TOTAL IONIZING DOSE TEST REPORT

No. 08T-RT1280-FP21573
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J.J. Wang
(650) 318-4576
jih-jong.wang@actel.com

I. SUMMARY TABLE

Parameters	Tolerance
1. Gross Functional	Pass 10 krad(SiO_2)
2. $I_{DDSTDBY}$	Pass 8 krad(SiO_2)
3. V_{IL}/V_{IH}	Pass 10 krad(SiO_2)
4. V_{OL}/V_{OH}	Pass 10 krad(SiO_2)
5. Propagation Delays	Pass 10 krad(SiO_2)
6. Rising/Falling Edge Transient	Pass 10 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	RT1280
Package	CQFP172
Foundry	MEC
Technology	0.8 um CMOS
Die Lot Number	FP21573
Quantity Tested	6
Serial Numbers	DUT 1, DUT 2, DUT 3, DUT 4, DUT 5, DUT 6

B. *Irradiation*

Table 2 lists the irradiation parameters.

Table 2. Irradiation Parameters

Facility	DMEA
Radiation Source	Co-60
Dose Rate	1 krad(SiO_2)/min (±5%)
Data Mode	Static
Temperature	Room
Bias	5.0 V

C. *Test Method*

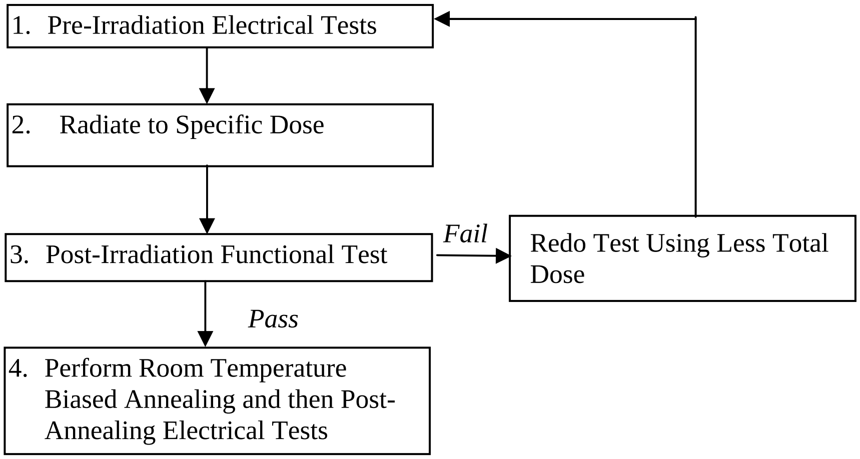

Figure 1 TID test flow chart

The test method basically is in compliance with the military standard TM1019.6. Figure 1 is 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 RT1280 product, the adverse effects due to interface state at the gate SiO_2/Si interface are negligible, and the dominant annealing effect in this device is the reduction of trapped holes in the SiO_2. So the accelerated annealing basically alleviates the radiation effects on the DUT.

Section 3.11 extended room temperature anneal test is also applied. Room temperature annealing for approximately 30 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. However, 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. Thus sampling few pins is sufficient to prove that the radiation effects at the measured level 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. Since 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
DUT 1	10	0.13	251	71
DUT 2	10	0.13	250	67
DUT 3	10	0.13	226	61
DUT 4	8	0.13	110	30
DUT 5	8	0.13	105	29
DUT 6	8	0.13	104	29

Figures 2 to 7 show the in-flux I_{CC}. As shown in Table 4, although the post annealing of 8 krad(SiO_2)-DUT didn't recover the I_{CC} to within the spec of 25 mA, from the trend of annealing it is obvious that longer annealing will reduce ICC to within the spec.

