TOTAL IONIZING DOSE TEST REPORT

No. 07T-RT14100A-UBCL011
September 24, 2007
J.J. Wang
(650) 318-4576
jih-jong.wang@actel.com

I. Summary Table

Parameters	Tolerance
1. Gross Functional	Pass 8 krad(SiO_2)
2. $I_{DDSTDBY}$	Pass 8 krad(SiO_2)
3. V_{IL}/V_{IH}	Pass 8 krad(SiO_2)
4. V_{OL}/V_{OH}	Pass 8 krad(SiO_2)
5. Propagation Delays	Pass 8 krad(SiO_2)
6. Rising/Falling Edge Transient	Pass 8 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	UBCL011
Quantity Tested	6
Serial Numbers	2706, 2742, 2743, 2756, 2757, 2767

B. Irradiation

Table 2 lists the irradiation parameters.

Table 2 Irradiation Parameters

Facility	DMEA
Radiation Source	Co-60
Dose Rate	0.5 or 1 krad(SiO_2)/min (±10%)
Data Mode	Static
Temperature	Room
Bias	5.0 V

C. Test Method

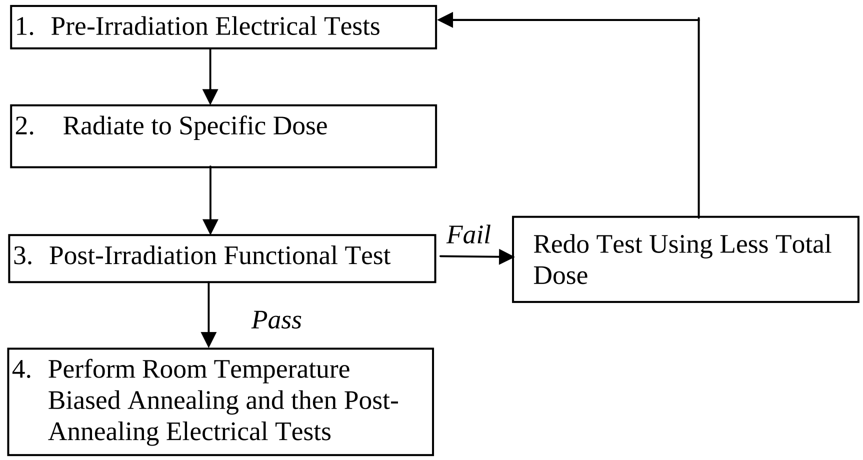

Figure 1 TID test flow chart

The test method 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 RT14100A 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 1 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_{CCA} (mA)		
		Pre-irrad	Post-irrad	Post-ann
2706	8	< 1	11.3	4.3
2742	8	< 1	14.6	4.2
2743	8	< 1	<20	4.2
2756	8	< 1	10.5	3.7
2757	8	< 1	13.4	2.6
2767	10	< 1	372.3	7.2

Figures 2 to 6 show the in-flux I_{CC}. The high I_{CC} surge near 8.5 krad(SiO_2) in Figure 6 is due to charge pump degradation. Note that in every DUT, the I_{CC} at 8 krad(SiO_2) is below the spec of 25 mA.

Table 4 show the pre-irradiation, post-irradiation and post-annealing I_{CC}; every DUT passes 25 mA spec.

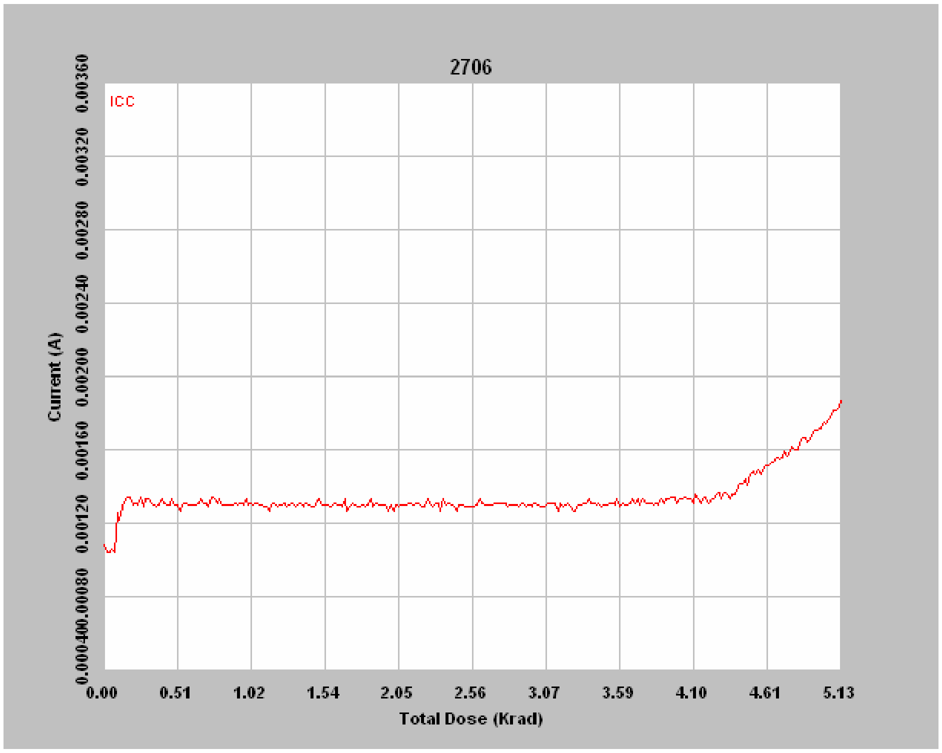

Figure 2a DUT 2706 in-flux I_{CC}, 0 to 5 krad(SiO_2).

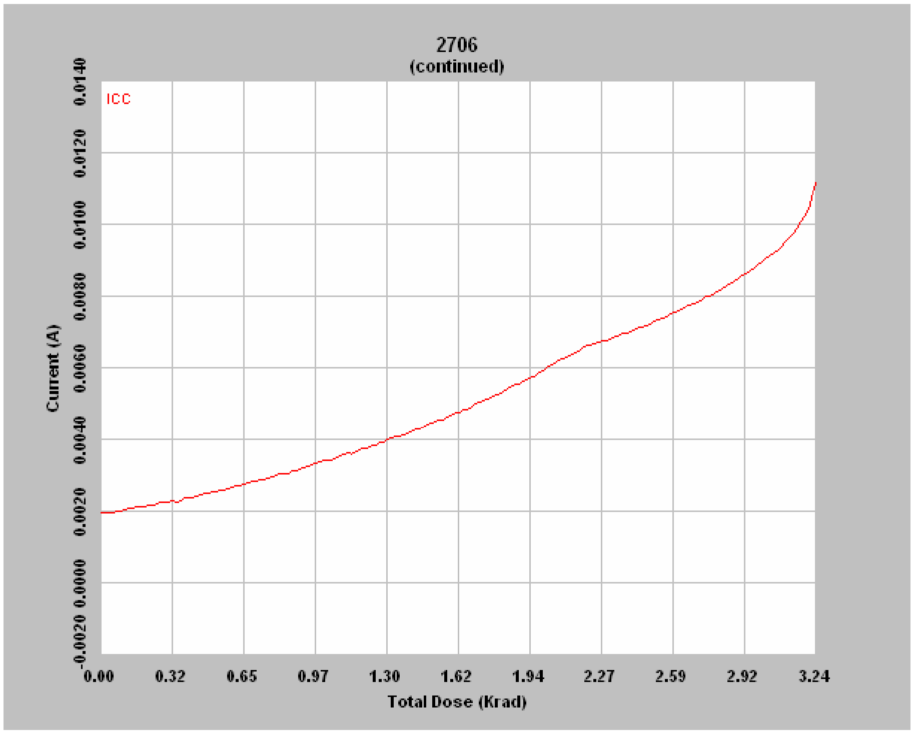

Figure 2b DUT 2706 in-flux I_{CC}, > 5 krad(SiO_2).

