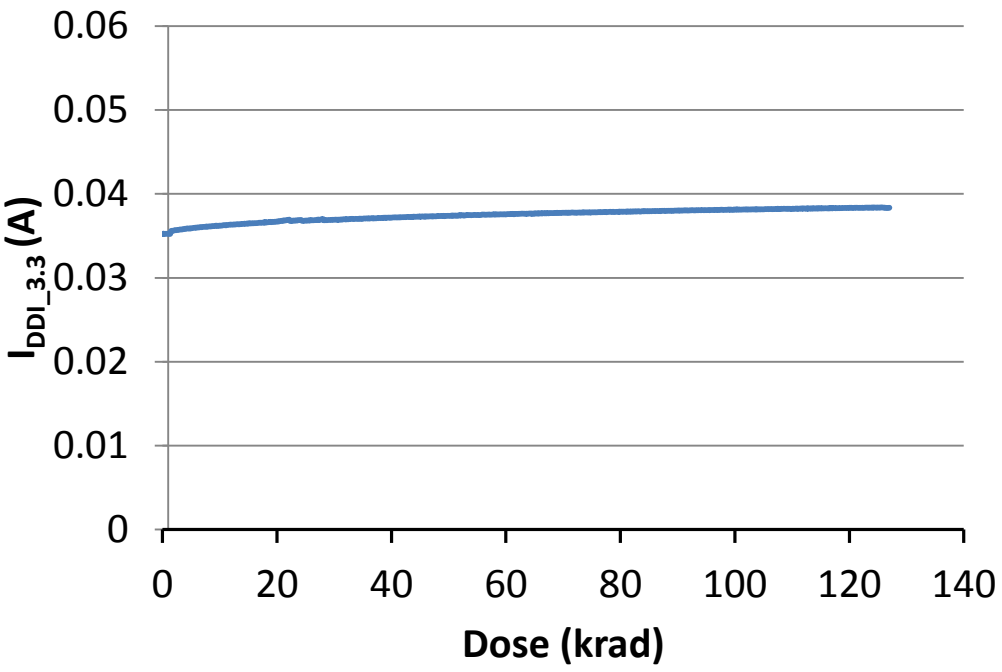

Fig. 16. DUT 1703 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

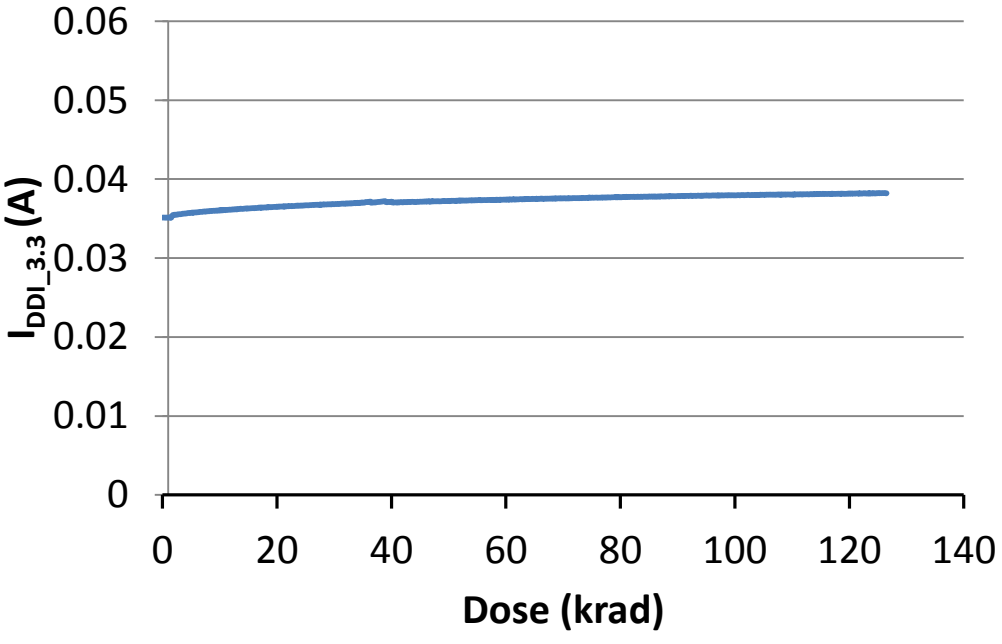

Fig. 17. DUT 1744 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

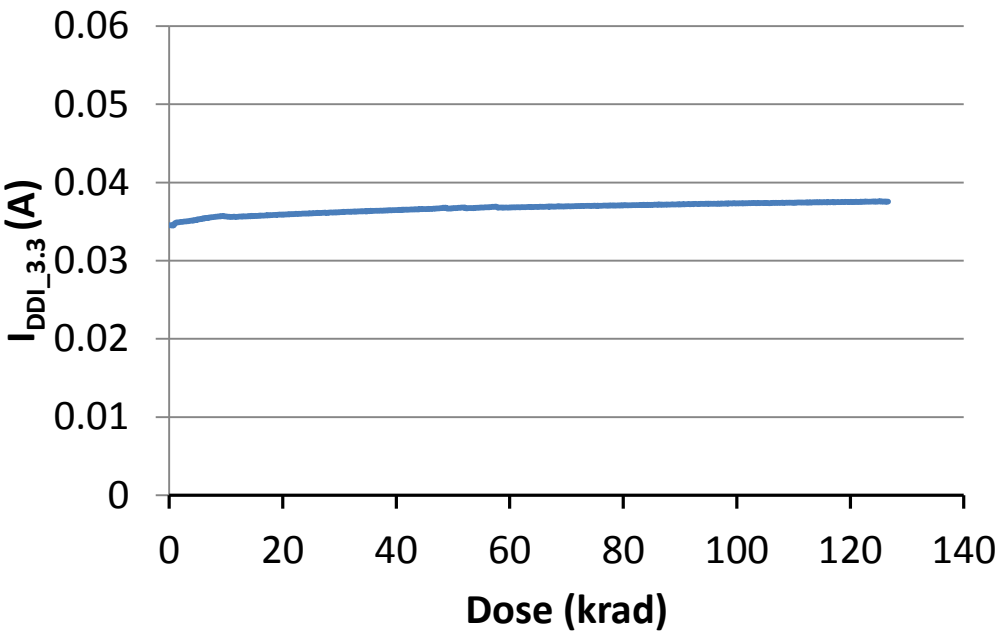

Fig. 18. DUT 1786 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

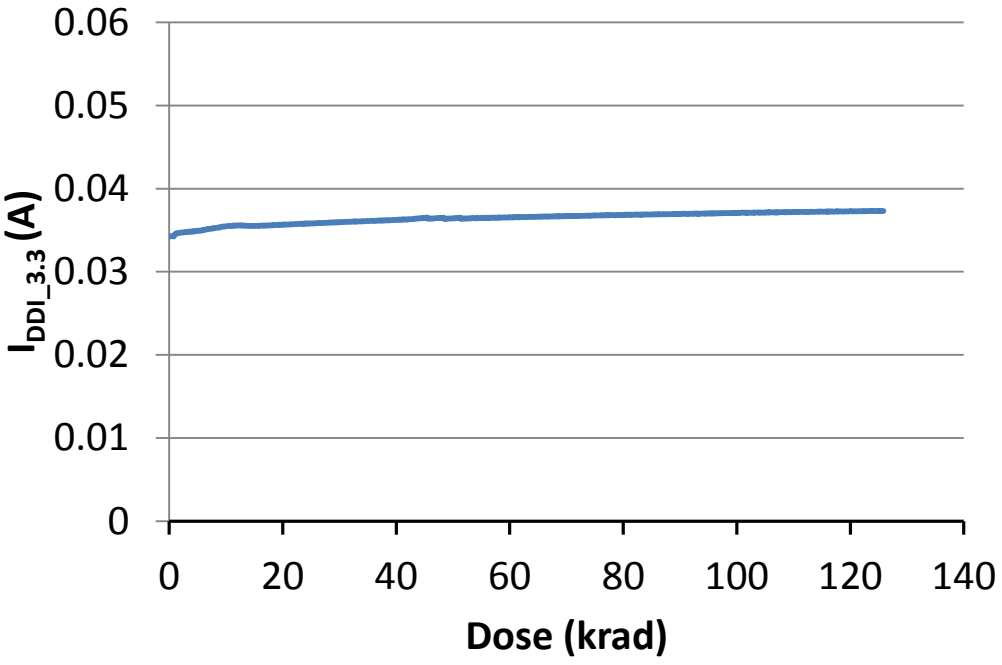

Fig. 19. DUT 1793 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

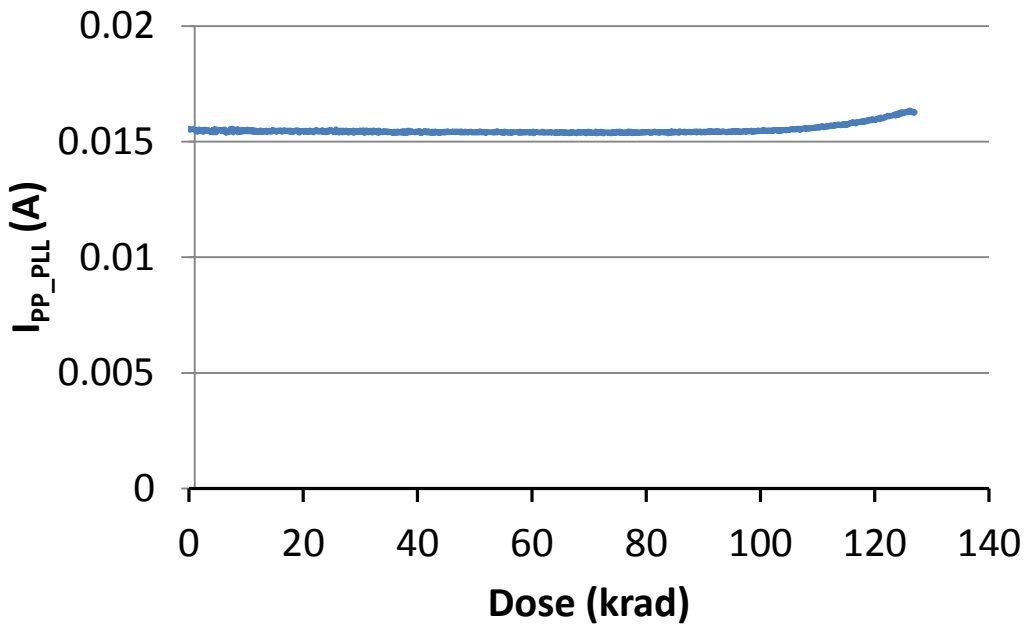

Fig. 20. DUT 1658 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

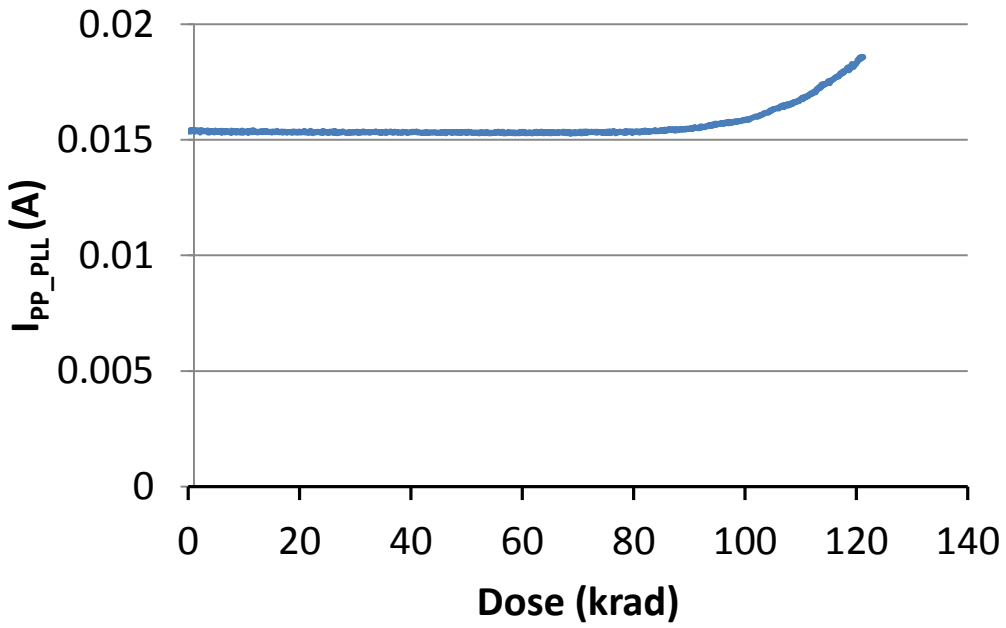

Fig. 21. DUT 1690 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

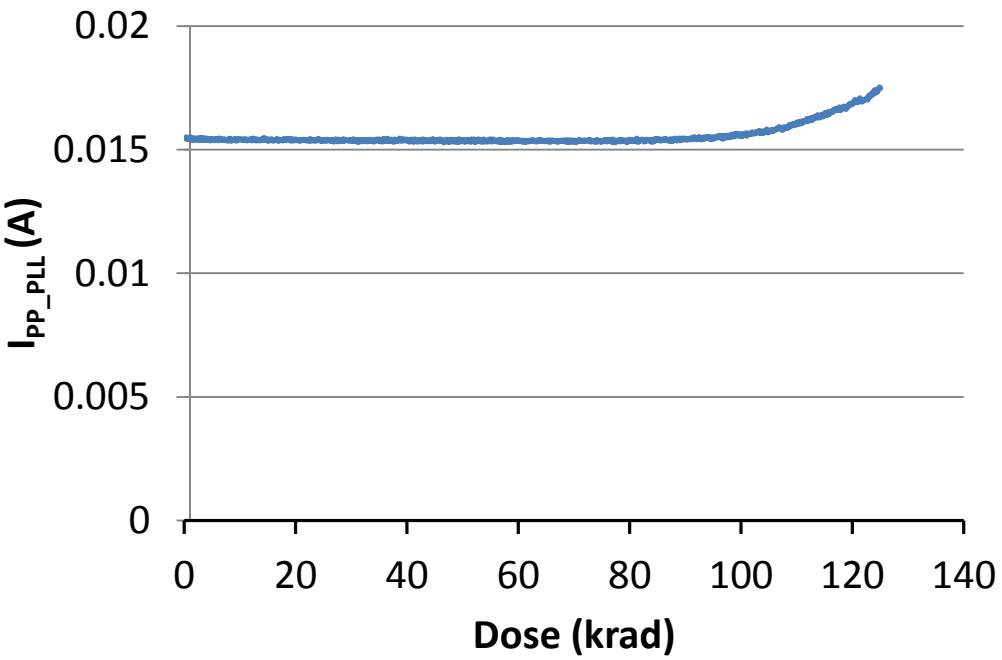

Fig. 22. DUT 1703 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

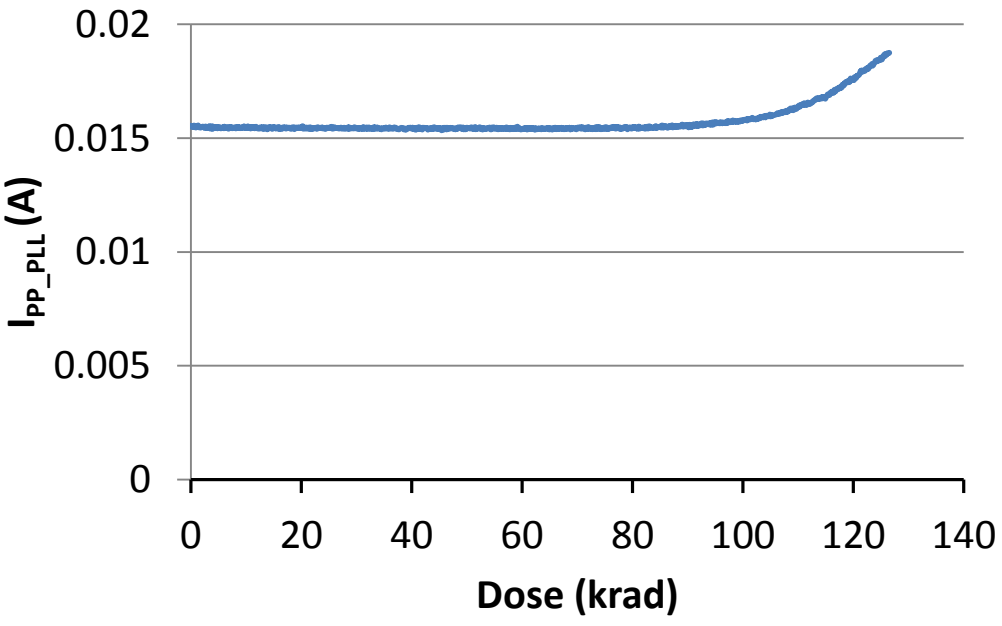

Fig. 23. DUT 1744 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

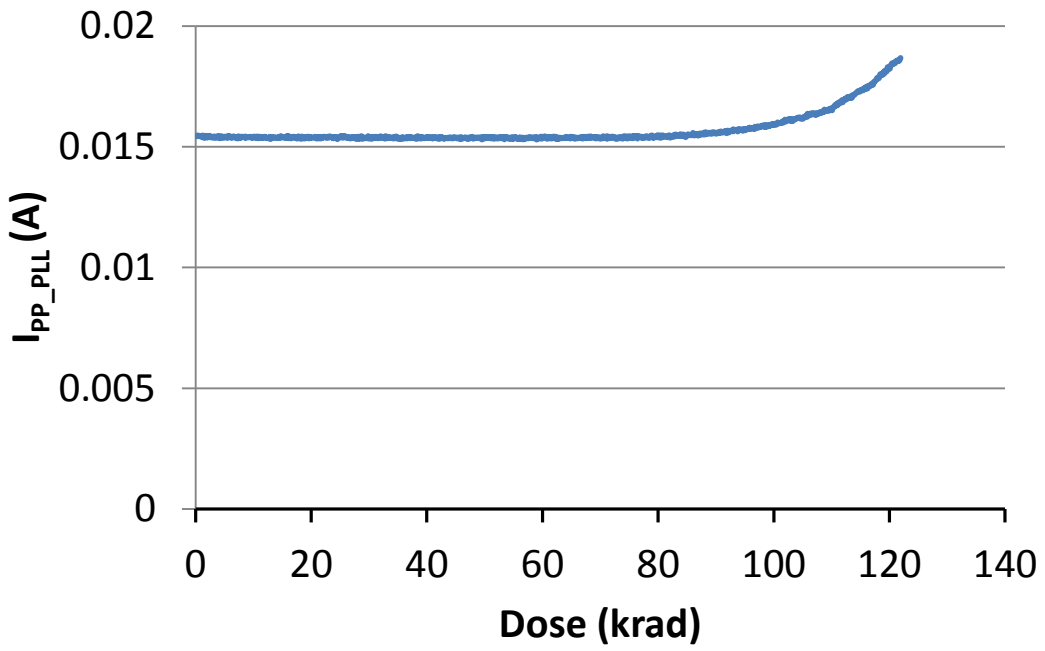

Fig. 24. DUT 1786 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

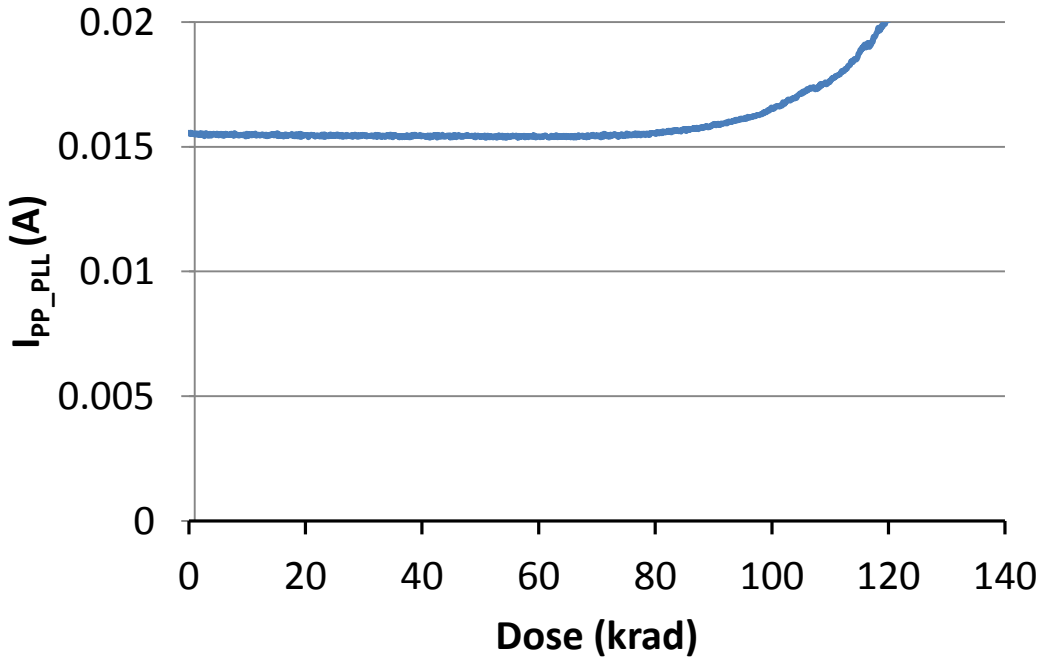

Fig. 25. DUT 1793 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

C. Single-Ended Input Logic Threshold (VIL/VIH)

The input switching threshold, or trip point, is defined as the applied input voltage at which the output of the design starts to switch. VIH is the input trip point when the input is going high to low and VIL is the input trip point when the input is going low to high. The input logic threshold (VIL/VIH) is measured on all single-ended inputs as well as all differential input and recorded as pass or fail. All I/Os are tested at their respective I/O standards and are compliant to the JEDEC specs. Refer to http://www.microsemi.com/document-portal/doc_view/135193-ds0131-rtg4-fpga-datasheet for more information.

The 3 DUTs tested passed with respect to the testing specification pre and post-irradiation. This pass/fail is determined as part of the ATE test program used to perform pre and post-irradiation electrical parametric measurements.

Table. 7. VIH Summary

DUT	Pre-irradiation	Post-irradiation
1658	Passed	Passed
1690	Passed	Passed
1703	Passed	Passed
1744	Passed	Passed
1786	Passed	Passed
1793	Passed	Passed

Table. 8. VIL Summary

DUT	Pre-irradiation	Post-irradiation
1658	Passed	Passed
1690	Passed	Passed
1703	Passed	Passed
1744	Passed	Passed
1786	Passed	Passed
1793	Passed	Passed

D. Output-Drive Voltage (VOL/VOH)

The pre-irradiation and post-irradiation output-drive voltages (VOL/VOH) are performed on all available IOs. The measurements performed pre and post irradiation are within the specification limits; in each case, the radiation-induced degradation is within 10%. For the purpose of this report, the measurements presented below in tables 9 through 32 are sampled on several pins used in the burn in design.

Table. 9. LVCMOS 25 VOH – DUT 1658

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.1311	2.1304	2.1994	2.1989	2.1697	2.1688	2.1495	2.1484	2.1151	2.1137	2.1004	2.0986
EPCSRST_N_0	B31	2.1311	2.1309	2.1997	2.1993	2.1696	2.1692	2.1491	2.1485	2.1144	2.1133	2.0996	2.0985
EPCSRST_N_1	B32	2.1325	2.1322	2.2019	2.2019	2.1731	2.1730	2.1520	2.1518	2.1198	2.1194	2.1058	2.1058
EPCSRST_N_2	B34	2.1314	2.1310	2.2005	2.1999	2.1710	2.1703	2.1491	2.1484	2.1159	2.1149	2.1016	2.1003
EPCSRST_N_3	B35	2.1322	2.1319	2.2019	2.2019	2.1731	2.1728	2.1520	2.1520	2.1202	2.1200	2.1069	2.1065
EPCSRST_N_4	B36	2.1310	2.1302	2.1999	2.1990	2.1702	2.1687	2.1482	2.1462	2.1143	2.1115	2.1001	2.0964
EPCSRST_N_5	B37	2.1321	2.1319	2.2017	2.2012	2.1723	2.1720	2.1511	2.1507	2.1183	2.1182	2.1048	2.1042
MONITOR	K23	2.1311	2.1311	2.2017	2.2019	2.1735	2.1737	2.1529	2.1532	2.1226	2.1234	2.1102	2.1106
PLL_MON	L20	2.1318	2.1305	2.2035	2.2029	2.1761	2.1761	2.1572	2.1624	2.1287	2.1246	2.1168	2.1139
TOGGLE_MON	L22	2.1319	2.1311	2.2033	2.2027	2.1758	2.1752	2.1558	2.1553	2.1268	2.1263	2.1149	2.1141

Table. 10. LVCMOS 25 VOH – DUT 1690

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.1310	2.1307	2.1996	2.1992	2.1698	2.1693	2.1495	2.1487	2.1152	2.1141	2.1005	2.0990
EPCSRST_N_0	B31	2.1316	2.1315	2.1999	2.1995	2.1699	2.1697	2.1494	2.1488	2.1145	2.1139	2.0995	2.0990
EPCSRST_N_1	B32	2.1330	2.1331	2.2022	2.2024	2.1732	2.1734	2.1521	2.1523	2.1195	2.1200	2.1057	2.1060
EPCSRST_N_2	B34	2.1322	2.1317	2.2007	2.2005	2.1714	2.1709	2.1495	2.1490	2.1160	2.1152	2.1017	2.1008
EPCSRST_N_3	B35	2.1326	2.1325	2.2024	2.2022	2.1736	2.1735	2.1527	2.1525	2.1208	2.1204	2.1073	2.1067
EPCSRST_N_4	B36	2.1318	2.1316	2.2002	2.2000	2.1705	2.1701	2.1484	2.1481	2.1145	2.1140	2.1002	2.0989
EPCSRST_N_5	B37	2.1322	2.1317	2.2017	2.2015	2.1725	2.1723	2.1514	2.1509	2.1187	2.1181	2.1050	2.1041
MONITOR	K23	2.1316	2.1320	2.2021	2.2023	2.1742	2.1745	2.1539	2.1540	2.1237	2.1242	2.1113	2.1113
PLL_MON	L20	2.1324	2.1320	2.2038	2.2015	2.1767	2.1755	2.1581	2.1588	2.1295	2.1393	2.1175	2.1223
TOGGLE_MON	L22	2.1330	2.1321	2.2041	2.2036	2.1768	2.1761	2.1565	2.1560	2.1276	2.1269	2.1158	2.1149

Table. 11. LVCMOS 25 VOH – DUT 1703

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.1312	2.1309	2.2008	2.2003	2.1718	2.1708	2.1522	2.1509	2.1195	2.1179	2.1055	2.1037
EPCSRST_N_0	B31	2.1313	2.1307	2.2004	2.1998	2.1713	2.1704	2.1513	2.1502	2.1179	2.1162	2.1035	2.1018
