Total Ionizing Dose Test Report

No. 11T-RT3PE3000L-CG896-QHR8G

October 2011

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TOTAL IONIZING DOSE TEST REPORT

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I. Summary Table

Parameter	Tolerance
1. Gross Functionality	Passed 30 krads (SiO_2)
2. Power Supply Current (I_{CCA}/I_{CCI})	Passed 30 krads (SiO_2)
3. Input Threshold (V_{TIL}/V_{IH})	Passed 30 krads (SiO_2)
4. Output Drive (V_{OL}/V_{OH})	Passed 30 krads (SiO_2)
5. Propagation Delay	Passed 30 krads (SiO_2) per 10%-degradation criterion
6. Transition Time	Passed 30 krads (SiO_2)

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-896
Foundry	United Microelectronics Corp.
Technology	0.13 µm CMOS and Embedded Flash
DUT Design	RTA3PE3KL_CG896_TID
Die Lot Number	QHR8G
Quantity Tested	5
Total Dose: DUT Serial Number	5365, 5478, 5505, 5536, 5622
Radiation Facility	Defense Microelectronics Activity
Radiation Source	Co-60
Dose Rate	7.5 krad (SiO_2)/Min. (±5%)
Irradiation Temperature	Room
Irradiation and Measurement Bias (V_{CCI}/V_{CCA})	Static at 3.3 V / 1.5 V

B. Test Method

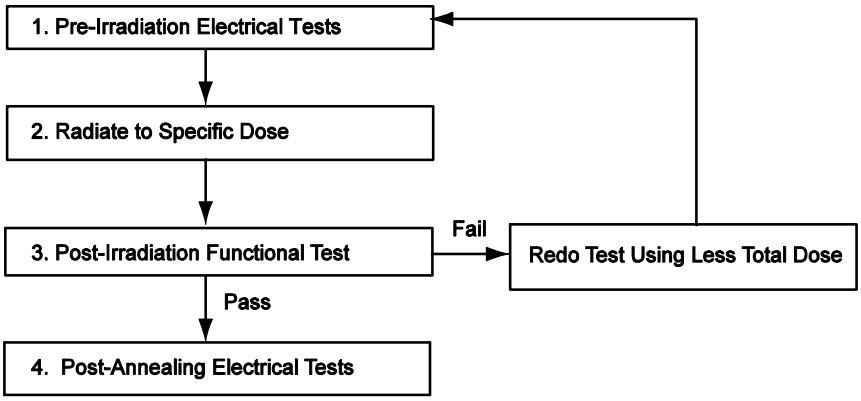


Figure 1 Parametric Test Flow Chart

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_CG896_TID, to test total dose effects in typical space applications.

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

a. PLL Block

There are 6 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 8 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 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 3 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
5365	30 krad	2.27	2.31	64.47	64.45
5478	30 krad	2.85	3.01	64.48	64.48
5505	30 krad	2.76	2.82	64.48	64.47
5536	30 krad	2.78	2.91	64.49	64.47
5622	30 krad	2.54	2.64	64.48	64.49

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); data are presented with statistics of all 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.
5365	30 krad	-0.225	-0.086	0.102	0.048	-0.363	-0.071	0.235	0.069
5478	30 krad	-0.368	-0.108	0.074	0.053	-0.401	-0.090	0.255	0.074
5505	30 krad	-0.232	-0.084	0.091	0.045	-0.376	-0.070	0.255	0.071
5536	30 krad	-0.271	-0.144	0.051	0.047	-0.401	-0.116	0.180	0.071
5622	30 krad	-0.275	-0.109	0.091	0.053	-0.378	-0.088	0.185	0.074

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.
5365	30 krad	-0.109	0.022	0.356	0.064	-0.254	0.019	0.404	0.075
5478	30 krad	-0.159	0.023	1.346	0.082	-0.254	0.021	1.416	0.093
5505	30 krad	-0.159	0.027	2.883	0.135	-0.279	0.020	2.806	0.135
5536	30 krad	-0.120	0.026	0.512	0.070	-0.249	0.020	0.596	0.080
5622	30 krad	-0.120	0.021	3.246	0.153	-0.254	0.019	3.345	0.162

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 are presented with statistics of all I/O pins used (~340 sample size of each DUT). In each case, the post-annealing data vary 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.
5365	30 krad	149.515	160.387	195.408	6.193	150.683	161.100	196.496	6.541
5478	30 krad	149.850	159.317	186.379	5.533	150.056	160.479	189.951	5.932
5505	30 krad	150.180	160.272	189.576	5.887	150.119	161.299	190.906	6.336
5536	30 krad	150.334	160.019	189.075	5.676	151.122	160.929	189.964	5.995
5622	30 krad	149.201	159.837	196.285	6.556	150.432	161.170	197.626	6.821

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.
5365	30 krad	80.447	83.112	88.500	1.124	80.757	83.258	88.604	1.188
5478	30 krad	80.630	82.806	87.409	0.943	80.539	83.121	88.167	1.030
5505	30 krad	80.388	82.891	87.246	0.990	80.549	83.147	88.104	1.069
5536	30 krad	81.054	83.095	87.660	0.998	81.081	83.266	88.104	1.060
5622	30 krad	80.258	82.647	88.438	1.150	80.110	83.090	88.918	1.202

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.
5365	30 krad	86.243	90.319	101.731	2.102	86.383	90.585	102.043	2.218
5478	30 krad	86.356	89.822	98.710	1.833	86.634	90.245	100.271	1.980
5505	30 krad	86.232	90.050	99.599	1.949	86.509	90.491	100.097	2.119
5536	30 krad	86.747	90.180	99.348	1.904	86.885	90.480	99.894	2.012
5622	30 krad	86.106	89.866	101.981	2.211	86.195	90.416	102.357	2.310

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.
5365	30 krad	114.448	120.338	137.408	3.135	114.801	120.674	137.777	3.309
5478	30 krad	114.737	119.709	132.802	2.745	114.864	120.315	135.327	2.962
5505	30 krad	114.527	120.061	134.273	2.933	114.738	120.656	135.077	3.150
5536	30 krad	115.015	120.180	134.273	2.838	115.114	120.589	134.763	3.014
5622	30 krad	114.196	119.746	137.784	3.294	114.362	120.485	138.593	3.441

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.
5365	30 krad	172.369	183.623	217.980	6.218	173.392	184.347	219.041	6.580
5478	30 krad	172.693	182.510	209.020	5.496	173.204	183.570	213.029	5.904
5505	30 krad	173.068	183.186	212.149	5.854	172.953	184.234	213.766	6.311
5536	30 krad	173.187	183.138	211.710	5.674	173.706	184.014	212.635	6.001
5622	30 krad	171.676	182.688	218.733	6.566	172.702	184.042	220.486	6.837

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.
5365	30 krad	102.769	106.202	110.953	1.270	103.133	106.332	111.120	1.330
5478	30 krad	103.032	105.637	110.262	0.986	102.952	105.945	110.806	1.075
5505	30 krad	102.738	105.516	109.631	1.025	102.505	105.819	110.430	1.116
5536	30 krad	103.263	105.783	110.514	1.063	103.050	105.890	111.057	1.136
5622	30 krad	101.857	105.145	110.634	1.231	102.066	105.626	111.087	1.288

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.
5365	30 krad	52.687	54.766	60.284	1.081	52.634	54.943	60.406	1.154
5478	30 krad	52.529	54.537	59.031	0.923	52.600	54.710	59.946	0.999
5505	30 krad	52.561	54.548	59.030	0.976	52.697	54.773	59.444	1.061
5536	30 krad	52.805	54.571	59.031	0.957	52.759	54.741	59.695	1.018
5622	30 krad	52.309	54.377	60.284	1.128	52.257	54.652	60.595	1.174

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.
5365	30 krad	2.724	3.076	3.468	0.124	2.181	3.119	3.688	0.169
5478	30 krad	2.725	3.063	3.413	0.123	2.244	3.127	3.562	0.158
5505	30 krad	2.734	3.076	3.468	0.122	2.495	3.128	3.939	0.145
5536	30 krad	2.725	3.043	3.476	0.124	2.307	3.109	3.499	0.158
5622	30 krad	2.708	3.043	3.413	0.125	2.432	3.127	3.876	0.153

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.
5365	30 krad	2.221	2.598	3.029	0.128	1.867	2.637	3.128	0.152
5478	30 krad	2.222	2.597	3.013	0.124	1.805	2.637	3.060	0.155
5505	30 krad	2.222	2.598	2.951	0.126	1.867	2.667	3.248	0.169
5536	30 krad	2.231	2.598	3.029	0.127	1.867	2.659	3.186	0.158
5622	30 krad	2.231	2.597	2.974	0.121	2.118	2.637	3.248	0.156

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.
5365	30 krad	201.283	206.104	217.980	2.211	202.072	206.589	218.802	2.293
5478	30 krad	201.049	205.852	215.057	1.984	201.905	206.586	216.243	2.071
5505	30 krad	201.439	205.986	215.318	2.073	202.344	206.736	216.145	2.167
5536	30 krad	202.689	206.885	216.619	2.021	203.244	207.509	216.770	2.082
5622	30 krad	200.893	205.985	218.293	2.328	202.266	206.980	219.427	2.367

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.
5365	30 krad	205.983	206.062	218.058	2.215	202.340	206.568	218.802	2.284
5478	30 krad	201.049	205.785	214.745	1.995	201.603	206.511	216.321	2.073
5505	30 krad	201.283	205.983	215.475	2.058	201.953	206.729	216.165	2.161
5536	30 krad	202.767	206.863	216.619	2.025	203.634	207.369	216.712	2.077
5622	30 krad	200.971	205.989	218.449	2.325	202.032	206.885	219.427	2.374

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.
5365	30 krad	4.311	5.018	5.656	0.228	3.813	5.237	5.767	0.239
5478	30 krad	4.154	5.015	5.529	0.222	4.047	5.236	5.924	0.239
5505	30 krad	4.233	5.018	5.594	0.222	4.204	5.297	5.924	0.230
5536	30 krad	4.389	5.018	5.685	0.224	4.282	5.240	5.846	0.236
5622	30 krad	4.315	5.000	5.749	0.228	4.204	5.236	5.846	0.233

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.
5365	30 krad	4.467	5.125	5.685	0.222	4.360	5.391	5.924	0.220
5478	30 krad	4.467	5.139	5.841	0.225	4.438	5.393	6.002	0.234
5505	30 krad	4.467	5.174	5.763	0.223	4.516	5.446	6.080	0.231
5536	30 krad	4.467	5.174	5.828	0.225	4.594	5.394	6.158	0.246
5622	30 krad	4.545	5.124	5.841	0.235	4.516	5.392	6.002	0.219

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.
5365	30 krad	211.634	220.310	243.657	4.186	213.138	220.620	245.681	4.469
5478	30 krad	211.946	219.559	237.627	3.678	212.591	220.248	239.792	4.053
5505	30 krad	212.181	220.205	239.038	3.935	212.904	220.860	241.305	4.307
5536	30 krad	213.119	220.924	239.351	3.812	214.312	221.154	240.915	4.082
5622	30 krad	211.790	220.304	243.814	4.413	213.217	221.028	246.072	4.648

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.
5365	30 krad	174.282	185.054	221.033	6.225	175.750	186.066	222.005	6.524
5478	30 krad	174.182	184.173	211.543	5.608	175.046	185.464	214.991	5.967
5505	30 krad	174.651	184.972	214.848	5.950	175.516	186.219	216.301	6.346
5536	30 krad	175.298	185.020	214.457	5.727	175.829	186.062	215.520	6.005
5622	30 krad	174.517	185.118	222.050	6.584	175.985	186.476	223.255	6.817