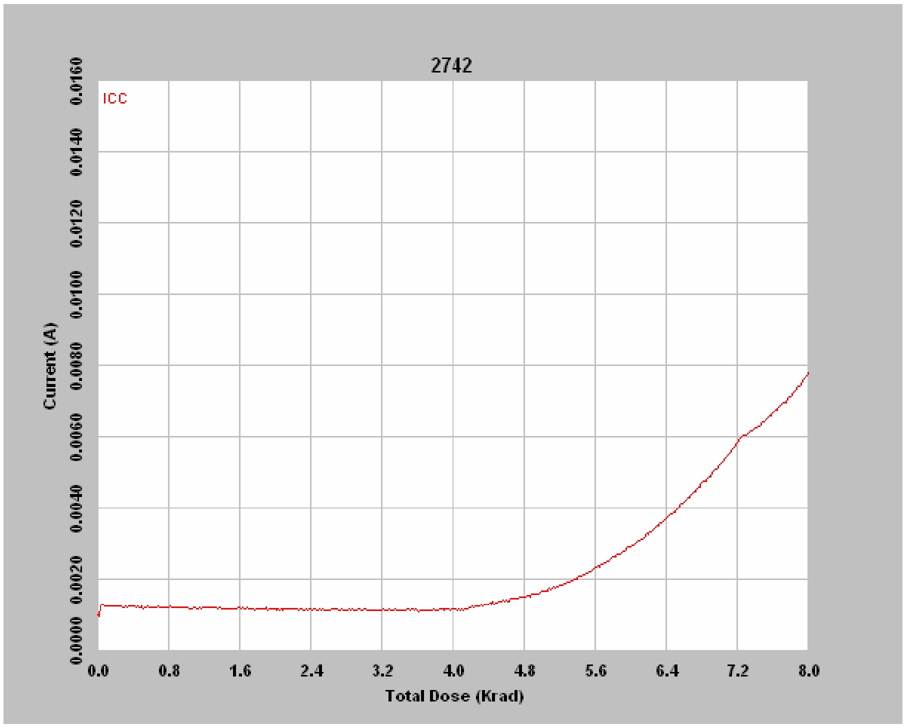

Figure 3 DUT 2742 in-flux I_{CC}

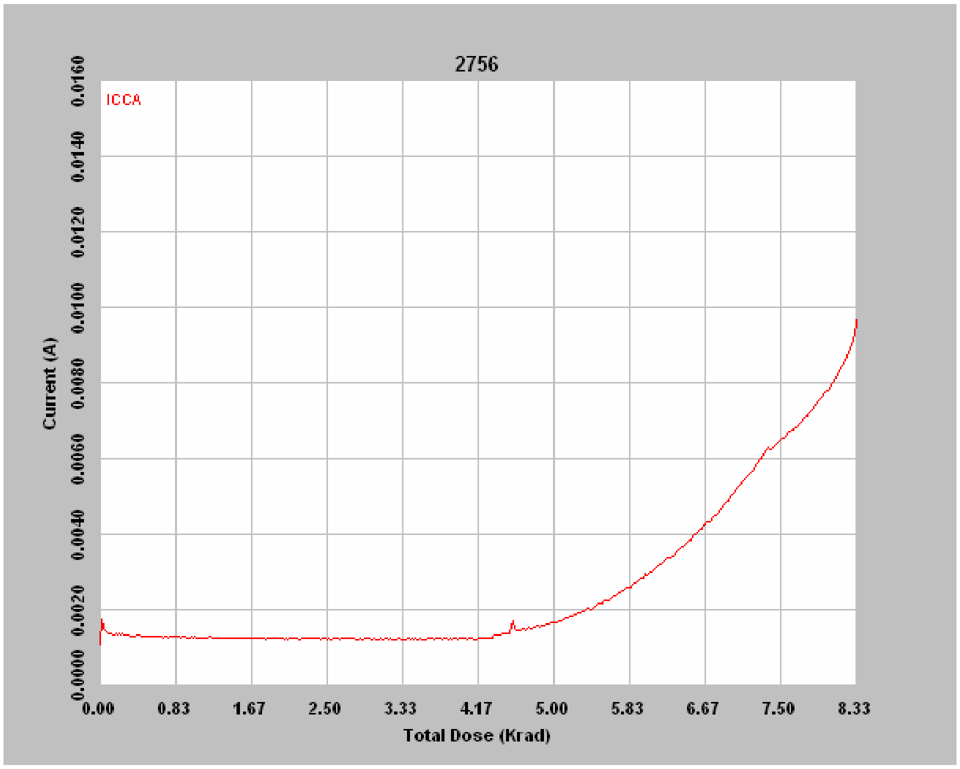

Figure 4 DUT 2756 in-flux I_{CC}

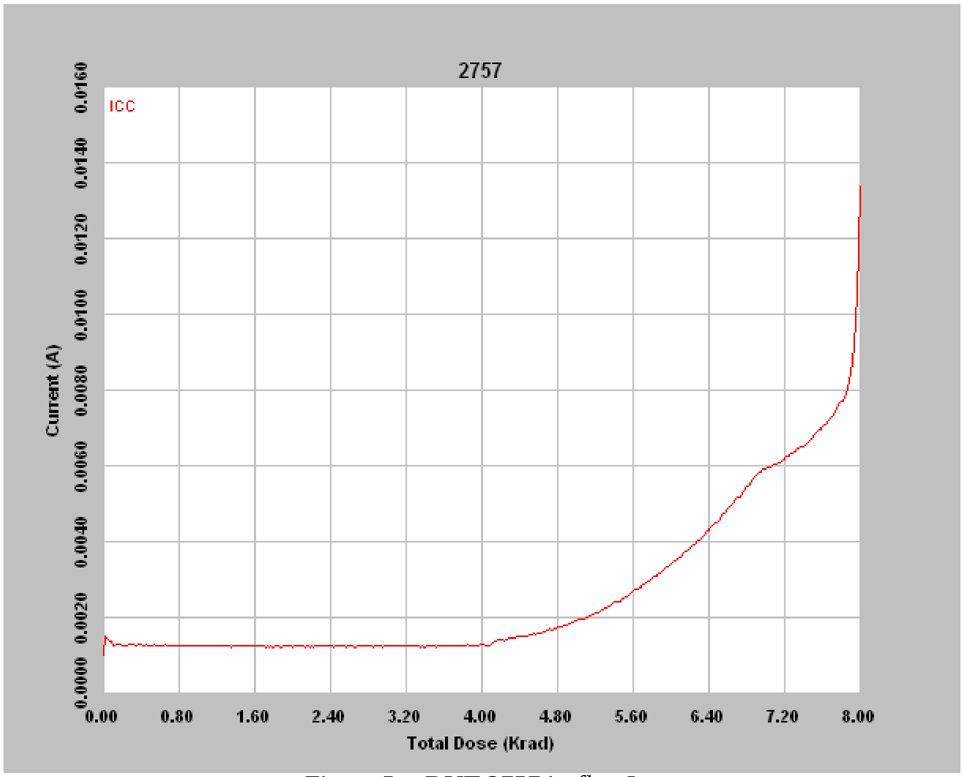

Figure 5 DUT 2757 in-flux I_{CC}

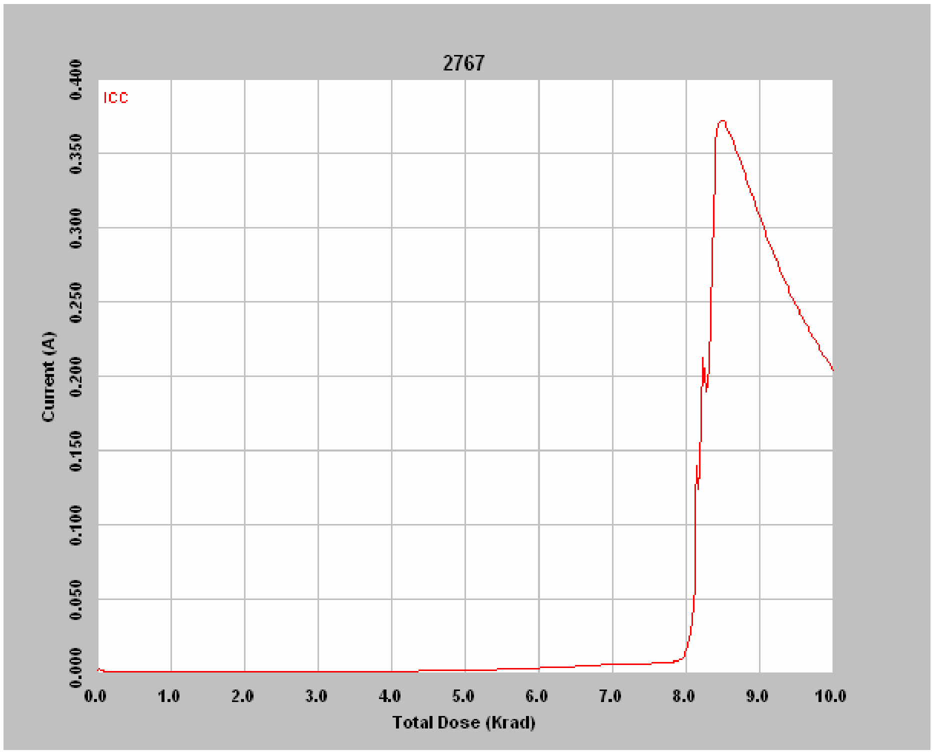

Figure 6 DUT 2767 in-flux I_{CC}

C. Input Logic Threshold

Table 4 lists the input logic threshold of each DUT for pre-irradiation and post-annealing; every data is with 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
2706	1.33	1.318	1.22	1.235
2742	1.316	1.311	1.204	1.228
2743	1.317	1.314	1.197	1.230
2756	1.319	1.31	1.224	1.226
2757	1.318	1.308	1.226	1.233
2767	1.314	1.306	1.216	1.234

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

	2706		2742		2743	
Current (mA)	Pre-Irrad (mV)	Post-Ann (mV)	Pre-Irrad (mV)	Post-Ann (mV)	Pre-Irrad (mV)	Post-Ann (mV)
0	-35.2	-32.2	-38.4	-33.1	-39.8	-33.4
1	-11.2	-8	-13.7	-8.1	-15.3	-9
2	14.1	16.9	11.2	16.7	10.2	15.8
5	91.9	91.4	88.4	91.8	88.6	91.3
10	225	219.6	225	221.8	225	220.5
20	499	479.8	498.4	481.9	501	481.9
24	616	590.3	617	592.3	620	592.3

Table 6b V_{OL} for various drive currents

	2756		2757		2767	
Current (mA)	Pre-Irrad (mV)	Post-Ann (mV)	Pre-Irrad (mV)	Post-Ann (mV)	Pre-Irrad (mV)	Post-Ann (mV)
0	-37	-34.3	-37.5	-32.2	-37.4	-34.2
1	-12.3	-9.9	-13.7	-8.7	-13.1	-9.6
2	12.3	13.4	11.2	14.9	11.7	14.8
5	89.5	88.6	87.3	88.5	89.1	88.5
10	224	216.9	218.2	212.8	221	216
