Total Ionizing Dose Test Report

No. 18T-RT4G150-LG1657-K418A

January 26, 2018

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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	K418A
Quantity Tested	6
Serial Number (Dose)	10407 (125 krad), 10410 (125 krad), 10436 (125 krad), 10465 (125 krad), 10466 (125 krad), 10468 (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

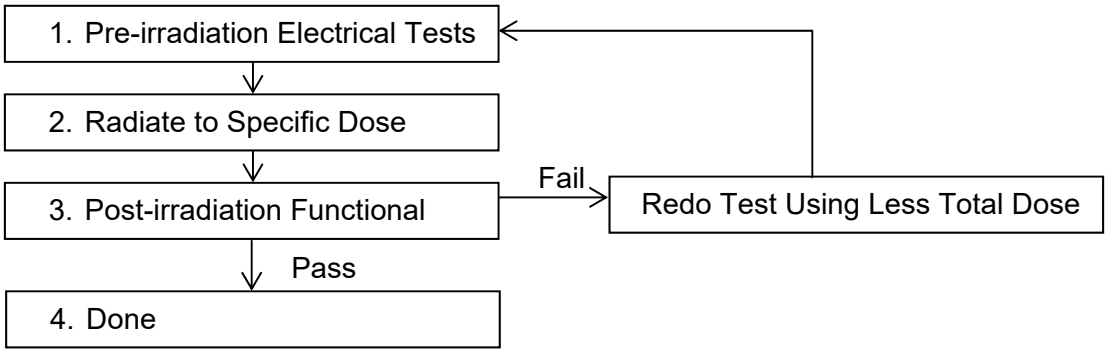

Fig. 1. Parametric test flow chart

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 (%)
10407	125 krad	0.363	0.378	4.13
10410	125 krad	0.329	0.339	3.04
10436	125 krad	0.298	0.307	3.02
10465	125 krad	0.335	0.359	7.16
10466	125 krad	0.336	0.353	5.06
10468	125 krad	0.353	0.362	2.55

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

DUT	Total Dose	Pre-irradiation (A)	Post-irradiation (A)	Increase (%)
10407	125 krad	0.0102	0.0126	23.53
10410	125 krad	0.0091	0.0114	25.27
10436	125 krad	0.0082	0.0102	24.39
10465	125 krad	0.0095	0.0116	22.11
10466	125 krad	0.0101	0.0126	24.75
10468	125 krad	0.009	0.0111	23.33

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

DUT	Total Dose	Pre-irradiation (A)	Post-irradiation (A)	Increase (%)
10407	125 krad	0.0345	0.0377	9.28
10410	125 krad	0.0333	0.0365	9.61
10436	125 krad	0.0328	0.0358	9.15
10465	125 krad	0.036	0.0368	2.22
10466	125 krad	0.0341	0.0371	8.80
10468	125 krad	0.033	0.0359	8.79

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

DUT	Total Dose	Pre-irradiation (A)	Post-irradiation (A)	Increase (%)
10407	125 krad	0.0156	0.0155	-0.64
10410	125 krad	0.0157	0.0167	6.37
10436	125 krad	0.0157	0.0158	0.64
10465	125 krad	0.0156	0.027	73.08
10466	125 krad	0.0156	0.0184	17.95
10468	125 krad	0.0155	0.017	9.68