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.
5365	30 krad	205.851	220.073	267.612	8.282	207.820	221.455	269.201	8.705
5478	30 krad	206.282	219.040	255.667	7.476	207.116	220.516	259.743	7.932
5505	30 krad	206.672	220.170	260.254	7.929	207.350	221.795	262.012	8.467
5536	30 krad	206.711	220.057	259.392	7.627	208.445	221.380	260.606	7.990
5622	30 krad	206.320	220.220	269.335	8.762	207.820	222.020	271.076	9.086

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.
5365	30 krad	233.982	255.276	326.639	12.334	237.073	257.095	329.211	13.056
5478	30 krad	234.944	253.608	308.634	11.142	235.743	255.389	314.900	11.946
5505	30 krad	234.686	255.406	314.975	11.821	236.213	257.402	318.272	12.748
5536	30 krad	235.467	254.655	313.879	11.361	237.464	256.510	316.318	12.031
5622	30 krad	234.373	255.351	328.596	13.063	237.699	257.653	331.868	13.631

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.
5365	30 krad	10.202	10.441	10.722	0.086	10.203	10.516	10.837	0.098
5478	30 krad	10.033	10.277	10.585	0.088	10.012	10.327	10.754	0.105
5505	30 krad	9.974	10.200	10.475	0.093	9.892	10.261	10.611	0.111
5536	30 krad	9.616	9.856	10.160	0.098	9.636	9.939	10.261	0.112
5622	30 krad	10.206	10.439	10.736	0.093	10.104	10.488	10.845	0.110

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.
5365	30 krad	12.884	13.145	13.424	0.095	12.850	13.214	13.556	0.112
5478	30 krad	12.707	12.969	13.326	0.101	12.663	13.026	13.456	0.118
5505	30 krad	12.593	12.872	13.175	0.107	12.528	12.926	13.280	0.124
5536	30 krad	12.155	12.434	12.708	0.111	12.185	12.511	12.806	0.124
5622	30 krad	12.889	13.133	13.463	0.101	12.805	13.177	13.577	0.118

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.
5365	30 krad	6.319	6.505	6.672	0.064	6.252	6.559	6.906	0.081
5478	30 krad	6.201	6.386	6.568	0.067	6.148	6.438	6.736	0.085
5505	30 krad	6.169	6.350	6.593	0.070	6.100	6.403	6.706	0.087
5536	30 krad	5.936	6.131	6.366	0.073	5.875	6.195	6.482	0.094
5622	30 krad	6.294	6.514	6.745	0.070	6.202	6.553	6.859	0.094

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.
5365	30 krad	8.788	9.039	9.302	0.079	8.793	9.096	9.397	0.091
5478	30 krad	8.635	8.886	9.170	0.080	8.636	8.935	9.257	0.095
5505	30 krad	8.619	8.830	9.097	0.082	8.536	8.883	9.197	0.101
5536	30 krad	8.310	8.526	8.767	0.090	8.287	8.591	8.898	0.106
5622	30 krad	8.802	9.031	9.300	0.085	8.728	9.070	9.437	0.100

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.
5365	30 krad	3.561	3.718	3.887	0.053	3.536	3.770	4.091	0.073
5478	30 krad	3.481	3.643	3.825	0.054	3.434	3.687	4.036	0.078
5505	30 krad	3.453	3.628	3.800	0.053	3.356	3.673	3.965	0.079
5536	30 krad	3.335	3.499	3.685	0.061	3.307	3.555	3.842	0.081
5622	30 krad	3.578	3.733	3.969	0.059	3.456	3.773	4.116	0.082

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.
5365	30 krad	4.739	4.930	5.085	0.058	4.718	4.983	5.336	0.079
5478	30 krad	4.669	4.834	5.008	0.060	4.603	4.881	5.187	0.081
5505	30 krad	4.640	4.807	5.066	0.060	4.543	4.855	5.162	0.083
5536	30 krad	4.458	4.638	4.912	0.067	4.409	4.698	4.965	0.085
5622	30 krad	4.740	4.934	5.135	0.064	4.702	4.981	5.269	0.083

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.
5365	30 krad	17.742	18.011	18.304	0.108	17.737	18.081	18.449	0.119
5478	30 krad	17.604	17.888	18.303	0.122	17.565	17.944	18.435	0.134
5505	30 krad	17.449	17.737	18.121	0.127	17.374	17.784	18.188	0.141
5536	30 krad	16.844	17.142	17.442	0.120	16.856	17.234	17.560	0.137
5622	30 krad	17.678	17.962	18.359	0.112	17.632	17.991	18.464	0.126

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.
5365	30 krad	19.397	19.700	20.104	0.108	19.367	19.771	20.168	0.124
5478	30 krad	19.303	19.603	20.037	0.124	19.266	19.658	20.143	0.137
5505	30 krad	19.161	19.453	19.854	0.127	19.057	19.497	19.893	0.149
5536	30 krad	18.506	18.807	19.193	0.125	18.498	18.889	19.260	0.137
5622	30 krad	19.383	19.632	20.099	0.111	19.257	19.667	20.168	0.126

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 are presented with statistics of all I/O pins used (~340 sample size of each DUT). In each case, the post-annealing data vary 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.
5365	30 krad	1.436	1.468	1.479	0.006	1.436	1.468	1.481	0.006
5478	30 krad	1.444	1.471	1.482	0.005	1.441	1.471	1.484	0.006
5505	30 krad	1.439	1.467	1.478	0.006	1.439	1.467	1.479	0.006
5536	30 krad	1.443	1.471	1.482	0.005	1.443	1.471	1.483	0.006
5622	30 krad	1.435	1.469	1.481	0.006	1.435	1.469	1.481	0.007

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.
5365	30 krad	1.229	1.241	1.250	0.002	1.228	1.242	1.250	0.002
5478	30 krad	1.229	1.243	1.250	0.002	1.229	1.244	1.252	0.002
5505	30 krad	1.227	1.240	1.247	0.002	1.226	1.240	1.248	0.002
5536	30 krad	1.231	1.245	1.251	0.002	1.231	1.246	1.252	0.002
5622	30 krad	1.231	1.243	1.250	0.002	1.230	1.244	1.251	0.002

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.
5365	30 krad	1.220	1.234	1.241	0.003	1.218	1.235	1.242	0.003
5478	30 krad	1.222	1.236	1.243	0.002	1.219	1.237	1.245	0.003
5505	30 krad	1.219	1.232	1.240	0.003	1.216	1.233	1.241	0.003
5536	30 krad	1.223	1.238	1.243	0.002	1.221	1.238	1.245	0.003
5622	30 krad	1.223	1.235	1.242	0.003	1.220	1.236	1.243	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.
5365	**30 krad**	1.184	1.198	1.207	0.004	1.179	1.199	1.208	0.004
5478	**30 krad**	1.186	1.201	1.210	0.003	1.182	1.202	1.211	0.003
5505	**30 krad**	1.182	1.196	1.205	0.003	1.178	1.197	1.206	0.004
5536	**30 krad**	1.187	1.203	1.210	0.003	1.184	1.203	1.211	0.003
5622	**30 krad**	1.185	1.200	1.208	0.003	1.183	1.200	1.209	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.
5365	30 krad	1.150	1.180	1.192	0.006	1.150	1.181	1.195	0.007
5478	30 krad	1.157	1.184	1.196	0.005	1.154	1.184	1.198	0.006
5505	30 krad	1.151	1.179	1.190	0.006	1.151	1.179	1.192	0.006
5536	30 krad	1.157	1.184	1.196	0.006	1.157	1.185	1.197	0.006
5622	30 krad	1.149	1.182	1.194	0.006	1.148	1.182	1.195	0.007

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.
5365	30 krad	0.900	0.929	0.945	0.004	0.901	0.930	0.946	0.004
5478	30 krad	0.902	0.932	0.945	0.004	0.901	0.933	0.947	0.004
5505	30 krad	0.896	0.925	0.940	0.004	0.895	0.926	0.941	0.004
5536	30 krad	0.904	0.936	0.946	0.004	0.905	0.936	0.947	0.004
5622	30 krad	0.904	0.932	0.944	0.004	0.905	0.933	0.945	0.004

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.
5365	30 krad	1.027	1.038	1.044	0.002	1.027	1.039	1.045	0.002
5478	30 krad	1.028	1.040	1.045	0.002	1.027	1.040	1.046	0.002
5505	30 krad	1.026	1.037	1.043	0.002	1.026	1.038	1.043	0.002
5536	30 krad	1.029	1.041	1.045	0.002	1.029	1.042	1.046	0.002
5622	30 krad	1.029	1.039	1.044	0.002	1.029	1.040	1.045	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.
5365	30 krad	1.132	1.133	1.134	0.000	1.133	1.134	1.135	0.000
5478	30 krad	1.132	1.133	1.134	0.000	1.133	1.135	1.135	0.000
5505	30 krad	1.132	1.133	1.135	0.000	1.133	1.134	1.135	0.000
5536	30 krad	1.132	1.133	1.134	0.000	1.133	1.135	1.135	0.000
5622	30 krad	1.133	1.133	1.134	0.000	1.133	1.135	1.135	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.
5365	30 krad	1.394	1.395	1.396	0.000	1.395	1.396	1.397	0.000
5478	30 krad	1.394	1.395	1.396	0.000	1.395	1.396	1.397	0.000
5505	30 krad	1.394	1.395	1.396	0.000	1.395	1.396	1.397	0.000
5536	30 krad	1.394	1.395	1.396	0.000	1.394	1.396	1.397	0.000
5622	30 krad	1.394	1.395	1.396	0.000	1.395	1.396	1.397	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.
5365	30 krad	2.633	2.645	2.657	0.004	2.631	2.646	2.657	0.004
5478	30 krad	2.636	2.649	2.660	0.003	2.634	2.650	2.662	0.003
5505	30 krad	2.633	2.644	2.653	0.003	2.631	2.645	2.655	0.003
5536	30 krad	2.638	2.651	2.659	0.003	2.636	2.652	2.660	0.003
5622	30 krad	2.636	2.648	2.657	0.003	2.634	2.648	2.658	0.003

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.
5365	30 krad	2.633	2.645	2.657	0.004	2.631	2.646	2.658	0.004
5478	30 krad	2.636	2.649	2.661	0.003	2.634	2.650	2.662	0.003
5505	30 krad	2.633	2.644	2.653	0.003	2.631	2.645	2.654	0.003
5536	30 krad	2.638	2.651	2.659	0.003	2.636	2.652	2.661	0.003
5622	30 krad	2.636	2.648	2.657	0.003	2.634	2.648	2.658	0.003

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.
5365	30 krad	2.989	2.990	2.991	0.000	2.990	2.992	2.992	0.000
5478	30 krad	2.989	2.990	2.991	0.000	2.991	2.992	2.992	0.000
5505	30 krad	2.989	2.990	2.991	0.000	2.991	2.992	2.993	0.000
5536	30 krad	2.989	2.990	2.991	0.000	2.991	2.992	2.992	0.000
5622	30 krad	2.989	2.990	2.991	0.000	2.991	2.992	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.
5365	30 krad	2.689	2.690	2.691	0.000	2.691	2.691	2.692	0.000
5478	30 krad	2.689	2.690	2.691	0.000	2.691	2.692	2.692	0.000
5505	30 krad	2.689	2.690	2.691	0.000	2.691	2.691	2.692	0.000
5536	30 krad	2.689	2.690	2.691	0.000	2.691	2.692	2.692	0.000
5622	30 krad	2.689	2.690	2.691	0.000	2.691	2.692	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.
5365	30 krad	2.613	2.631	2.644	0.005	2.611	2.631	2.644	0.005
5478	30 krad	2.616	2.635	2.651	0.005	2.614	2.635	2.650	0.004
5505	30 krad	2.612	2.629	2.642	0.005	2.610	2.629	2.641	0.005
5536	30 krad	2.620	2.637	2.649	0.004	2.617	2.637	2.648	0.004
5622	30 krad	2.614	2.633	2.646	0.005	2.614	2.633	2.645	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.
5365	30 krad	2.674	2.703	2.715	0.006	2.675	2.703	2.718	0.006
5478	30 krad	2.680	2.706	2.720	0.006	2.676	2.707	2.722	0.006
5505	30 krad	2.675	2.702	2.714	0.006	2.675	2.702	2.716	0.006
5536	30 krad	2.681	2.708	2.720	0.006	2.681	2.708	2.721	0.006
5622	30 krad	2.672	2.704	2.718	0.006	2.673	2.705	2.719	0.007