20	498	475.4	484.6	465.7	491.6	473.6
24	615	584.7	599.6	573.4	608.2	583

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

	2706		2742		2743	
Current (mA)	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
0	4.981	4.993	4.977	4.992	4.978	4.992
-1	4.93	4.944	4.927	4.942	4.927	4.943
-2	4.88	4.893	4.875	4.891	4.875	4.89
-5	4.724	4.735	4.716	4.73	4.716	4.727
-10	4.451	4.466	4.438	4.454	4.434	4.452
-20	3.848	3.86	3.817	3.833	3.811	3.826
-24	3.576	3.59	3.534	3.555	3.526	3.547

Table 7b V_{OH} for various drive currents

	2756		2757		2767	
Current (mA)	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
0	4.979	4.988	4.981	4.991	4.981	4.99
-1	4.928	4.939	4.929	4.94	4.93	4.94
-2	4.876	4.888	4.877	4.889	4.88	4.889
-5	4.719	4.729	4.717	4.726	4.724	4.724
-10	4.442	4.455	4.434	4.446	4.451	4.446
-20	3.826	3.84	3.806	3.818	3.848	3.816
-24	3.548	3.568	3.518	3.535	3.576	3.532
-50	-0.848	-0.845	-0.865	-0.864	-0.836	-0.861

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
2706	8	881.1	894.45	1.52%
2742	8	876.6	886.15	1.09%
2743	8	883.45	898.6	1.71%
2756	8	877.5	891.4	1.58%
2757	8	904.3	919.15	1.64%
2767	10	912.6	959.3	5.12%

F. Transient Characteristics

The rising and falling edge transient of an output is measured pre-irradiation and post-annealing. Figures 7 to 18 show the pre-irradiation and post-annealing transition edges. In each case, the radiation-induced transition-time degradation is not observable.

