Total Ionizing Dose Test Report

No. 13T-RT3PE3000L-CG484-QKN6Y

November 24, 2013

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I. Summary Table

Parameter	Tolerance
1. Gross Functionality	Passed 30 krads (SiO2)
2. Power Supply Current (ICCA/ICCI)	Passed 30 krads (SiO2)
3. Input Threshold (VTIL/VIH)	Passed 30 krads (SiO2)
4. Output Drive (VOL/VOH)	Passed 30 krads (SiO2)
5. Propagation Delay	Passed 30 krads (SiO2) per 10%-degradation criterion
6. Transition Time	Passed 30 krads (SiO2)

II. Total Ionizing Dose (TID) Testing

This testing for the flash-based FPGA is developed on the base of an extensive database from the TID testing of many generations of antifuse-based FPGAs. Early TID studies can be found in the public domain, for example, http://www.klabs.org/index_klabs_dot_org.htm. Other reliability reports are also available on the Microsemi SoC Products Group website:

http://www.microsemi.com/soc/products/milaero/hireldata.aspx.

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

Table 1 lists the DUT and irradiation parameters. During irradiation each input is grounded through a jumper; during annealing each input is grounded through a resistor.

Table 1 DUT and Irradiation Parameters

Part Number	RT3PE3000L
Package	CCGA-484
Foundry	United Microelectronics Corp.
Technology	0.13 µm CMOS and Embedded Flash
DUT Design	RTA3PE3KL_CG484_TID
Die Lot Number	QKN6Y
Quantity Tested	4
Total Dose: DUT Serial Number	9485, 9499, 9525, 9526
Radiation Facility	Defense Microelectronics Activity
Radiation Source	Co-60
Dose Rate	10 krad (SiO2)/Min. (±5%)
Irradiation Temperature	Room
Irradiation and Measurement Bias (VCCI/VCCA)	Static at 3.3 V / 1.5 V

B. Test Method

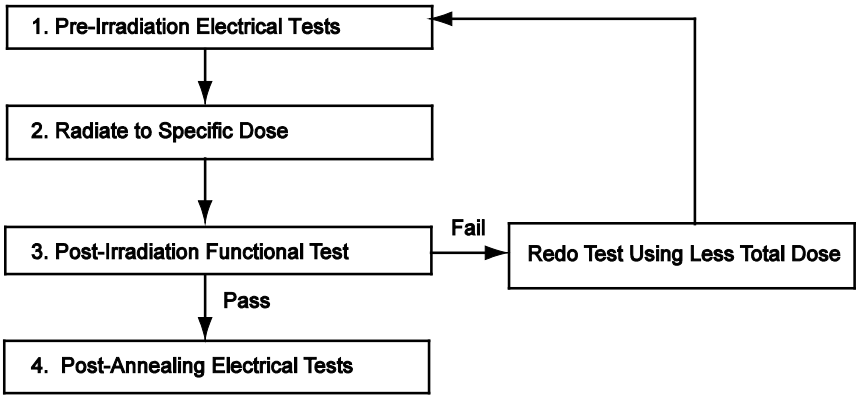


Figure 1 Parametric Test Flow Chart

The test method generally follows the guidelines in the military standard TM1019.8. Figure 1 is the flow chart showing the steps for parametric tests, irradiation, and post-irradiation annealing.

The accelerated aging, or rebound test mentioned in TM1019.8, is unnecessary because there is no adverse time dependent effect (TDE) in Microsemi products manufactured by sub-micron CMOS technology. The test data with a high dose are compared to test data with a low dose rate for devices manufactured by several generations of sub-micron CMOS technologies. The results always show the low dose rate degrades less than the high dose rate; thus indicating that the elevated rebound annealing would artificially reduce the radiation effects. Therefore, only room temperature annealing is performed in this report. The experiment is repeated on the flash-based FPGA technology and shows similar results.

The duration of the room temperature annealing is approximately 7 days.

C. Design

DUTs use a high utilization generic design, RTA3PE3KL_CG484_TID, to test total dose effects in typical space applications.

Below are the descriptions by blocks. Appendix A contains the block diagrams and schematics illustrating the logic design.

a. PLL Block

There are six dynamically configurable PLLs in the RTA3PE3000 device. All of them are configured in the following manner; with GLA coming from the PLL and GLB/GLC bypassed for other global signals. Five of the PLLs have a default multiplying factor of x4 and the last one is x16.

Dynamic configuration is applied by sending IR = 16 through the UJTAG. The lock signal of each PLL is routed out to an I/O for observation.

b. UFROM / SRAM Block

There are 112 basic 4608-bit blocks in the RTA3PE3000 device. Each of these blocks is configured in the 512x8 configuration. The stimulus for the SRAM blocks is written into the UFROM during programming.

During test/TID, the contents in the UFROM is read and written into each of the 112 SRAM blocks. The SRAM blocks are configured in a dual port mode where two different bytes of data are written/read from two different addresses at any given time. The read back data is MUXed and compared with the expected value. To ensure the original data in the UFROM is correct, its content goes through a CRC check during each test cycle.

An additional SRAM disturb mode is available. During the non-disturb mode, the dual port operation for read/write between address (port) A and address (port) B must be greater than eight to avoid operating SRAM cells in the same physical row. The disturb mode will force address A and B to be adjacent to each other all the time to stimulate the disturb violation.

c. Pattern Generator Block

A multi-bit shift register with varying feedback length allows for different pattern configurations, as shown in Table 2 below. The pattern generator block is used to supply the stimulus for the array shift register and I/O test blocks.

d. I/O Block

The I/O block is composed of four separate blocks, each with its own pattern generator and checker block. Each block also gets its own clock, reset, and OE from a separate PLL block. Separation of these blocks is based on the four quadrants: UL, UR, LL, LR. The reason for this scheme is to fully utilize the quadrant clocks in the device.

Since the number of bonded I/Os is different in each quadrant, the number of stages in each I/O weave block also varies slightly (from 138 to 146). The SSO of the device can be changed based on the pattern generator's configuration. The existing burn-in mode or TID will use a 25% SSO rate. The SSO can also be completely eliminated by disabling the OE of the device, which will route the signal internally instead of going through the bi-buf.

e. Array Shift Registers Block

There are 4 individual array shift register chains used as core logic fillers. Each chain is made up of 3,500 D-FF with asynchronous reset/set. The pattern generator supplies the stimulus into the array shift-register, which gets shifted out and compared by the pattern checker. During TID, the internal toggle rate is fixed at 25% SSR.

f. Delay Path Block

The delay path block has three individual inverter chains with input stimulus coming from a counter during TID or I/O during test. The inverter chains are 30 stages and travels across the quadrants. The path covers the outer edges and center of the die to provide better sampling of the different areas in the die.

g. Monitor Block

This block is used to indicate that all BISTs in the design are passing. The passing monitor signal is half of the CLK. When a BIST fails, the monitor signal provides a signature that makes it possible to determine which specific block in the design that is failing. The failing monitor signal consists of up to 9 pulses. Pulse 0 is always present in the failing Monitor signal, while pulses 1-7, which represent a passing blocks in the Burn-in design, and are only present when the respective block is passing. The pulse number and the corresponding block that it represents is as follows:

1. UFROM/SRAM Block
2. I/O UR Block
3. I/O UL Block
4. I/O LR Block
5. I/O LL Block
6. Array 1 Block
7. Array 2 Block
8. Array 3 Block
9. Array 4 Block

D. Parametric Measurements

Table 2 lists each tested electrical parameter and the corresponding logic design.

The functionality is measured on the output pins. I_{CC} is measured on the power supplies of the logic-array (ICCA) and I/O (ICCI) respectively. The input logic thresholds (VIL/VIH) and output-drive voltages (VOL/VOH) are measured on nets listed in Row 3 and 4 of Table 2.

The propagation delays are measured on the SPEEDOUT output of the inverter chains. The delay is measured as the time delay from the time of triggering edge at the “clk” input to the time of switching state at the output SPEEDOUT. Both the low-to-high and high-to-low output transitions are measured; the propagation delay is defined as the average of these two transitions.

The transition characteristics, measured on the output SPEEDOUT, are displayed from Figure 3 through Figure 12 as oscilloscope snapshots showing the rising and falling edge during logic transitions.

Table 2 Logic Design for Parametric Measurements

Parameters	Logic Design
1. Functionality	All key architectural functions
2. ICC (ICCA/ICCI)	DUT power supply pins
3. Input Threshold (VIL/VIH)	Input buffers (SPEEDIN, RESETn, INPUT_SRAM_DISTURB, INPUT_SETn, INPUT_oe, INPUT_IO_Shift_En, INPUT_IO_Pattern_Length[0..2], INPUT_IO_Johnson, INPUT_FROM_SRAM_START, INPUT_A_Shift_En, INPUT_A_Pattern_Length[0..2], INPUT_A_Johnson, clk, BIST, FF, IO_Outs_UR[0..76], IO_Outs_UL[0..74], IO_Outs_LR[0..66], IO_Outs_LL[0..79])
4. Output Drive (VOL/VOH)	Output buffers (UFROM_MONITOR, SRAM_OUT[0..7], LOCK[0..5], LED, BIST_MONITOR, Array_Monitor, SPEEDOUT, Array_out[0..3])
5. Propagation Delay	Chains of inverters (clk to SPEEDOUT)
6. Transition Characteristic	Output (SPEEDOUT)

III. Test Results

A. Functionality

Every DUT passes functional tests after 30 krads and annealing from results of the standard testing.

B. Power Supply Current (ICCA and ICCI)

Table 3 shows the pre-irradiation and post-annealing ICCA and ICCI measured at the nominal VCC at 1.5 V and 3.3 V, respectively. In most cases, the currents after irradiation and annealing are at the level as those before the irradiation.

It shows the total dose effects to ICC currents up to 30 krads are insignificant. And this indicates that the Post-annealing ICCA and ICCI for all DUTs pass the specification with very good margins.

Table 3 Post Irradiation and Post-Annealing ICC

DUT	Total Dose	ICCA at 1.5 V (mA)		ICCI at 3.3 V (mA)	
		Pre-rad	Post-ann	Pre-rad	Post-ann
9485	30 krad	4.73	4.92	69.00	68.67
9499	30 krad	4.67	4.85	68.33	68.24
9525	30 krad	5.22	5.35	68.76	68.65
9526	30 krad	6.44	6.57	68.60	68.48

C. Continuity and Input Logic Threshold (VIL/VIH)

Standard I/O parametric tests are applied to check the total dose effects to the I/O drivability.

Table 4a through Table 4c list the pre-irradiation and post-annealing input logic thresholds. All data are within the specification limits (test specification minimum and maximum values are given in brackets); and data is presented with statistics of all the I/O pins used (~340 sample size of each DUT).

Table 4a Pre-Irradiation and Post-Annealing Input Thresholds

Testname		pci_pcix_iil (uA) [-5.0, 5.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-0.332	-0.071	0.192	0.075	-0.415	-0.049	0.272	0.075
9499	30 krad	-0.362	-0.060	0.167	0.077	-0.440	-0.047	0.140	0.074
9525	30 krad	-0.412	-0.066	0.195	0.083	-0.515	-0.064	0.140	0.077
9526	30 krad	-0.362	-0.074	0.192	0.078	-0.465	-0.052	0.159	0.077

Table 4b Pre-Irradiation and Post-Annealing Input Thresholds

Testname		pci_pcix_iih (uA) [-5.0, 5.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-0.262	0.029	0.417	0.084	-0.339	0.029	0.354	0.085
9499	30 krad	-0.230	0.027	0.392	0.084	-0.339	0.029	0.361	0.088
9525	30 krad	-0.237	0.037	0.429	0.085	-0.314	0.029	0.379	0.089
9526	30 krad	-0.212	0.031	1.320	0.113	-0.364	0.031	1.302	0.118

D. Low Output-Drive Voltage (VOL and Ipd)

The pre-irradiation and post-annealing VOL and Ipd are listed in Table 5a through Table 6h. The post-annealing data are within the specification limits (test specification minimum and maximum values are given in brackets); data is presented with the statistics of all I/O pins used (~340 sample size of each DUT). In each case, the post-annealing data varies insignificantly.