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.
5365	30 krad	2.636	2.677	2.693	0.008	2.637	2.677	2.696	0.009
5478	30 krad	2.646	2.681	2.698	0.007	2.641	2.681	2.700	0.008
5505	30 krad	2.639	2.676	2.692	0.008	2.639	2.676	2.694	0.008
5536	30 krad	2.646	2.682	2.698	0.007	2.646	2.682	2.699	0.008
5622	30 krad	2.635	2.679	2.696	0.008	2.635	2.679	2.696	0.009

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.
5365	30 krad	2.652	2.718	2.741	0.012	2.652	2.718	2.741	0.013
5478	30 krad	2.669	2.722	2.743	0.011	2.663	2.721	2.745	0.012
5505	30 krad	2.659	2.717	2.740	0.012	2.659	2.717	2.739	0.012
5536	30 krad	2.665	2.722	2.744	0.011	2.665	2.722	2.744	0.012
5622	30 krad	2.649	2.719	2.743	0.013	2.649	2.718	2.741	0.013

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.
5365	30 krad	-15.541	-15.017	-14.395	0.196	-15.606	-14.980	-14.335	0.199
5478	30 krad	-15.487	-14.836	-14.204	0.221	-15.479	-14.786	-14.149	0.222
5505	30 krad	-15.128	-14.499	-14.028	0.194	-15.038	-14.449	-13.951	0.195
5536	30 krad	-15.465	-14.844	-14.302	0.204	-15.345	-14.810	-14.167	0.207
5622	30 krad	-15.745	-15.085	-14.258	0.216	-15.763	-15.049	-14.358	0.216

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.
5365	30 krad	-19.037	-18.387	-17.736	0.228	-18.912	-18.345	-17.599	0.225
5478	30 krad	-18.929	-18.190	-17.497	0.248	-18.872	-18.134	-17.436	0.248
5505	30 krad	-18.503	-17.818	-17.231	0.219	-18.419	-17.752	-17.217	0.219
5536	30 krad	-18.931	-18.194	-17.560	0.236	-18.694	-18.133	-17.430	0.232
5622	30 krad	-19.262	-18.477	-17.521	0.249	-19.173	-18.418	-17.661	0.247

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.
5365	30 krad	-10.180	-9.797	-9.374	0.139	-10.163	-9.776	-9.267	0.144
5478	30 krad	-10.111	-9.668	-9.200	0.157	-10.205	-9.632	-9.205	0.162
5505	30 krad	-9.865	-9.425	-9.090	0.143	-9.863	-9.406	-8.966	0.146
5536	30 krad	-10.114	-9.688	-9.275	0.145	-10.113	-9.669	-9.210	0.150
5622	30 krad	-10.331	-9.848	-9.239	0.150	-10.347	-9.813	-9.341	0.157

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.
5365	30 krad	-13.643	-13.101	-12.548	0.176	-13.488	-13.058	-12.469	0.175
5478	30 krad	-13.528	-12.929	-12.368	0.197	-13.483	-12.887	-12.317	0.199
5505	30 krad	-13.189	-12.635	-12.196	0.172	-13.137	-12.593	-12.117	0.176
5536	30 krad	-13.530	-12.945	-12.422	0.183	-13.412	-12.907	-12.349	0.186
5622	30 krad	-13.799	-13.165	-12.426	0.187	-13.773	-13.113	-12.492	0.192

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.
5365	30 krad	-6.277	-6.020	-5.708	0.100	-6.322	-6.008	-5.564	0.110
5478	30 krad	-6.245	-5.948	-5.556	0.115	-6.328	-5.927	-5.523	0.126
5505	30 krad	-6.063	-5.770	-5.486	0.105	-6.140	-5.755	-5.427	0.112
5536	30 krad	-6.245	-5.973	-5.647	0.102	-6.314	-5.951	-5.574	0.113
5622	30 krad	-6.373	-6.065	-5.625	0.108	-6.445	-6.053	-5.676	0.118

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.
5365	30 krad	-7.975	-7.661	-7.290	0.117	-7.949	-7.649	-7.240	0.125
5478	30 krad	-7.950	-7.563	-7.142	0.132	-8.004	-7.536	-7.123	0.141
5505	30 krad	-7.750	-7.355	-7.060	0.119	-7.764	-7.336	-6.972	0.125
5536	30 krad	-7.954	-7.592	-7.270	0.121	-7.914	-7.562	-7.166	0.129
5622	30 krad	-8.086	-7.716	-7.181	0.124	-8.121	-7.692	-7.286	0.132

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.
5365	30 krad	-37.566	-36.469	-35.489	0.367	-37.452	-36.426	-35.453	0.358
5478	30 krad	-37.497	-36.351	-35.298	0.363	-37.288	-36.232	-35.202	0.360
5505	30 krad	-36.886	-35.755	-34.415	0.359	-36.650	-35.672	-34.420	0.357
5536	30 krad	-37.345	-36.262	-35.152	0.379	-37.151	-36.183	-35.091	0.375
5622	30 krad	-37.948	-36.700	-35.339	0.402	-37.793	-36.602	-35.433	0.402

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.
5365	30 krad	-76.889	-74.863	-72.909	0.695	-76.476	-74.521	-72.718	0.686
5478	30 krad	-76.818	-74.750	-72.861	0.683	-76.335	-74.292	-72.464	0.670
5505	30 krad	-75.516	-73.603	-71.865	0.699	-75.045	-73.199	-71.366	0.689
5536	30 krad	-76.482	-74.541	-72.376	0.729	-75.896	-74.101	-71.988	0.719
5622	30 krad	-77.864	-75.401	-72.957	0.777	-77.273	-74.943	-72.765	0.770

F. Propagation Delay

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

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

DUT	Pre-Irradiation (ns)	Post-30 krad (ns)	Post-Annealing (ns)
5365	115.573	122.285	121.928
5478	115.332	123.374	123.272
5505	117.166	124.419	124.463
5536	117.690	126.476	126.438
5622	114.815	121.287	121.292

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

DUT	(Compared to Pre-irradiation)	Post-30 krad (%)	Post-Annealing (%)
5365	-	5.8%	5.5%
5478	-	7.0%	6.9%
5505	-	6.2%	6.2%
5536	-	7.5%	7.4%
5622	-	5.6%	5.6%

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

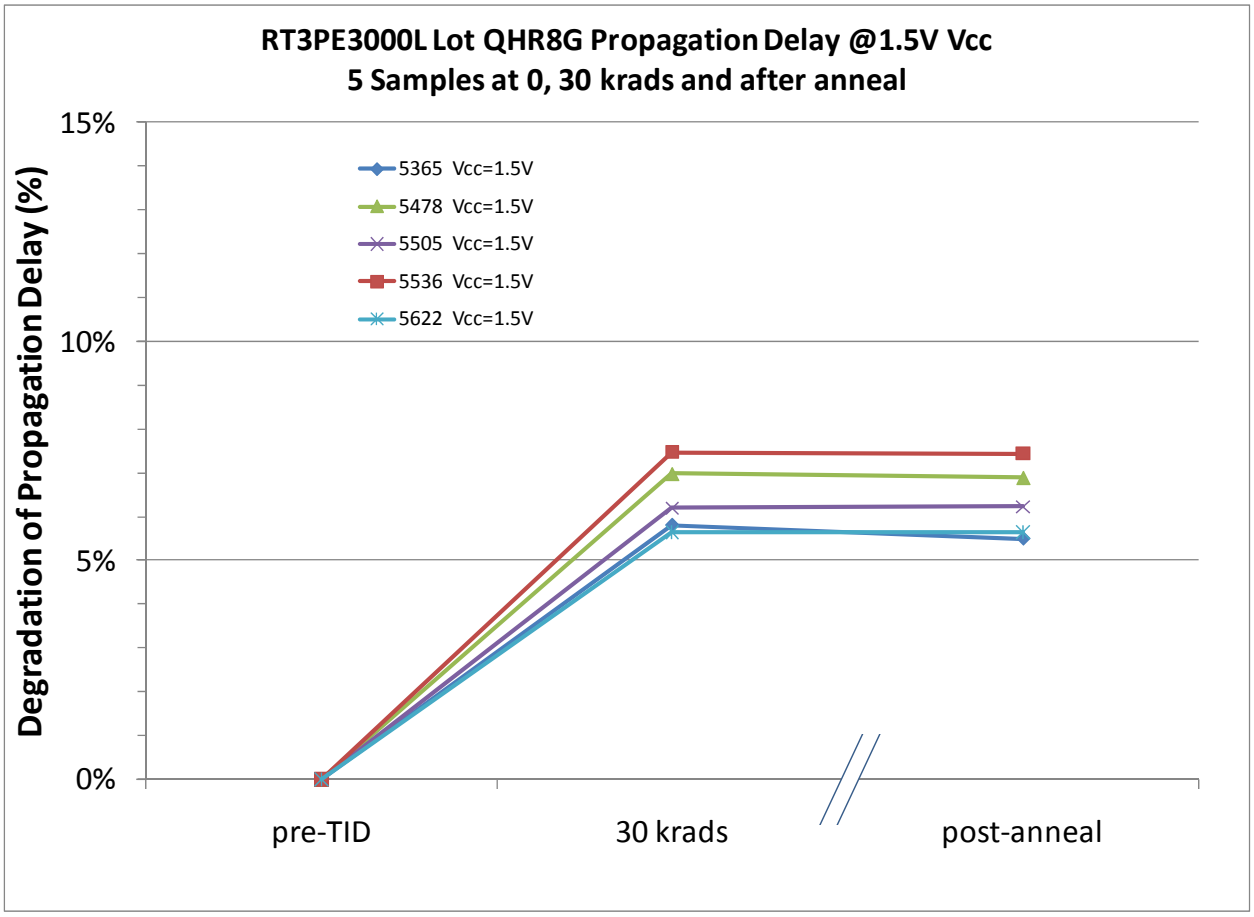


Figure 2 Degradation of Propagation Delay versus TID and Annealing

G. Transition Time

Figures 3a to Figure 12b show pre-irradiation and post-annealing transition edges. In each case, the radiation effect is not significant.