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

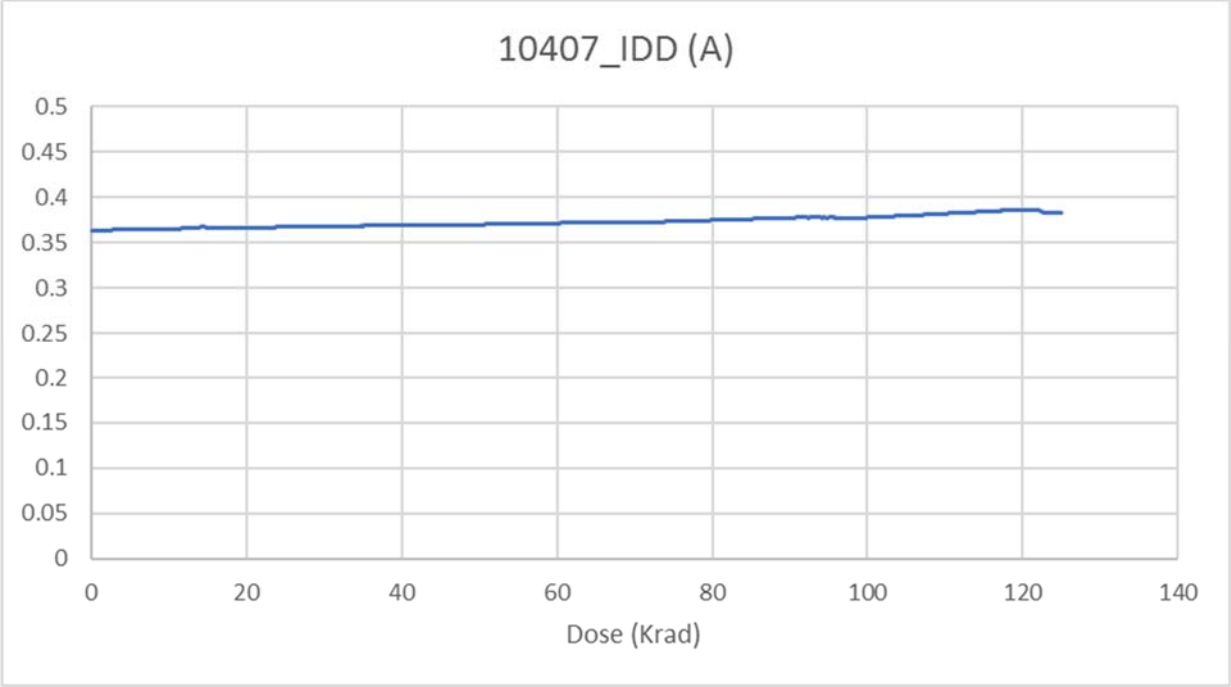

Fig. 2. DUT 10407 core power supply current (I_{DD}) versus TID

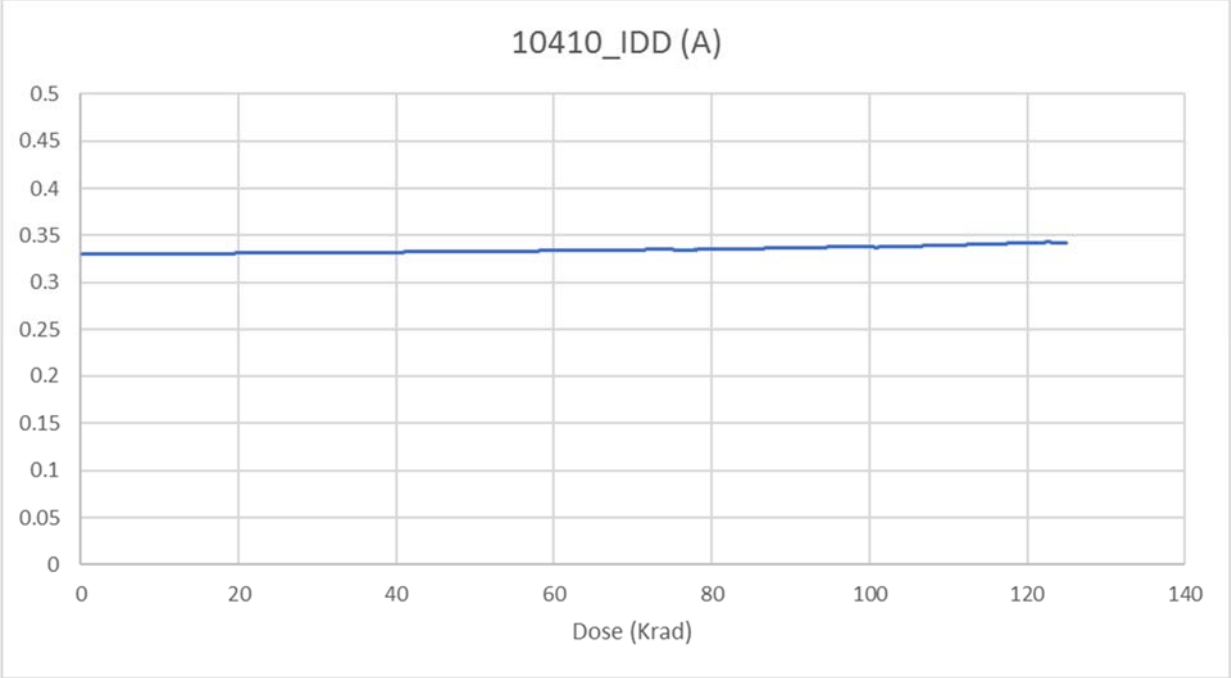

Fig. 3. DUT 10410 core power supply current (I_{DD}) versus TID

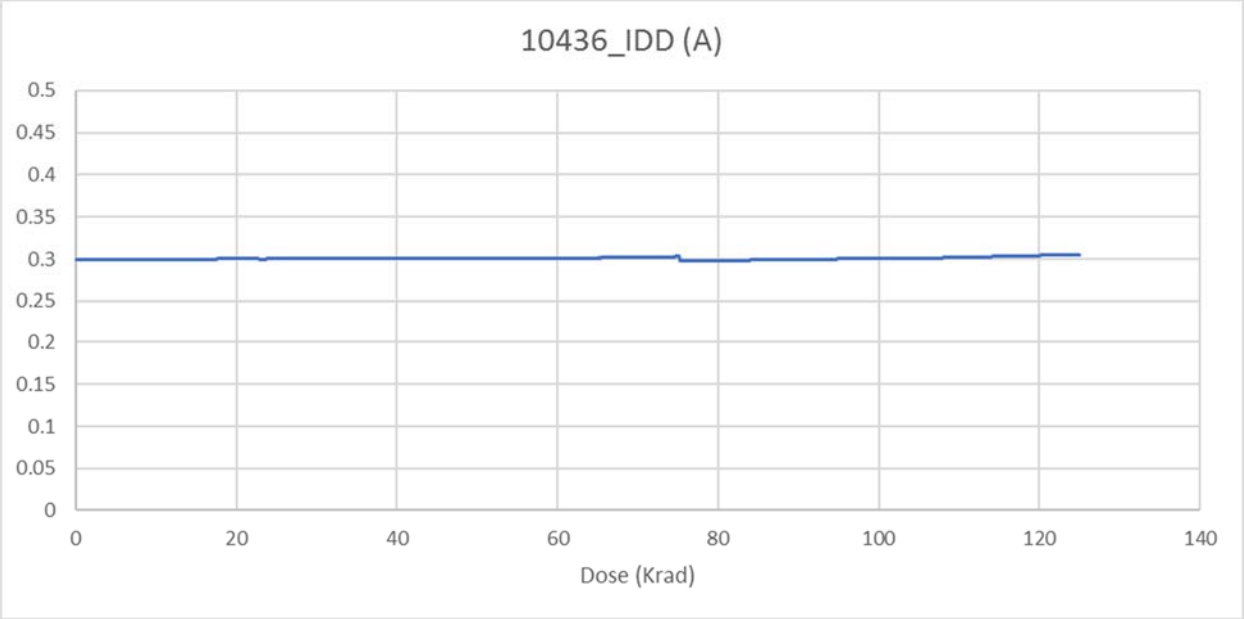

Fig. 4. DUT 10436 core power supply current (I_{DD}) versus TID

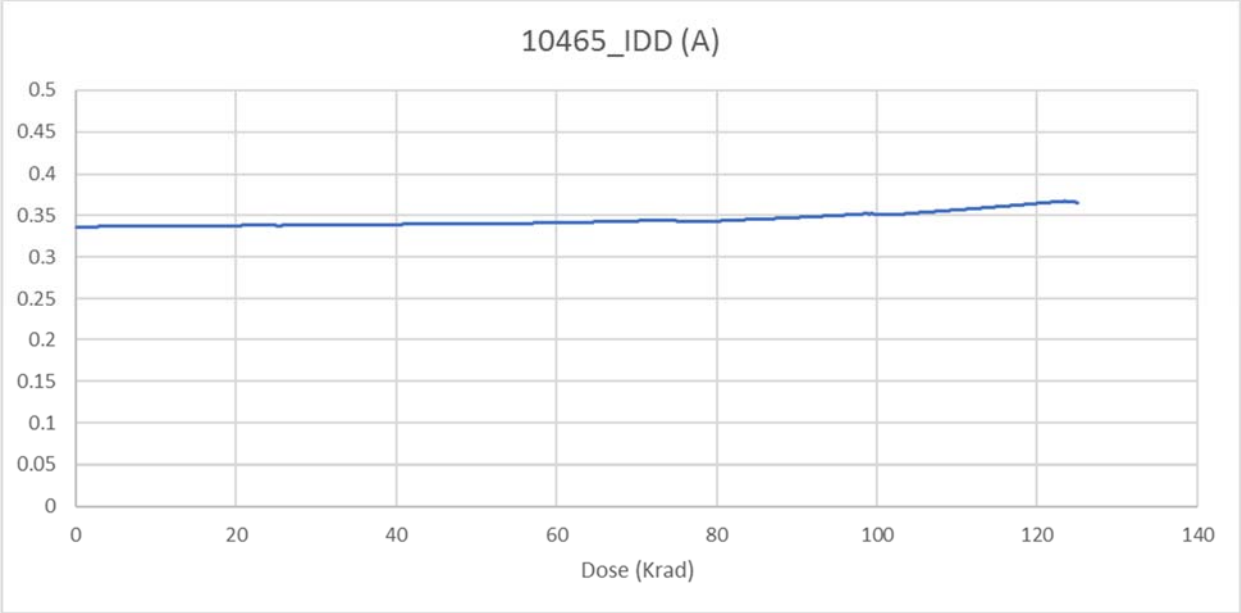

Fig. 5. DUT 10465 core power supply current (I_{DD}) versus TID

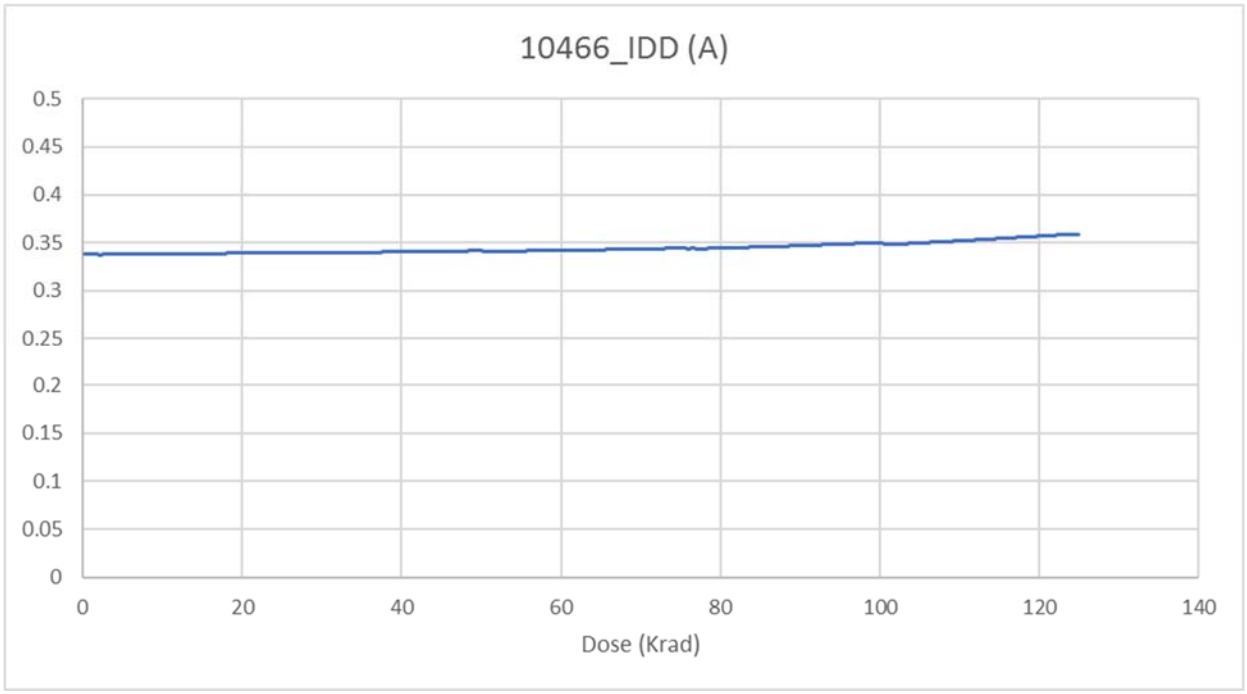

Fig. 6. DUT 10466 core power supply current (I_{DD}) versus TID

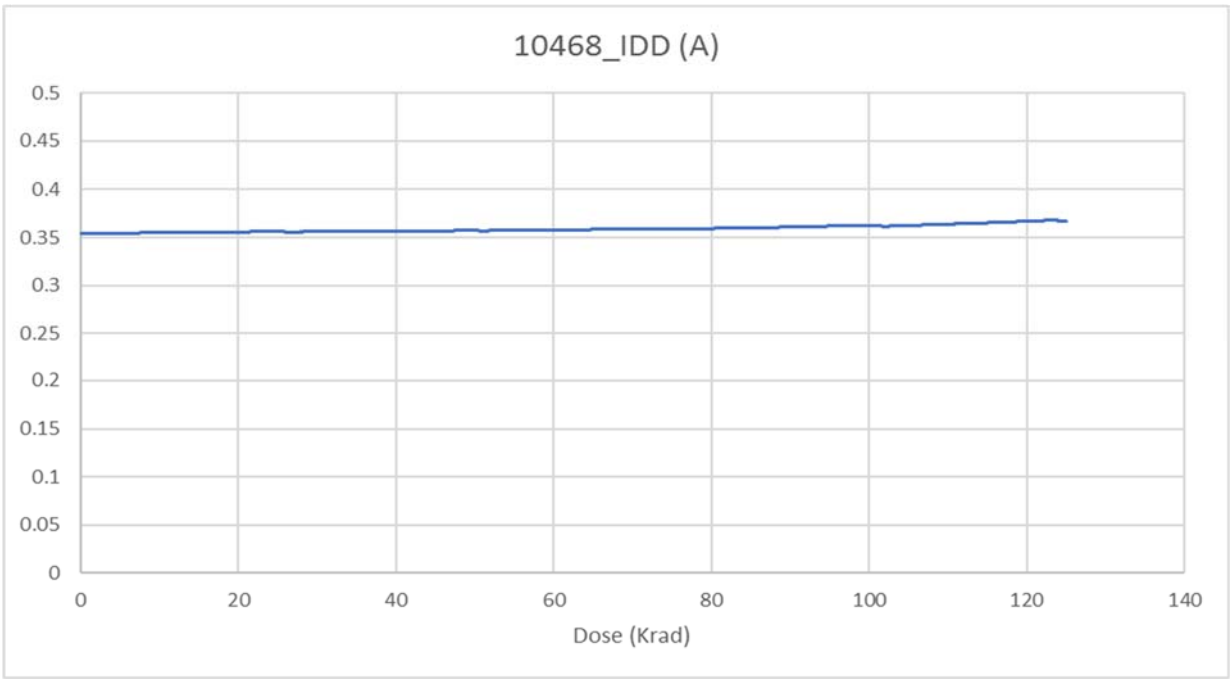

Fig. 7. DUT 10468 core power supply current (I_{DD}) versus TID

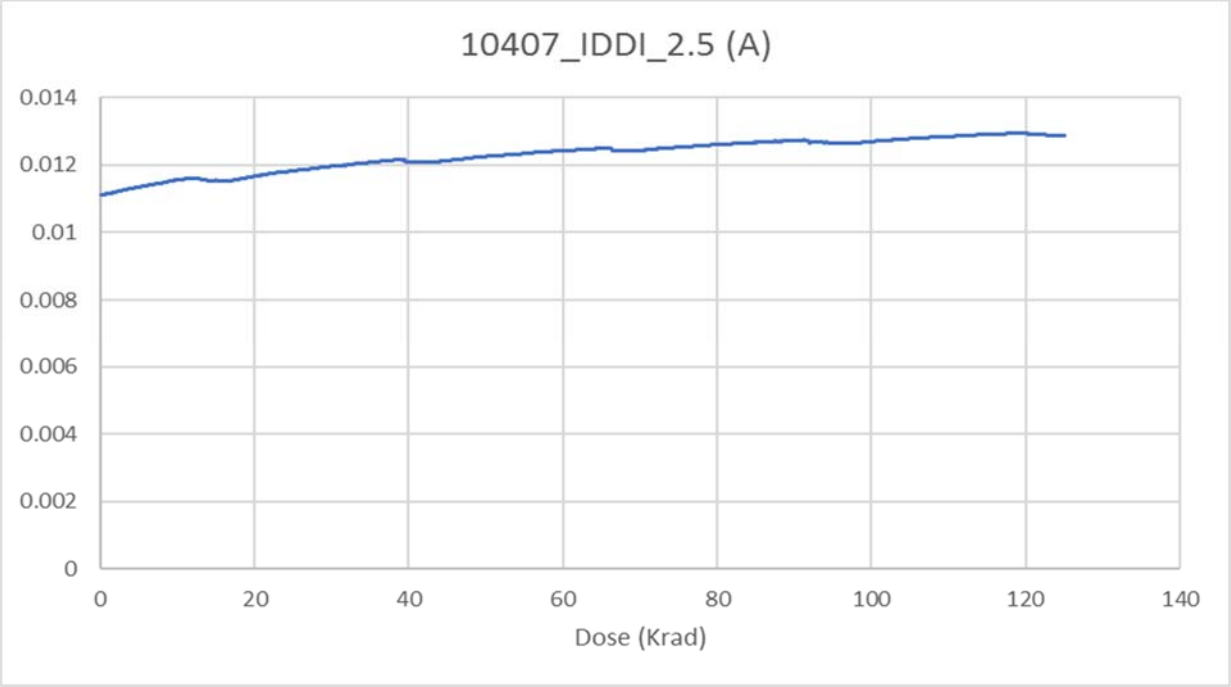

Fig. 8. DUT 10407 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

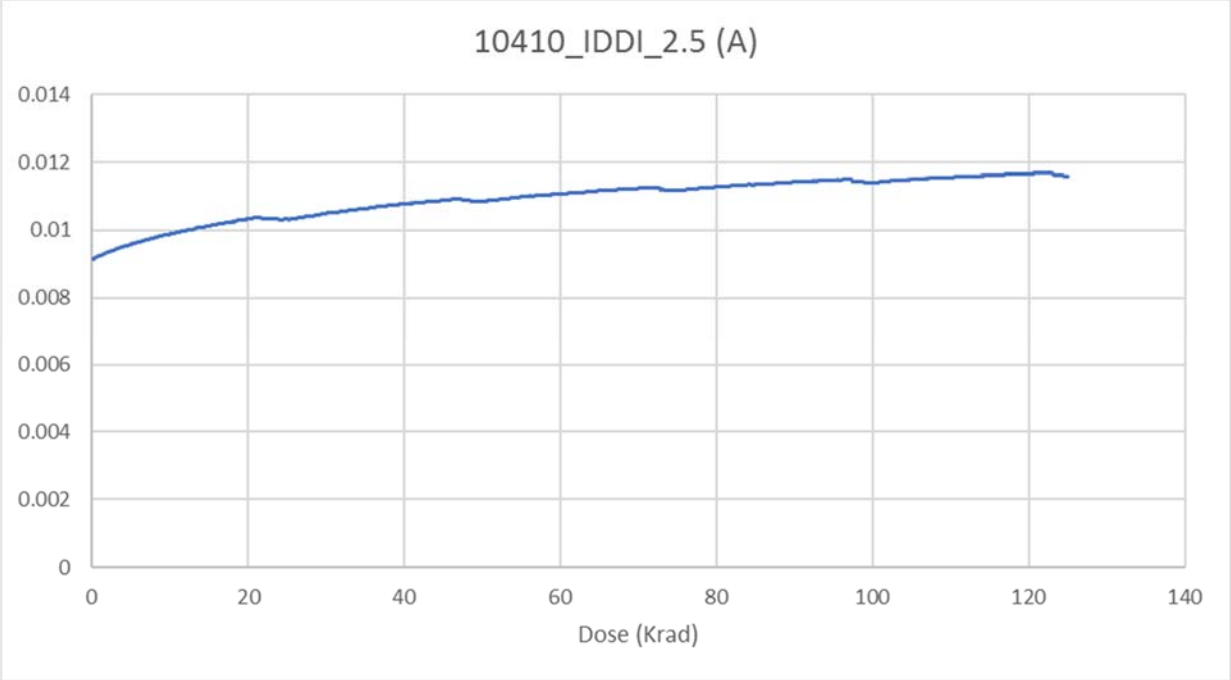

Fig. 9. DUT 10410 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

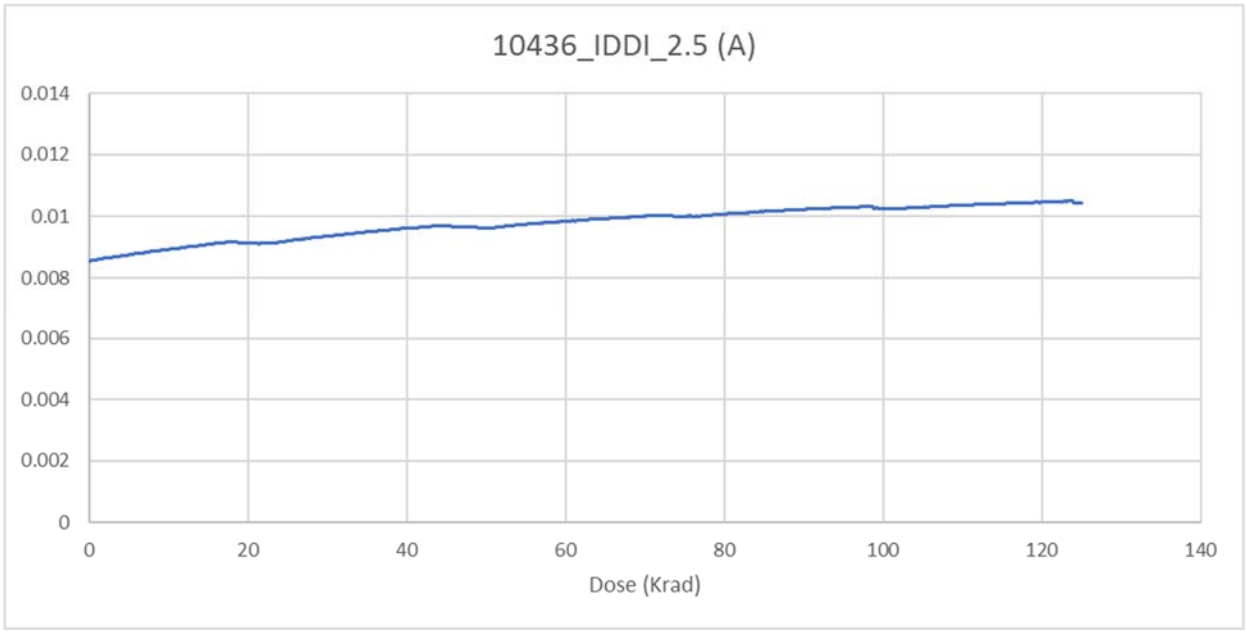

Fig. 10. DUT 10436 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

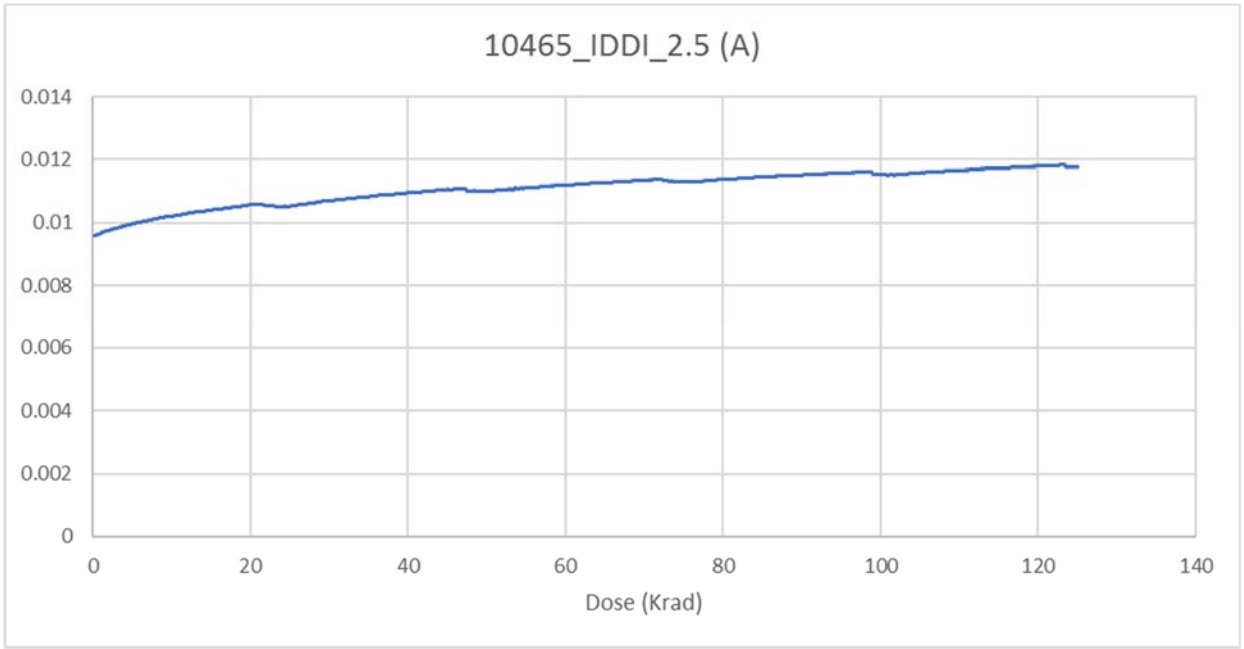

Fig. 11. DUT 10465 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

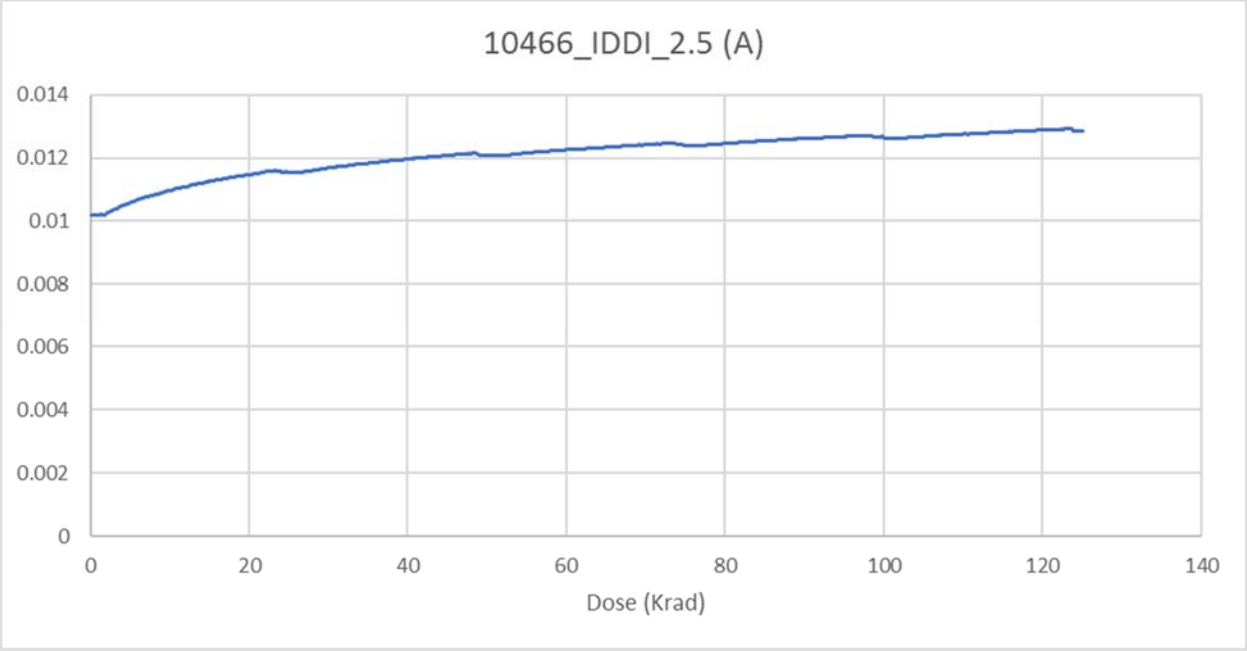

Fig. 12. DUT 10466 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

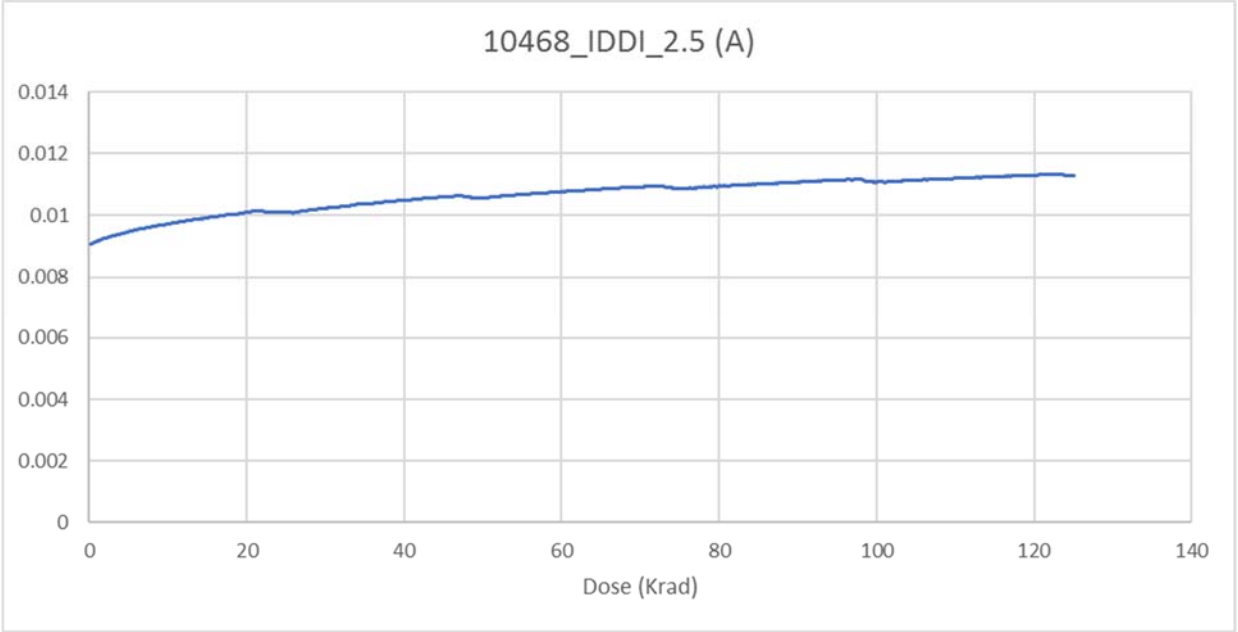

Fig. 13. DUT 10468 I/O bank 2.5V power supply current ($I_{DDI\_2.5}$) versus TID