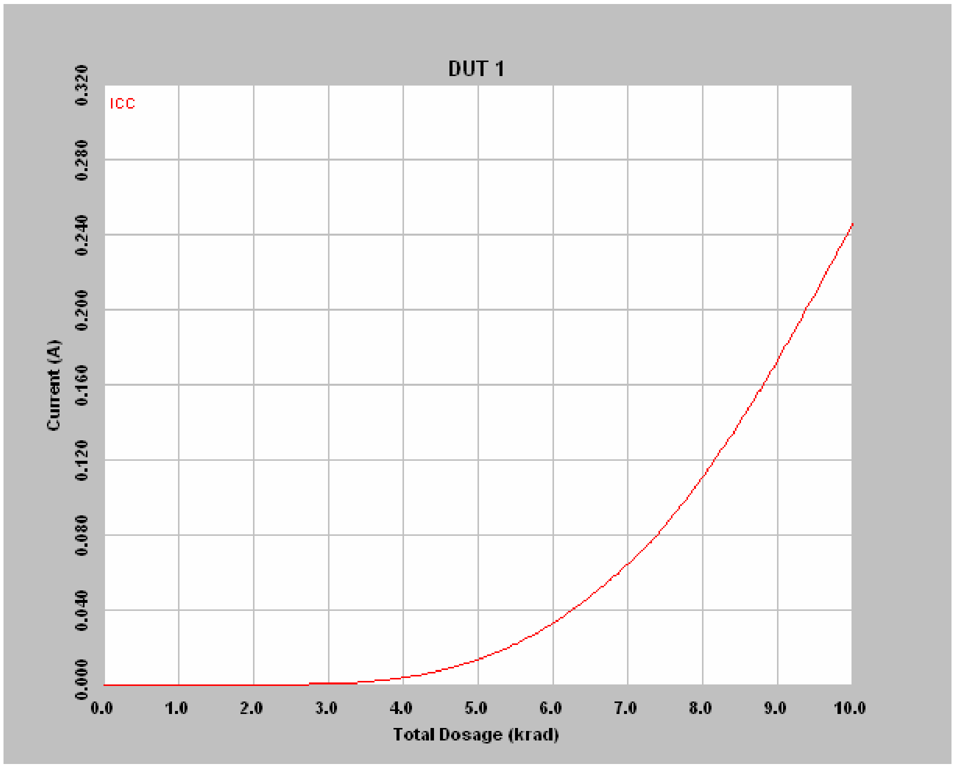

Figure 2 DUT 1 in-flux I_{CC}

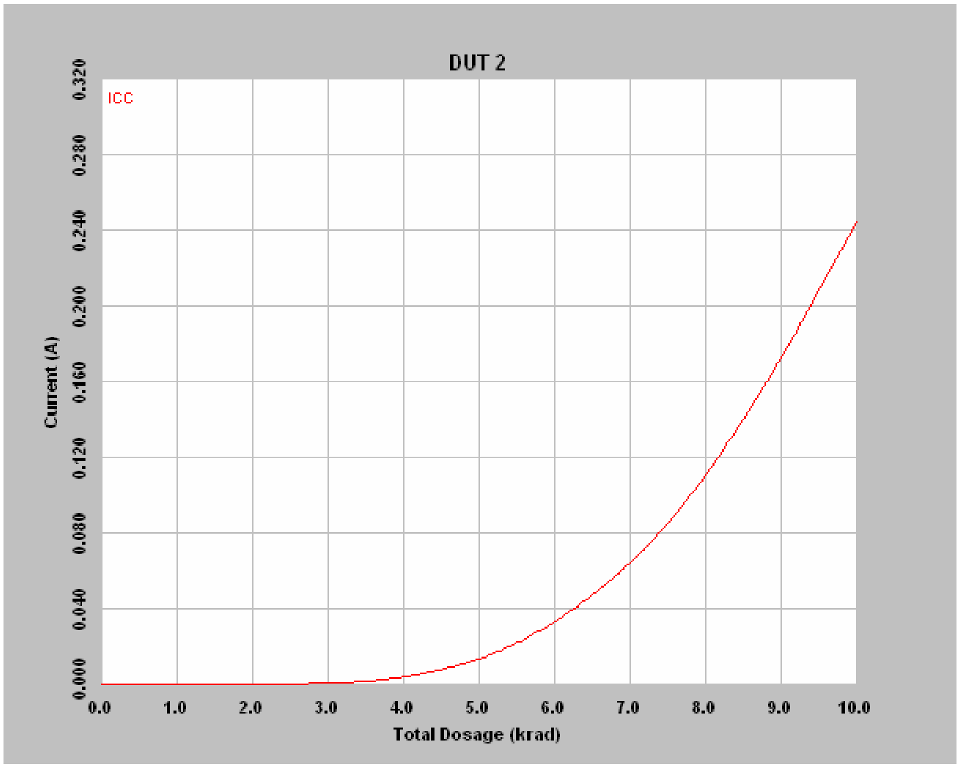

Figure 3 DUT 2 in-flux I_{CC}

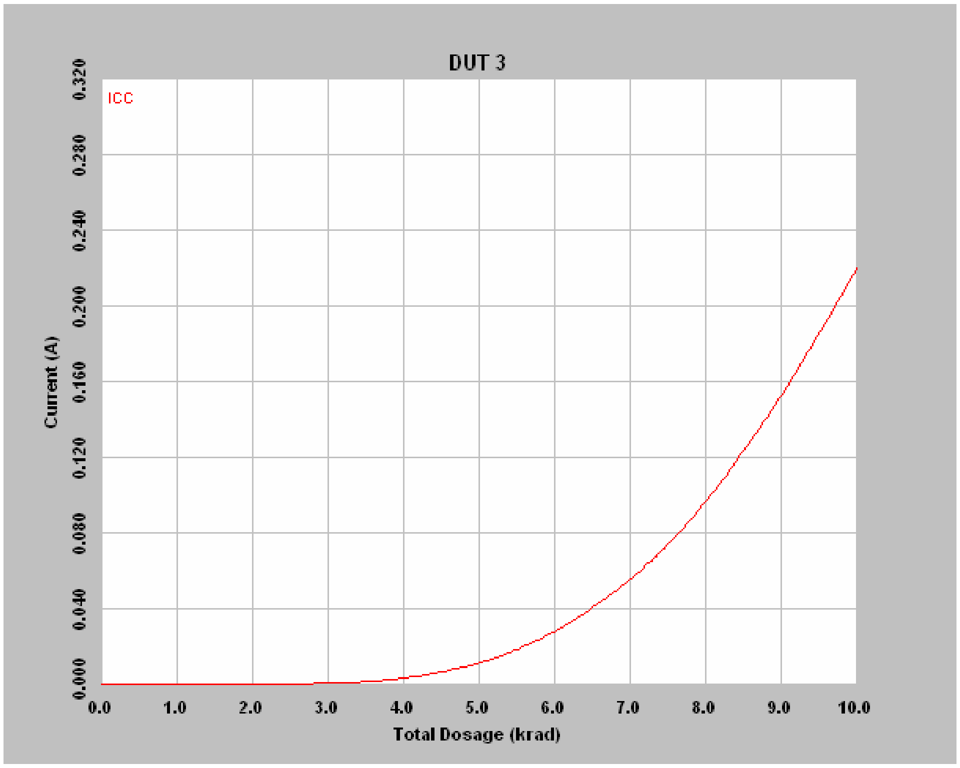

Figure 4 DUT 3 in-flux I_{CC}

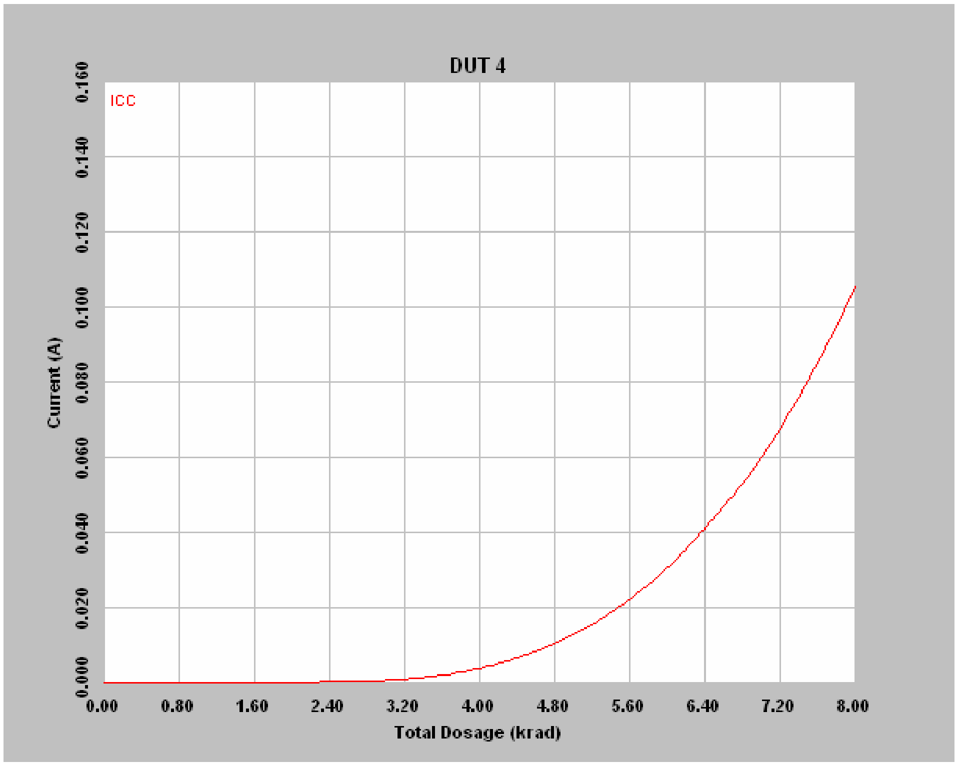

Figure 5 DUT 4 in-flux I_{CC}

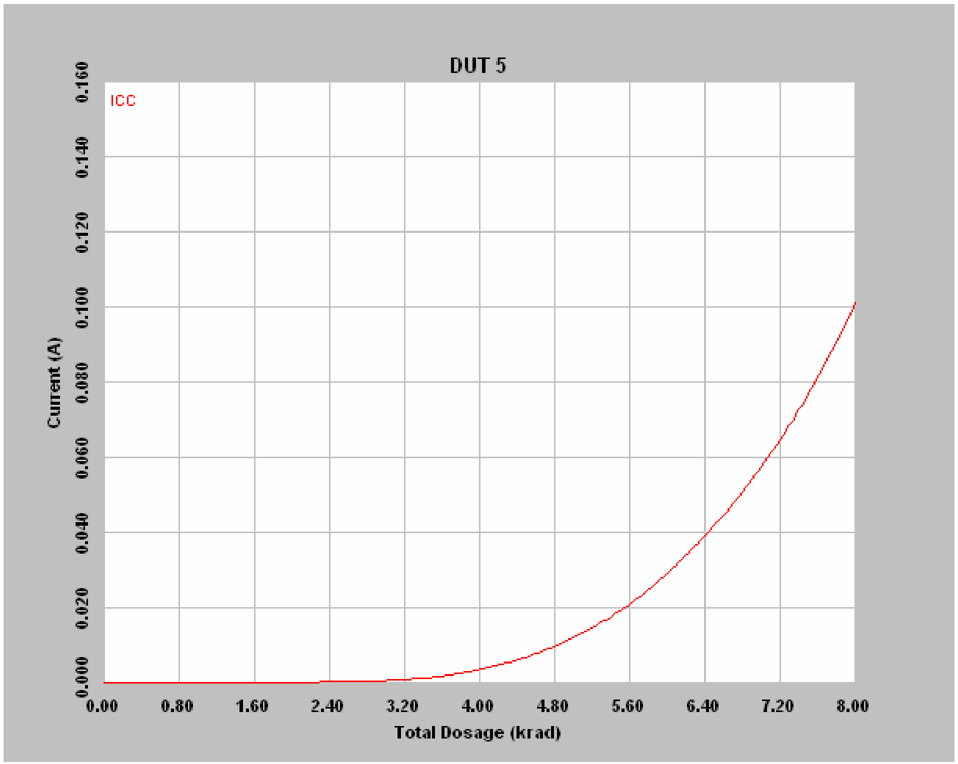

Figure 6 DUT 5 in-flux I_{CC}

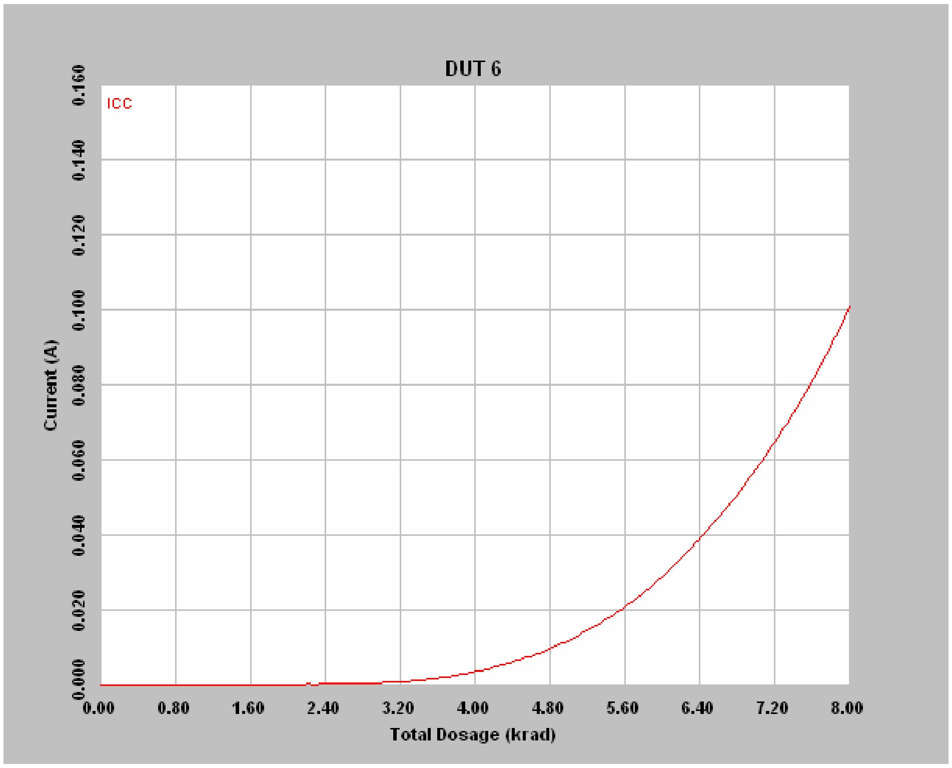

Figure 7 DUT 6 in-flux I_{CC}

C. *Input Logic Threshold*

Table 5 lists the input logic threshold of each DUT for pre-irradiation and post-annealing; every data is within the spec.