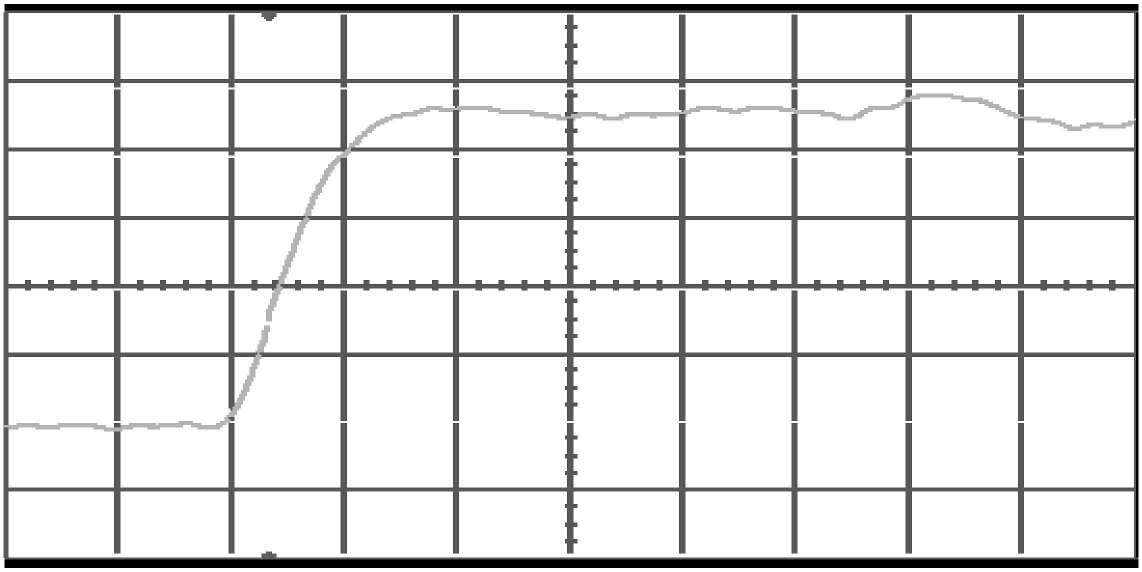

Figure 7(a) DUT 2706 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

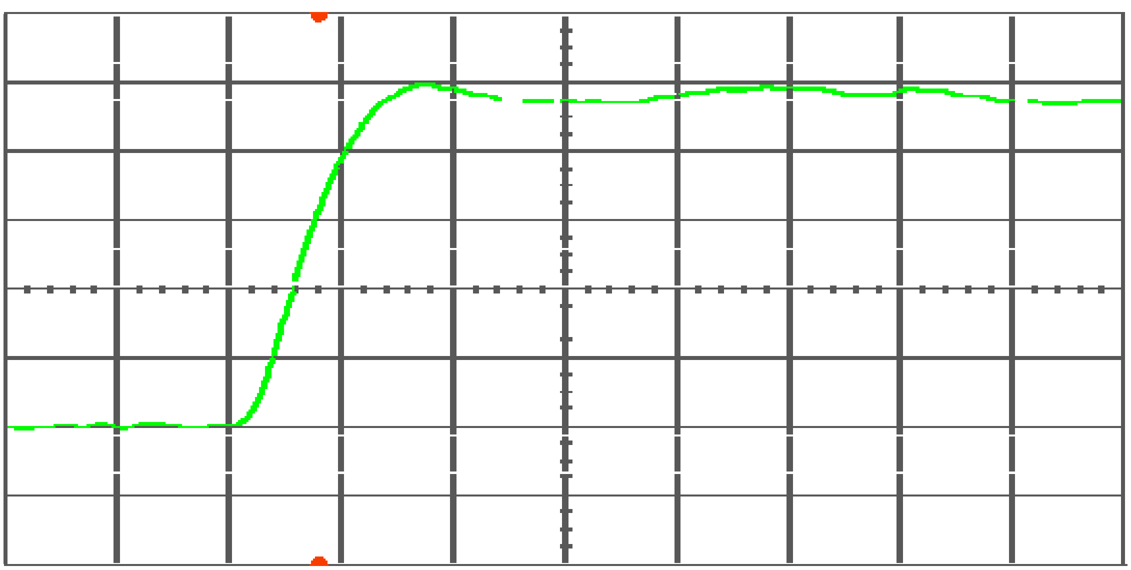

Figure 7(b) DUT 2706 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

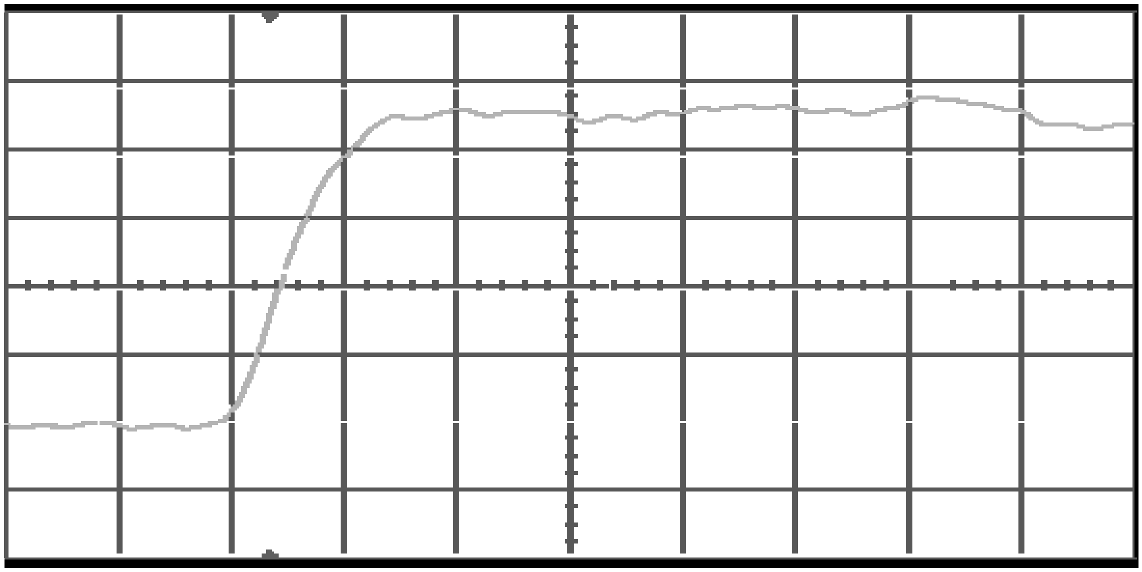