Table 5a Pre-Irradiation and Post-Annealing VOL

Testname		cmos18_vol_5x (mV) [0.0, 405.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	154.431	163.615	191.818	6.119	154.365	163.530	198.196	5.985
9499	30 krad	153.426	163.969	193.089	6.604	153.360	164.125	191.470	6.097
9525	30 krad	149.783	160.361	204.932	6.514	150.471	160.982	194.864	6.008
9526	30 krad	153.112	162.947	193.968	6.290	154.114	163.011	192.295	6.168

Table 5b Pre-Irradiation and Post-Annealing VOL

Testname		cmos15_vol_2x (mV) [0.0, 320.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	85.435	87.315	91.493	1.010	85.336	87.257	96.700	1.104
9499	30 krad	85.223	87.410	92.248	1.326	85.393	87.498	92.338	1.206
9525	30 krad	82.825	84.910	91.807	1.103	83.383	85.246	90.453	1.011
9526	30 krad	84.972	86.845	91.609	1.064	84.707	86.781	91.403	1.050

Table 5c Pre-Irradiation and Post-Annealing VOL

Testname		cmos15_vol_3x (mV) [0.0, 320.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	90.840	94.017	102.808	1.986	91.181	93.973	104.471	2.004
9499	30 krad	90.488	94.134	103.855	2.303	90.607	94.260	103.528	2.126
9525	30 krad	87.913	91.650	105.877	2.144	88.534	92.061	103.088	1.993
9526	30 krad	90.237	93.598	103.541	2.084	90.175	93.496	102.962	2.026

Table 5d Pre-Irradiation and Post-Annealing VOL

Testname		cmos15_vol_4x (mV) [0.0, 320.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	120.444	125.223	138.890	3.005	120.759	125.158	141.244	2.993
9499	30 krad	119.822	125.346	139.900	3.440	119.942	125.503	139.232	3.164
9525	30 krad	116.681	121.935	143.125	3.231	116.990	122.500	139.044	3.003
9526	30 krad	119.696	124.515	139.712	3.131	119.974	124.560	138.730	3.046

Table 5e Pre-Irradiation and Post-Annealing VOL

Testname		cmos15_vol_5x (mV) [0.0, 320.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	181.411	190.374	218.282	6.056	181.377	190.536	223.529	5.948
9499	30 krad	179.870	190.587	219.966	6.730	179.869	190.850	218.248	6.192
9525	30 krad	174.845	185.559	228.298	6.473	176.037	186.327	219.946	5.993
9526	30 krad	179.744	189.480	220.029	6.273	180.623	189.525	218.185	6.066

Table 5f Pre-Irradiation and Post-Annealing VOL

Testname		cmos12_vol_2x (mV) [0.0, 285.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	111.770	114.106	118.047	1.081	111.795	114.068	128.862	1.344
9499	30 krad	110.965	113.892	119.215	1.584	111.255	113.974	118.991	1.438
9525	30 krad	107.950	110.072	116.681	1.167	108.431	110.519	115.534	1.094
9526	30 krad	111.016	113.467	118.424	1.150	110.915	113.409	117.923	1.129

Table 5g Pre-Irradiation and Post-Annealing VOL

Testname		cmos12_vol_3x (mV) [0.0, 285.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	56.543	58.077	62.326	0.981	56.425	58.068	65.291	1.033
9499	30 krad	56.140	57.968	62.766	1.204	56.120	58.045	62.605	1.101
9525	30 krad	54.622	56.276	63.165	1.074	54.675	56.474	61.600	0.998
9526	30 krad	55.952	57.717	62.785	1.043	55.909	57.668	62.228	1.017

Table 5h Pre-Irradiation and Post-Annealing VOL

Testname		cmos12_vol_3xE1 (mV) [-100.0, 100.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.735	3.116	3.623	0.172	2.699	3.129	3.480	0.124
9499	30 krad	2.735	3.116	3.811	0.180	2.819	3.114	3.453	0.125
9525	30 krad	2.689	3.049	3.434	0.177	2.737	3.040	3.380	0.121
9526	30 krad	2.626	3.098	3.560	0.176	2.674	3.076	3.453	0.126

Table 5i Pre-Irradiation and Post-Annealing VOL

Testname		cmos12_vol_3xE2 (mV) [-100.0, 100.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.123	2.563	3.183	0.178	2.254	2.563	2.914	0.125
9499	30 krad	2.169	2.560	3.120	0.182	2.128	2.573	2.877	0.129
9525	30 krad	2.186	2.547	3.057	0.168	2.128	2.510	2.762	0.117
9526	30 krad	2.120	2.560	3.120	0.180	2.191	2.563	2.887	0.123

Table 5j Pre-Irradiation and Post-Annealing VOL

Testname		lvttl_vol_1x12 (mV) [0.0, 360.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	205.554	208.984	217.976	2.067	205.525	209.122	222.583	2.116
9499	30 krad	205.465	210.246	220.947	2.651	205.699	210.455	220.757	2.463
9525	30 krad	200.853	205.544	218.442	2.239	202.181	206.549	217.160	2.111
9526	30 krad	204.382	208.041	218.586	2.182	204.274	208.189	218.114	2.140

Table 5k Pre-Irradiation and Post-Annealing VOL

Testname		lvttl_vol_1x (mV) [0.0, 360.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	205.700	208.975	217.741	2.063	205.430	209.028	222.505	2.121
9499	30 krad	205.465	210.198	220.869	2.667	205.699	210.513	220.679	2.456
9525	30 krad	201.088	205.543	217.425	2.222	202.416	206.548	217.317	2.109
9526	30 krad	204.303	208.116	218.586	2.181	204.352	208.112	217.410	2.115

Table 5l Pre-Irradiation and Post-Annealing VOL

Testname		lvttl_vol_1xE1 (mV) [0.0, 200.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	4.410	5.039	5.705	0.215	4.702	5.249	5.786	0.192
9499	30 krad	4.254	5.079	5.626	0.229	4.770	5.278	5.864	0.217
9525	30 krad	4.254	5.001	5.489	0.238	4.624	5.200	5.755	0.201
9526	30 krad	4.410	5.020	5.705	0.225	4.624	5.239	5.864	0.209

Table 5m Pre-Irradiation and Post-Annealing VOL

Testname		lvttl_vol_1xE2 (mV) [0.0, 200.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	4.644	5.211	5.724	0.216	4.614	5.434	5.990	0.215
9499	30 krad	4.644	5.235	5.939	0.238	4.858	5.442	6.068	0.220
9525	30 krad	4.566	5.117	5.724	0.238	4.770	5.328	6.021	0.206
9526	30 krad	4.566	5.191	5.783	0.226	4.848	5.396	5.990	0.209

Table 5n Pre-Irradiation and Post-Annealing VOL

Testname		lvttl_vol_2x (mV) [0.0, 360.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	214.924	221.427	240.652	4.115	215.313	221.687	243.279	4.008
9499	30 krad	214.611	222.756	242.372	4.689	214.922	223.115	241.715	4.284
9525	30 krad	210.077	218.126	241.111	4.311	211.639	219.364	240.855	4.050
9526	30 krad	214.136	220.552	242.496	4.311	214.050	220.827	239.525	4.130

Table 5o Pre-Irradiation and Post-Annealing VOL

Testname		lvttl_vol_3x (mV) [0.0, 360.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	175.292	184.822	213.754	6.169	175.292	185.026	218.959	5.981
9499	30 krad	174.510	185.767	214.523	6.624	174.588	186.115	213.094	6.111
9525	30 krad	171.774	182.372	215.002	6.309	172.790	183.300	216.847	6.017
9526	30 krad	174.354	184.169	216.945	6.385	174.979	184.316	213.094	6.154

Table 5p Pre-Irradiation and Post-Annealing VOL

Testname		lvttl_vol_4x (mV) [0.0, 400.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	206.716	219.628	258.246	8.244	206.715	219.521	265.253	7.982
9499	30 krad	206.091	220.515	258.515	8.782	206.402	220.836	256.729	8.105
9525	30 krad	202.417	216.725	257.917	8.393	203.432	217.490	262.281	8.045
9526	30 krad	205.544	218.874	261.875	8.502	206.402	218.896	257.042	8.196

Table 5q Pre-Irradiation and Post-Annealing VOL

Testname		lvttl_vol_5x (mV) [0.0, 400.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	233.528	252.796	310.792	12.394	233.604	252.731	322.573	11.995
9499	30 krad	232.981	253.670	311.258	13.014	233.292	254.283	307.559	12.017
9525	30 krad	229.151	250.022	310.838	12.588	229.774	250.623	318.429	12.063
9526	30 krad	232.356	252.015	317.509	12.790	233.214	252.094	309.670	12.282

Table 6a Pre-Irradiation and Post-Annealing Ipd

Testname		cmos18_ipd_weak (cmos18_ipd_weak_min) (uA) [4.1, 16.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	8.750	9.057	9.392	0.108	8.850	9.147	9.461	0.113
9499	30 krad	8.538	8.943	9.331	0.114	8.594	9.013	9.388	0.122
9525	30 krad	9.054	9.489	9.833	0.136	9.130	9.515	9.836	0.124
9526	30 krad	8.600	9.026	9.297	0.139	8.599	9.122	9.421	0.143

Table 6b Pre-Irradiation and Post-Annealing Ipd

Testname		cmos18_ipd_weak (cmos18_ipd_weak_max) (uA) [4.1, 20.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	11.266	11.560	11.960	0.119	11.341	11.646	11.962	0.128
9499	30 krad	10.988	11.399	11.771	0.134	11.053	11.475	11.846	0.140
9525	30 krad	11.550	12.083	12.463	0.156	11.652	12.091	12.504	0.146
9526	30 krad	11.022	11.537	11.859	0.166	11.089	11.628	11.972	0.166

Table 6c Pre-Irradiation and Post-Annealing Ipd

Testname		cmos15_ipd_weak (cmos15_ipd_weak_minU) (uA) [2.4, 21.7]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	5.333	5.581	5.826	0.086	5.347	5.642	5.895	0.092
9499	30 krad	5.188	5.509	5.800	0.085	5.156	5.570	5.855	0.095
9525	30 krad	5.459	5.856	6.112	0.107	5.581	5.876	6.144	0.096
9526	30 krad	5.228	5.540	5.797	0.106	5.203	5.607	5.888	0.106

Table 6d Pre-Irradiation and Post-Annealing Ipd

Testname		cmos15_ipd_weak (cmos15_ipd_weak_maxU) (uA) [2.4, 21.7]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	7.551	7.833	8.125	0.099	7.604	7.910	8.204	0.103
9499	30 krad	7.388	7.722	8.039	0.106	7.390	7.791	8.116	0.113
9525	30 krad	7.781	8.206	8.529	0.123	7.882	8.221	8.515	0.112
9526	30 krad	7.401	7.798	8.093	0.126	7.417	7.871	8.146	0.123

Table 6e Pre-Irradiation and Post-Annealing Ipd

Testname		cmos12_ipd_weak (cmos12_ipd_weak_minU) (uA) [0.8, 21.7]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.895	3.131	3.378	0.078	2.890	3.175	3.426	0.082
9499	30 krad	2.838	3.097	3.317	0.073	2.772	3.145	3.417	0.080
9525	30 krad	2.963	3.297	3.515	0.086	3.023	3.327	3.556	0.081
9526	30 krad	2.830	3.104	3.345	0.086	2.839	3.147	3.392	0.088