EPCSRST_N_1	B32	2.1326	2.1326	2.2030	2.2030	2.1748	2.1748	2.1543	2.1544	2.1232	2.1235	2.1100	2.1100
EPCSRST_N_2	B34	2.1311	2.1310	2.2013	2.2013	2.1723	2.1723	2.1515	2.1511	2.1192	2.1195	2.1057	2.1054
EPCSRST_N_3	B35	2.1324	2.1324	2.2028	2.2029	2.1749	2.1748	2.1546	2.1545	2.1240	2.1241	2.1114	2.1107
EPCSRST_N_4	B36	2.1312	2.1308	2.2003	2.2003	2.1712	2.1706	2.1494	2.1489	2.1166	2.1157	2.1024	2.1014
EPCSRST_N_5	B37	2.1323	2.1320	2.2019	2.2017	2.1735	2.1729	2.1524	2.1520	2.1208	2.1201	2.1077	2.1065
MONITOR	K23	2.1304	2.1301	2.2011	2.2012	2.1732	2.1732	2.1526	2.1529	2.1224	2.1227	2.1101	2.1101
PLL_MON	L20	2.1309	2.1282	2.2030	2.2027	2.1757	2.1770	2.1570	2.1574	2.1285	2.1207	2.1164	2.1089
TOGGLE_MON	L22	2.1312	2.1307	2.2027	2.2022	2.1748	2.1745	2.1549	2.1543	2.1259	2.1249	2.1138	2.1128

Table. 12. LVCMOS 25 VOH – DUT 1744

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.1314	2.1309	2.2010	2.2006	2.1722	2.1712	2.1525	2.1515	2.1195	2.1183	2.1054	2.1037
EPCSRST_N_0	B31	2.1323	2.1321	2.2011	2.2008	2.1720	2.1714	2.1523	2.1515	2.1187	2.1175	2.1043	2.1030
EPCSRST_N_1	B32	2.1333	2.1332	2.2036	2.2033	2.1751	2.1751	2.1547	2.1547	2.1237	2.1240	2.1104	2.1102
EPCSRST_N_2	B34	2.1321	2.1316	2.2019	2.2016	2.1731	2.1723	2.1519	2.1515	2.1197	2.1190	2.1062	2.1052
EPCSRST_N_3	B35	2.1329	2.1327	2.2032	2.2031	2.1753	2.1750	2.1551	2.1547	2.1245	2.1241	2.1116	2.1110
EPCSRST_N_4	B36	2.1311	2.1308	2.2005	2.2000	2.1707	2.1701	2.1491	2.1482	2.1156	2.1147	2.1012	2.0999
EPCSRST_N_5	B37	2.1324	2.1323	2.2019	2.2018	2.1730	2.1726	2.1517	2.1516	2.1196	2.1195	2.1060	2.1054
MONITOR	K23	2.1315	2.1315	2.2022	2.2024	2.1746	2.1744	2.1544	2.1543	2.1246	2.1247	2.1122	2.1116
PLL_MON	L20	2.1320	2.1305	2.2037	2.2028	2.1766	2.1792	2.1578	2.1581	2.1293	2.1277	2.1174	2.1218
TOGGLE_MON	L22	2.1321	2.1315	2.2035	2.2032	2.1759	2.1757	2.1560	2.1556	2.1271	2.1265	2.1152	2.1143

Table. 13. LVCMOS 25 VOH – DUT 1786

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.1312	2.1311	2.2011	2.2005	2.1720	2.1715	2.1522	2.1518	2.1193	2.1188	2.1055	2.1044
EPCSRST_N_0	B31	2.1311	2.1312	2.2005	2.2004	2.1714	2.1710	2.1515	2.1513	2.1182	2.1178	2.1037	2.1031
EPCSRST_N_1	B32	2.1334	2.1333	2.2031	2.2027	2.1747	2.1743	2.1544	2.1539	2.1229	2.1225	2.1101	2.1089
EPCSRST_N_2	B34	2.1314	2.1311	2.2018	2.2011	2.1727	2.1721	2.1518	2.1510	2.1197	2.1186	2.1063	2.1046
EPCSRST_N_3	B35	2.1324	2.1322	2.2033	2.2029	2.1752	2.1746	2.1548	2.1544	2.1246	2.1238	2.1116	2.1104
EPCSRST_N_4	B36	2.1313	2.1310	2.2007	2.2000	2.1710	2.1703	2.1493	2.1487	2.1160	2.1150	2.1015	2.1004
EPCSRST_N_5	B37	2.1317	2.1317	2.2018	2.2016	2.1728	2.1726	2.1520	2.1518	2.1198	2.1197	2.1065	2.1059
MONITOR	K23	2.1315	2.1315	2.2023	2.2025	2.1742	2.1743	2.1536	2.1539	2.1236	2.1241	2.1113	2.1114
PLL_MON	L20	2.1321	2.1317	2.2036	2.2033	2.1765	2.1762	2.1578	2.1548	2.1293	2.1267	2.1173	2.1144
TOGGLE_MON	L22	2.1317	2.1311	2.2033	2.2026	2.1757	2.1754	2.1555	2.1550	2.1266	2.1261	2.1144	2.1139

Table. 14. LVCMOS 25 VOH – DUT 1793

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.1323	2.1312	2.2014	2.2005	2.1723	2.1711	2.1528	2.1510	2.1199	2.1179	2.1059	2.1034
EPCSRST_N_0	B31	2.1325	2.1317	2.2013	2.2003	2.1721	2.1710	2.1524	2.1507	2.1189	2.1168	2.1046	2.1022
EPCSRST_N_1	B32	2.1341	2.1333	2.2038	2.2031	2.1755	2.1746	2.1550	2.1540	2.1240	2.1228	2.1111	2.1093
EPCSRST_N_2	B34	2.1329	2.1320	2.2022	2.2012	2.1729	2.1719	2.1521	2.1509	2.1198	2.1183	2.1063	2.1044
EPCSRST_N_3	B35	2.1333	2.1324	2.2037	2.2026	2.1756	2.1744	2.1554	2.1542	2.1250	2.1231	2.1123	2.1095
EPCSRST_N_4	B36	2.1318	2.1310	2.2004	2.1997	2.1708	2.1696	2.1492	2.1477	2.1155	2.1138	2.1012	2.0988
EPCSRST_N_5	B37	2.1325	2.1317	2.2020	2.2015	2.1731	2.1722	2.1523	2.1514	2.1201	2.1192	2.1065	2.1050
MONITOR	K23	2.1315	2.1309	2.2019	2.2015	2.1744	2.1739	2.1539	2.1535	2.1239	2.1236	2.1117	2.1110
PLL_MON	L20	2.1323	2.1309	2.2039	2.2031	2.1768	2.1760	2.1584	2.1571	2.1300	2.1291	2.1183	2.1139
TOGGLE_MON	L22	2.1323	2.1314	2.2036	2.2027	2.1761	2.1750	2.1562	2.1548	2.1272	2.1258	2.1155	2.1136

Table. 15. LVCMOS 25 VOL – DUT 1658

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	236.2905	235.6139	169.8435	169.5573	198.8182	198.6071	221.6963	221.5478	254.6558	254.8716	268.7975	269.1639
EPCSRST_N_0	B31	235.8003	235.3625	169.7052	169.4567	198.8936	198.6071	222.0357	221.9124	255.6489	255.4749	270.0294	270.0313
EPCSRST_N_1	B32	235.1684	234.3895	167.6683	167.3534	195.8258	195.3353	216.3884	215.9609	248.2240	247.8093	261.7692	261.5052
EPCSRST_N_2	B34	236.5744	236.1470	169.4635	169.3494	198.0603	198.0343	219.1376	219.2625	251.9147	252.2156	265.8742	266.4639
EPCSRST_N_3	B35	236.1225	235.2934	168.1077	167.7049	196.3154	195.5487	216.5641	216.1366	248.0985	247.5708	261.2797	260.8650
EPCSRST_N_4	B36	237.3276	236.9128	170.2920	170.5671	199.1901	199.9299	220.5185	221.6602	253.6722	255.9440	268.0962	270.7823
EPCSRST_N_5	B37	236.2480	235.3687	168.6349	168.1317	196.9556	196.4149	217.5810	217.1283	249.4543	249.1902	263.1250	262.8987
MONITOR	K23	234.2394	233.5049	166.0982	165.4523	193.3773	192.5929	212.5518	211.8301	242.4948	241.3455	254.9343	253.6970
PLL_MON	L20	233.8952	231.7197	164.8405	164.6859	191.2105	191.0947	210.7430	205.7886	238.6841	237.9794	250.3482	242.6553
TOGGLE_MON	L22	233.9676	233.3196	165.2158	164.6808	191.8006	191.3911	210.5819	209.8085	239.2620	238.6140	251.3563	250.6331