Figure 8(a) DUT 2742 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

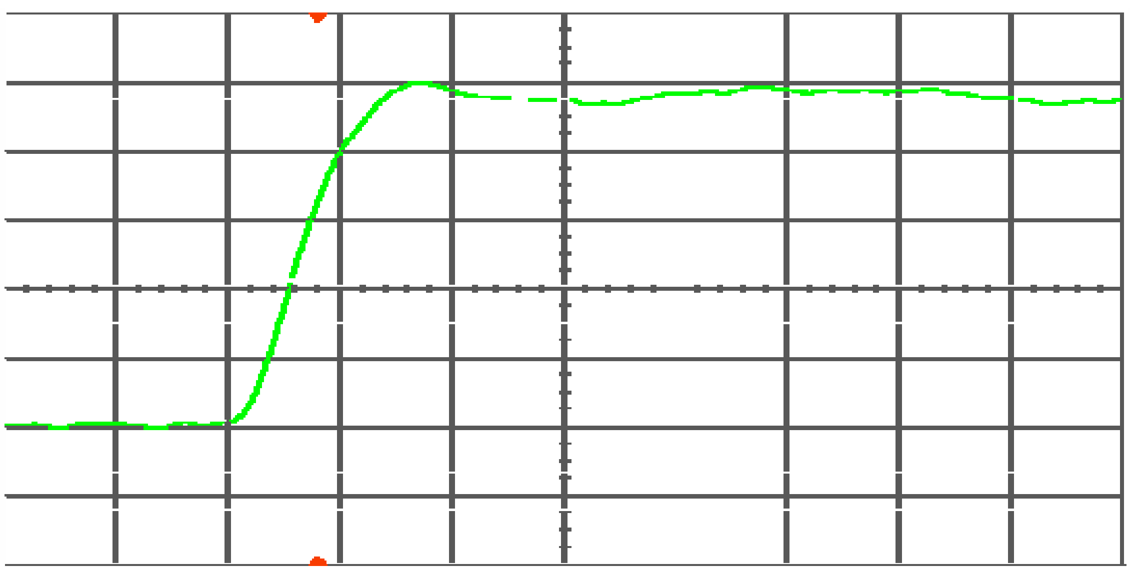

Figure 8(b) DUT 2742 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

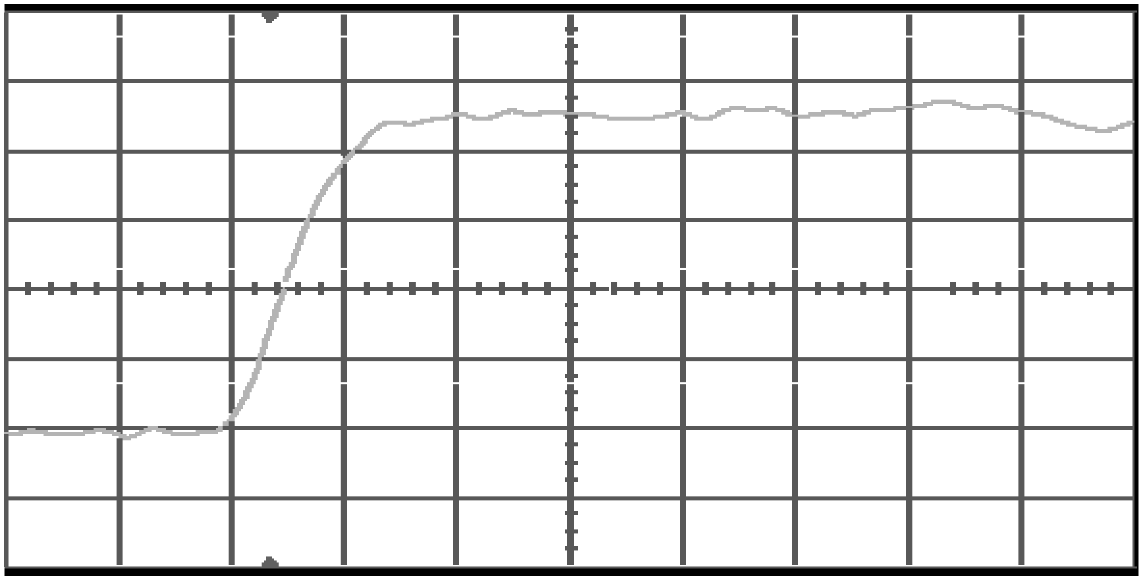

Figure 9(a) DUT 2743 pre-radiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