Table 6f Pre-Irradiation and Post-Annealing Ipd

Testname		cmos12_ipd_weak (cmos12_ipd_weak_maxU) (uA) [1.4, 15.8]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	3.854	4.193	4.431	0.083	3.952	4.246	4.523	0.088
9499	30 krad	3.888	4.140	4.342	0.079	3.851	4.196	4.474	0.086
9525	30 krad	4.061	4.405	4.627	0.097	4.127	4.424	4.688	0.086
9526	30 krad	3.853	4.160	4.370	0.093	3.895	4.216	4.486	0.094

Table 6g Pre-Irradiation and Post-Annealing Ipd

Testname		lvttl_ipd_weak_ (lvttl_ipd_weak_min) (uA) [8.9, 27.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	16.085	16.462	16.971	0.146	16.238	16.552	16.947	0.152
9499	30 krad	15.788	16.221	16.680	0.152	15.821	16.307	16.812	0.161
9525	30 krad	16.517	17.102	17.562	0.184	16.597	17.074	17.545	0.174
9526	30 krad	15.843	16.475	16.870	0.206	15.968	16.575	16.973	0.204

Table 6h Pre-Irradiation and Post-Annealing Ipd

Testname		lvttl_ipd_weak_ (lvttl_ipd_weak_max) (uA) [8.9, 29.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	17.912	18.269	18.813	0.153	18.043	18.375	18.835	0.157
9499	30 krad	17.587	18.015	18.486	0.156	17.602	18.104	18.568	0.162
9525	30 krad	18.280	18.922	19.476	0.196	18.345	18.904	19.446	0.186
9526	30 krad	17.691	18.303	18.702	0.213	17.795	18.409	18.817	0.212

E. High Output-Drive Voltage (VOH and Ipu)

The pre-irradiation and post-annealing VOH are listed in Table 7a through Table 8j. The post-annealing data are within the specification limits (test specification minimum and maximum are given in brackets); data is presented with statistics of all the I/O pins used (~340 sample size of each DUT). In each case, the post-annealing data varies insignificantly.

Table 7a Pre-Irradiation and Post-Annealing VOH

Testname		cmos18_voh_5x (V) [1.3, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	1.926	1.982	2.001	0.012	1.915	1.982	2.000	0.012
9499	30 krad	1.920	1.981	2.000	0.013	1.929	1.981	1.999	0.012
9525	30 krad	1.899	1.982	2.002	0.013	1.913	1.981	2.000	0.012
9526	30 krad	1.914	1.982	2.002	0.012	1.924	1.982	2.001	0.012

Table 7b Pre-Irradiation and Post-Annealing VOH

Testname		cmos15_voh_2x (V) [1.1, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	1.223	1.236	1.243	0.003	1.223	1.236	1.243	0.003
9499	30 krad	1.222	1.236	1.244	0.003	1.223	1.236	1.244	0.003
9525	30 krad	1.223	1.236	1.243	0.003	1.223	1.236	1.243	0.003
9526	30 krad	1.222	1.236	1.243	0.003	1.222	1.236	1.243	0.003

Table 7c Pre-Irradiation and Post-Annealing VOH

Testname		cmos15_voh_3x (V) [1.1, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	1.214	1.229	1.236	0.003	1.214	1.229	1.236	0.003
9499	30 krad	1.214	1.229	1.237	0.003	1.214	1.229	1.237	0.003
9525	30 krad	1.215	1.230	1.237	0.003	1.214	1.229	1.236	0.003
9526	30 krad	1.213	1.229	1.236	0.003	1.214	1.229	1.236	0.003

Table 7d Pre-Irradiation and Post-Annealing VOH

Testname		cmos15_voh_4x (V) [1.1, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	1.175	1.192	1.200	0.004	1.176	1.192	1.200	0.004
9499	30 krad	1.176	1.192	1.201	0.004	1.176	1.192	1.202	0.004
9525	30 krad	1.175	1.193	1.201	0.004	1.176	1.193	1.201	0.004
9526	30 krad	1.174	1.192	1.201	0.004	1.176	1.193	1.201	0.004

Table 7e Pre-Irradiation and Post-Annealing VOH

Testname		cmos15_voh_5x (V) [1.1, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	1.149	1.176	1.188	0.006	1.144	1.177	1.187	0.006
9499	30 krad	1.144	1.176	1.186	0.007	1.150	1.176	1.187	0.006
9525	30 krad	1.138	1.177	1.188	0.006	1.144	1.177	1.187	0.006
9526	30 krad	1.143	1.177	1.188	0.006	1.149	1.177	1.187	0.006

Table 7f Pre-Irradiation and Post-Annealing VOH

Testname		cmos12_voh_2x (V) [0.8, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	0.885	0.916	0.930	0.005	0.886	0.916	0.930	0.005
9499	30 krad	0.885	0.916	0.932	0.006	0.886	0.916	0.932	0.006
9525	30 krad	0.887	0.917	0.932	0.005	0.887	0.917	0.931	0.005
9526	30 krad	0.883	0.915	0.930	0.006	0.884	0.915	0.930	0.005

Table 7g Pre-Irradiation and Post-Annealing VOH

Testname		cmos12_voh_3x (V) [0.9, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	1.023	1.034	1.039	0.002	1.023	1.034	1.039	0.002
9499	30 krad	1.022	1.034	1.041	0.002	1.023	1.034	1.040	0.002
9525	30 krad	1.023	1.034	1.040	0.002	1.023	1.034	1.040	0.002
9526	30 krad	1.022	1.034	1.040	0.002	1.023	1.034	1.040	0.002

Table 7h Pre-Irradiation and Post-Annealing VOH

Testname		cmos12_voh_3xE1 (V) [1.0, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	1.132	1.133	1.134	0.000	1.133	1.133	1.134	0.000
9499	30 krad	1.132	1.133	1.134	0.000	1.133	1.133	1.134	0.000
9525	30 krad	1.132	1.133	1.134	0.000	1.132	1.133	1.134	0.000
9526	30 krad	1.132	1.133	1.134	0.000	1.133	1.133	1.134	0.000

Table 7i Pre-Irradiation and Post-Annealing VOH

Testname		cmos12_voh_3xE2 (V) [1.3, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	1.394	1.395	1.396	0.000	1.394	1.395	1.396	0.000
9499	30 krad	1.394	1.395	1.396	0.000	1.395	1.395	1.396	0.000
9525	30 krad	1.394	1.395	1.396	0.000	1.395	1.395	1.396	0.000
9526	30 krad	1.394	1.395	1.396	0.000	1.395	1.395	1.396	0.000

Table 7j Pre-Irradiation and Post-Annealing VOH

Testname		lvttl_voh_1x12 (V) [2.5, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.629	2.642	2.651	0.004	2.629	2.642	2.652	0.004
9499	30 krad	2.627	2.641	2.651	0.004	2.629	2.642	2.652	0.004
9525	30 krad	2.630	2.642	2.652	0.004	2.629	2.641	2.650	0.004
9526	30 krad	2.628	2.643	2.653	0.004	2.629	2.643	2.654	0.004

Table 7k Pre-Irradiation and Post-Annealing VOH

Testname		lvttl_voh_1x (V) [2.5, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.629	2.642	2.651	0.004	2.629	2.642	2.652	0.004
9499	30 krad	2.627	2.641	2.651	0.004	2.629	2.642	2.652	0.004
9525	30 krad	2.630	2.642	2.652	0.004	2.629	2.641	2.650	0.004
9526	30 krad	2.628	2.643	2.653	0.004	2.629	2.643	2.653	0.004

Table 7l Pre-Irradiation and Post-Annealing VOH

Testname		lvttl_voh_1xE1 (V) [2.8, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.990	2.991	2.991	0.000	2.990	2.991	2.992	0.000
9499	30 krad	2.990	2.991	2.991	0.000	2.990	2.991	2.991	0.000
9525	30 krad	2.990	2.991	2.991	0.000	2.990	2.991	2.992	0.000
9526	30 krad	2.990	2.991	2.991	0.000	2.990	2.991	2.992	0.000

Table 7m Pre-Irradiation and Post-Annealing VOH

Testname		lvttl_voh_1xE2 (V) [2.5, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.687	2.688	2.689	0.000	2.690	2.691	2.691	0.000
9499	30 krad	2.687	2.688	2.689	0.000	2.690	2.691	2.692	0.000
9525	30 krad	2.687	2.688	2.689	0.000	2.690	2.691	2.692	0.000
9526	30 krad	2.687	2.688	2.689	0.000	2.690	2.691	2.692	0.000

Table 7n Pre-Irradiation and Post-Annealing VOH

Testname		lvttl_voh_2x (V) [2.5, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.607	2.628	2.638	0.005	2.607	2.628	2.638	0.005
9499	30 krad	2.604	2.627	2.638	0.005	2.611	2.628	2.639	0.005
9525	30 krad	2.612	2.628	2.639	0.005	2.606	2.627	2.638	0.005
9526	30 krad	2.602	2.628	2.640	0.005	2.610	2.629	2.641	0.005

Table 7o Pre-Irradiation and Post-Annealing VOH

Testname		lvttl_voh_3x (V) [2.4, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.676	2.704	2.715	0.006	2.671	2.704	2.715	0.006
9499	30 krad	2.671	2.704	2.714	0.007	2.678	2.703	2.714	0.006
9525	30 krad	2.677	2.704	2.715	0.006	2.671	2.703	2.714	0.006
9526	30 krad	2.669	2.704	2.716	0.007	2.677	2.705	2.715	0.006

Table 7p Pre-Irradiation and Post-Annealing VOH

Testname		lvttl_voh_4x (V) [2.4, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.642	2.679	2.694	0.008	2.635	2.679	2.693	0.008
9499	30 krad	2.636	2.679	2.692	0.009	2.644	2.678	2.691	0.008
9525	30 krad	2.644	2.679	2.693	0.008	2.635	2.678	2.692	0.008
9526	30 krad	2.633	2.679	2.694	0.008	2.642	2.680	2.694	0.008

Table 7q Pre-Irradiation and Post-Annealing VOH

Testname		lvttl_voh_5x (V) [2.4, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	2.665	2.723	2.742	0.012	2.655	2.723	2.741	0.012
9499	30 krad	2.663	2.723	2.741	0.013	2.671	2.723	2.741	0.011
9525	30 krad	2.667	2.723	2.742	0.012	2.656	2.722	2.741	0.012
9526	30 krad	2.656	2.723	2.743	0.012	2.667	2.724	2.742	0.012

Table 8a Pre-Irradiation and Post-Annealing Ipu

Testname		cmos18_ipu_weak (cmos18_ipu_weak_Min.U) (uA) [-18.0, -6.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-14.504	-13.964	-13.473	0.198	-14.467	-13.893	-13.386	0.191
9499	30 krad	-14.424	-13.973	-13.499	0.186	-14.399	-13.885	-13.337	0.183
9525	30 krad	-14.644	-14.128	-13.694	0.181	-14.542	-13.992	-13.507	0.187
9526	30 krad	-14.469	-13.974	-13.396	0.204	-14.514	-13.882	-13.333	0.201

Table 8b Pre-Irradiation and Post-Annealing Ipu

Testname		cmos18_ipu_weak (cmos18_ipu_weak_Max.U) (uA) [-25.0, -6.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-17.811	-17.229	-16.647	0.229	-17.854	-17.137	-16.532	0.221
9499	30 krad	-17.801	-17.234	-16.694	0.219	-17.695	-17.142	-16.510	0.213
9525	30 krad	-17.999	-17.430	-16.942	0.212	-17.873	-17.260	-16.758	0.219
9526	30 krad	-17.822	-17.240	-16.666	0.233	-17.859	-17.144	-16.516	0.231