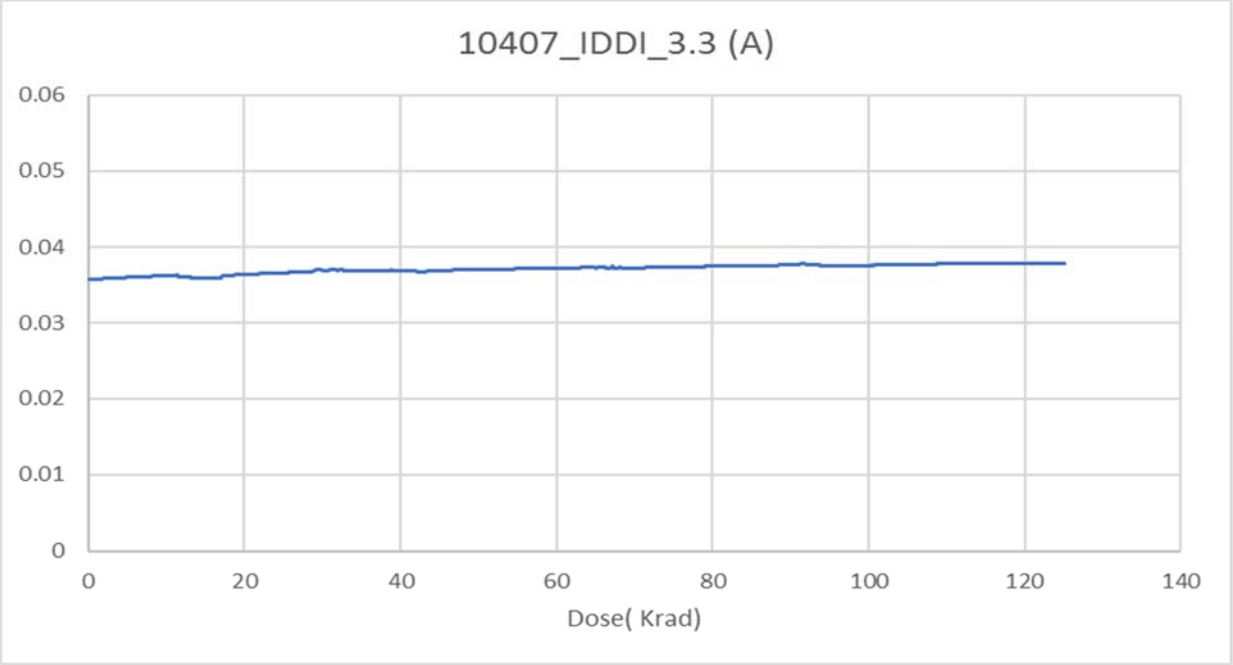

Fig. 14. DUT 10407 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

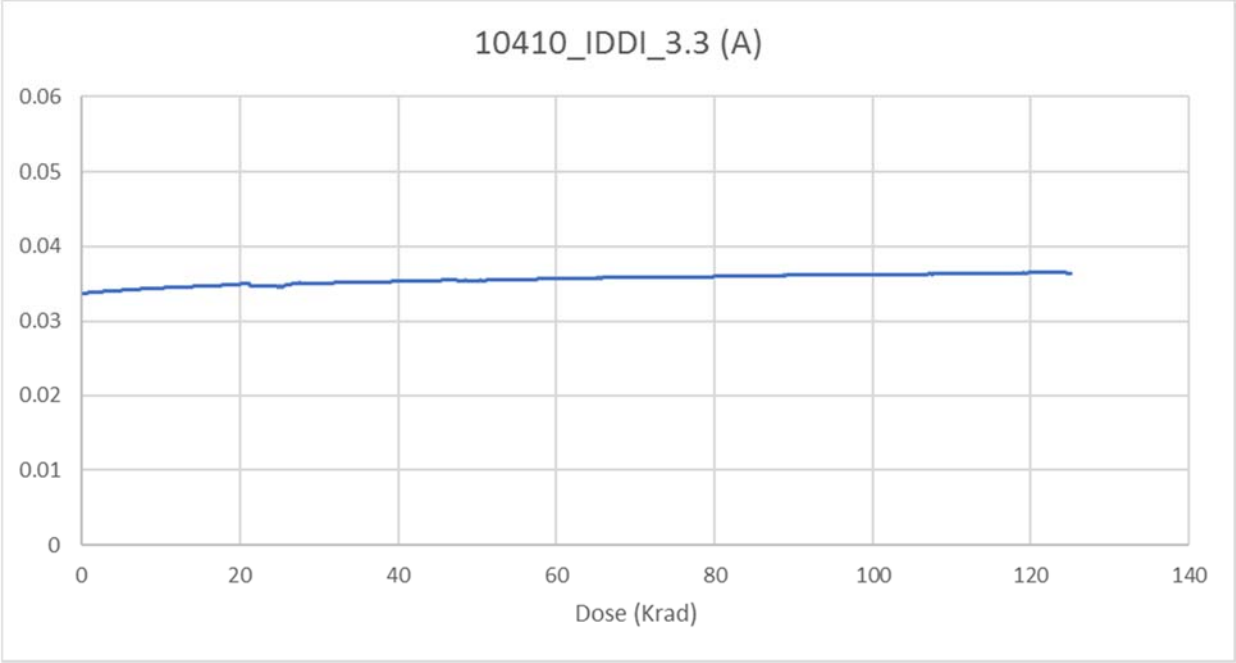

Fig. 15. DUT 10410 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

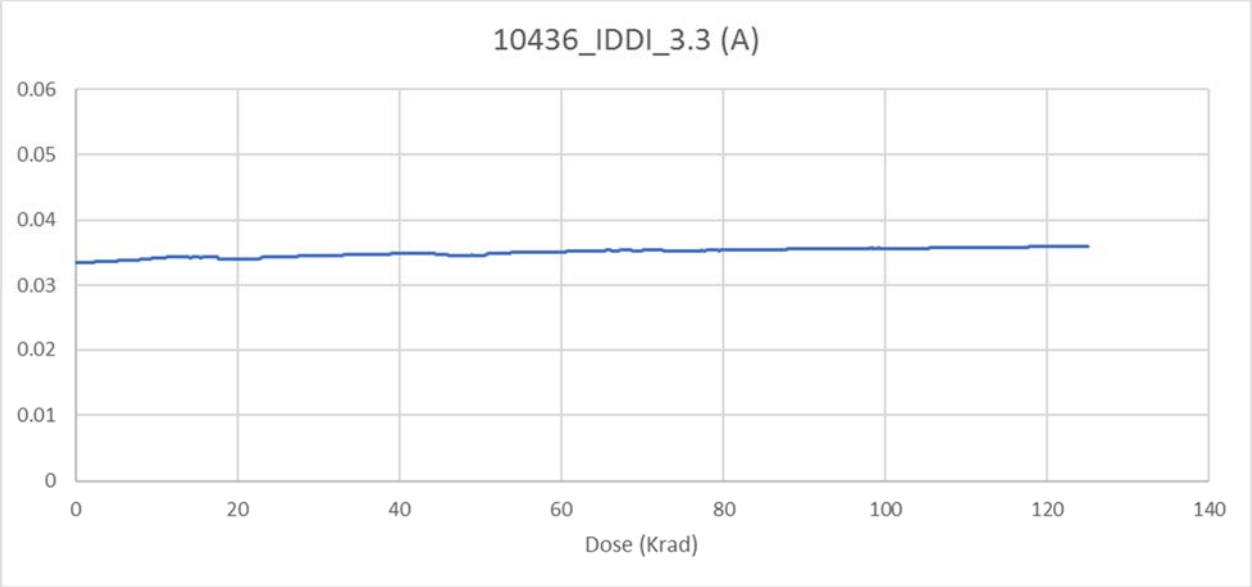

Fig. 16. DUT 10436 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

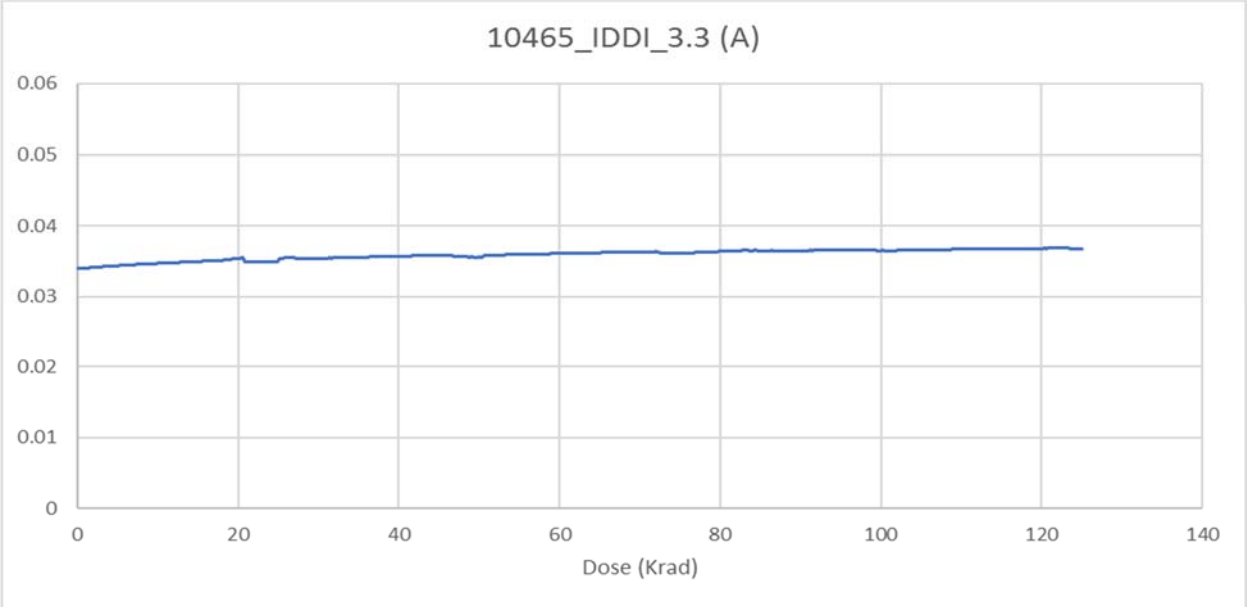

Fig. 17. DUT 10465 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

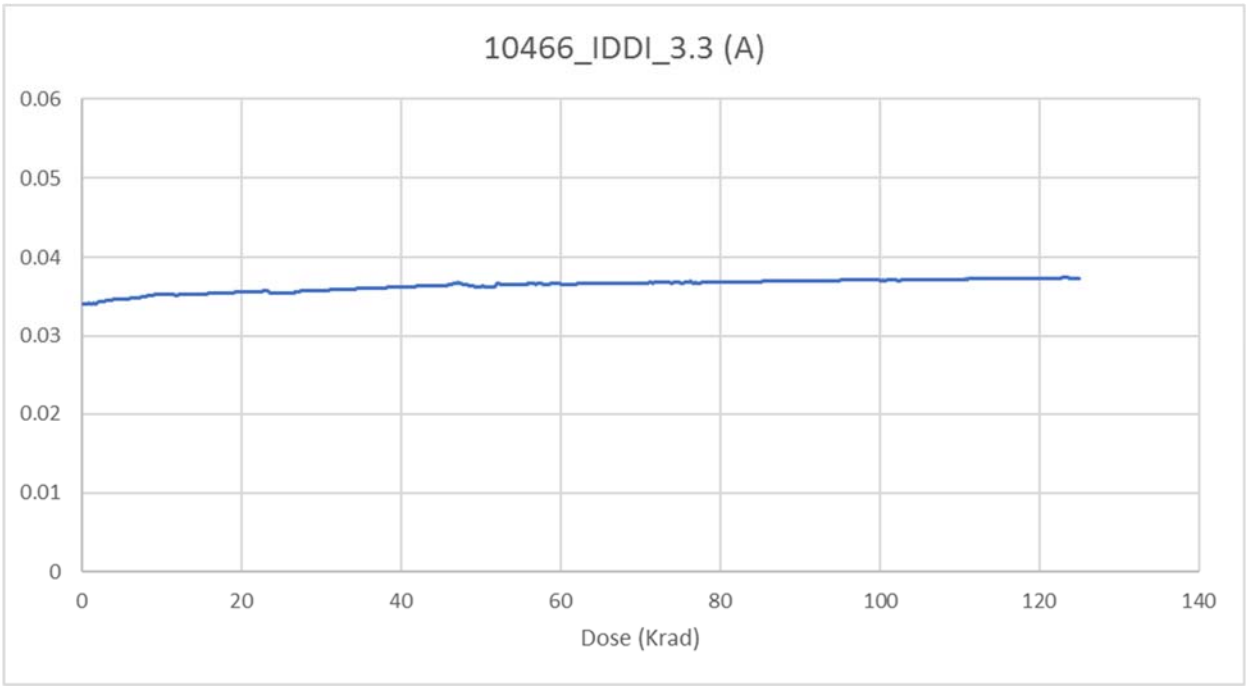

Fig. 18. DUT 10466 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

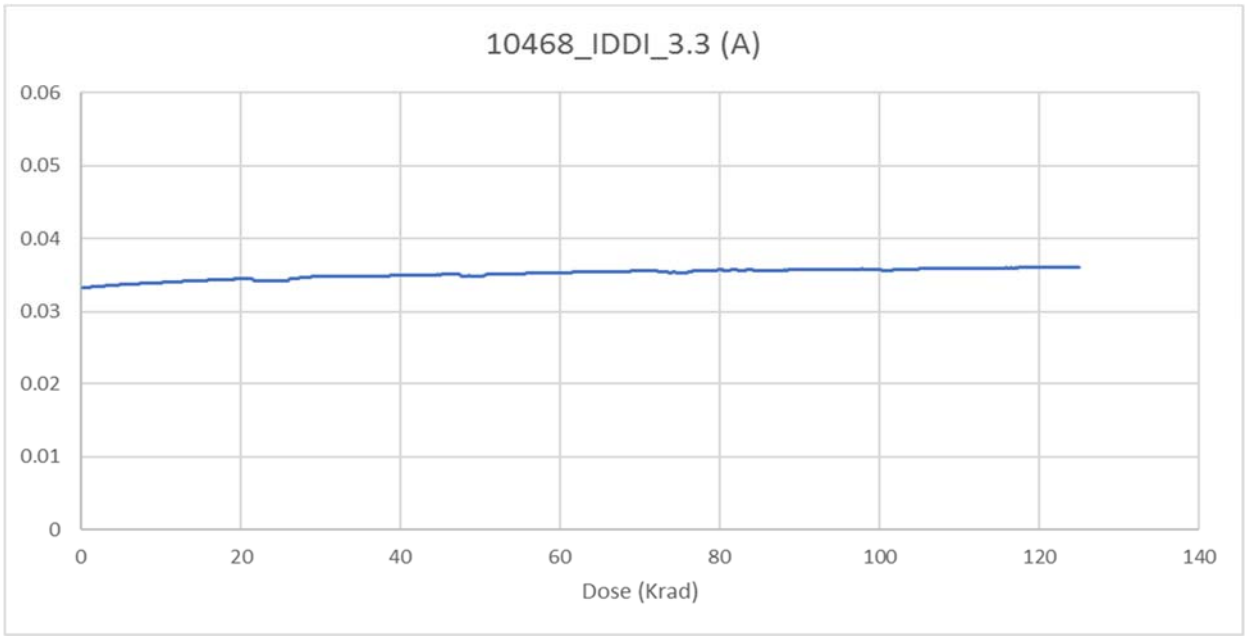

Fig. 19. DUT 10468 I/O bank 3.3V power supply current ($I_{DDI\_3.3}$) versus TID

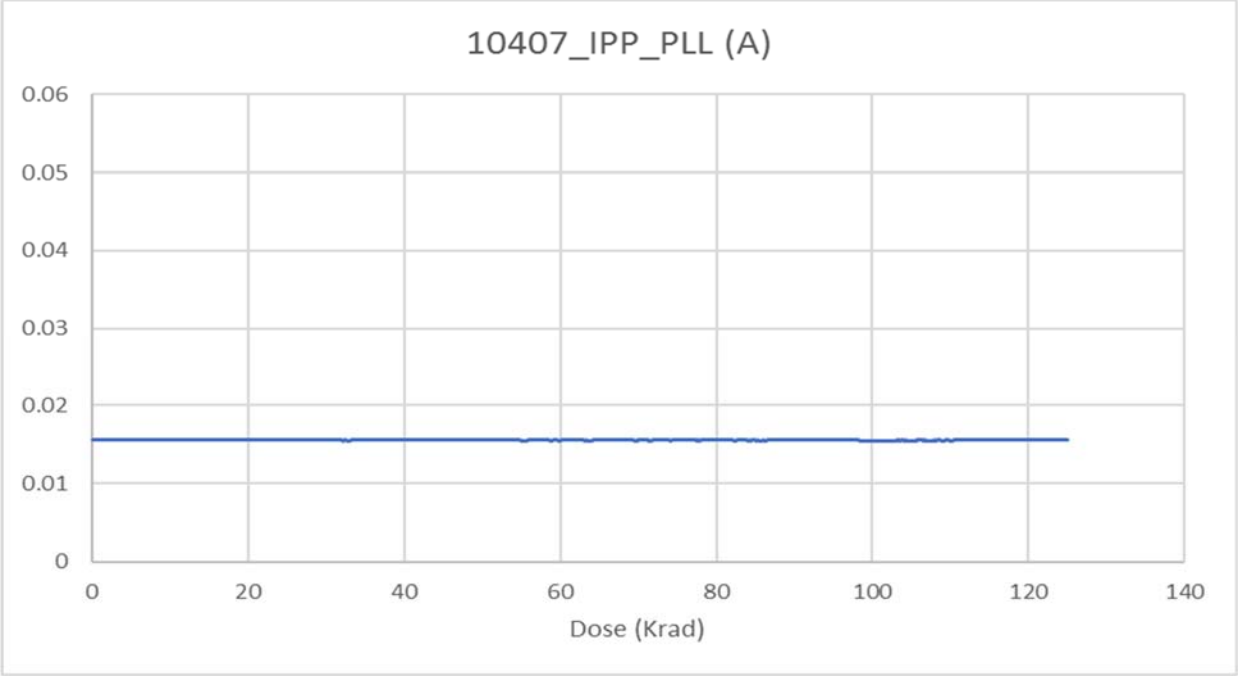

Fig. 20. DUT 10407 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

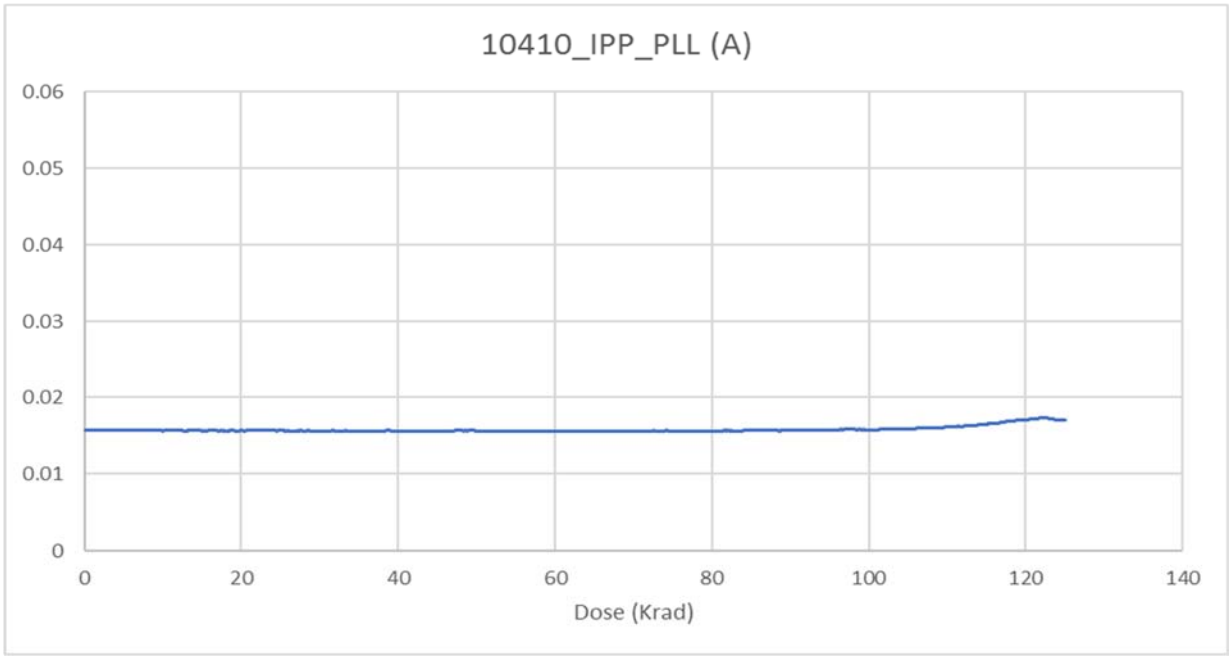

Fig. 21. DUT 10410 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

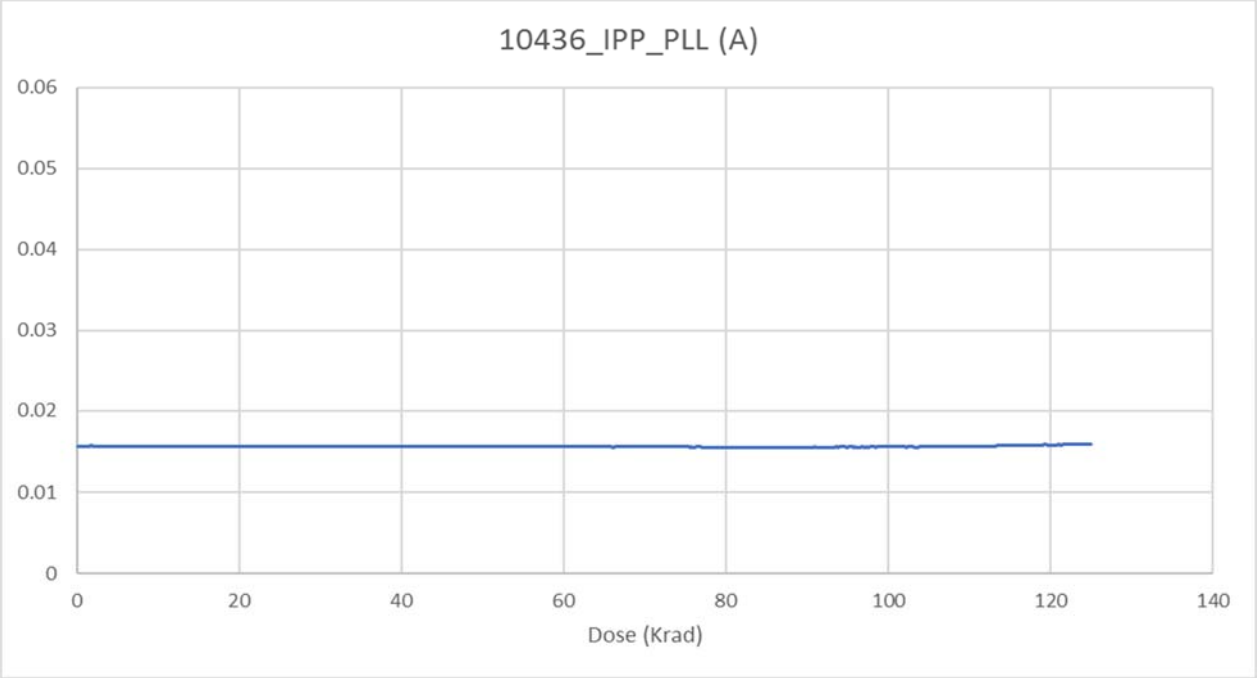

Fig. 22. DUT 10436 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

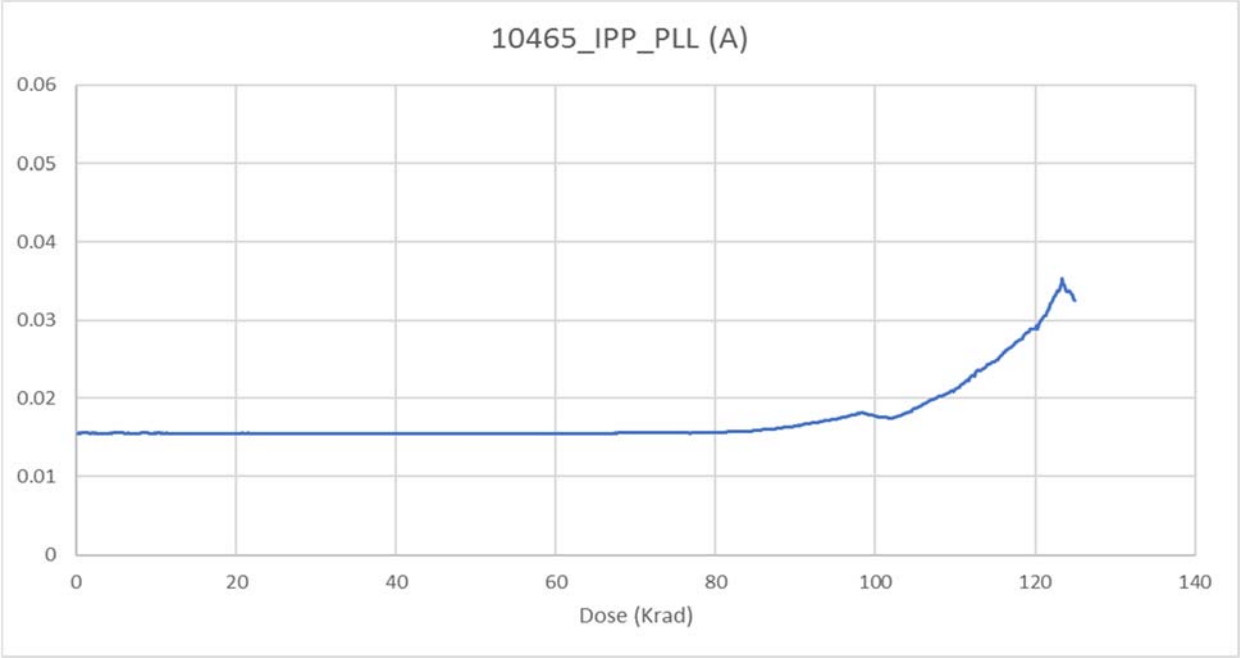

Fig. 23. DUT 10465 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

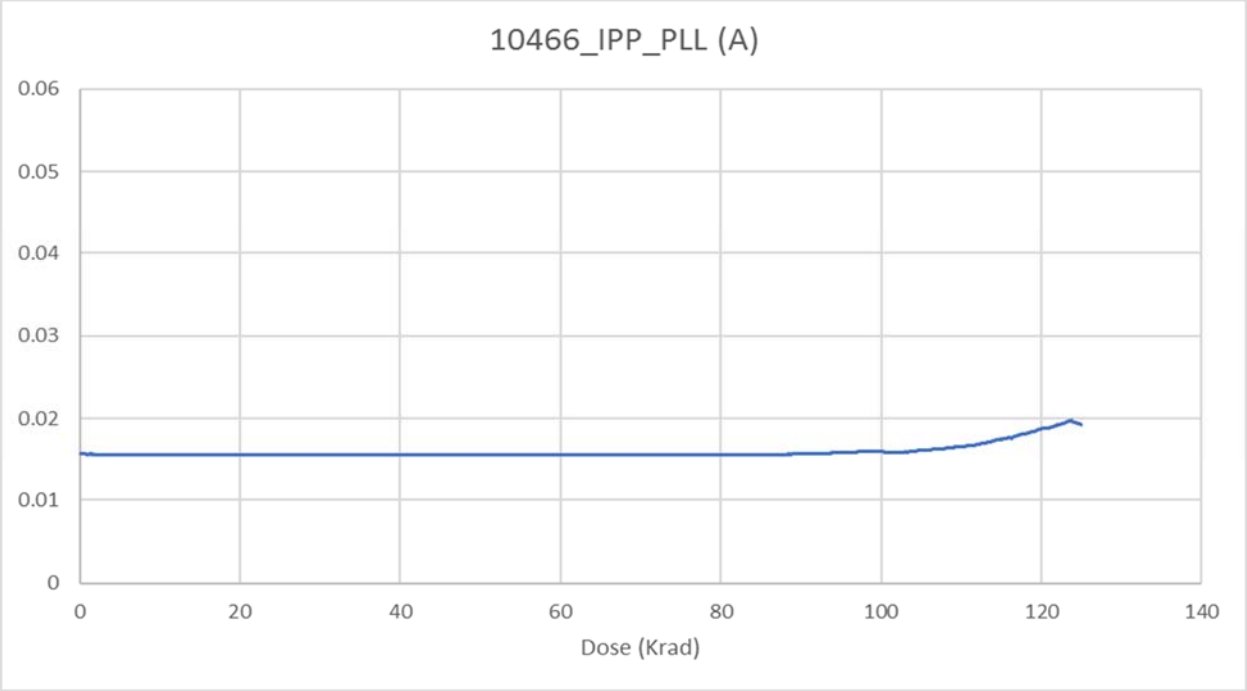

Fig. 24. DUT 10466 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

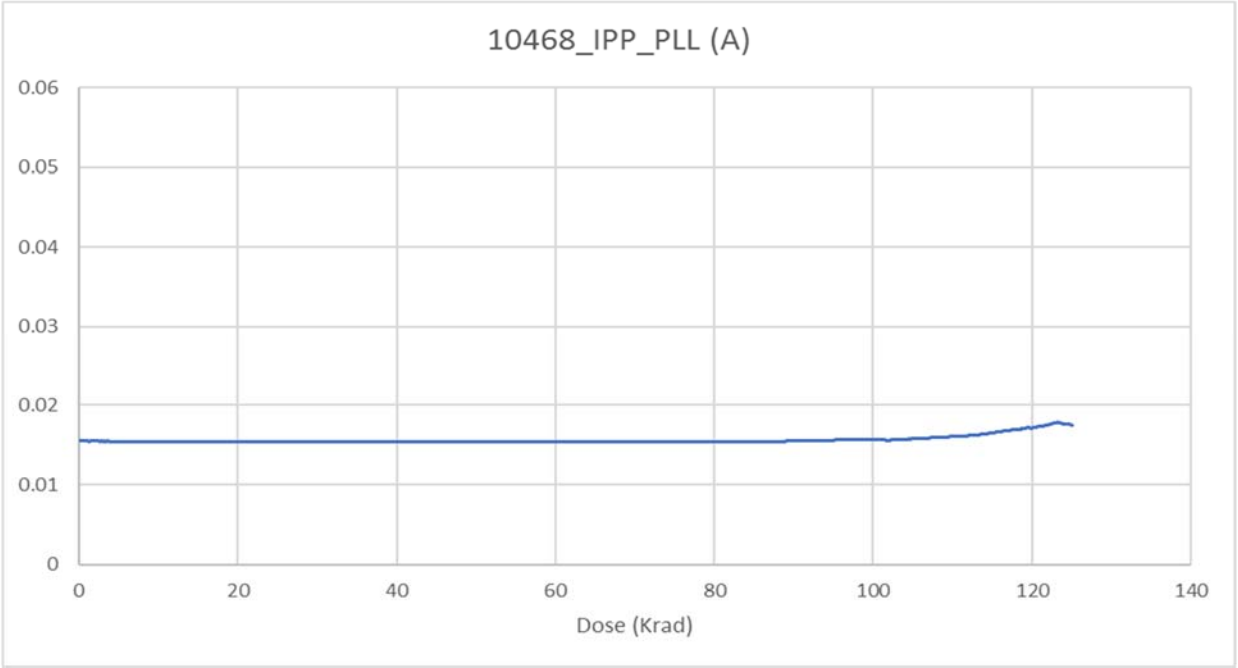

Fig. 25. DUT 10468 charge pump and PLL power supply current (I_{PP_PLL}) versus TID

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
10407	Passed	Passed
10410	Passed	Passed
10436	Passed	Passed
10465	Passed	Passed
10466	Passed	Passed
10468	Passed	Passed

Table. 8. VIL Summary

DUT	Pre-irradiation	Post-irradiation
10407	Passed	Passed
10410	Passed	Passed
10436	Passed	Passed
10465	Passed	Passed
10466	Passed	Passed
10468	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 10407

		2mA		4mA		6mA		8mA		12mA		14mA	
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	2.1268	2.1292	2.1963	2.1997	2.1666	2.1707	2.1466	2.1504	2.1122	2.1181	2.0979	2.1047
EPCSRST_N_0	B31	2.1276	2.1312	2.1951	2.2004	2.1643	2.1714	2.1428	2.1506	2.1067	2.1181	2.0909	2.1046
EPCSRST_N_1	B32	2.1302	2.1317	2.2001	2.2021	2.1717	2.1739	2.1514	2.1534	2.1203	2.1229	2.107	2.11
EPCSRST_N_2	B34	2.1279	2.1293	2.1985	2.2003	2.1693	2.1715	2.1486	2.1502	2.1166	2.1187	2.1028	2.1055
EPCSRST_N_3	B35	2.129	2.1302	2.2	2.2017	2.1718	2.1732	2.1516	2.1532	2.1213	2.1224	2.1083	2.1099
EPCSRST_N_4	B36	2.1275	2.1293	2.1968	2.1991	2.1668	2.1696	2.1453	2.1479	2.1113	2.1149	2.0969	2.1013
EPCSRST_N_5	B37	2.1284	2.1299	2.1983	2.2006	2.1694	2.1721	2.1485	2.1508	2.1164	2.1195	2.1024	2.1064
MONITOR	K23	2.1306	2.1295	2.2019	2.2012	2.1741	2.1734	2.1544	2.1533	2.1248	2.1233	2.1122	2.1109
PLL_MON	L20	2.1308	2.1303	2.2033	2.2027	2.1754	2.1755	2.1574	2.157	2.1237	2.1283	2.1169	2.1166
TOGGLE_MON	L22	2.1314	2.1311	2.2031	2.203	2.1756	2.1759	2.1561	2.1568	2.1269	2.1283	2.115	2.1164