Table. 16. LVCMOS 25 VOL – DUT 1690

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	235.4106	234.4198	169.0893	168.6145	198.0766	197.5764	220.8164	220.4919	253.8513	253.7277	268.1313	268.1206
EPCSRST_N_0	B31	235.0083	234.2815	169.2401	168.7905	198.4914	197.9032	221.5706	220.8565	255.0204	254.5196	269.6146	269.0634
EPCSRST_N_1	B32	234.2269	233.2095	167.1913	166.4747	195.2609	194.4566	215.8486	215.0695	247.7470	246.8803	261.3299	260.6265
EPCSRST_N_2	B34	235.2688	234.4272	168.8232	168.4707	197.6084	197.2184	218.4472	218.3335	251.2620	251.2992	265.3093	265.6981
EPCSRST_N_3	B35	235.1935	234.0882	167.4674	166.9140	195.2985	194.7077	215.6854	215.2327	247.1068	246.8050	260.4260	260.3754
EPCSRST_N_4	B36	235.8965	235.0423	169.6769	169.2616	198.7633	198.1975	219.9159	219.6265	253.3333	253.2199	267.5062	267.7067
EPCSRST_N_5	B37	235.5073	234.3518	168.1579	167.5668	196.3028	195.7621	217.0161	216.5509	249.0777	248.8010	262.7861	262.5974
MONITOR	K23	233.1965	232.2358	165.3443	164.7110	192.4349	191.4746	211.2953	210.5736	241.0749	240.0262	253.3888	252.3525
PLL_MON	L20	232.7515	230.1862	163.9858	165.8675	190.3936	186.4314	209.6494	205.5749	237.5906	227.7729	249.1290	254.6216
TOGGLE_MON	L22	232.5499	231.5507	164.0239	163.5140	190.6088	189.9483	209.0639	208.3156	237.6937	237.0081	249.6626	248.9519

Table. 17. LVCMOS 25 VOL – DUT 1703

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	236.6299	235.9282	168.8505	168.6271	197.1464	197.0358	219.3959	219.3355	250.8847	251.0376	264.2344	264.5381
EPCSRST_N_0	B31	236.8185	236.2047	169.2527	169.2179	197.8000	197.8655	220.4141	220.6805	252.6697	253.2249	266.5725	267.1653
EPCSRST_N_1	B32	235.6580	234.6782	167.2038	166.6253	194.5579	193.9670	214.5054	213.9272	245.1359	244.3696	258.0409	257.3877
EPCSRST_N_2	B34	237.3401	236.5738	169.1120	168.6464	197.2192	196.7037	217.7567	217.1409	249.1530	248.6504	262.4597	261.9948
EPCSRST_N_3	B35	236.6246	235.5570	167.6306	167.0270	195.2106	194.2934	215.0075	214.3038	245.2237	244.4073	257.5764	257.0612
EPCSRST_N_4	B36	238.1185	237.4024	170.4552	170.0273	199.1273	198.7625	219.9912	219.9152	252.3039	252.5169	266.1881	266.5392
EPCSRST_N_5	B37	237.1267	236.0717	168.4717	168.0313	196.6166	196.1011	216.9407	216.5885	248.0357	247.9097	261.2545	261.1663
MONITOR	K23	235.4205	234.6232	166.8647	166.3445	194.1940	193.4976	213.4817	212.7096	243.3869	242.3004	255.9647	254.7650
PLL_MON	L20	235.0265	232.0214	165.5318	166.5840	191.9647	192.2637	211.6605	207.6363	239.5137	232.8259	251.2406	257.3366
TOGGLE_MON	L22	235.1093	234.2731	166.0187	165.6217	192.9047	192.4449	211.7613	211.0631	240.7424	240.1948	252.7489	252.3142

Table. 18. LVCMOS 25 VOL – DUT 1744

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	235.9888	235.3374	168.2471	167.9734	196.6059	196.3068	218.8177	218.6692	250.4322	250.5474	263.9705	264.0604
EPCSRST_N_0	B31	235.3477	235.1111	168.3477	168.2626	196.8447	196.7844	219.3205	219.3606	251.6138	251.8673	265.4663	265.8831
EPCSRST_N_1	B32	234.8420	234.2765	166.6640	166.1357	194.0683	193.5653	214.0283	213.5757	244.7090	244.1813	257.5387	257.1743
EPCSRST_N_2	B34	236.3735	235.8708	168.5847	168.3200	196.4660	196.4275	216.9031	217.0028	248.3747	248.6378	261.7567	262.2082
EPCSRST_N_3	B35	235.8337	235.0297	167.2164	166.6881	194.3570	193.9419	214.1790	213.8895	244.1944	243.9428	256.8985	256.7223
EPCSRST_N_4	B36	237.7293	236.9253	170.2041	169.9646	199.0018	198.7876	219.9285	220.1286	252.9316	253.2701	267.0668	267.6063
EPCSRST_N_5	B37	236.4740	235.5193	168.4090	167.9183	196.6418	196.0634	217.1541	216.6890	248.8015	248.4872	262.1458	262.0827
MONITOR	K23	233.9881	233.4798	165.6584	165.4021	192.5983	192.3668	211.6597	211.4280	241.0874	240.8052	253.3134	253.1818
PLL_MON	L20	233.8198	233.0521	164.5515	164.1580	190.9466	191.2330	210.4036	205.1601	238.2190	238.2936	249.8329	252.8618
TOGGLE_MON	L22	233.9174	233.2193	164.9398	164.6557	191.6501	191.2029	210.3310	209.8085	238.9609	238.5513	251.0301	250.6331

Table. 19. LVCMOS 25 VOL – DUT 1786

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	235.8631	235.0986	168.2345	167.7849	196.4424	196.0051	218.6291	218.3801	250.1556	250.0320	263.6939	263.5073
EPCSRST_N_0	B31	235.8883	235.2620	168.8002	168.4260	197.3098	196.8096	219.7102	219.3732	251.8401	251.4524	265.6298	265.2420
EPCSRST_N_1	B32	234.4654	233.7618	166.8021	166.4496	194.1059	193.9670	214.1037	214.2034	244.6086	244.9596	257.6391	258.2413
EPCSRST_N_2	B34	236.2857	235.7578	168.3211	168.2071	196.3781	196.5028	216.7775	217.0405	248.1613	248.8889	261.4178	262.5221
EPCSRST_N_3	B35	236.1601	235.2682	167.1034	166.6127	194.4825	193.9921	214.0158	213.8644	244.1567	244.1436	256.7855	256.8730
EPCSRST_N_4	B36	237.3653	236.5613	169.8149	169.5377	198.5875	198.3231	219.6648	219.6391	252.5299	252.7554	266.5270	267.0539
EPCSRST_N_5	B37	236.7878	235.7202	168.3964	167.8681	196.4534	195.8249	216.9156	216.4379	248.5128	247.9599	261.7567	261.4174
MONITOR	K23	234.0258	233.3415	165.5830	165.1633	192.8244	192.1406	211.8859	211.4531	241.4518	240.7801	253.8663	253.0185
PLL_MON	L20	233.5307	233.2784	164.5389	164.2711	190.8712	190.9062	210.1773	211.2187	238.1310	233.0395	249.6192	242.5799
TOGGLE_MON	L22	234.4945	233.7462	165.4792	164.9568	192.0390	191.5165	210.7450	210.0971	239.5882	238.9277	251.7327	250.9091

Table. 20. LVCMOS 25 VOL – DUT 1793

		2mA		4mA		6mA		8mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	235.3603	235.3500	167.9831	168.2500	196.1910	196.5079	218.4406	218.9961	249.8665	250.9496	263.4048	264.6135
EPCSRST_N_0	B31	235.1592	235.2620	168.2848	168.7654	196.8573	197.4255	219.3708	220.1651	251.3875	252.7975	265.2401	266.7504
EPCSRST_N_1	B32	233.9758	233.8120	166.2121	166.3240	193.6540	193.9544	213.4760	213.9899	244.1065	244.7336	256.9612	257.9023
EPCSRST_N_2	B34	235.4446	235.3436	168.1955	168.4958	196.2651	196.6660	216.7022	217.2790	248.3747	249.3031	261.6437	262.9991
EPCSRST_N_3	B35	235.2939	235.0548	166.6766	166.9140	193.9553	194.3687	213.6392	214.3038	243.6420	245.0475	256.3838	258.0781
EPCSRST_N_4	B36	236.6497	236.5864	169.9028	170.2156	198.7884	199.3274	219.9661	220.8442	253.0069	254.3497	267.1547	268.8114
EPCSRST_N_5	B37	236.1852	235.8081	168.3085	168.1317	196.3028	196.3773	216.7650	217.0907	248.2868	248.9516	261.8069	262.5095
MONITOR	K23	233.9504	233.9070	165.7087	165.7790	192.7616	192.6935	211.8984	212.0186	241.4895	241.5842	253.7532	253.8352
PLL_MON	L20	233.6062	232.8007	164.3001	164.6482	190.4313	190.3154	209.9385	212.5385	237.5529	239.1484	249.1793	248.9778
TOGGLE_MON	L22	233.4657	233.3196	164.7767	164.9693	191.4745	191.6671	210.1554	210.4107	238.7727	239.2664	250.8670	251.3607

Table. 21. LVTTL VOH – DUT 1658

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.9186	2.9182	2.9081	2.9074	2.8877	2.8864	2.8672	2.8658	2.8478	2.8460
EPCSRST_N_0	B31	2.9184	2.9183	2.9081	2.9079	2.8874	2.8866	2.8662	2.8654	2.8464	2.8454
EPCSRST_N_1	B32	2.9196	2.9196	2.9105	2.9104	2.8918	2.8917	2.8732	2.8728	2.8540	2.8537
EPCSRST_N_2	B34	2.9186	2.9183	2.9087	2.9085	2.8889	2.8882	2.8689	2.8680	2.8491	2.8479
EPCSRST_N_3	B35	2.9194	2.9192	2.9103	2.9100	2.8919	2.8916	2.8734	2.8733	2.8551	2.8547
EPCSRST_N_4	B36	2.9183	2.9178	2.9082	2.9071	2.8879	2.8861	2.8676	2.8646	2.8472	2.8431
EPCSRST_N_5	B37	2.9194	2.9191	2.9097	2.9094	2.8909	2.8903	2.8717	2.8713	2.8528	2.8520
MONITOR	K23	2.9191	2.9191	2.9105	2.9104	2.8933	2.8937	2.8766	2.8770	2.8597	2.8604
PLL_MON	L20	2.9199	2.9197	2.9121	2.9121	2.8969	2.8964	2.8819	2.8809	2.8672	2.8658
TOGGLE_MON	L22	2.9198	2.9190	2.9119	2.9116	2.8964	2.8958	2.8810	2.8805	2.8649	2.8643

Table. 22. LVTTL VOH – DUT 1690

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.9188	2.9183	2.9085	2.9080	2.8881	2.8871	2.8675	2.8665	2.8478	2.8463
EPCSRST_N_0	B31	2.9189	2.9189	2.9085	2.9084	2.8877	2.8871	2.8666	2.8664	2.8464	2.8459
EPCSRST_N_1	B32	2.9204	2.9202	2.9109	2.9110	2.8921	2.8924	2.8732	2.8733	2.8541	2.8542
EPCSRST_N_2	B34	2.9196	2.9194	2.9095	2.9093	2.8894	2.8889	2.8696	2.8688	2.8495	2.8483
EPCSRST_N_3	B35	2.9199	2.9197	2.9111	2.9108	2.8926	2.8923	2.8744	2.8738	2.8558	2.8549
EPCSRST_N_4	B36	2.9191	2.9190	2.9090	2.9086	2.8885	2.8879	2.8678	2.8672	2.8474	2.8464
EPCSRST_N_5	B37	2.9195	2.9194	2.9101	2.9101	2.8913	2.8908	2.8722	2.8716	2.8530	2.8520
MONITOR	K23	2.9197	2.9198	2.9115	2.9115	2.8944	2.8948	2.8778	2.8785	2.8610	2.8614
PLL_MON	L20	2.9201	2.9188	2.9131	2.9128	2.8977	2.8976	2.8826	2.8819	2.8683	2.8672
TOGGLE_MON	L22	2.9209	2.9204	2.9131	2.9127	2.8977	2.8971	2.8819	2.8815	2.8663	2.8654

Table. 23. LVTTL VOH – DUT 1703

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.9189	2.9183	2.9091	2.9082	2.8904	2.8893	2.8715	2.8701	2.8534	2.8516
EPCSRST_N_0	B31	2.9186	2.9182	2.9086	2.9079	2.8895	2.8882	2.8699	2.8683	2.8511	2.8493
EPCSRST_N_1	B32	2.9199	2.9197	2.9115	2.9115	2.8939	2.8941	2.8764	2.8763	2.8588	2.8588
EPCSRST_N_2	B34	2.9185	2.9181	2.9092	2.9091	2.8910	2.8909	2.8724	2.8722	2.8537	2.8535
EPCSRST_N_3	B35	2.9196	2.9195	2.9113	2.9112	2.8943	2.8940	2.8773	2.8768	2.8599	2.8599
EPCSRST_N_4	B36	2.9182	2.9181	2.9084	2.9079	2.8890	2.8881	2.8697	2.8685	2.8500	2.8487
EPCSRST_N_5	B37	2.9195	2.9191	2.9101	2.9100	2.8922	2.8916	2.8740	2.8730	2.8557	2.8548
MONITOR	K23	2.9181	2.9182	2.9095	2.9092	2.8928	2.8929	2.8761	2.8766	2.8590	2.8596
PLL_MON	L20	2.9187	2.9196	2.9117	2.9100	2.8967	2.8940	2.8815	2.8805	2.8669	2.8700
TOGGLE_MON	L22	2.9190	2.9184	2.9112	2.9107	2.8952	2.8949	2.8797	2.8790	2.8636	2.8626

Table. 24. LVTTL VOH – DUT 1744

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.9191	2.9186	2.9096	2.9093	2.8907	2.8899	2.8717	2.8706	2.8534	2.8521
EPCSRST_N_0	B31	2.9195	2.9191	2.9097	2.9093	2.8905	2.8895	2.8707	2.8697	2.8520	2.8506
EPCSRST_N_1	B32	2.9204	2.9205	2.9119	2.9119	2.8944	2.8944	2.8768	2.8767	2.8591	2.8591
EPCSRST_N_2	B34	2.9192	2.9190	2.9099	2.9096	2.8915	2.8909	2.8729	2.8722	2.8542	2.8533
EPCSRST_N_3	B35	2.9201	2.9199	2.9116	2.9113	2.8949	2.8942	2.8777	2.8769	2.8605	2.8600
EPCSRST_N_4	B36	2.9183	2.9179	2.9086	2.9082	2.8888	2.8877	2.8689	2.8677	2.8486	2.8473
EPCSRST_N_5	B37	2.9197	2.9194	2.9104	2.9100	2.8915	2.8913	2.8730	2.8724	2.8543	2.8536
MONITOR	K23	2.9195	2.9193	2.9120	2.9119	2.8948	2.8948	2.8785	2.8782	2.8618	2.8616
PLL_MON	L20	2.9203	2.9196	2.9126	2.9140	2.8976	2.8956	2.8827	2.8822	2.8681	2.8676
TOGGLE_MON	L22	2.9202	2.9195	2.9123	2.9119	2.8968	2.8961	2.8813	2.8807	2.8654	2.8647

Table. 25. LVTTL VOH – DUT 1786

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.9187	2.9184	2.9094	2.9090	2.8905	2.8898	2.8717	2.8707	2.8534	2.8524
EPCSRST_N_0	B31	2.9182	2.9183	2.9086	2.9084	2.8893	2.8889	2.8698	2.8694	2.8512	2.8507
EPCSRST_N_1	B32	2.9203	2.9201	2.9113	2.9111	2.8939	2.8931	2.8764	2.8752	2.8586	2.8575
EPCSRST_N_2	B34	2.9186	2.9181	2.9099	2.9093	2.8913	2.8903	2.8729	2.8716	2.8544	2.8525
EPCSRST_N_3	B35	2.9195	2.9193	2.9114	2.9111	2.8944	2.8938	2.8775	2.8768	2.8604	2.8596
EPCSRST_N_4	B36	2.9184	2.9180	2.9088	2.9085	2.8890	2.8882	2.8692	2.8679	2.8490	2.8477
EPCSRST_N_5	B37	2.9189	2.9186	2.9099	2.9099	2.8915	2.8913	2.8730	2.8727	2.8545	2.8541
MONITOR	K23	2.9194	2.9191	2.9103	2.9107	2.8941	2.8942	2.8775	2.8778	2.8608	2.8610
PLL_MON	L20	2.9197	2.9194	2.9122	2.9127	2.8974	2.8968	2.8824	2.8813	2.8679	2.8656
TOGGLE_MON	L22	2.9195	2.9188	2.9116	2.9110	2.8960	2.8956	2.8802	2.8800	2.8643	2.8638

