



# Total Ionizing Dose Test Report

**No. 11T-RT3PE600L-CG484-QJA2H**

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April 2011

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## TOTAL IONIZING DOSE TEST REPORT

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C.K. Huang and J.J. Wang

(650) 318-4209, 318-4576

*chang-kai.huang@microsemi.com, jih-jong.wang@microsemi.com*

### I. Summary Table

Parameter	Tolerance
1. Gross Functionality	Passed 30 krads ( $\text{SiO}_2$ )
2. Power Supply Current ( $I_{\text{CCA}}/I_{\text{CCI}}$ )	Passed 30 krads ( $\text{SiO}_2$ )
3. Input Threshold ( $V_{\text{TII}}/V_{\text{IH}}$ )	Passed 30 krads ( $\text{SiO}_2$ )
4. Output Drive ( $V_{\text{OL}}/V_{\text{OH}}$ )	Passed 30 krads ( $\text{SiO}_2$ )
5. Propagation Delay	Passed 25 krads ( $\text{SiO}_2$ ) per 10%-degradation criterion
6. Transition Time	Passed 30 krads ( $\text{SiO}_2$ )

### 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](http://www.klabs.org/index_klabs_dot_org.htm). Other reliability reports are also available on the Microsemi SoC Products Group (formerly Actel) website:  
<http://www.actel.com/products/milaero/hireldata.aspx>.

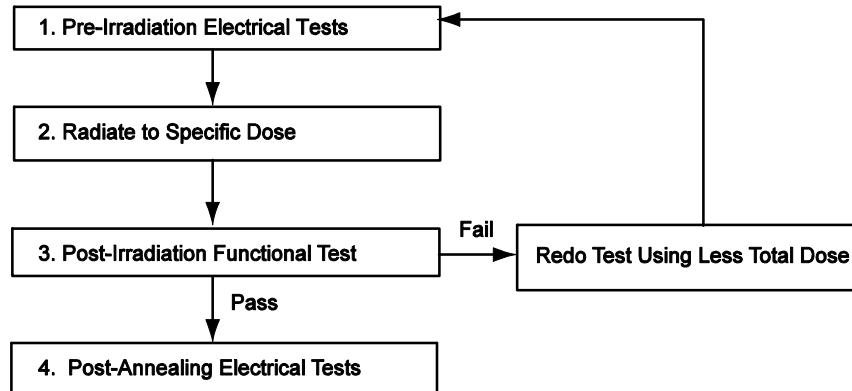
#### A. Device-Under-Test (DUT) and Irradiation Parameters

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	RT3PE600L
Package	CCGA-484
Foundry	United Microelectronics Corp.
Technology	0.13 $\mu\text{m}$ CMOS and Embedded Flash
DUT Design	A3PE600L
Die Lot Number	QJA2H
Quantity Tested	5
Total Dose: DUT Serial Number	17190, 17191, 17193, 17224, 17229
Radiation Facility	Defense Microelectronics Activity
Radiation Source	Co-60
Dose Rate	5 krad ( $\text{SiO}_2$ )/Min. ( $\pm 5\%$ )
Irradiation Temperature	Room
Irradiation and Measurement Bias ( $V_{\text{CCI}}/V_{\text{CCA}}$ )	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(CG484\_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 coMin.g 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 programMin.g.

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 2 different bytes of data is written/read from 2 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

Multi-bit shift register with varying feedback length allows for different pattern configuration 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. IO Block

The IO Block is composed of 4 separate blocks, each with their 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 4 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. IO UR Block
3. IO UL Block
4. IO LR Block
5. IO 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 ( $I_{CCA}$ ) and I/O ( $I_{CCI}$ ) respectively. The input logic thresholds ( $V_{IL}/V_{IH}$ ) and output-drive voltages ( $V_{OL}/V_{OH}$ ) 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 5 through Figure 18 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. $I_{CC}$ ( $I_{CCA}/I_{CCI}$ )	DUT power supply pins
3. Input Threshold ( $V_{IL}/V_{IH}$ )	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 ( $V_{OL}/V_{OH}$ )	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 ( $I_{CCA}$ and $I_{CCI}$ )

Table 3 shows the pre-irradiation and Post-Annealing  $I_{CCA}$  and  $I_{CCI}$  measured at the high Vcc corners at 1.3 V or 1.575 V and 3.6 V, respectively. In most cases, the currents after irradiation and annealing are at the level or even lower than 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  $I_{CCA}$  and  $I_{CCI}$  for all DUTs pass the specification with very good margins.

**Table 3 Post Irradiation and Post-Annealing I<sub>CC</sub>**

DUT	Total Dose	$I_{CCA}$ at 1.3V (mA)		$I_{CCA}$ at 1.575V (mA)		$I_{CCI}$ at 3.6V (mA)	
		Pre-rad	Post-ann	Pre-rad	Post-ann	Pre-rad	Post-ann
17190	30 krad	0.912	0.696	1.895	1.616	0.053	0.035
17191	30 krad	0.976	0.824	2.120	1.822	0.048	0.032
17193	30 krad	0.735	0.622	1.703	1.561	0.047	0.034
17224	30 krad	2.059	1.851	3.741	3.371	0.021	0.016
17229	30 krad	0.567	1.799	1.570	1.468	0.021	0.017

### 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 Continuity**

Testname		cont_to_vss (V) [-1.5, -0.2]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	-0.303	-0.301	-0.298	0.001	-0.309	-0.306	-0.303	0.001
17191	30 krad	-0.305	-0.303	-0.300	0.001	-0.310	-0.308	-0.305	0.001
17193	30 krad	-0.306	-0.303	-0.300	0.001	-0.309	-0.306	-0.304	0.001
17224	30 krad	-0.314	-0.312	-0.309	0.001	-0.318	-0.314	-0.311	0.001
17229	30 krad	-0.313	-0.310	-0.307	0.001	-0.316	-0.313	-0.310	0.001

**Table 4b 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.
17190	30 krad	-0.378	-0.142	0.069	0.077	-0.297	-0.089	0.117	0.061
17191	30 krad	-0.400	-0.134	0.110	0.076	-0.301	-0.083	0.117	0.063
17193	30 krad	-0.350	-0.121	0.092	0.071	-0.303	-0.085	0.142	0.058
17224	30 krad	-0.275	-0.027	0.193	0.071	-0.229	-0.025	0.142	0.060
17229	30 krad	-0.275	-0.031	0.193	0.068	-0.222	-0.023	0.167	0.061

**Table 4c 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.
17190	30 krad	-0.225	0.038	0.290	0.075	-0.181	0.017	0.259	0.063
17191	30 krad	-0.225	0.029	0.243	0.074	-0.204	0.019	0.171	0.065
17193	30 krad	-0.199	0.039	0.244	0.072	-0.179	0.020	0.181	0.064
17224	30 krad	-0.225	0.032	0.258	0.071	-0.225	0.014	0.192	0.065
17229	30 krad	-0.192	0.032	0.430	0.077	-0.205	0.019	0.345	0.069

#### D. Low Output-Drive Voltage ( $V_{OL}$ and $I_{pd}$ )

The pre-irradiation and post-annealing  $V_{OL}$  and  $I_{pd}$  are listed in Table 5a through Table 6j. 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  $V_{OL}$**

Testname		hstli_volt_4x (mV) [0.0, 400.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	163.224	170.952	181.389	2.956	158.235	166.085	189.326	3.782
17191	30 krad	160.271	168.474	178.520	3.070	155.787	163.991	176.603	3.211
17193	30 krad	161.172	167.852	180.127	3.212	157.754	164.701	174.745	3.042
17224	30 krad	161.360	168.961	180.363	3.113	159.111	166.866	179.770	3.500
17229	30 krad	162.365	170.173	183.079	3.238	159.365	167.385	188.882	3.601

**Table 5b Pre-Irradiation and Post-Annealing  $V_{OL}$**

Testname		hstlii_volt_5x (mV) [0.0, 400.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	230.587	244.923	265.487	5.552	223.514	237.940	274.363	6.892
17191	30 krad	226.818	241.454	261.486	5.718	220.311	234.933	258.141	5.982
17193	30 krad	227.614	240.586	263.533	6.023	223.015	235.832	255.567	5.697
17224	30 krad	228.514	242.658	264.523	5.871	224.732	239.492	261.601	6.496
17229	30 krad	229.959	244.143	268.097	6.081	225.565	239.984	280.176	6.712

**Table 5c Pre-Irradiation and Post-Annealing  $V_{OL}$**

Testname		gtl33_volt_5x (mV) [0.0, 400.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	199.492	217.374	246.740	7.537	194.485	212.637	272.247	9.400
17191	30 krad	197.082	215.331	244.897	7.753	191.973	210.912	246.657	8.096
17193	30 krad	196.872	214.264	245.047	8.143	192.664	211.052	238.603	7.684
17224	30 krad	194.924	214.096	244.352	7.912	192.183	212.105	243.517	8.692
17229	30 krad	196.349	214.791	246.178	8.160	192.915	212.141	261.662	8.997

**Table 5d Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		gtl25_vol_5x (mV) [0.0, 400.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	217.623	236.044	265.425	7.618	210.837	229.594	275.077	9.205
17191	30 krad	215.133	233.241	263.226	7.821	208.592	227.605	268.276	8.299
17193	30 krad	214.483	231.961	261.970	8.205	208.952	227.709	256.456	7.727
17224	30 krad	213.248	232.589	261.970	7.960	208.952	229.623	262.187	8.858
17229	30 krad	215.425	233.041	264.324	8.118	209.219	229.909	284.404	9.117

**Table 5e Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		gtlp33_vol_5x (mV) [0.0, 600.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	354.760	386.022	437.703	13.212	345.803	377.460	461.600	16.114
17191	30 krad	350.312	382.614	434.519	13.601	341.280	374.214	433.244	14.256
17193	30 krad	350.144	380.561	434.615	14.274	342.494	374.822	422.844	13.444
17224	30 krad	346.626	380.439	433.493	13.862	341.489	376.498	435.468	15.319
17229	30 krad	349.411	381.785	436.415	14.327	343.184	376.517	473.528	15.831

**Table 5f Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		gtlp25_vol_5x (mV) [0.0, 600.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	370.423	400.203	448.239	12.423	359.345	389.654	452.819	14.755
17191	30 krad	365.334	396.197	443.966	12.809	355.295	385.952	443.293	13.429
17193	30 krad	365.403	393.744	444.601	13.491	356.246	386.355	431.505	12.683
17224	30 krad	362.858	394.391	444.280	13.074	356.466	389.335	449.268	14.419
17229	30 krad	365.837	396.181	448.150	13.534	358.224	389.549	478.031	14.717

**Table 5g Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		sstl2i_vol_4x (mV) [0.0, 540.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	219.499	233.244	254.511	5.609	212.923	226.906	255.735	6.557
17191	30 krad	216.233	230.645	251.778	5.790	210.443	224.665	243.954	5.921
17193	30 krad	216.738	229.294	251.401	6.051	211.848	225.167	245.242	5.746
17224	30 krad	215.073	229.420	251.589	5.900	211.597	226.468	252.150	6.479
17229	30 krad	216.390	230.625	253.641	6.110	212.390	226.572	259.881	6.463

**Table 5h Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		sstl2ii_vol_5x (mV) [0.0, 350.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	195.628	211.793	237.765	6.756	190.288	206.450	239.734	7.812
17191	30 krad	193.335	209.649	235.848	6.955	187.997	204.684	228.497	7.037
17193	30 krad	193.081	208.483	235.063	7.264	188.614	204.881	229.377	6.871
17224	30 krad	191.730	208.800	235.974	7.101	188.645	206.445	236.874	7.763
17229	30 krad	193.147	209.654	237.375	7.342	189.462	206.370	236.445	7.603

**Table 5i Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		sstl3i_vol_2x (mV) [0.0, 700.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	438.644	450.465	469.284	5.347	427.079	439.036	464.786	6.189
17191	30 krad	432.574	444.479	464.039	5.605	421.145	433.665	452.598	5.707
17193	30 krad	431.192	442.955	465.735	5.627	424.644	435.471	454.577	5.350
17224	30 krad	427.996	440.430	461.686	5.377	423.060	436.105	459.420	6.008
17229	30 krad	431.349	443.511	468.781	5.695	425.366	437.324	460.815	6.018

**Table 5j Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		sstl3ii_vol_3x (mV) [0.0, 500.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	321.549	340.830	370.886	7.935	312.505	332.119	371.117	9.045
17191	30 krad	316.963	336.807	366.896	8.170	308.863	329.025	356.421	8.251
17193	30 krad	317.460	335.477	366.487	8.529	310.970	329.672	358.338	8.066
17224	30 krad	314.162	334.446	365.796	8.321	309.306	330.269	361.695	8.986
17229	30 krad	316.241	336.098	369.046	8.589	310.653	330.868	368.171	9.025

**Table 5k Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		cmos25_vol_1x (mV) [0.0, 630.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	239.319	243.826	249.025	1.641	231.320	236.197	244.066	1.891
17191	30 krad	235.236	239.772	245.696	1.734	228.306	232.974	238.964	1.802
17193	30 krad	234.642	239.060	245.194	1.709	230.043	234.046	239.273	1.640
17224	30 krad	233.889	238.432	243.892	1.674	230.190	234.648	241.337	1.862
17229	30 krad	236.115	240.498	247.329	1.741	231.571	235.781	245.493	1.882

**Table 5l Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		cmos25_vol_2x (mV) [0.0, 630.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	248.428	256.495	266.702	3.023	240.550	248.760	263.656	3.538
17191	30 krad	244.533	252.752	262.931	3.174	237.536	245.722	255.236	3.251
17193	30 krad	244.629	251.759	263.345	3.256	239.483	246.654	256.740	3.090
17224	30 krad	243.528	251.207	262.931	3.199	239.572	247.532	261.895	3.554
17229	30 krad	245.287	253.107	266.359	3.308	240.173	248.319	267.484	3.577

**Table 5m Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		cmos25_vol_3x (mV) [0.0, 630.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	199.303	210.503	227.365	4.495	193.334	204.584	226.988	5.230
17191	30 krad	196.539	207.970	224.726	4.647	191.073	202.618	217.910	4.751
17193	30 krad	196.788	206.829	224.286	4.835	192.539	203.074	219.104	4.578
17224	30 krad	195.534	206.800	224.601	4.733	192.225	204.138	224.803	5.266
17229	30 krad	196.539	208.035	226.855	4.905	192.831	204.404	232.990	5.293

**Table 5n Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		cmos25_vol_4x (mV) [0.0, 700.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	234.922	249.689	272.357	5.992	227.993	242.840	272.509	6.949
17191	30 krad	231.718	246.811	269.341	6.184	225.293	240.525	260.887	6.316
17193	30 krad	232.095	245.508	269.027	6.447	227.013	241.003	262.520	6.087
17224	30 krad	230.530	245.617	269.655	6.300	226.574	242.436	269.627	6.992
17229	30 krad	231.843	246.866	272.200	6.523	227.302	242.622	281.621	7.032

**Table 5o Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		cmos25_vol_5x (mV) [0.0, 700.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	264.195	285.825	320.742	9.016	256.310	278.090	322.300	10.391
17191	30 krad	260.740	282.921	317.788	9.320	253.422	275.841	307.696	9.503
17193	30 krad	260.502	281.304	316.846	9.704	254.455	276.158	308.890	9.164
17224	30 krad	258.868	281.972	318.103	9.483	254.204	278.229	319.103	10.506
17229	30 krad	260.992	283.083	320.246	9.819	255.522	278.263	335.656	10.598

**Table 5p Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		cmos18_vol_1x (mV) [0.0, 405.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	145.844	148.420	151.425	0.880	140.780	143.517	147.561	0.992
17191	30 krad	143.143	145.781	149.101	0.996	138.583	141.380	144.854	1.049
17193	30 krad	142.507	145.301	148.159	0.892	139.828	142.133	144.917	0.864
17224	30 krad	142.758	145.581	148.222	0.880	140.707	143.200	146.362	0.978
17229	30 krad	144.579	147.002	150.672	0.948	141.596	144.084	149.676	1.033