Table. 10. LVCMOS 25 VOH – DUT 10410

		2mA		4mA		6mA		8mA		12mA		14mA	
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	2.1278	2.1298	2.1974	2.2	2.1679	2.1709	2.1474	2.1507	2.1135	2.1178	2.0991	2.1043
EPCSRST_N_0	B31	2.1283	2.1315	2.1956	2.2001	2.1649	2.171	2.1437	2.1503	2.1077	2.1175	2.0918	2.1039
EPCSRST_N_1	B32	2.1303	2.1317	2.2004	2.2022	2.1719	2.174	2.1519	2.1537	2.1204	2.1231	2.1072	2.1102
EPCSRST_N_2	B34	2.1296	2.1307	2.1992	2.2006	2.1699	2.1718	2.149	2.1508	2.1169	2.1188	2.103	2.1058
EPCSRST_N_3	B35	2.1302	2.1312	2.2005	2.2019	2.1721	2.1734	2.1522	2.1534	2.1216	2.1229	2.1084	2.1101
EPCSRST_N_4	B36	2.1287	2.1299	2.1972	2.1991	2.1671	2.1695	2.1451	2.1478	2.1113	2.1149	2.0968	2.1007
EPCSRST_N_5	B37	2.1293	2.1306	2.1987	2.2007	2.1697	2.1719	2.1487	2.151	2.1164	2.1191	2.1023	2.1058
MONITOR	K23	2.1311	2.1301	2.2022	2.2015	2.1746	2.1737	2.1552	2.1536	2.1253	2.1238	2.113	2.1115
PLL_MON	L20	2.1317	2.131	2.2036	2.2031	2.174	2.1757	2.1579	2.1573	2.1283	2.1283	2.1169	2.1165
TOGGLE_MON	L22	2.1319	2.1315	2.2032	2.203	2.1754	2.1758	2.1557	2.1567	2.1265	2.1277	2.1141	2.1159

Table. 11. LVCMOS 25 VOH – DUT 10436

		2mA		4mA		6mA		8mA		12mA		14mA	
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	2.1294	2.1317	2.1965	2.2	2.166	2.1704	2.1444	2.1495	2.1084	2.1155	2.0925	2.1013
EPCSRST_N_0	B31	2.1301	2.1331	2.1967	2.2007	2.1657	2.1713	2.1441	2.1503	2.1077	2.1161	2.0917	2.1021
EPCSRST_N_1	B32	2.132	2.1332	2.2004	2.2022	2.1718	2.1737	2.1508	2.1526	2.1185	2.1208	2.1047	2.1075
EPCSRST_N_2	B34	2.1308	2.132	2.1992	2.2008	2.1697	2.1715	2.1484	2.1502	2.1152	2.1172	2.101	2.1034
EPCSRST_N_3	B35	2.1318	2.1331	2.2007	2.2021	2.1721	2.1737	2.1515	2.153	2.1198	2.1215	2.1064	2.1079
EPCSRST_N_4	B36	2.1307	2.1321	2.1984	2.2006	2.1689	2.1712	2.1468	2.1493	2.1129	2.1163	2.0983	2.1022
EPCSRST_N_5	B37	2.1314	2.1326	2.2001	2.2019	2.1711	2.1731	2.1499	2.1523	2.1175	2.1204	2.1035	2.107
MONITOR	K23	2.1342	2.1329	2.2036	2.2031	2.1761	2.1752	2.1565	2.155	2.1267	2.1249	2.114	2.1124
PLL_MON	L20	2.1358	2.1341	2.2055	2.2046	2.1786	2.1777	2.1598	2.1594	2.1293	2.131	2.1193	2.1192
TOGGLE_MON	L22	2.1344	2.134	2.2048	2.2048	2.1778	2.1779	2.1583	2.159	2.1295	2.1307	2.1177	2.1192

Table. 12. LVCMOS 25 VOH – DUT 10465

		2mA		4mA		6mA		8mA		12mA		14mA	
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	2.1282	2.1303	2.1969	2.1998	2.1672	2.1704	2.1466	2.1495	2.1123	2.1164	2.0976	2.1029
EPCSRST_N_0	B31	2.1289	2.1321	2.1958	2.2005	2.1649	2.1713	2.1432	2.1504	2.107	2.1169	2.0912	2.1031
EPCSRST_N_1	B32	2.1309	2.1324	2.2002	2.2022	2.1717	2.1738	2.1512	2.1533	2.1198	2.1218	2.1061	2.1086
EPCSRST_N_2	B34	2.1293	2.1306	2.1986	2.2003	2.1693	2.1713	2.1487	2.1502	2.116	2.1181	2.1021	2.1046
EPCSRST_N_3	B35	2.1304	2.1319	2.2005	2.2021	2.1719	2.1736	2.1515	2.1531	2.1204	2.1222	2.1073	2.1093
EPCSRST_N_4	B36	2.1289	2.1304	2.1977	2.1997	2.1678	2.1701	2.1463	2.1488	2.1125	2.1157	2.0978	2.1017
EPCSRST_N_5	B37	2.1298	2.1314	2.1992	2.2012	2.1702	2.1723	2.1492	2.1515	2.1168	2.1195	2.1027	2.1061
MONITOR	K23	2.1321	2.131	2.2024	2.2017	2.1746	2.1738	2.1547	2.1536	2.1247	2.123	2.1119	2.1108
PLL_MON	L20	2.1337	2.1318	2.2042	2.2034	2.177	2.1763	2.1585	2.1578	2.1297	2.1291	2.1182	2.1173
TOGGLE_MON	L22	2.1325	2.1326	2.2032	2.2037	2.1757	2.1766	2.156	2.1579	2.1262	2.1294	2.1138	2.1176

Table. 13. LVCMOS 25 VOH – DUT 10466

		2mA		4mA		6mA		8mA		12mA		14mA	
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	2.1264	2.1286	2.1957	2.1987	2.1659	2.1691	2.1453	2.1484	2.1106	2.115	2.0958	2.1011
EPCSRST_N_0	B31	2.1265	2.1297	2.1942	2.1991	2.1635	2.1696	2.142	2.1486	2.1056	2.1154	2.0897	2.1016
EPCSRST_N_1	B32	2.1293	2.1304	2.1991	2.2008	2.1702	2.1723	2.1496	2.1516	2.1175	2.1201	2.104	2.107
EPCSRST_N_2	B34	2.1278	2.1293	2.1978	2.1996	2.1686	2.1703	2.1475	2.1492	2.1146	2.1168	2.1009	2.1035
EPCSRST_N_3	B35	2.1287	2.1301	2.1993	2.2004	2.1703	2.1718	2.15	2.1516	2.1193	2.1205	2.1058	2.1075
EPCSRST_N_4	B36	2.1279	2.1292	2.1967	2.1989	2.1671	2.1694	2.1455	2.148	2.1116	2.1148	2.097	2.1009
EPCSRST_N_5	B37	2.1284	2.1297	2.1978	2.1999	2.1689	2.1712	2.1478	2.1504	2.1154	2.1186	2.1018	2.1056
MONITOR	K23	2.1298	2.1286	2.2008	2.2003	2.1728	2.1719	2.1527	2.1514	2.1228	2.1208	2.1101	2.1084
PLL_MON	L20	2.13	2.1296	2.2025	2.2019	2.1753	2.1743	2.1564	2.1557	2.1276	2.1269	2.1158	2.1151
TOGGLE_MON	L22	2.1308	2.1303	2.2022	2.2022	2.1749	2.175	2.1554	2.1561	2.1262	2.1273	2.1144	2.1156

Table. 14. LVCMOS 25 VOH – DUT 10468

		2mA		4mA		6mA		8mA		12mA		14mA	
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	2.1285	2.1304	2.1968	2.2001	2.1669	2.1708	2.1463	2.1503	2.1113	2.117	2.0964	2.103
EPCSRST_N_0	B31	2.1293	2.1321	2.1965	2.2006	2.1662	2.1711	2.1449	2.1505	2.1087	2.1169	2.0933	2.1031
EPCSRST_N_1	B32	2.1312	2.1324	2.2005	2.2023	2.1718	2.1739	2.1511	2.1535	2.1195	2.1219	2.1058	2.109
EPCSRST_N_2	B34	2.1298	2.131	2.1991	2.201	2.17	2.1719	2.149	2.1509	2.1163	2.1185	2.1028	2.1052
EPCSRST_N_3	B35	2.1312	2.1324	2.2006	2.2025	2.1726	2.1739	2.1519	2.1537	2.121	2.1226	2.108	2.1097
EPCSRST_N_4	B36	2.1293	2.1305	2.1979	2.1999	2.1684	2.1708	2.1472	2.1492	2.1133	2.1166	2.0987	2.1027
EPCSRST_N_5	B37	2.1307	2.1323	2.1994	2.2015	2.1707	2.1731	2.1498	2.1522	2.1175	2.1204	2.1041	2.1075
MONITOR	K23	2.1321	2.1311	2.2024	2.2019	2.1747	2.1738	2.1553	2.1539	2.1251	2.1234	2.1125	2.1111
PLL_MON	L20	2.1329	2.1318	2.2042	2.2033	2.1771	2.1762	2.1585	2.1578	2.13	2.1291	2.1258	2.1174
TOGGLE_MON	L22	2.1326	2.1324	2.2037	2.2039	2.1766	2.1769	2.157	2.1582	2.1282	2.1298	2.116	2.1182

Table. 15. LVCMOS 25 VOL – DUT 10407

		2mA		4mA		6mA		8mA		12mA		14mA	
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	239.1748	238.6355	171.0573	169.6063	200.0692	197.5748	223.0976	218.6203	255.9182	249.9309	270.1853	262.998
EPCSRST_N_0	B31	238.4206	236.9267	172.3898	169.0158	202.5706	197.3109	226.831	218.6328	261.9519	250.1822	277.3251	263.5131
EPCSRST_N_1	B32	235.9967	235.4747	167.7331	167.0621	195.3122	194.4723	215.5352	214.1947	246.1522	244.2806	259.1195	256.8803
EPCSRST_N_2	B34	238.5575	238.3262	169.5031	169.1725	197.6596	197.0224	218.4224	217.599	250.0562	248.5014	263.2997	261.5157
EPCSRST_N_3	B35	237.8797	237.7358	168.1474	167.9037	195.6637	195.2135	215.6231	214.9735	245.7505	244.8962	258.3914	257.32
EPCSRST_N_4	B36	239.022	238.5524	171.4363	170.504	200.5594	198.9821	222.1758	220.0862	255.4038	252.2826	269.7394	266.0254
EPCSRST_N_5	B37	238.3316	237.7986	169.5784	168.7579	197.7726	196.6958	218.6735	217.0085	250.4579	248.0618	263.9273	261.076
MONITOR	K23	236.9069	236.8572	167.0073	167.3254	194.0348	194.5051	213.4855	213.8474	242.7873	242.9362	254.8498	255.3077
PLL_MON	L20	235.9224	235.7931	165.7616	165.6215	192.1442	192.0712	211.7646	211.6724	241.8048	239.2677	247.5363	250.8245
TOGGLE_MON	L22	235.7823	235.6335	166.0252	165.535	192.5982	191.7779	211.543	210.9483	240.3617	238.749	252.1427	250.1934

Table. 16. LVCMOS 25 VOL – DUT 10410

		2mA		4mA		6mA		8mA		12mA		14mA	
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	236.7362	236.3487	169.3981	168.2493	198.2214	196.2932	221.1493	217.5523	253.6807	249.0263	267.7719	262.1813
EPCSRST_N_0	B31	236.1328	235.1049	171.0699	168.3624	200.9365	196.6199	225.0963	218.0046	259.8275	249.7927	275.1505	263.2116
EPCSRST_N_1	B32	234.528	234.319	166.4653	166.0697	194.0444	193.2915	214.2799	213.039	244.7588	243.0621	257.7386	255.6618
EPCSRST_N_2	B34	235.4569	235.1104	168.2101	167.7404	196.3416	195.7034	216.916	215.9533	248.5372	246.8935	261.8812	260.1087
EPCSRST_N_3	B35	235.1808	234.9345	166.9297	166.5219	194.195	193.8694	214.1418	213.6419	244.3069	243.4892	256.8725	256.1768
EPCSRST_N_4	B36	236.7876	236.2912	170.1433	169.273	199.1786	197.9017	220.795	219.031	254.1485	251.3279	268.5092	265.1587
EPCSRST_N_5	B37	235.8837	235.55	168.2101	167.6022	196.5173	195.5024	217.4056	216.0413	249.3281	247.195	262.8477	260.2218
MONITOR	K23	235.0096	234.9732	165.5874	165.9187	192.5395	192.9351	211.8018	212.2774	240.9151	241.3285	253.0782	253.6247
PLL_MON	L20	234.8163	233.2879	164.3916	164.3374	190.749	190.5857	208.9742	210.1869	236.3372	237.8829	250.1381	249.5026
TOGGLE_MON	L22	234.0384	234.0757	165.1721	164.6053	191.8203	190.886	210.8906	210.1694	239.8473	238.1334	251.7788	249.7788

Table. 17. LVCMOS 25 VOL – DUT 10436

		2mA		4mA		6mA		8mA		12mA		14mA	
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	235.4541	234.4766	170.1774	167.9729	199.956	196.6199	223.965	218.3439	258.6711	251.024	273.9186	264.8952
EPCSRST_N_0	B31	234.1971	233.283	170.0014	167.6965	200.132	196.2178	224.4301	218.0298	259.8652	250.8733	275.5402	264.8198
EPCSRST_N_1	B32	232.4442	232.3844	166.0761	165.7431	193.969	193.3166	214.7569	213.8932	246.466	245.1725	260.1237	258.2998
EPCSRST_N_2	B34	233.9255	233.8793	167.8084	167.5269	196.2286	195.7411	217.3428	216.5312	249.7674	248.6648	263.739	262.2945
EPCSRST_N_3	B35	233.3606	233.1381	166.3146	166.2078	194.0067	193.7186	214.5812	213.956	245.7254	245.1097	258.881	257.9732
EPCSRST_N_4	B36	234.528	234.2562	168.5993	167.9917	197.5718	196.4571	219.1128	217.6492	252.4789	250.0466	266.8647	263.9025
EPCSRST_N_5	B37	233.7999	233.7537	167.0804	166.4968	195.262	194.3342	215.9244	214.8479	247.9598	245.8509	261.5799	259.1289
MONITOR	K23	231.8431	231.9462	164.0293	164.5119	190.8558	191.4153	210.2689	210.9335	239.533	240.0725	251.6834	252.6073
PLL_MON	L20	229.1979	230.4679	162.6822	162.5624	188.7003	188.6092	208.1447	208.0216	235.7213	235.5539	247.2723	246.9722
TOGGLE_MON	L22	231.3912	231.4251	163.0643	162.6959	189.4365	188.675	208.1304	207.6066	236.5351	235.0807	248.1781	246.4749

Table. 18. LVCMOS 25 VOL – DUT 10465

		2mA		4mA		6mA		8mA		12mA		14mA	
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	237.9932	237.5801	170.6048	169.6189	199.7424	198.0271	223.1605	219.5124	256.1948	251.602	270.6001	265.0586
EPCSRST_N_0	B31	237.3521	236.0472	171.9624	169.1037	202.2187	197.6376	226.6173	219.2988	261.8513	251.5266	277.4383	265.1339
EPCSRST_N_1	B32	235.6076	235.3239	167.595	167.1626	195.3373	194.6733	215.8365	215.0363	247.1941	245.7881	260.3873	258.6641
EPCSRST_N_2	B34	237.1139	236.8565	169.5031	169.1097	197.7475	197.1606	218.5731	217.8753	250.4704	249.2803	264.2662	262.684
EPCSRST_N_3	B35	236.4361	236.1405	167.7833	167.6022	195.4377	195.113	215.8616	215.3629	246.6543	245.8634	259.5965	258.5762
EPCSRST_N_4	B36	237.8797	237.6479	170.7584	169.8885	199.643	198.5047	221.1967	219.6089	254.4121	252.0942	268.7979	265.9375
EPCSRST_N_5	B37	237.0888	236.7057	169.0888	168.3183	197.396	196.4194	218.3596	216.9709	250.37	248.2879	263.9273	261.3147
MONITOR	K23	235.2106	235.149	166.2408	166.622	193.3814	193.8017	212.8824	213.659	242.6491	243.3004	254.9503	255.8226
PLL_MON	L20	234.854	234.2447	164.7561	164.7025	191.101	190.9886	210.5831	210.7786	238.4237	238.2983	249.4845	249.9055
TOGGLE_MON	L22	234.7159	234.4526	165.7617	164.8315	192.5731	190.8986	211.8316	209.9935	241.1647	237.7942	253.3973	249.3768

Table. 19. LVCMOS 25 VOL – DUT 10466

		2mA		4mA		6mA		8mA		12mA		14mA	
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	239.4262	238.9998	171.5979	170.4733	200.8485	199.0825	224.4049	220.8065	257.4392	252.7202	271.8823	266.3527
EPCSRST_N_0	B31	238.6469	237.7183	172.792	170.0335	203.0357	198.6428	227.3589	220.3542	262.8192	252.6449	278.2302	266.2522
EPCSRST_N_1	B32	236.6118	236.3917	168.4486	168.0168	196.3416	195.716	217.0667	216.0664	248.3615	246.8181	261.6803	259.5937
EPCSRST_N_2	B34	237.9927	237.8112	169.8922	169.6122	198.2999	197.7384	219.1882	218.5914	251.3366	250.1345	265.0069	263.3874
EPCSRST_N_3	B35	237.7542	237.673	168.8252	168.6198	196.5424	196.3441	216.8658	216.5814	247.7087	246.9689	260.5505	259.6942
EPCSRST_N_4	B36	238.4697	238.1252	171.0346	170.2779	199.9443	198.9067	221.4854	220.0485	254.864	252.559	269.1619	266.2139
EPCSRST_N_5	B37	238.3567	237.9996	169.9173	169.3232	198.3375	197.1355	219.2635	217.7999	250.9851	248.5517	264.5926	261.6162
MONITOR	K23	237.1959	237.3721	167.5601	168.0287	194.9772	195.5601	214.7672	215.3043	244.3705	244.9583	256.8603	257.5936
PLL_MON	L20	236.1235	236.196	166.101	166.1125	192.7601	192.5118	214.7057	212.3396	240.2211	240.086	251.9229	251.6931
TOGGLE_MON	L22	236.1211	236.1611	166.4267	165.9872	193.0624	192.3558	212.0323	211.5387	240.7256	239.3771	252.494	250.8592

Table. 20. LVCMOS 25 VOL – DUT 10468

		2mA		4mA		6mA		8mA		12mA		14mA	
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	236.6859	236.2482	170.0643	168.6263	199.1767	196.9591	222.5948	218.5952	255.9685	250.4586	270.5121	264.0534
EPCSRST_N_0	B31	235.3786	234.7908	170.3534	168.2619	200.1194	196.733	224.0907	218.4193	258.6585	250.7979	273.9438	264.3926
EPCSRST_N_1	B32	233.9757	233.9547	166.5155	166.2078	194.3456	193.6055	214.7695	213.9434	245.9639	244.6324	259.3705	257.5838
EPCSRST_N_2	B34	235.9967	236.1907	168.2478	168.0419	196.4796	196.03	217.3303	216.9457	249.4034	248.1874	262.9356	261.4277
EPCSRST_N_3	B35	234.7916	234.9722	167.0176	166.9616	194.446	194.3216	214.8197	214.5338	245.3488	244.8208	258.2784	257.521
EPCSRST_N_4	B36	236.9005	236.8062	169.8546	169.2604	198.5635	197.4998	219.9539	218.6667	252.9183	250.838	267.2539	264.4049
EPCSRST_N_5	B37	235.3565	235.2611	168.1474	167.6022	196.2914	195.2763	217.1671	215.8528	248.7883	246.7051	262.0946	259.5309
MONITOR	K23	234.419	234.5587	165.801	166.3583	192.8411	193.5003	212.4929	213.1314	241.7319	242.5468	254.0205	255.0314
PLL_MON	L20	229.927	233.0739	163.9642	164.1108	190.3594	190.2836	208.4338	210.0358	237.6318	237.5808	255.6057	249.0494
TOGGLE_MON	L22	233.524	233.8496	164.4695	164.2787	191.055	190.3207	209.8994	209.7297	238.2916	237.2792	250.2231	248.6105

Table. 21. LVTTL VOH – DUT 10407

		2mA		4mA		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
TID_BUF_OUT	A33	2.914	2.9175	2.9039	2.9081	2.8838	2.8897	2.8637	2.8714	2.8444	2.8534
EPCSRST_N_0	B31	2.914	2.9186	2.9029	2.9091	2.8805	2.8904	2.8579	2.8713	2.8365	2.8529
EPCSRST_N_1	B32	2.9169	2.9193	2.9079	2.9107	2.8901	2.8934	2.8728	2.8764	2.855	2.8593
EPCSRST_N_2	B34	2.9149	2.9169	2.9057	2.9084	2.8875	2.8903	2.8689	2.8721	2.8502	2.854
EPCSRST_N_3	B35	2.9159	2.918	2.9074	2.9096	2.8904	2.893	2.8736	2.8762	2.8565	2.8594
EPCSRST_N_4	B36	2.9146	2.9171	2.9041	2.9074	2.8839	2.8879	2.8635	2.8685	2.8434	2.8494
EPCSRST_N_5	B37	2.9151	2.9177	2.9061	2.9087	2.8875	2.8908	2.8687	2.873	2.85	2.855
MONITOR	K23	2.9179	2.9169	2.9099	2.909	2.8934	2.8929	2.8777	2.8764	2.8615	2.8602
PLL_MON	L20	2.9183	2.918	2.9121	2.9105	2.8965	2.8956	2.8813	2.8809	2.866	2.8664
TOGGLE_MON	L22	2.9191	2.9187	2.911	2.911	2.8957	2.8962	2.8801	2.881	2.8648	2.8665

Table. 22. LVTTL VOH – DUT 10410

		2mA		4mA		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
TID_BUF_OUT	A33	2.9152	2.9185	2.9055	2.9091	2.8855	2.8902	2.8655	2.8716	2.8462	2.8533
EPCSRST_N_0	B31	2.9152	2.9193	2.9037	2.9092	2.8815	2.89	2.8592	2.8711	2.8379	2.8523
EPCSRST_N_1	B32	2.917	2.9194	2.9084	2.9111	2.8905	2.8939	2.8731	2.8768	2.8555	2.8597
EPCSRST_N_2	B34	2.9165	2.9188	2.9068	2.9092	2.8882	2.8911	2.8694	2.8726	2.8507	2.8548
EPCSRST_N_3	B35	2.9172	2.9193	2.9088	2.9108	2.8913	2.8934	2.8743	2.8766	2.8571	2.8596
EPCSRST_N_4	B36	2.9154	2.918	2.9052	2.9081	2.8846	2.888	2.8642	2.8688	2.8435	2.8489
EPCSRST_N_5	B37	2.9161	2.9187	2.907	2.9095	2.8879	2.8911	2.8689	2.8729	2.8499	2.8546
MONITOR	K23	2.9186	2.9176	2.9108	2.9097	2.8945	2.8934	2.8783	2.8772	2.8623	2.8609
PLL_MON	L20	2.9195	2.9187	2.9121	2.9114	2.8958	2.8963	2.8821	2.8812	2.8676	2.8668
TOGGLE_MON	L22	2.9193	2.919	2.9116	2.9112	2.8956	2.8961	2.8798	2.8809	2.8639	2.8658