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

	V_{IL} (V)		V_{IH} (V)	
	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
DUT 1	1.265	1.278	1.231	1.241
DUT 2	1268	1.287	1.23	1.251
DUT 3	1.264	1.284	1.225	1.249
DUT 4	1.281	1.291	1.241	1.254
DUT 5	1.279	1.293	1.241	1.256
DUT 6	1.279	1.259	1.239	1.295

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 (mV)

	DUT 1		DUT 2		DUT 3	
Current (mA)	Pre-Irrad (mV)	Post-Ann (mV)	Pre-Irrad (mV)	Post-Ann (mV)	Pre-Irrad (mV)	Post-Ann (mV)
0	-24	-49	-24	-51	-23	-48
1	10	-12	9	-12	10	-12
2	24	14	24	15	23	14
5	61	32	58	32	47	32
10	250	170	245	174	227	165
20	537	379	529	386	487	367
24	628	541	609	544	561	529

Table 6b V_{OL} for various drive currents (mV)

	DUT 4		DUT 5		DUT 6	
Current (mA)	Pre-Irrad (mV)	Post-Ann (mV)	Pre-Irrad (mV)	Post-Ann (mV)	Pre-Irrad (mV)	Post-Ann (mV)
0	-20	-50	-22	-51	-22	-51
1	11	-13	10	-14	11	-11
2	24	14	23	13	24	13
5	56	30	48	31	55	31
10	238	163	219	160	238	163
20	513	362	467	359	518	362
24	582	522	554	514	588	522

Figure 7a and 7b show the V_{OH} characteristic curves 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)

	DUT 1		DUT 2		DUT 3	
Current (mA)	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
0	4.879	4.928	4.88	4.927	4.879	4.93
1	4.798	4.852	4.7993	4.854	4.799	4.861
2	4.762	4.793	4.767	4.793	4.767	4.794
5	4.5205	4.584	4.523	4.583	4.522	4.598
10	4.118	4.264	4.164	4.264	4.139	4.265
20	2.336	3.192	2.7	3.196	2.542	3.25
24	-0.7604	0.976	-0.522	1.113	-0.712	1.567

Table 7b V_{OH} for various drive currents (V)

	DUT 4		DUT 5		DUT 6	
Current (mA)	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
0	4.876	4.931	4.878	4.931	4.878	4.932
1	4.780	4.863	4.799	4.865	4.800	4.864
2	4.773	4.795	4.767	4.795	4.769	4.975
5	4.526	4.604	4.522	4.610	4.524	4.610
10	4.174	4.266	4.152	4.266	4.156	4.266
20	2.720	3.310	2.623	3.341	2.661	3.338
24	-0.630	1.910	-0.686	2.035	-0.656	2.110

E. Propagation Delays

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

Table 8 Radiation-Induced Propagation Delay Degradations

DUT	Total Dose krad(SiO_2)	Pre-Irradiation (ns)	Post-Annealing (ns)	Degradation
DUT 1	10	1000.8	1002.7	0.19%
DUT 2	10	999.2	983.8	-1.55%
DUT 3	10	998.3	981.0	-1.74%
DUT 4	8	1002.8	985.9	-1.69%
DUT 5	8	1001.6	985.6	-1.60%
DUT 6	8	994.5	975.4	-1.92%

F. Transient Characteristics

The rising and falling edge transient of an output is measured pre-irradiation and post-annealing. Figures 8 to 19 show the pre-irradiation and post-annealing transition edges. In each case, the radiation-induced transition-time degradation is not observable.