Table 8c Pre-Irradiation and Post-Annealing Ipu

Testname		cmos15_ipu_weak (cmos15_ipu_weak_Min.U) (uA) [-21.7, -3.8]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-9.461	-9.046	-8.687	0.144	-9.498	-8.976	-8.603	0.139
9499	30 krad	-9.377	-9.037	-8.674	0.140	-9.380	-8.975	-8.616	0.134
9525	30 krad	-9.536	-9.143	-8.784	0.133	-9.523	-9.065	-8.656	0.139
9526	30 krad	-9.430	-9.026	-8.677	0.145	-9.384	-8.960	-8.529	0.143

Table 8d Pre-Irradiation and Post-Annealing Ipu

Testname		cmos15_ipu_weak (cmos15_ipu_weak_Max.U) (uA) [-21.7, -3.8]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-12.625	-12.169	-11.721	0.177	-12.635	-12.101	-11.630	0.168
9499	30 krad	-12.585	-12.167	-11.752	0.165	-12.551	-12.092	-11.639	0.165
9525	30 krad	-12.741	-12.305	-11.930	0.163	-12.685	-12.181	-11.732	0.167
9526	30 krad	-12.641	-12.159	-11.703	0.180	-12.653	-12.089	-11.558	0.181

Table 8e Pre-Irradiation and Post-Annealing Ipu

Testname		cmos12_ipu_weak (cmos12_ipu_weak_Min.U) (uA) [-21.7, -1.4]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-5.836	-5.498	-5.142	0.109	-5.860	-5.452	-5.152	0.106
9499	30 krad	-5.769	-5.495	-5.200	0.102	-5.784	-5.448	-5.218	0.104
9525	30 krad	-5.861	-5.560	-5.286	0.099	-5.985	-5.509	-5.203	0.108
9526	30 krad	-5.780	-5.480	-5.167	0.107	-5.788	-5.431	-5.061	0.110

Table 8f Pre-Irradiation and Post-Annealing Ipu

Testname		cmos12_ipu_weak (cmos12_ipu_weak_Max.U) (uA) [-15.8, -3.8]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-7.411	-7.039	-6.689	0.125	-7.466	-6.991	-6.630	0.121
9499	30 krad	-7.348	-7.033	-6.701	0.118	-7.332	-6.981	-6.688	0.117
9525	30 krad	-7.458	-7.119	-6.785	0.111	-7.441	-7.048	-6.697	0.123
9526	30 krad	-7.361	-7.023	-6.664	0.122	-7.365	-6.972	-6.607	0.123

Table 8g Pre-Irradiation and Post-Annealing Ipu

Testname		lvttl_ipu_weak_ (lvttl_ipu_weak_Min.) (uA) [-102.0, -12.7]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-35.697	-34.649	-33.623	0.405	-35.495	-34.497	-33.464	0.393
9499	30 krad	-35.688	-34.700	-33.837	0.374	-35.523	-34.524	-33.597	0.372
9525	30 krad	-36.083	-34.990	-34.132	0.388	-35.765	-34.724	-33.865	0.385
9526	30 krad	-35.829	-34.740	-33.706	0.417	-35.764	-34.566	-33.518	0.416

Table 8h Pre-Irradiation and Post-Annealing Ipu

Testname		lvttl_ipu_weak_ (lvttl_ipu_weak_Max.) (uA) [-112.0, -12.7]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
9485	30 krad	-72.922	-70.943	-68.976	0.784	-72.541	-70.633	-68.653	0.771
9499	30 krad	-73.068	-71.105	-69.376	0.738	-72.756	-70.737	-69.013	0.726
9525	30 krad	-73.948	-71.748	-70.067	0.766	-73.305	-71.152	-69.550	0.762
9526	30 krad	-73.300	-71.191	-69.137	0.816	-72.982	-70.858	-68.827	0.812

F. Propagation Delay

DUTs are irradiated to 30 krads. Table 9a and Table 9b lists the pre-irradiation, post-30-krad-irradiation, and post-annealing propagation delay at 1.5 V VCC and lists the degradation in percentage.

Table 9 Propagation Delay to Irradiation Dose, Vcc=1.5 V

DUT	Pre-Irradiation (ns)	Post-30 krad (ns)	Post-Annealing (ns)
9485	693.134	737.985	733.210
9499	687.158	740.500	741.850
9525	682.361	739.408	735.950
9526	681.889	745.635	745.600

Table 9b Radiation-Induced Propagation Delay Degradation in Percentage, Vcc=1.5 V

DUT	(Compared to Pre-irradiation)	Post-30 krad (%)	Post-Annealing (%)
9485	–	6.5%	5.8%
9499	–	7.8%	8.0%
9525	–	8.4%	7.9%
9526	–	9.3%	9.3%

Figure 2 has the percentage of the degradation on propagation delay in Tables 9b plotted.

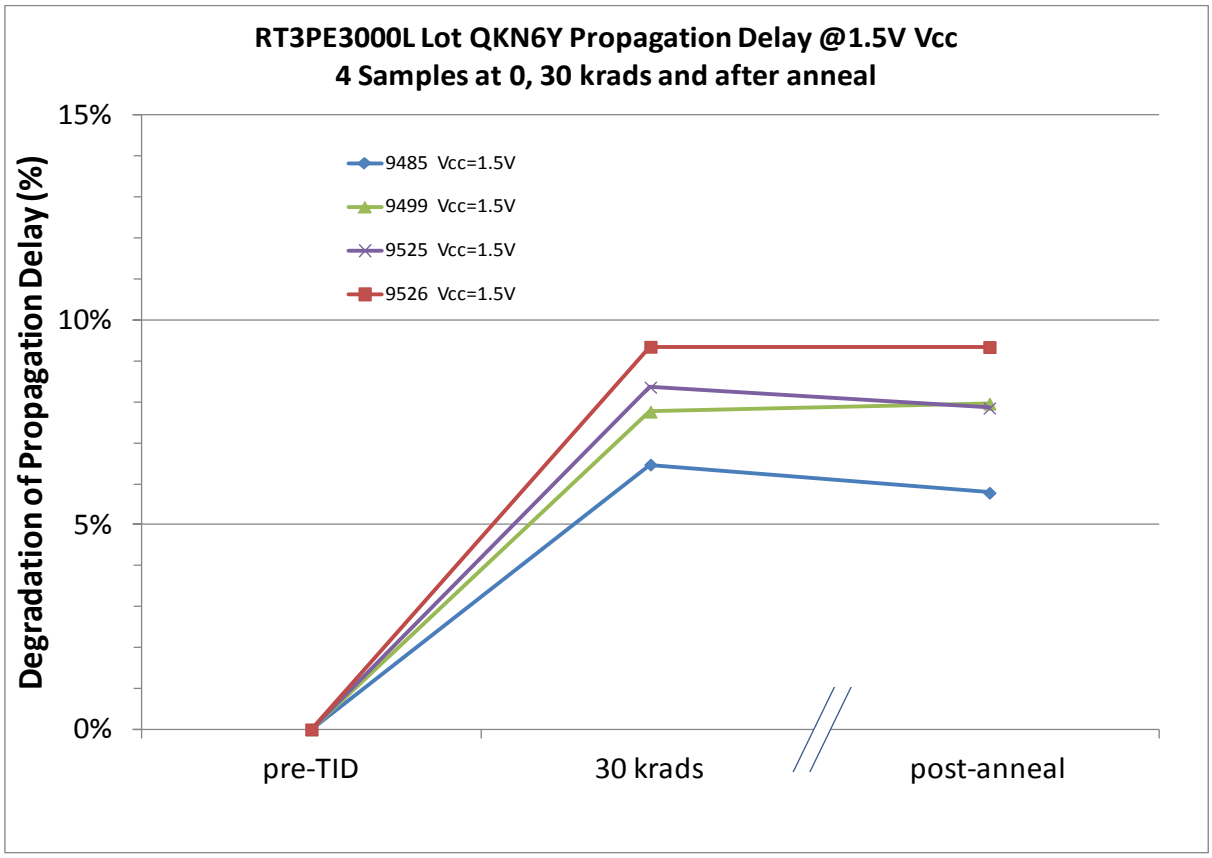


Figure 2 Degradation of Propagation Delay versus TID and Annealing

G. Transition Time

Figures 3a to Figure 10b show pre-irradiation and post-annealing transition edges. In each case, the radiation effect is not significant.