**Table 5q Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		cmos18_vol_2x (mV) [0.0, 405.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	150.681	154.701	159.904	1.524	145.442	149.803	157.467	1.776
17191	30 krad	147.778	152.179	157.455	1.642	143.417	147.744	153.636	1.712
17193	30 krad	147.845	151.709	157.517	1.618	144.924	148.483	153.526	1.540
17224	30 krad	148.097	152.023	157.616	1.593	145.740	149.741	156.216	1.777
17229	30 krad	149.173	153.439	159.841	1.675	146.180	150.384	160.545	1.846

**Table 5r Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		cmos18_vol_3x (mV) [0.0, 405.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	161.235	168.832	179.483	2.965	156.100	163.637	179.332	3.464
17191	30 krad	158.596	166.428	176.907	3.094	153.777	161.876	174.508	3.214
17193	30 krad	158.848	165.666	177.238	3.192	155.410	162.351	172.797	3.028
17224	30 krad	158.722	166.267	177.661	3.133	156.117	163.943	177.968	3.505
17229	30 krad	159.664	167.378	179.939	3.245	156.540	164.294	185.175	3.602

**Table 5s Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	155.832	166.662	183.693	4.469	151.015	162.005	184.355	5.152
17191	30 krad	153.571	164.858	181.871	4.615	149.131	160.514	178.846	4.767
17193	30 krad	153.936	163.935	181.683	4.816	150.403	160.869	177.007	4.548
17224	30 krad	153.496	164.795	182.437	4.708	150.905	162.627	185.261	5.279
17229	30 krad	154.450	165.676	184.335	4.882	151.454	162.629	192.338	5.348

**Table 5t Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	85.538	87.736	90.378	0.773	82.647	84.982	88.792	0.902
17191	30 krad	84.002	86.219	88.997	0.832	81.328	83.792	86.746	0.897
17193	30 krad	83.909	85.981	88.934	0.813	82.406	84.234	86.908	0.788
17224	30 krad	84.161	86.359	89.186	0.796	83.035	85.108	88.761	0.909
17229	30 krad	85.040	87.173	90.504	0.851	83.392	85.555	90.740	0.935

**Table 5u Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	90.940	94.796	99.931	1.482	88.101	91.956	99.591	1.713
17191	30 krad	89.244	93.349	98.360	1.534	86.720	90.834	96.554	1.608
17193	30 krad	89.499	93.008	98.857	1.581	87.787	91.168	96.053	1.501
17224	30 krad	89.746	93.456	99.051	1.551	88.299	92.188	99.511	1.744
17229	30 krad	90.312	94.205	100.427	1.615	88.478	92.530	103.055	1.783

**Table 5v Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	120.465	126.194	134.115	2.216	116.795	122.436	133.497	2.560
17191	30 krad	118.518	124.428	132.167	2.310	114.786	121.054	129.936	2.414
17193	30 krad	118.769	123.976	132.646	2.393	116.419	121.494	129.193	2.257
17224	30 krad	119.083	124.667	133.109	2.332	116.996	122.959	133.459	2.589
17229	30 krad	119.837	125.612	134.907	2.429	117.360	123.312	139.371	2.662

**Table 5w Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	181.148	192.222	208.766	4.443	175.062	186.448	208.717	5.128
17191	30 krad	178.070	189.638	205.749	4.593	172.865	184.341	203.992	4.820
17193	30 krad	178.384	188.860	206.189	4.804	174.623	184.815	200.820	4.543
17224	30 krad	179.138	190.335	207.634	4.704	175.961	187.568	208.332	5.174
17229	30 krad	180.269	191.503	209.457	4.863	176.507	187.805	219.230	5.365

**Table 5x Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	109.974	112.558	115.940	0.857	106.070	108.961	112.588	0.980
17191	30 krad	107.650	110.409	113.616	0.985	104.563	107.194	110.677	1.037
17193	30 krad	107.901	110.231	112.906	0.848	105.777	107.903	110.768	0.818
17224	30 krad	109.032	111.413	114.070	0.859	107.348	109.621	112.776	0.921
17229	30 krad	109.911	112.591	115.689	0.921	107.817	110.406	116.312	1.005

**Table 5y Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	55.573	57.583	60.043	0.752	53.945	55.948	59.596	0.868
17191	30 krad	54.568	56.641	59.101	0.798	53.066	55.222	58.142	0.836
17193	30 krad	54.705	56.578	59.290	0.794	53.631	55.560	58.151	0.765
17224	30 krad	55.082	57.021	59.590	0.777	54.259	56.268	59.591	0.870
17229	30 krad	55.510	57.503	60.546	0.828	54.572	56.584	62.277	0.915

**Table 5z Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	2.659	2.993	3.267	0.120	2.772	3.086	3.449	0.134
17191	30 krad	2.470	2.953	3.261	0.142	2.709	3.028	3.388	0.133
17193	30 krad	2.514	2.937	3.324	0.149	2.772	3.059	3.449	0.126
17224	30 krad	2.576	2.950	3.307	0.127	2.745	3.086	3.449	0.135
17229	30 krad	2.659	2.973	3.324	0.133	2.773	3.134	3.514	0.139

**Table 5aa Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	2.093	2.491	2.867	0.127	2.207	2.584	2.885	0.126
17191	30 krad	2.093	2.444	2.867	0.124	2.117	2.557	2.885	0.134
17193	30 krad	2.093	2.434	2.805	0.113	2.306	2.583	2.946	0.119
17224	30 krad	2.137	2.434	2.742	0.123	2.270	2.631	3.008	0.124
17229	30 krad	2.156	2.461	2.758	0.124	2.270	2.620	3.074	0.137

**Table 5ab Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	210.604	215.184	220.111	1.614	204.472	209.072	218.128	1.904
17191	30 krad	207.166	211.765	217.142	1.699	201.894	206.371	212.580	1.764
17193	30 krad	207.453	211.325	217.532	1.700	204.003	207.495	212.887	1.630
17224	30 krad	205.525	209.865	215.493	1.678	202.285	206.898	213.200	1.810
17229	30 krad	207.088	211.503	218.626	1.742	203.613	207.792	219.896	1.877

**Table 5ac Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	210.604	215.219	220.267	1.618	204.628	209.061	217.048	1.876
17191	30 krad	207.166	211.741	217.142	1.700	201.960	206.365	212.424	1.741
17193	30 krad	207.297	211.360	217.298	1.699	203.769	207.435	212.731	1.606
17224	30 krad	204.978	209.873	215.415	1.680	202.363	206.882	213.748	1.818
17229	30 krad	207.088	211.596	218.548	1.727	203.535	207.888	218.958	1.886

**Table 5ad Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	4.647	5.235	5.704	0.203	4.506	5.171	5.904	0.242
17191	30 krad	4.516	5.157	5.649	0.215	4.506	5.078	5.781	0.236
17193	30 krad	4.569	5.088	5.652	0.201	4.506	5.113	5.818	0.237
17224	30 krad	4.569	5.063	5.652	0.187	4.506	5.113	5.826	0.226
17229	30 krad	4.491	5.088	5.571	0.215	4.584	5.114	5.826	0.225

**Table 5ae Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

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.
17190	30 krad	4.750	5.376	5.962	0.214	4.722	5.270	6.061	0.242
17191	30 krad	4.647	5.313	5.964	0.221	4.702	5.209	6.061	0.234
17193	30 krad	4.804	5.261	5.730	0.191	4.644	5.269	5.904	0.236
17224	30 krad	4.413	5.235	5.886	0.210	4.584	5.235	5.983	0.251
17229	30 krad	4.647	5.298	5.805	0.199	4.662	5.269	5.983	0.232

**Table 5af Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		Ivttl_volt_2x (mV) [0.0, 360.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	220.449	228.401	238.944	3.061	213.924	221.727	237.997	3.584
17191	30 krad	217.011	225.124	235.973	3.192	211.492	219.342	232.912	3.325
17193	30 krad	217.714	224.487	236.051	3.293	212.830	220.161	230.682	3.115
17224	30 krad	215.136	223.252	234.801	3.229	211.658	220.006	233.759	3.541
17229	30 krad	216.620	224.788	238.082	3.316	212.518	220.556	243.500	3.712

**Table 5ag Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		Ivttl_volt_3x (mV) [0.0, 360.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	180.054	191.043	207.989	4.518	174.868	185.992	210.697	5.301
17191	30 krad	177.398	188.763	206.191	4.674	172.602	184.359	201.632	4.842
17193	30 krad	177.599	187.830	205.722	4.867	174.225	184.773	200.981	4.598
17224	30 krad	175.880	187.314	205.175	4.756	173.365	185.124	203.813	5.176
17229	30 krad	176.460	188.299	206.515	4.913	173.774	185.343	214.737	5.452

**Table 5ah Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		Ivttl_volt_4x (mV) [0.0, 400.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	212.010	226.822	249.731	6.012	206.269	220.987	254.581	7.047
17191	30 krad	209.354	224.363	247.542	6.227	204.316	219.092	241.749	6.416
17193	30 krad	209.487	223.312	246.995	6.476	205.476	219.538	241.155	6.116
17224	30 krad	207.479	222.810	246.604	6.332	204.304	220.067	246.054	6.888
17229	30 krad	208.885	223.759	247.459	6.523	205.097	220.265	256.709	7.169

**Table 5ai Pre-Irradiation and Post-Annealing V<sub>OL</sub>**

Testname		Ivttl_volt_5x (mV) [0.0, 400.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	239.982	261.573	296.632	9.039	233.133	254.991	305.818	10.570
17191	30 krad	236.999	259.067	294.756	9.350	230.711	253.150	287.027	9.590
17193	30 krad	236.686	257.587	293.662	9.719	231.727	253.268	286.566	9.167
17224	30 krad	234.498	257.681	293.662	9.483	230.633	254.661	295.884	10.301
17229	30 krad	236.217	258.377	294.052	9.802	231.648	254.377	311.108	10.746

**Table 6a Pre-Irradiation and Post-Annealing Ipd**

Testname		cmos25_ipd_weak (cmos25_ipd_weak_Min.) (uA) [9.5, 27.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	19.667	20.286	20.711	0.206	20.648	21.209	21.605	0.203
17191	30 krad	20.541	20.825	21.181	0.134	21.349	21.679	22.126	0.146
17193	30 krad	20.816	21.144	21.531	0.131	21.493	21.817	22.199	0.128
17224	30 krad	20.208	20.661	21.160	0.180	20.870	21.186	21.671	0.167
17229	30 krad	20.616	20.977	21.358	0.140	21.269	21.588	21.989	0.140

**Table 6b Pre-Irradiation and Post-Annealing Ipd**

Testname		cmos25_ipd_weak (cmos25_ipd_weak_Max.) (uA) [9.5, 30.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	23.614	24.350	24.769	0.238	24.740	25.426	25.818	0.238
17191	30 krad	24.639	25.013	25.396	0.154	25.579	25.974	26.452	0.159
17193	30 krad	25.006	25.366	25.778	0.142	25.790	26.116	26.543	0.136
17224	30 krad	24.414	24.888	25.471	0.202	25.041	25.465	26.035	0.194
17229	30 krad	24.883	25.251	25.647	0.161	25.565	25.924	26.324	0.157

**Table 6c Pre-Irradiation and Post-Annealing Ipd**

Testname		cmos18_ipd_weak (cmos18_ipd_weak_Min.) (uA) [4.1, 14.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	8.743	9.120	9.396	0.122	9.213	9.534	9.764	0.108
17191	30 krad	9.153	9.365	9.613	0.089	9.502	9.742	10.023	0.085
17193	30 krad	9.244	9.511	9.837	0.094	9.568	9.816	10.064	0.083
17224	30 krad	9.010	9.276	9.595	0.107	9.274	9.495	9.747	0.092
17229	30 krad	9.148	9.423	9.707	0.091	9.343	9.680	9.906	0.088

**Table 6d Pre-Irradiation and Post-Annealing Ipd**

Testname		cmos18_ipd_weak (cmos18_ipd_weak_Max.) (uA) [4.1, 14.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	11.074	11.537	11.835	0.141	11.739	12.064	12.311	0.127
17191	30 krad	11.597	11.834	12.120	0.096	12.080	12.329	12.599	0.095
17193	30 krad	11.747	12.028	12.361	0.097	12.150	12.410	12.672	0.090
17224	30 krad	11.429	11.756	12.090	0.120	11.789	12.041	12.322	0.111
17229	30 krad	11.622	11.935	12.215	0.101	11.936	12.278	12.524	0.097

**Table 6e Pre-Irradiation and Post-Annealing IpD**

Testname		cmos15_ipd_weak (cmos15_ipd_weak_Min.U) (uA) [2.4, 21.7]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	5.360	5.663	5.908	0.097	5.612	5.919	6.175	0.085
17191	30 krad	5.618	5.801	6.064	0.077	5.789	6.047	6.247	0.072
17193	30 krad	5.662	5.908	6.189	0.082	5.905	6.097	6.329	0.070
17224	30 krad	5.491	5.754	6.052	0.087	5.688	5.898	6.125	0.075
17229	30 krad	5.629	5.846	6.103	0.080	5.704	6.011	6.191	0.074

**Table 6f Pre-Irradiation and Post-Annealing IpD**

Testname		cmos15_ipd_weak (cmos15_ipd_weak_Max.U) (uA) [2.4, 21.7]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	7.515	7.879	8.149	0.110	7.963	8.243	8.434	0.101
17191	30 krad	7.899	8.079	8.323	0.083	8.176	8.428	8.628	0.082
17193	30 krad	7.955	8.223	8.513	0.088	8.228	8.478	8.686	0.077
17224	30 krad	7.774	8.017	8.349	0.099	8.004	8.217	8.452	0.085
17229	30 krad	7.891	8.146	8.398	0.087	8.122	8.378	8.573	0.082

**Table 6g Pre-Irradiation and Post-Annealing IpD**

Testname		cmos12_ipd_weak (cmos12_ipd_weak_Min.U) (uA) [1.4, 21.7]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	2.955	3.233	3.458	0.084	3.181	3.373	3.547	0.071
17191	30 krad	3.084	3.311	3.556	0.074	3.211	3.444	3.622	0.066
17193	30 krad	3.185	3.365	3.616	0.076	3.286	3.481	3.669	0.065
17224	30 krad	3.059	3.284	3.533	0.074	3.112	3.368	3.547	0.063
17229	30 krad	3.084	3.338	3.593	0.078	3.186	3.433	3.622	0.065

**Table 6h Pre-Irradiation and Post-Annealing IpD**

Testname		cmos12_ipd_weak (cmos12_ipd_weak_Max.U) (uA) [2.4, 15.8]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	3.957	4.278	4.528	0.089	4.259	4.480	4.649	0.076
17191	30 krad	4.187	4.385	4.615	0.074	4.335	4.570	4.797	0.069
17193	30 krad	4.238	4.470	4.715	0.079	4.383	4.612	4.822	0.072
17224	30 krad	4.087	4.350	4.603	0.083	4.258	4.462	4.673	0.068
17229	30 krad	4.163	4.423	4.656	0.075	4.308	4.549	4.723	0.069

**Table 6i Pre-Irradiation and Post-Annealing IpD**

Testname		Ivttl_ipd_weak_ (Ivttl_ipd_weak_Min.) (uA) [8.9, 22.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	15.660	16.151	16.465	0.172	16.380	16.856	17.157	0.163
17191	30 krad	16.294	16.577	16.915	0.110	16.983	17.239	17.600	0.109
17193	30 krad	16.452	16.797	17.133	0.109	17.047	17.309	17.575	0.097
17224	30 krad	16.236	16.599	16.965	0.138	16.531	16.971	17.307	0.131
17229	30 krad	16.469	16.800	17.095	0.118	16.921	17.264	17.562	0.112

**Table 6j Pre-Irradiation and Post-Annealing IpD**

Testname		Ivttl_ipd_weak_ (Ivttl_ipd_weak_Max.) (uA) [8.9, 23.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	16.587	17.103	17.446	0.180	17.342	17.844	18.144	0.167
17191	30 krad	17.243	17.564	17.889	0.116	17.971	18.258	18.625	0.116
17193	30 krad	17.478	17.798	18.109	0.108	18.071	18.335	18.587	0.097
17224	30 krad	17.288	17.612	17.997	0.144	17.711	18.020	18.386	0.133
17229	30 krad	17.514	17.837	18.103	0.115	17.968	18.317	18.632	0.116

## E. High Output-Drive Voltage ( $V_{OH}$ and $I_{pu}$ )

The pre-irradiation and post-annealing  $V_{OH}$  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  $V_{OH}$**

