TOTAL IONIZING DOSE TEST REPORT

No. 08T-RT14100A-FP2732701
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I. SUMMARY TABLE

Parameters	Tolerance
1. Gross Functional	Pass 7.5 krad(SiO_2)
2. $I_{DDSTDBY}$	Pass 7.5 krad(SiO_2)
3. V_{IL}/V_{IH}	Pass 7.5 krad(SiO_2)
4. V_{OL}/V_{OH}	Pass 7.5 krad(SiO_2)
5. Propagation Delays	Pass 7.5 krad(SiO_2)
6. Rising/Falling Edge Transient	Pass 7.5 krad(SiO_2)

II. TOTAL IONIZING DOSE (TID) TESTING

This section describes the device under test (DUT), the irradiation parameters, and the test method.

A. Device Under Test (DUT)

Table 1 lists the DUT information.

Table 1 DUT Information

Part Number	RT14100A
Package	CQFP256
Foundry	MEC
Technology	0.8 µm CMOS
Die Lot Number	FP2732701
Quantity Tested	5
Serial Numbers	DUT 1, DUT 2, DUT 3, DUT 4, DUT 5

B. Irradiation

Table 2 lists the irradiation parameters.

Table 2 Irradiation Parameters

Facility	DMEA
Radiation Source	Co-60
Dose Rate	5 krad(SiO_2)/min (±10%)
Data Mode	Static
Temperature	Room
Bias	5.0 V

C. Test Method

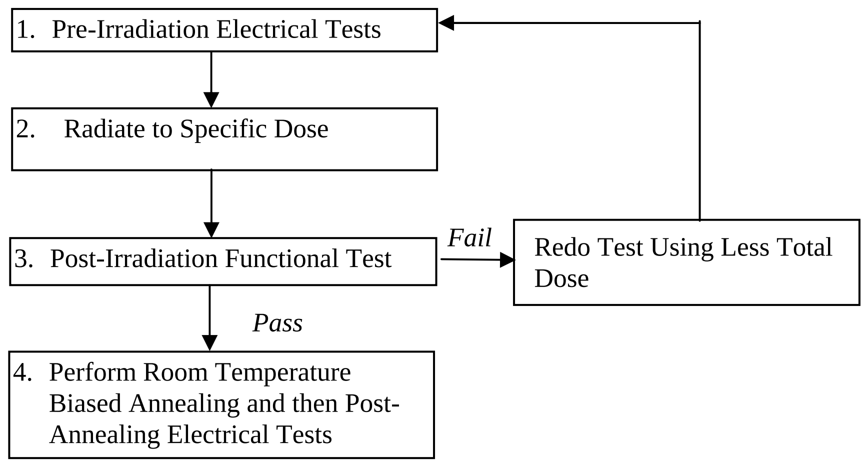

Figure 1 TID test flow chart

The test method is based on military standard TM1019.6. Figure 1 shows the flow chart of the testing sequence. The accelerated annealing test in section 3.12 is not performed lot-to-lot. This is because, for the CMOS technology used by the RT14100A product, the adverse effects due to interface state at the gate SiO_2/Si interface are negligible; the dominant annealing effect in this device is the reduction of trapped holes in the SiO_2. Therefore, the accelerated annealing alleviates the radiation effects on the DUT.

TM1019.6 section 3.11 extended room temperature anneal test is also applied; room temperature annealing for approximately 5 days was done on each device before the final parameter measurements.

D. Electrical Parameter Measurements

The electrical parameters were measured on the bench. Compared to an automatic tester, this bench setup has less noise, while it samples selected pins for threshold voltage measurements. The conservative dose level used to measure the parameters usually is too low to show any threshold voltage changes. I_{CC} usually dictates the dose level for parameter measurements, and consequently determines the radiation tolerance. Therefore, sampling few pins is sufficient to prove that the radiation effects cause no concerns on the threshold voltages. Other advantages for this bench setup are the in-flux measurement of I_{CC} and the measurement of the signal transient characteristic. Table 3 lists the corresponding logic design for each electrical measurement.

Table 3 Logic Design for each Measured Parameter

Parameter/Characteristics	Logic Design
1. Functionality	All key architectural functions
2. I_{CC}	DUT power supply
3. V_{IL}/V_{IH}	TTL compatible input buffer
4. V_{OL}/V_{OH}	TTL compatible output buffer
5. Propagation Delays	String of inverters
6. Rising/Falling Edge	TTL compatible output

III. Test Results

A. Functional Test

Referring to Figure 1, the post irradiation functional test is performed on one IO design. Based on extensive database, the functionality versus total dose is determined by the TID tolerance of the charge pump; this test provides a fast and effective test for on-site post-irradiation functional test. The post annealing functional test is performed on key architectural functions includes IO, combinational logic, and shift registers.

Every DUT passed the post-irradiation and post-annealing functional tests.

B. *In-Flux and Post-Annealing I_{CC}*

Table 4 Pre-irradiation, Post-irradiation and Post-annealing I_{CC}

DUT	Total Dose krad(SiO_2)	I_{CC} (mA)		
		Pre-irrad	Post-irrad	Post-ann
1	7.5	< 1	11.3	< Post-irrad
2	7.5	< 1	8.3	< Post-irrad
3	7.5	< 1	8.2	< Post-irrad
4	7.5	< 1	9	< Post-irrad
5	7.5	< 1	8.9	< Post-irrad

Figures 2 to 6 show the in-flux I_{CC}. Note that in every DUT, the I_{CC} at 7.5 krad(SiO_2) is below the spec of 25 mA.

Table 4 shows the pre-irradiation and post-irradiation I_{CC}. Since every post-irradiation DUT passes 25 mA spec, there is no need to measure the post-annealing data.

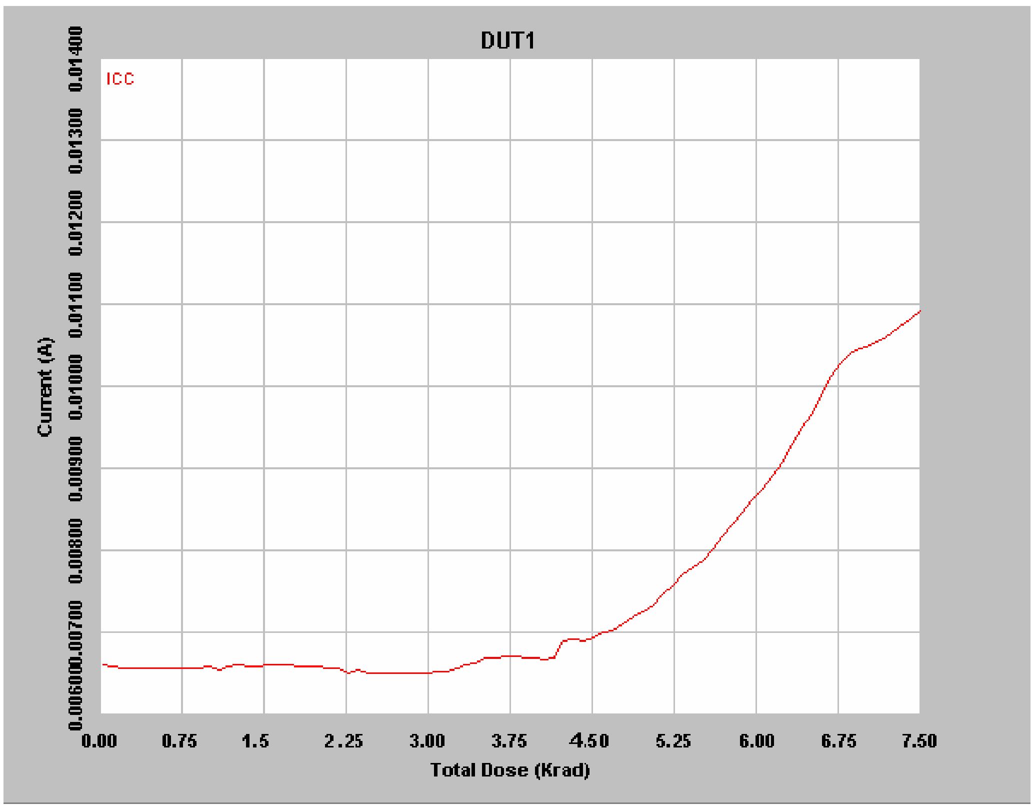

Figure 2 DUT 1 in-flux I_{CC}, 0 to 7.5 krad(SiO2)(SiO_2).