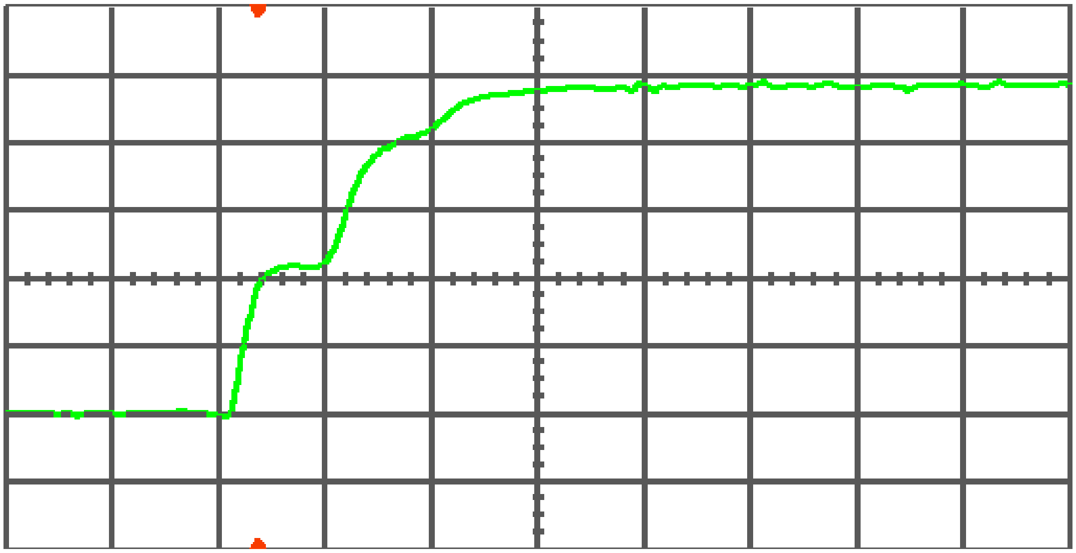

Figure 8(a) DUT 1 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

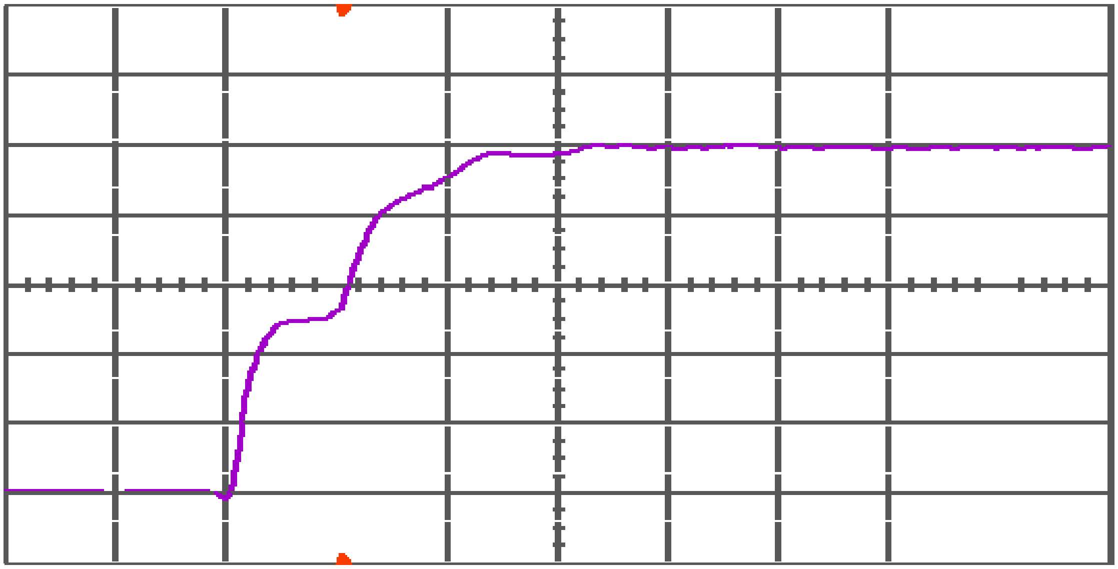

Figure 8(b) DUT 1 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

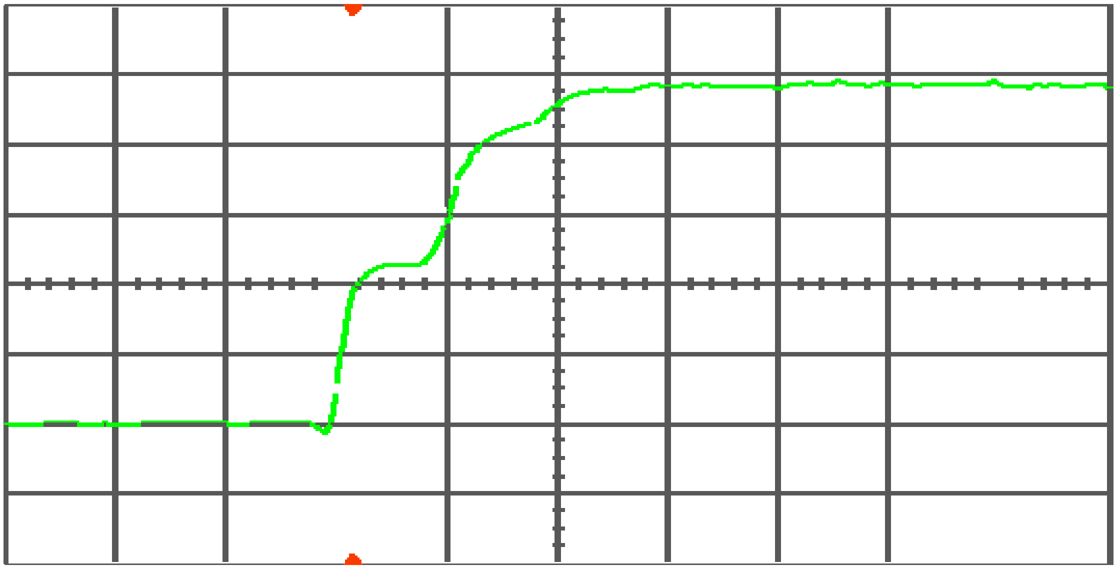

Figure 9(a) DUT 2 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

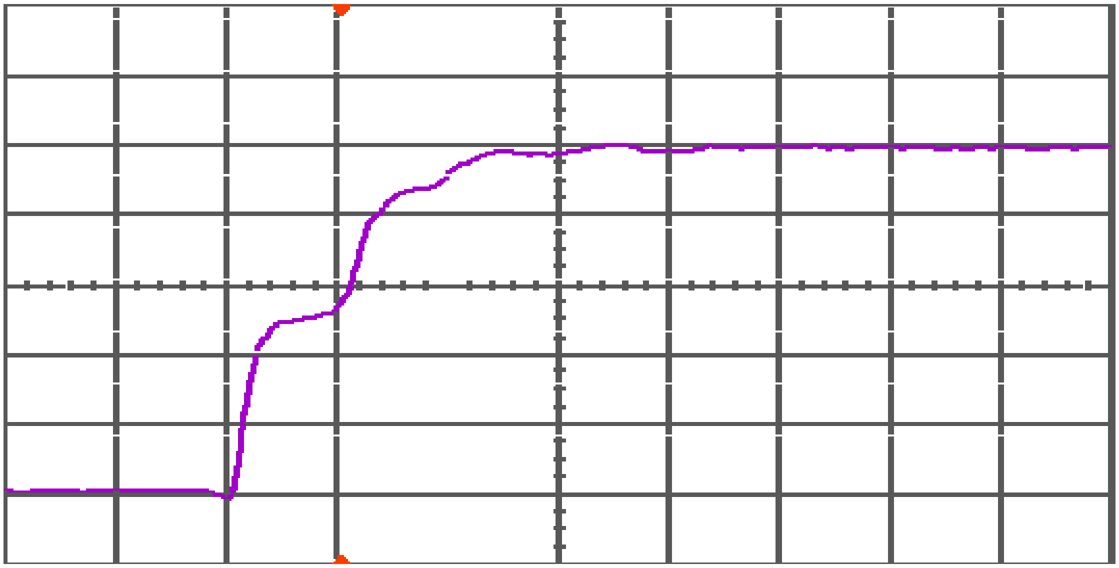

Figure 9(b) DUT 2 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

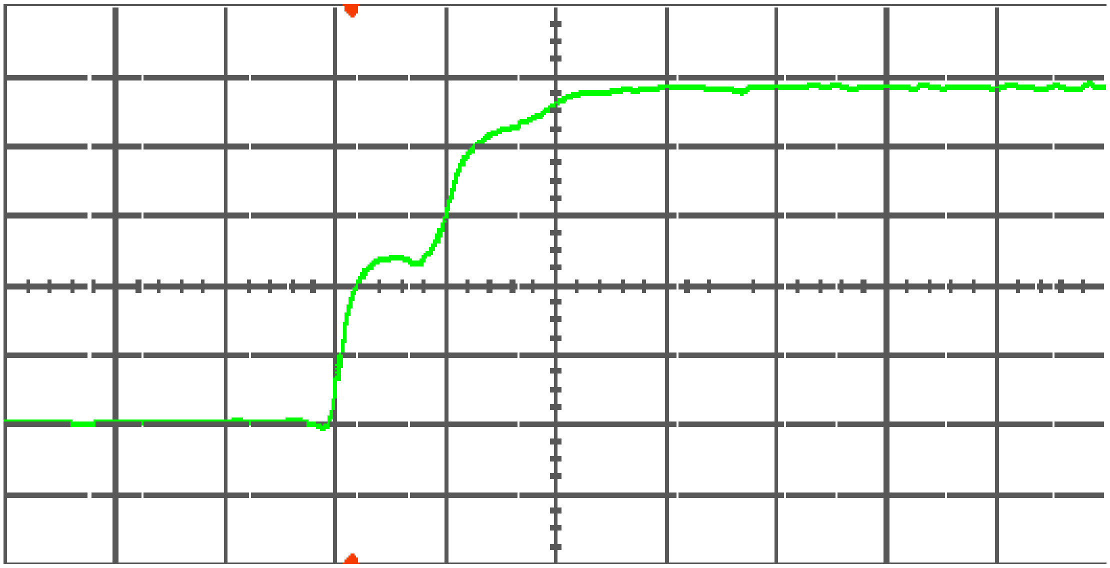

Figure 10(a) DUT 3 pre-radiation rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