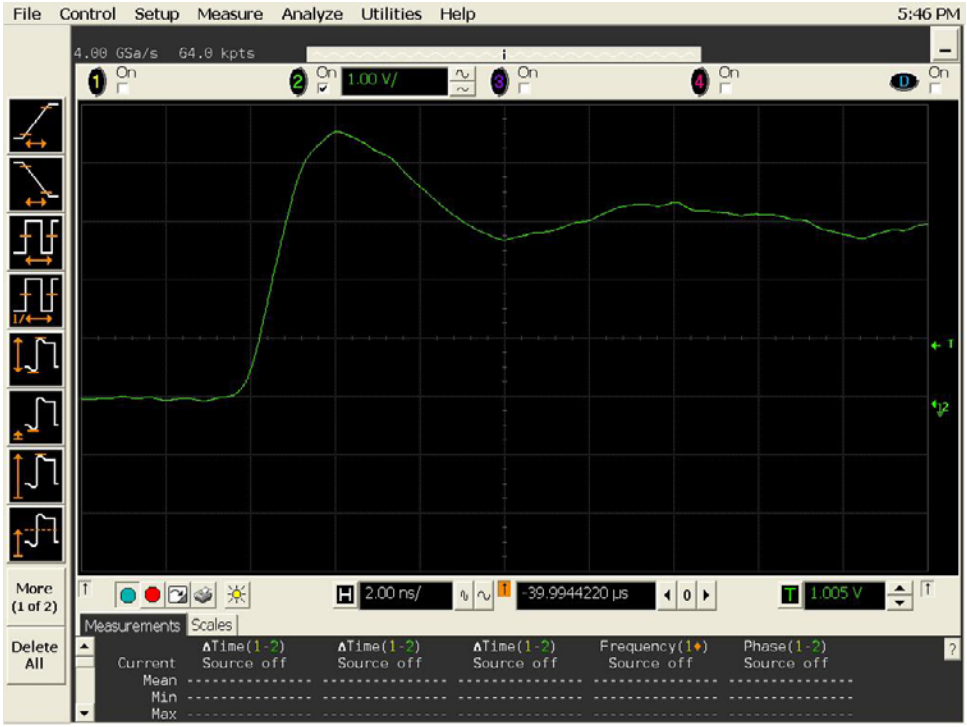


Figure 3a DUT 5365 Pre-Irradiation Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

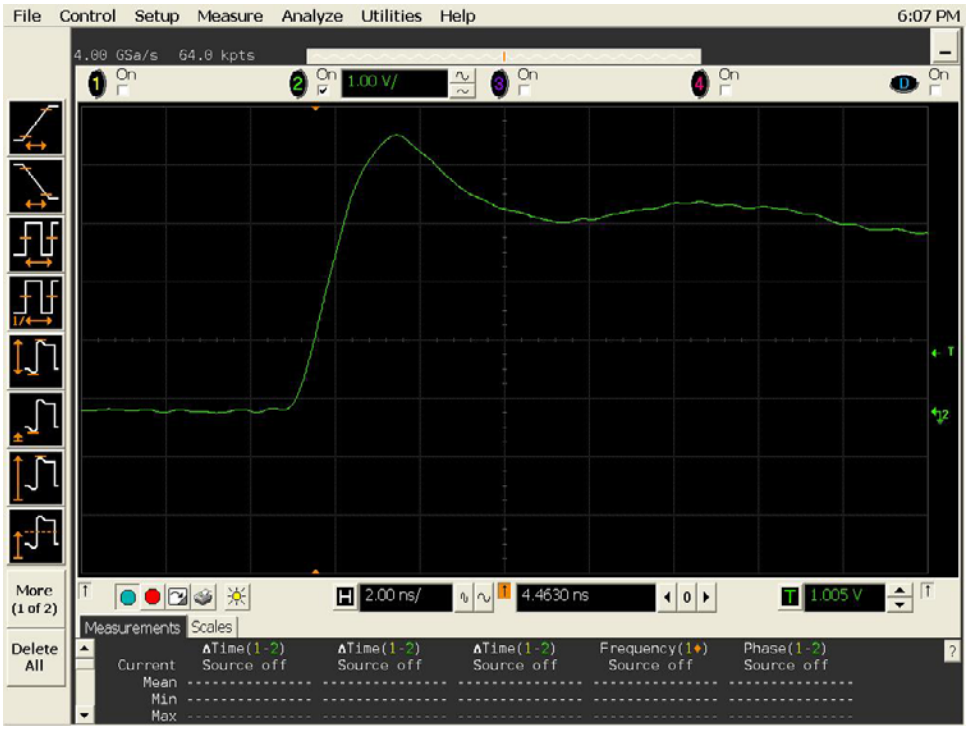


Figure 3b DUT 5365 Post-Annealing Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

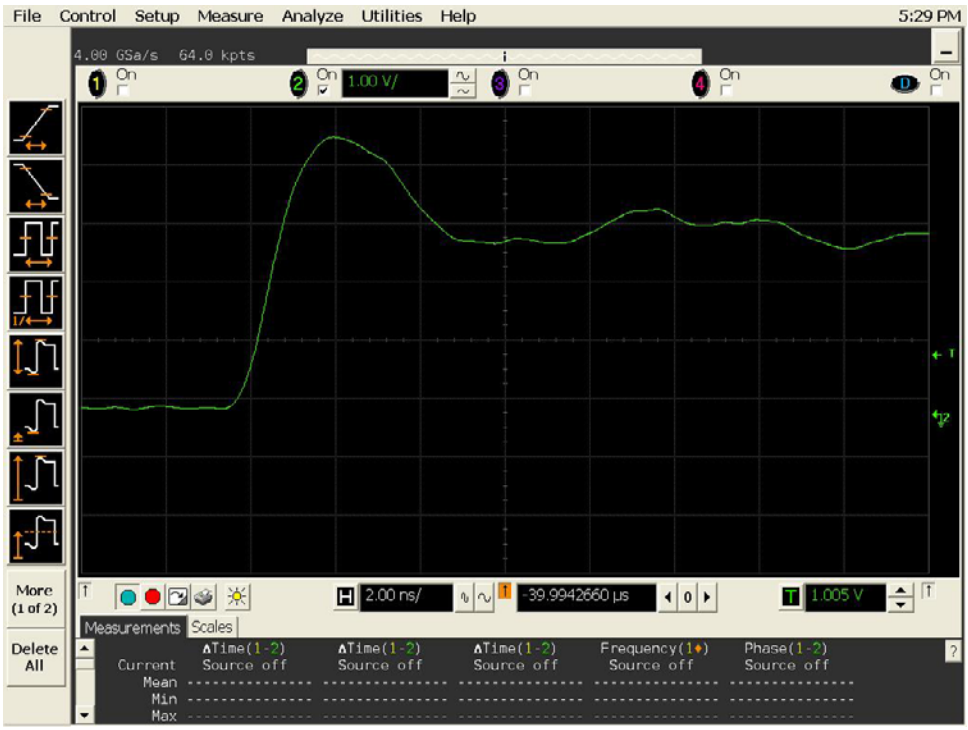


Figure 4a DUT 5478 Pre-Irradiation Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

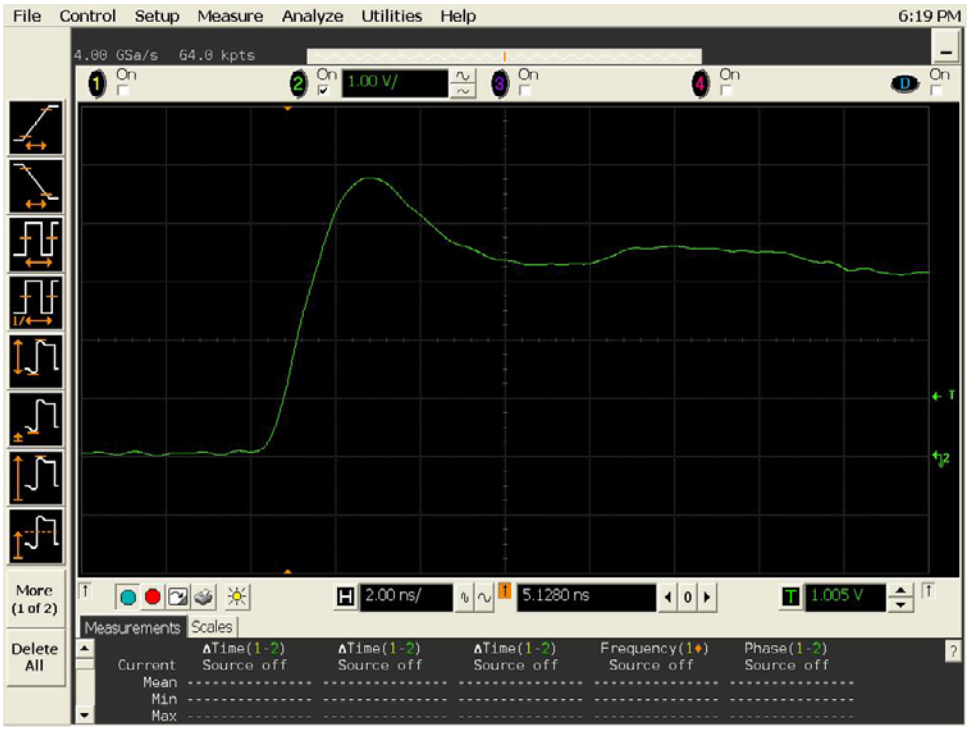


Figure 4b DUT 5478 Post-Annealing Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

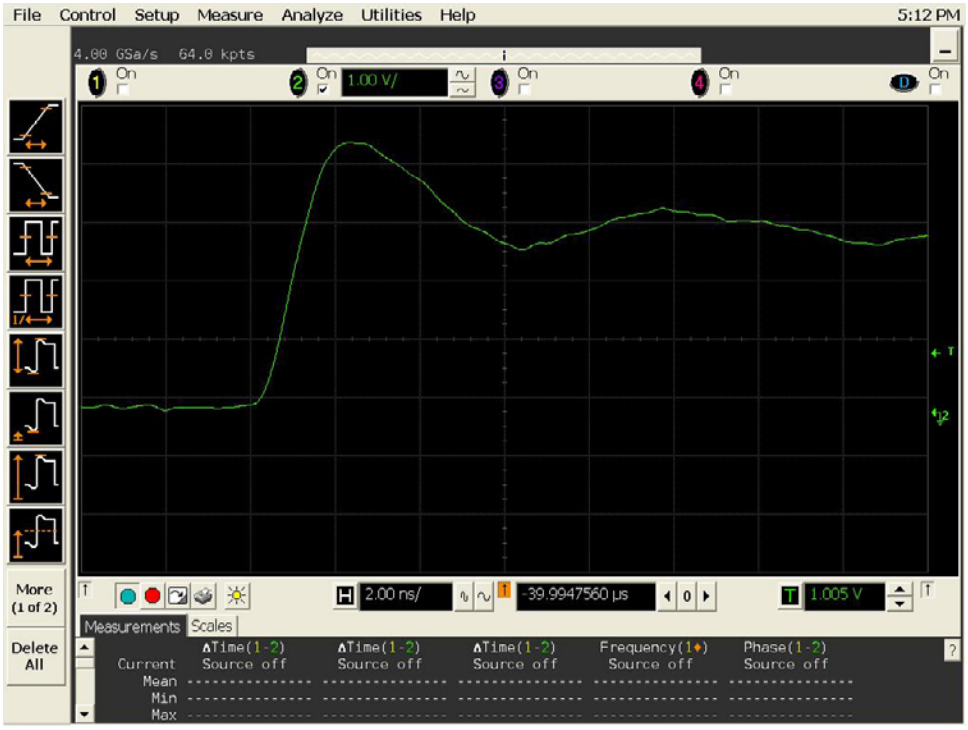


Figure 5a DUT 5505 Pre-Irradiation Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

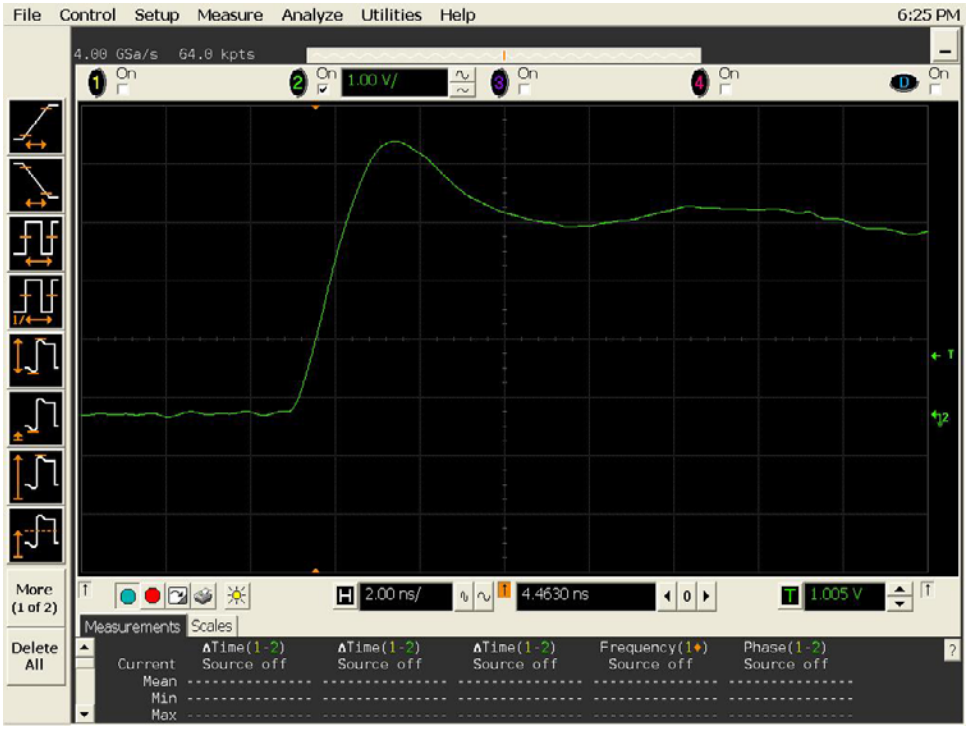


Figure 5b DUT 5505 Post-Annealing Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