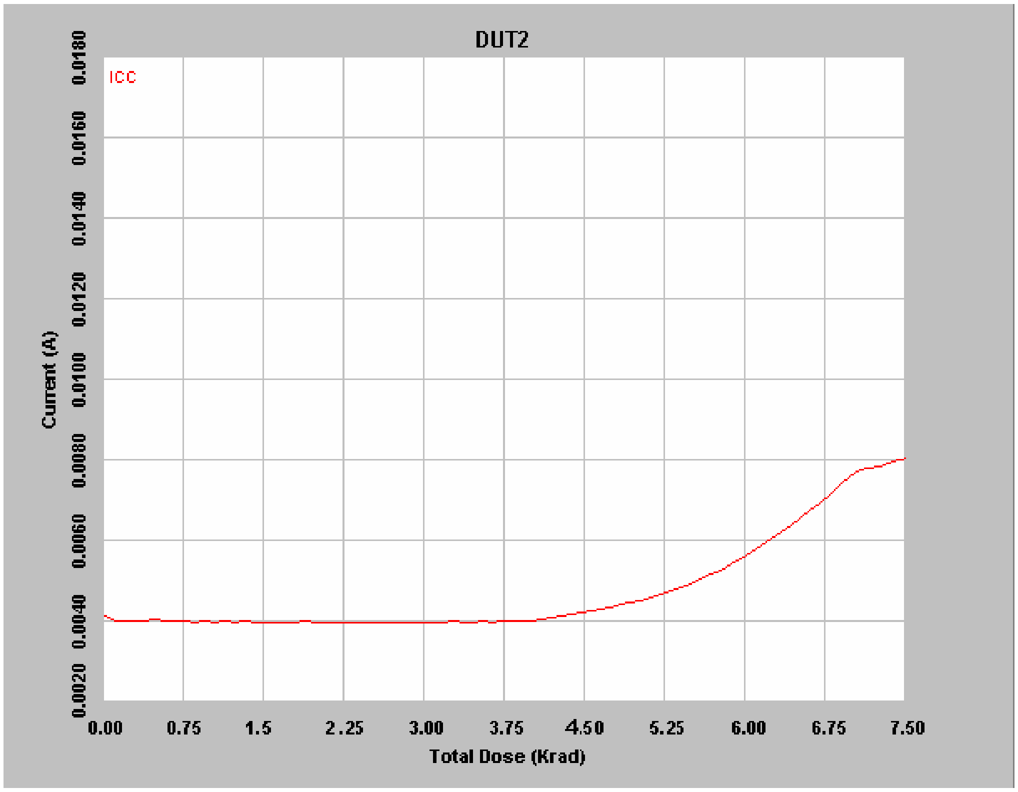

Figure 3 DUT 2 in-flux I_{CC}, 0 to 7.5 krad(SiO2).

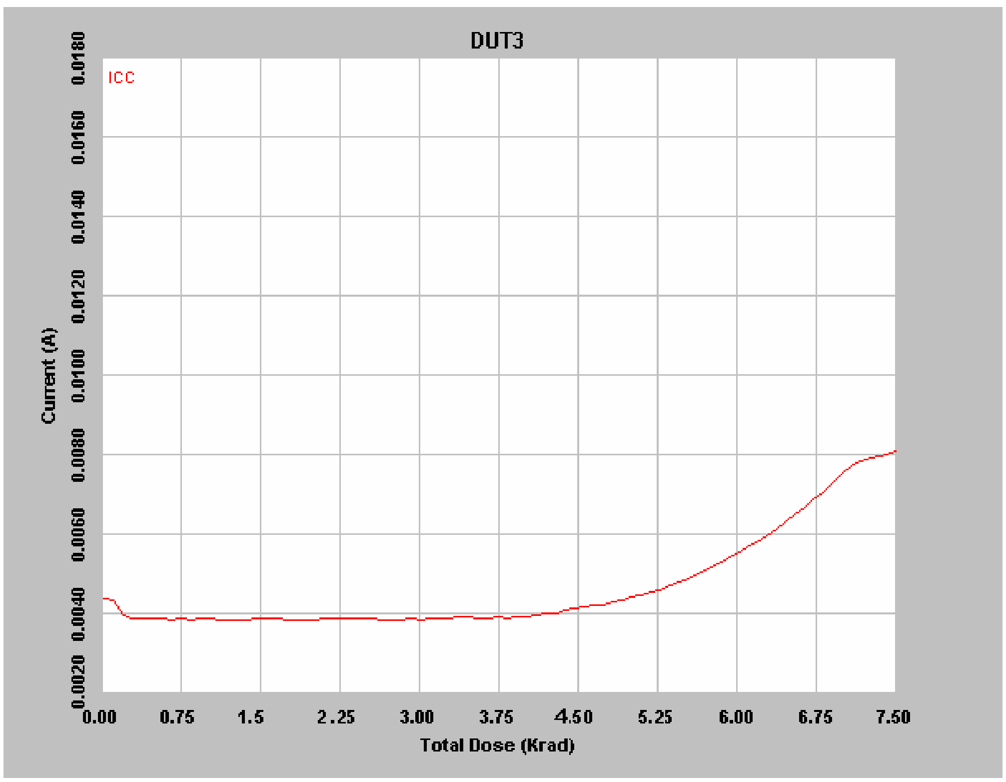

Figure 4 DUT 3 in-flux I_{CC}, 0 to 7.5 krad(SiO2).

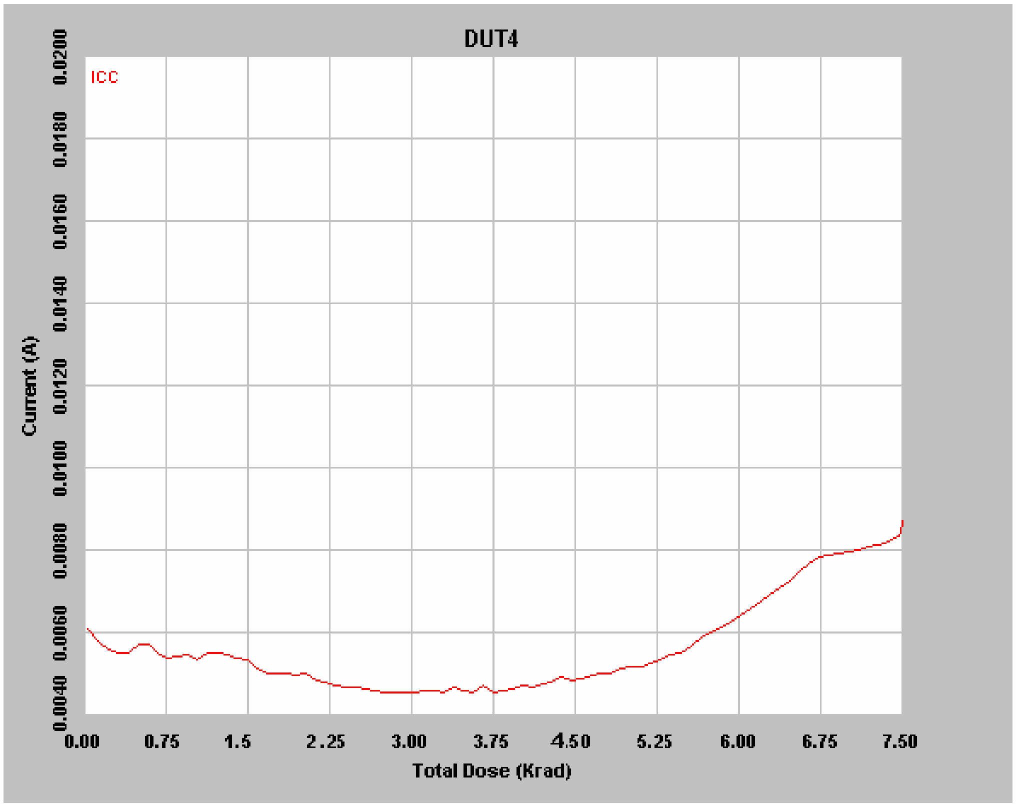

Figure 5 DUT 4 in-flux I_{CC}, 0 to 7.5 krad(SiO2).

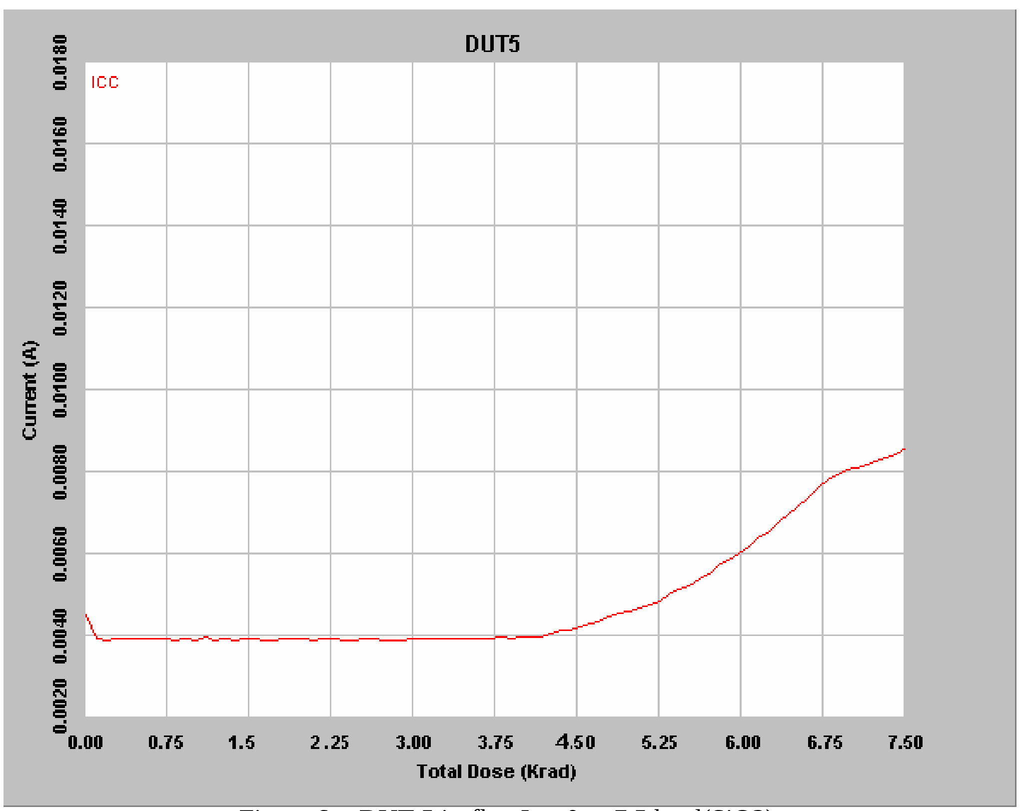

Figure 6 DUT 5 in-flux I_{CC}, 0 to 7.5 krad(SiO2).