Testname		hstli_voh_4x (V) [1.0, 1.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.100	1.120	1.131	0.004	1.107	1.127	1.138	0.004
17191	30 krad	1.103	1.123	1.134	0.004	1.110	1.129	1.141	0.004
17193	30 krad	1.099	1.120	1.132	0.004	1.105	1.125	1.138	0.004
17224	30 krad	1.084	1.107	1.123	0.005	1.089	1.111	1.127	0.005
17229	30 krad	1.079	1.107	1.123	0.006	1.084	1.111	1.128	0.006

**Table 7b Pre-Irradiation and Post-Annealing  $V_{OH}$**

Testname		hstlii_voh_5x (V) [1.0, 1.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.097	1.118	1.133	0.006	1.088	1.125	1.140	0.007
17191	30 krad	1.100	1.120	1.135	0.006	1.104	1.126	1.142	0.006
17193	30 krad	1.095	1.118	1.134	0.006	1.102	1.123	1.140	0.006
17224	30 krad	1.086	1.108	1.125	0.006	1.089	1.111	1.130	0.007
17229	30 krad	1.082	1.108	1.126	0.006	1.075	1.112	1.131	0.007

**Table 7c Pre-Irradiation and Post-Annealing  $V_{OH}$**

Testname		sstl2i_voh_4x (V) [1.7, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.924	1.945	1.960	0.006	1.927	1.956	1.972	0.006
17191	30 krad	1.929	1.947	1.963	0.006	1.940	1.958	1.974	0.006
17193	30 krad	1.923	1.945	1.962	0.006	1.932	1.954	1.971	0.006
17224	30 krad	1.920	1.941	1.958	0.006	1.927	1.948	1.966	0.007
17229	30 krad	1.913	1.939	1.957	0.006	1.918	1.947	1.966	0.007

**Table 7d Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

Testname		sstl2ii_voh_5x (V) [1.9, 2.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	2.035	2.062	2.079	0.007	2.035	2.070	2.087	0.008
17191	30 krad	2.037	2.063	2.081	0.007	2.047	2.071	2.089	0.007
17193	30 krad	2.035	2.063	2.080	0.007	2.043	2.069	2.087	0.007
17224	30 krad	2.033	2.060	2.078	0.007	2.039	2.066	2.085	0.008
17229	30 krad	2.033	2.059	2.078	0.007	2.040	2.066	2.084	0.007

**Table 7e Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

Testname		sstl3i_voh_2x (V) [1.9, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	2.298	2.321	2.336	0.006	2.312	2.335	2.352	0.007
17191	30 krad	2.303	2.327	2.345	0.007	2.316	2.340	2.358	0.007
17193	30 krad	2.295	2.320	2.339	0.007	2.305	2.330	2.349	0.007
17224	30 krad	2.291	2.315	2.334	0.007	2.298	2.322	2.342	0.007
17229	30 krad	2.276	2.310	2.330	0.008	2.288	2.318	2.339	0.008

**Table 7f Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

Testname		sstl3ii_voh_3x (V) [2.1, 3.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	2.434	2.462	2.482	0.008	2.437	2.472	2.493	0.009
17191	30 krad	2.439	2.465	2.487	0.008	2.450	2.475	2.498	0.008
17193	30 krad	2.431	2.462	2.484	0.009	2.439	2.469	2.493	0.008
17224	30 krad	2.430	2.459	2.482	0.008	2.435	2.463	2.488	0.009
17229	30 krad	2.419	2.455	2.480	0.009	2.429	2.461	2.487	0.009

**Table 7g Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

Testname		cmos25_voh_1x (V) [1.7, 2.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.843	1.862	1.869	0.003	1.857	1.876	1.883	0.003
17191	30 krad	1.847	1.866	1.875	0.004	1.860	1.879	1.887	0.004
17193	30 krad	1.844	1.862	1.871	0.004	1.855	1.872	1.881	0.004
17224	30 krad	1.832	1.855	1.868	0.004	1.842	1.864	1.876	0.004
17229	30 krad	1.825	1.852	1.863	0.005	1.836	1.861	1.873	0.005

**Table 7h Pre-Irradiation and Post-Annealing VOH**

Testname		cmos25_voh_2x (V) [1.7, 2.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.829	1.847	1.857	0.004	1.843	1.861	1.871	0.004
17191	30 krad	1.833	1.852	1.863	0.004	1.846	1.865	1.876	0.004
17193	30 krad	1.828	1.848	1.860	0.004	1.839	1.858	1.871	0.004
17224	30 krad	1.818	1.840	1.855	0.005	1.828	1.849	1.863	0.005
17229	30 krad	1.811	1.837	1.852	0.005	1.822	1.847	1.862	0.005

**Table 7i Pre-Irradiation and Post-Annealing VOH**

Testname		cmos25_voh_3x (V) [1.8, 2.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.930	1.948	1.961	0.005	1.935	1.959	1.972	0.005
17191	30 krad	1.933	1.951	1.964	0.005	1.943	1.961	1.975	0.005
17193	30 krad	1.929	1.948	1.962	0.005	1.938	1.957	1.972	0.005
17224	30 krad	1.926	1.944	1.959	0.005	1.931	1.950	1.967	0.006
17229	30 krad	1.916	1.941	1.957	0.006	1.924	1.949	1.966	0.006

**Table 7j Pre-Irradiation and Post-Annealing VOH**

Testname		cmos25_voh_4x (V) [1.7, 2.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.898	1.920	1.935	0.006	1.898	1.931	1.948	0.007
17191	30 krad	1.902	1.922	1.939	0.006	1.914	1.933	1.951	0.006
17193	30 krad	1.896	1.920	1.937	0.007	1.906	1.929	1.947	0.006
17224	30 krad	1.893	1.915	1.933	0.006	1.897	1.922	1.942	0.007
17229	30 krad	1.884	1.913	1.932	0.007	1.886	1.921	1.941	0.007

**Table 7k Pre-Irradiation and Post-Annealing VOH**

Testname		cmos25_voh_5x (V) [1.7, 2.5]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.944	1.980	2.002	0.009	1.942	1.990	2.012	0.010
17191	30 krad	1.946	1.981	2.004	0.009	1.958	1.990	2.014	0.009
17193	30 krad	1.943	1.980	2.003	0.010	1.953	1.988	2.012	0.009
17224	30 krad	1.941	1.977	2.001	0.009	1.946	1.983	2.008	0.010
17229	30 krad	1.940	1.976	2.000	0.010	1.929	1.983	2.008	0.010

**Table 7l Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

Testname		cmos18_voh_1x (V) [1.3, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.364	1.382	1.388	0.003	1.372	1.390	1.396	0.003
17191	30 krad	1.367	1.385	1.391	0.003	1.374	1.392	1.399	0.003
17193	30 krad	1.366	1.382	1.390	0.003	1.371	1.387	1.395	0.003
17224	30 krad	1.350	1.373	1.384	0.004	1.355	1.377	1.388	0.004
17229	30 krad	1.346	1.371	1.382	0.004	1.352	1.376	1.388	0.004

**Table 7m Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

Testname		cmos18_voh_2x (V) [1.3, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.358	1.375	1.382	0.003	1.366	1.382	1.390	0.003
17191	30 krad	1.360	1.377	1.385	0.003	1.367	1.384	1.392	0.003
17193	30 krad	1.358	1.375	1.383	0.003	1.364	1.380	1.389	0.003
17224	30 krad	1.343	1.365	1.377	0.004	1.348	1.369	1.381	0.004
17229	30 krad	1.339	1.364	1.376	0.005	1.345	1.369	1.381	0.005

**Table 7n Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

Testname		cmos18_voh_3x (V) [1.2, 2.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	1.339	1.359	1.370	0.004	1.347	1.367	1.379	0.004
17191	30 krad	1.343	1.362	1.374	0.004	1.349	1.369	1.381	0.004
17193	30 krad	1.340	1.360	1.372	0.004	1.345	1.365	1.378	0.004
17224	30 krad	1.328	1.350	1.365	0.005	1.333	1.354	1.369	0.005
17229	30 krad	1.320	1.349	1.365	0.005	1.328	1.354	1.370	0.005

**Table 7o Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	1.449	1.467	1.479	0.004	1.448	1.472	1.484	0.005
17191	30 krad	1.452	1.468	1.480	0.005	1.456	1.473	1.485	0.005
17193	30 krad	1.449	1.467	1.479	0.005	1.454	1.471	1.484	0.005
17224	30 krad	1.445	1.463	1.476	0.005	1.447	1.466	1.480	0.005
17229	30 krad	1.445	1.463	1.476	0.005	1.439	1.467	1.480	0.005

**Table 7p Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	1.229	1.240	1.245	0.002	1.234	1.245	1.249	0.002
17191	30 krad	1.231	1.242	1.247	0.002	1.235	1.246	1.251	0.002
17193	30 krad	1.230	1.240	1.245	0.002	1.234	1.244	1.249	0.002
17224	30 krad	1.220	1.234	1.241	0.003	1.222	1.237	1.244	0.003
17229	30 krad	1.217	1.233	1.240	0.003	1.222	1.236	1.244	0.003

**Table 7q Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	1.220	1.233	1.240	0.002	1.226	1.238	1.244	0.002
17191	30 krad	1.222	1.234	1.241	0.002	1.227	1.239	1.245	0.002
17193	30 krad	1.221	1.233	1.240	0.002	1.224	1.237	1.243	0.002
17224	30 krad	1.212	1.226	1.235	0.003	1.215	1.229	1.238	0.003
17229	30 krad	1.209	1.226	1.235	0.003	1.213	1.229	1.238	0.003

**Table 7r Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	1.183	1.197	1.205	0.003	1.189	1.203	1.211	0.003
17191	30 krad	1.185	1.199	1.207	0.003	1.191	1.204	1.212	0.003
17193	30 krad	1.184	1.197	1.206	0.003	1.188	1.201	1.210	0.003
17224	30 krad	1.175	1.189	1.200	0.003	1.178	1.192	1.203	0.004
17229	30 krad	1.170	1.189	1.199	0.004	1.175	1.192	1.204	0.004

**Table 7s Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	1.162	1.179	1.191	0.005	1.164	1.185	1.197	0.005
17191	30 krad	1.164	1.180	1.193	0.005	1.169	1.186	1.199	0.005
17193	30 krad	1.161	1.179	1.192	0.005	1.166	1.184	1.197	0.005
17224	30 krad	1.154	1.172	1.185	0.005	1.157	1.175	1.189	0.005
17229	30 krad	1.153	1.172	1.186	0.005	1.147	1.176	1.190	0.005

**Table 7t Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	0.902	0.927	0.936	0.004	0.909	0.933	0.943	0.004
17191	30 krad	0.904	0.929	0.938	0.004	0.910	0.935	0.944	0.004
17193	30 krad	0.904	0.927	0.937	0.004	0.909	0.932	0.942	0.004
17224	30 krad	0.871	0.909	0.926	0.007	0.875	0.913	0.930	0.007
17229	30 krad	0.868	0.910	0.925	0.007	0.874	0.914	0.930	0.007

**Table 7u Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	1.028	1.038	1.042	0.002	1.032	1.041	1.045	0.002
17191	30 krad	1.029	1.038	1.043	0.002	1.033	1.041	1.046	0.002
17193	30 krad	1.029	1.037	1.042	0.002	1.031	1.040	1.045	0.002
17224	30 krad	1.020	1.031	1.038	0.002	1.022	1.033	1.040	0.002
17229	30 krad	1.018	1.031	1.038	0.003	1.021	1.034	1.041	0.003

**Table 7v Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	1.132	1.133	1.134	0.000	1.134	1.134	1.135	0.000
17191	30 krad	1.132	1.133	1.134	0.000	1.134	1.134	1.135	0.000
17193	30 krad	1.132	1.133	1.134	0.000	1.134	1.134	1.135	0.000
17224	30 krad	1.132	1.133	1.134	0.000	1.133	1.134	1.135	0.000
17229	30 krad	1.132	1.133	1.134	0.000	1.133	1.134	1.135	0.000

**Table 7w Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	1.394	1.395	1.396	0.000	1.395	1.396	1.397	0.000
17191	30 krad	1.394	1.395	1.396	0.000	1.396	1.396	1.397	0.000
17193	30 krad	1.394	1.395	1.396	0.000	1.396	1.396	1.397	0.000
17224	30 krad	1.394	1.395	1.396	0.000	1.395	1.396	1.397	0.000
17229	30 krad	1.394	1.395	1.395	0.000	1.395	1.396	1.397	0.000

**Table 7x Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	2.636	2.645	2.650	0.002	2.643	2.653	2.658	0.002
17191	30 krad	2.638	2.648	2.654	0.002	2.645	2.655	2.661	0.003
17193	30 krad	2.636	2.645	2.651	0.002	2.641	2.650	2.656	0.003
17224	30 krad	2.632	2.644	2.651	0.003	2.637	2.648	2.655	0.003
17229	30 krad	2.627	2.641	2.647	0.003	2.632	2.646	2.653	0.003

**Table 7y Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	2.636	2.645	2.650	0.002	2.643	2.653	2.658	0.002
17191	30 krad	2.638	2.648	2.654	0.002	2.645	2.655	2.661	0.003
17193	30 krad	2.636	2.645	2.651	0.002	2.641	2.650	2.657	0.003
17224	30 krad	2.632	2.644	2.651	0.003	2.636	2.648	2.655	0.003
17229	30 krad	2.627	2.641	2.648	0.003	2.632	2.646	2.653	0.003

**Table 7z Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	2.990	2.991	2.991	0.000	2.991	2.992	2.992	0.000
17191	30 krad	2.990	2.991	2.991	0.000	2.991	2.992	2.992	0.000
17193	30 krad	2.990	2.991	2.991	0.000	2.991	2.991	2.992	0.000
17224	30 krad	2.990	2.991	2.991	0.000	2.991	2.991	2.992	0.000
17229	30 krad	2.990	2.991	2.991	0.000	2.991	2.991	2.992	0.000

**Table 7aa Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	2.690	2.691	2.691	0.000	2.691	2.692	2.692	0.000
17191	30 krad	2.690	2.691	2.691	0.000	2.691	2.692	2.692	0.000
17193	30 krad	2.690	2.691	2.691	0.000	2.691	2.691	2.692	0.000
17224	30 krad	2.690	2.691	2.691	0.000	2.691	2.691	2.692	0.000
17229	30 krad	2.690	2.690	2.691	0.000	2.691	2.691	2.692	0.000

**Table 7ab Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	2.619	2.630	2.638	0.003	2.622	2.637	2.645	0.004
17191	30 krad	2.622	2.633	2.642	0.003	2.627	2.640	2.648	0.004
17193	30 krad	2.618	2.630	2.639	0.004	2.622	2.635	2.644	0.003
17224	30 krad	2.617	2.628	2.638	0.004	2.620	2.632	2.642	0.004
17229	30 krad	2.610	2.625	2.635	0.004	2.609	2.630	2.640	0.004

**Table 7ac Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	2.687	2.704	2.715	0.004	2.687	2.710	2.722	0.005
17191	30 krad	2.690	2.705	2.718	0.005	2.695	2.711	2.724	0.005
17193	30 krad	2.686	2.703	2.716	0.005	2.691	2.708	2.721	0.005
17224	30 krad	2.687	2.702	2.715	0.005	2.689	2.705	2.719	0.005
17229	30 krad	2.682	2.700	2.714	0.005	2.678	2.704	2.719	0.005

**Table 7ad Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	2.655	2.678	2.693	0.006	2.656	2.685	2.700	0.007
17191	30 krad	2.658	2.679	2.695	0.006	2.666	2.686	2.702	0.006
17193	30 krad	2.654	2.678	2.694	0.006	2.660	2.682	2.699	0.006
17224	30 krad	2.655	2.677	2.693	0.006	2.658	2.680	2.697	0.007
17229	30 krad	2.652	2.675	2.692	0.006	2.646	2.679	2.697	0.007

**Table 7ae Pre-Irradiation and Post-Annealing V<sub>OH</sub>**

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.
17190	30 krad	2.683	2.720	2.742	0.009	2.680	2.725	2.748	0.010
17191	30 krad	2.684	2.720	2.743	0.009	2.693	2.726	2.749	0.009
17193	30 krad	2.683	2.720	2.742	0.010	2.689	2.724	2.747	0.009
17224	30 krad	2.683	2.719	2.742	0.009	2.684	2.721	2.746	0.010
17229	30 krad	2.681	2.718	2.741	0.010	2.670	2.721	2.745	0.011