Table. 26. LVTTL VOH – DUT 1793

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	2.9196	2.9184	2.9098	2.9087	2.8910	2.8892	2.8718	2.8697	2.8537	2.8512
EPCSRST_N_0	B31	2.9192	2.9186	2.9097	2.9087	2.8900	2.8886	2.8704	2.8685	2.8518	2.8495
EPCSRST_N_1	B32	2.9208	2.9203	2.9120	2.9116	2.8946	2.8938	2.8772	2.8759	2.8593	2.8579
EPCSRST_N_2	B34	2.9199	2.9193	2.9100	2.9094	2.8914	2.8904	2.8729	2.8713	2.8542	2.8520
EPCSRST_N_3	B35	2.9201	2.9196	2.9119	2.9109	2.8950	2.8935	2.8781	2.8758	2.8608	2.8582
EPCSRST_N_4	B36	2.9187	2.9182	2.9087	2.9079	2.8886	2.8872	2.8686	2.8666	2.8483	2.8458
EPCSRST_N_5	B37	2.9196	2.9187	2.9104	2.9098	2.8918	2.8907	2.8730	2.8718	2.8545	2.8528
MONITOR	K23	2.9189	2.9185	2.9115	2.9109	2.8940	2.8937	2.8774	2.8773	2.8609	2.8604
PLL_MON	L20	2.9197	2.9195	2.9126	2.9125	2.8979	2.8966	2.8831	2.8808	2.8685	2.8667
TOGGLE_MON	L22	2.9199	2.9190	2.9122	2.9113	2.8966	2.8955	2.8811	2.8797	2.8653	2.8636

Table. 27. LVTTL VOL – DUT 1658

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	216.0850	215.4897	229.4696	229.2181	246.2081	246.1436	258.6140	258.9776	287.8542	288.2833
EPCSRST_N_0	B31	215.7715	215.4584	229.1248	228.7166	246.5216	246.2690	267.3037	267.0810	289.2998	289.3643
EPCSRST_N_1	B32	215.0610	214.5557	223.8736	223.3373	242.2489	241.6819	260.9055	260.5891	280.1978	279.7707
EPCSRST_N_2	B34	216.2797	215.7433	225.4674	225.6499	245.3114	245.0258	264.9680	264.9017	284.9807	285.5328
EPCSRST_N_3	B35	215.8422	215.3057	224.8424	224.1499	242.5302	241.9632	261.0305	260.4016	279.6705	279.1807
EPCSRST_N_4	B36	217.0923	216.8371	226.5299	227.0563	246.4677	247.7760	266.6868	268.7457	287.3909	290.4412
EPCSRST_N_5	B37	215.9672	215.1807	225.1549	224.5249	243.8739	243.1195	262.4055	261.9329	281.6038	281.4403
MONITOR	K23	214.1059	213.5118	221.4842	220.7654	239.1171	238.0862	255.4682	254.5629	272.3372	271.0745
PLL_MON	L20	213.3008	212.8069	221.9881	222.1815	235.8939	234.6497	250.6748	249.4928	266.9395	261.5474
TOGGLE_MON	L22	213.8954	213.0517	220.5904	219.2777	236.9838	236.2037	252.3449	251.7217	268.0800	267.3443

Table. 28. LVTTL VOL – DUT 1690

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	215.3327	214.7061	228.3725	227.7450	245.1110	245.0466	257.7695	257.6013	287.0874	287.3405
EPCSRST_N_0	B31	215.2073	214.4241	228.6232	227.7137	246.0827	245.4540	266.6768	266.2033	289.0609	288.4593
EPCSRST_N_1	B32	214.2485	213.5244	223.0611	222.2123	241.4676	240.5881	260.4679	259.5577	279.8212	278.9045
EPCSRST_N_2	B34	215.0297	214.3057	224.6549	224.2749	244.2489	244.3383	264.0617	264.4017	284.3906	284.8423
EPCSRST_N_3	B35	214.9985	214.1182	223.4986	222.7748	241.5301	241.1819	260.0617	259.6202	278.6160	278.6785
EPCSRST_N_4	B36	215.5610	214.9307	225.9361	225.4937	245.9052	245.6196	266.0618	266.0893	286.8134	287.0643
EPCSRST_N_5	B37	215.3422	214.4932	224.4986	223.7436	242.9677	242.2757	261.9055	261.7141	281.2020	281.1767
MONITOR	K23	212.9178	212.0736	220.6400	219.7961	237.6164	236.7418	254.1864	253.0310	270.6785	269.5793
PLL_MON	L20	212.3321	211.3383	220.6756	225.4314	234.5502	234.5247	249.5498	247.4617	265.4940	266.5878
TOGGLE_MON	L22	212.4875	211.3622	219.1200	217.7446	235.1693	234.4829	251.1560	250.0948	266.3612	265.6129

Table. 29. LVTTL VOL – DUT 1703

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	216.1790	215.7718	228.8427	228.3719	243.9199	243.8868	256.6434	256.1311	282.4992	283.0917
EPCSRST_N_0	B31	216.5865	216.2420	229.3755	228.9047	245.0170	245.2346	264.2945	264.7615	285.1390	286.0835
EPCSRST_N_1	B32	215.2797	214.6807	223.4986	223.0248	240.3426	239.7443	257.8116	257.1201	275.9170	275.0505
EPCSRST_N_2	B34	217.0298	216.3370	225.9674	225.5562	243.8114	243.3383	262.0617	261.5578	280.9008	280.3481
EPCSRST_N_3	B35	216.1547	215.3995	224.4361	223.7749	241.0926	240.2131	258.0929	257.2764	275.4023	274.7367
EPCSRST_N_4	B36	217.7485	217.1183	227.4362	227.0250	246.3427	246.1196	265.6243	265.6205	285.1689	285.5704
EPCSRST_N_5	B37	216.6548	215.7433	225.1549	224.4311	242.8739	242.4632	261.1242	260.9016	279.3567	279.4192
MONITOR	K23	215.2001	214.2935	222.9536	221.7346	239.9299	239.1492	256.5937	255.5634	273.3801	272.0672
PLL_MON	L20	214.3320	215.4631	222.8005	224.5564	236.6439	237.3996	251.3935	251.6490	267.5930	262.8547
TOGGLE_MON	L22	214.8965	213.9903	221.7166	220.3727	238.3917	237.5177	254.1281	253.3799	269.7612	269.2010

Table. 30. LVTTL VOL – DUT 1744

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	215.7715	215.3017	228.2157	227.6823	243.2616	243.0719	255.3923	255.6306	282.2352	282.5889
EPCSRST_N_0	B31	215.5208	215.1136	227.9650	227.6196	243.7318	243.6361	263.1661	263.4451	284.1459	284.6379
EPCSRST_N_1	B32	214.6860	214.1807	222.7173	222.6811	239.9364	239.2756	257.5929	257.1201	275.3772	274.8120
EPCSRST_N_2	B34	216.1235	215.5245	224.9986	224.9624	243.1552	242.9945	261.2805	261.5578	280.1476	280.6494
EPCSRST_N_3	B35	215.6547	214.7745	223.6549	223.3061	240.0614	239.6193	257.1866	256.8389	274.6742	274.5233
EPCSRST_N_4	B36	217.4985	216.8371	226.6862	226.3375	246.3740	246.4009	265.9368	266.2768	286.2611	286.9137
EPCSRST_N_5	B37	216.2797	215.3057	224.9674	224.5249	243.1552	242.5570	261.8430	261.2453	280.5744	280.3983
MONITOR	K23	213.6682	213.3555	221.0777	220.8904	237.9291	237.6798	254.0300	253.8126	270.5152	270.2829
PLL_MON	L20	213.2695	212.6507	221.6443	222.4940	235.1439	236.6184	250.1435	250.5240	266.2356	263.4329
TOGGLE_MON	L22	213.8328	212.8327	220.0898	219.4028	236.8274	236.1411	252.1572	251.5340	267.8040	267.3317

Table. 31. LVTTL VOL – DUT 1786

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	215.3641	214.9882	227.8083	227.4629	243.1676	242.7585	255.5799	255.9747	281.9084	281.8724
EPCSRST_N_0	B31	215.8029	215.2390	228.4665	227.9331	244.4841	243.9182	263.6363	263.3511	284.3847	284.0471
EPCSRST_N_1	B32	214.5922	213.8369	222.6861	222.8061	239.9364	239.9631	257.4366	257.8077	275.5404	276.1176
EPCSRST_N_2	B34	216.0922	215.7120	224.5299	224.6499	242.9364	242.9007	260.9680	261.9016	279.8337	281.0888
EPCSRST_N_3	B35	215.9047	215.0557	223.6236	223.0873	240.2489	239.7443	257.1241	257.0889	274.3353	274.5735
EPCSRST_N_4	B36	217.0923	216.5558	226.2799	226.0562	245.9052	245.6509	265.4368	265.3705	285.6585	286.1353
EPCSRST_N_5	B37	216.4360	215.6495	224.8424	224.5562	242.9364	242.3070	261.3430	260.7141	280.1224	279.6828
MONITOR	K23	213.7932	213.4493	221.0777	220.8279	238.3042	237.4609	254.6866	253.8126	271.2440	270.2955
PLL_MON	L20	212.9570	212.2445	221.4568	221.1191	235.1127	235.3997	250.2060	247.5867	265.9842	268.3853
TOGGLE_MON	L22	214.2395	213.4584	221.2787	220.0598	237.3593	236.3914	253.2209	252.0659	268.6571	267.8210

Table. 32. LVTTL VOL – DUT 1793

		2mA		4mA		6mA		12mA		16mA	
Pin Name	Pin#	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad	Pre-rad	Post-rad
TID_BUF_OUT	A33	215.1133	215.2076	227.8083	227.8704	242.9482	243.4480	255.4861	255.9434	281.7575	283.2300
EPCSRST_N_0	B31	215.2700	215.4584	227.7769	227.9957	243.8885	244.5764	263.2288	264.3227	284.1459	285.8195
EPCSRST_N_1	B32	213.9985	213.9307	222.3736	222.7748	239.4676	239.8694	256.9991	257.4326	274.7998	275.8414
EPCSRST_N_2	B34	215.2485	215.2745	224.5924	224.7437	242.7177	243.4008	261.0617	262.2766	280.0848	281.6914
EPCSRST_N_3	B35	215.1547	214.9620	223.1548	223.3061	239.5926	240.4319	256.5929	257.8702	274.0968	275.9167
EPCSRST_N_4	B36	216.6548	216.6183	226.4362	227.1188	246.3115	246.9634	266.0305	267.3394	286.3364	288.1941
EPCSRST_N_5	B37	216.0610	215.7433	224.7799	224.7437	242.9364	243.0257	261.2492	261.7766	280.2103	281.0763
MONITOR	K23	213.8870	213.9808	221.3904	221.1718	238.3042	238.3676	254.6866	254.7505	271.1812	271.2379
PLL_MON	L20	213.3008	213.5882	221.7068	220.3066	234.9877	235.7747	249.6435	251.8365	265.5443	270.0696
TOGGLE_MON	L22	213.6763	213.1455	220.4652	219.8721	236.7336	236.5478	252.2510	252.5978	267.7413	268.3354

E. Propagation Delay

Table 33 lists the pre-irradiation and post-irradiation propagation delay measurements. It shows that the change due to radiation on each DUT is not significant and every DUT passes the 10% degradation criterion.

Table. 33. Pre-irradiation and Post-irradiation Propagation Delay Change

DUT	Total Dose	Pre-irradiation (µs)	Post-irradiation (µs)	Change Degradation (%)
1658	125 krad	0.475	0.472	-0.52
1690	125 krad	0.480	0.475	-1.04
1703	125 krad	0.485	0.482	-0.61
1744	125 krad	0.472	0.470	-0.31
1786	125 krad	0.479	0.476	-0.62
1793	125 krad	0.480	0.481	0.31

F. Transition Time

The figures below show the pre-irradiation and post-annealing transitions edges. In each case the radiation induced transition degradation is not observable.