C. *Input Logic Threshold*

Table 4 lists the input logic threshold of each DUT for pre-irradiation and post-annealing; every data is within the spec, and the radiation-induced Δ is within ±10%.

Table 5 Input Logic Threshold (V_{IL}/V_{IH}) Results (V)

DUT	V_{IL} (V)		V_{IH} (V)	
	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
1	1.34	1.317	1.24	1.324
2	1.34	1.301	1.21	1.31
3	1.32	1.31	1.23	1.319
4	1.33	1.31	1.22	1.318
5	1.33	1.304	1.23	1.315

D. *Output Characteristic*

Tables 6a and 6b show the V_{OL} characteristics for the pre-irradiated and post-annealed DUT; every data is within the spec. The spec is that when I_{OL} = 6 mA, V_{OL} cannot exceed 0.4 V.

Table 6a V_{OL} for various drive currents

V_{OL} (mV)	DUT1		DUT2		DUT3	
Current (mA)	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
0	9.2	0.6	7.7	0.6	8.9	0.6
1	41.7	21.7	41	21.9	40.9	21.8
2	69.1	45.2	68.3	45.6	68.2	45.4
5	124.4	116.2	125.8	117.2	125.7	116.7
10	250	235.8	250.8	237.6	250.8	236.9
20	496.2	481.9	498.5	486	497.4	484.1
24	607.7	583.7	609.3	588.8	608.5	586.5
50	1373.9	1331	1379.7	1343	1376.2	1340

Table 6b V_{OL} for various drive currents

V_{OL} (mV)	DUT4		DUT5	
Current (mA)	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
0	8.4	0.5	7.9	0.6
1	40.4	21.8	39	21.4
2	68.5	45.5	67.3	44.8
5	124.1	116.9	121.4	115.3
10	249.9	237.5	245.5	234
20	497.7	485.3	489.3	478
24	608.5	588	603.2	578.9
50	1378.5	1341	1354	1316

Figure 7a and 7b show the V_{OH} characteristic for the pre-irradiated and post-annealed DUT; every data is within the spec. The spec is that when I_{OH} = -4 mA, V_{OH} cannot be lower than 3.7 V.

Table 7a V_{OH} for various drive currents

V_{OH} (V)	DUT1		DUT2		DUT3	
Current (mA)	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
0	5.019	4.95	5.018	4.952	5.02	4.951
-1	4.944	4.916	4.944	4.917	4.946	4.919
-2	4.897	4.845	4.898	4.847	4.9	4.851
-5	4.706	4.567	4.708	4.643	4.716	4.649
-10	4.395	3.388	4.397	3.427	4.409	3.468
-20	3.653	1.883	3.667	1.988	3.72	2.104
-24	3.325	0.082	3.337	0.48	3.372	0.847
-50	-0.854	-0.982	-0.857	-0.984	-0.848	-0.983

Table 7b V_{OH} for various drive currents

V_{OH} (V)	DUT4		DUT5	
Current (mA)	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
0	5.019	4.95	5.018	4.964
-1	4.943	4.916	4.944	4.918
-2	4.896	4.845	4.897	4.851
-5	4.705	4.639	4.708	4.645
-10	4.394	3.371	4.399	3.43
-20	3.648	1.916	3.674	2.011
-24	3.316	0.22	3.343	0.547
-50	-0.857	-0.983	-0.853	-0.982

E. Propagation Delays

Table 8a and 8b list the pre-irradiation and post-annealing propagation delays. The results show small radiation effects; in any case the percentage change is below ±10%.

Table 8a Radiation-Induced Propagation Delay Degradations (L to H Transition)

DUT	Pre-Irradiation (ns)	Post-Annealing (ns)	Degradation
DUT1	937.3	960	2.42%
DUT2	925.7	952	2.84%
DUT3	921.4	949	3.00%
DUT4	937.1	956	2.02%
DUT5	933.2	963	3.19%

Table 8b Radiation-Induced Propagation Delay Degradations (H to L Transition)

DUT	Pre-Irradiation (ns)	Post-Annealing (ns)	Degradation
DUT 1	954.6	989	3.60%
DUT 2	942.3	972	3.15%
DUT 3	938.3	968	3.17%
DUT 4	953.9	981	2.84%
DUT 5	950.2	985	3.66%

F. Transient Characteristics

The rising and falling edge transient of an output is measured pre-irradiation and post-annealing. Figures 9 to 18 show the pre-irradiation and post-annealing transition edges. In each case, the radiation-induced transition-time degradation is not observable.