**Table 8a Pre-Irradiation and Post-Annealing Ipu**

Testname		cmos25_ipu_weak (cmos25_ipu_weak_Min.) (uA) [-80.0, -10.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	-28.335	-27.697	-27.092	0.263	-29.144	-28.374	-27.771	0.285
17191	30 krad	-28.576	-27.871	-27.166	0.261	-29.115	-28.475	-27.713	0.261
17193	30 krad	-28.616	-27.964	-27.042	0.277	-29.154	-28.415	-27.490	0.276
17224	30 krad	-28.393	-27.770	-27.039	0.265	-28.869	-28.119	-27.343	0.287
17229	30 krad	-28.801	-28.001	-27.539	0.215	-29.170	-28.438	-27.818	0.217

**Table 8b Pre-Irradiation and Post-Annealing Ipu**

Testname		cmos25_ipu_weak (cmos25_ipu_weak_Max.) (uA) [-85.0, -10.0]							
DUT	Total Dose	Pre-Radiation				Post-Anneal			
		Min.	Median	Max.	Std. Dev.	Min.	Median	Max.	Std. Dev.
17190	30 krad	-49.521	-48.374	-47.349	0.443	-50.544	-49.274	-48.210	0.471
17191	30 krad	-49.806	-48.708	-47.536	0.430	-50.539	-49.465	-48.254	0.432
17193	30 krad	-49.902	-48.840	-47.450	0.447	-50.565	-49.360	-47.936	0.446
17224	30 krad	-49.631	-48.557	-47.320	0.443	-50.094	-48.873	-47.601	0.462
17229	30 krad	-50.133	-48.967	-48.144	0.351	-50.561	-49.426	-48.582	0.354

**Table 8c 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.
17190	30 krad	-15.315	-14.879	-14.424	0.163	-15.653	-15.178	-14.763	0.174
17191	30 krad	-15.415	-14.924	-14.483	0.168	-15.613	-15.177	-14.719	0.164
17193	30 krad	-15.490	-15.012	-14.412	0.177	-15.579	-15.174	-14.634	0.170
17224	30 krad	-15.240	-14.800	-14.345	0.164	-15.427	-14.914	-14.422	0.177
17229	30 krad	-15.541	-14.939	-14.529	0.143	-15.615	-15.110	-14.652	0.140

**Table 8d 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.
17190	30 krad	-18.724	-18.177	-17.716	0.186	-19.057	-18.550	-18.083	0.202
17191	30 krad	-18.875	-18.278	-17.790	0.192	-19.093	-18.606	-18.092	0.188
17193	30 krad	-18.864	-18.359	-17.689	0.203	-19.072	-18.570	-17.904	0.195
17224	30 krad	-18.699	-18.180	-17.684	0.189	-18.907	-18.306	-17.753	0.203
17229	30 krad	-18.950	-18.349	-17.960	0.156	-19.099	-18.551	-18.156	0.154

**Table 8e 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.
17190	30 krad	-10.126	-9.707	-9.352	0.123	-10.271	-9.903	-9.595	0.129
17191	30 krad	-10.226	-9.732	-9.370	0.131	-10.231	-9.882	-9.596	0.120
17193	30 krad	-10.128	-9.791	-9.407	0.132	-10.245	-9.893	-9.516	0.122
17224	30 krad	-10.001	-9.604	-9.240	0.127	-10.074	-9.680	-9.339	0.133
17229	30 krad	-10.176	-9.720	-9.376	0.110	-10.184	-9.823	-9.495	0.104

**Table 8f 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.
17190	30 krad	-13.385	-12.956	-12.525	0.147	-13.625	-13.215	-12.852	0.159
17191	30 krad	-13.510	-13.008	-12.593	0.153	-13.610	-13.226	-12.820	0.152
17193	30 krad	-13.485	-13.065	-12.536	0.158	-13.634	-13.227	-12.687	0.154
17224	30 krad	-13.285	-12.874	-12.475	0.150	-13.475	-12.980	-12.569	0.161
17229	30 krad	-13.511	-13.012	-12.680	0.128	-13.588	-13.161	-12.799	0.122

**Table 8g 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.
17190	30 krad	-6.291	-5.998	-5.729	0.097	-6.367	-6.093	-5.831	0.098
17191	30 krad	-6.416	-5.994	-5.706	0.106	-6.375	-6.075	-5.808	0.098
17193	30 krad	-6.341	-6.045	-5.700	0.106	-6.384	-6.092	-5.846	0.091
17224	30 krad	-6.241	-5.872	-5.568	0.102	-6.261	-5.913	-5.658	0.107
17229	30 krad	-6.391	-5.947	-5.718	0.093	-6.336	-6.002	-5.740	0.086

**Table 8h 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.
17190	30 krad	-7.995	-7.615	-7.278	0.107	-8.019	-7.744	-7.467	0.112
17191	30 krad	-8.071	-7.617	-7.312	0.114	-8.028	-7.729	-7.447	0.106
17193	30 krad	-7.995	-7.670	-7.334	0.115	-8.080	-7.735	-7.419	0.108
17224	30 krad	-7.870	-7.486	-7.120	0.112	-7.906	-7.542	-7.260	0.118
17229	30 krad	-7.995	-7.587	-7.328	0.099	-8.056	-7.661	-7.342	0.096

**Table 8i 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.
17190	30 krad	-36.919	-36.079	-35.337	0.319	-37.754	-36.782	-36.085	0.338
17191	30 krad	-37.199	-36.350	-35.550	0.307	-37.753	-36.953	-36.085	0.304
17193	30 krad	-37.136	-36.407	-35.471	0.317	-37.739	-36.821	-35.903	0.310
17224	30 krad	-37.059	-36.315	-35.421	0.327	-37.529	-36.574	-35.607	0.348
17229	30 krad	-37.499	-36.583	-35.980	0.256	-37.841	-36.987	-36.404	0.250

**Table 8j 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.
17190	30 krad	-56.083	-54.792	-53.773	0.469	-57.202	-55.821	-54.801	0.500
17191	30 krad	-56.349	-55.197	-53.950	0.442	-57.232	-56.072	-54.876	0.444
17193	30 krad	-56.410	-55.319	-53.853	0.453	-57.228	-55.870	-54.527	0.455
17224	30 krad	-56.266	-55.168	-53.881	0.482	-56.927	-55.590	-54.162	0.506
17229	30 krad	-56.897	-55.588	-54.721	0.379	-57.383	-56.163	-55.325	0.378

## F. Propagation Delay

DUTs are irradiated up to 30 krads with measurement at every 10 krads. Table 9a through Table 9d list the pre-irradiation, post-10/20/30-krad-irradiation and post-annealing propagation delay, both 1.5 V Vcc and 1.2 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-10 krad (ns)	Post-20 krad (ns)	Post-30 krad (ns)	Post-Annealing (ns)
17190	364	375	387	402	399
17191	349	362	373	387	384
17193	371	381	395	410	406
17224	325	336	346	360	358
17229	360	369	382	396	390

**Table 9b Propagation Delay to Irradiation Dose, Vcc=1.2 V**

DUT	Pre-Irradiation (ns)	Post-10 krad (ns)	Post-20 krad (ns)	Post-30 krad (ns)	Post-Annealing (ns)
17190	445	456	470	488	481
17191	428	439	452	467	461
17193	455	464	480	496	490
17224	396	406	417	433	428
17229	442	452	468	482	472

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

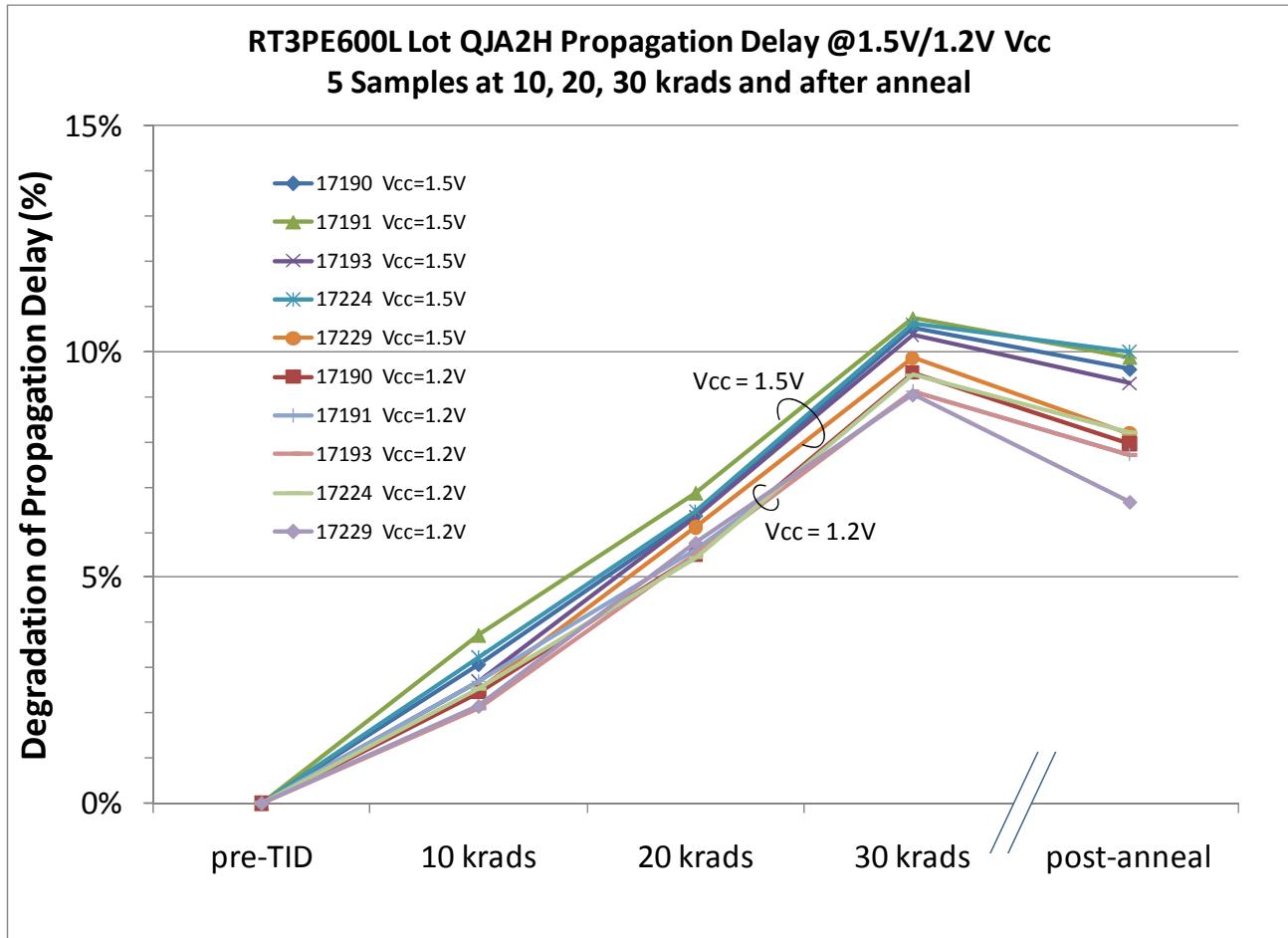
DUT	(Compared to Pre-irradiation)	Post-10 krad (%)	Post-20 krad (%)	Post-30 krad (%)	Post-Annealing (%)
17190	-	3.1%	6.4%	10.5%	9.6%
17191	-	3.7%	6.9%	10.7%	9.9%
17193	-	2.7%	6.3%	10.4%	9.3%
17224	-	3.2%	6.5%	10.6%	10.0%
17229	-	2.5%	6.1%	9.9%	8.2%

**Table 9d Radiation-Induced Propagation Delay Degradation in Percentage, Vcc=1.2 V**

DUT	(Compared to Pre-irradiation)	Post-10 krad (%)	Post-20 krad (%)	Post-30 krad (%)	Post-Annealing (%)
17190	-	2.5%	5.5%	9.5%	8.0%
17191	-	2.7%	5.6%	9.1%	7.7%
17193	-	2.1%	5.5%	9.1%	7.7%
17224	-	2.5%	5.4%	9.5%	8.2%
17229	-	2.1%	5.8%	9.0%	6.7%

Figure 2 has the percentage of the degradation on propagation delay in tables 9c and 9d plotted.

A near linear trend of the propagation delay to the total dose is seen at this range. The interpolated 10% degradation at 1.5 V Vcc is to the five DUTs are between 27.5 krads to 29 krads. Under this assumption of a linear dependence, all DUTs would have passed 25 krads with the criterion of 10% degradation on propagation delay.



**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.

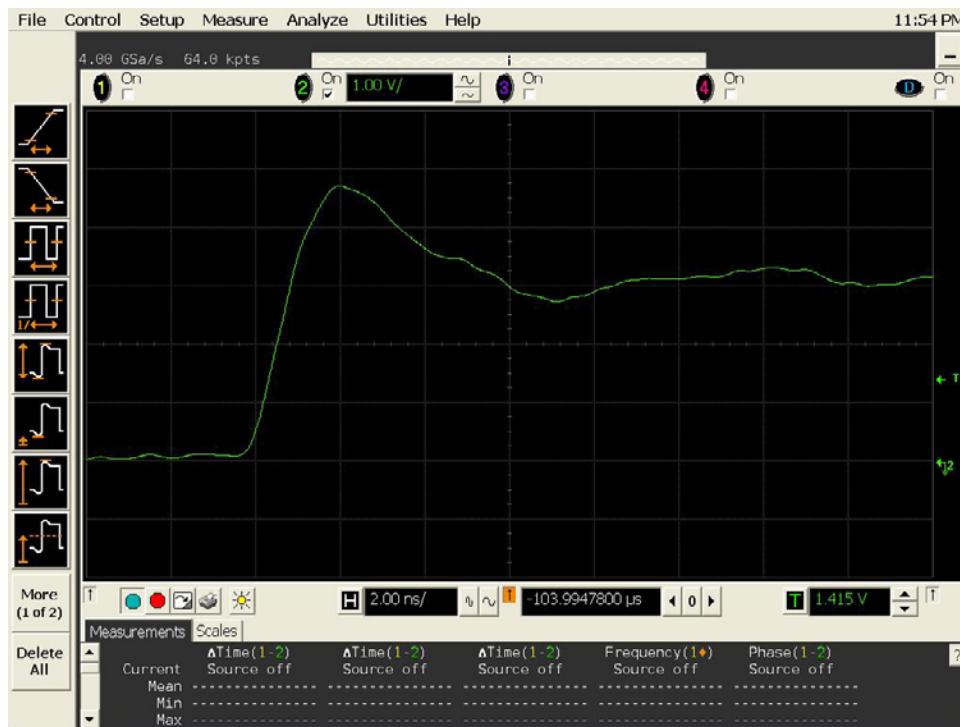


Figure 3a DUT 17190 Pre-Irradiation Rising Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