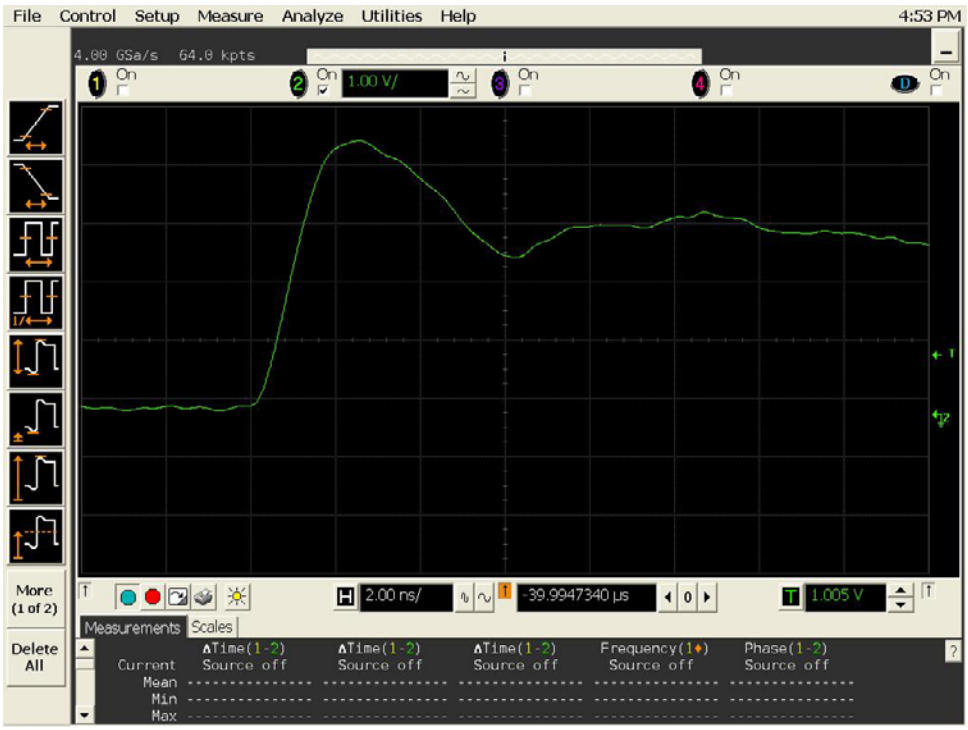


Figure 6a DUT 5536 Pre-Irradiation Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

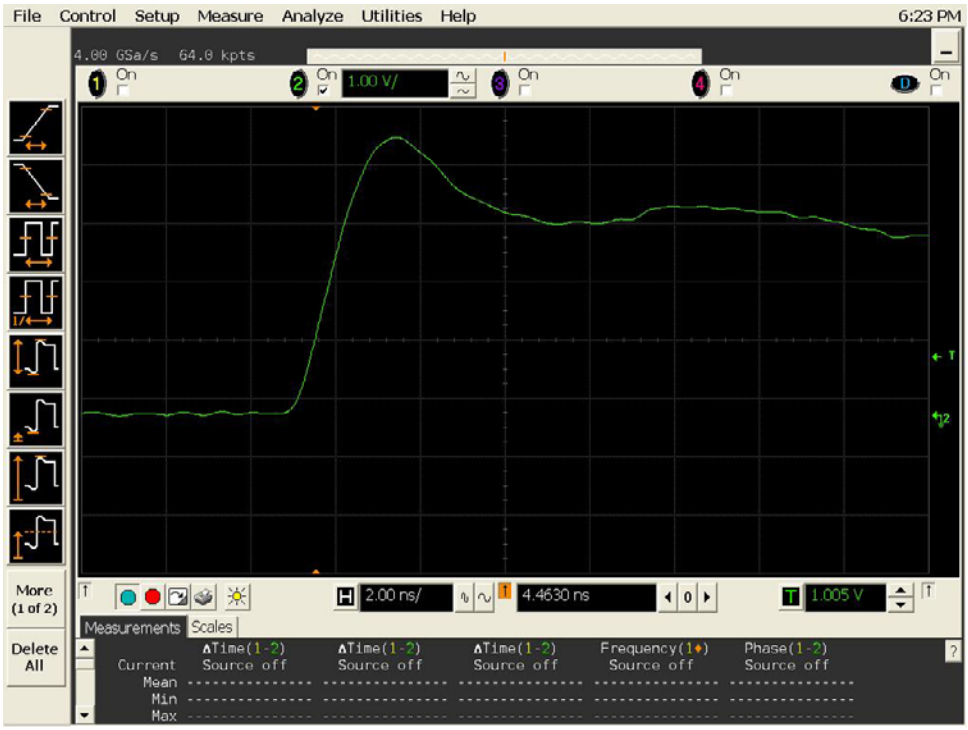


Figure 6b DUT 5536 Post-Annealing Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

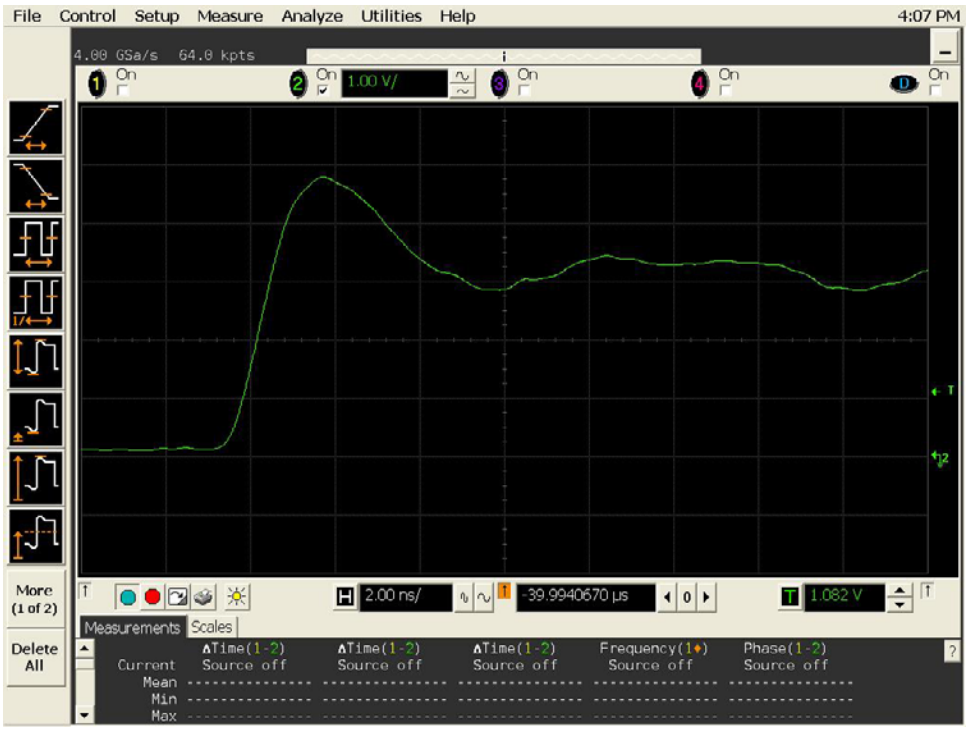


Figure 7a DUT 5622 Pre-Irradiation Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

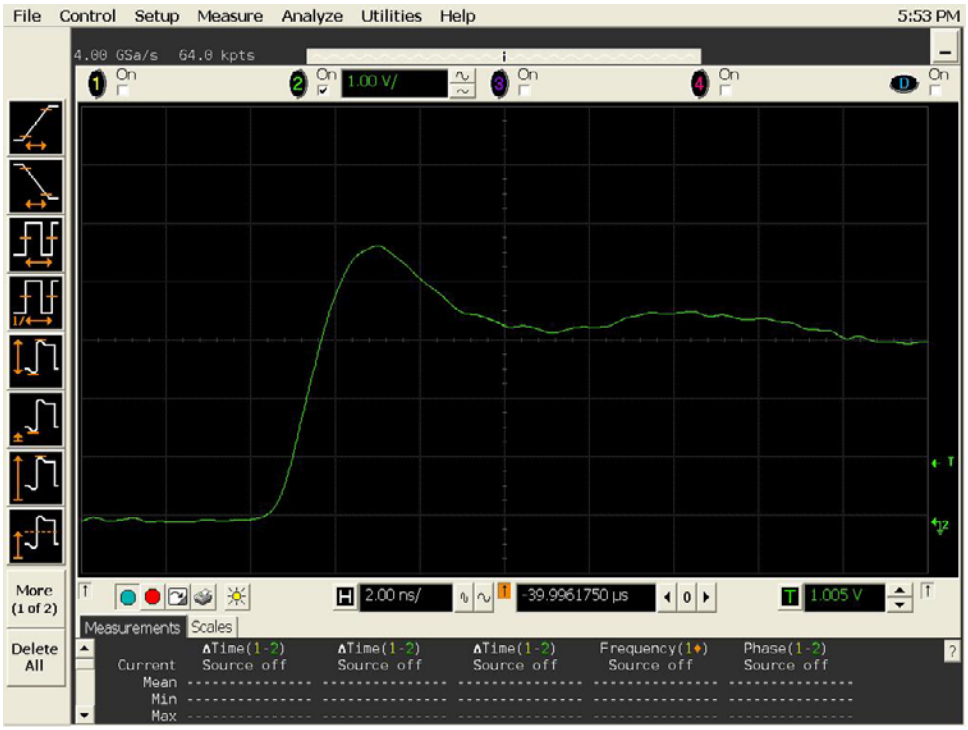


Figure 7b DUT 5622 Post-Annealing Rising Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

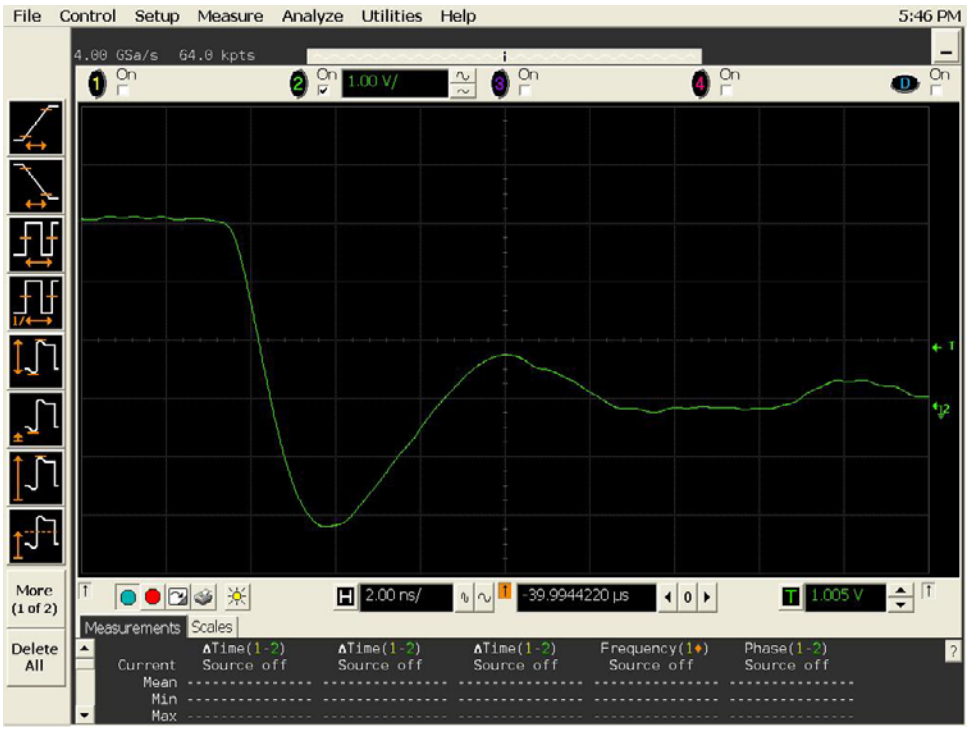


Figure 8a DUT 5365 Pre-Irradiation Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