Table. 23. LVTTL VOH – DUT 10436

		2mA		4mA		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
TID_BUF_OUT	A33	2.9162	2.9198	2.905	2.9095	2.8823	2.8894	2.8598	2.8694	2.8381	2.8495
EPCSRST_N_0	B31	2.9167	2.9206	2.9054	2.9104	2.8823	2.8902	2.8595	2.87	2.8374	2.85
EPCSRST_N_1	B32	2.9187	2.921	2.9092	2.9118	2.8902	2.8931	2.8712	2.8748	2.8522	2.8564
EPCSRST_N_2	B34	2.9173	2.9197	2.9074	2.91	2.8877	2.8904	2.868	2.8709	2.8482	2.8518
EPCSRST_N_3	B35	2.9186	2.9207	2.9095	2.9116	2.891	2.8934	2.8726	2.8751	2.8543	2.857
EPCSRST_N_4	B36	2.9171	2.9198	2.9069	2.9099	2.8865	2.89	2.8659	2.87	2.845	2.8503
EPCSRST_N_5	B37	2.9181	2.9203	2.9085	2.9113	2.8896	2.8928	2.8702	2.8742	2.8511	2.8559
MONITOR	K23	2.9213	2.9202	2.9125	2.9117	2.8962	2.8953	2.8796	2.8785	2.8633	2.8617
PLL_MON	L20	2.9226	2.9212	2.9146	2.9138	2.8996	2.8985	2.8846	2.8835	2.8697	2.8693
TOGGLE_MON	L22	2.9217	2.9214	2.9137	2.9135	2.8985	2.8987	2.8831	2.884	2.8676	2.8692

Table. 24. LVTTL VOH – DUT 10465

		2mA		4mA		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
TID_BUF_OUT	A33	2.9153	2.9184	2.9052	2.9086	2.8847	2.8895	2.8638	2.87	2.8445	2.8511
EPCSRST_N_0	B31	2.9155	2.9197	2.904	2.9095	2.8811	2.89	2.8584	2.8704	2.8367	2.8514
EPCSRST_N_1	B32	2.9173	2.9199	2.9081	2.9107	2.8902	2.893	2.8719	2.8754	2.8537	2.8575
EPCSRST_N_2	B34	2.9161	2.9183	2.9062	2.9088	2.8872	2.8902	2.8684	2.8717	2.8492	2.853
EPCSRST_N_3	B35	2.917	2.9195	2.9085	2.9107	2.8907	2.893	2.873	2.8756	2.8553	2.8582
EPCSRST_N_4	B36	2.9155	2.918	2.9056	2.9084	2.8853	2.8889	2.8648	2.8693	2.8445	2.8497
EPCSRST_N_5	B37	2.9166	2.919	2.9072	2.91	2.8881	2.8914	2.8691	2.8733	2.85	2.8548
MONITOR	K23	2.9195	2.9185	2.9109	2.9101	2.8943	2.8934	2.8777	2.8765	2.8609	2.8597
PLL_MON	L20	2.9198	2.9192	2.9126	2.9116	2.8978	2.8967	2.8824	2.8818	2.8678	2.8673
TOGGLE_MON	L22	2.9201	2.9202	2.9116	2.9124	2.8956	2.8973	2.8796	2.8824	2.8633	2.8676

Table. 25. LVTTL VOH – DUT 10466

		2mA		4mA		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
TID_BUF_OUT	A33	2.9136	2.9167	2.9032	2.9068	2.8827	2.8876	2.8622	2.8684	2.8425	2.8496
EPCSRST_N_0	B31	2.9133	2.9174	2.902	2.9076	2.8794	2.8879	2.8565	2.8686	2.835	2.8494
EPCSRST_N_1	B32	2.916	2.9182	2.9068	2.9092	2.8884	2.8915	2.8701	2.8737	2.8515	2.8556
EPCSRST_N_2	B34	2.9148	2.9171	2.9051	2.9075	2.8861	2.8889	2.8672	2.8702	2.848	2.8516
EPCSRST_N_3	B35	2.9155	2.9175	2.9065	2.9088	2.8889	2.8913	2.8712	2.8738	2.8537	2.8564
EPCSRST_N_4	B36	2.9145	2.9168	2.9043	2.907	2.8842	2.8878	2.8641	2.8683	2.8437	2.8489
EPCSRST_N_5	B37	2.9148	2.9174	2.9055	2.9082	2.8864	2.89	2.8677	2.872	2.8489	2.8541
MONITOR	K23	2.9171	2.916	2.9087	2.9078	2.892	2.8908	2.8754	2.8741	2.8589	2.8574
PLL_MON	L20	2.918	2.917	2.9102	2.9094	2.8954	2.8941	2.8805	2.8794	2.8643	2.865
TOGGLE_MON	L22	2.9182	2.9177	2.9102	2.9099	2.8948	2.8951	2.8792	2.8802	2.864	2.8656

Table. 26. LVTTL VOH – DUT 10468

		2mA		4mA		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
TID_BUF_OUT	A33	2.9157	2.919	2.9054	2.9092	2.8842	2.8899	2.8631	2.8705	2.8428	2.8517
EPCSRST_N_0	B31	2.9164	2.9203	2.905	2.91	2.8826	2.8903	2.8605	2.8706	2.8392	2.8513
EPCSRST_N_1	B32	2.9179	2.9202	2.9089	2.9115	2.8904	2.8936	2.8721	2.8761	2.8538	2.8581
EPCSRST_N_2	B34	2.9164	2.9187	2.9071	2.9095	2.8883	2.8911	2.8692	2.8726	2.8501	2.8538
EPCSRST_N_3	B35	2.9181	2.9202	2.9091	2.9111	2.8913	2.8938	2.8737	2.8765	2.8562	2.8591
EPCSRST_N_4	B36	2.9162	2.9186	2.9064	2.909	2.8859	2.8894	2.866	2.8702	2.8457	2.8509
EPCSRST_N_5	B37	2.9177	2.92	2.9078	2.9107	2.8891	2.8925	2.8702	2.8743	2.8515	2.8566
MONITOR	K23	2.9197	2.9186	2.9111	2.9103	2.8945	2.8938	2.8781	2.8769	2.8617	2.8604
PLL_MON	L20	2.9197	2.9194	2.9122	2.912	2.8981	2.897	2.8829	2.8823	2.8682	2.8676
TOGGLE_MON	L22	2.9199	2.9199	2.9125	2.9124	2.8968	2.8976	2.8816	2.8829	2.8663	2.8682

Table. 27. LVTTL VOL – DUT 10407

		2mA		4mA		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
TID_BUF_OUT	A33	218.9607	218.1929	232.4079	227.8853	247.9551	244.4874	268.2982	262.3401	289.7444	281.606
EPCSRST_N_0	B31	218.4279	216.8798	233.1601	227.1662	251.6225	244.1434	273.6582	262.8403	297.7013	282.4729
EPCSRST_N_1	B32	216.0625	215.6192	224.8429	223.5565	241.8412	240.3375	259.4645	257.4935	277.2085	274.6681
EPCSRST_N_2	B34	218.6872	217.9629	227.4364	226.0878	245.0597	243.8375	262.933	261.6497	282.0037	279.9818
EPCSRST_N_3	B35	217.8748	217.4317	226.1553	225.119	242.1225	241.3375	259.1521	258.1185	276.3549	275.1078
EPCSRST_N_4	B36	219.0934	218.3379	229.155	227.369	248.8718	246.7437	268.9011	265.7121	289.2469	284.994
EPCSRST_N_5	B37	218.406	217.5879	227.4051	225.5565	245.1847	243.4312	263.7454	261.4622	282.5561	279.2784
MONITOR	K23	216.5197	216.4675	224.4295	224.3118	239.7489	240.3755	255.5997	256.3141	272.2399	272.7534
PLL_MON	L20	215.6298	215.4852	225.6921	223.7687	237.2857	237.0535	252.0979	251.4949	268.1873	267.4421
TOGGLE_MON	L22	215.8967	215.2195	223.0606	223.0654	238.2956	236.8817	253.7808	251.5732	269.3561	266.9768

Table. 28. LVTTL VOL – DUT 10410

		2mA		4mA		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
TID_BUF_OUT	A33	216.6412	216.1294	229.9316	225.9468	245.6669	242.9866	265.3831	261.2458	286.9287	280.7516
EPCSRST_N_0	B31	216.4218	215.1289	231.2794	225.6654	249.6478	243.0491	271.5894	262.215	295.4638	281.9201
EPCSRST_N_1	B32	214.9063	214.4942	223.718	222.3378	240.4039	239.1188	257.6522	255.9623	275.7146	273.236
EPCSRST_N_2	B34	215.6875	215.0254	225.1241	224.1503	243.0911	242.15	261.7768	260.0247	280.4974	278.4367
EPCSRST_N_3	B35	215.375	214.7442	223.9055	222.8378	240.4664	239.775	257.4023	256.681	274.7606	273.8767
EPCSRST_N_4	B36	217.2499	216.2129	227.4364	225.619	247.1845	245.0249	267.3388	264.3059	288.0794	284.2403
EPCSRST_N_5	B37	216.0625	215.4629	225.3741	224.244	243.5911	242.0875	262.3393	260.2122	281.5769	278.5372
MONITOR	K23	214.9565	214.8736	222.6162	222.3429	238.0606	238.5628	253.7239	254.7203	270.3677	270.9323
PLL_MON	L20	213.6299	213.2346	221.8797	222.0182	235.7545	235.2406	250.7229	250.0571	266.8173	265.9944
TOGGLE_MON	L22	214.3013	214.1255	221.5903	221.9088	237.1381	235.8189	252.9987	250.823	269.1428	266.4115

Table. 29. LVTTL VOL – DUT 10436

		2mA		4mA		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
TID_BUF_OUT	A33	215.6068	214.5661	230.057	225.384	248.2059	243.4243	270.6804	263.4656	294.6719	284.0811
EPCSRST_N_0	B31	214.7605	213.5656	229.4928	224.5399	248.3626	242.9866	271.37	263.1842	295.8535	284.1691
EPCSRST_N_1	B32	213.0315	212.7442	222.3431	221.3378	240.5914	239.3375	259.4645	257.8997	278.765	276.5398
EPCSRST_N_2	B34	214.4376	214.1505	224.3742	223.5565	243.2786	242.4312	262.9017	261.6809	282.782	281.2003
EPCSRST_N_3	B35	213.9689	213.3692	223.0618	222.0566	240.3726	239.9	258.7459	257.806	277.334	276.1881
EPCSRST_N_4	B36	214.8126	214.3067	225.1554	224.0253	244.9972	243.4937	265.6202	262.9622	286.5479	282.9716
EPCSRST_N_5	B37	214.5314	213.838	223.6868	222.5878	241.9975	240.4	261.1206	258.7747	280.2337	277.3061
MONITOR	K23	212.049	212.3109	220.3339	220.4052	235.9659	236.7189	252.317	253.2514	269.1238	269.9023
PLL_MON	L20	213.8486	210.7027	218.5673	219.7051	236.5669	232.9899	248.0042	247.6814	263.9264	263.3884
TOGGLE_MON	L22	211.736	211.5935	219.025	219.8145	234.4164	232.9118	249.6827	247.8222	265.3037	263.0573

Table. 30. LVTTL VOL – DUT 10465

		2mA		4mA		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
TID_BUF_OUT	A33	217.8323	217.1924	231.5929	227.729	247.3282	244.9251	267.8593	263.9033	289.8324	283.8047
EPCSRST_N_0	B31	217.3621	215.7542	232.5019	226.7285	250.9016	244.4561	273.3761	263.6845	297.8144	284.056
EPCSRST_N_1	B32	215.75	215.1504	224.9054	223.9315	241.8412	240.8688	259.9333	258.6185	278.6646	276.6026
EPCSRST_N_2	B34	217.2186	216.7442	226.8427	225.9628	245.0284	244.15	263.9641	262.1497	282.9578	281.1249
EPCSRST_N_3	B35	216.125	215.9317	225.0616	224.3378	242.0287	241.1813	259.4958	258.681	277.6729	276.3011
EPCSRST_N_4	B36	217.9061	217.3379	227.8114	226.869	247.3407	245.4937	267.3075	264.8684	288.1673	284.7051
EPCSRST_N_5	B37	217.3124	216.3379	226.374	224.9628	244.591	242.775	263.6516	261.0872	282.644	279.6301
MONITOR	K23	214.8315	215.0298	223.3353	223.4992	238.9048	239.7192	255.3184	256.4704	272.3907	273.2809
PLL_MON	L20	213.8799	213.891	222.3797	222.6434	235.8482	235.5531	250.6604	250.2759	266.8676	266.3972
TOGGLE_MON	L22	214.6141	213.9067	221.9657	222.0964	238.1392	235.6001	254.1562	250.2291	270.4225	265.8085

Table. 31. LVTTL VOL – DUT 10466

		2mA		4mA		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
TID_BUF_OUT	A33	219.4936	218.5994	232.9094	229.0109	249.1462	246.4258	269.4893	265.1852	291.5922	285.2622
EPCSRST_N_0	B31	219.0548	217.4426	233.9438	228.1354	252.5002	245.8318	274.818	265.1852	298.9583	285.3878
EPCSRST_N_1	B32	217.0311	216.4004	225.999	225.2128	243.2786	242.2437	261.4956	259.806	280.2463	277.9216
EPCSRST_N_2	B34	218.1873	217.8691	227.6551	226.8065	245.7159	244.7437	264.7141	263.3372	284.0499	282.2304
EPCSRST_N_3	B35	217.8436	217.4942	226.6865	225.8378	243.7161	242.9937	261.1519	260.0872	278.8529	277.9342
EPCSRST_N_4	B36	218.5935	218.1504	228.9675	227.5565	248.0282	246.3999	268.12	265.3059	288.6317	285.283
EPCSRST_N_5	B37	218.406	217.7754	227.9363	226.369	246.0284	244.0562	264.5578	261.8997	283.4599	280.1074
MONITOR	K23	216.8636	217.155	225.3987	225.3744	240.9682	241.9693	257.3818	258.5018	274.5142	275.4036
PLL_MON	L20	215.8798	215.6728	225.4109	224.5814	237.9107	237.8975	252.9729	252.7453	268.9038	268.4366
TOGGLE_MON	L22	216.0844	215.8134	223.6863	224.1907	238.7648	237.5381	254.2188	252.4172	269.7827	267.5673

Table. 32. LVTTL VOL – DUT 10468

		2mA		4mA		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
TID_BUF_OUT	A33	216.5471	215.7229	230.3077	226.4158	247.0774	243.4243	267.9847	262.4964	290.3729	282.498
EPCSRST_N_0	B31	215.4187	214.6599	229.9002	225.5091	248.4253	243.3305	270.461	262.7778	294.1942	283.2393
EPCSRST_N_1	B32	214.3439	213.7755	223.3743	222.4316	240.5914	239.4625	258.8083	257.056	277.4344	275.2711
EPCSRST_N_2	B34	216.1562	215.8067	225.3741	224.6815	243.1849	242.4937	262.2143	260.9622	281.5769	279.8311
EPCSRST_N_3	B35	214.9063	214.7442	224.093	223.5253	240.4664	239.8688	258.1209	257.3372	276.0787	275.1203
EPCSRST_N_4	B36	216.7812	216.6504	226.9052	225.7753	246.0284	244.4	265.7452	263.3684	286.3848	283.1097
EPCSRST_N_5	B37	215.3438	215.0254	224.8741	223.5253	242.9349	241.4313	261.5894	259.306	280.535	277.4945
MONITOR	K23	214.0499	214.4986	222.4599	222.9679	238.0294	238.8754	254.3179	255.5953	271.3352	272.3138
PLL_MON	L20	212.8486	212.797	221.3797	221.4556	234.942	234.928	249.7854	249.5257	265.8997	265.5537
TOGGLE_MON	L22	213.4879	213.5628	220.6205	221.5963	235.918	234.8499	251.2156	249.4789	267.01	265.0045

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 (%)
10407	125 krad	0.438	0.441	0.67
10410	125 krad	0.441	0.441	0.14
10436	125 krad	0.449	0.451	0.48
10465	125 krad	0.444	0.447	0.66
10466	125 krad	0.446	0.447	0.13
10468	125 krad	0.440	0.442	0.38

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.