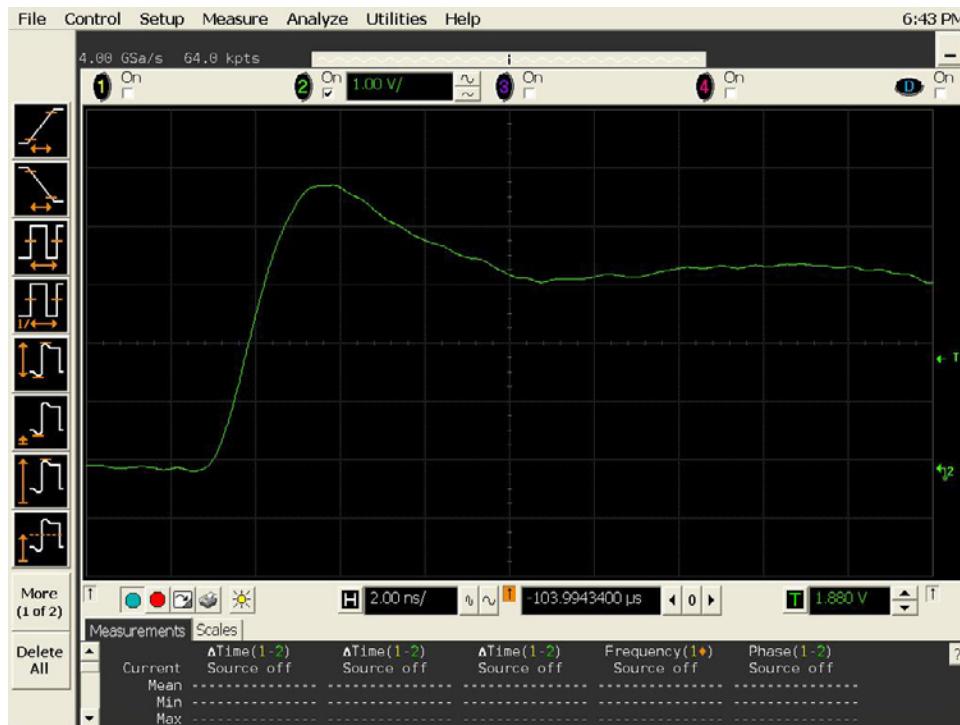
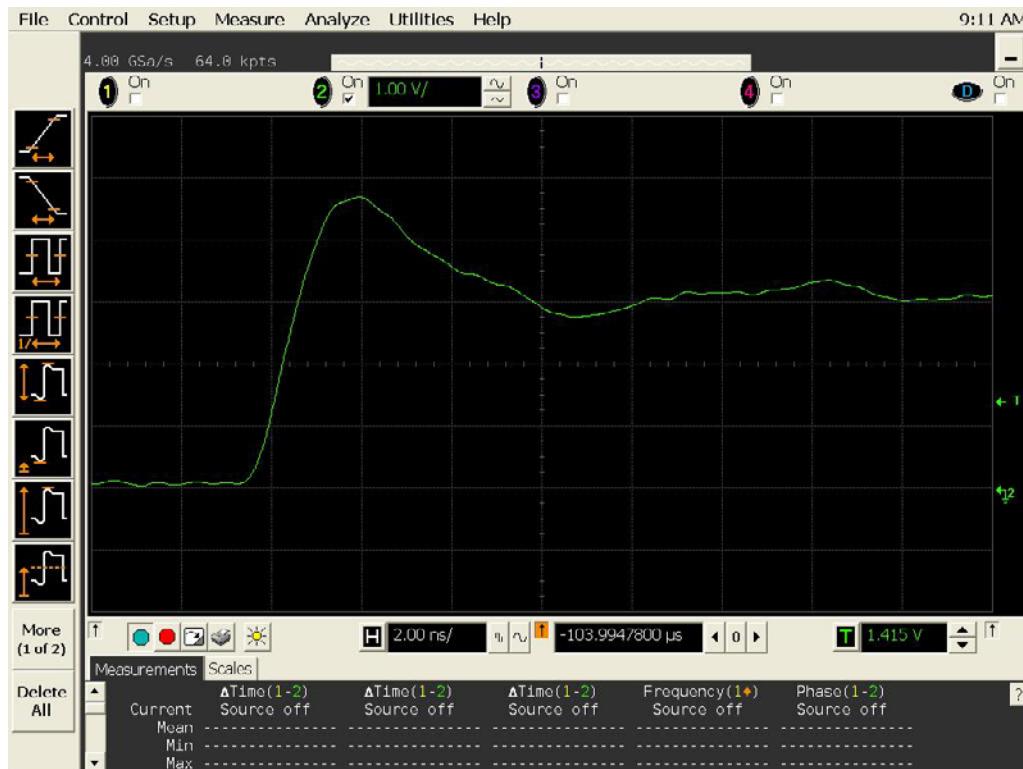
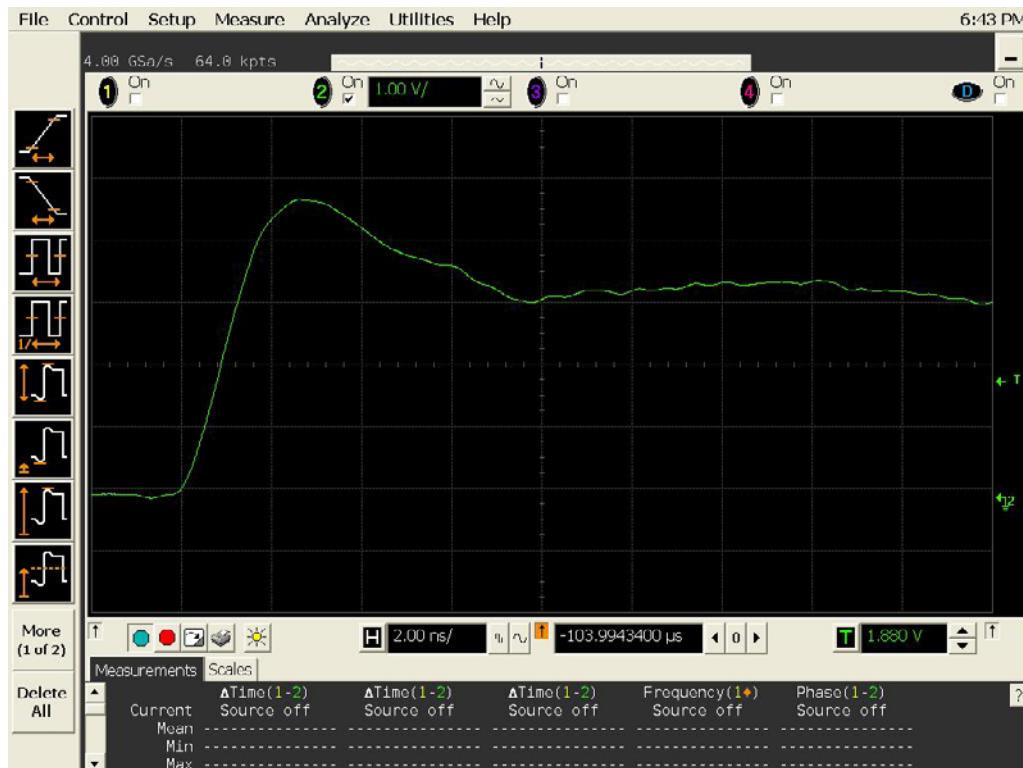


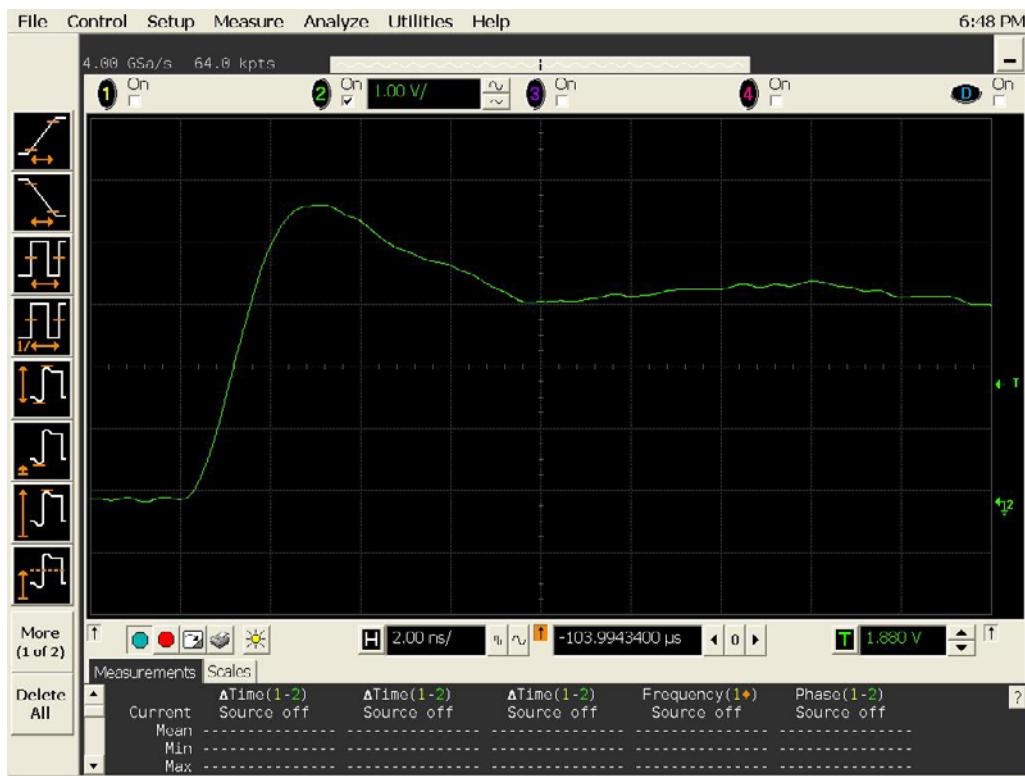
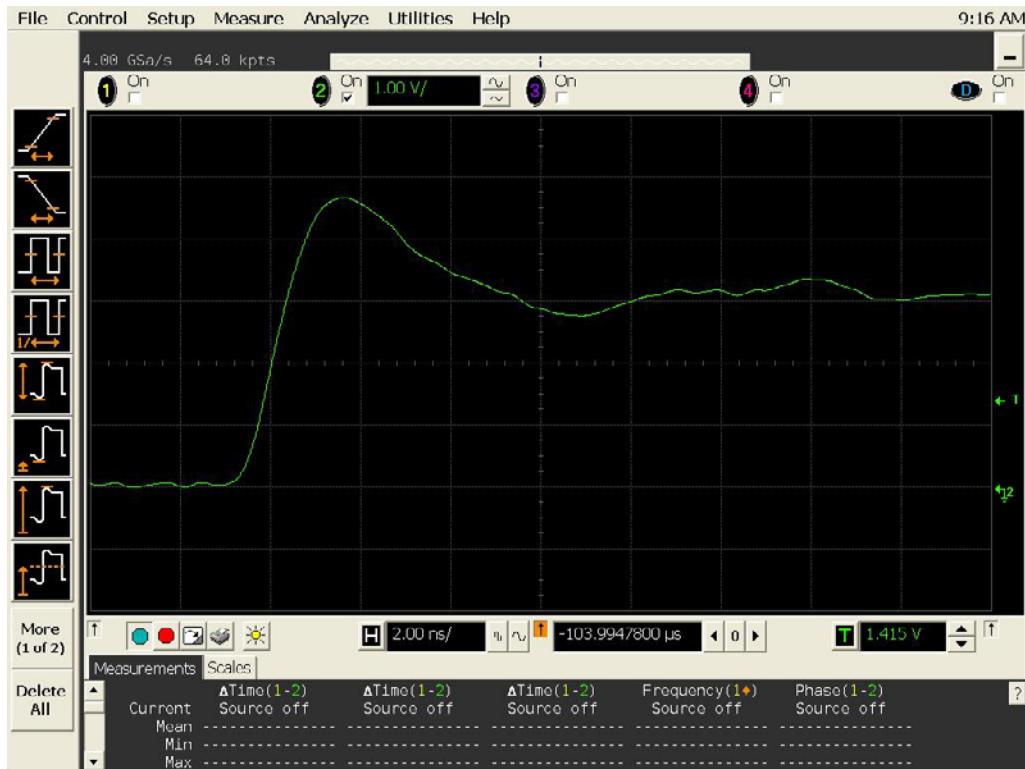
Figure 3b DUT 17190 Post-Annealing Rising Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.



**Figure 4a** DUT 17191 Pre-Irradiation Rising Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.



**Figure 4b** DUT 17191 Post-Annealing Rising Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.



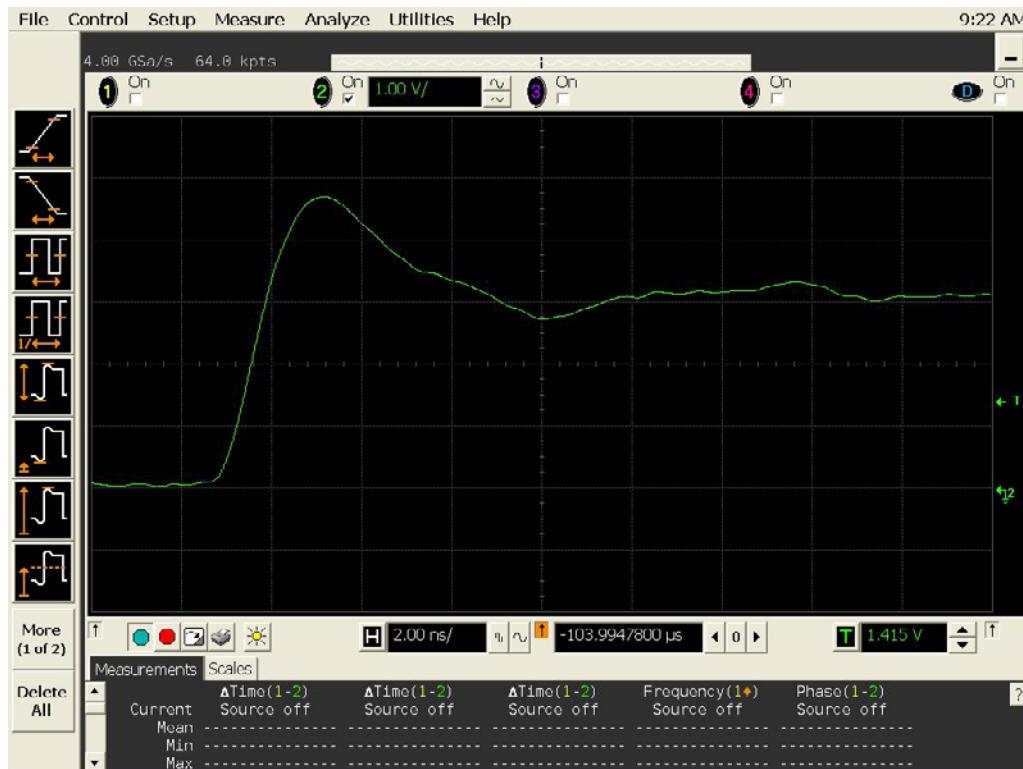


Figure 6a DUT 17224 Pre-Irradiation Rising Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

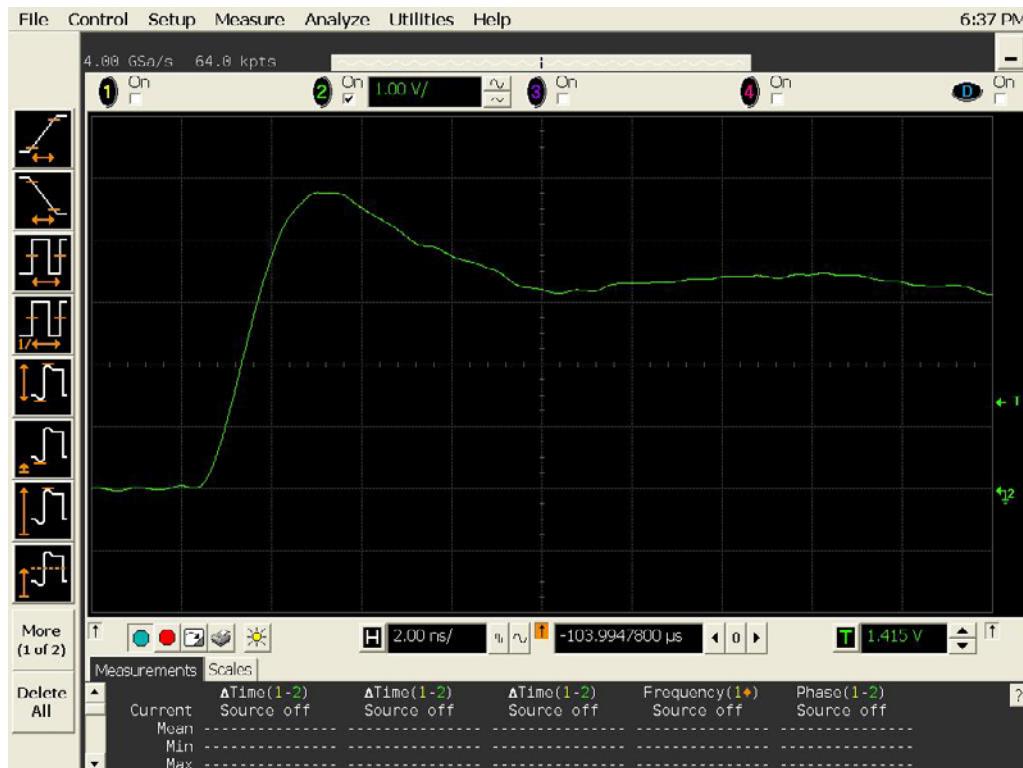


Figure 6b DUT 17224 Post-Annealing Rising Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