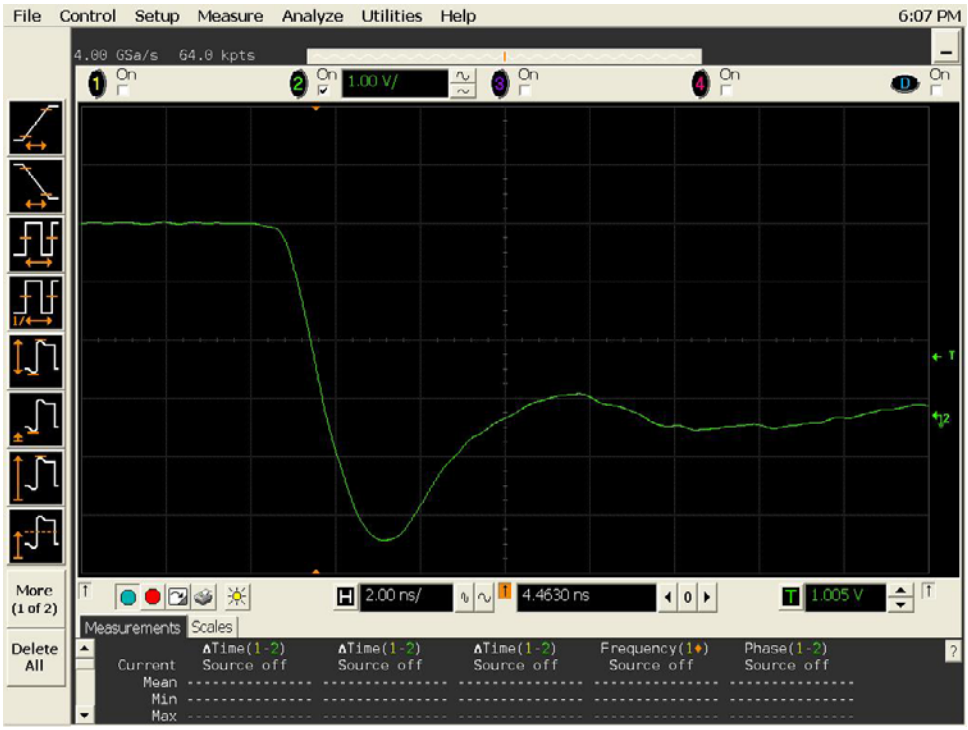


Figure 8b DUT 5365 Post-Annealing Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

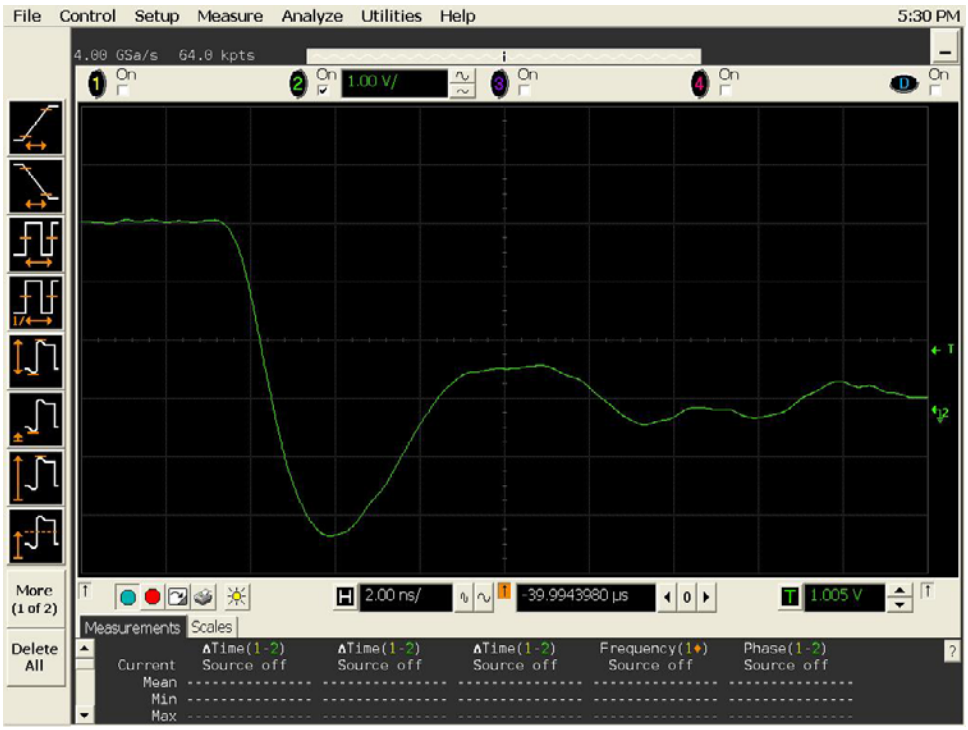


Figure 9a DUT 5478 Pre-Irradiation Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

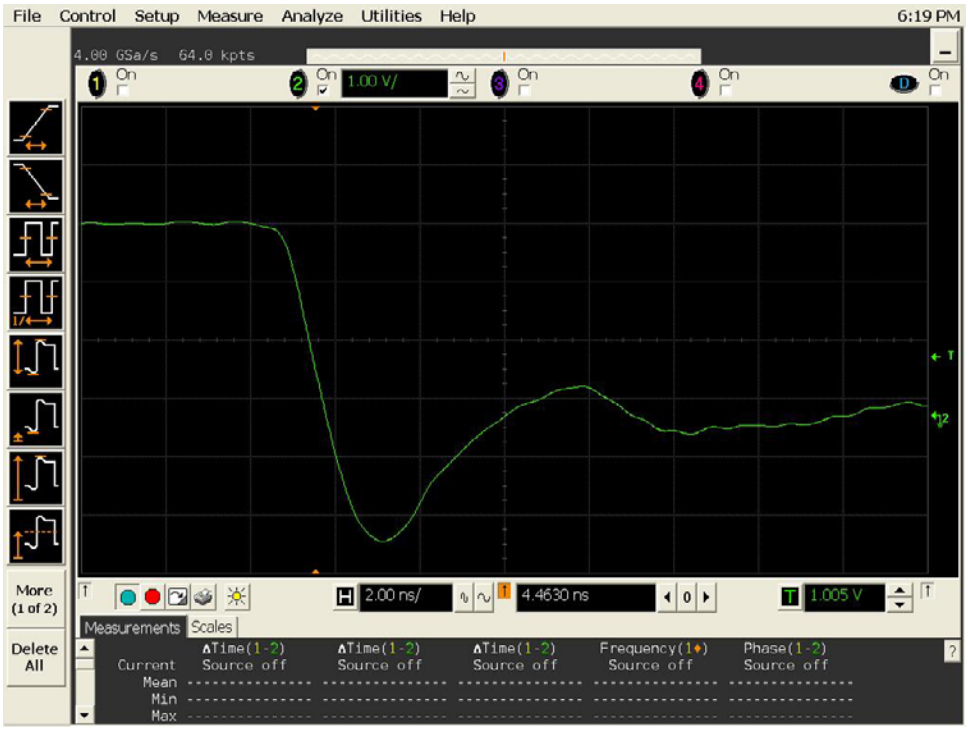


Figure 9b DUT 5478 Post-Annealing Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

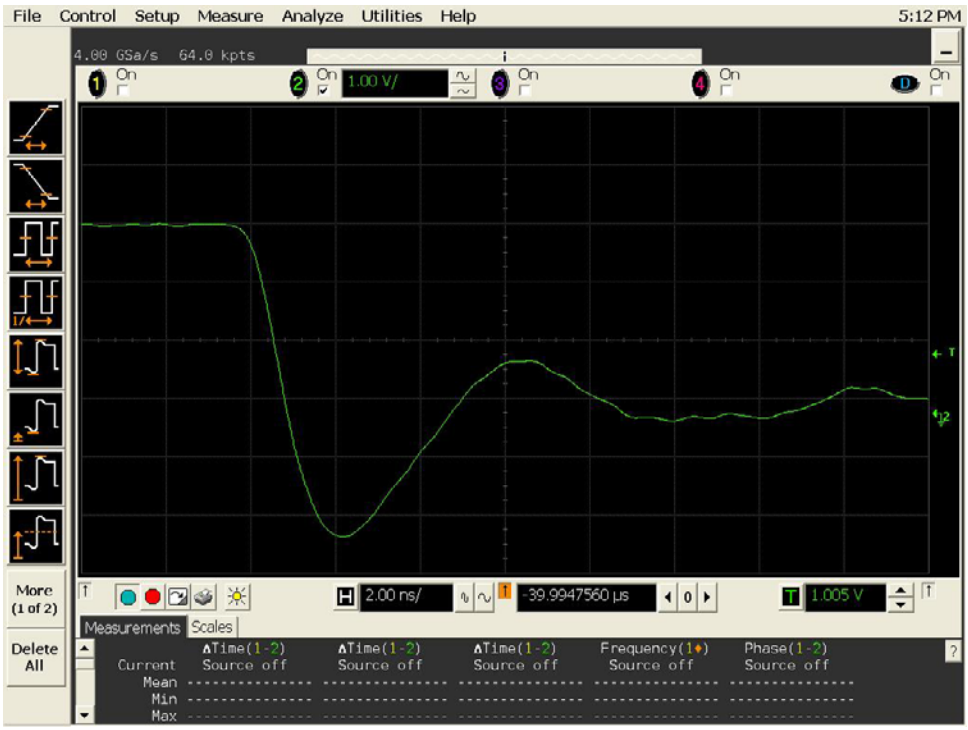


Figure 10a DUT 5505 Pre-Irradiation Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

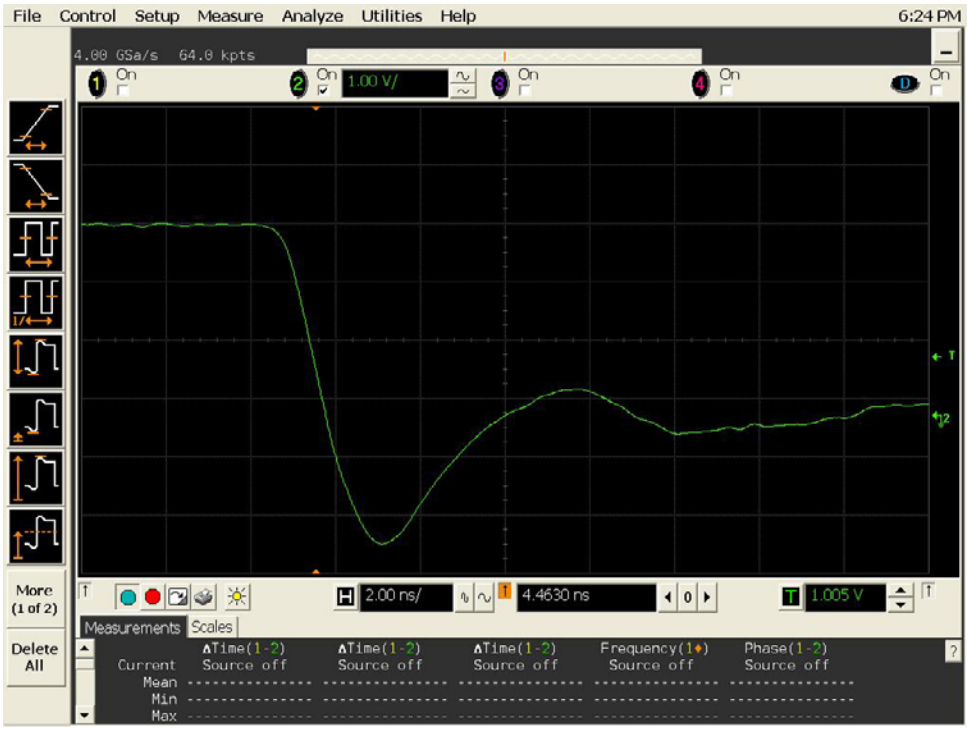


Figure 10b DUT 5505 Post-Annealing Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