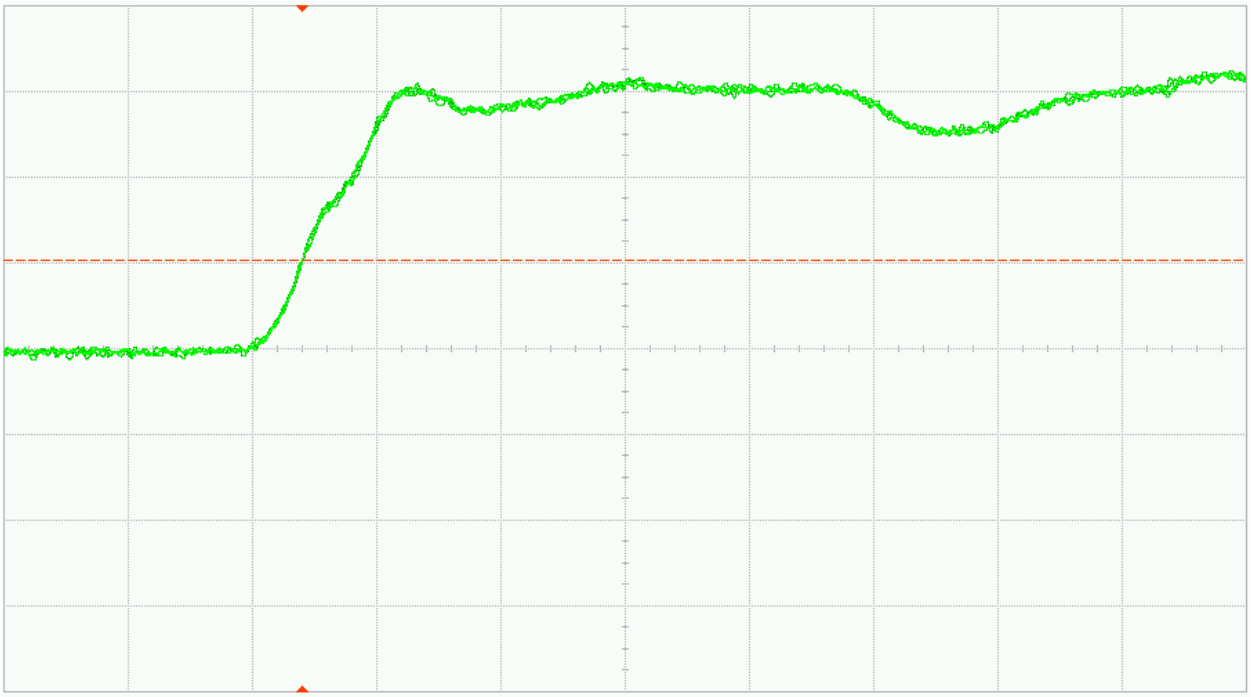

Fig. 26 (a). DUT 1658 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

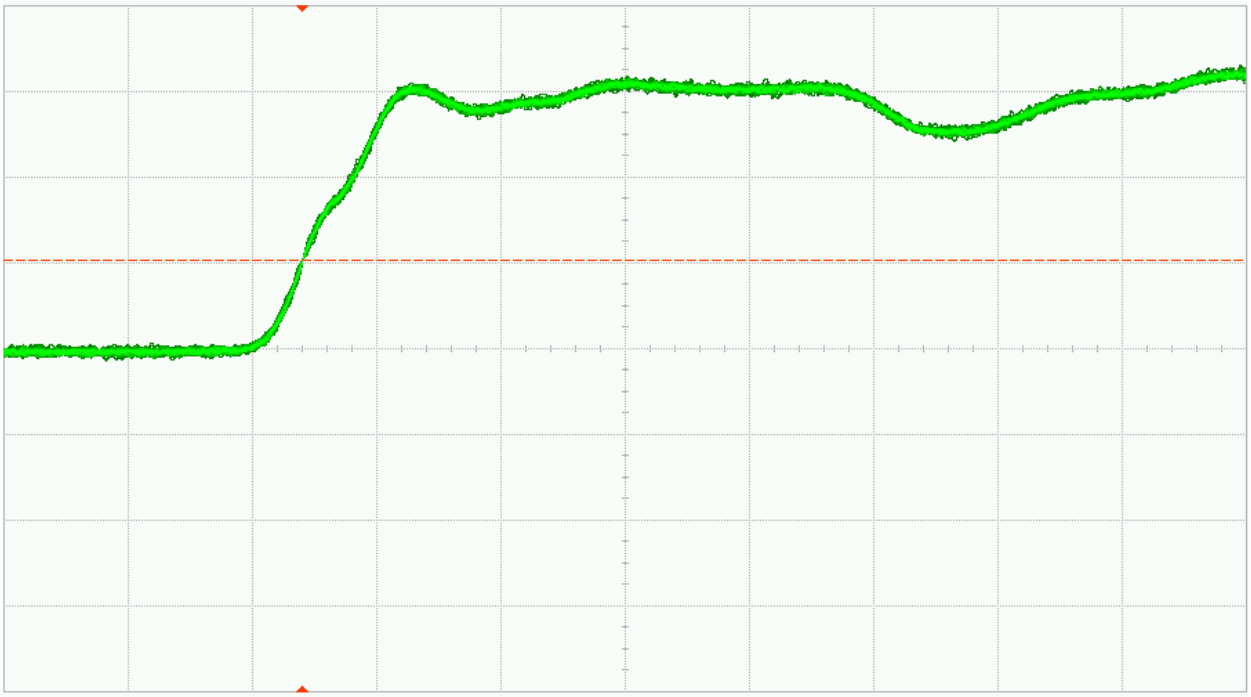

Fig. 26 (b). DUT 1658 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

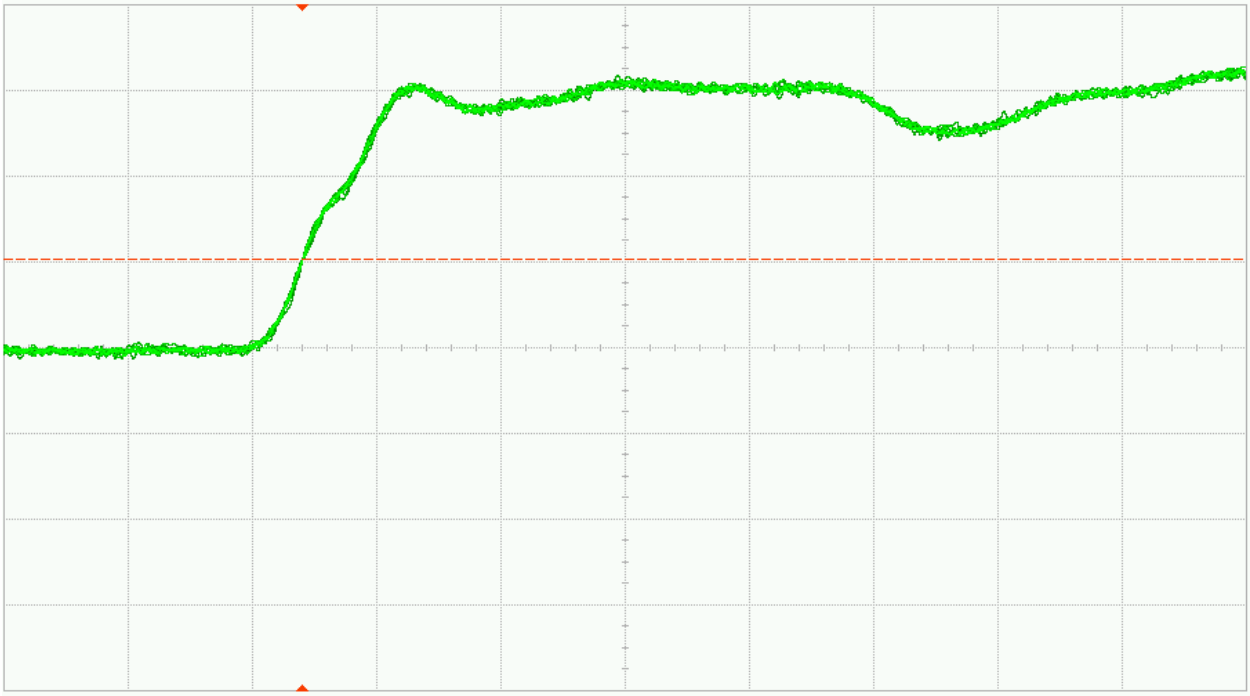

Fig. 27 (a). DUT 1690 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

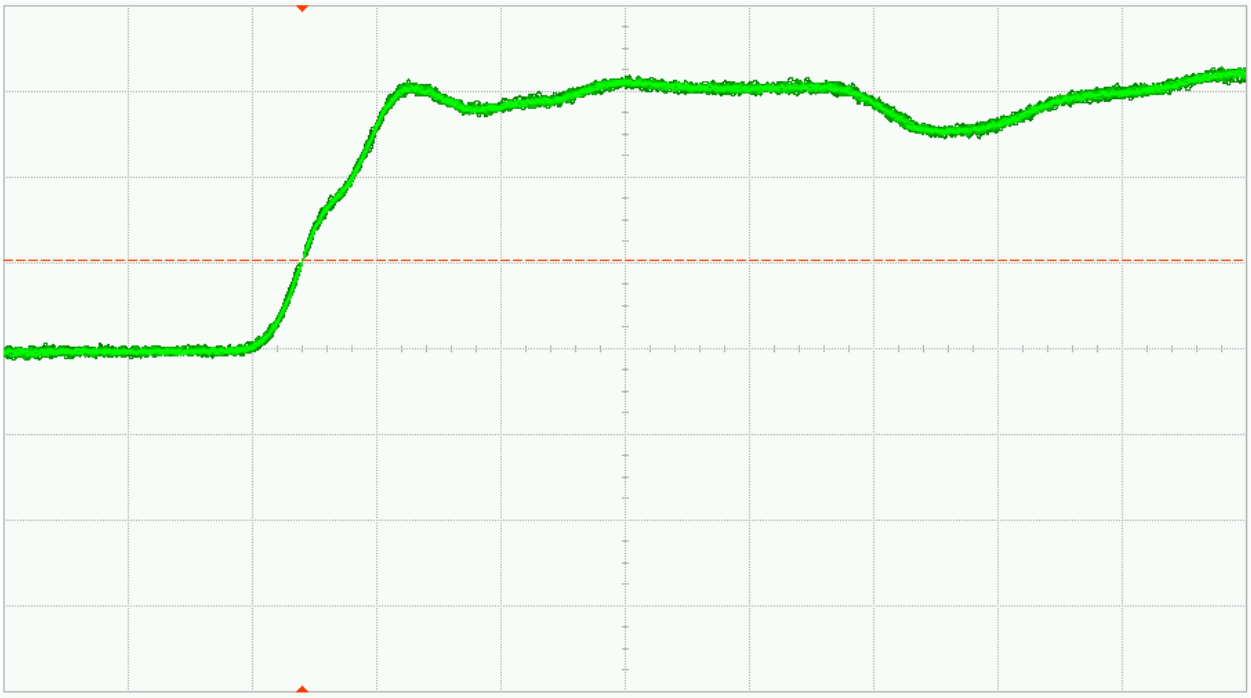

Fig. 27 (b). DUT 1690 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

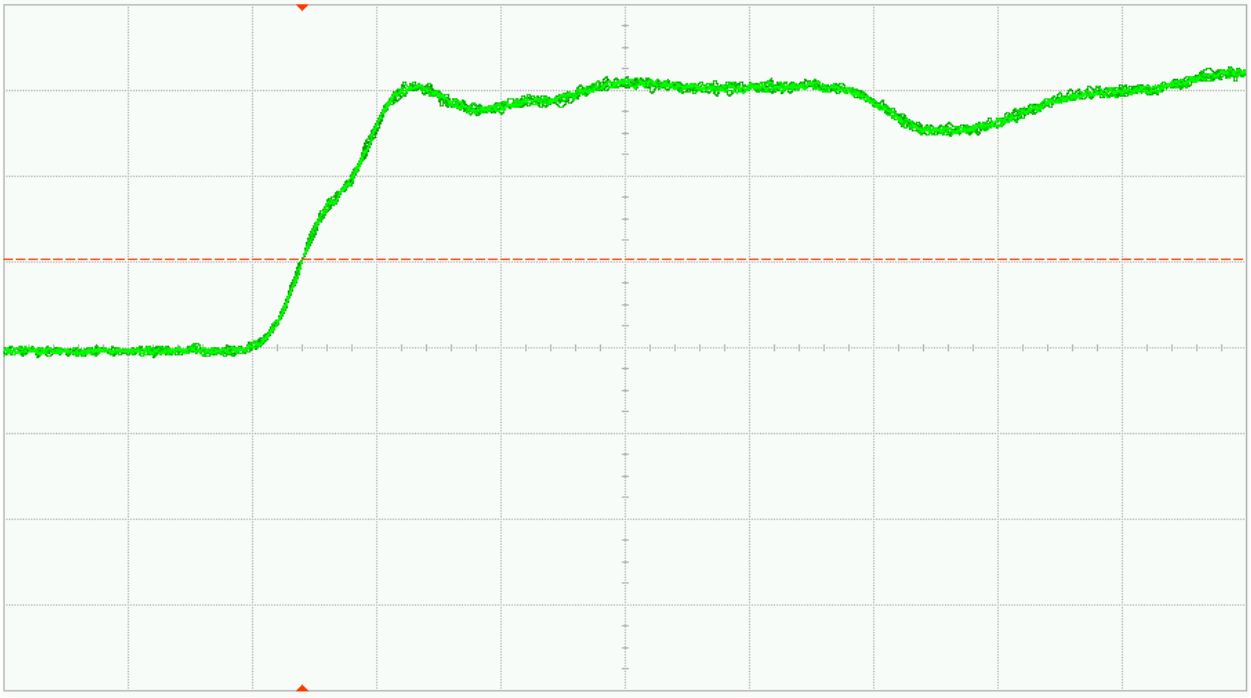

Fig. 28 (a). DUT 1703 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

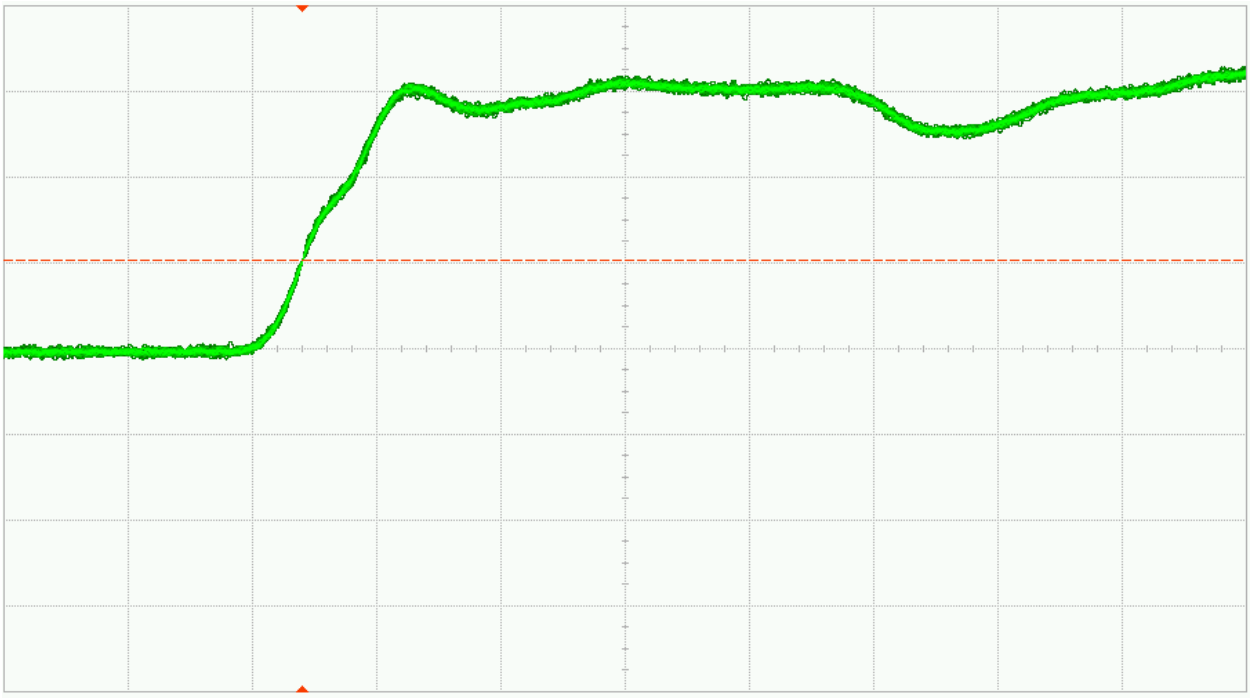

Fig. 28 (b). DUT 1703 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

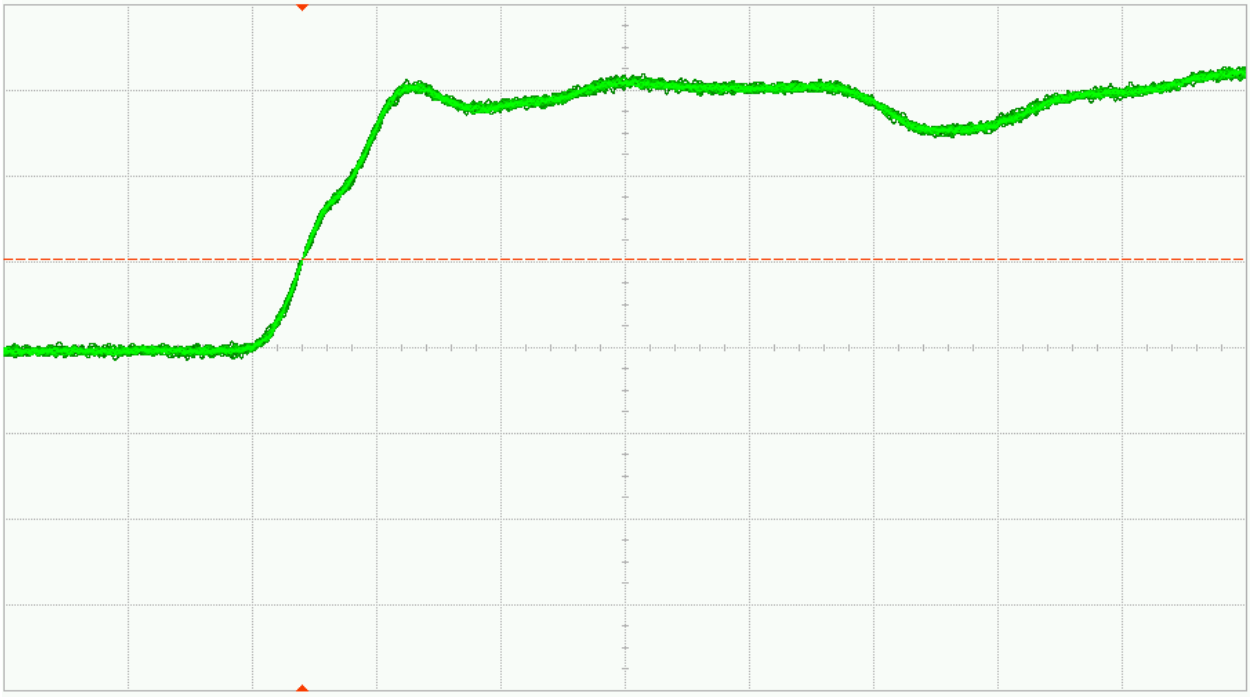

Fig. 29 (a). DUT 1744 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

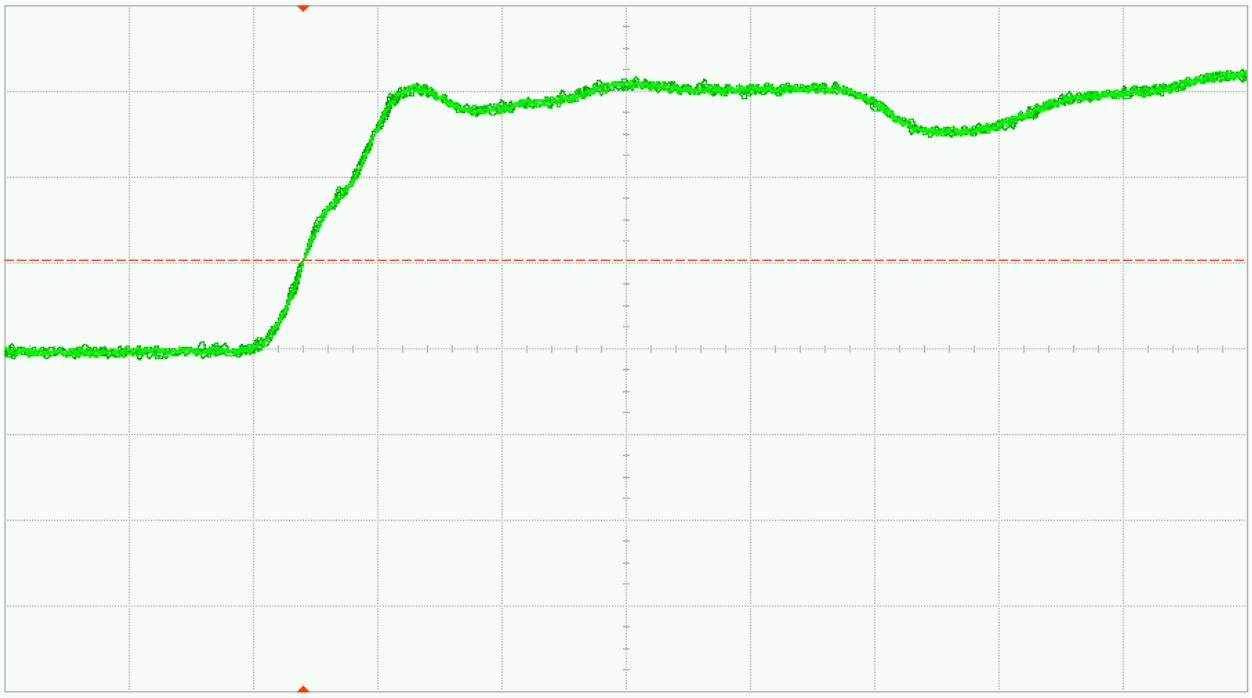

Fig. 29 (b). DUT 1744 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