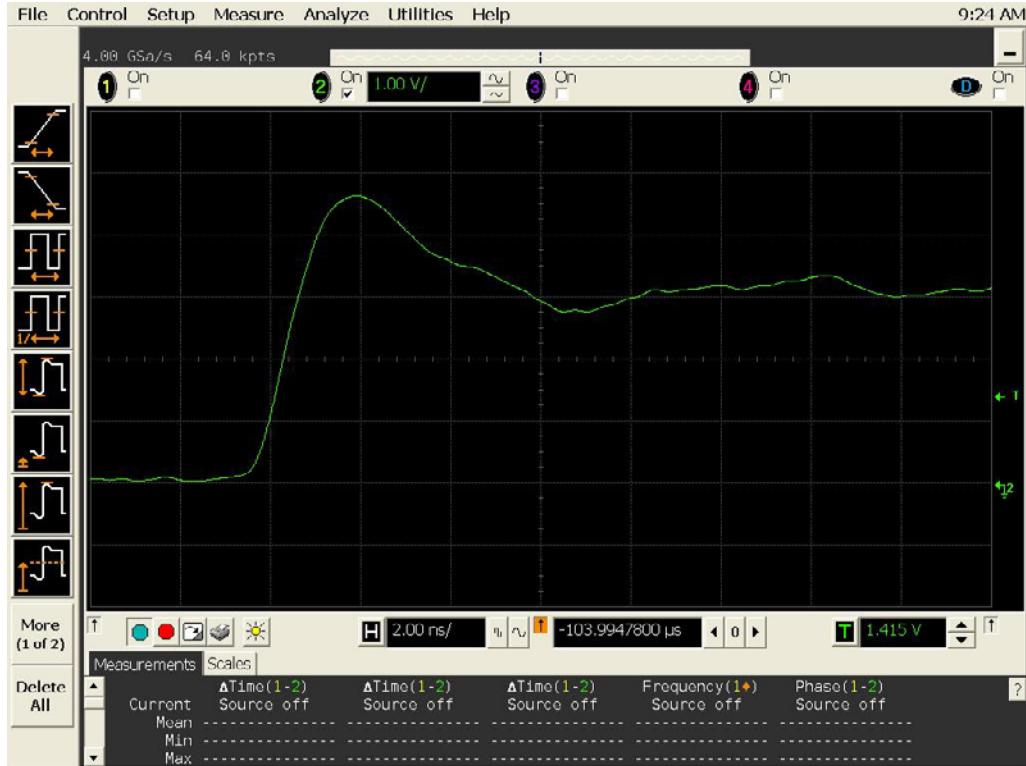


Figure 7a DUT 17229 Pre-Irradiation Rising Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

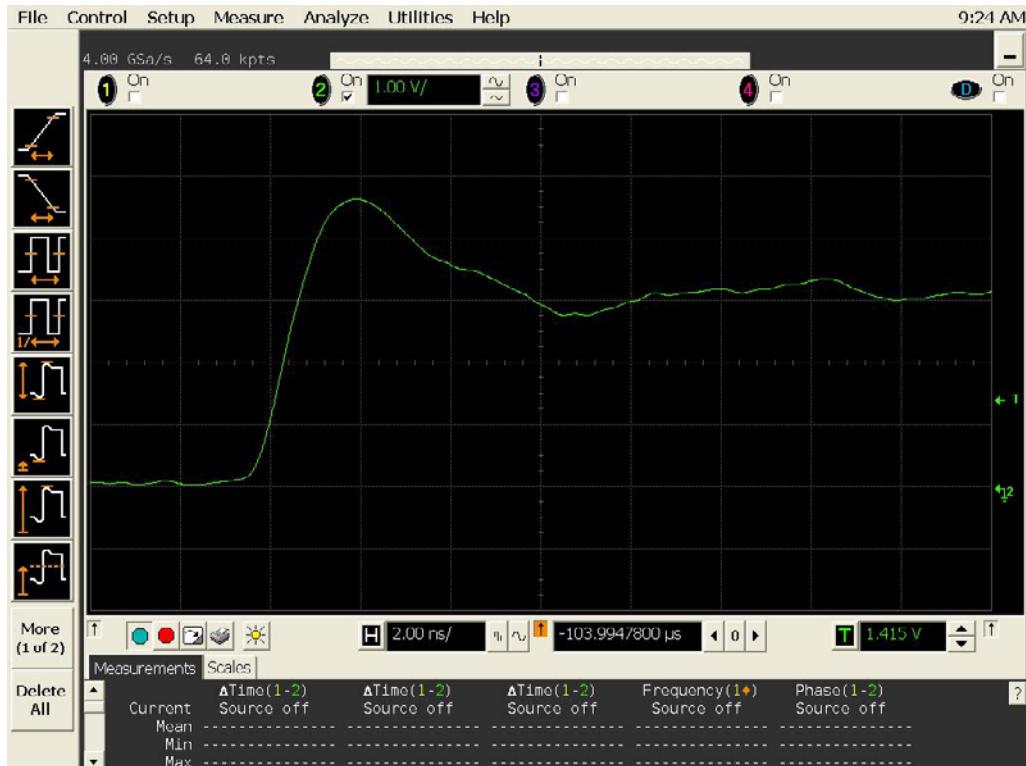
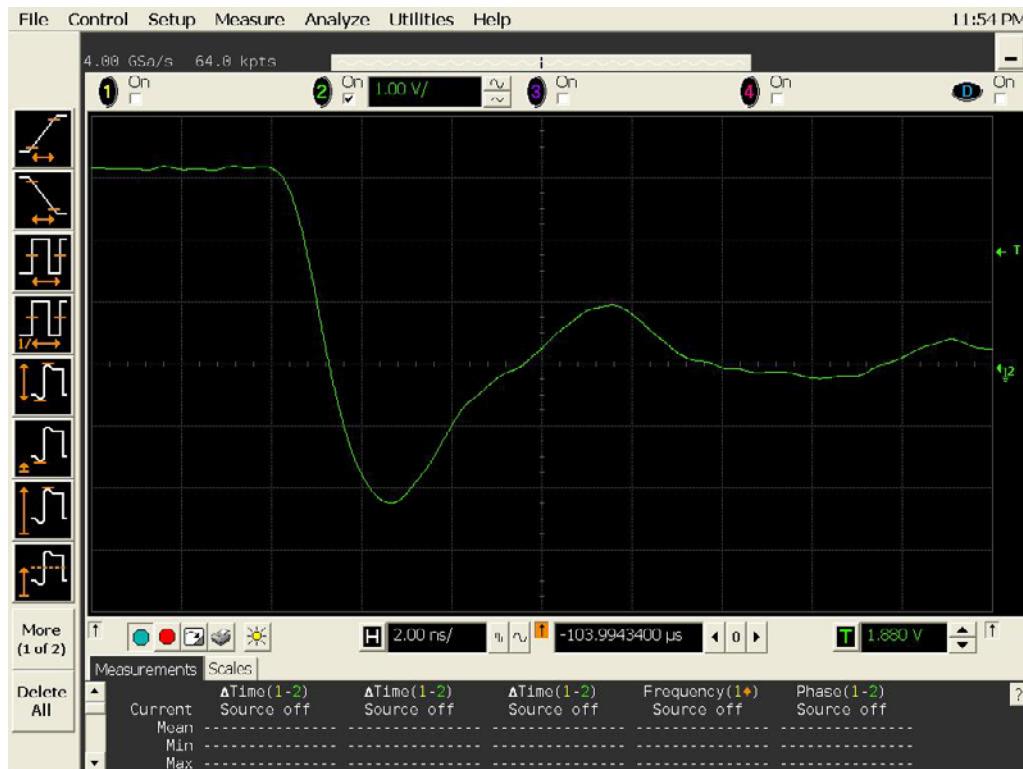
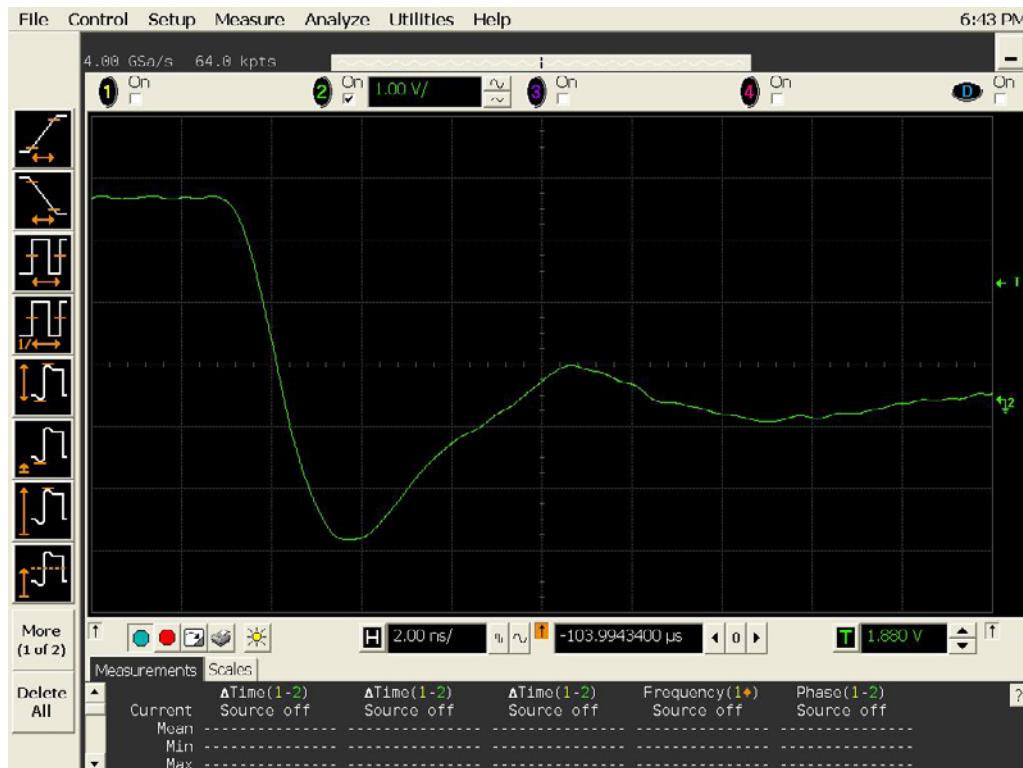


Figure 7b DUT 17229 Post-Annealing Rising Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.



**Figure 8a** DUT 17190 Pre-Irradiation Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.



**Figure 8b** DUT 17190 Post-Annealing Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

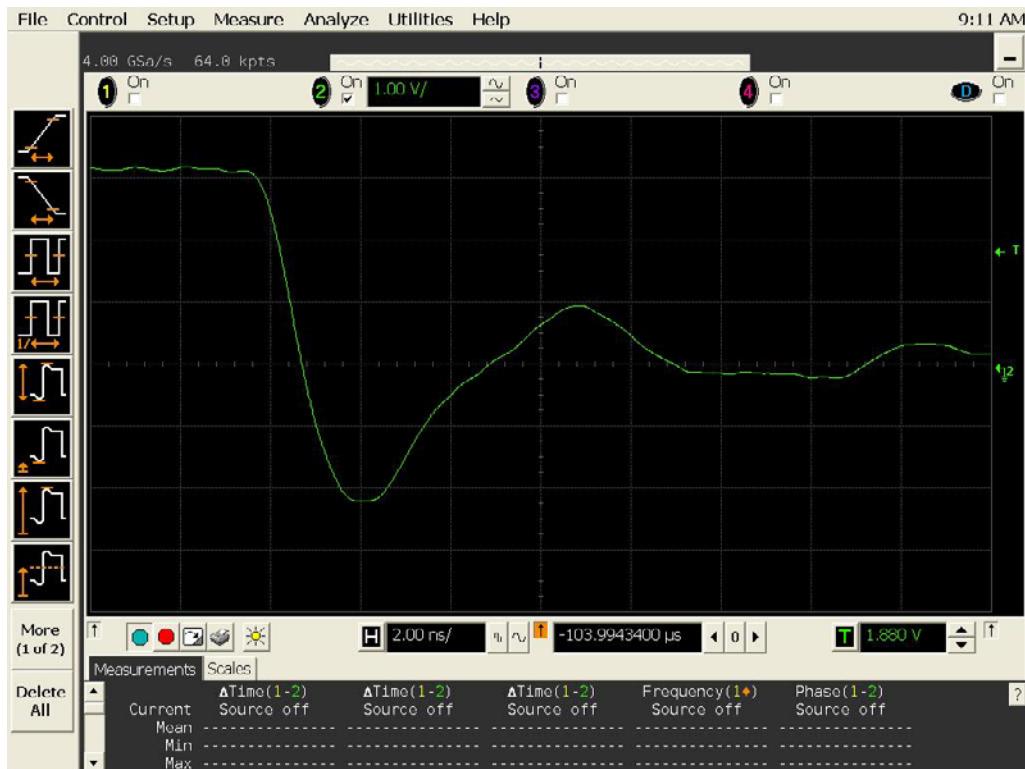


Figure 9a DUT 17191 Pre-Irradiation Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

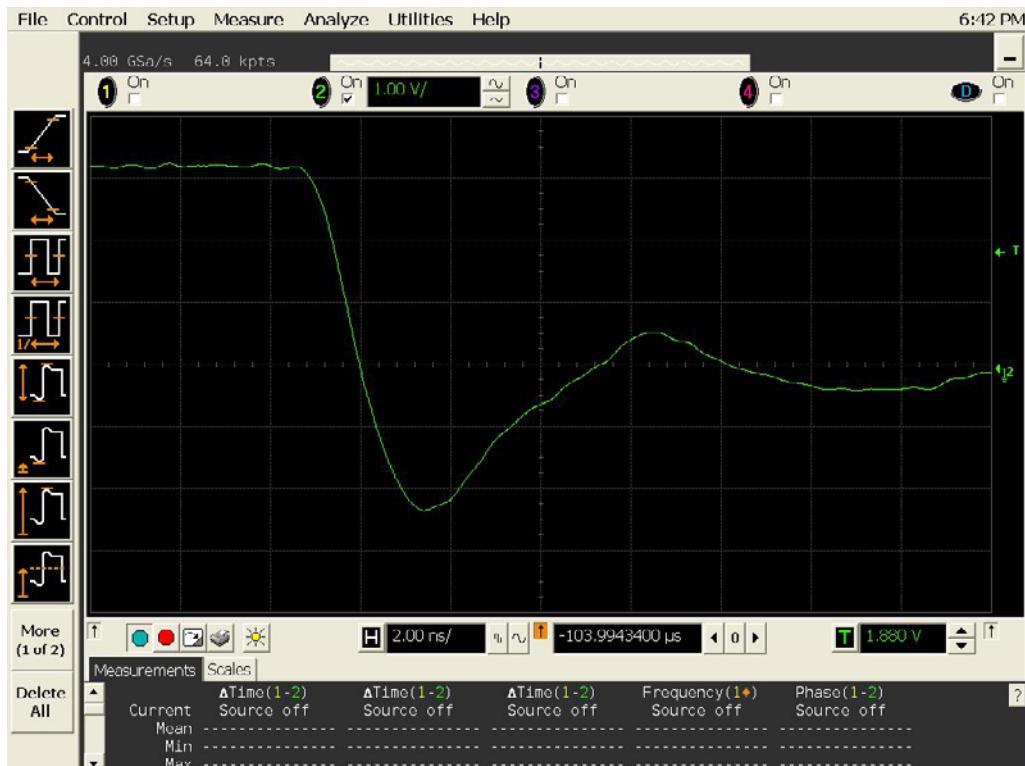


Figure 9b DUT 17191 Post-Annealing Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