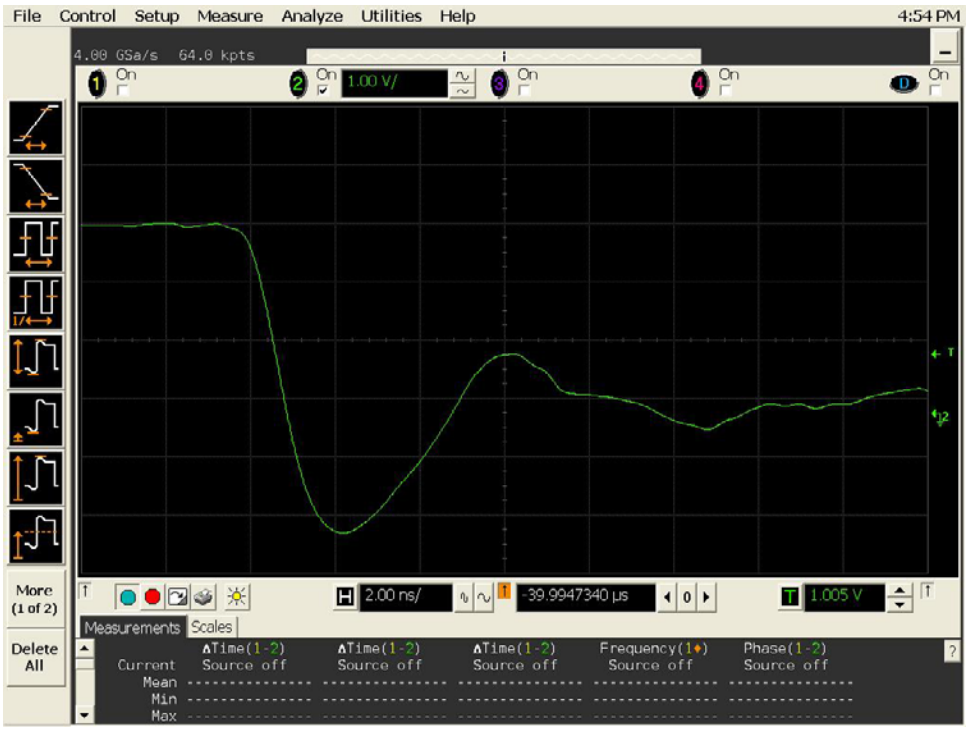


Figure 11a DUT 5536 Pre-Irradiation Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

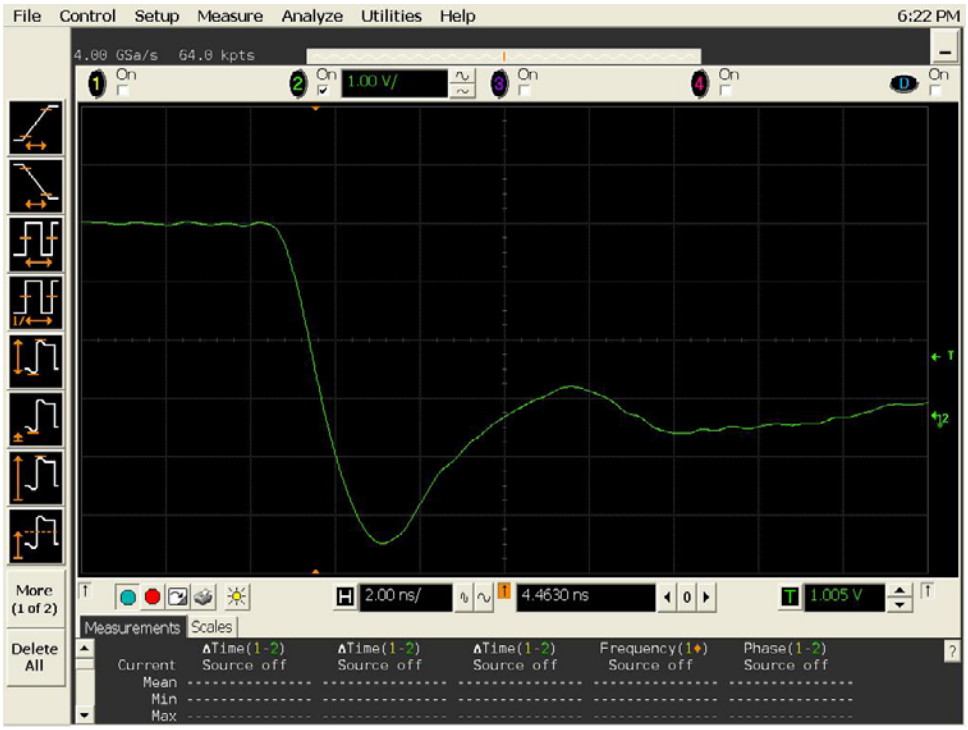


Figure 11b DUT 5536 Post-Annealing Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

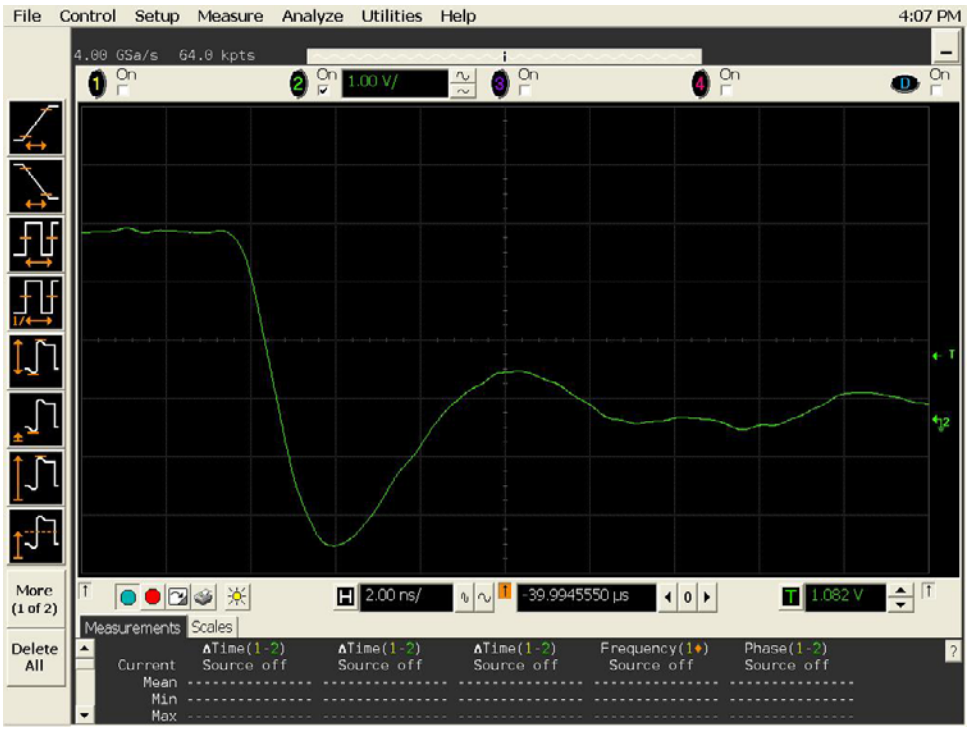


Figure 12a DUT 5622 Pre-Irradiation Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

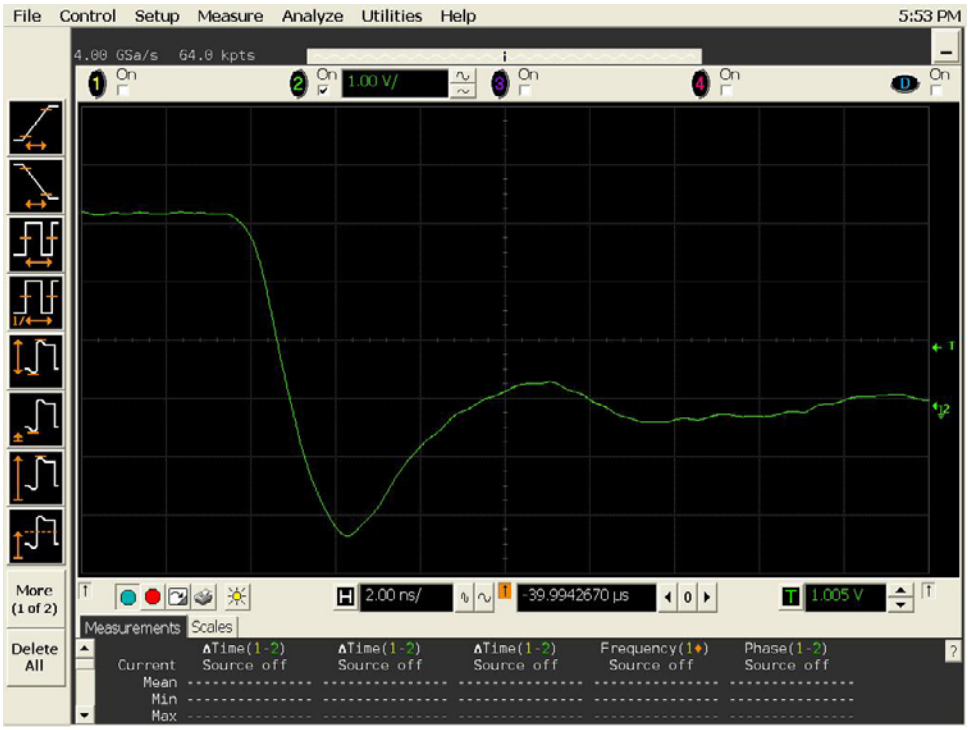
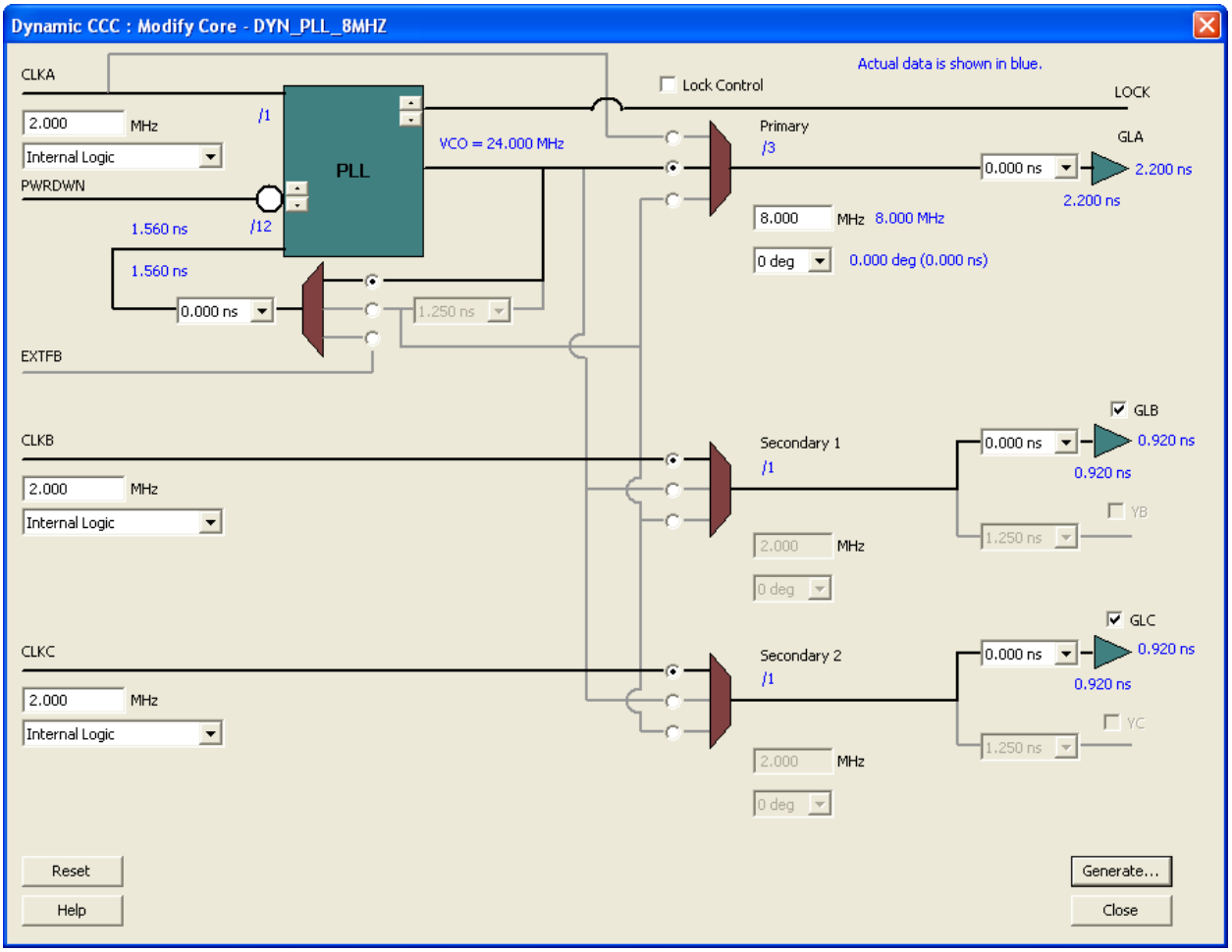