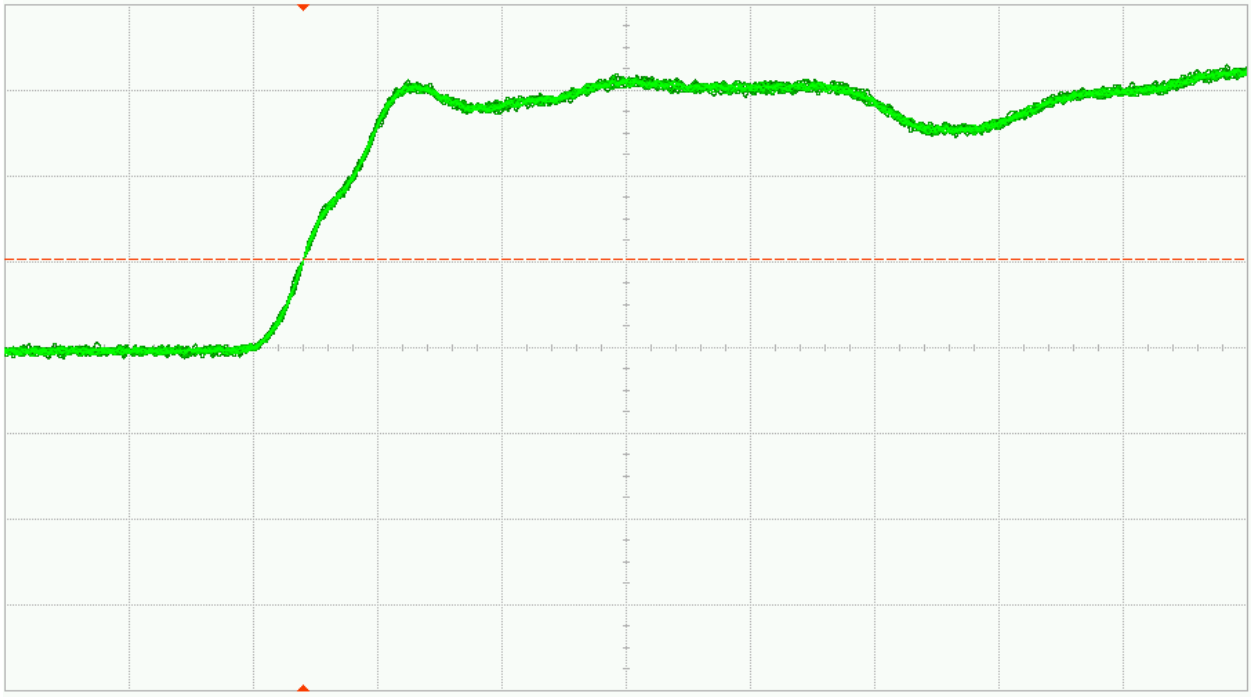

Fig. 30 (a). DUT 1786 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

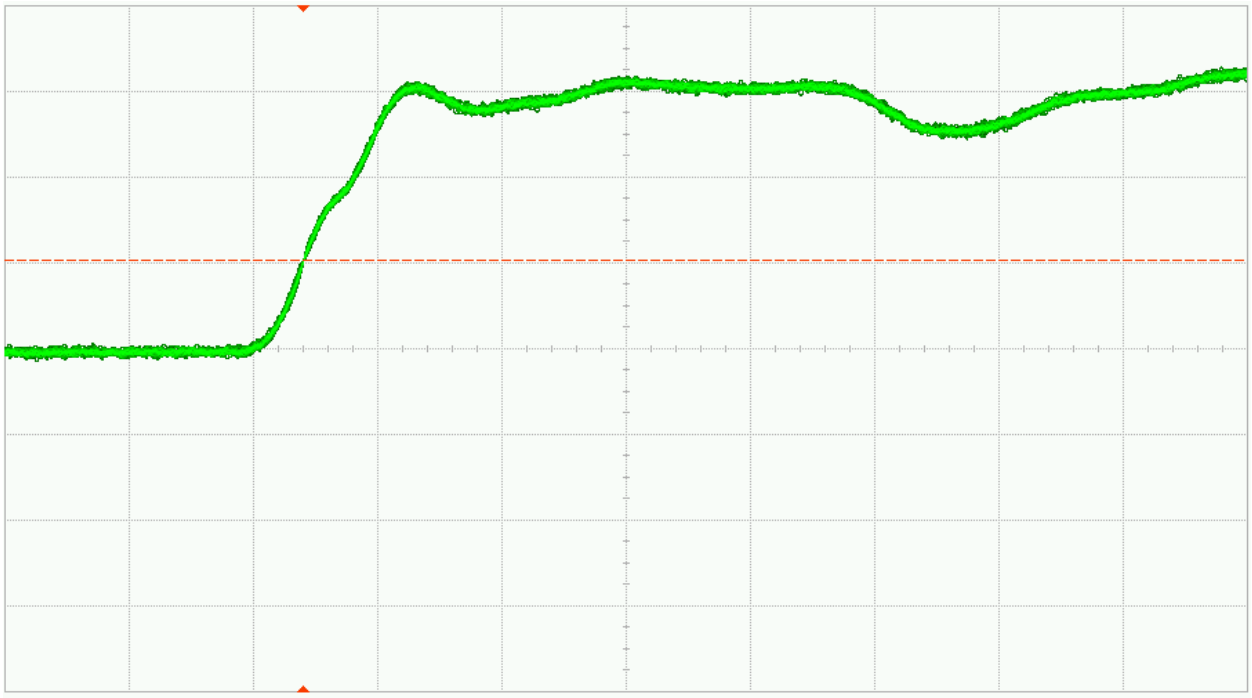

Fig. 30 (b). DUT 1786 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

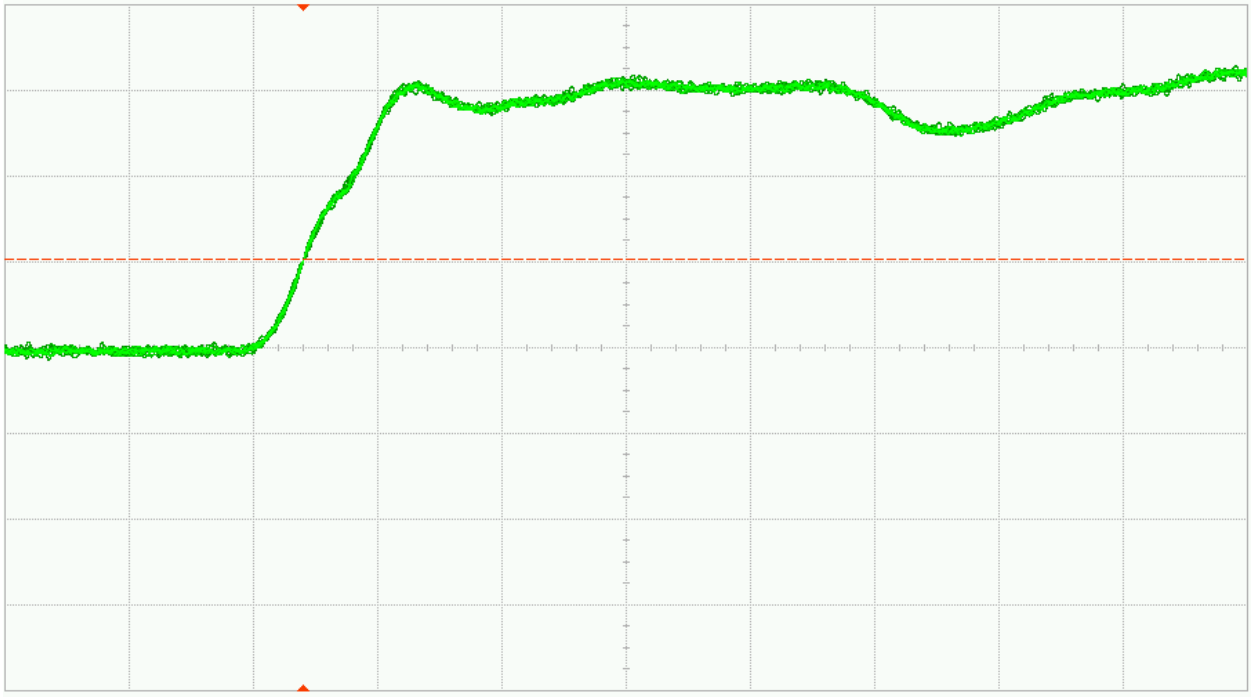

Fig. 31 (a). DUT 1793 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

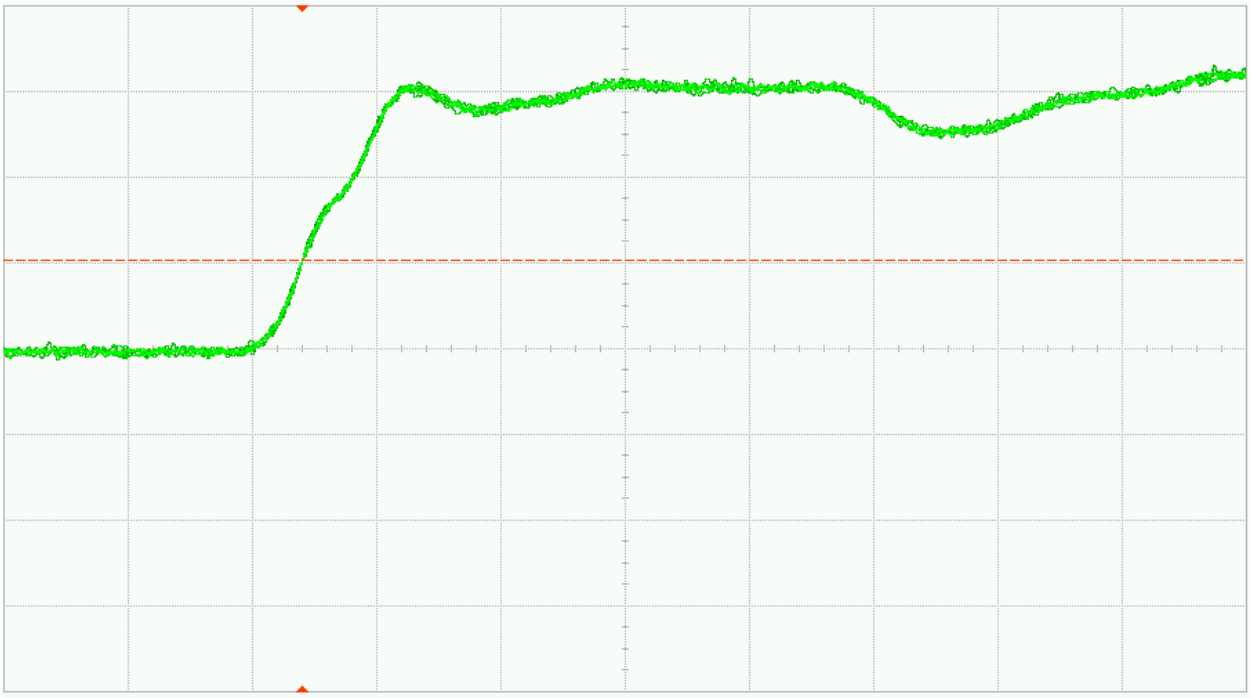

Fig. 31 (b). DUT 1793 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

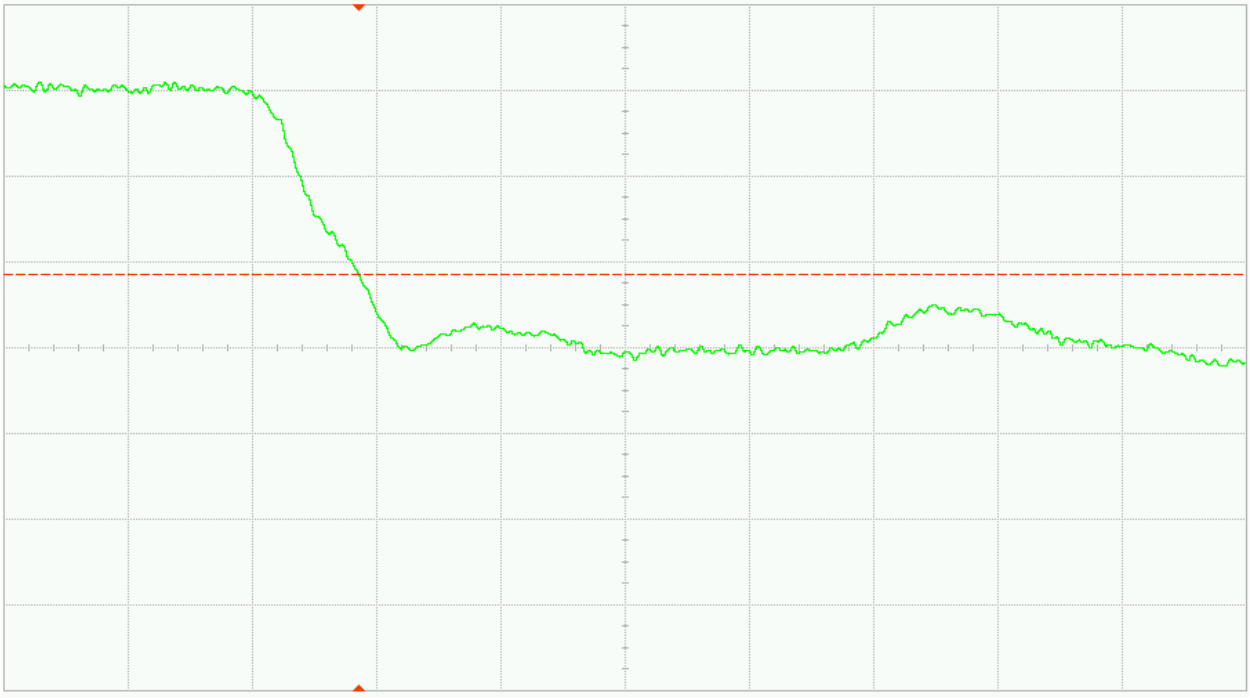

Fig. 32 (a). DUT 1758 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

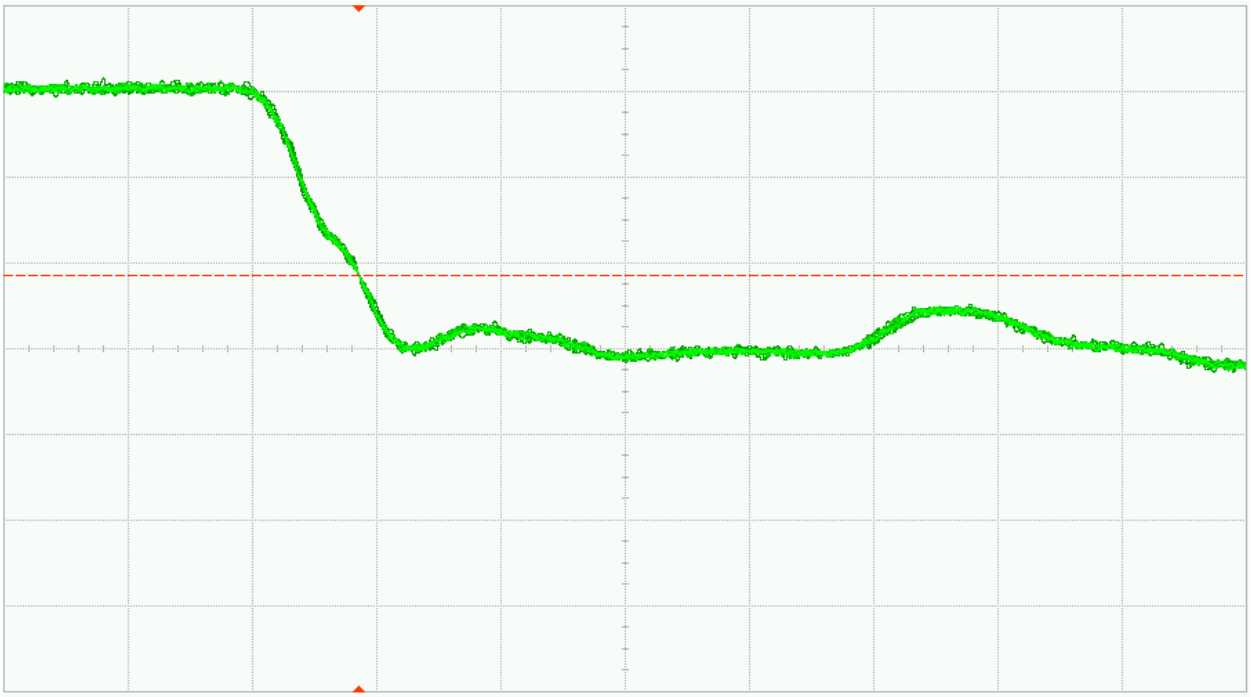

Fig. 32 (b). DUT 1658 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

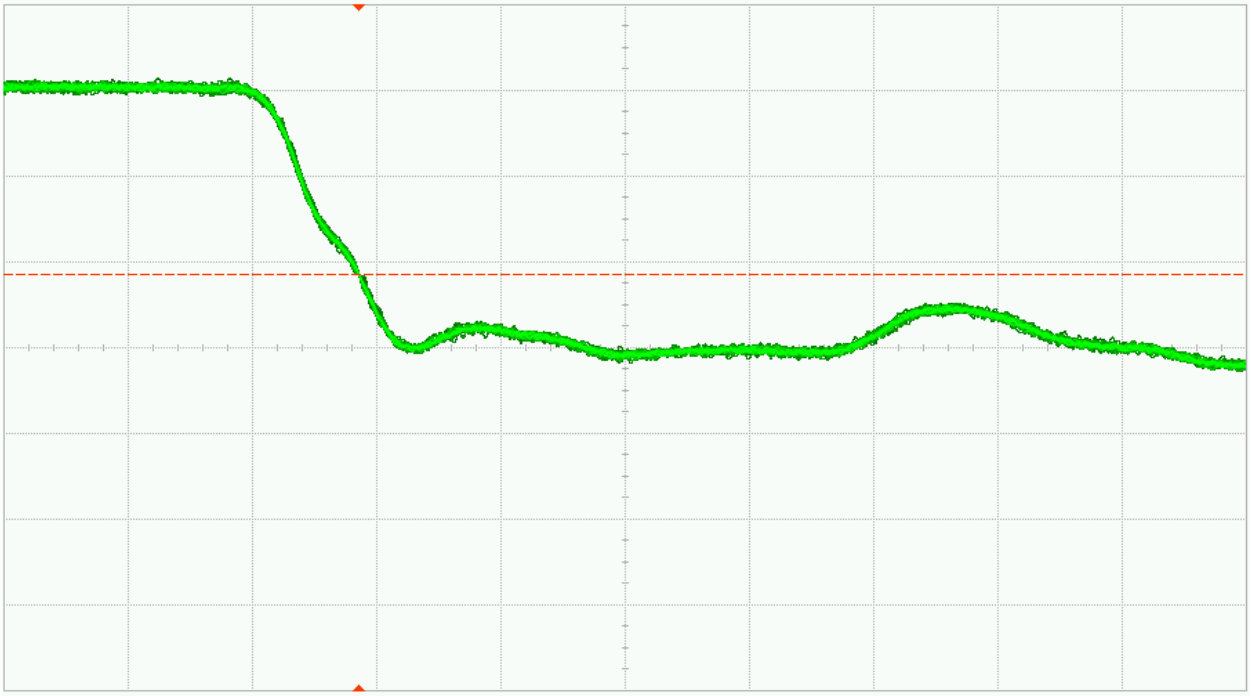

Fig. 33 (a). DUT 1690 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

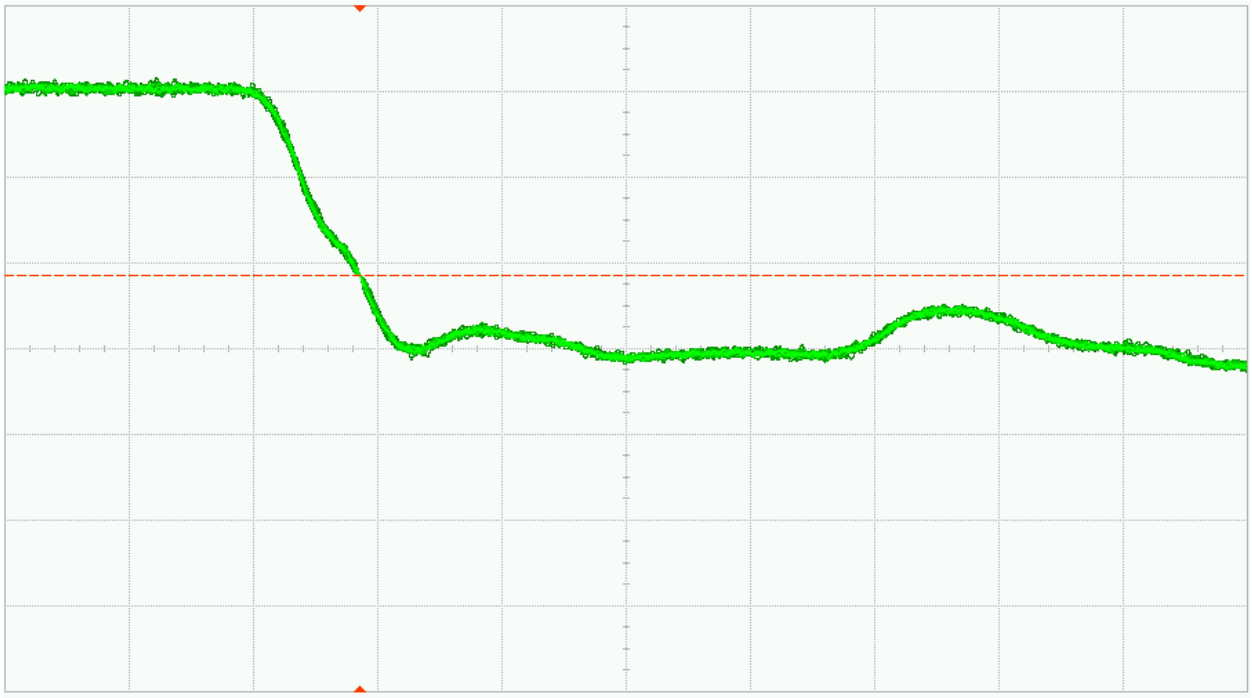

Fig. 33 (b). DUT 1690 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