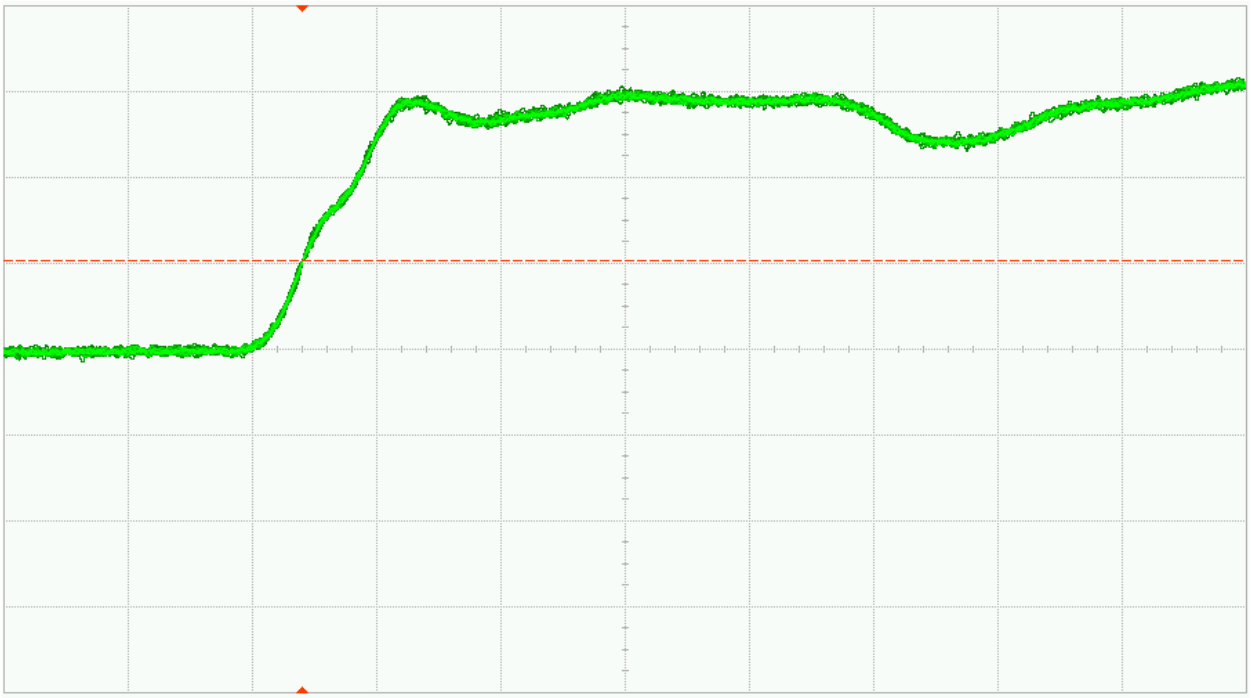

Fig. 26 (a). DUT 10407 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

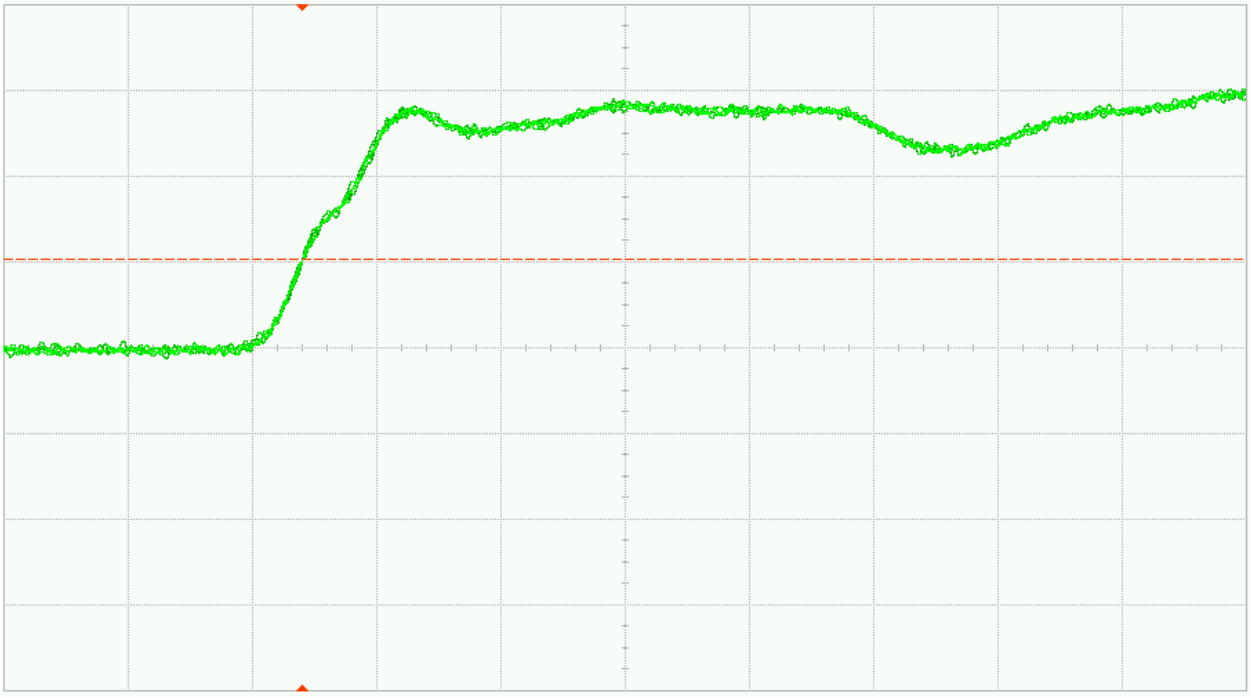

Fig. 26 (b). DUT 10407 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

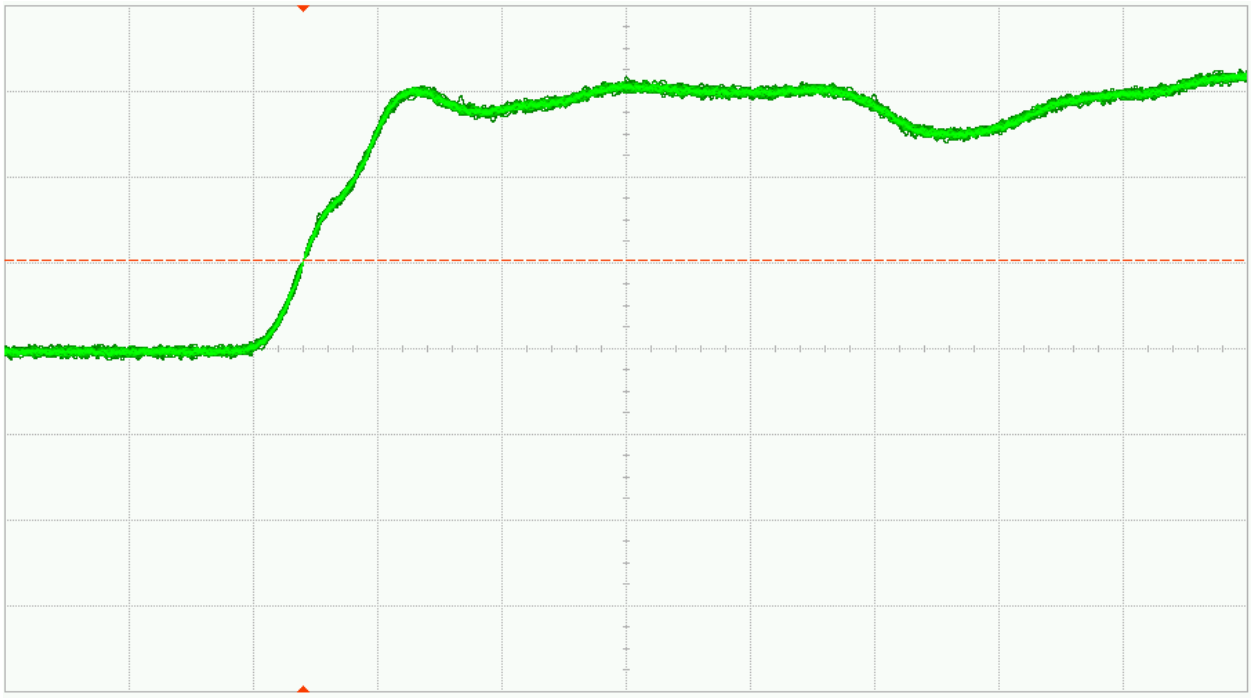

Fig. 27 (a). DUT 10410 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

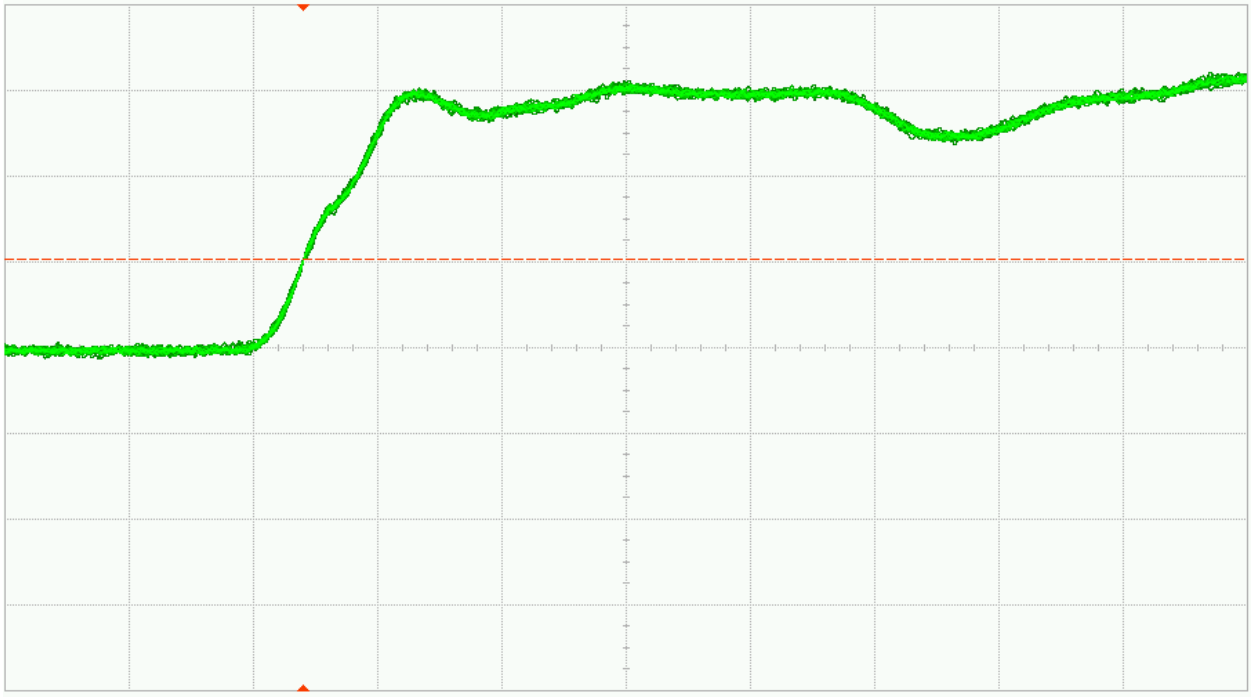

Fig. 27 (b). DUT 10410 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

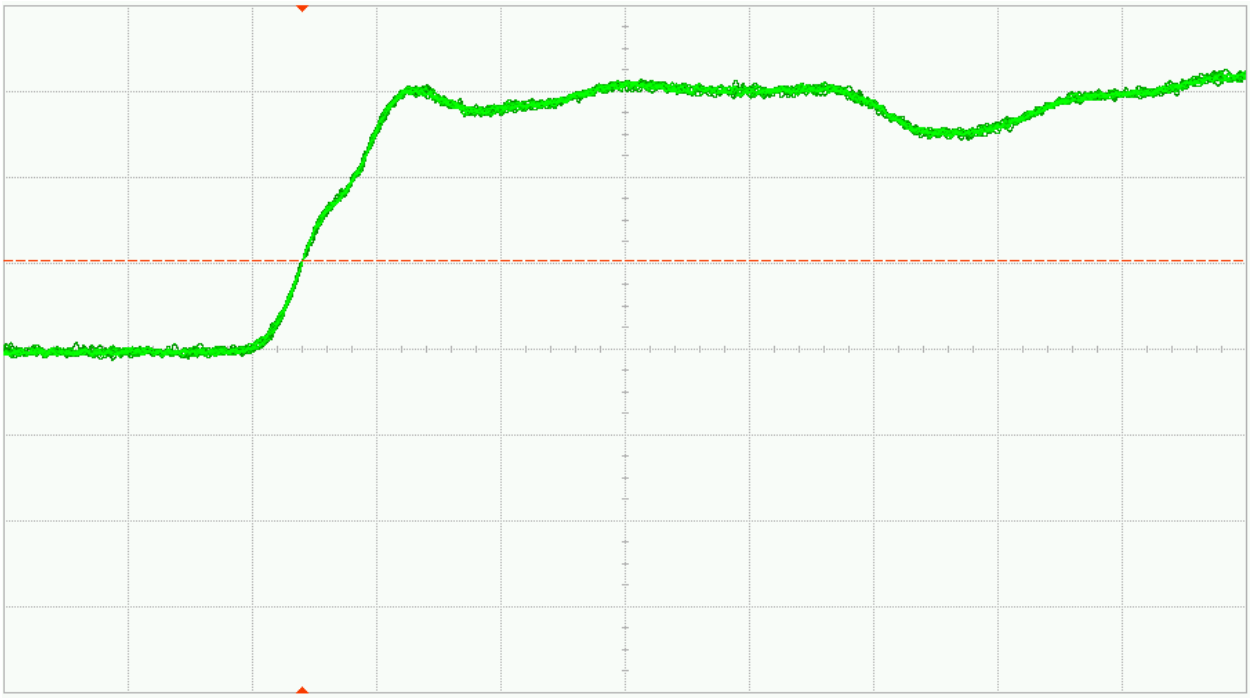

Fig. 28 (a). DUT 10436 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

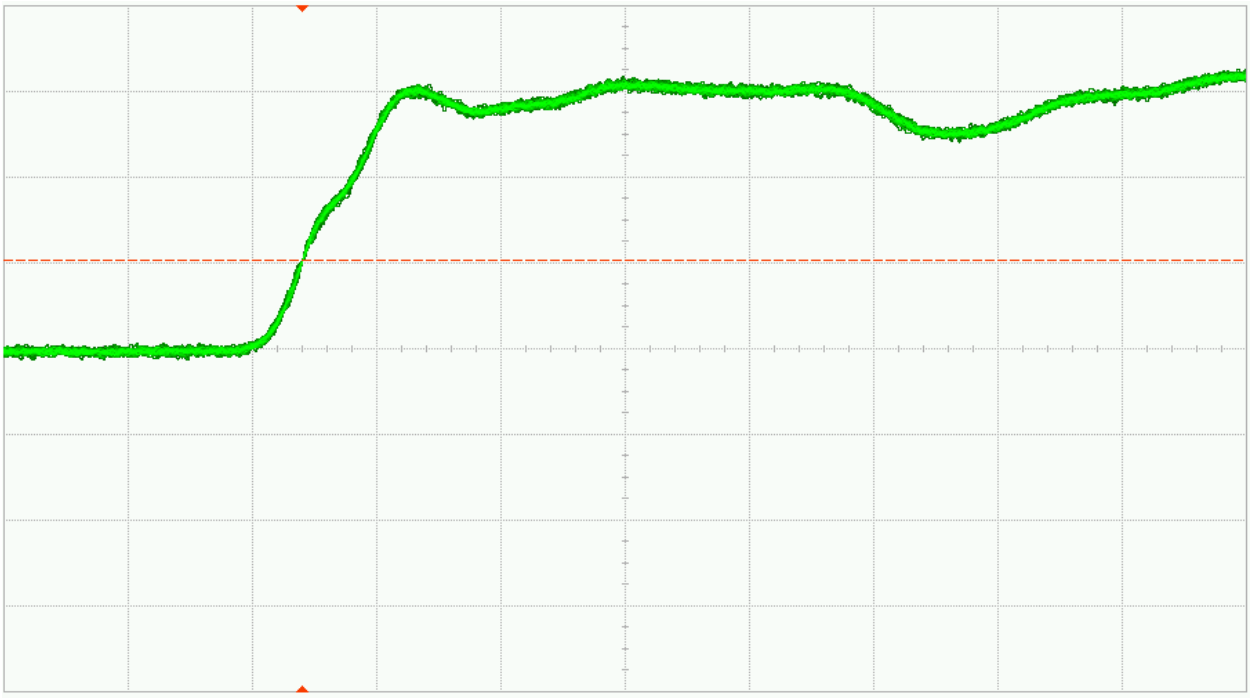

Fig. 28 (b). DUT 10436 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

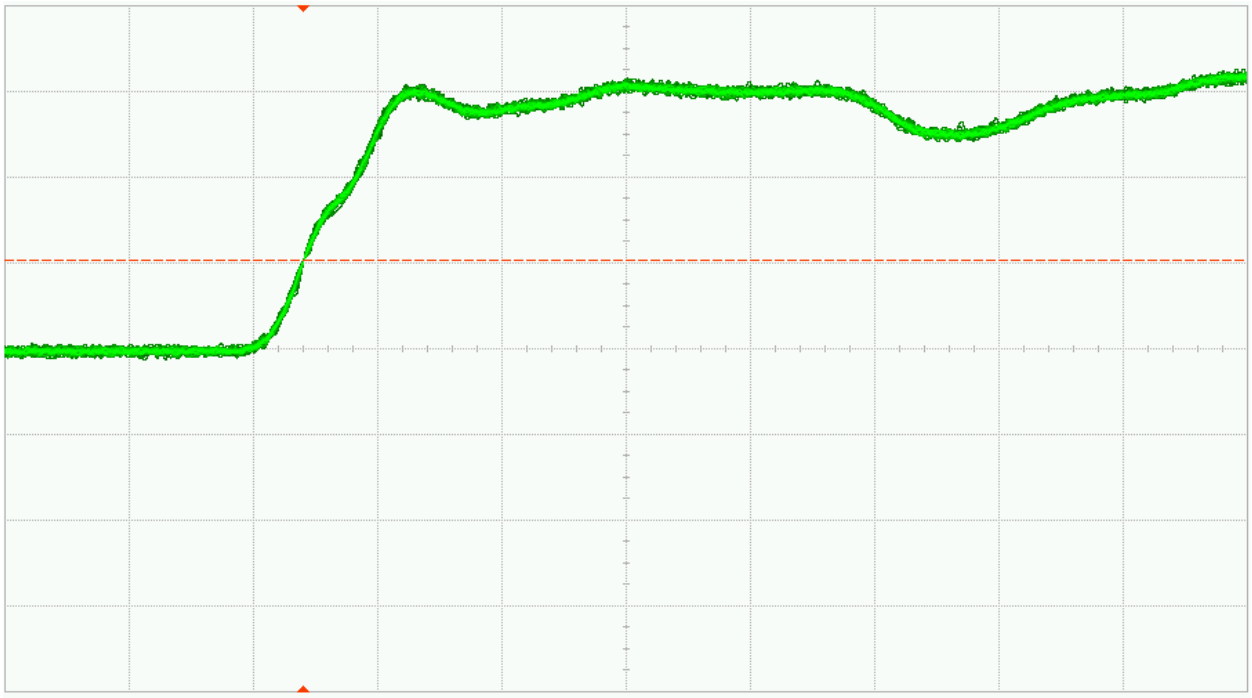

Fig. 29 (a). DUT 10465 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

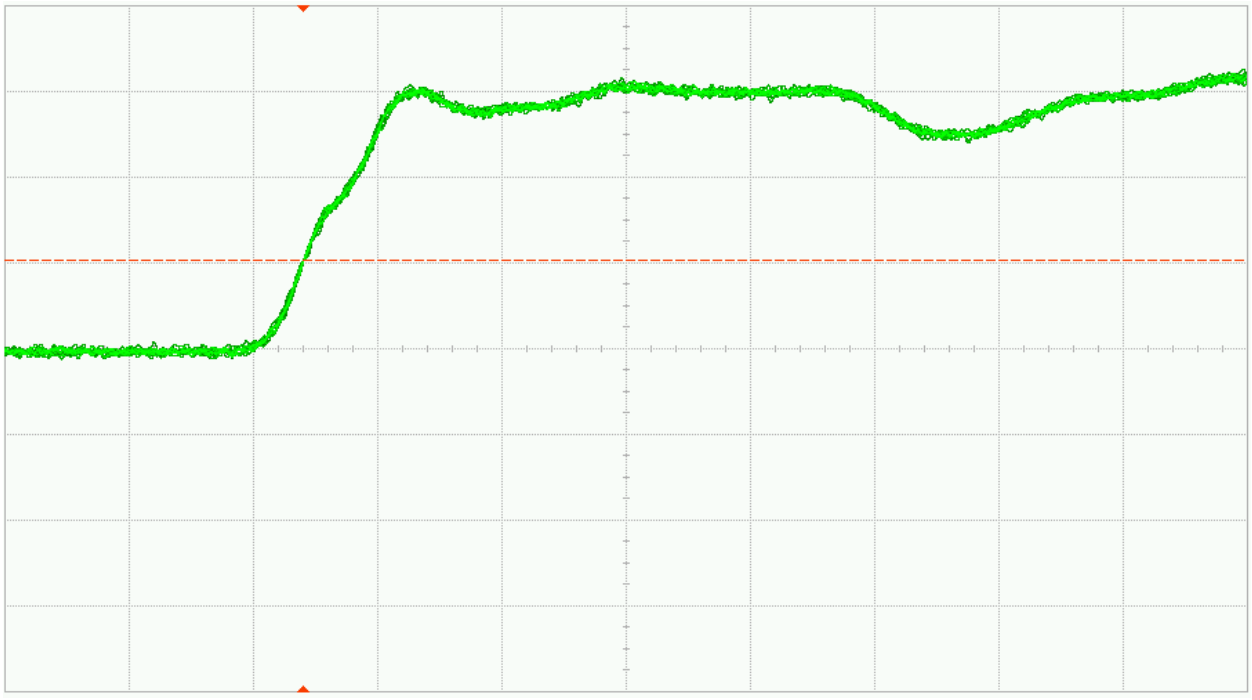

Fig. 29 (b). DUT 10465 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

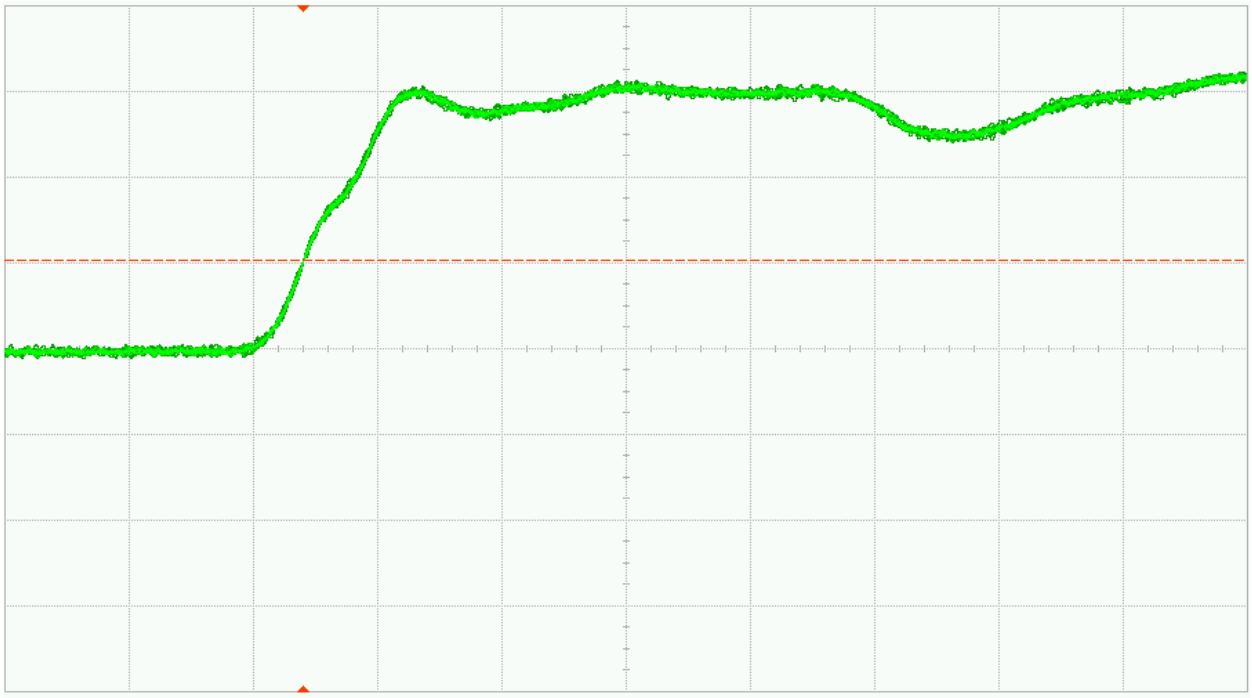

Fig. 30 (a). DUT 10466 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

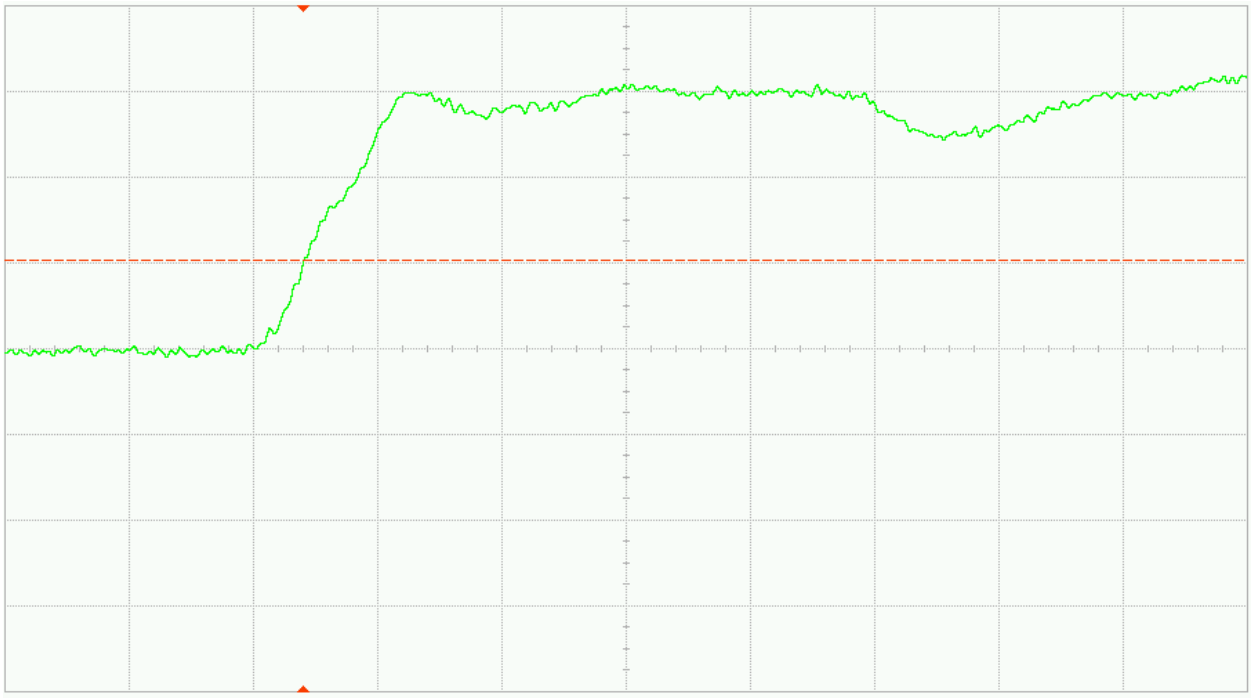

Fig. 30 (b). DUT 10466 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

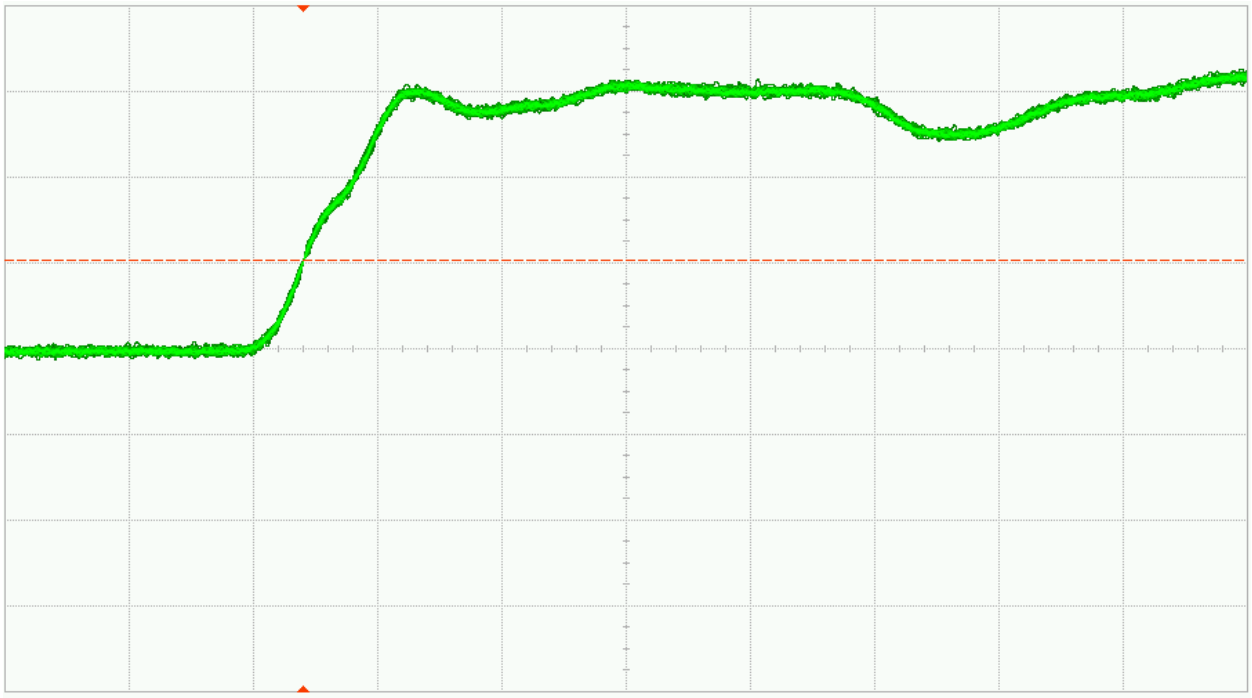

Fig. 31 (a). DUT 10468 pre-irradiation rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