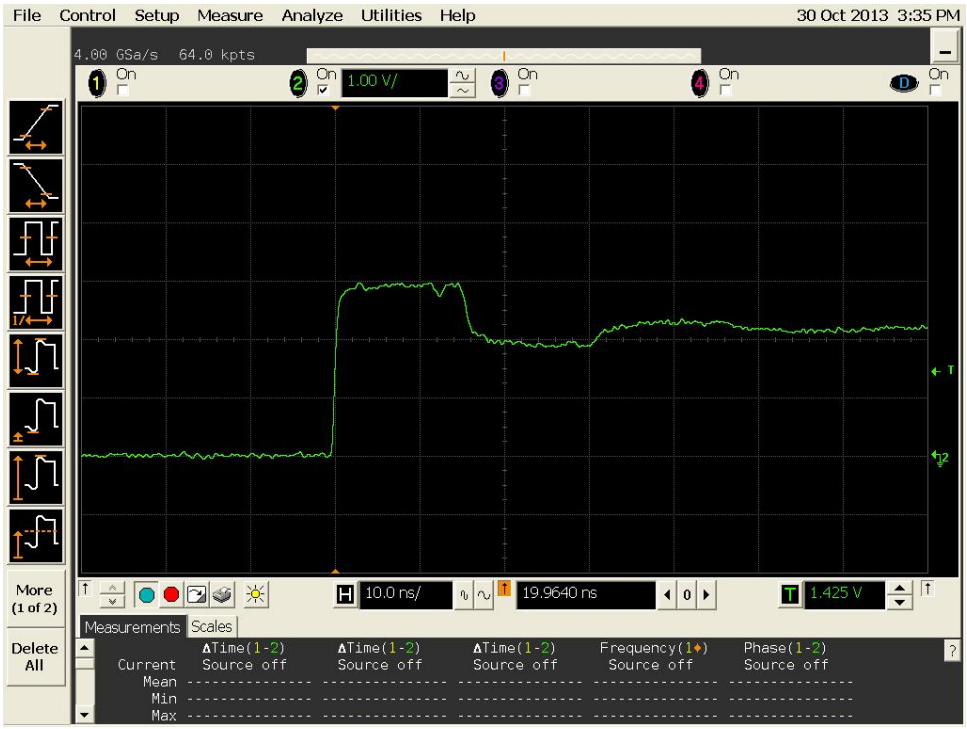


Figure 3a DUT 9485 Pre-Irradiation Rising Edge

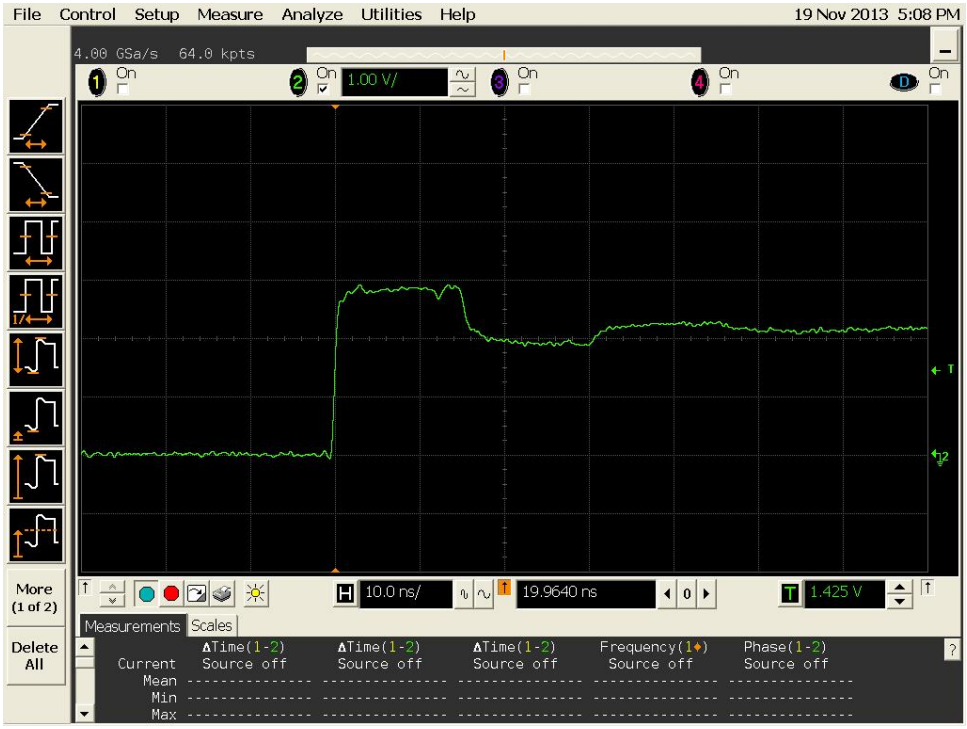


Figure 3b DUT 9485 Post-Annealing Rising Edge

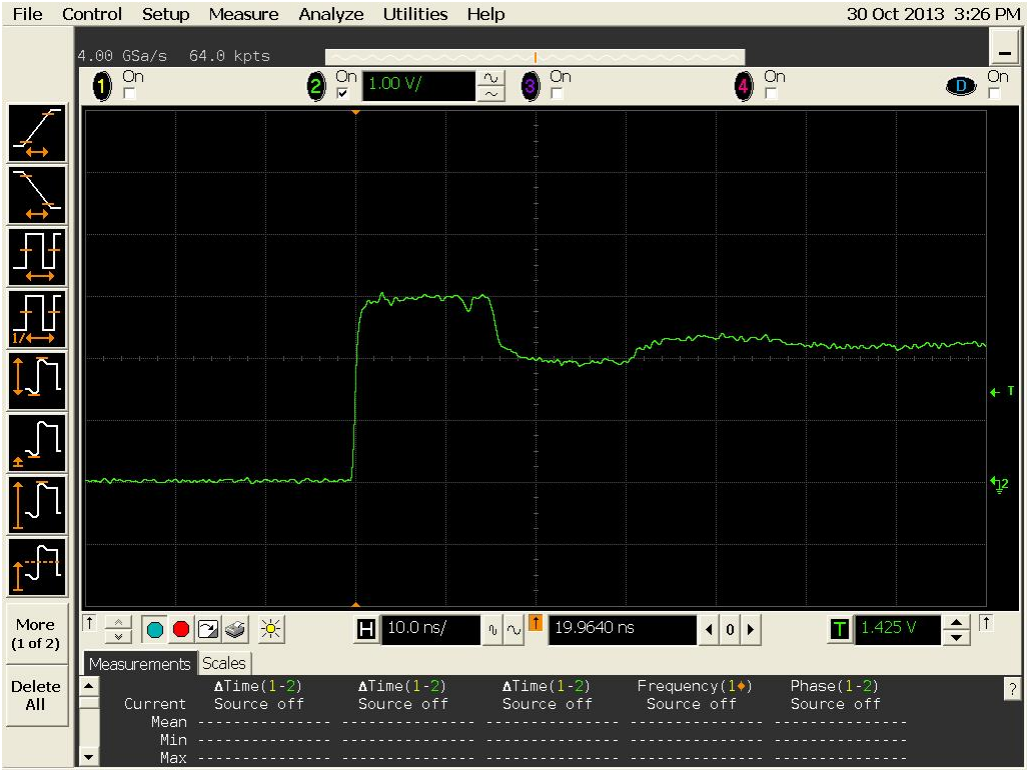


Figure 4a DUT 9499 Pre-Irradiation Rising Edge

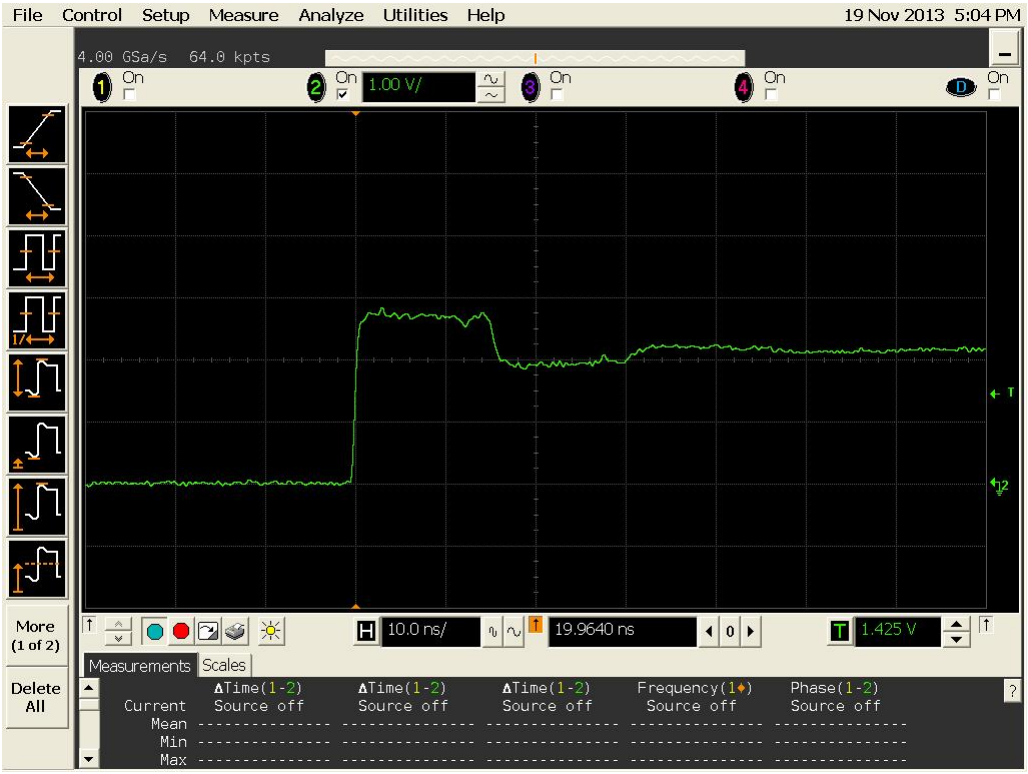


Figure 4b DUT 9499 Post-Annealing Rising Edge

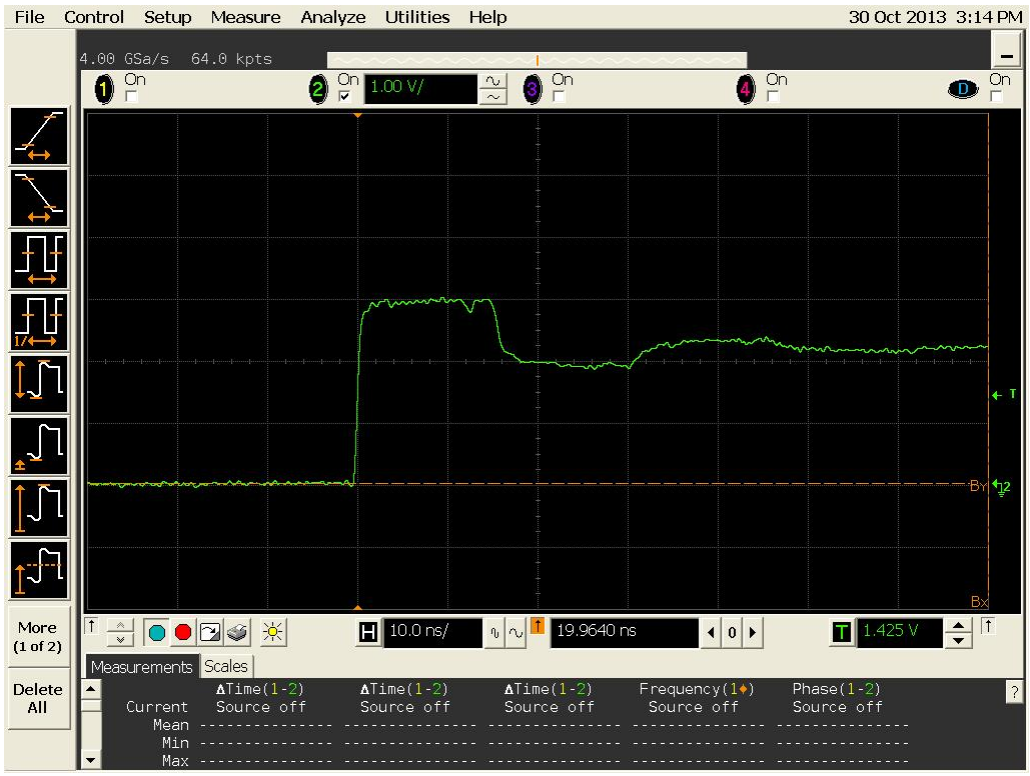


Figure 5a DUT 9525 Pre-Irradiation Rising Edge

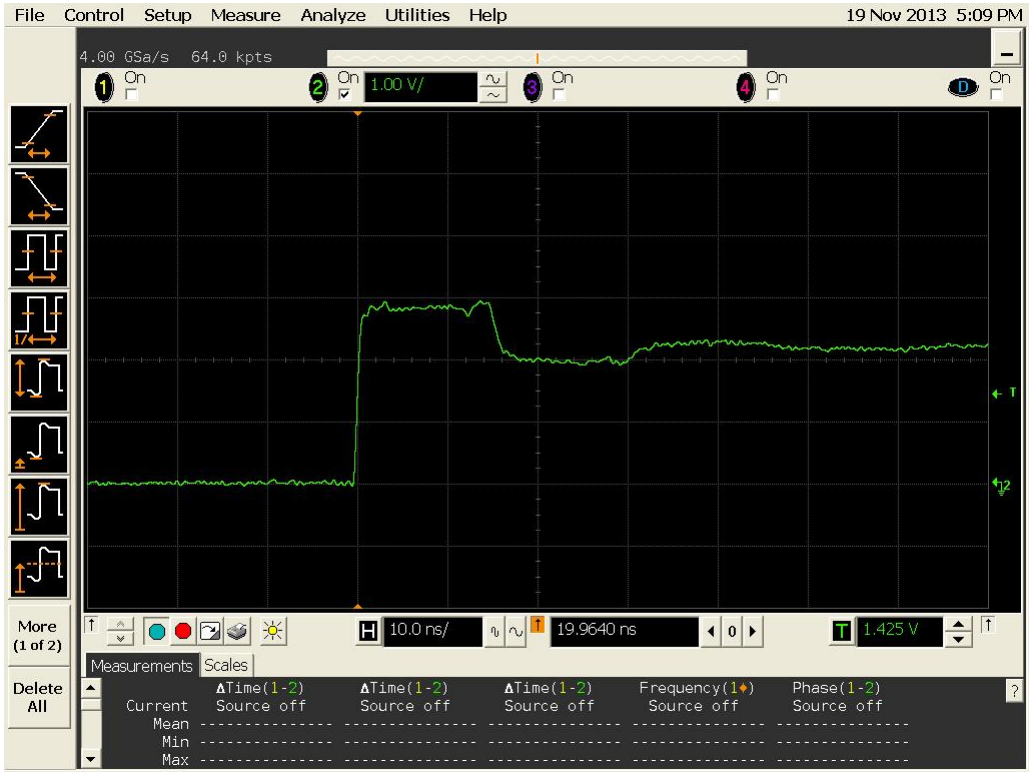