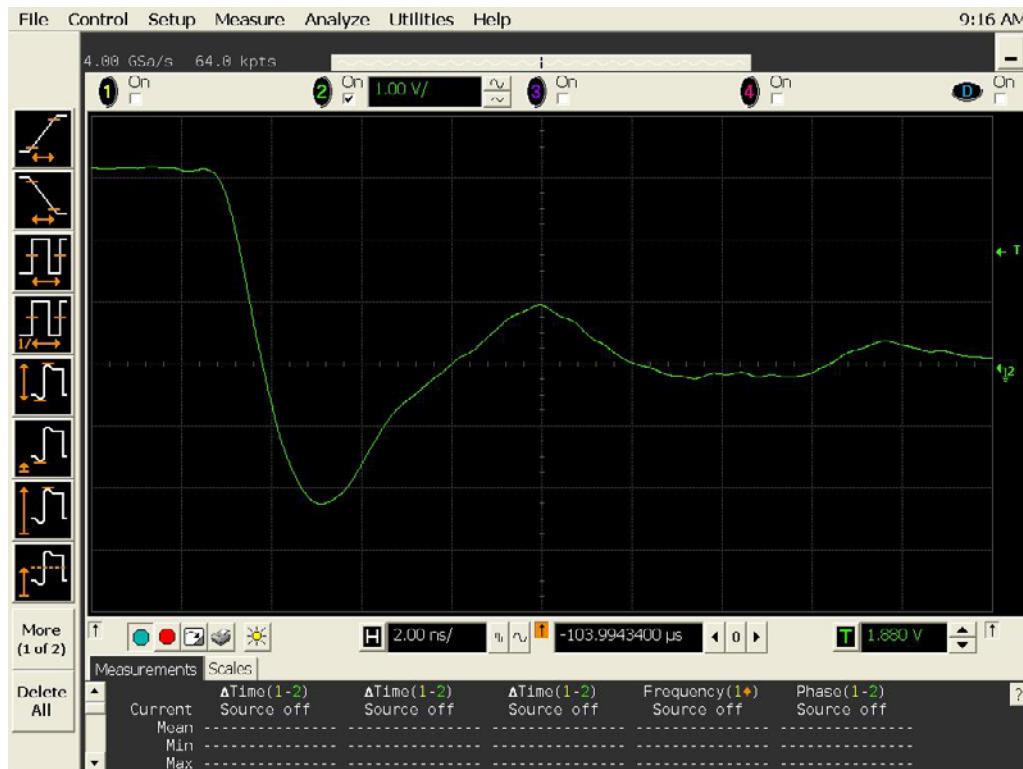


Figure 10a DUT 17193 Pre-Irradiation Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

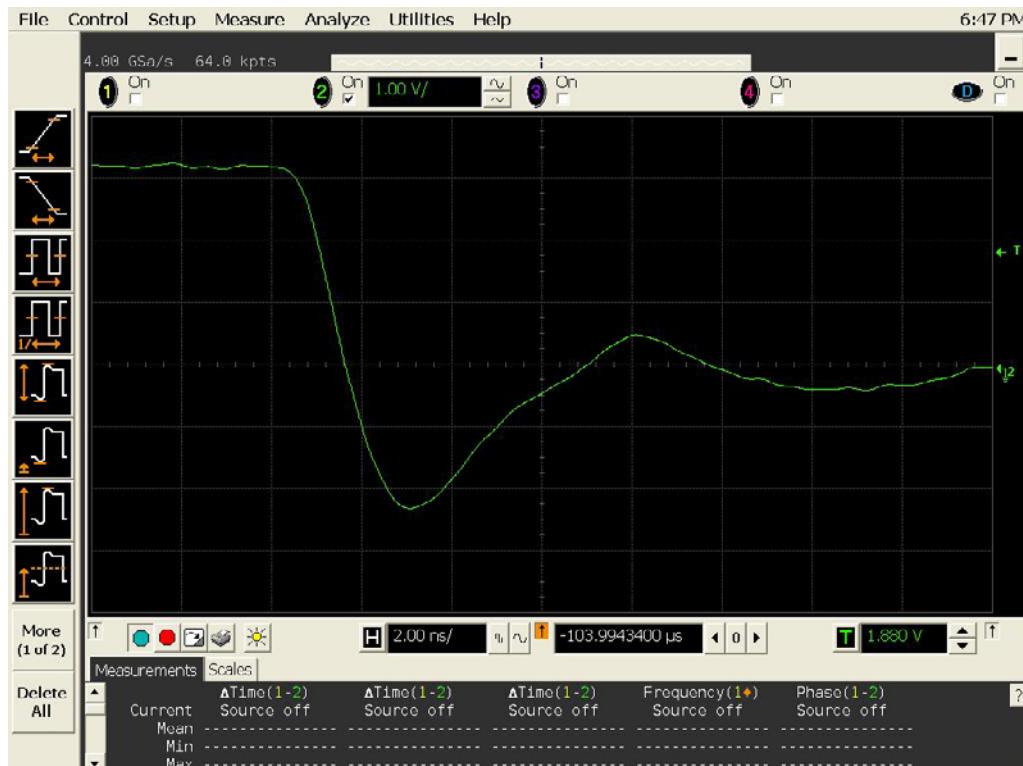


Figure 10b DUT 17193 Post-Annealing Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

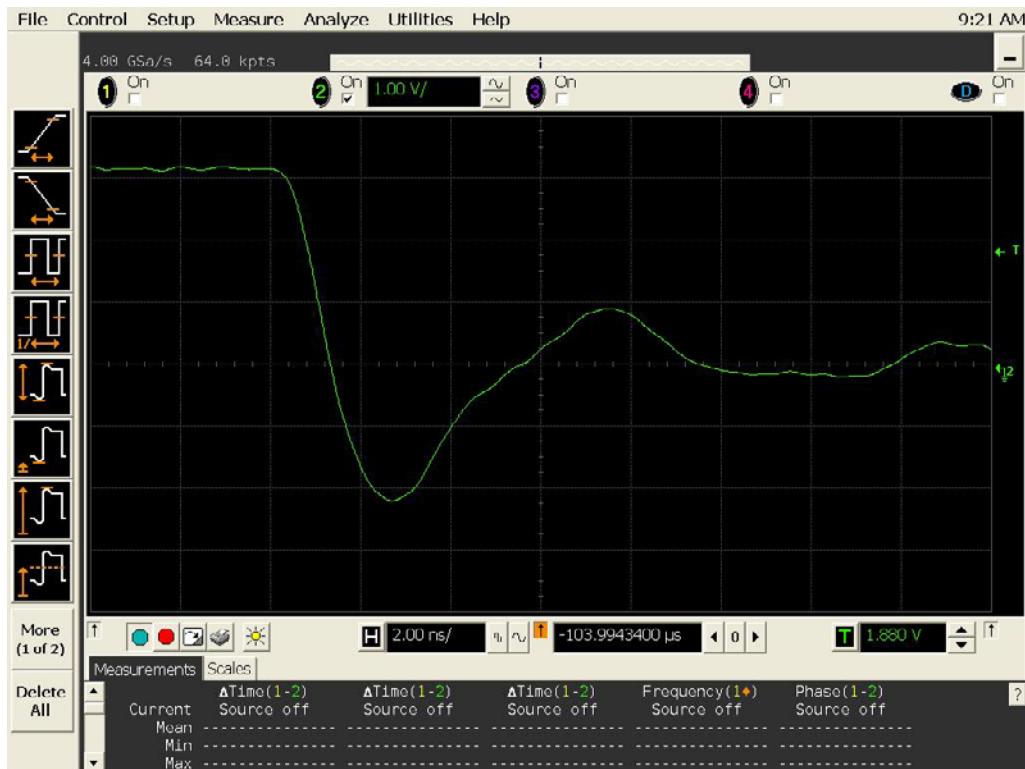


Figure 11a DUT 17224 Pre-Irradiation Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

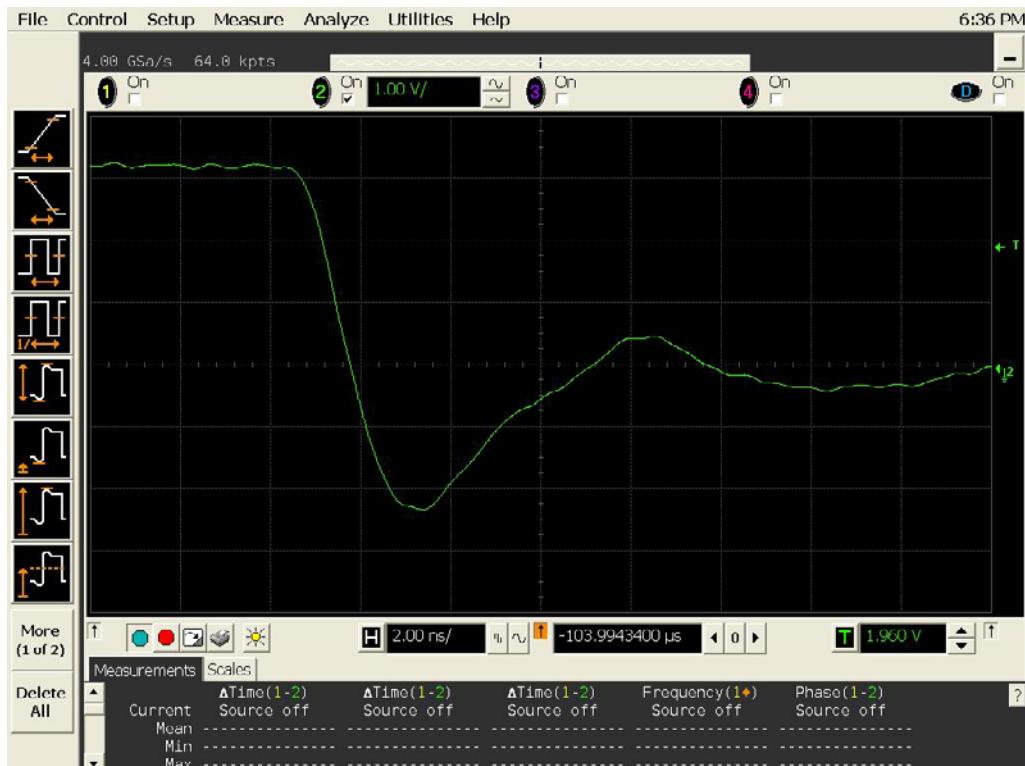
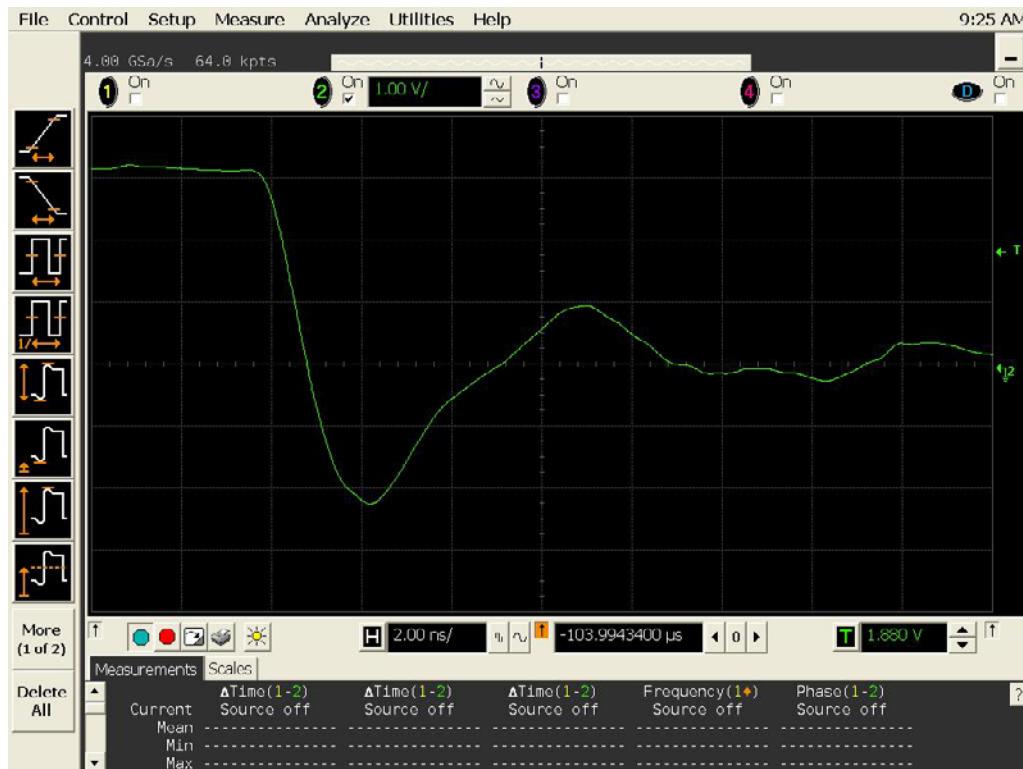
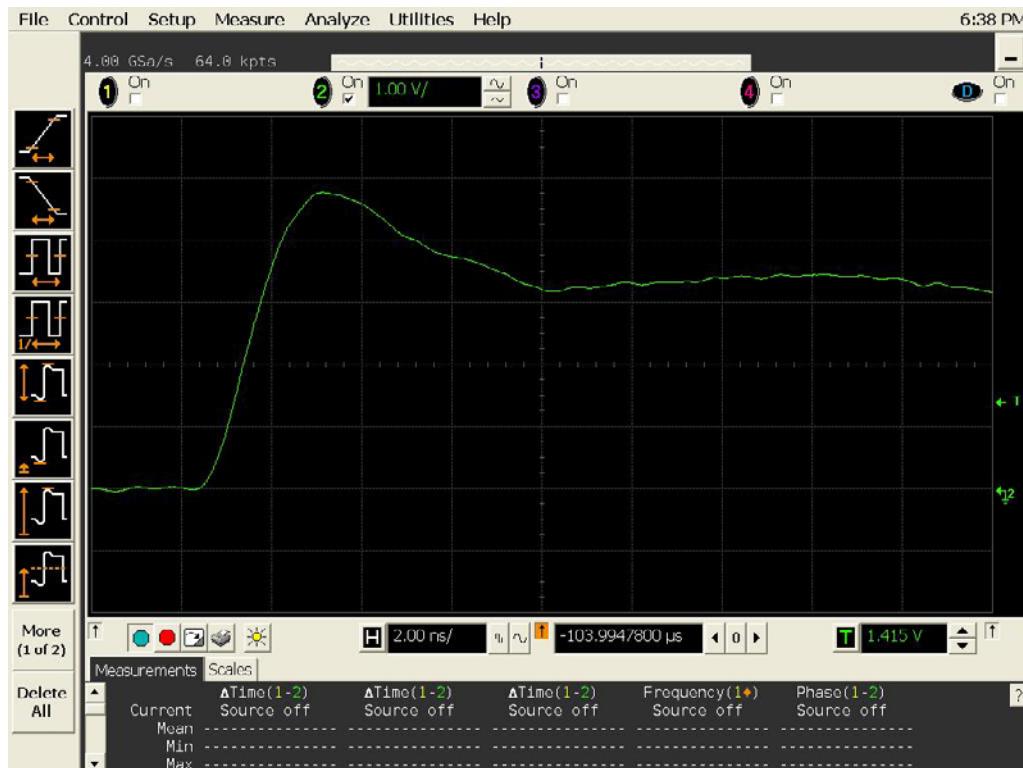


Figure 11b DUT 17224 Post-Annealing Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.