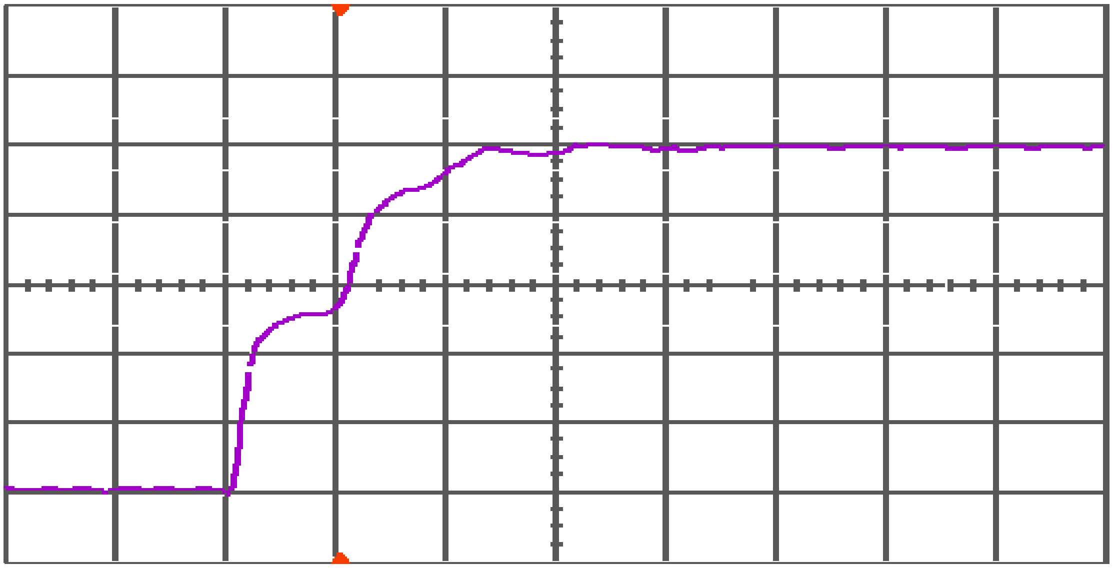

Figure 10(b) DUT 3 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

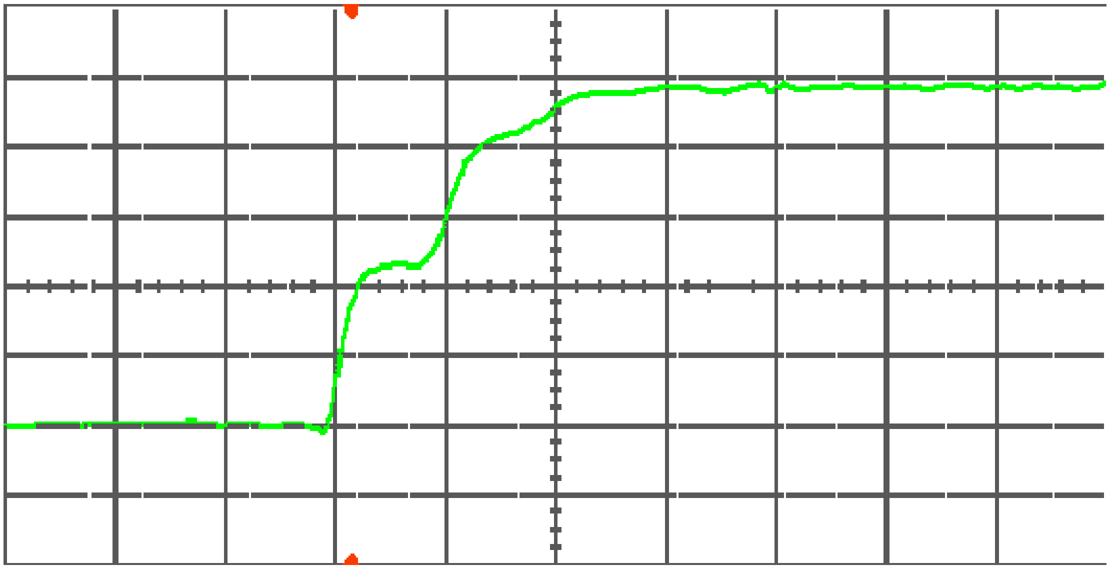

Figure 11(a) DUT 4 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

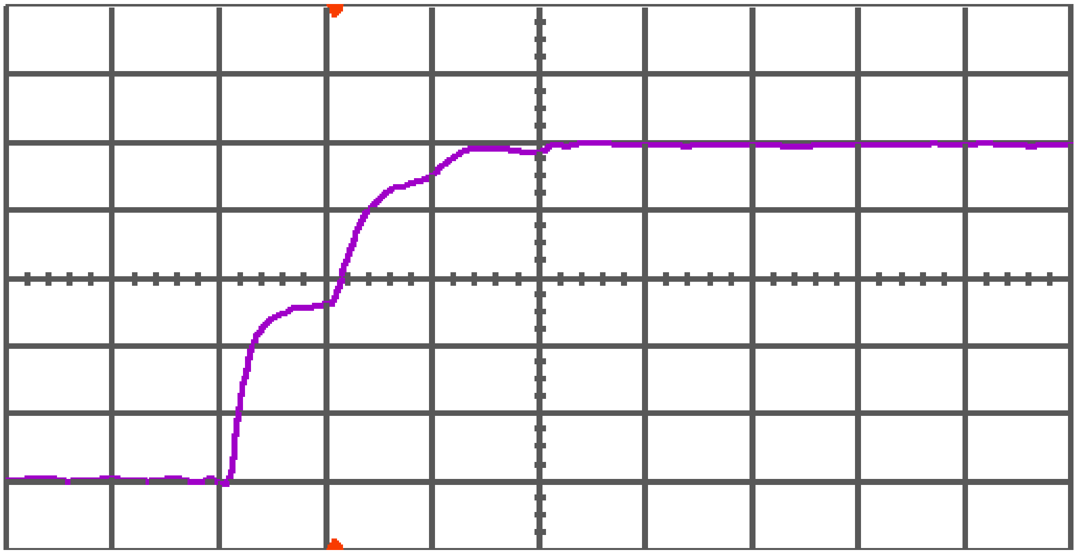

Figure 11(b) DUT 4 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

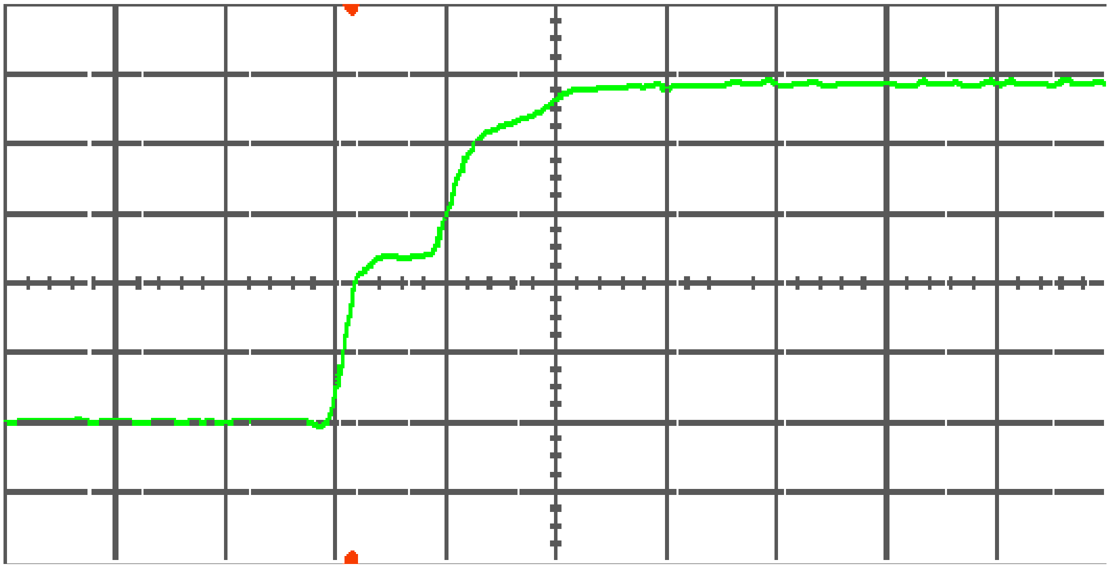

Figure 12(a) DUT 5 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

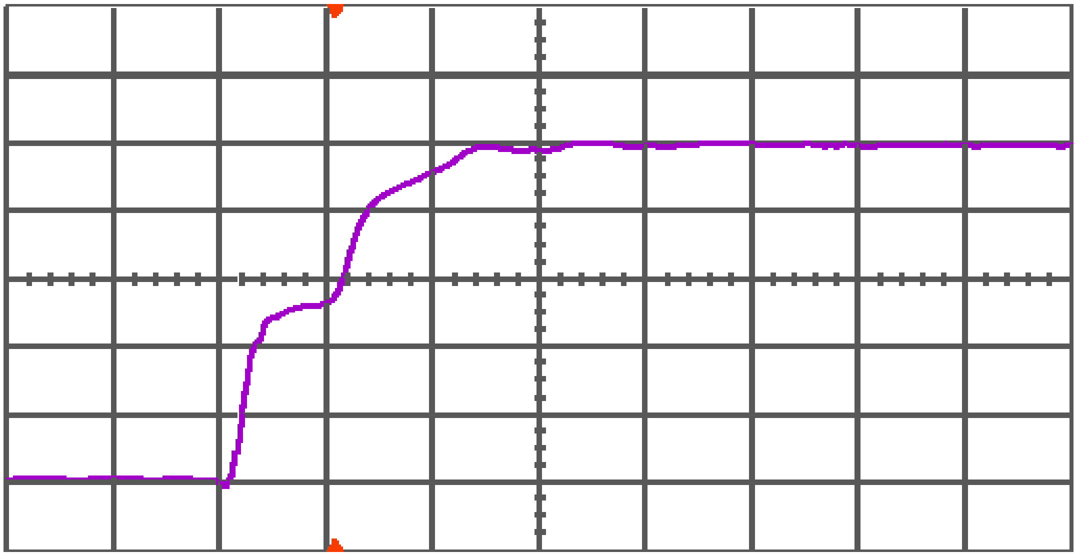

Figure 12(b) DUT 5 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