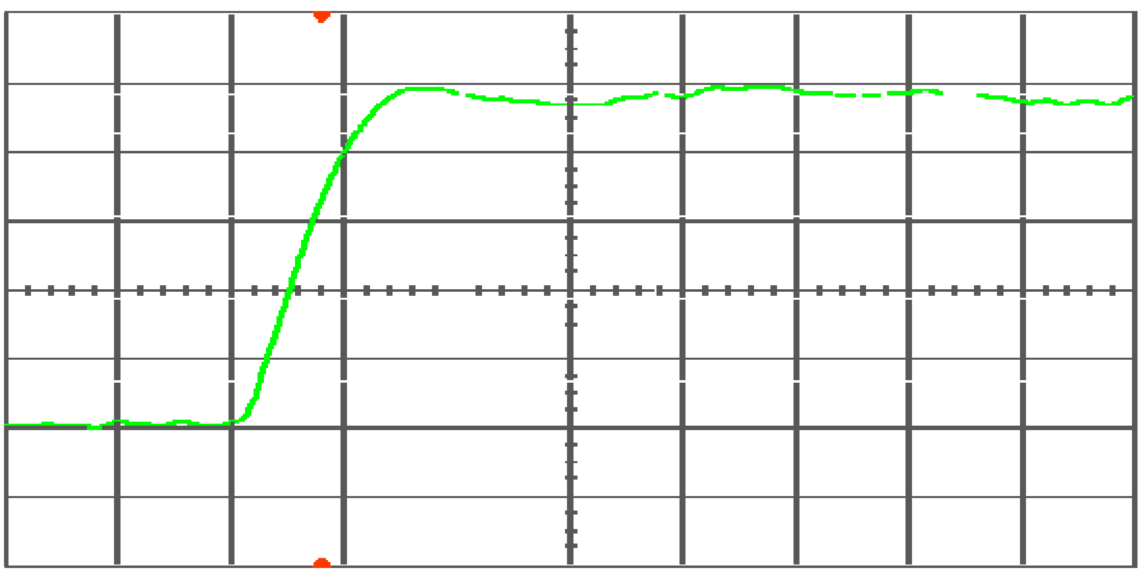

Figure 9(b) DUT 2743 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

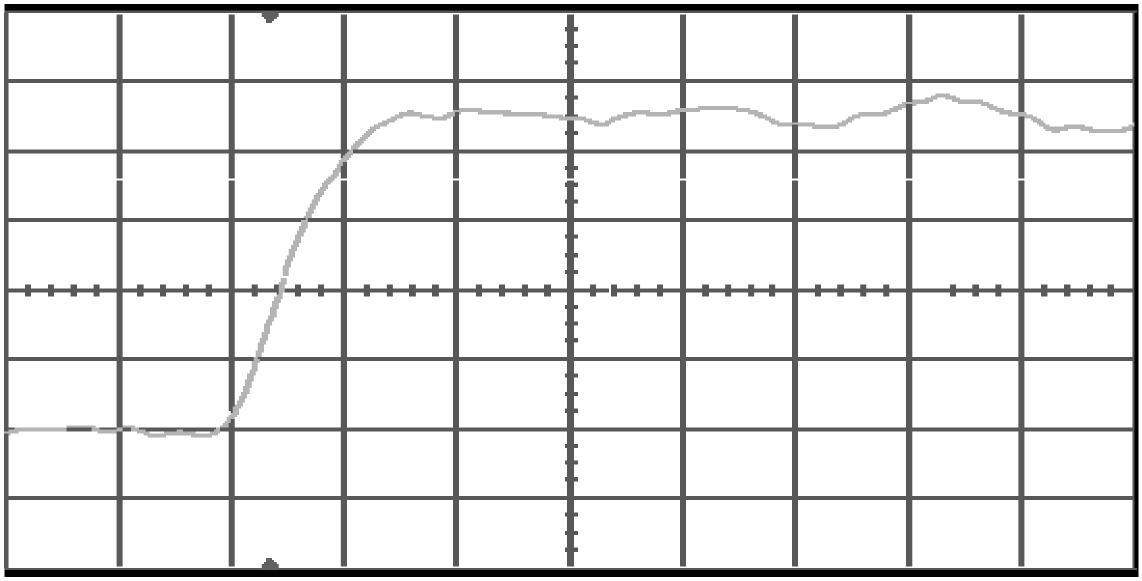
Figure 10(a) DUT 2756 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

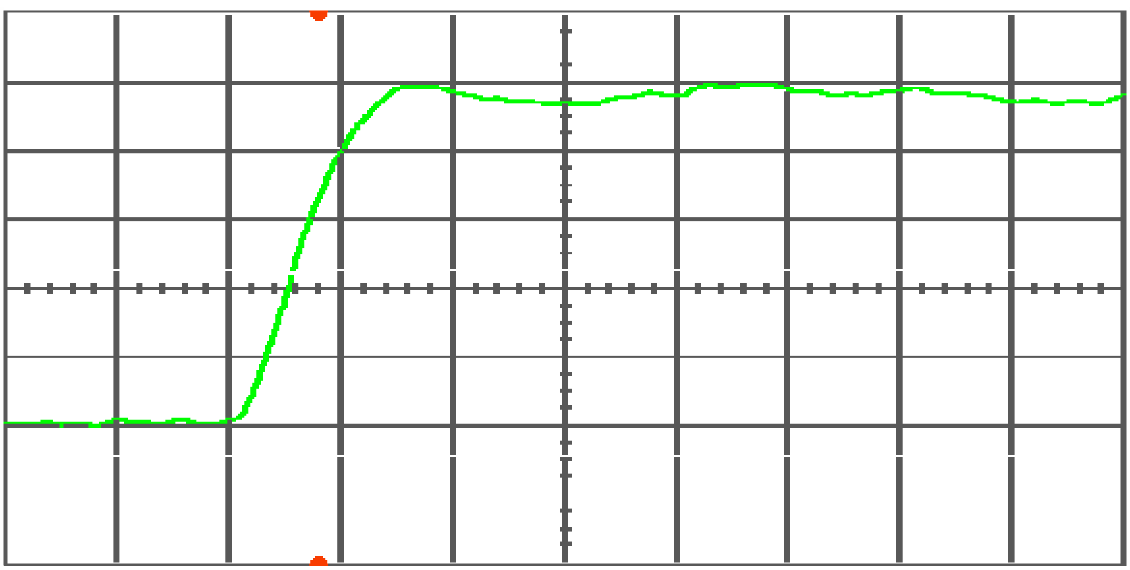
Figure 10(b) DUT 2756 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