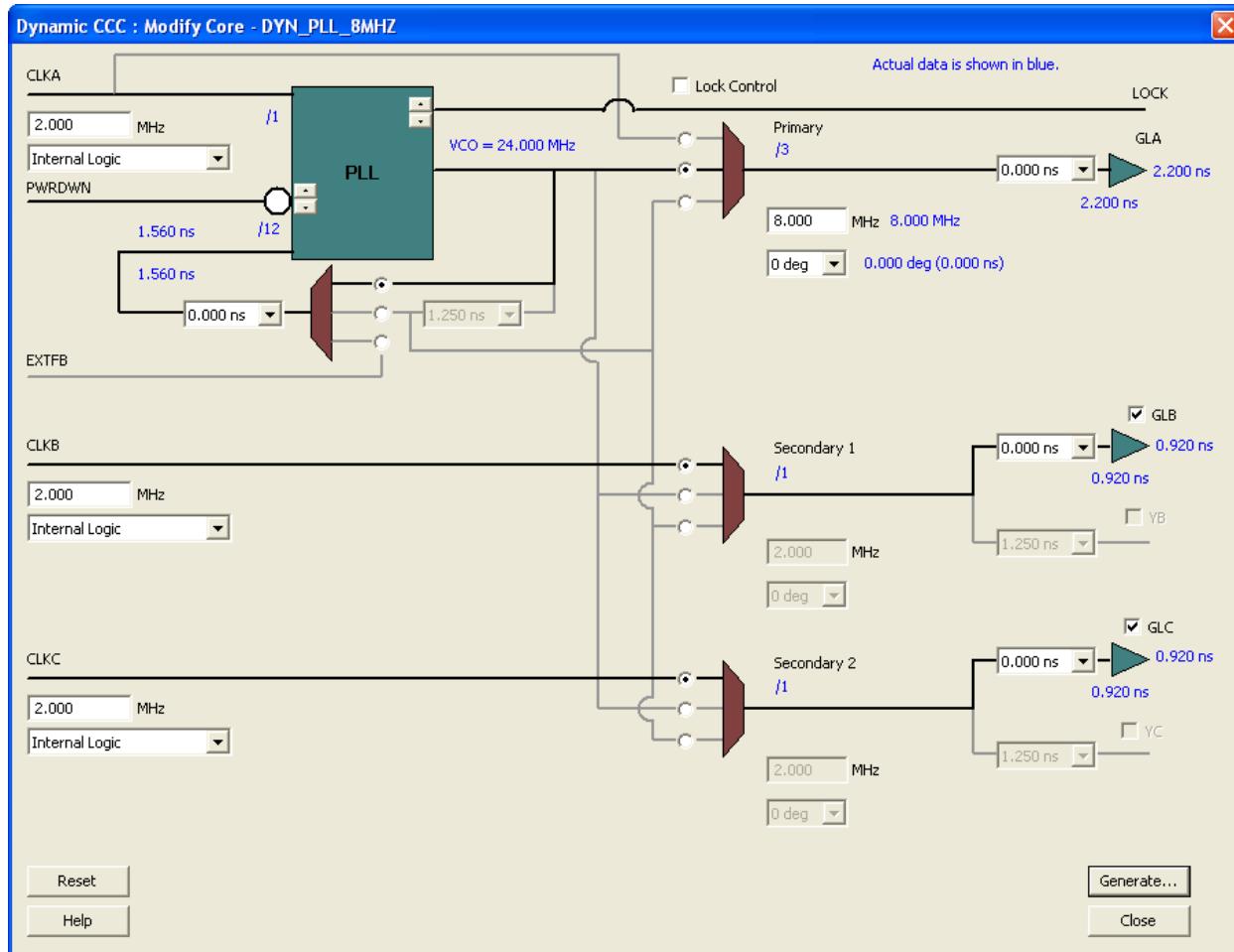
**Figure 12a** DUT 17229 Pre-Irradiation Falling Edge,  
abscissa scale is 1 V/div and ordinate scale is 2 ns/div.



**Figure 12b** DUT 17229 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

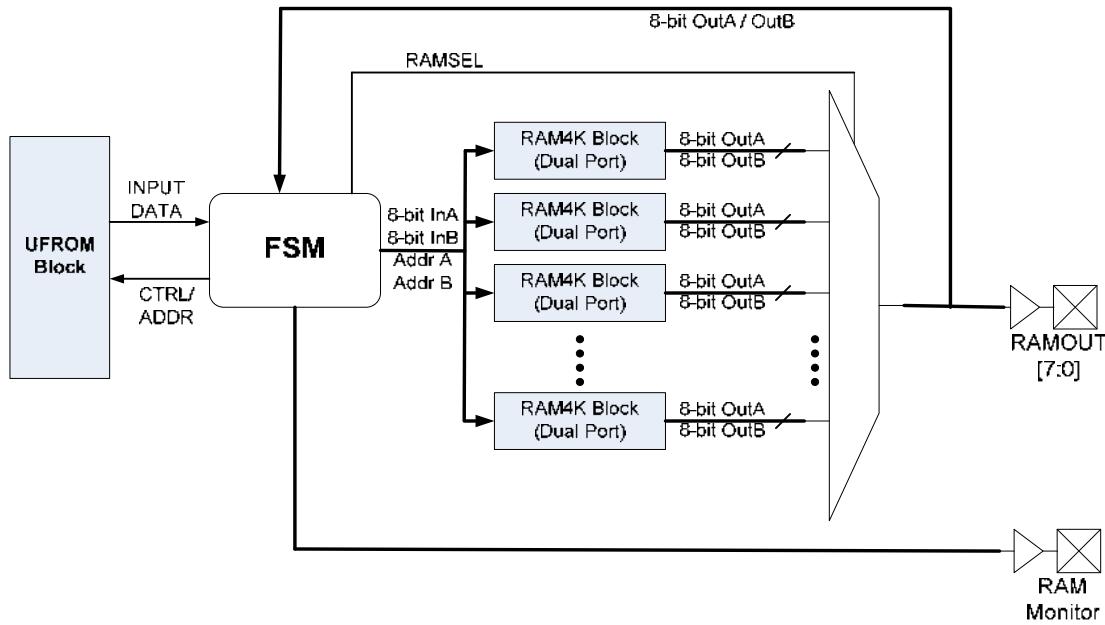
### A. PLL Block



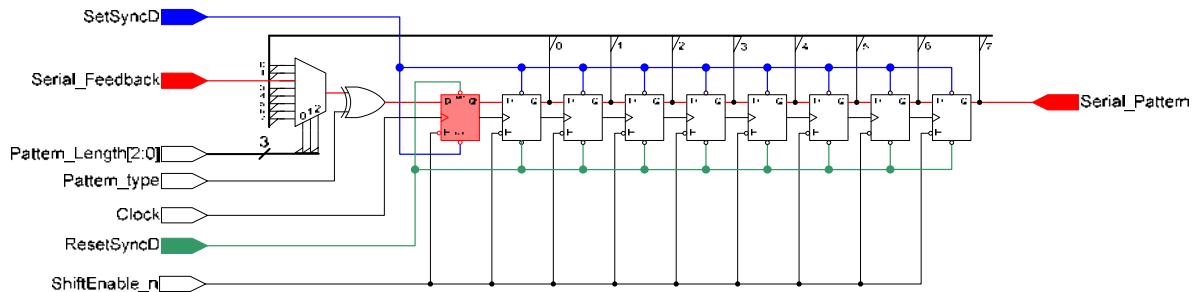
The following table lists the signals that go through each of the PLLs:

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

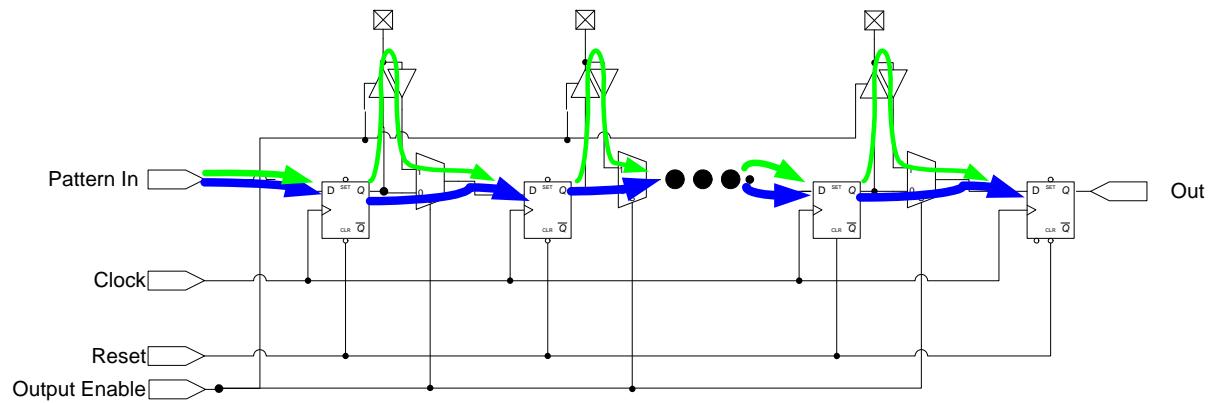


## C. Pattern Generators Block

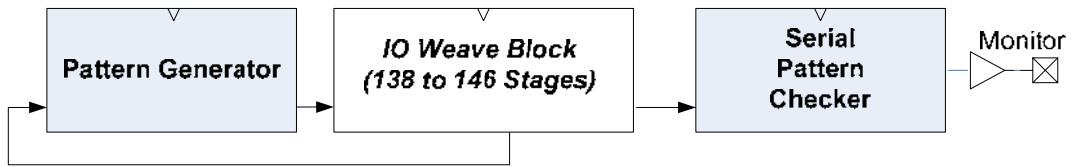


Patter n Type	Patter n Length	Code Length	$\Delta$ Bits	Switching Rate
0 000	1 0 $\Rightarrow$ 0 1	2	2	100.00%
0 001	1 0 0 $\Rightarrow$ 0 1 0 $\Rightarrow$ 0 0 1	3	2	66.67%
0 010	One hot I/O at a time switching in entire I/O ring	#Bits+9	2	N/A
0 011	1 0 0 0 0 $\Rightarrow$ 0 1 0 0 0 $\Rightarrow$ 0 0 1 0 0 $\Rightarrow$ 0 0 0 1 0 $\Rightarrow$ 0 0 0 0 1	5	2	40.00%
0 100	1 0 0 0 0 0 0 $\Rightarrow$ 0 1 0 0 0 0 0 $\Rightarrow$ 0 0 1 0 0 0 0 $\Rightarrow$ 0 0 0 1 0 0 0 $\Rightarrow$ 0 0 0 0 1 0 0 $\Rightarrow$ 0 0 0 0 0 1 0	6	2	33.33%
0 101	1 0 0 0 0 0 0 0 $\Rightarrow$ 0 1 0 0 0 0 0 0 $\Rightarrow$ 0 0 1 0 0 0 0 0 $\Rightarrow$ 0 0 0 1 0 0 0 0 $\Rightarrow$ 0 0 0 0 1 0 0 0 $\Rightarrow$ 0 0 0 0 0 1 0	7	2	28.57%
0 110	1 0 0 0 0 0 0 0 0 $\Rightarrow$ 0 1 0 0 0 0 0 0 0 $\Rightarrow$ 0 0 1 0 0 0 0 0 0 $\Rightarrow$ 0 0 0 1 0 0 0 0 0 $\Rightarrow$ 0 0 0 0 1 0 0 0 0 $\Rightarrow$ 0 0 0 0 0 1 0	8	2	25.00%
0 111	1 0 0 0 0 0 0 0 0 0 $\Rightarrow$ 0 1 0 0 0 0 0 0 0 0 $\Rightarrow$ 0 0 1 0 0 0 0 0 0 0 $\Rightarrow$ 0 0 0 1 0 0 0 0 0 0 $\Rightarrow$ 0 0 0 0 1 0 0 0 0 0 $\Rightarrow$ 0 0 0 0 0 1 0	9	2	22.22%
1 000	1 0 $\Rightarrow$ 1 1 $\Rightarrow$ 0 1 $\Rightarrow$ 0 0	2	1	50.00%
1 001	1 0 0 $\Rightarrow$ 1 1 0 $\Rightarrow$ 1 1 1 $\Rightarrow$ 0 1 1 $\Rightarrow$ 0 0 1 $\Rightarrow$ 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 0 $\Rightarrow$ 1 1 0 0 0 0 $\Rightarrow$ 1 1 1 0 0 0 $\Rightarrow$ 1 1 1 1 0 0 $\Rightarrow$ 1 1 1 1 1 0 $\Rightarrow$ 1 1 1 1 1 1 $\Rightarrow$ 0 1 1 1 1 1 $\Rightarrow$ 0 0 1 1 1 1 $\Rightarrow$ 5	5	1	20.00%
1 100	1 0 0 0 0 0 0 $\Rightarrow$ 1 1 0 0 0 0 0 $\Rightarrow$ 1 1 1 0 0 0 0 $\Rightarrow$ 1 1 1 1 0 0 0 $\Rightarrow$ 1 1 1 1 1 0 0 $\Rightarrow$ 1 1 1 1 1 1 0 $\Rightarrow$ 6	6	1	16.67%
1 101	1 0 0 0 0 0 0 0 $\Rightarrow$ 1 1 0 0 0 0 0 0 $\Rightarrow$ 1 1 1 0 0 0 0 0 $\Rightarrow$ 1 1 1 1 0 0 0 0 $\Rightarrow$ 1 1 1 1 1 0 0 0 $\Rightarrow$ 1 1 1 1 1 1 0 $\Rightarrow$ 7	7	1	14.29%
1 110	1 0 0 0 0 0 0 0 0 $\Rightarrow$ 1 1 0 0 0 0 0 0 0 $\Rightarrow$ 1 1 1 0 0 0 0 0 0 $\Rightarrow$ 1 1 1 1 0 0 0 0 0 $\Rightarrow$ 1 1 1 1 1 0 0 0 0 $\Rightarrow$ 8	8	1	12.50%
1 111	1 0 0 0 0 0 0 0 0 0 $\Rightarrow$ 1 1 0 0 0 0 0 0 0 0 $\Rightarrow$ 1 1 1 0 0 0 0 0 0 0 $\Rightarrow$ 1 1 1 1 0 0 0 0 0 0 $\Rightarrow$ 1 1 1 1 1 0 0 0 0 0 $\Rightarrow$ 1 1	9	1	11.11%

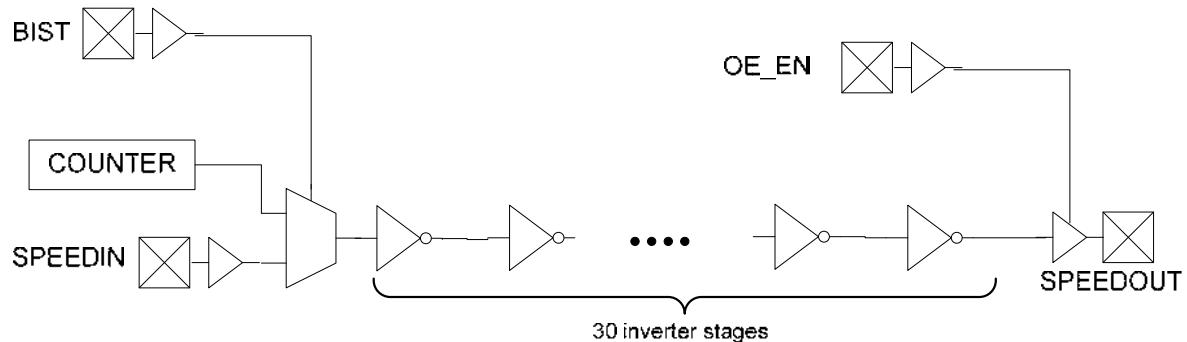
## D. I/O Block



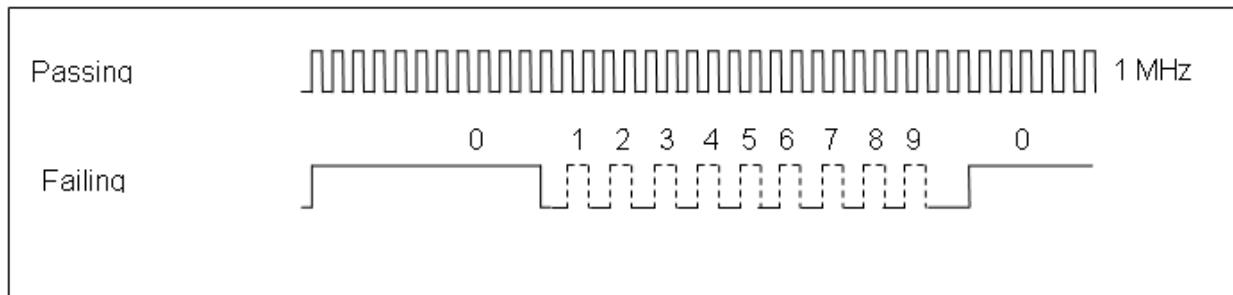
## E. Array Shift Registers Block



## F. Delay Path Block



## G. Monitor Block





**Microsemi Corporate Headquarters**  
2381 Morse Avenue, Irvine, CA 92614  
Phone: 949.221.7100 · Fax: 949.756.0308  
[www.microsemi.com](http://www.microsemi.com)

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