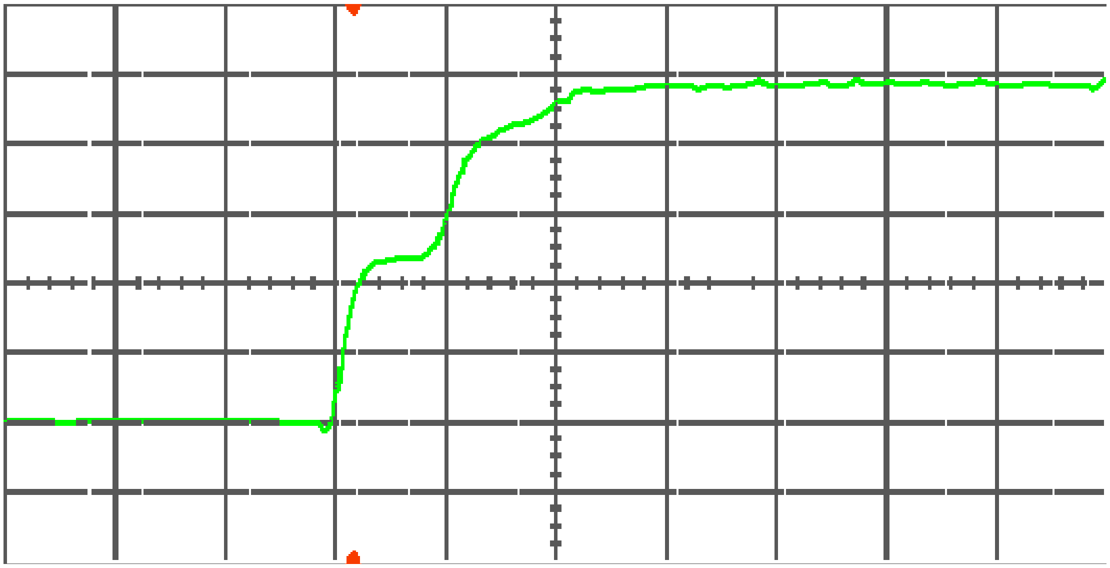

Figure 13(a) DUT 6 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

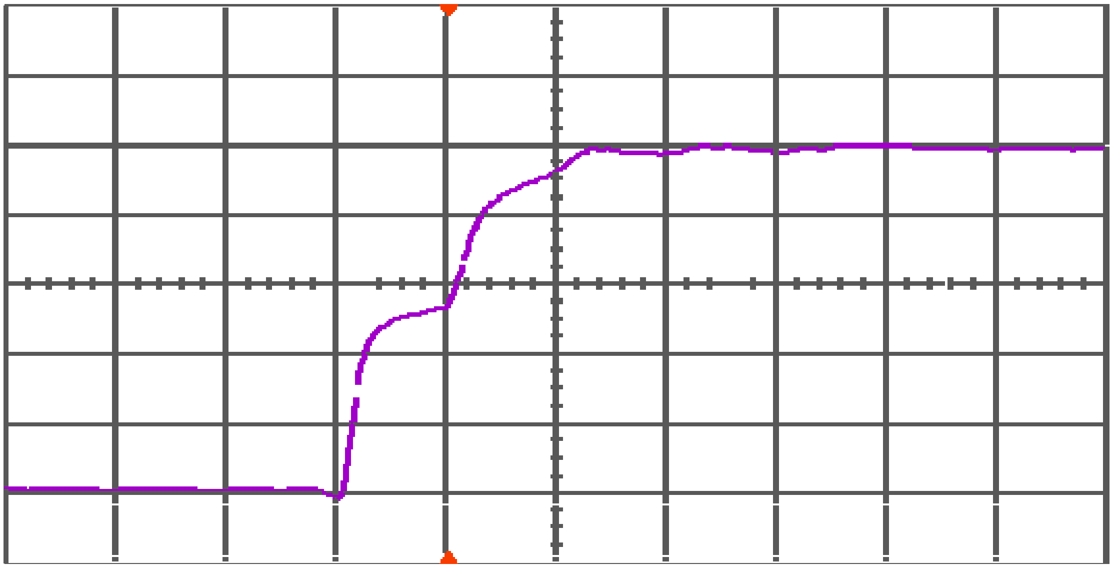

Figure 13(b) DUT 6 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

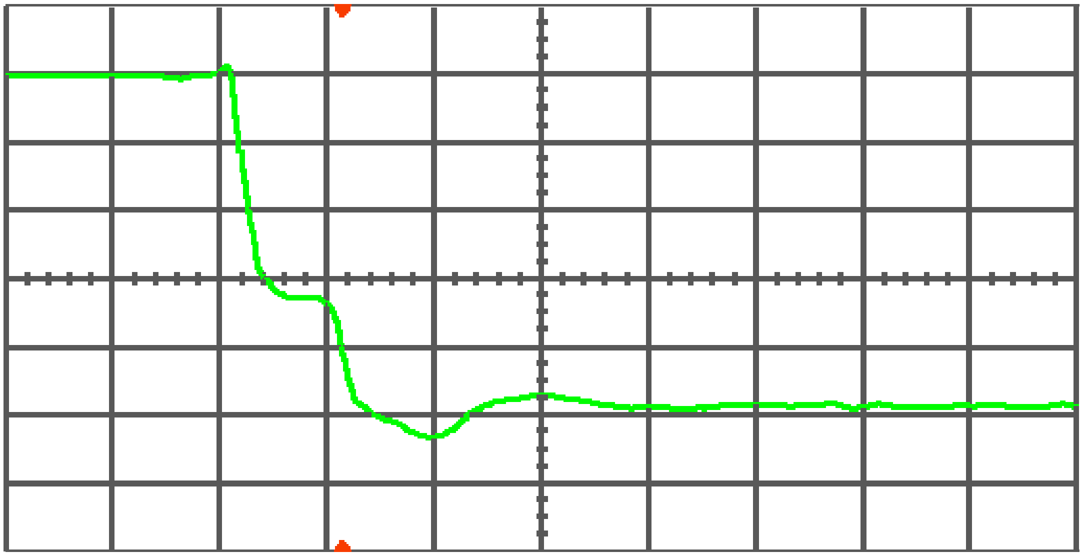

Figure 14(a) DUT 1 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

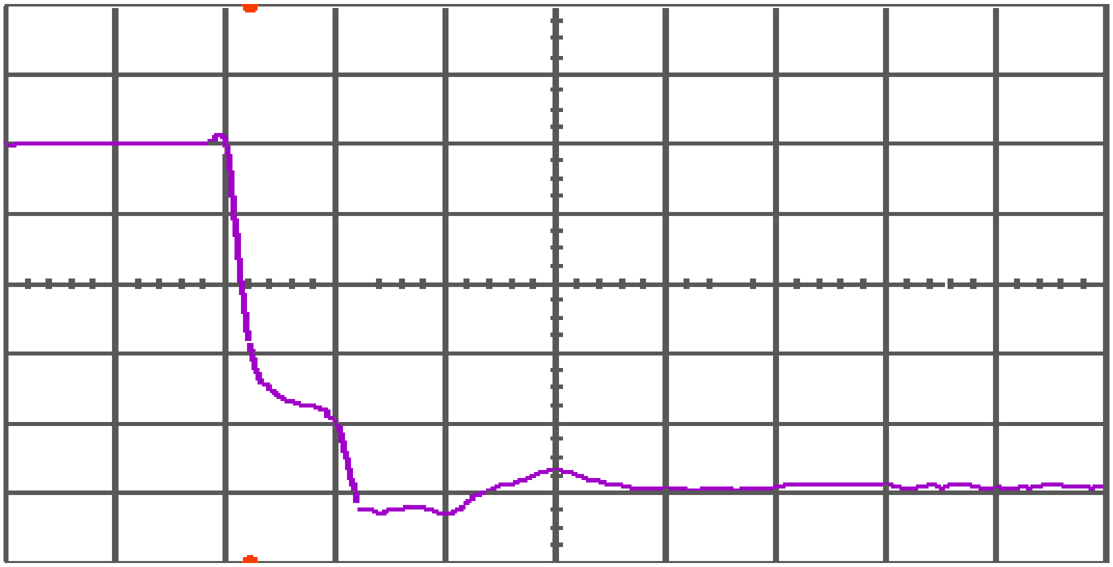

Figure 14(b) DUT 1 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

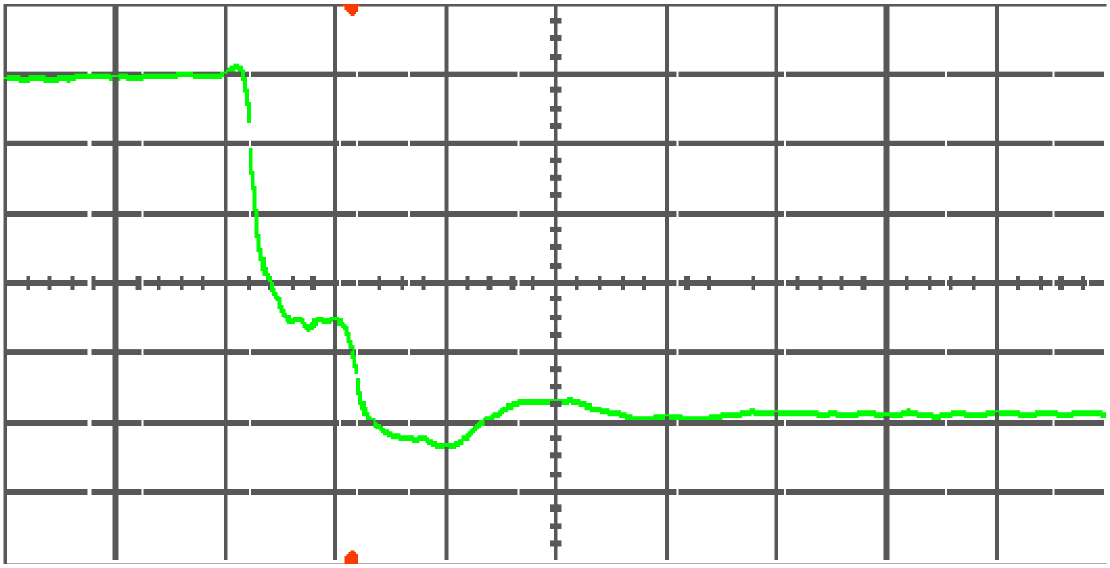