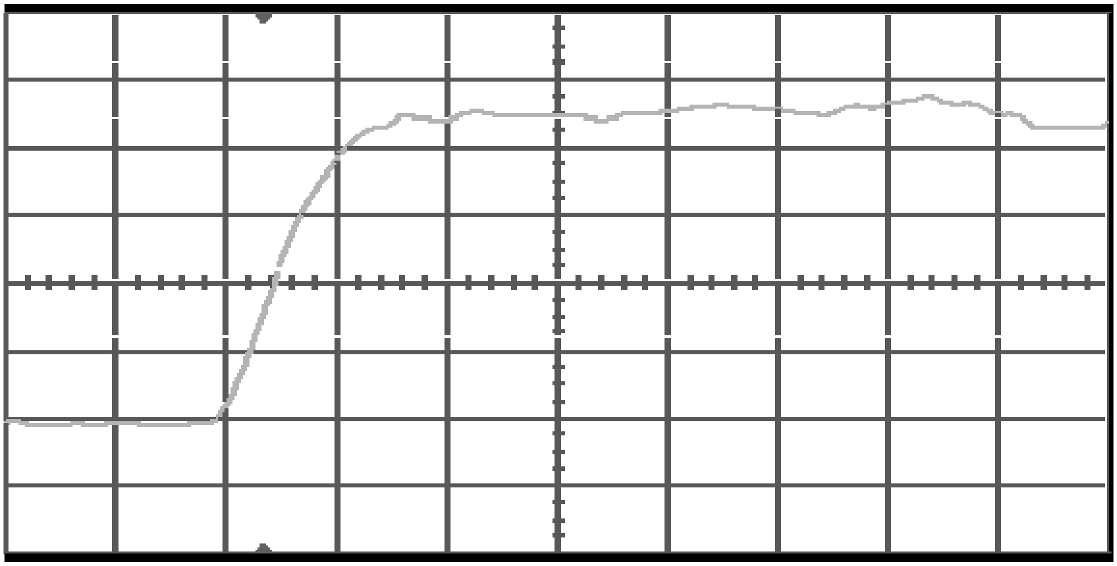

Figure 11(a) DUT 2757 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

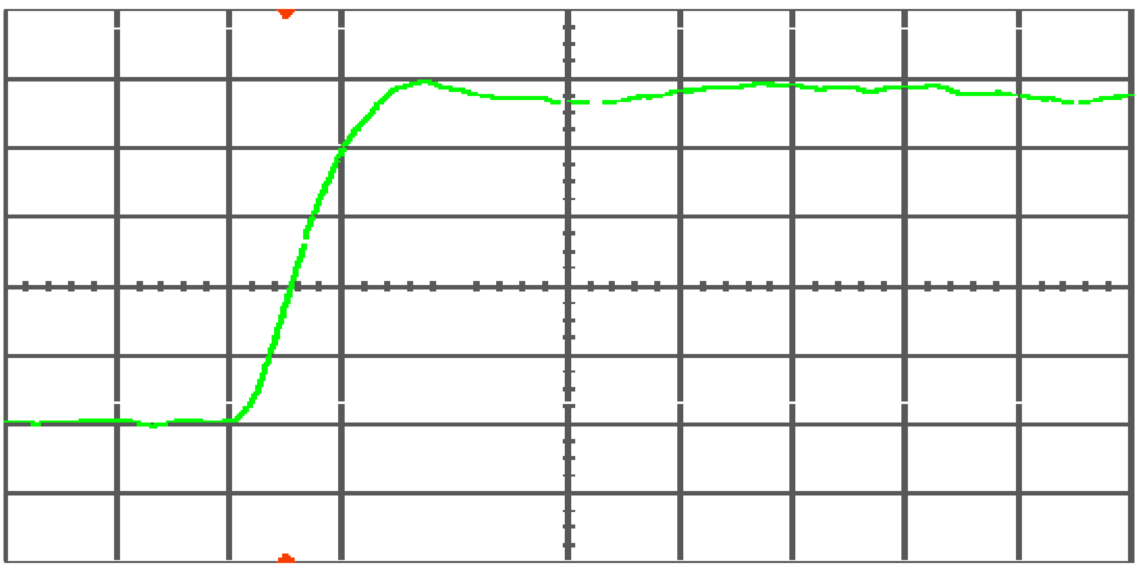

Figure 11(b) DUT 2757 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

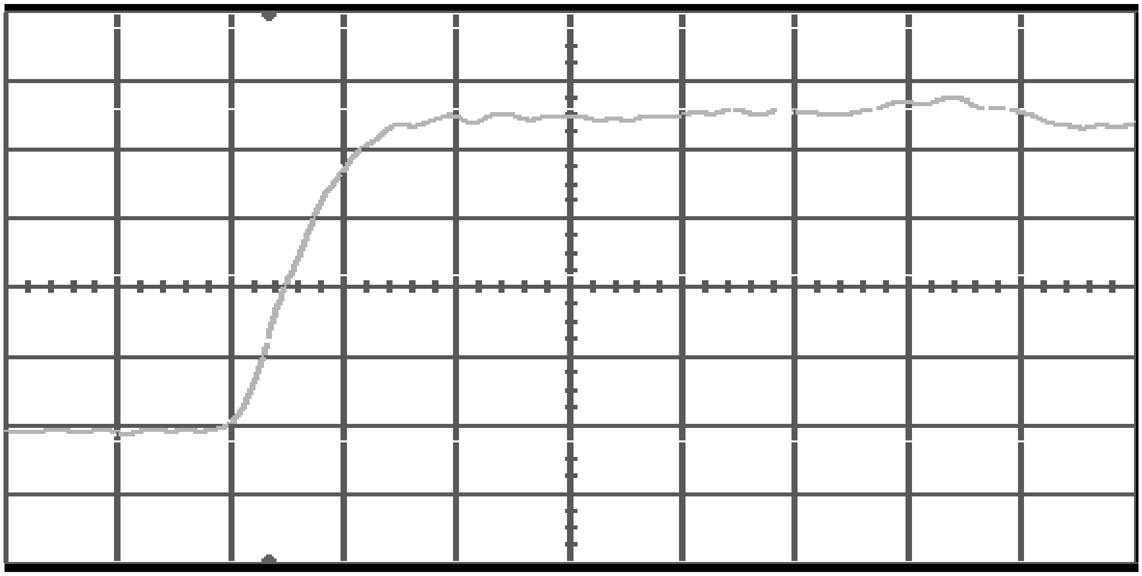

Figure 12(a) DUT 2767 pre-irradiation rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

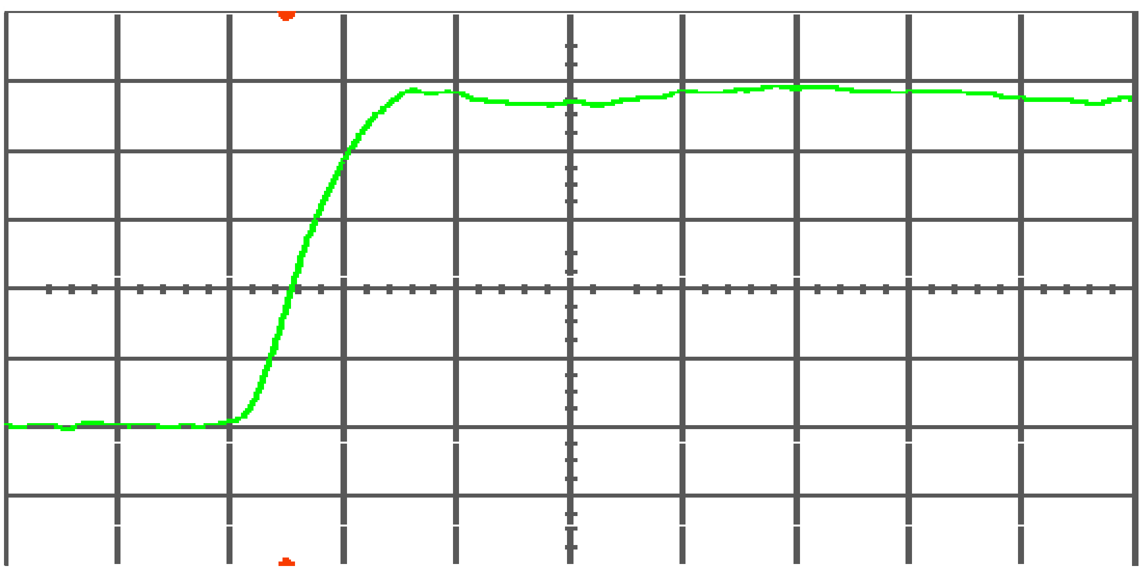

Figure 12(b) DUT 2767 post-annealing rising edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