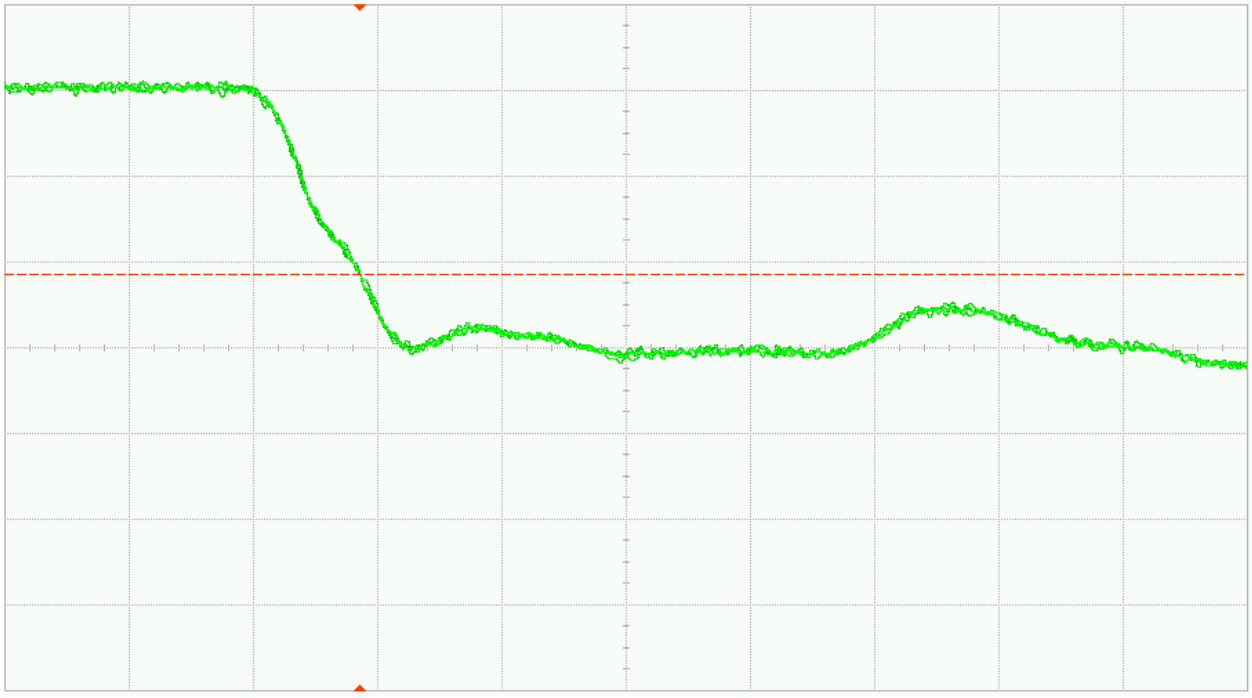

Fig. 34 (a). DUT 1703 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

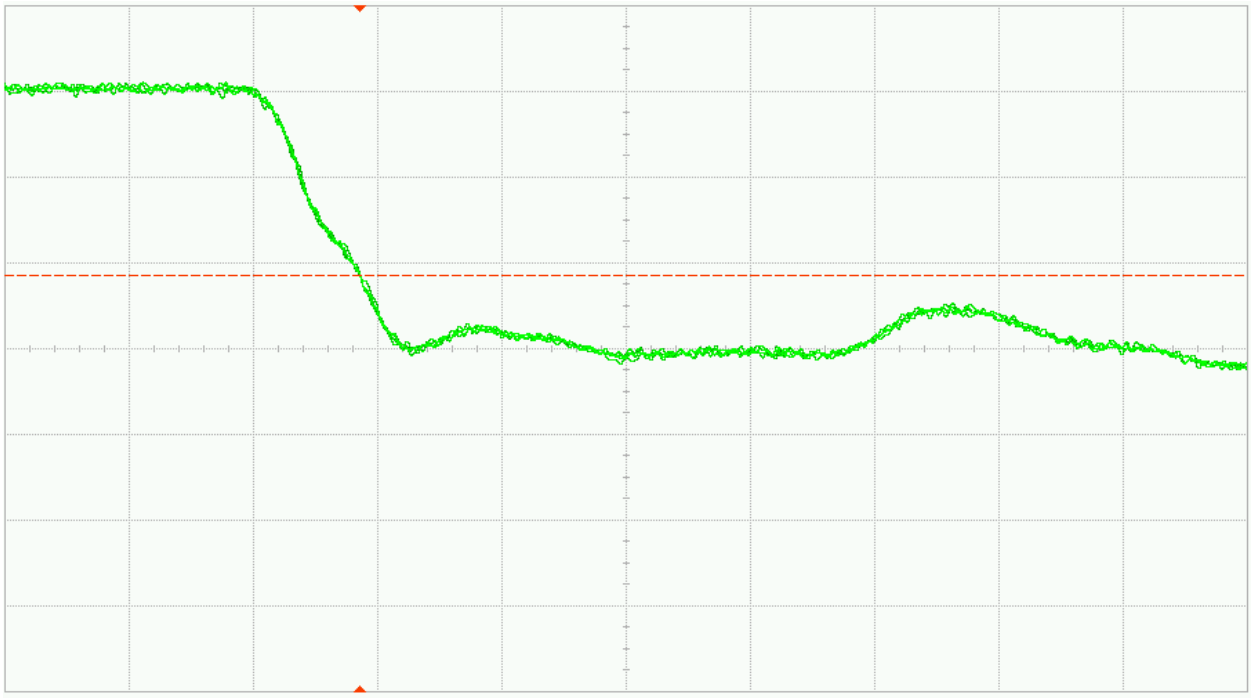

Fig. 34 (b). DUT 1703 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

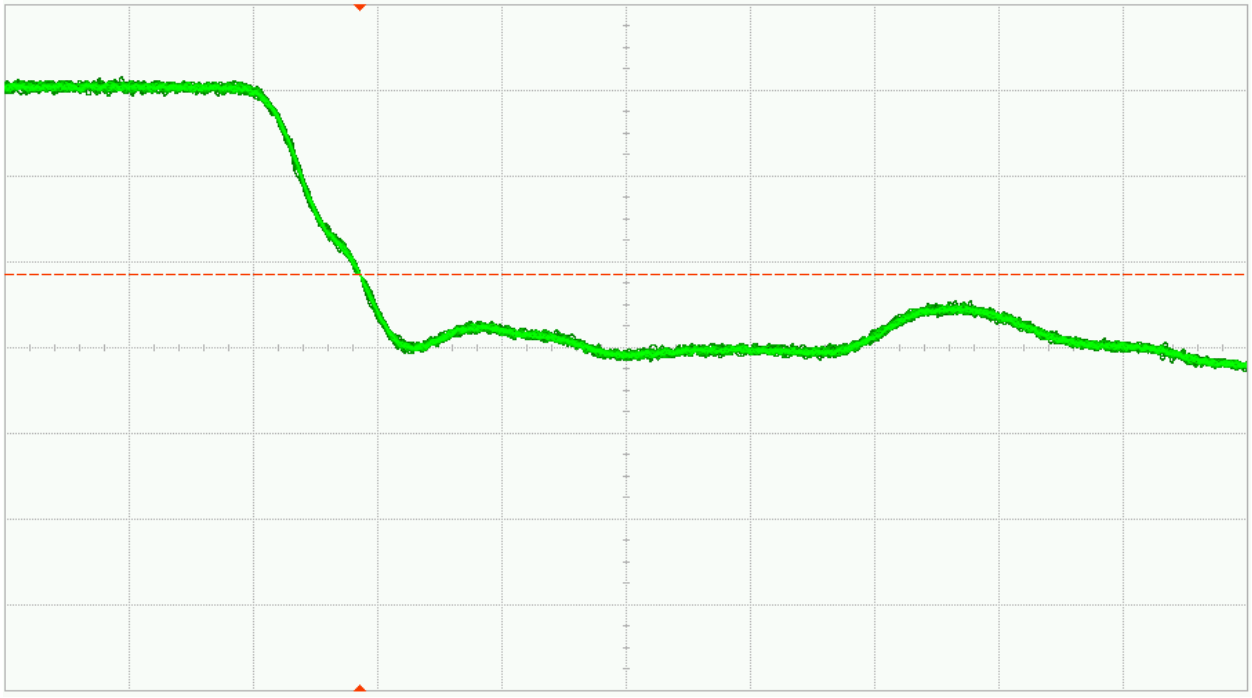

Fig. 35 (a). DUT 1744 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

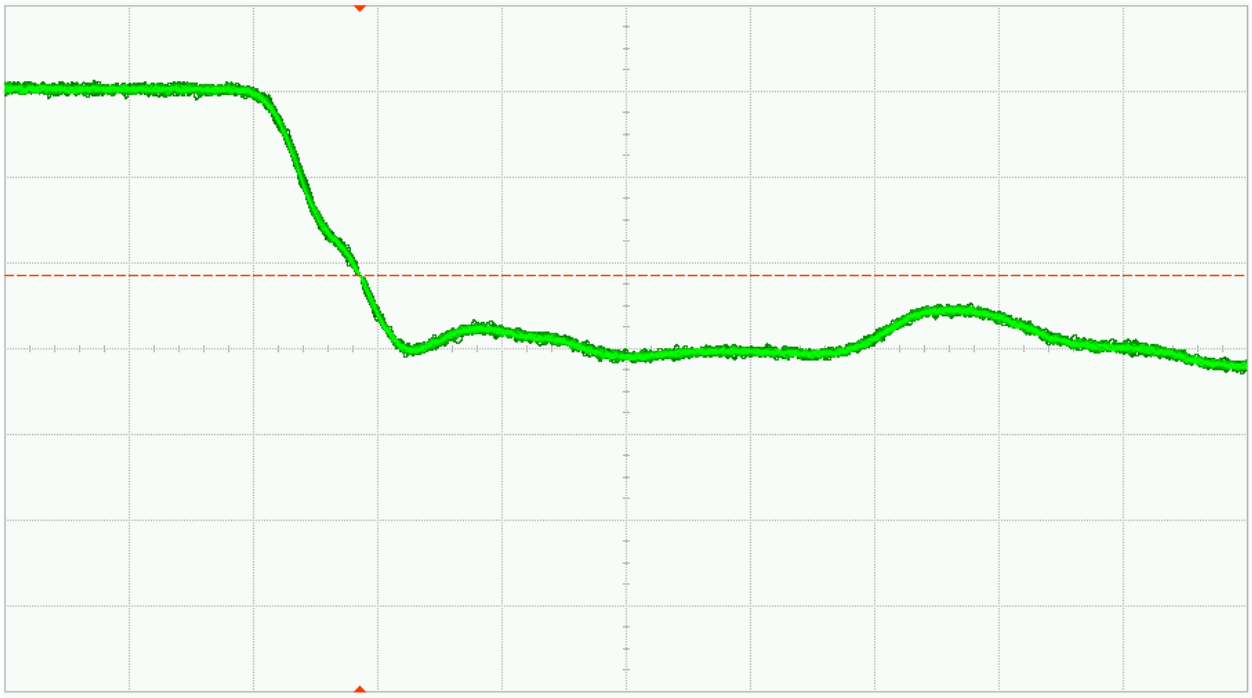

Fig. 35 (b). DUT 1744 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

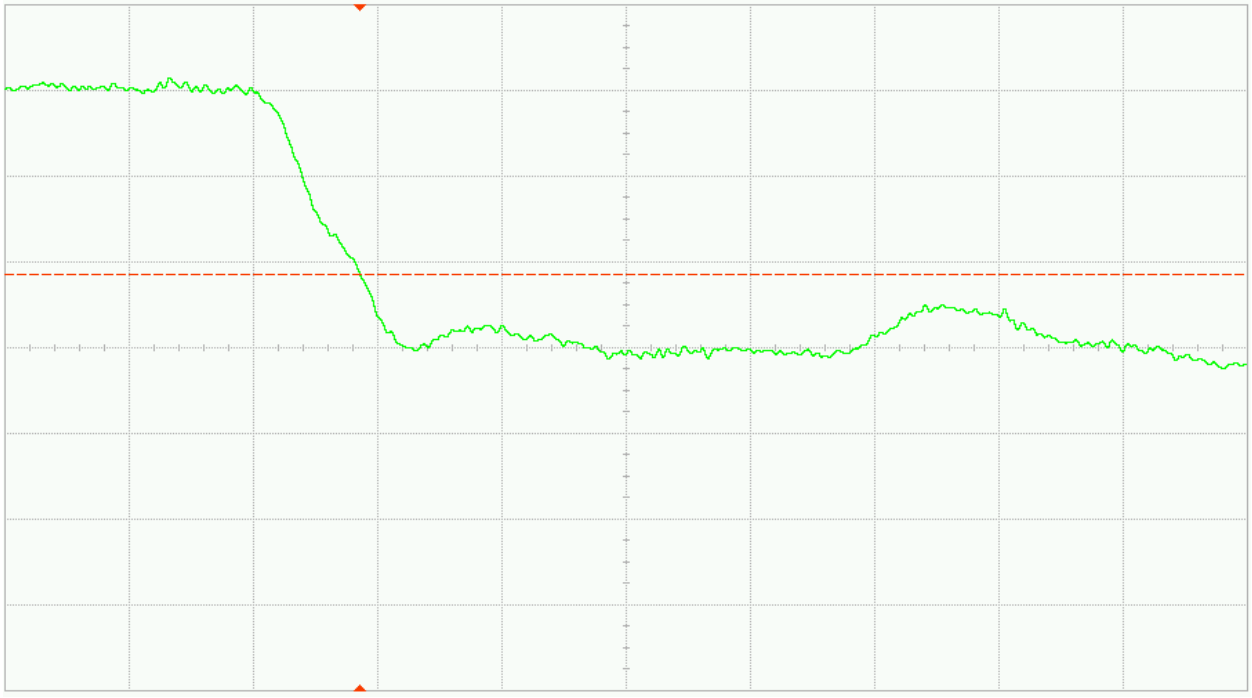

Fig. 36 (a). DUT 1786 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

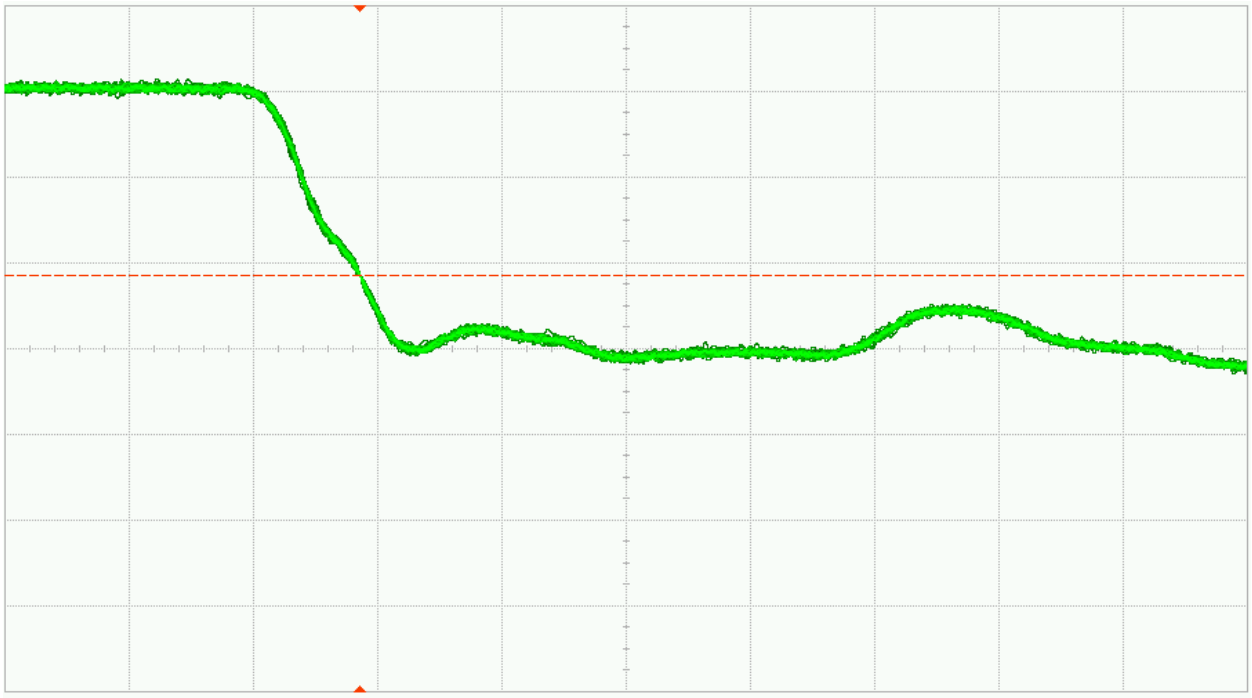

Fig. 36 (b). DUT 1786 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

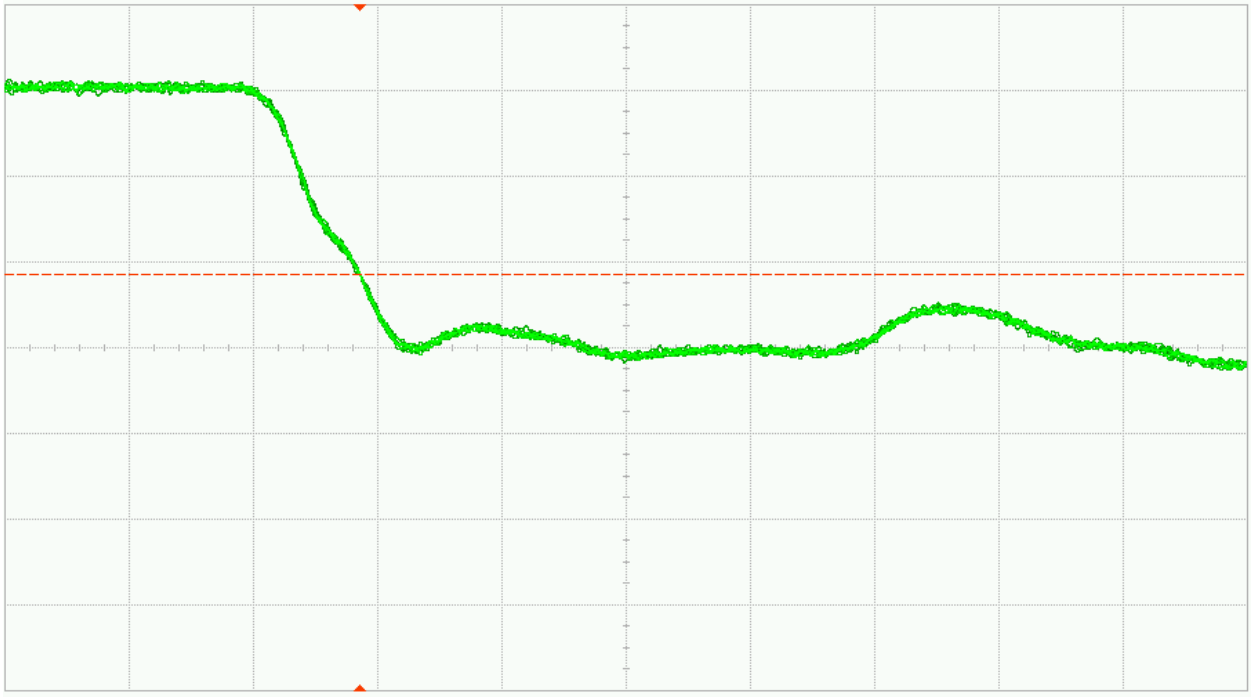

Fig. 37 (a). DUT 1793 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

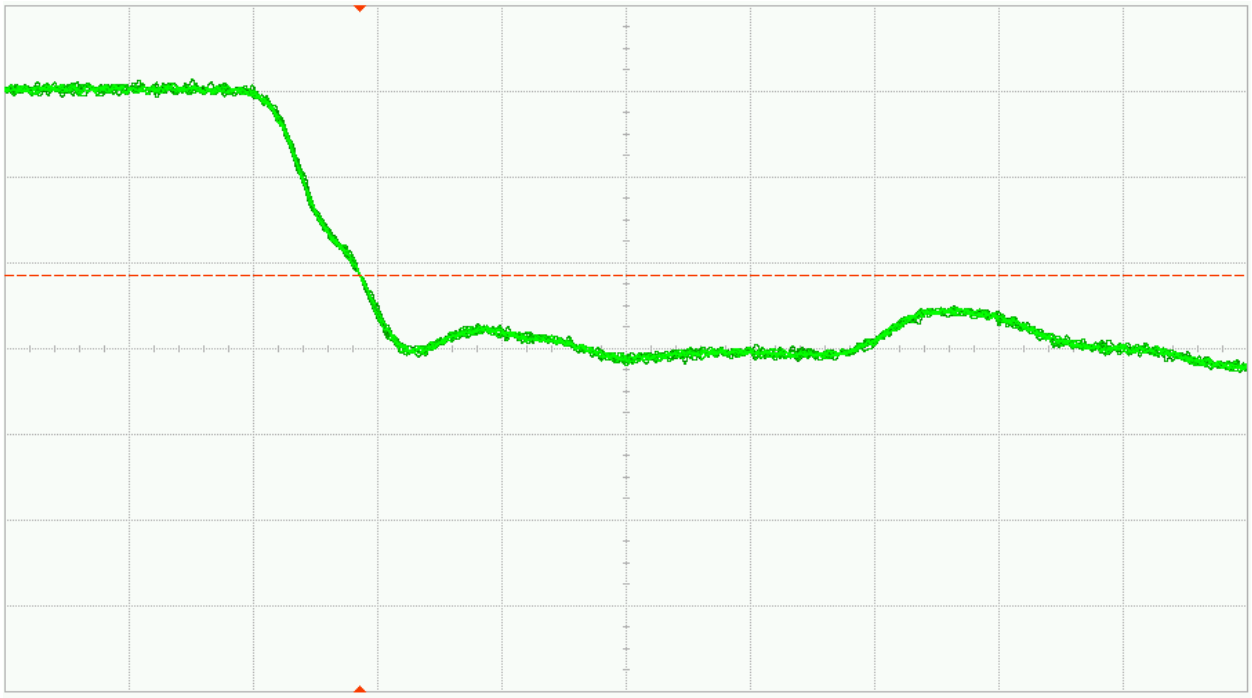