Figure 12b DUT 5622 Post-Annealing Falling Edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

Appendix A – DUT Design Block Diagrams and Schematics

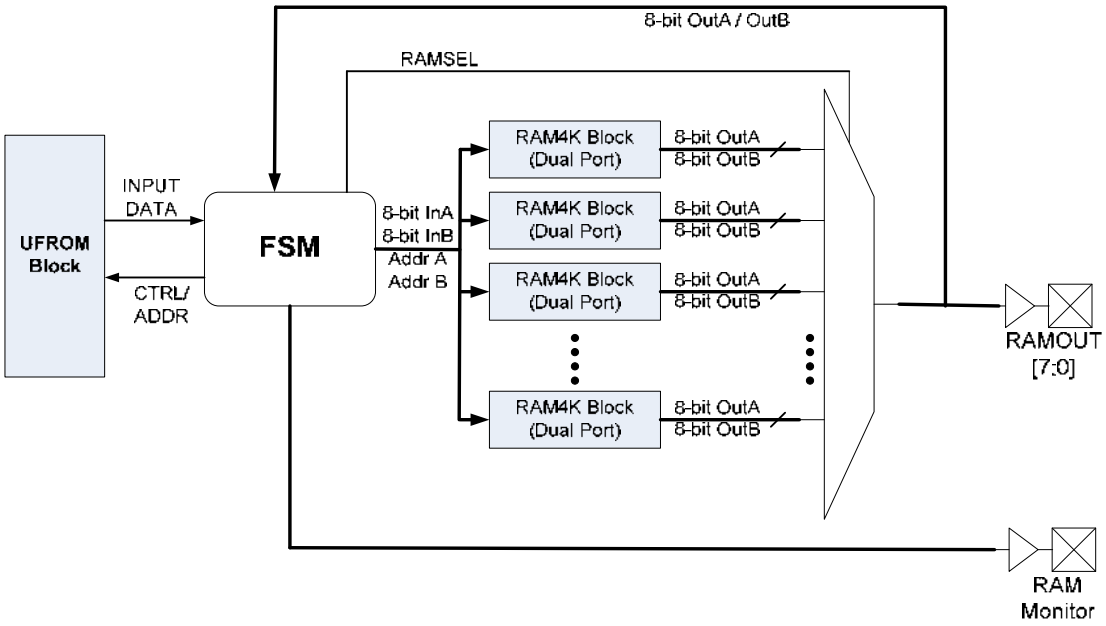
A. PLL Block



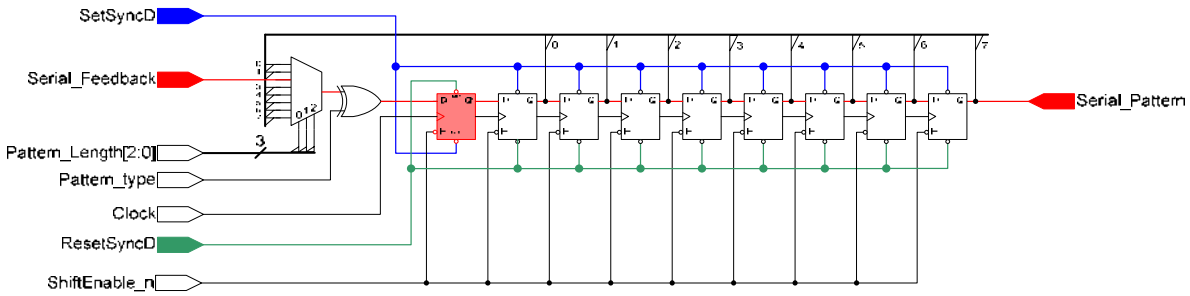
The following table lists the signals that go through each of the PLLs:

PLL	Multiply by	GLA	GLB	GLC
0	X4	CLK – upper right IO	RESET – upper right IO	OE – upper right IO
1	X4	CLK – upper left IO	RESET – upper left IO	OE – upper left IO
2	X4	CLK – lower right IO	RESET – lower right IO	OE – lower right IO
3	X4	CLK – lower left IO	RESET – lower left IO	OE – lower left IO
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

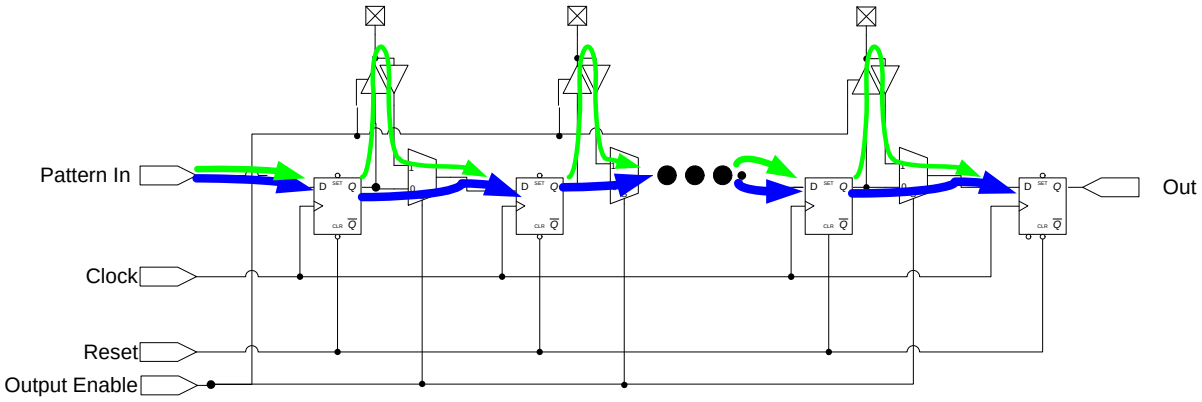


C. Pattern Generators Block

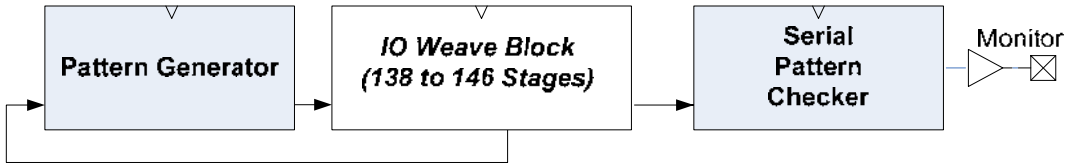


Pattern Type	Pattern Length		Code Length	Δ Bits	Switching Rate
0	000	1 0 ⇨ 0 1 ↰	2	2	100.00%
0	001	1 0 0 ⇨ 0 1 0 ⇨ 0 0 1 ↰	3	2	66.67%
0	010	**One hot I/O at a time switching in entire I/O ring**	#Bits+9	2	N/A
0	011	1 0 0 0 0 ⇨ 0 1 0 0 0 ⇨ 0 0 1 0 0 ⇨ 0 0 0 1 0 ⇨ 0 0 0 0 1 ↰	5	2	40.00%
0	100	1 0 0 0 0 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%

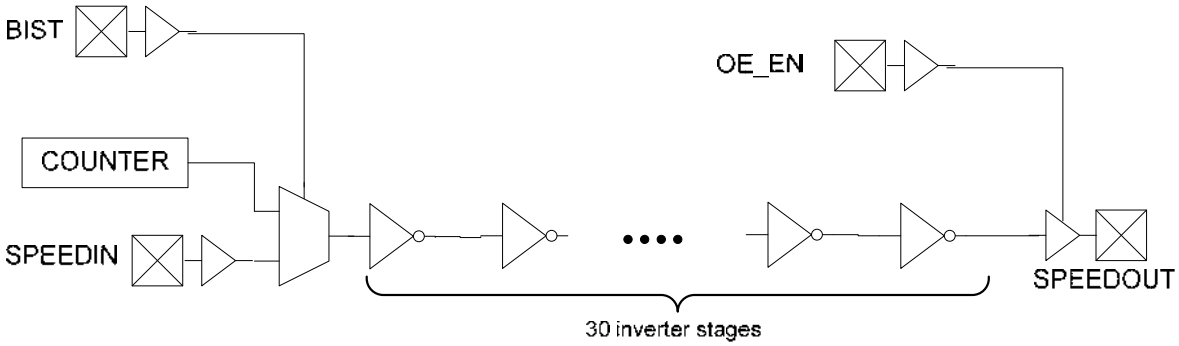
D. I/O Block



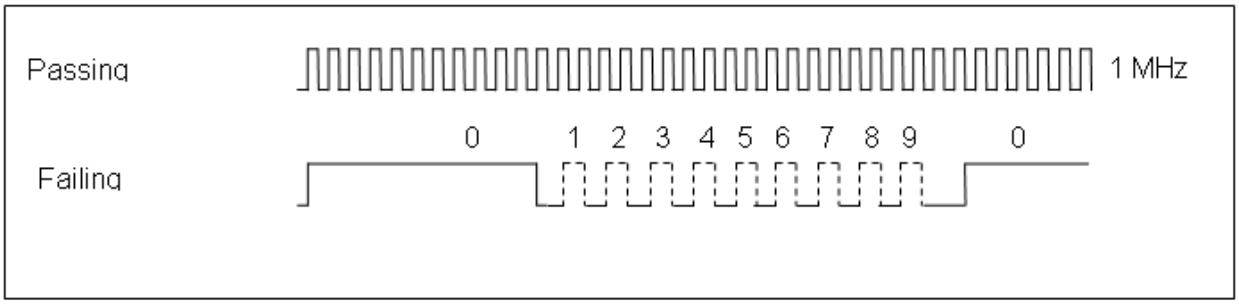
E. Array Shift Registers Block



F. Delay Path Block



G. Monitor Block



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