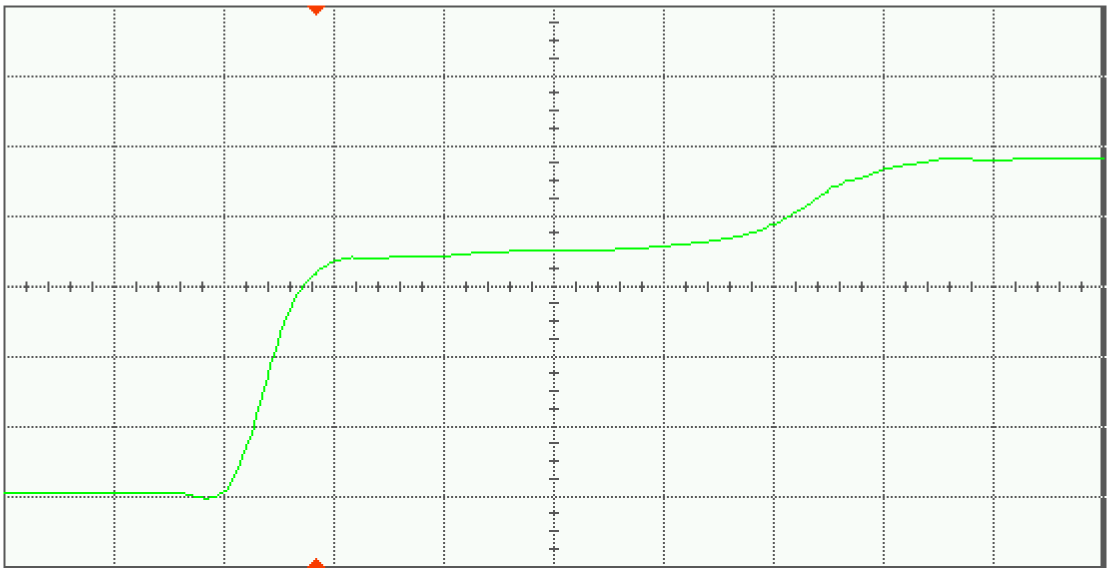

Figure 9(a) DUT 1 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

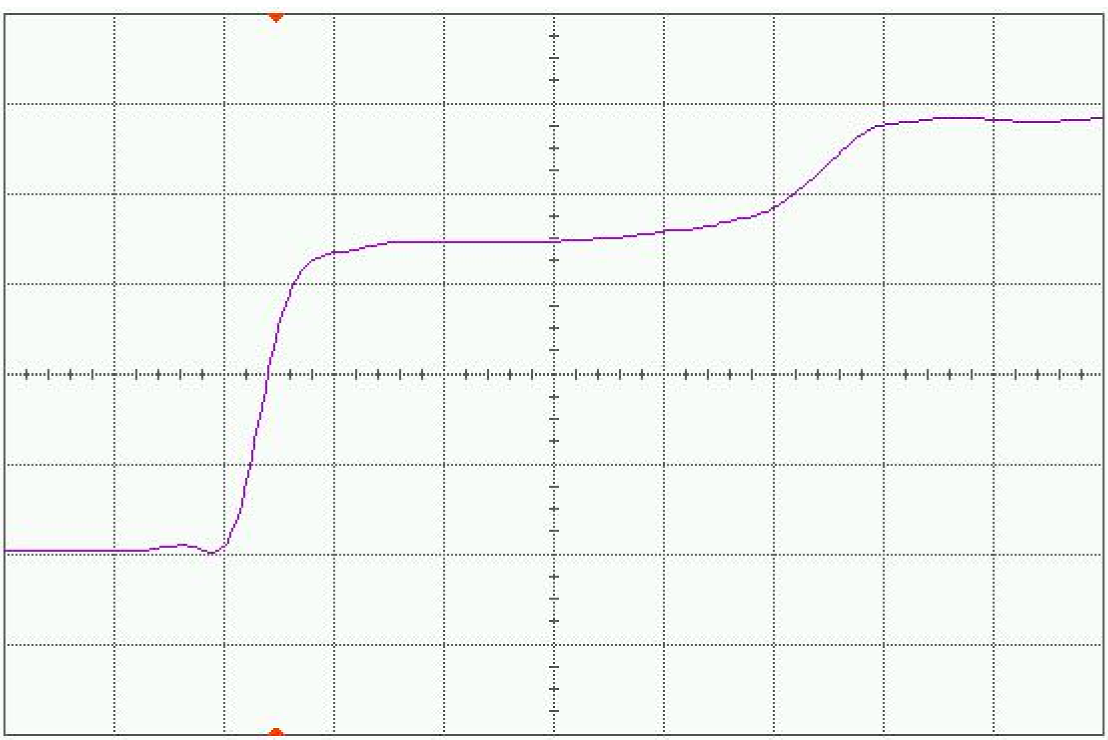

Figure 9(b) DUT1 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

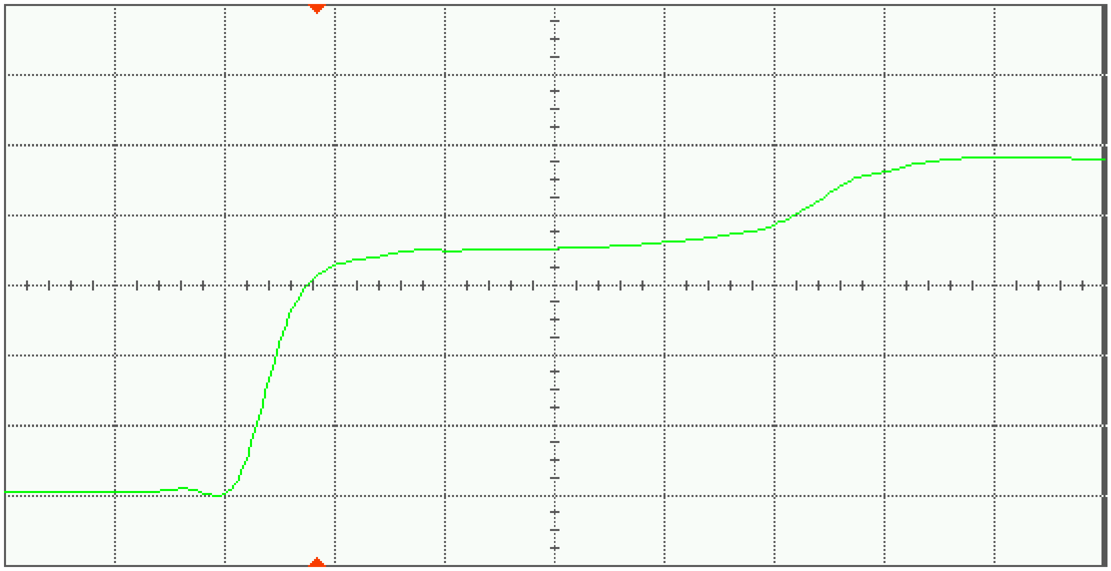

Figure 10(a) DUT2 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

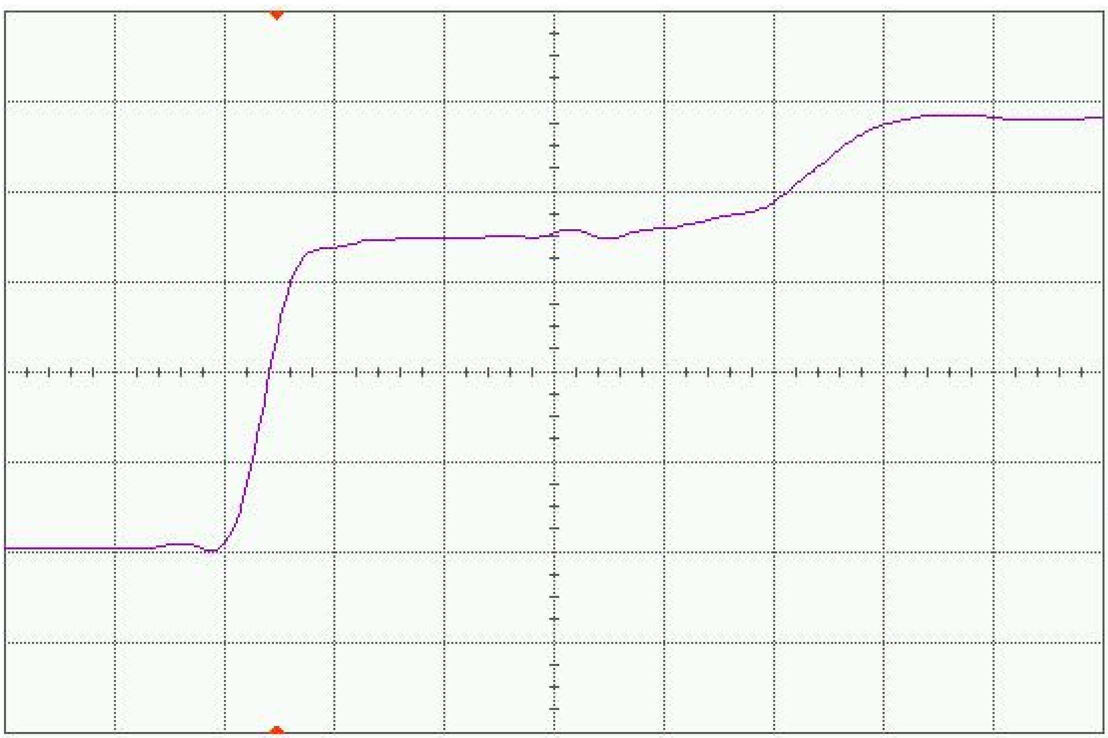

Figure 10(b) DUT 2 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