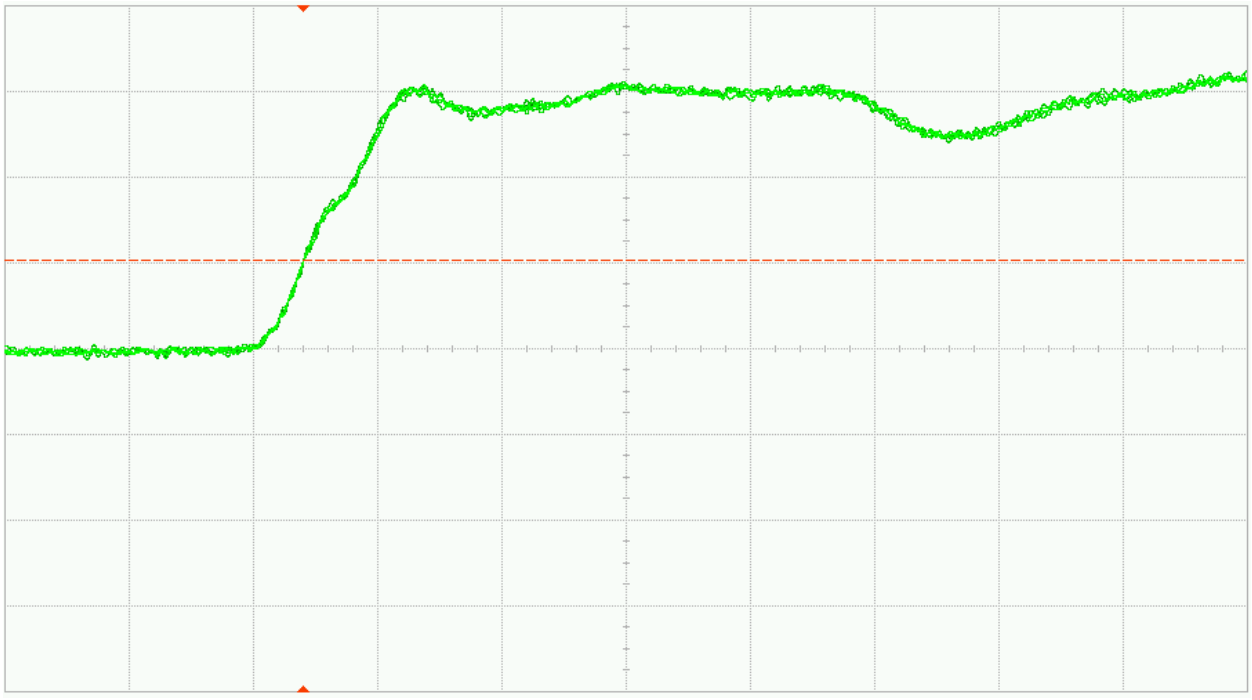

Fig. 31 (b). DUT 10468 post-annealing rising edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