Fig. 37 (b). DUT 1793 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

Appendix A

Table. 34. High level block diagrams of blocks used to perform fabric functional coverage pre and post-irradiation

Block	**Coverage**
Combo Block	combinatorial macros available in the RTG4 library
Register Block	sequential macros available in the RTG4 library
UPROM	
Embedded SRAM Blocks	full toggle coverage on 209 fabric LSRAM & 210 µRAM blocks using dual port/ two port configurations (x18 width)
Shift Register Block	core utilization
IO Block	IO utilization
Math Block	full toggle coverage on 462 fabric math blocks with maximum width configuration

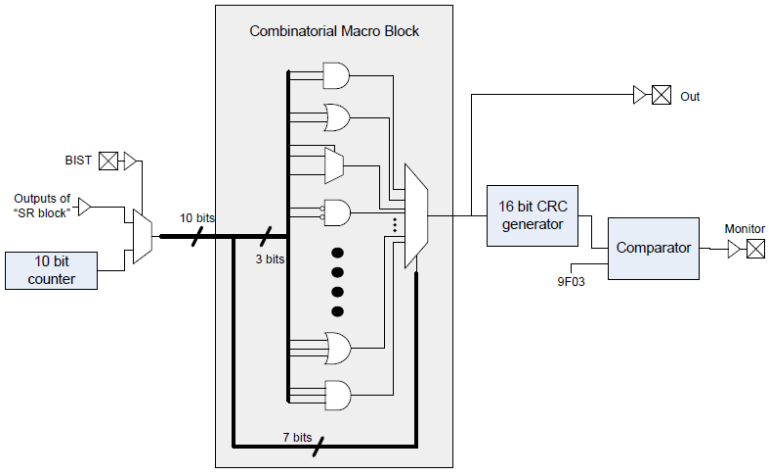

Fig. 38. Combo Block

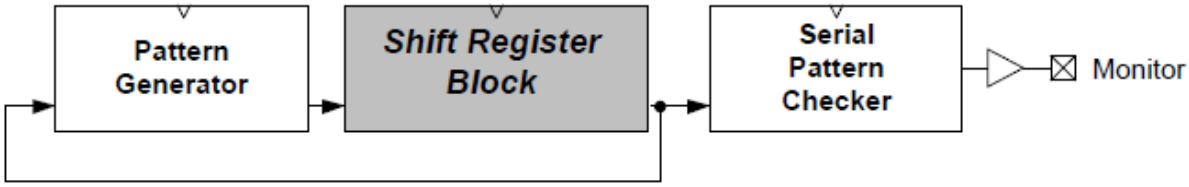

Fig. 39. Shift Register Block

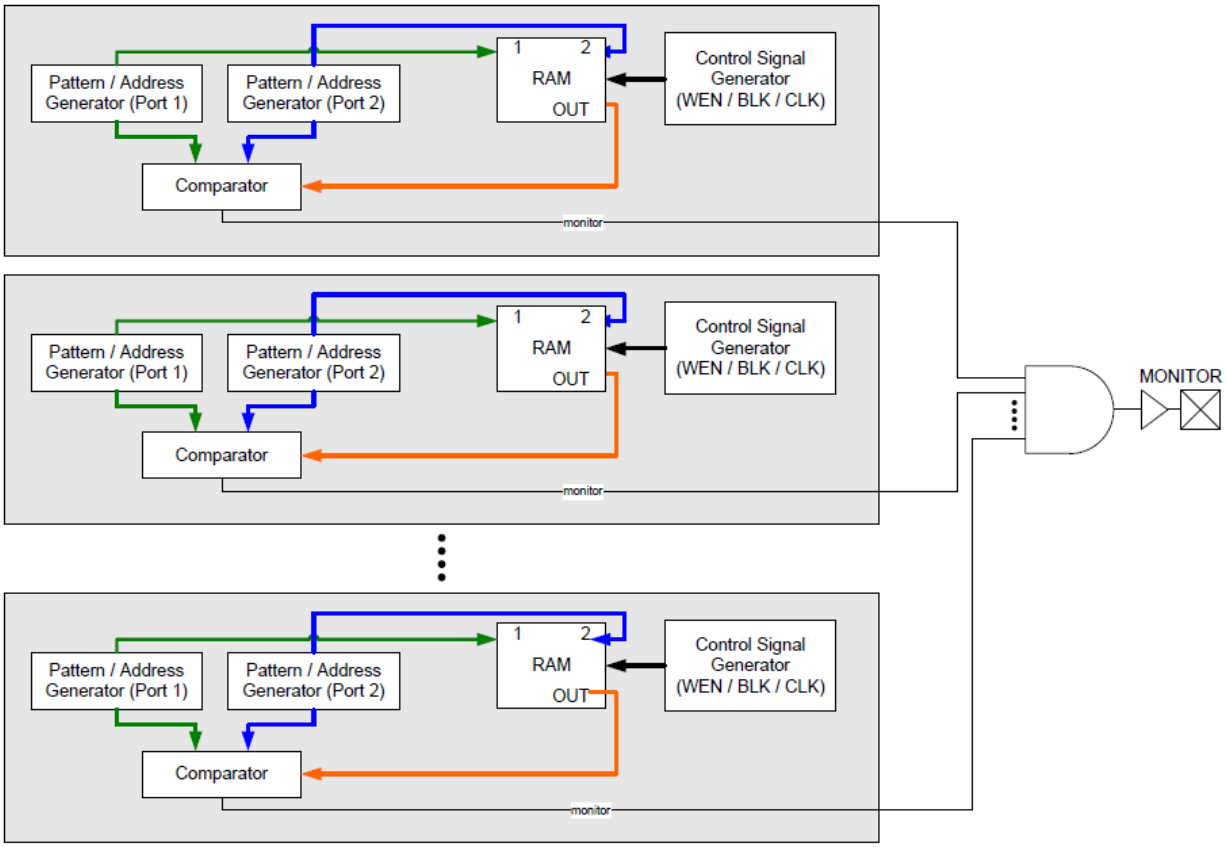

Fig. 40. Embedded Ram Blocks

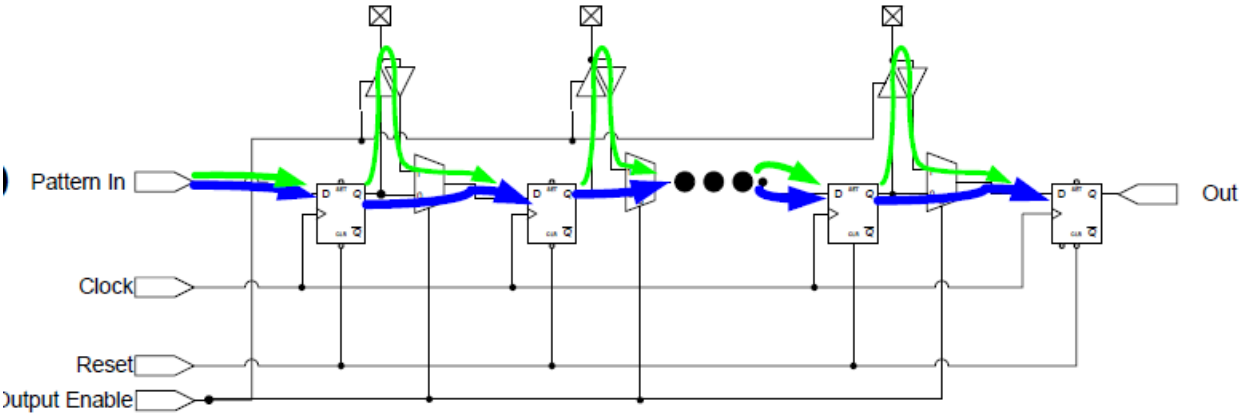

Fig. 41. IO Block

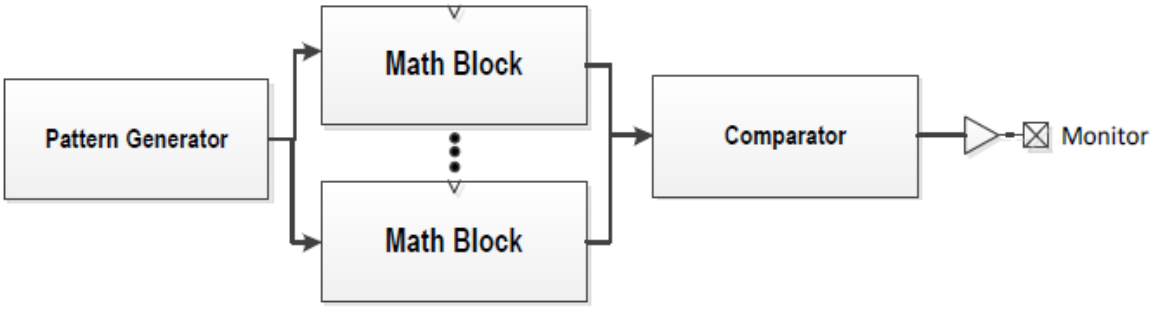

Fig. 42. Math Block