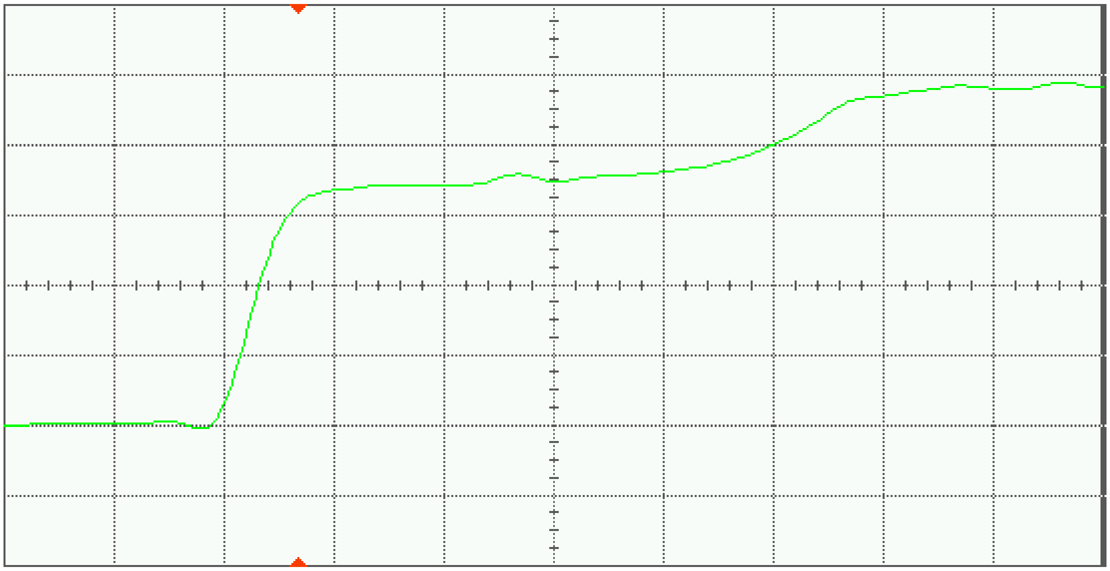

Figure 11(a) DUT3 pre-radiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

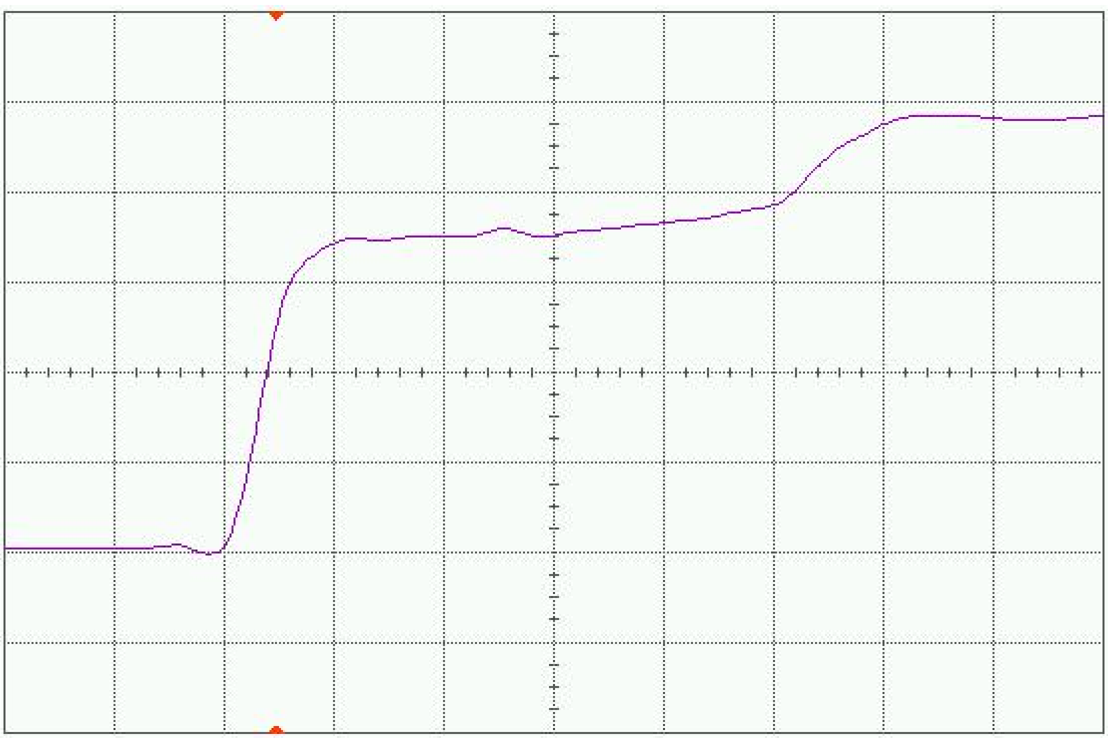

Figure 11(b) DUT3 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

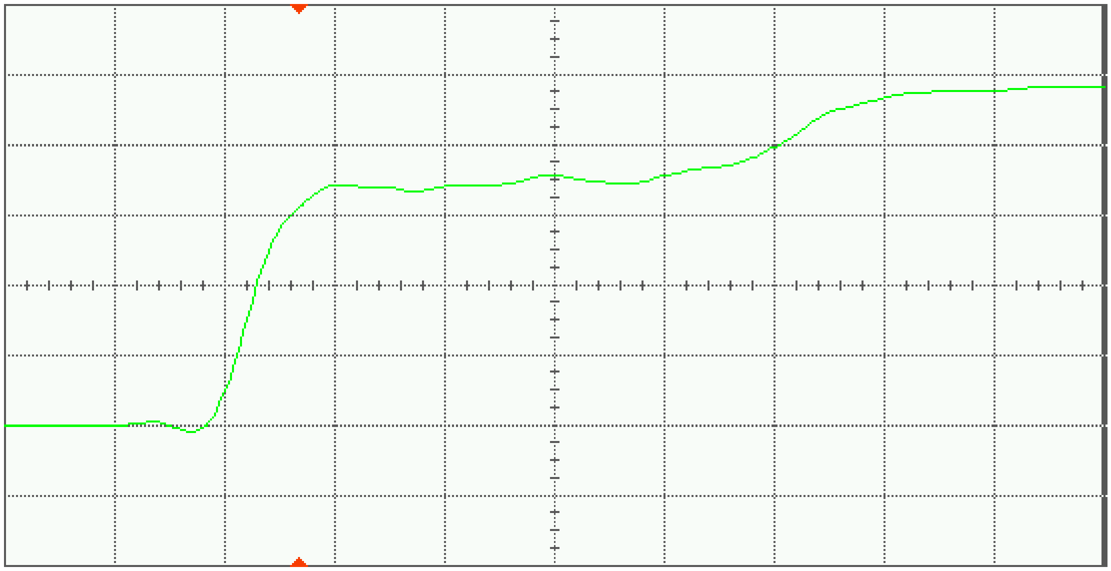

Figure 12(a) DUT4 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

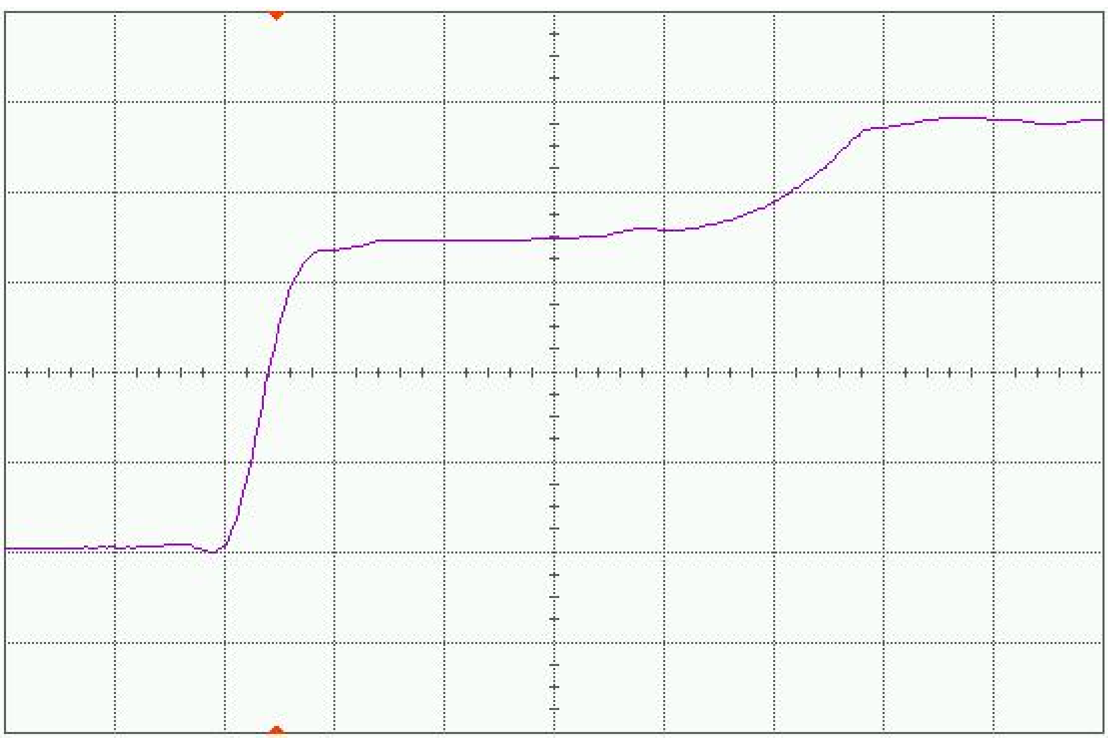

Figure 12(b) DUT4 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