Figure 5b DUT 9525 Post-Annealing Rising Edge

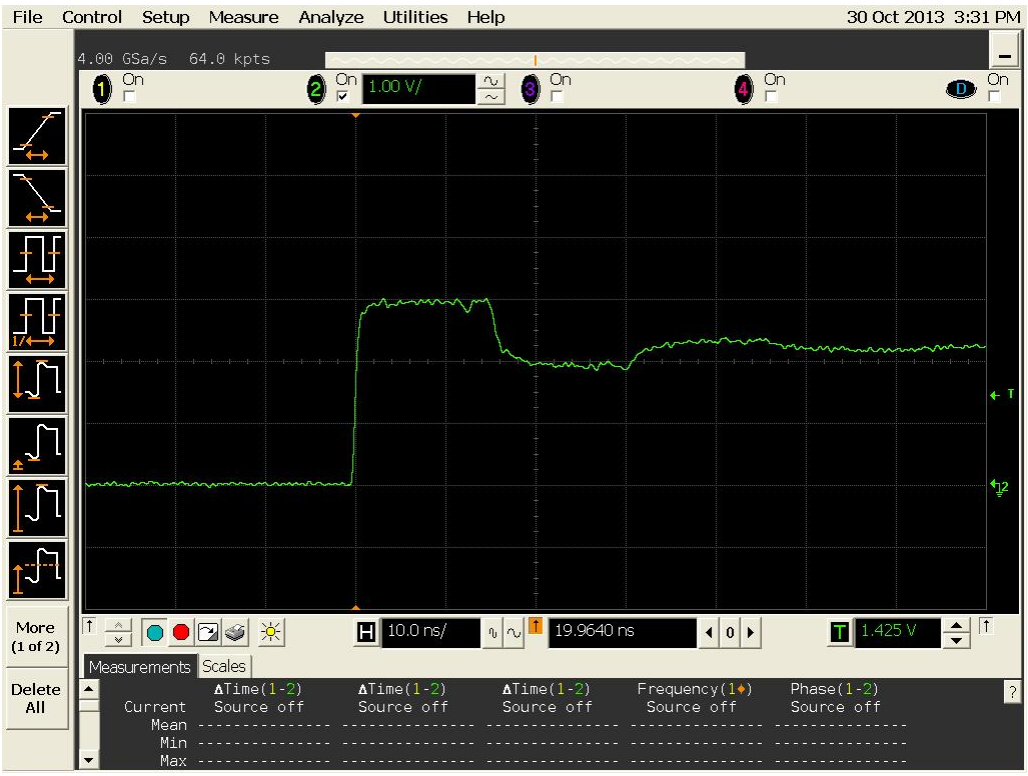


Figure 6a DUT 9526 Pre-Irradiation Rising Edge

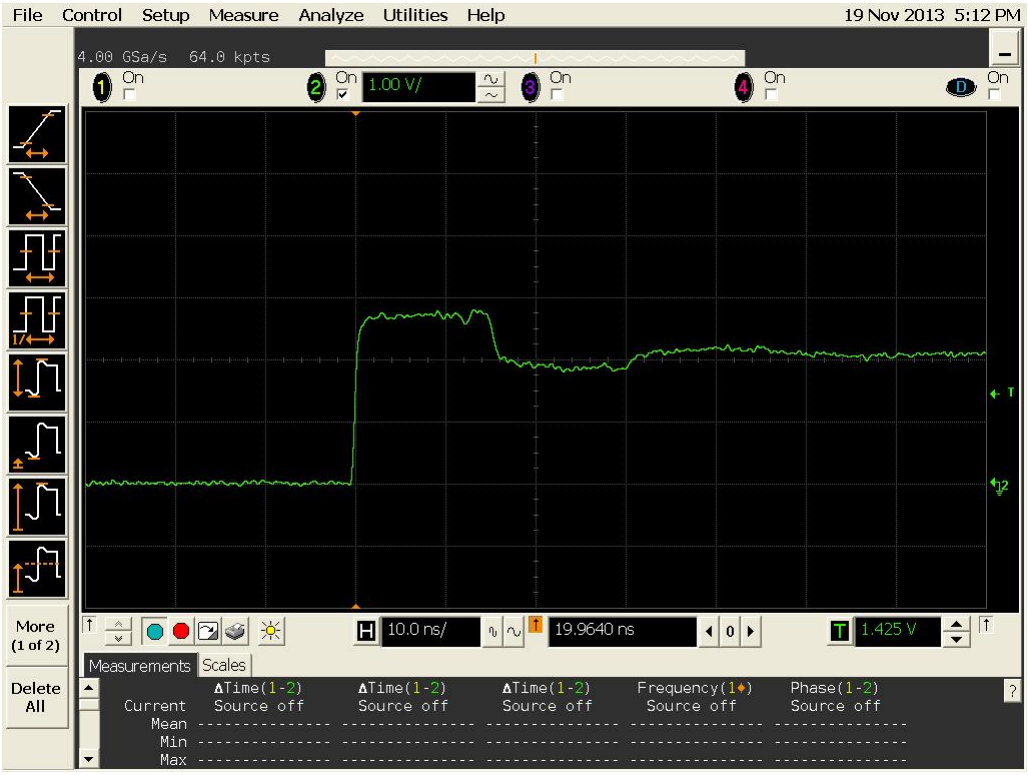


Figure 6b DUT 9526 Post-Annealing Rising Edge

Figure 7a DUT 9485 Pre-Irradiation Falling Edge

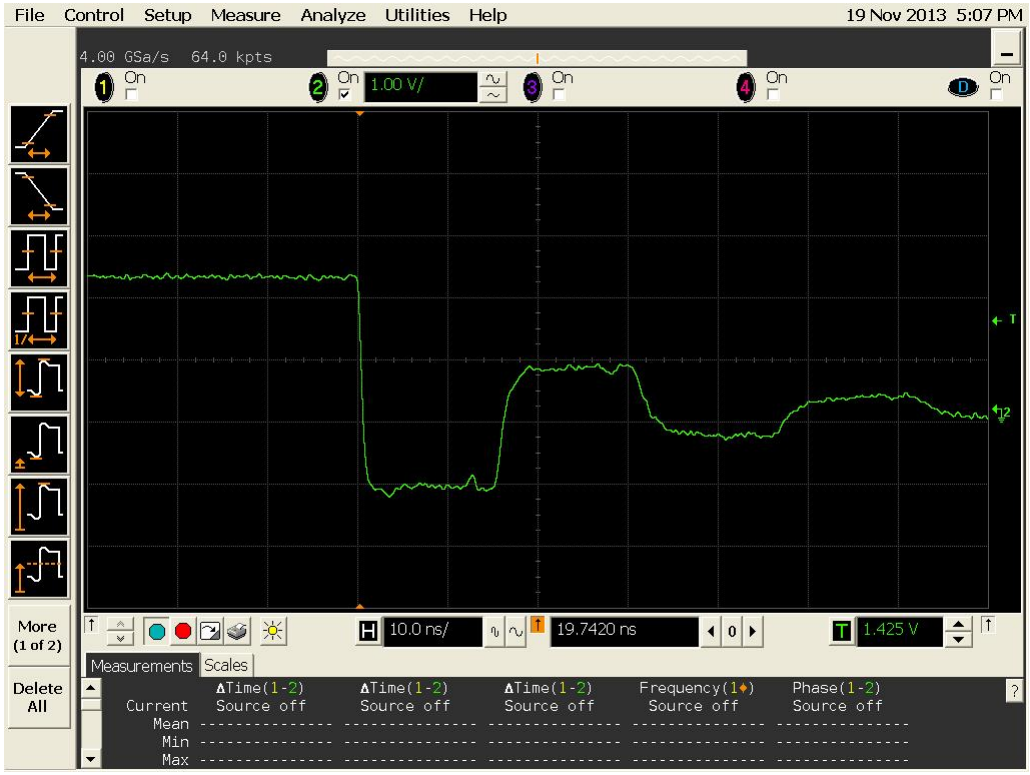


Figure 7b DUT 9485 Post-Annealing Falling Edge

Figure 8a DUT 9499 Pre-Irradiation Falling Edge

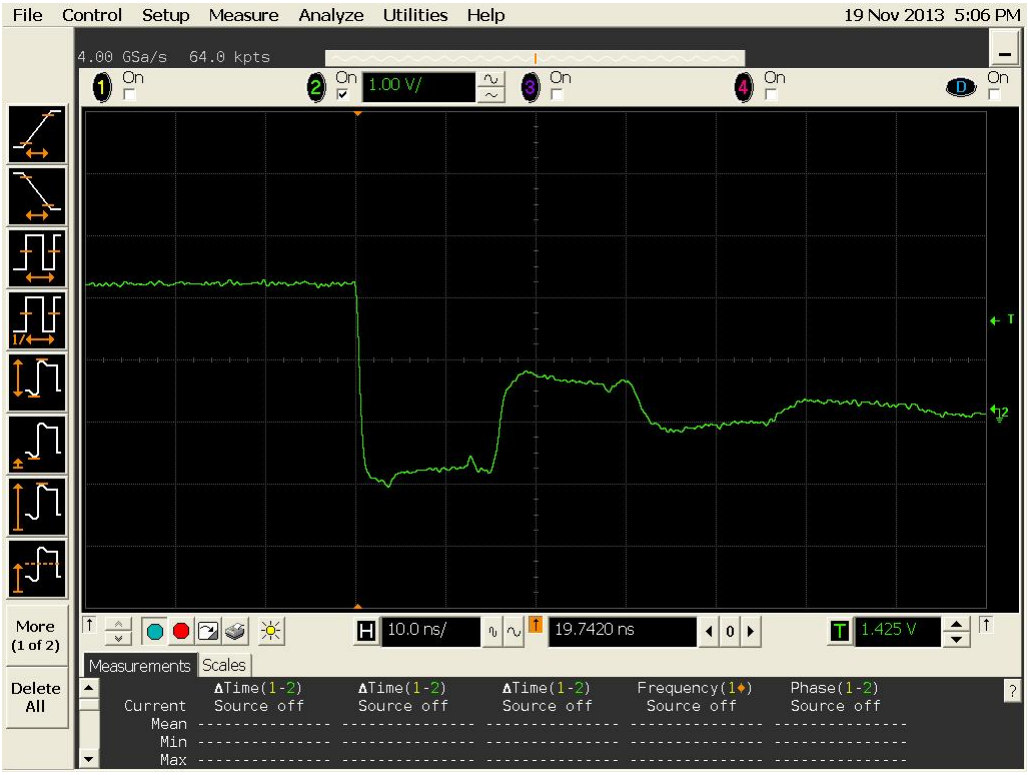


Figure 8b DUT 9499 Post-Annealing Falling Edge