Figure 15(a) DUT 2 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

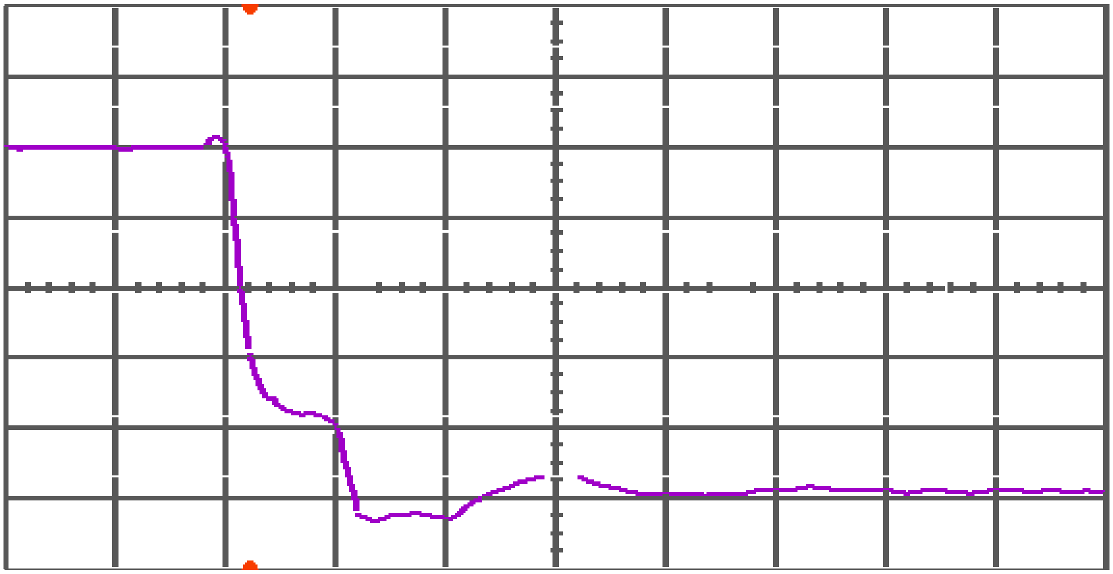

Figure 15(b) DUT 2 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

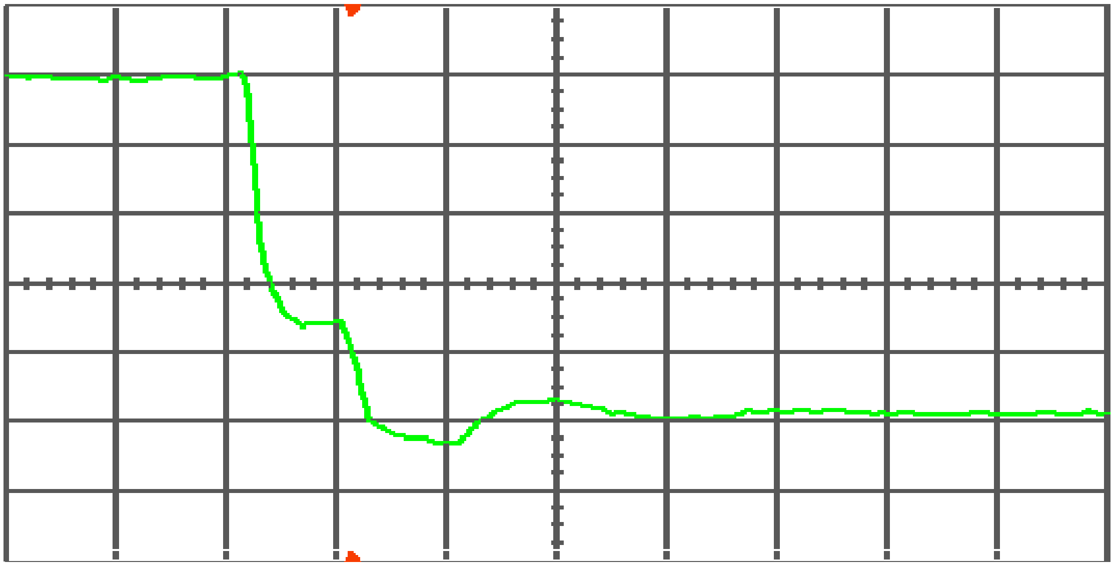

Figure 16a) DUT 3 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

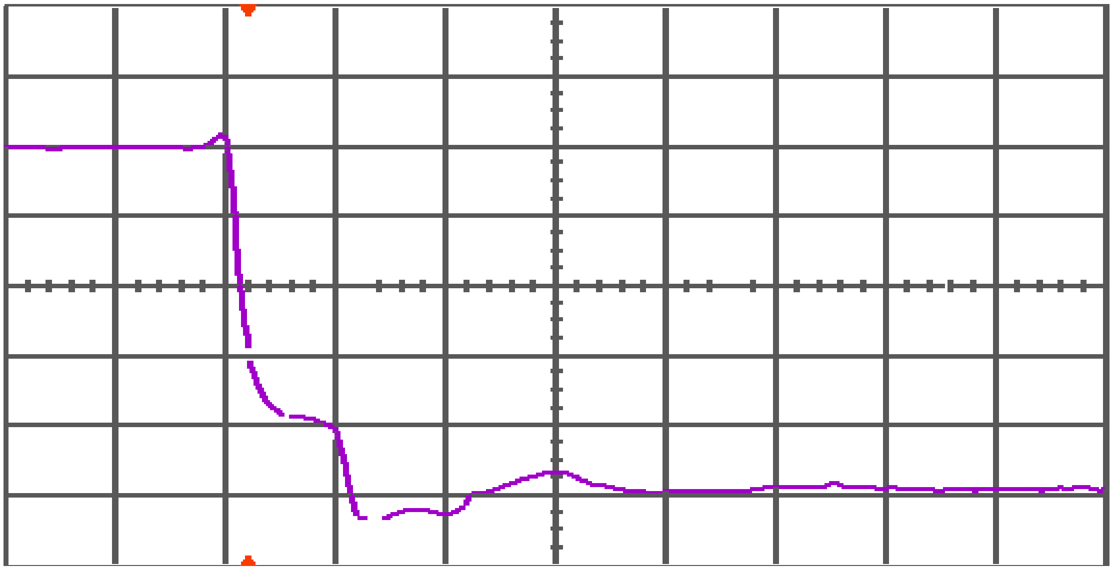

Figure 16(b) DUT 3 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

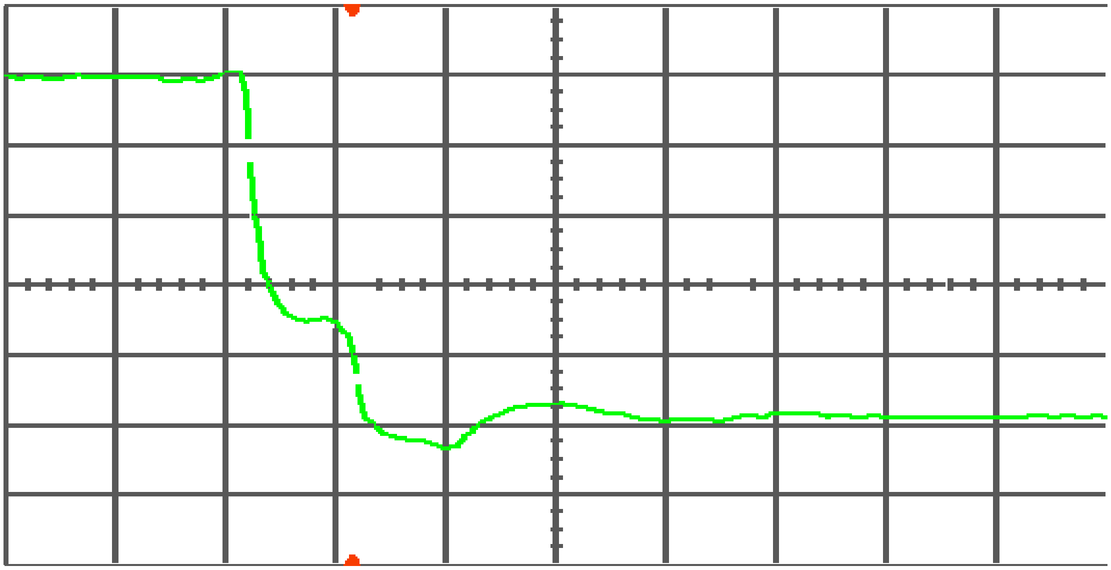

Figure 17(a) DUT 4 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

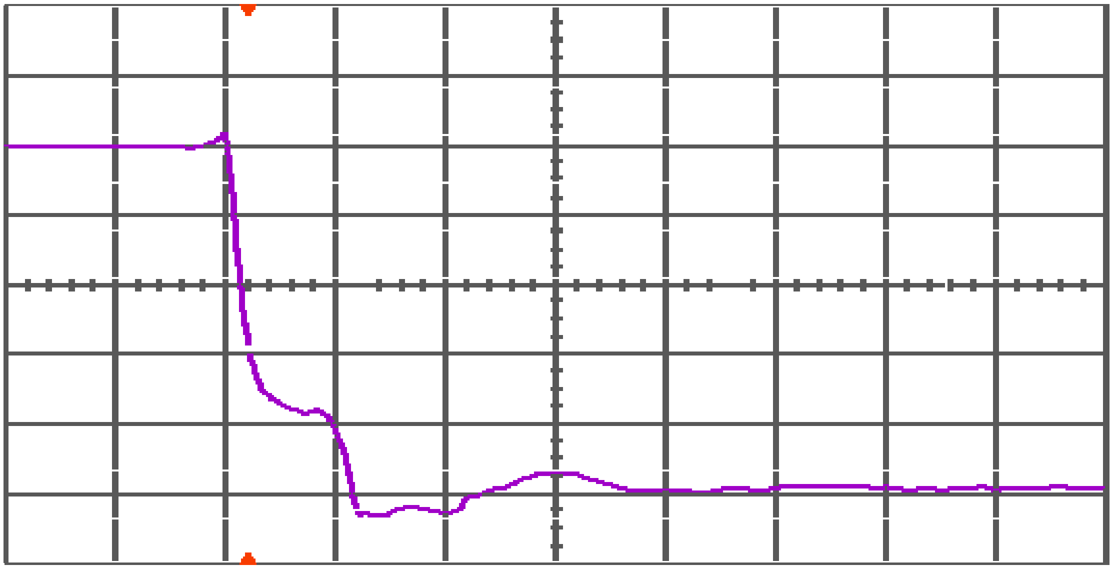