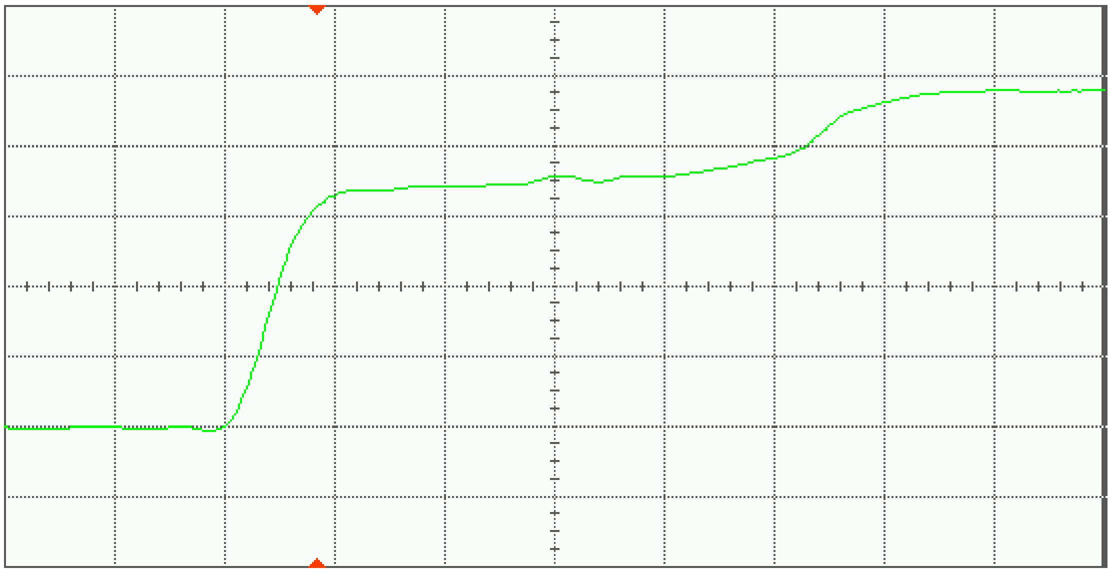

Figure 13(a) DUT5 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

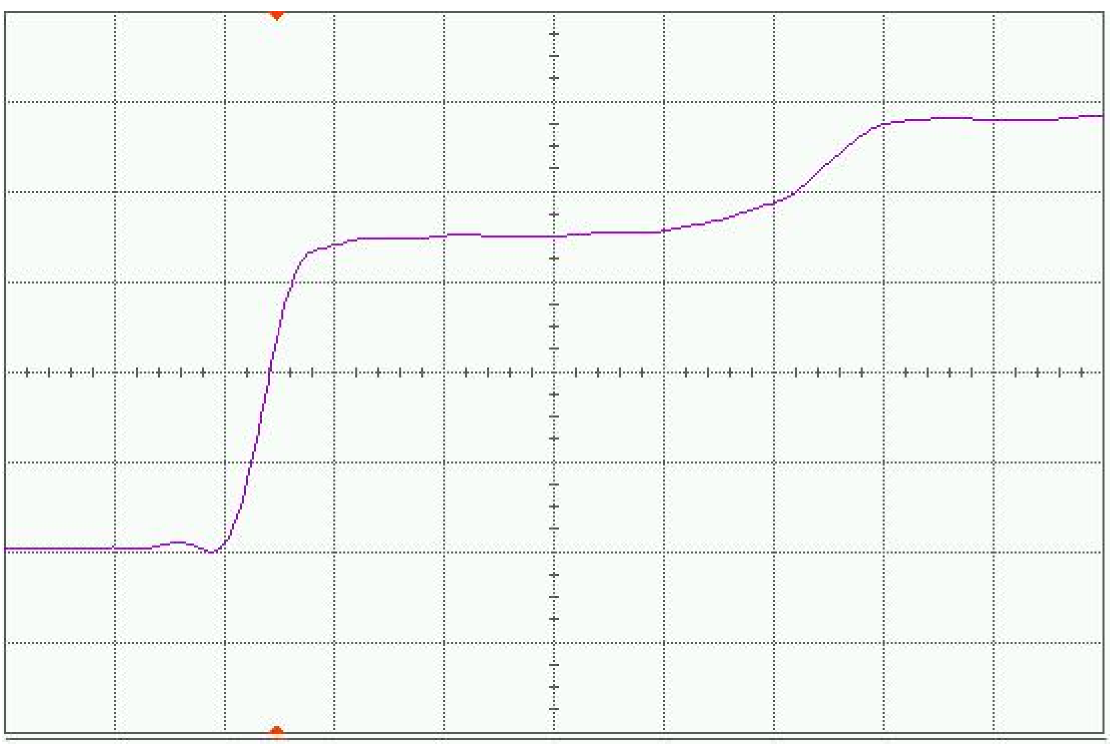

Figure 13(b) DUT5 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

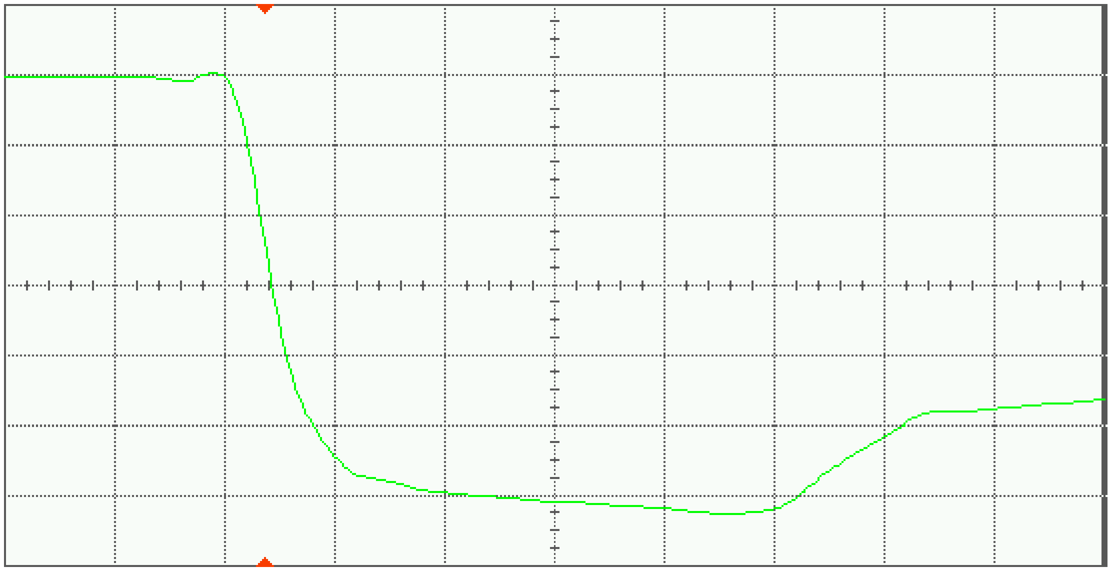

Figure 14(a) DUT1 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

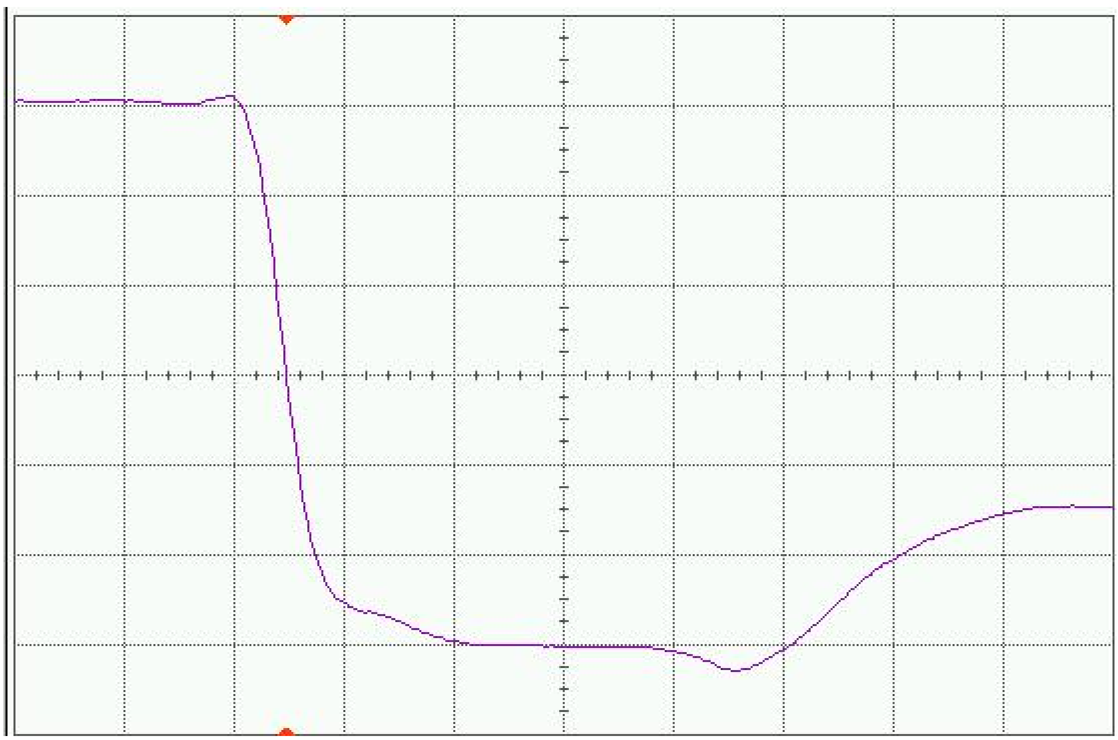

Figure 14(b) DUT1 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