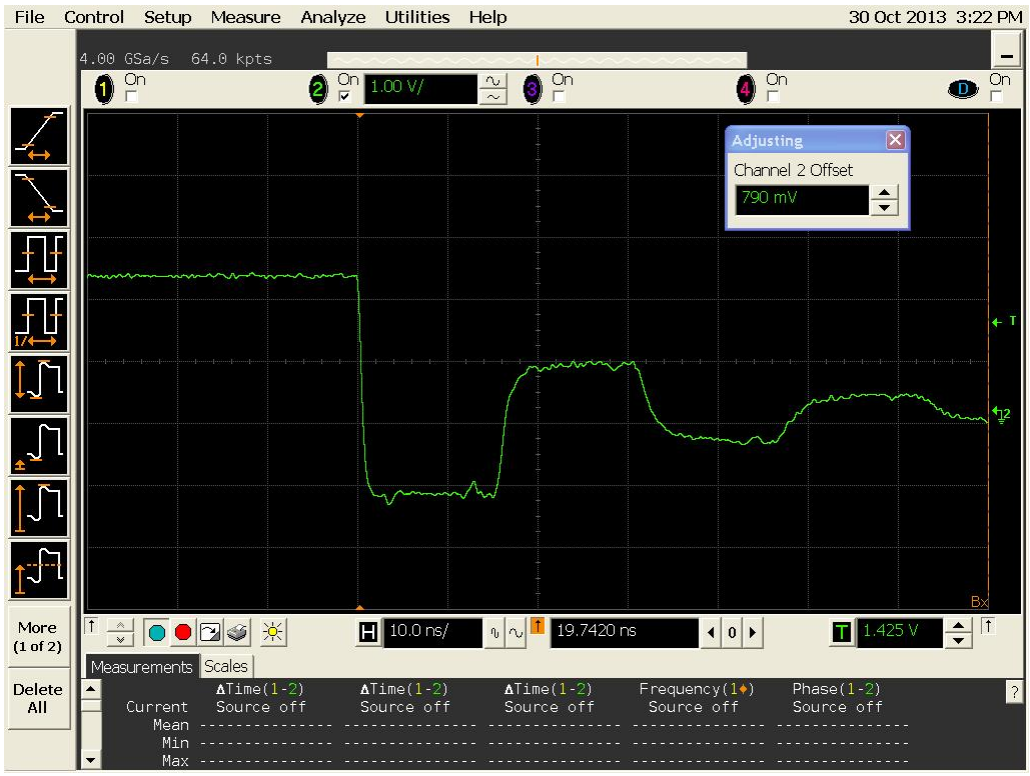


Figure 9a DUT 9525 Pre-Irradiation Falling Edge

Figure 9b DUT 9525 Post-Annealing Falling Edge

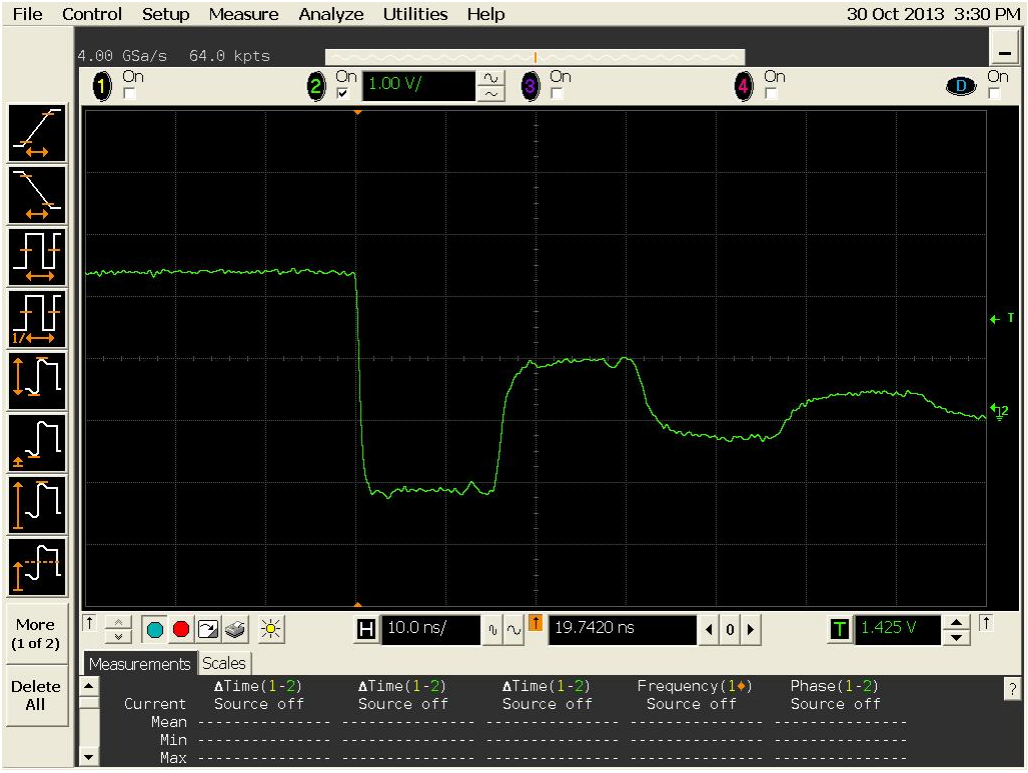


Figure 10a DUT 9526 Pre-Irradiation Falling Edge

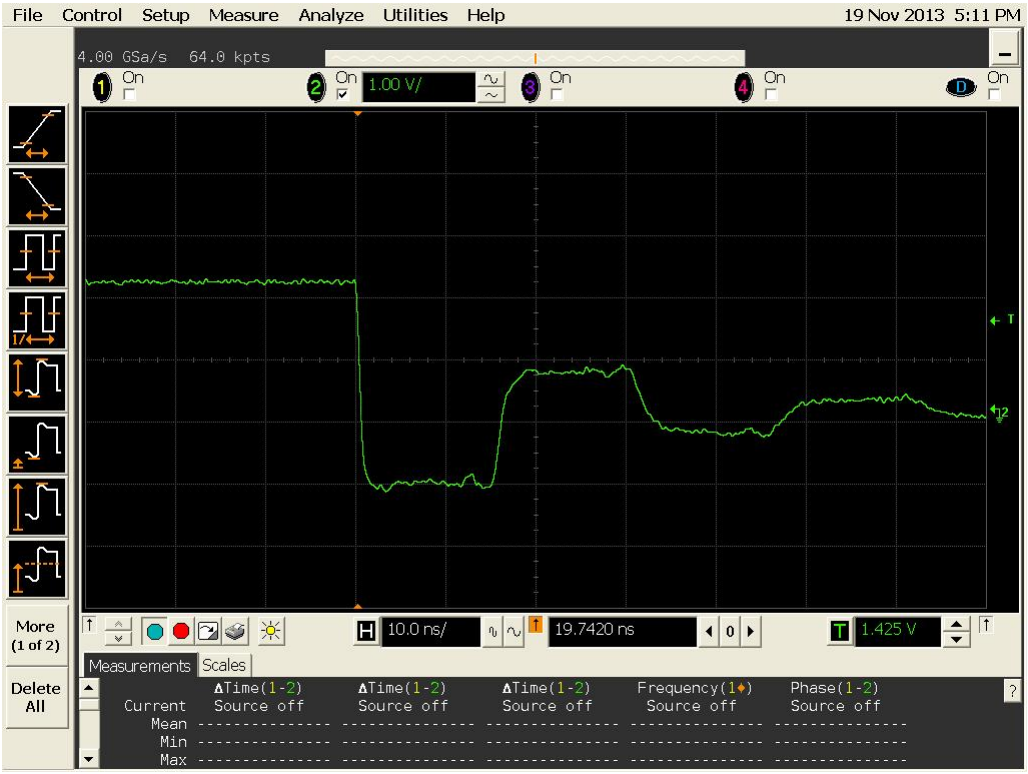


Figure 10b DUT 9526 Post-Annealing Falling Edge

Appendix A – DUT Design Block Diagrams and Schematics

A. PLL Block

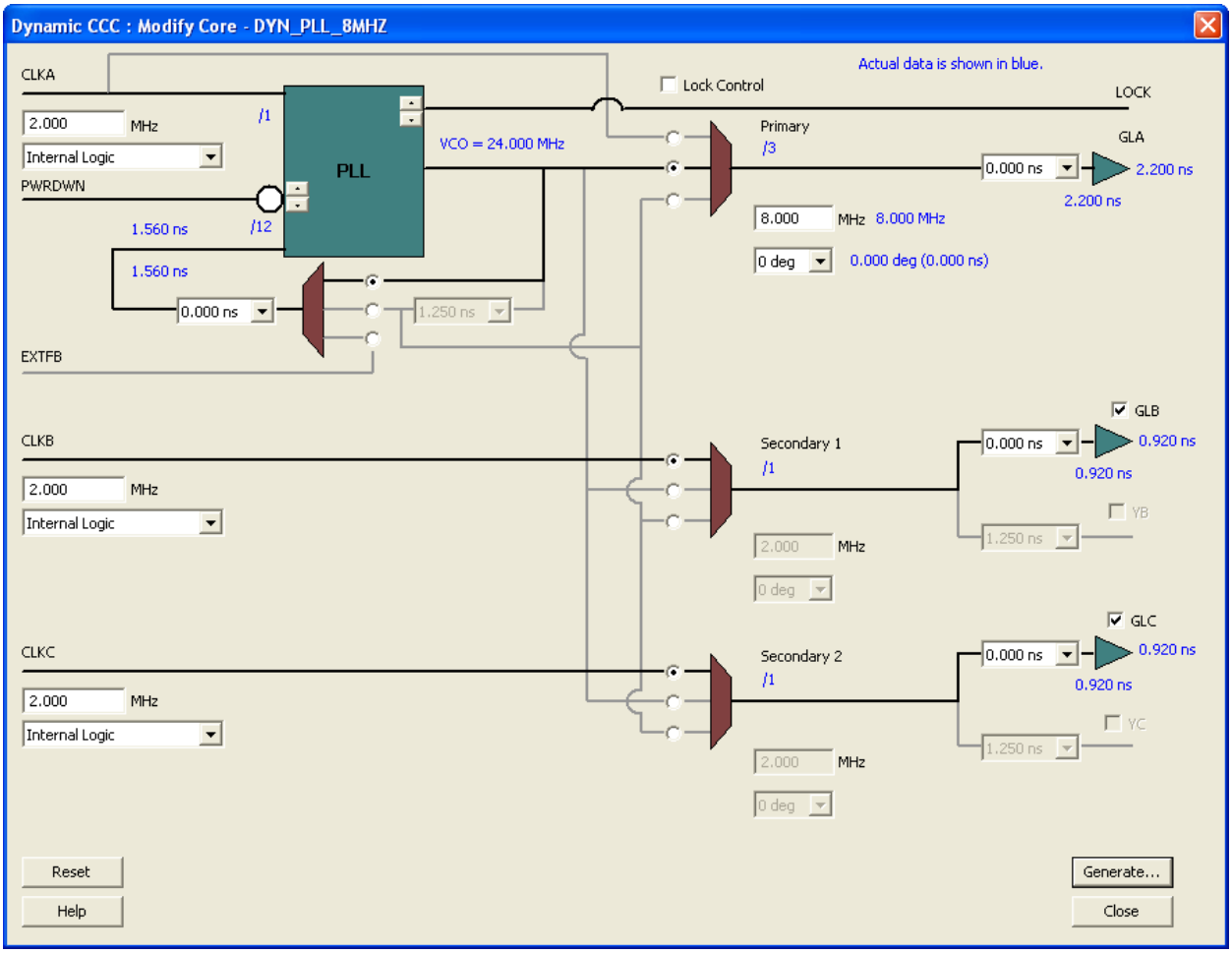
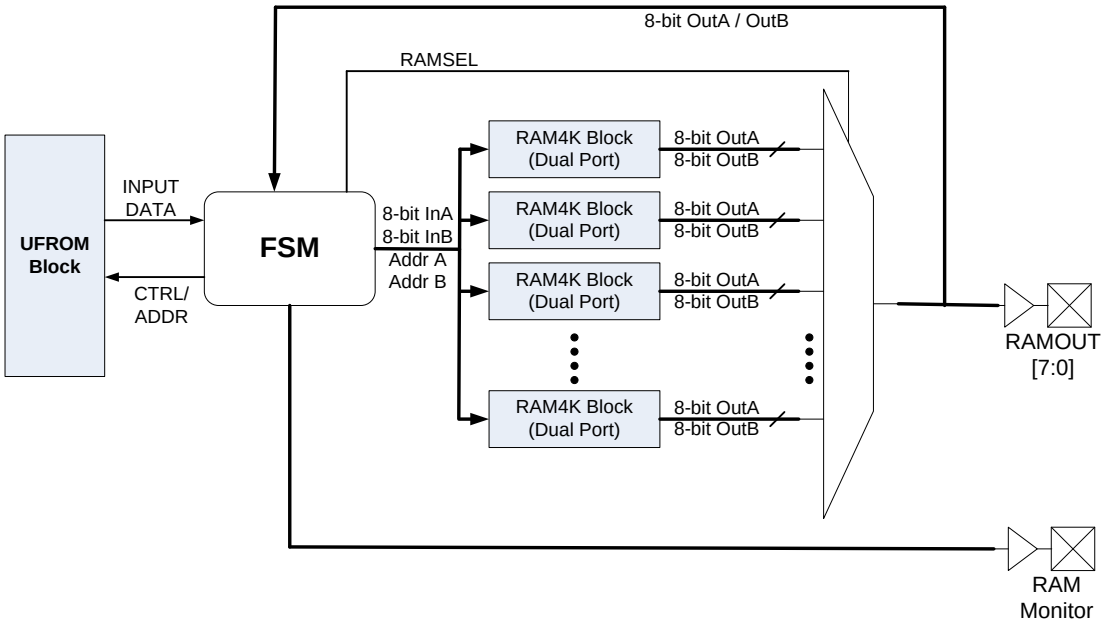