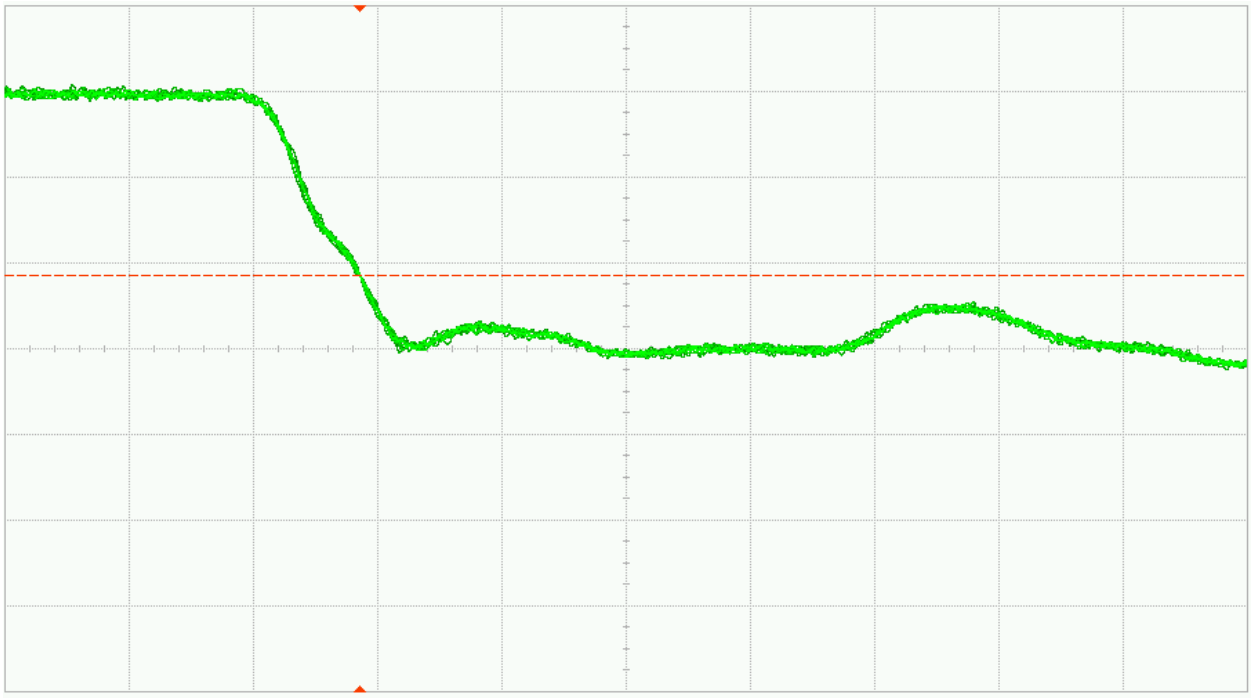

Fig. 32 (a). DUT 10407 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

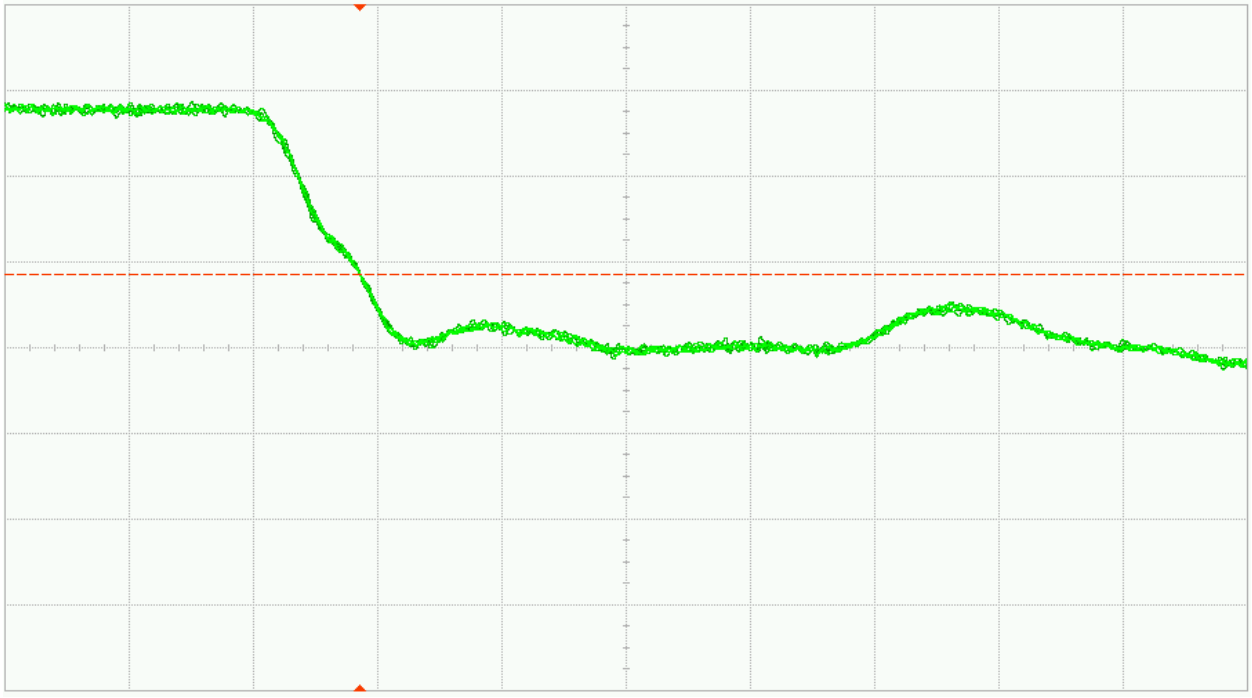

Fig. 32 (b). DUT 10407 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

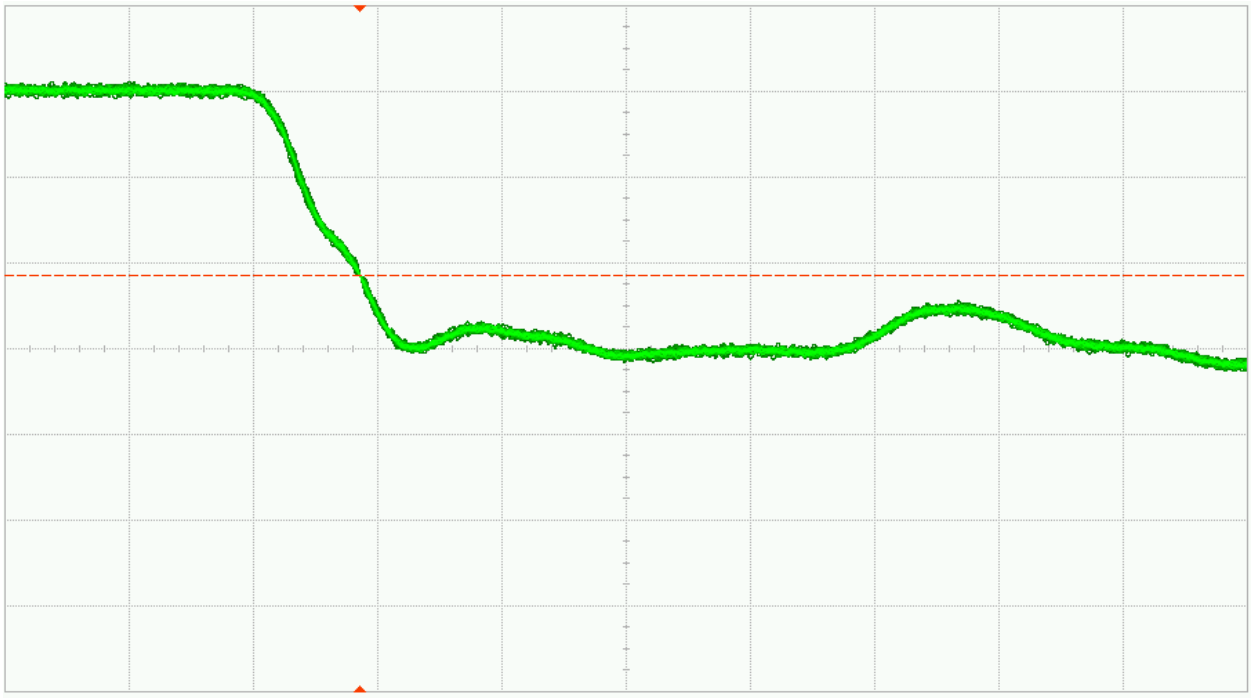

Fig. 33 (a). DUT 10410 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

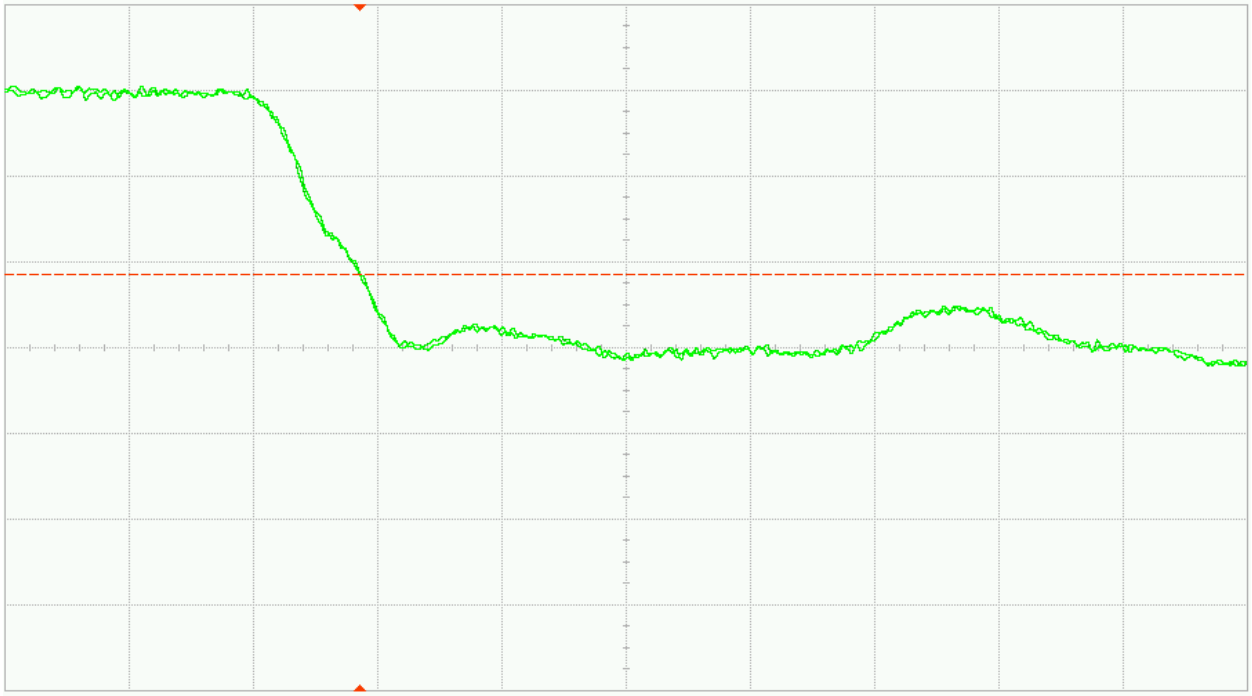

Fig. 33 (b). DUT 10410 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

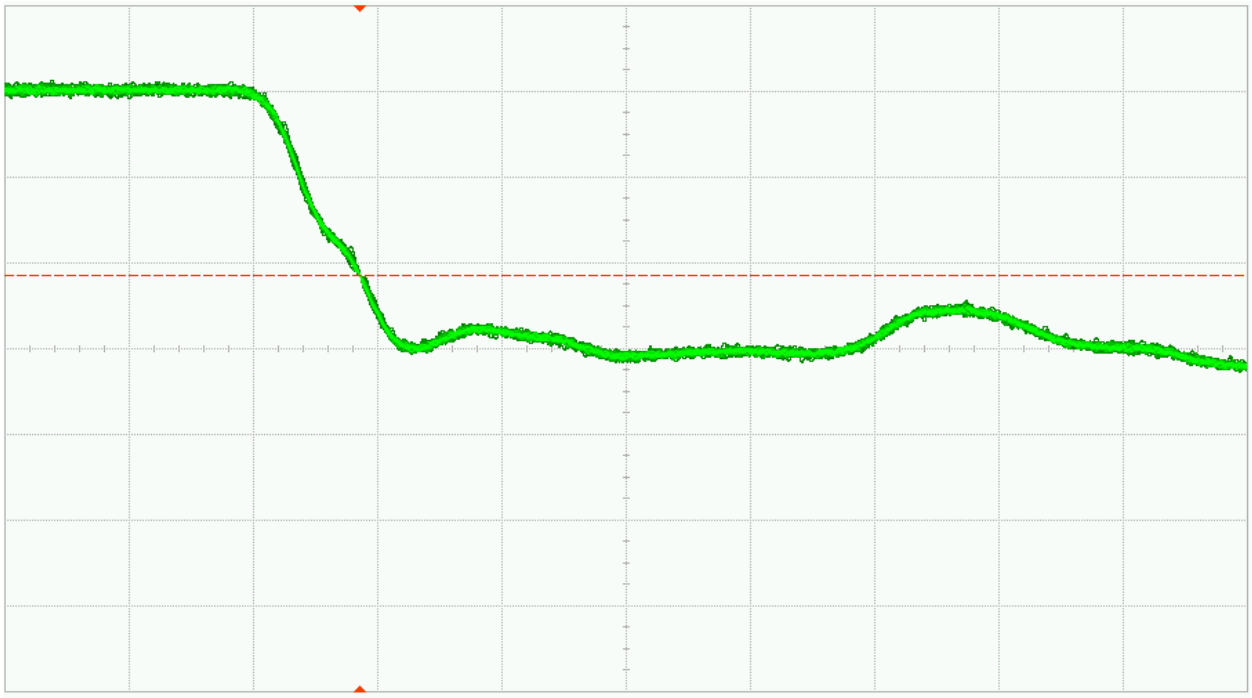

Fig. 34 (a). DUT 10436 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

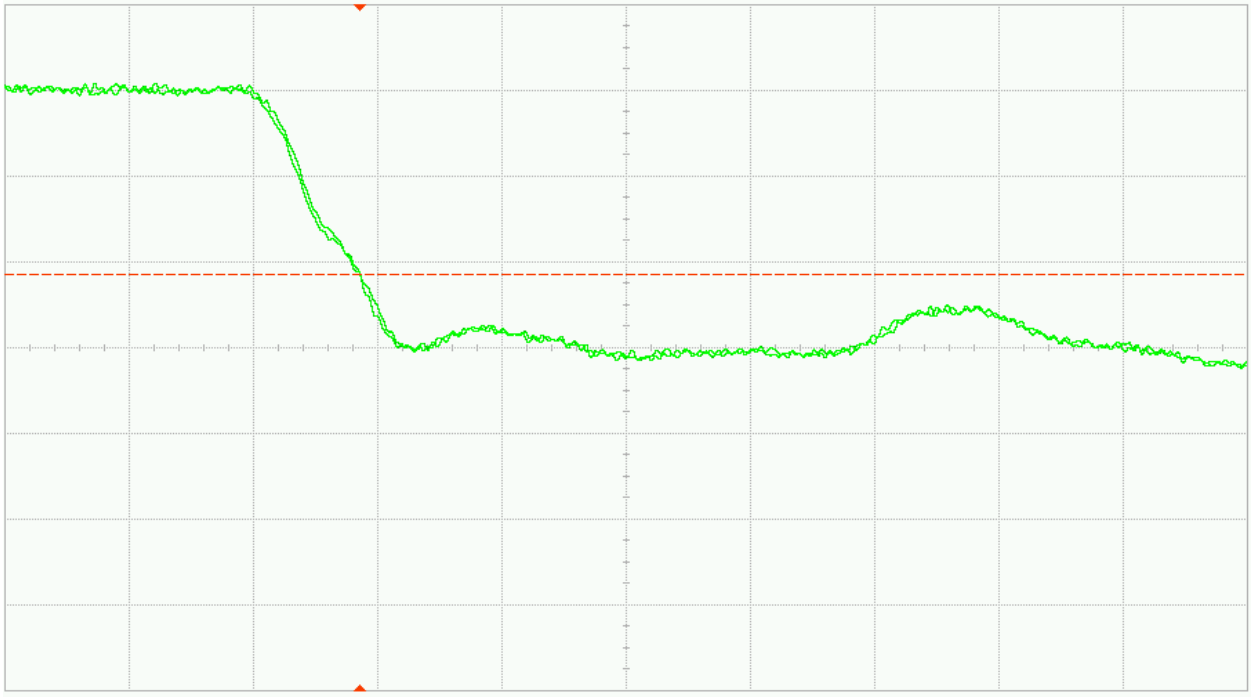

Fig. 34 (b). DUT 10436 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

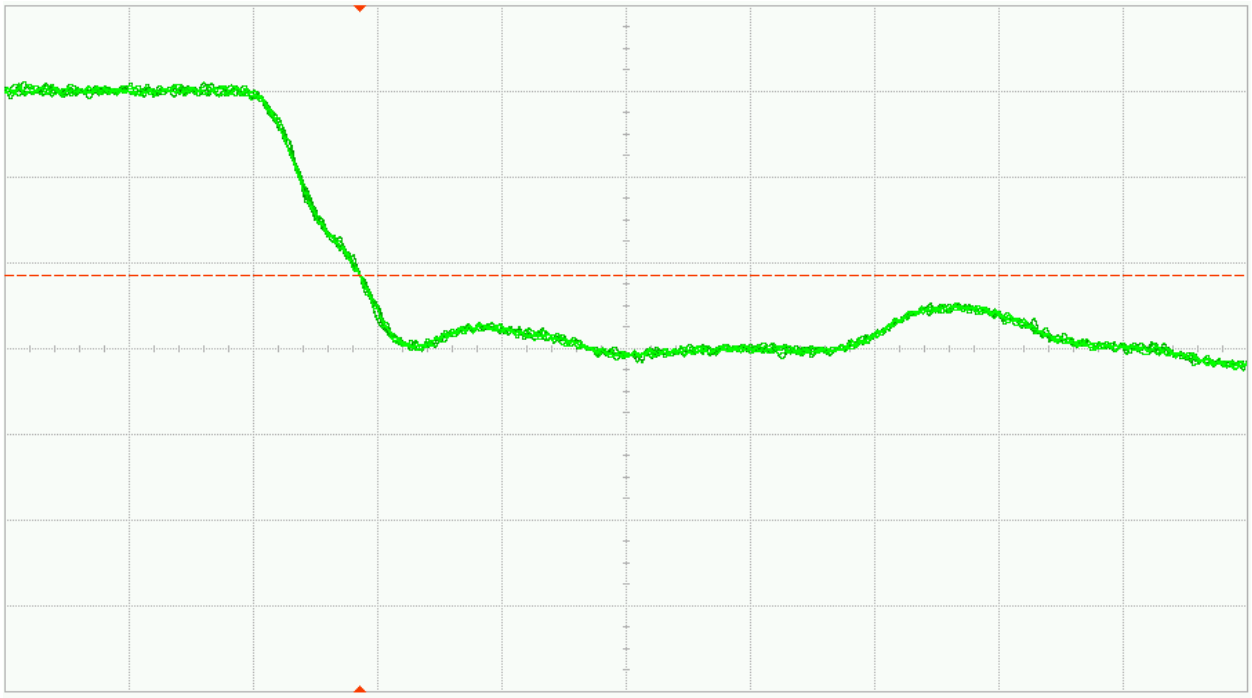

Fig. 35 (a). DUT 10465 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

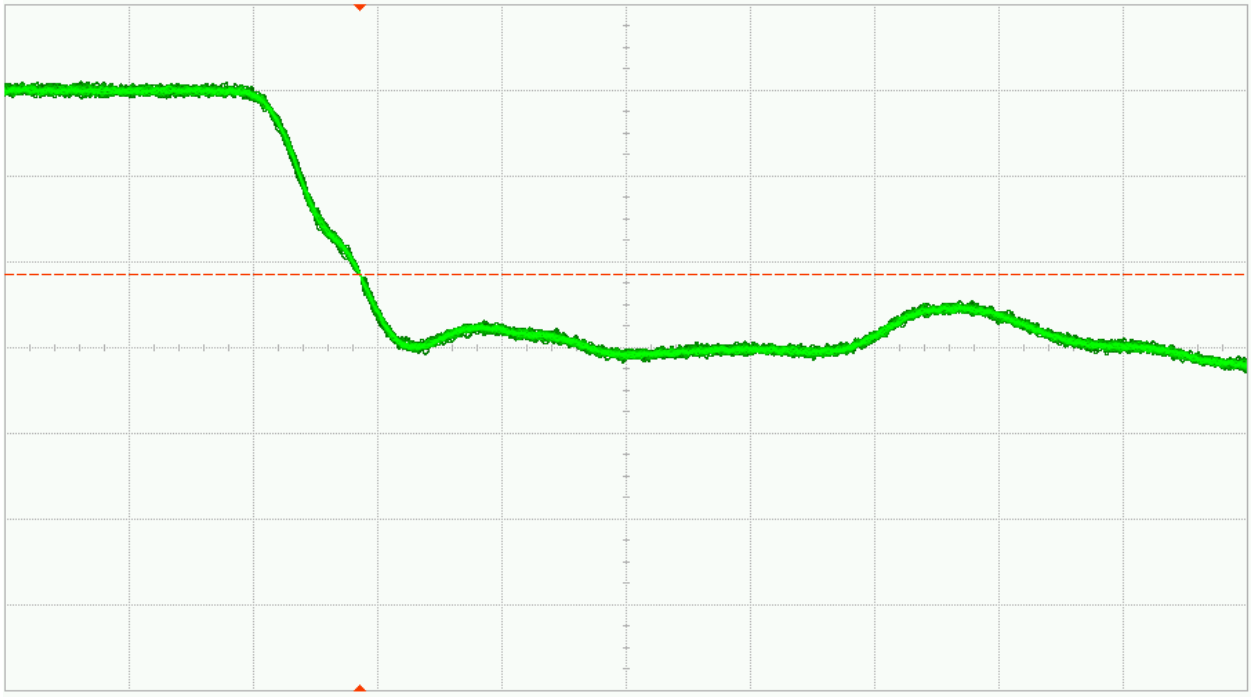

Fig. 35 (b). DUT 10465 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

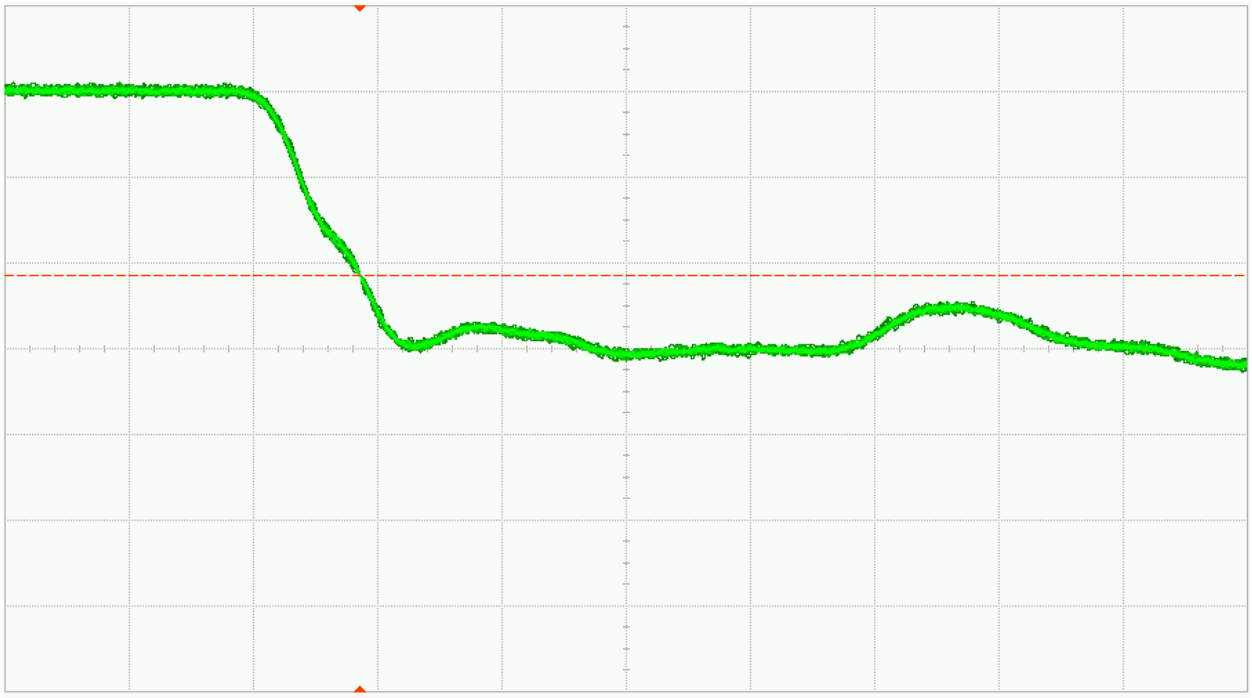

Fig. 36 (a). DUT 10466 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

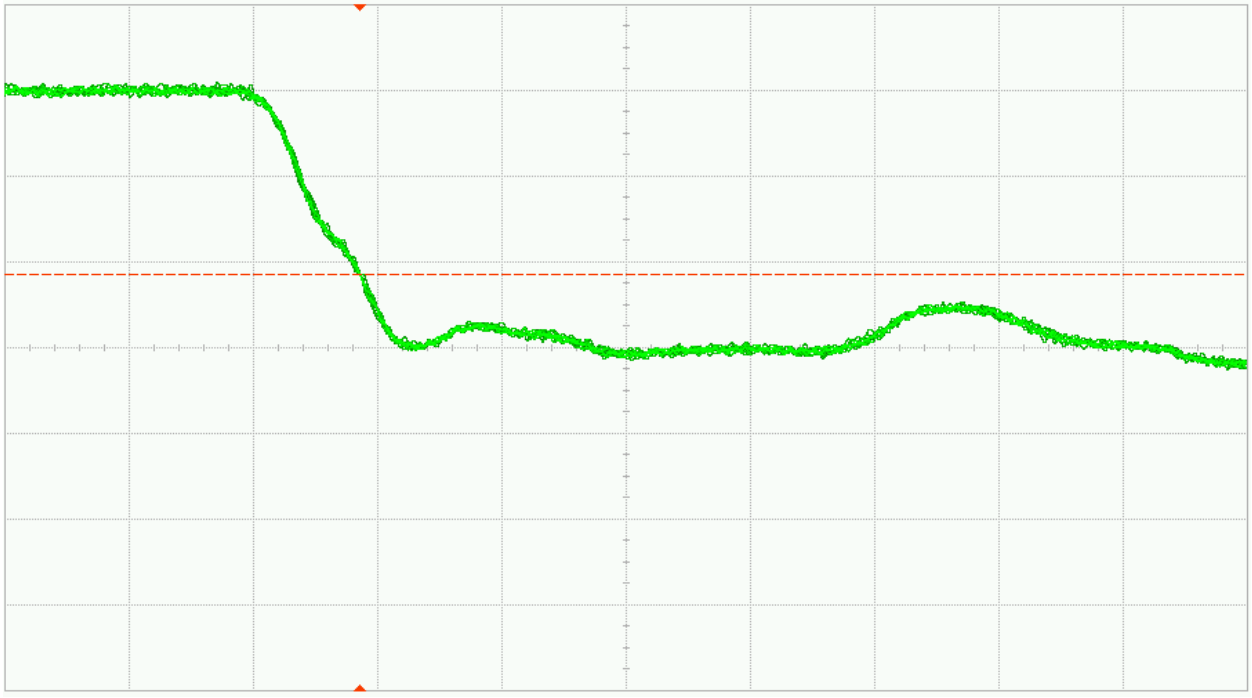

Fig. 36 (b). DUT 10466 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

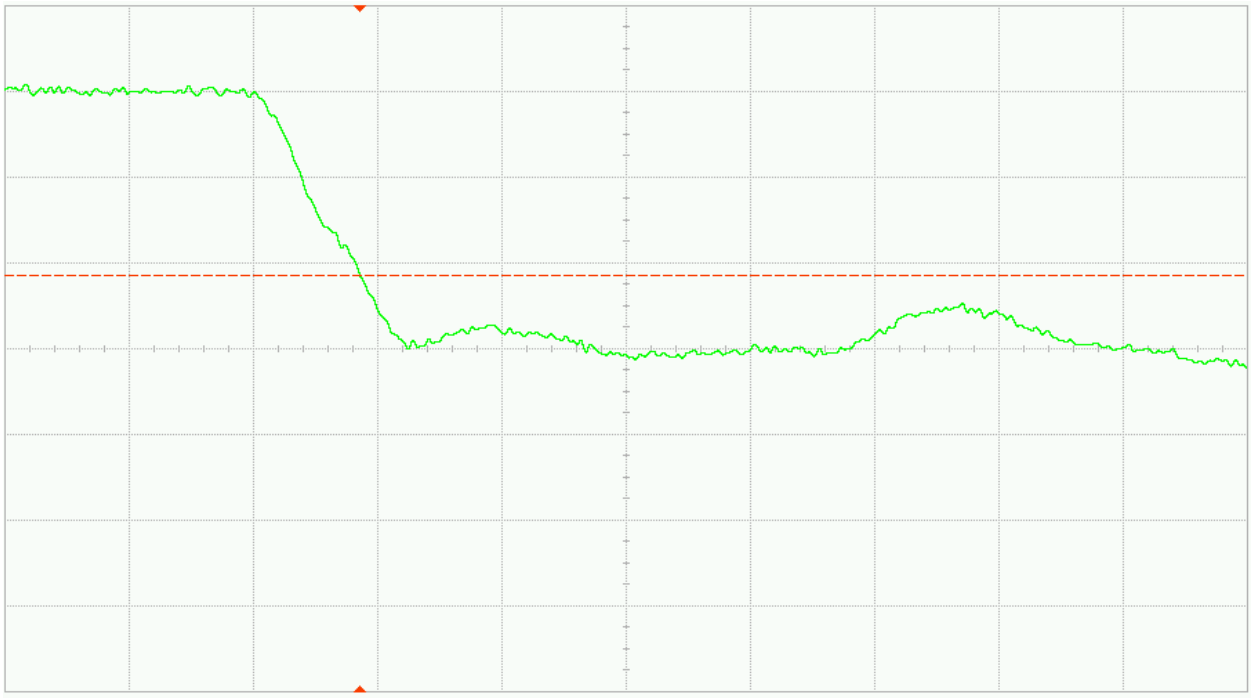

Fig. 37 (a). DUT 10468 pre-irradiation Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

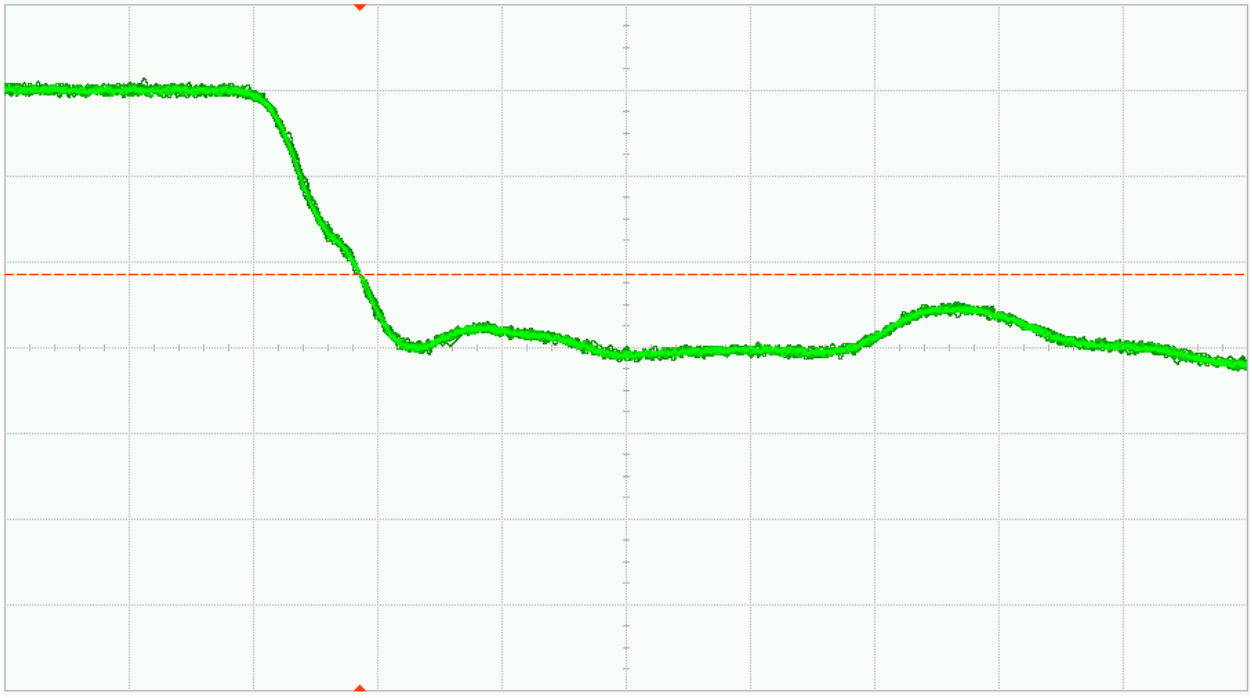

Fig. 37 (b). DUT 10468 post-annealing Falling edge, abscissa scale is 1V/div and ordinate scale is 2ns/div

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

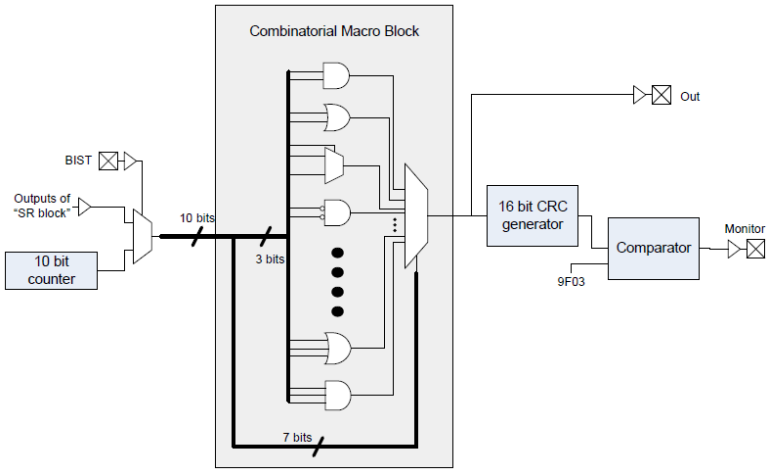

Fig. 38. Combo Block

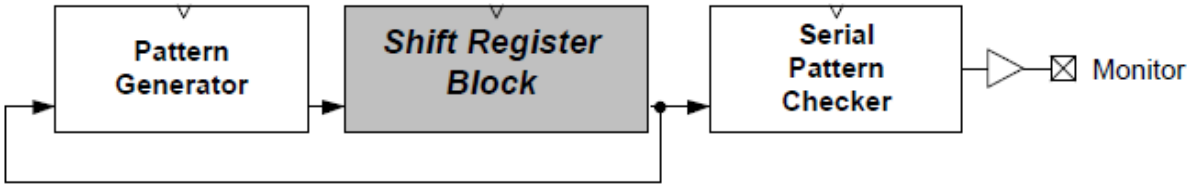

Fig. 39. Shift Register Block

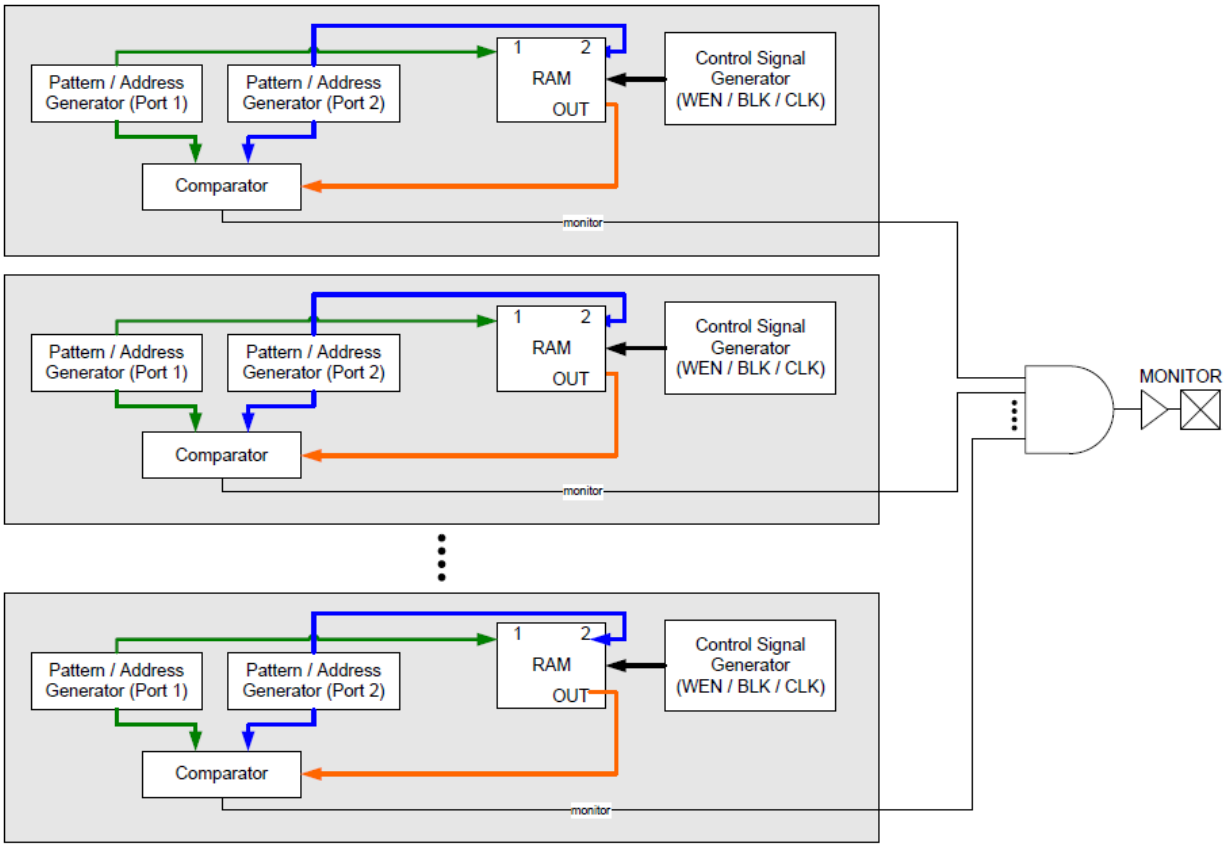

Fig. 40. Embedded Ram Blocks

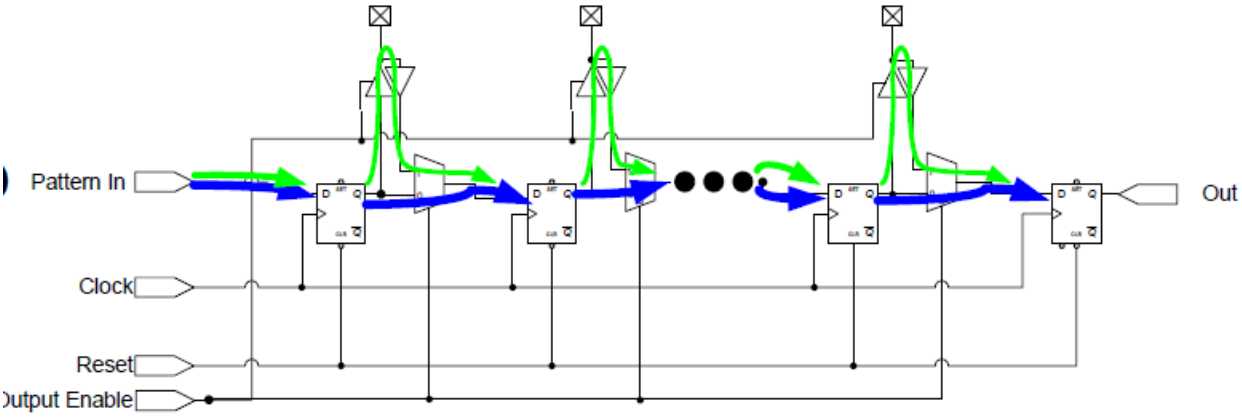

Fig. 41. IO Block

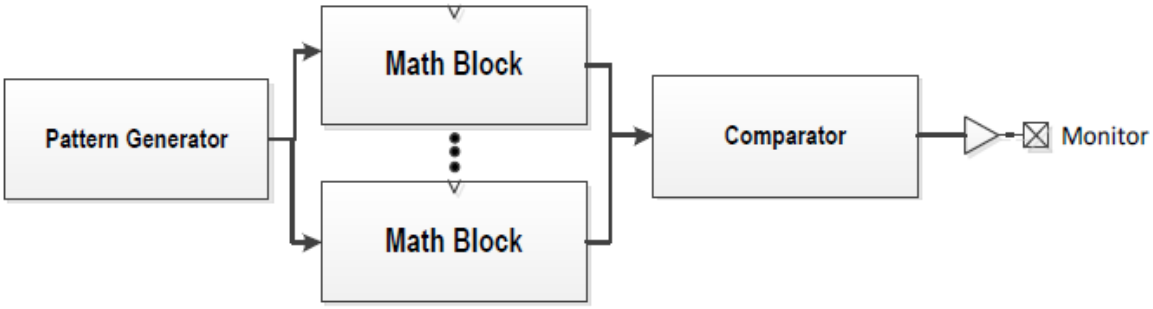

Fig. 42. Math Block