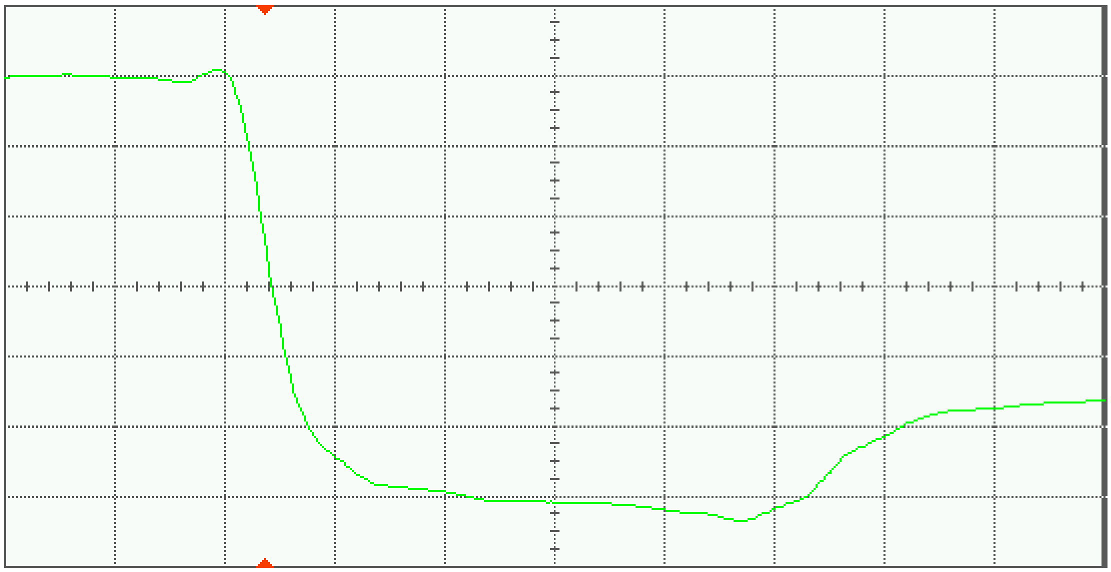

Figure 15(a) DUT2 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

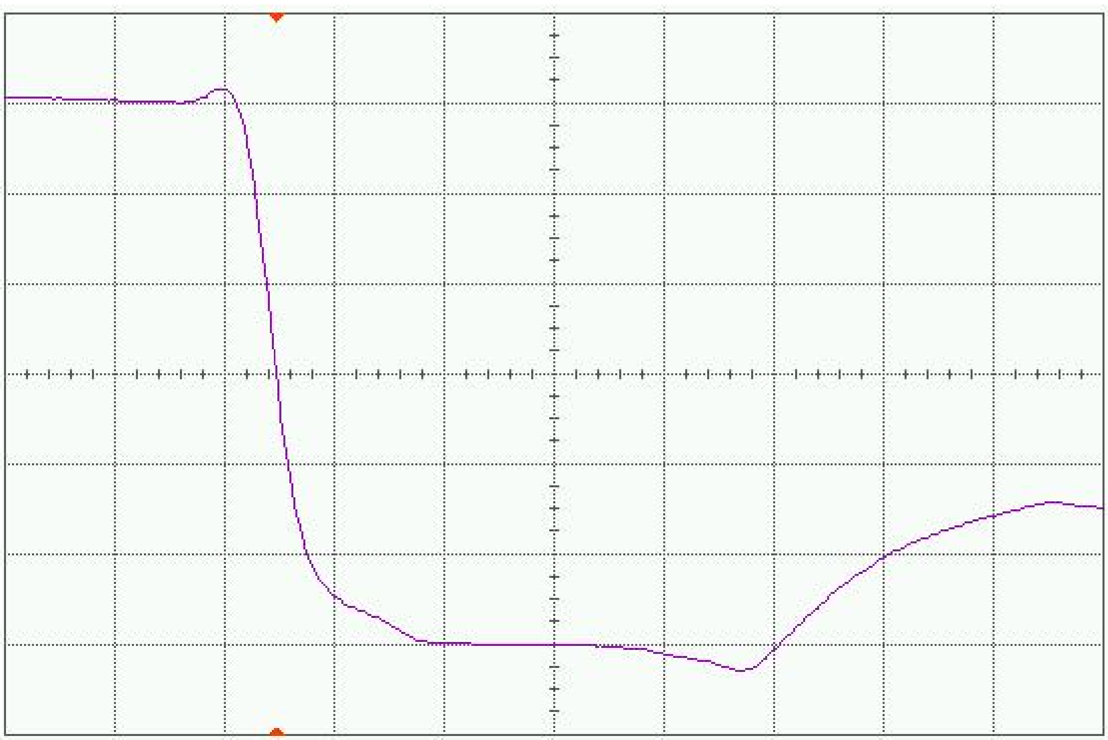

Figure 15(b) DUT2 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

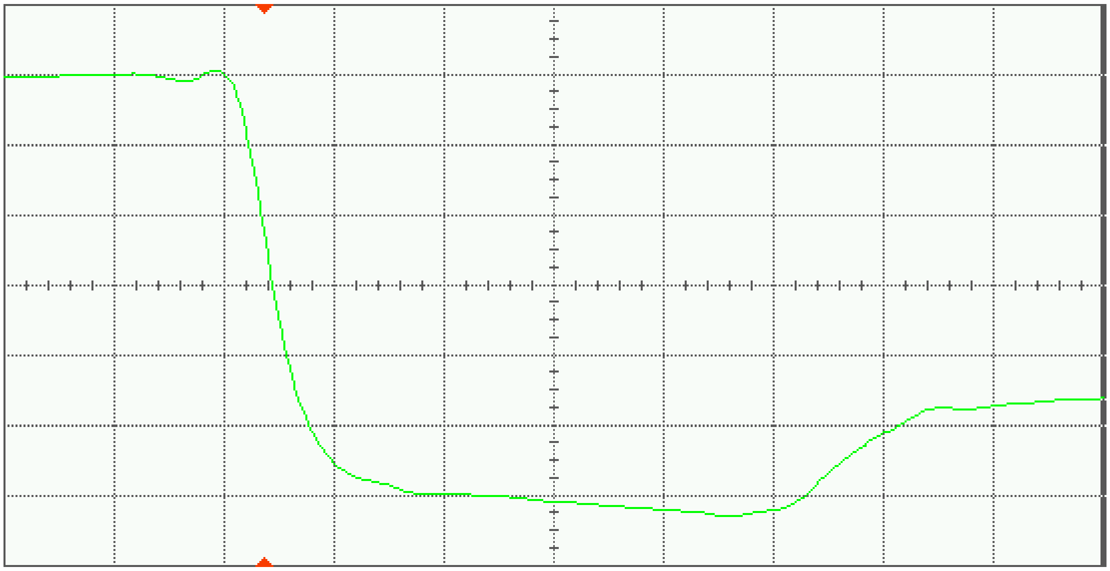

Figure 16(a) DUT3 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

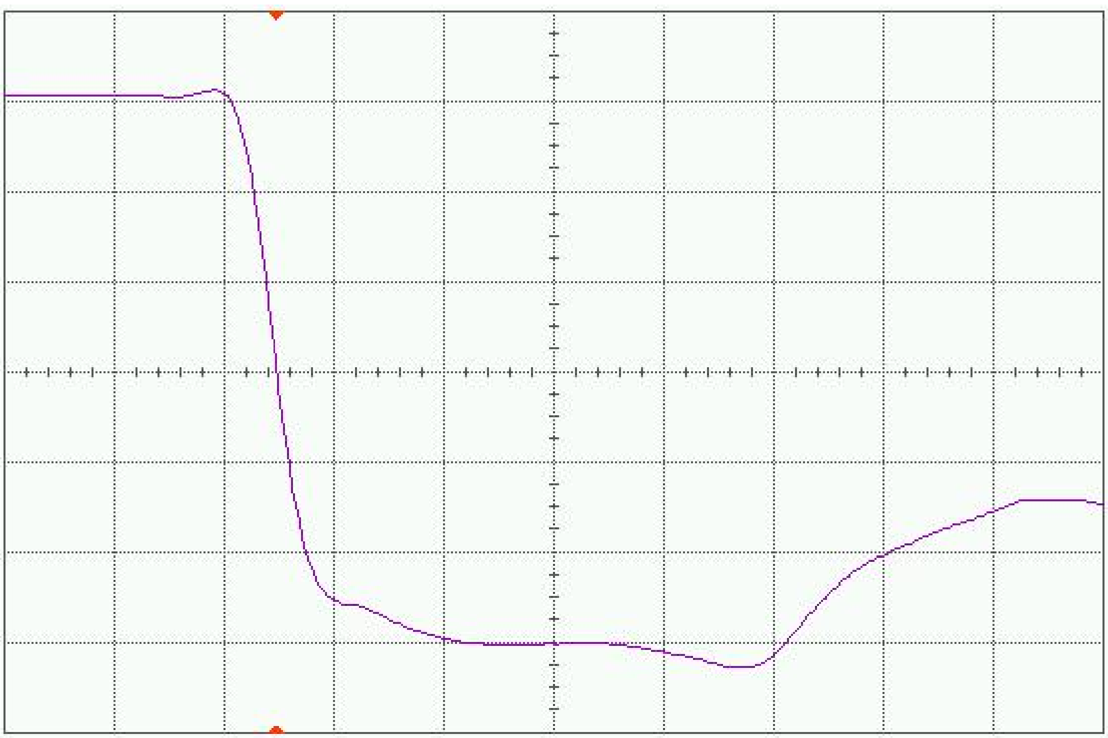

Figure 16(b) DUT3 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