Table 10 lists the signals that go through each of the PLLs:

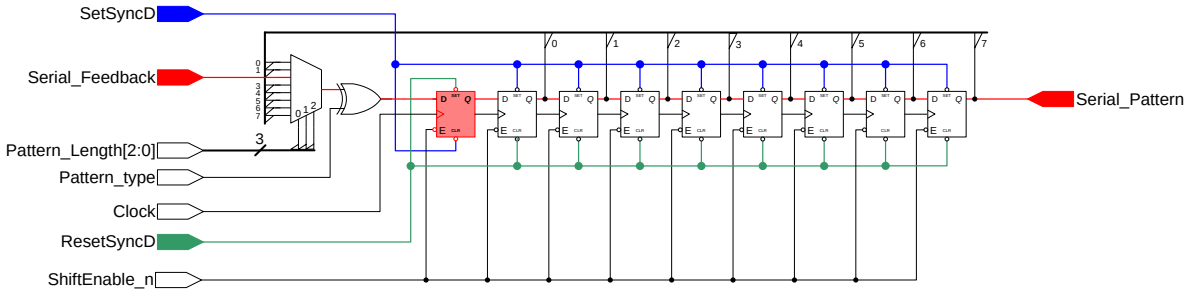
Table 10 Signals Through PLLs

PLL	Multiply-by	GLA	GLB	GLC
0	x4	CLK – upper right I/O	Reset – upper right I/O	OE – upper right I/O
1	x4	CLK –upper left I/O	Reset – upper left I/O	OE – upper left I/O
2	x4	CLK – lower right I/O	Reset – lower right I/O	OE – lower right I/O
3	x4	CLK – lower left I/O	Reset – lower left I/O	OE – lower left I/O
4	x16	CLK – array shift registers	Reset – array shift registers	SET – array shift registers
5	x4	CLK –SRAM block	Reset – SRAM block	Original CLK

B. UFROM/SRAM Block

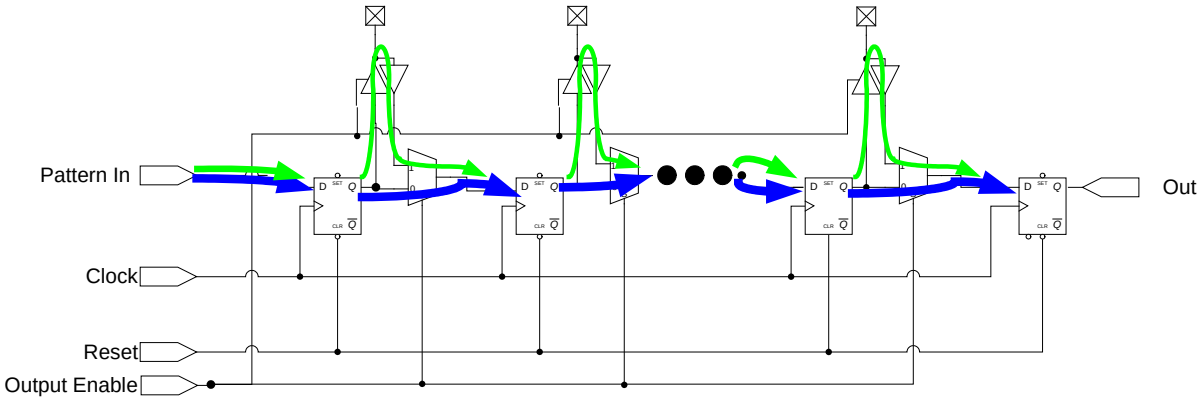


C. Pattern Generators Block

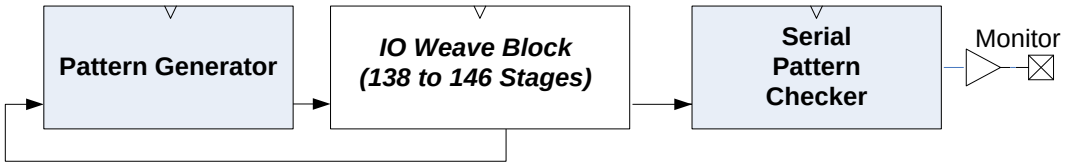


Pattern Type	Pattern Length		Code Length	Δ Bits	Switching Rate
0	000	1 0 ⇨ 0 1 ↰	2	2	100.00%
0	001	1 0 0 ⇨ 0 1 0 ⇨ 0 0 1 ↰	3	2	66.67%
0	010	**One hot I/O at a time switching in entire I/O ring**	#Bits+9	2	N/A
0	011	1 0 0 0 0 ⇨ 0 1 0 0 0 ⇨ 0 0 1 0 0 ⇨ 0 0 0 1 0 ⇨ 0 0 0 0 1 ↰	5	2	40.00%
0	100	1 0 0 0 0 0 ⇨ 0 1 0 0 0 0 ⇨ 0 0 1 0 0 0 ⇨ 0 0 0 1 0 0 ⇨ 0 0 0 0 0 1 ↰	6	2	33.33%
0	101	1 0 0 0 0 0 0 ⇨ 0 1 0 0 0 0 0 ⇨ 0 0 1 0 0 0 0 ⇨ 0 0 0 1 0 0 0 ⇨ 0 0 0 0 1 0 0 ⇨ 0 0	7	2	28.57%
0	110	1 0 0 0 0 0 0 0 ⇨ 0 1 0 0 0 0 0 0 ⇨ 0 0 1 0 0 0 0 0 ⇨ 0 0 0 1 0 0 0 0 ⇨ 0 0 0 0 1 0	8	2	25.00%
0	111	1 0 0 0 0 0 0 0 0 ⇨ 0 1 0 0 0 0 0 0 0 ⇨ 0 0 1 0 0 0 0 0 0 ⇨ 0 0 0 1 0 0 0 0 0 ⇨ 0 0	9	2	22.22%
1	000	1 0 ⇨ 1 1 ⇨ 0 1 ⇨ 0 0 ↰	2	1	50.00%
1	001	1 0 0 ⇨ 1 1 0 ⇨ 1 1 1 ⇨ 0 1 1 ⇨ 0 0 1 ⇨ 0 0 0 ↰	3	1	33.33%
1	010	**Wave of 0's followed by wave of 1's**	#Bits+9	1	N/A
1	011	1 0 0 0 0 ⇨ 1 1 0 0 0 ⇨ 1 1 1 0 0 ⇨ 1 1 1 1 0 ⇨ 1 1 1 1 1 ⇨ 0 1 1 1 1 ⇨ 0 0 1 1 1 ⇨	5	1	20.00%
1	100	1 0 0 0 0 0 ⇨ 1 1 0 0 0 0 ⇨ 1 1 1 0 0 0 ⇨ 1 1 1 1 0 0 ⇨ 1 1 1 1 1 0 ⇨ 1 1 1 1 1 1 ⇨	6	1	16.67%
1	101	1 0 0 0 0 0 0 ⇨ 1 1 0 0 0 0 0 ⇨ 1 1 1 0 0 0 0 ⇨ 1 1 1 1 0 0 0 ⇨ 1 1 1 1 1 0 0 ⇨ 1 1	7	1	14.29%
1	110	1 0 0 0 0 0 0 0 ⇨ 1 1 0 0 0 0 0 0 ⇨ 1 1 1 0 0 0 0 0 ⇨ 1 1 1 1 0 0 0 0 ⇨ 1 1 1 1 1 0	8	1	12.50%
1	111	1 0 0 0 0 0 0 0 0 ⇨ 1 1 0 0 0 0 0 0 0 ⇨ 1 1 1 0 0 0 0 0 0 ⇨ 1 1 1 1 0 0 0 0 0 ⇨ 1 1	9	1	11.11%

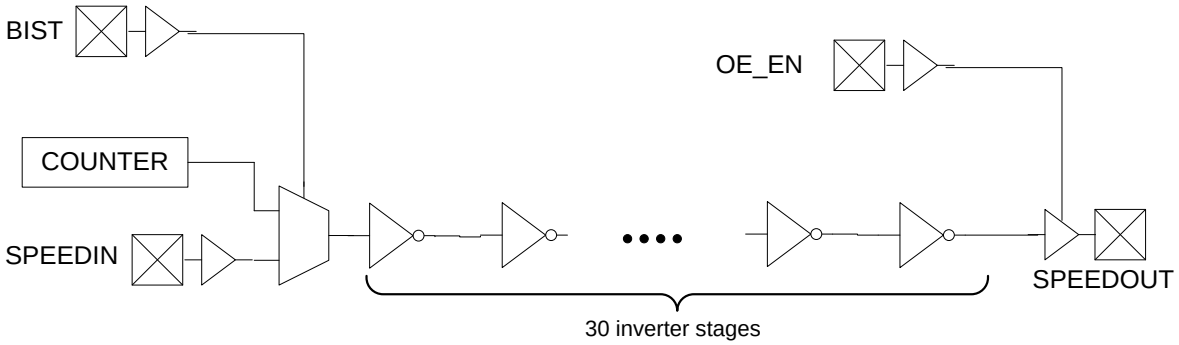
D. I/O Block



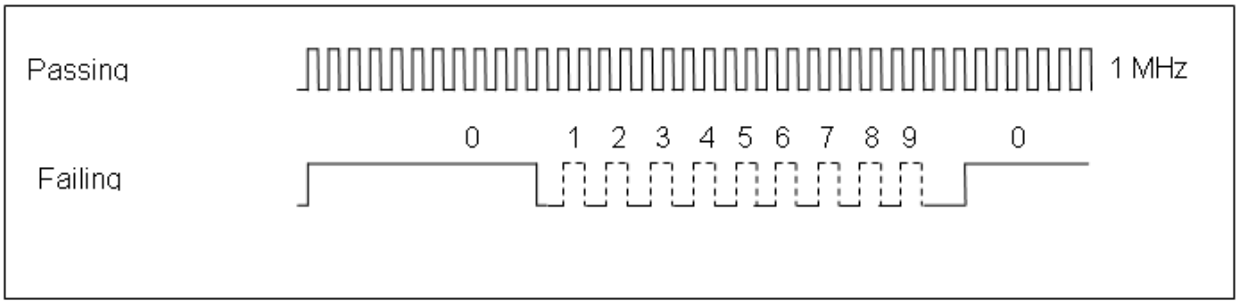
E. Array Shift Registers Block



F. Delay Path Block



G. Monitor Block



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