Figure 17(b) DUT 4 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

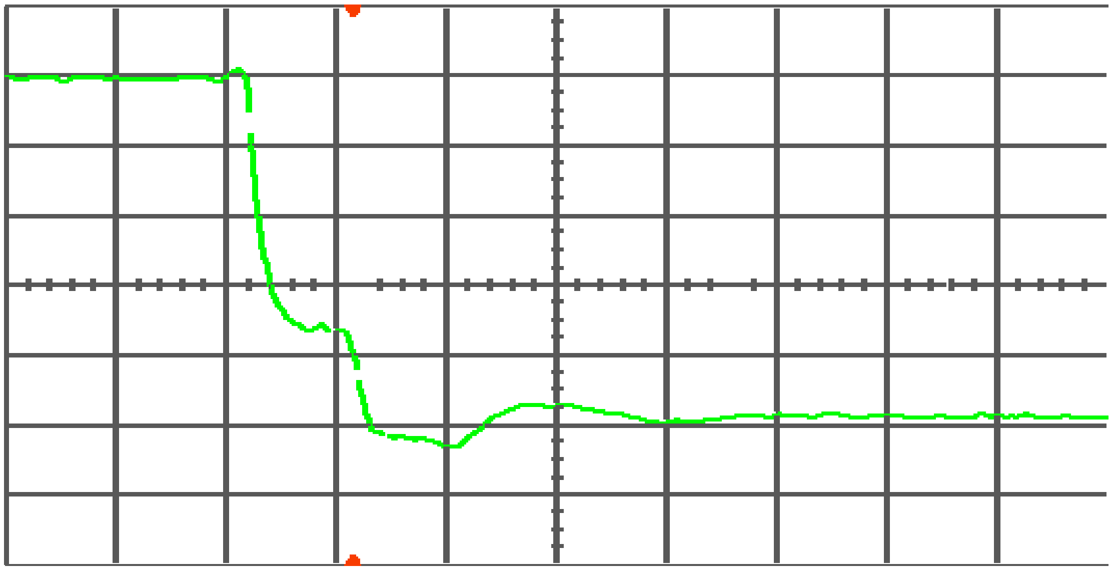

Figure 18(a) DUT 5 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

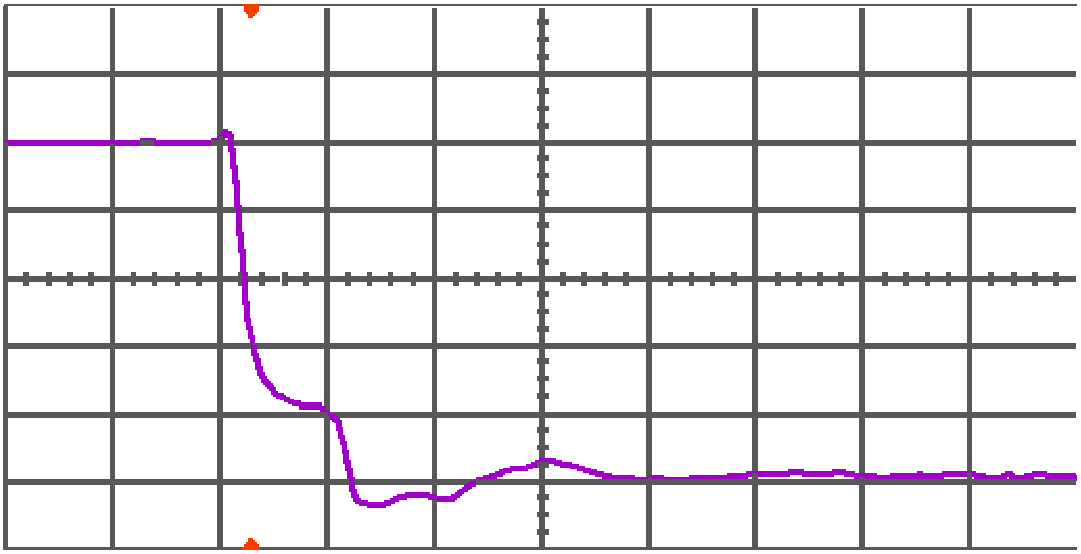

Figure 18(b) DUT 5 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

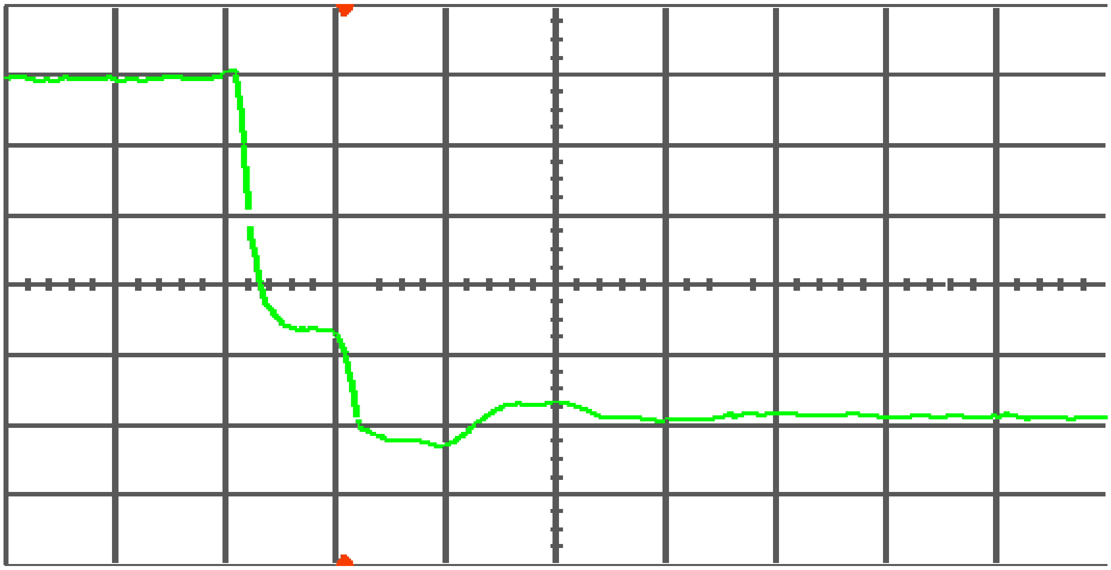

Figure 19(a) DUT 6 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.

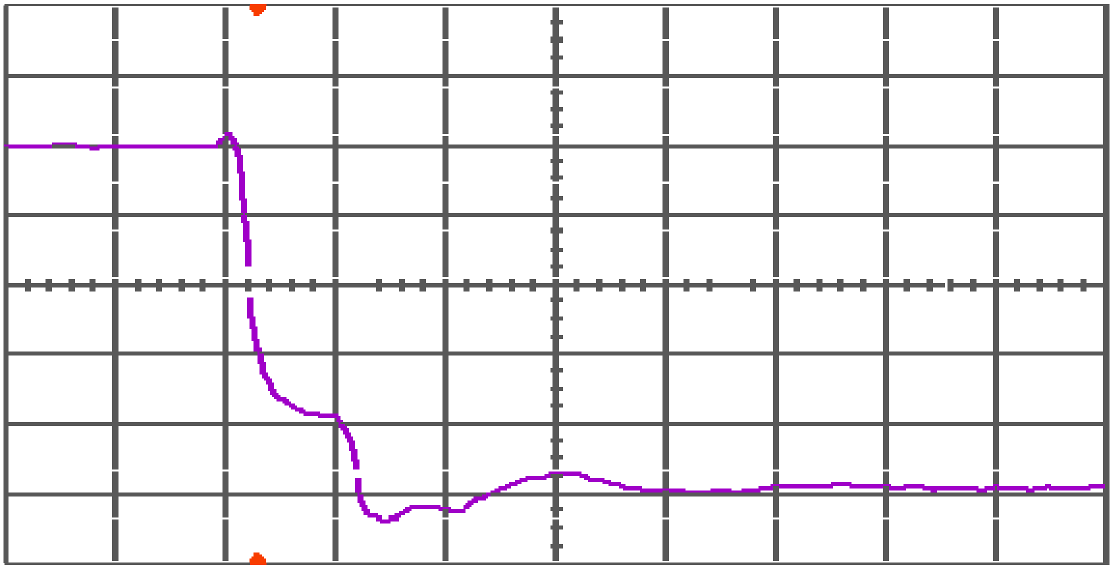

Figure 19(b) DUT 6 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 10 ns/div.