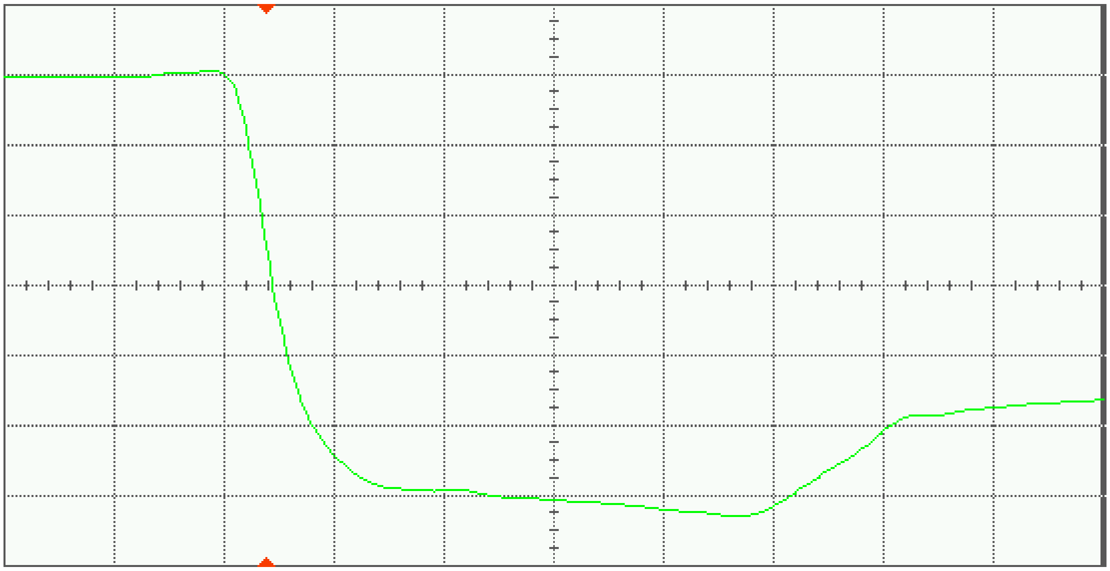
Figure 17(a) DUT4 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

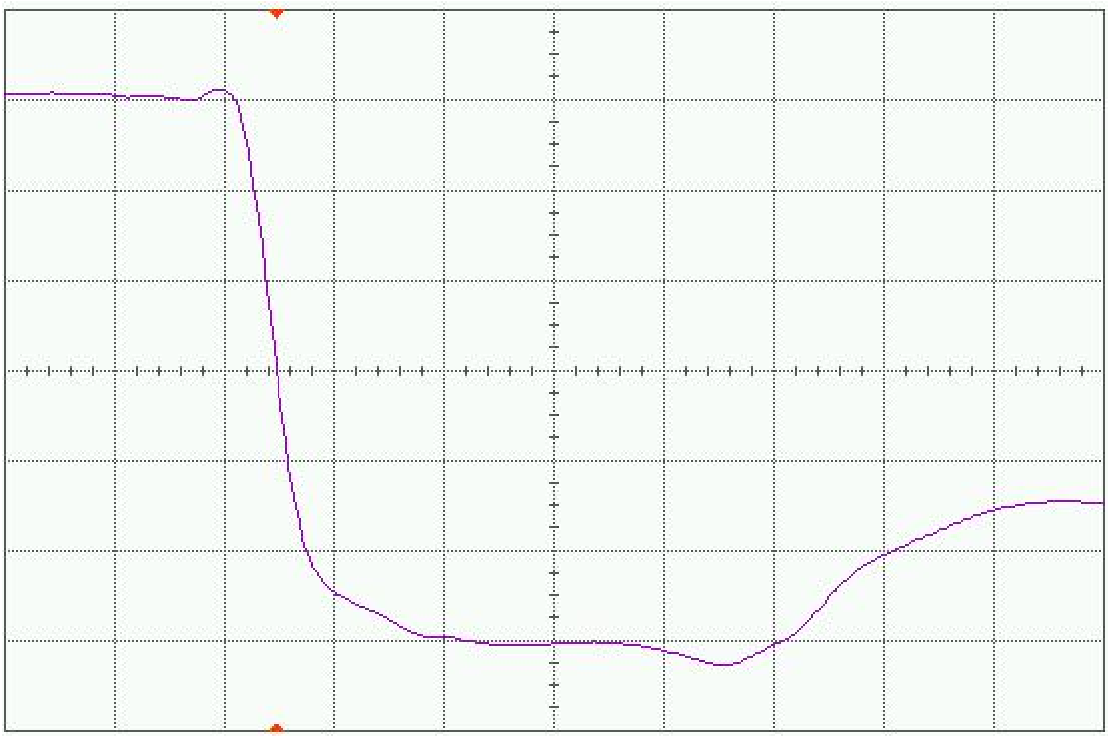
Figure 17(b) DUT4 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

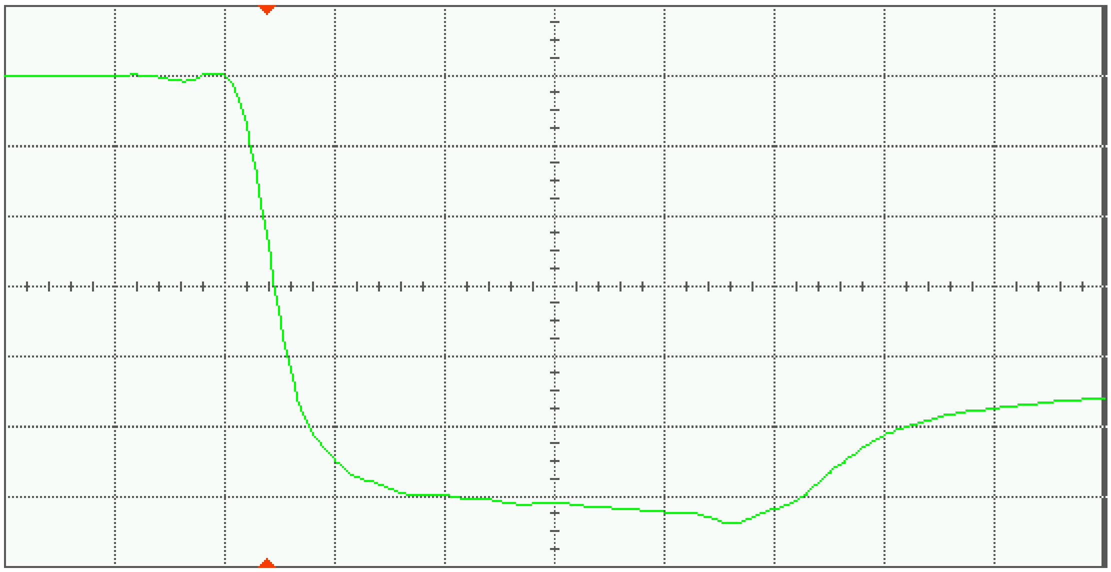

Figure 18(a) DUT5 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

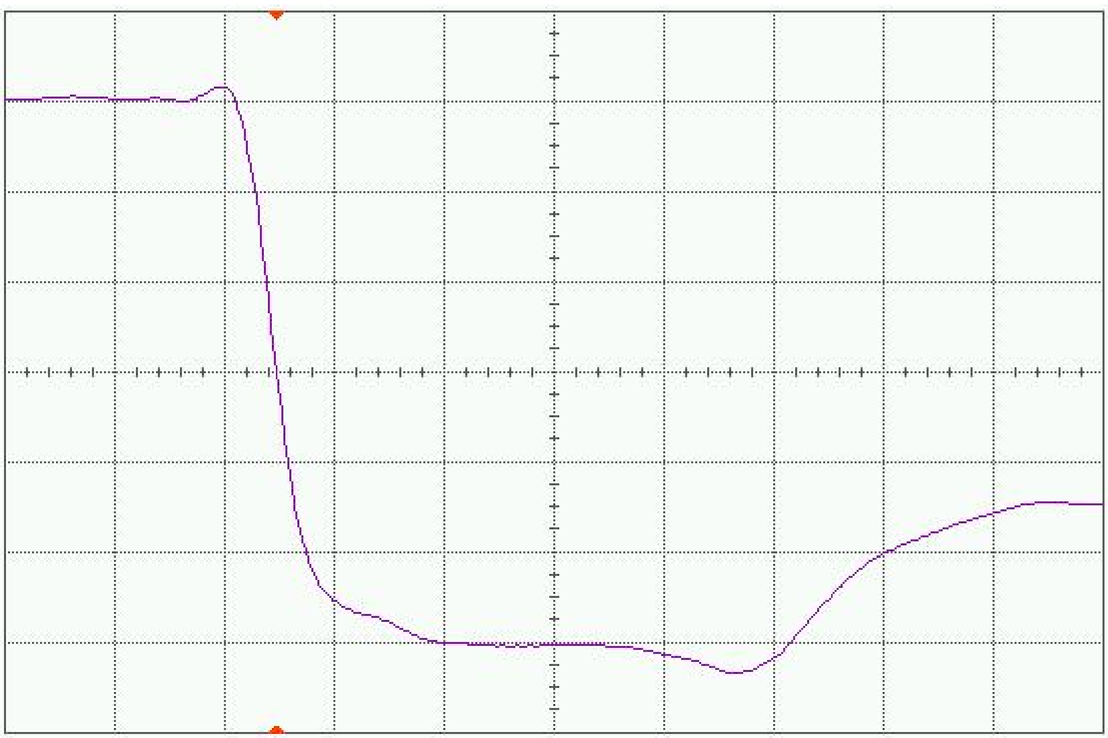

Figure 18(b) DUT5 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.