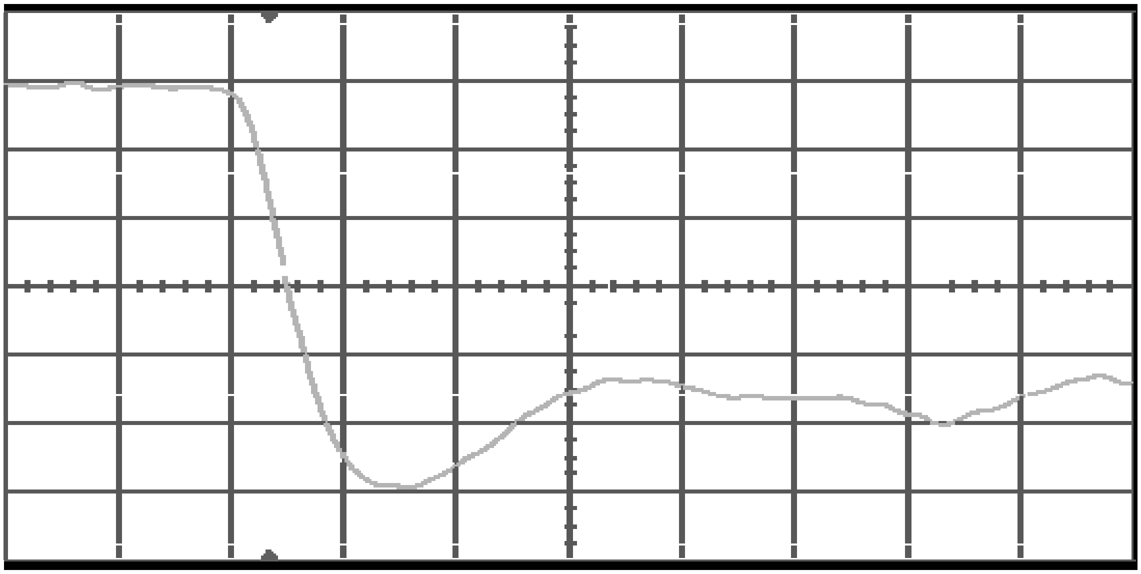

Figure 13(a) DUT 2706 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

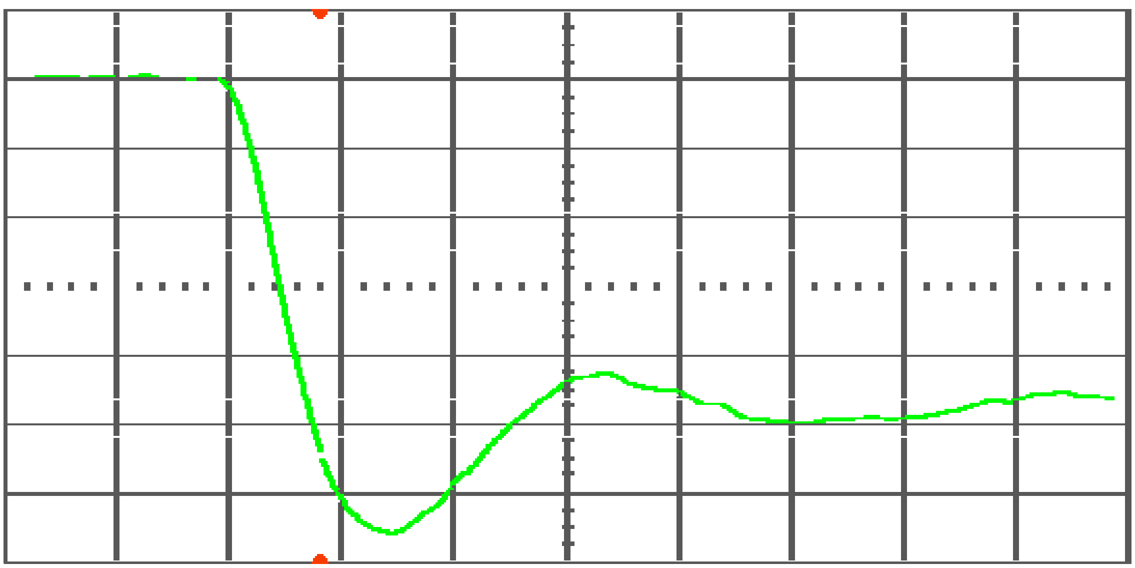

Figure 13(b) DUT 2706 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

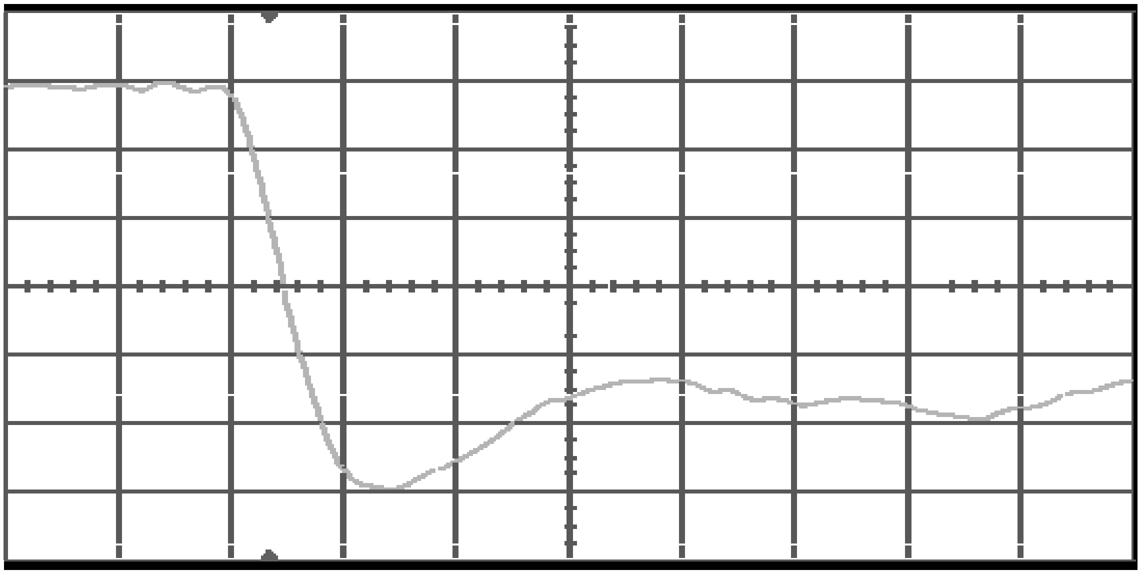

Figure 14(a) DUT 2742 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

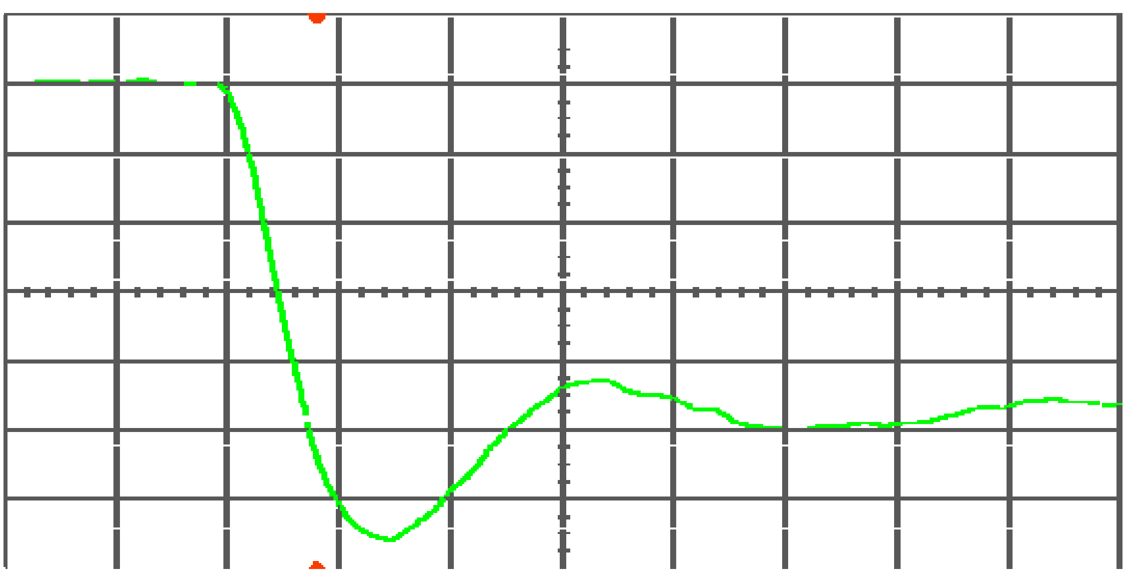

Figure 14(b) DUT 2742 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

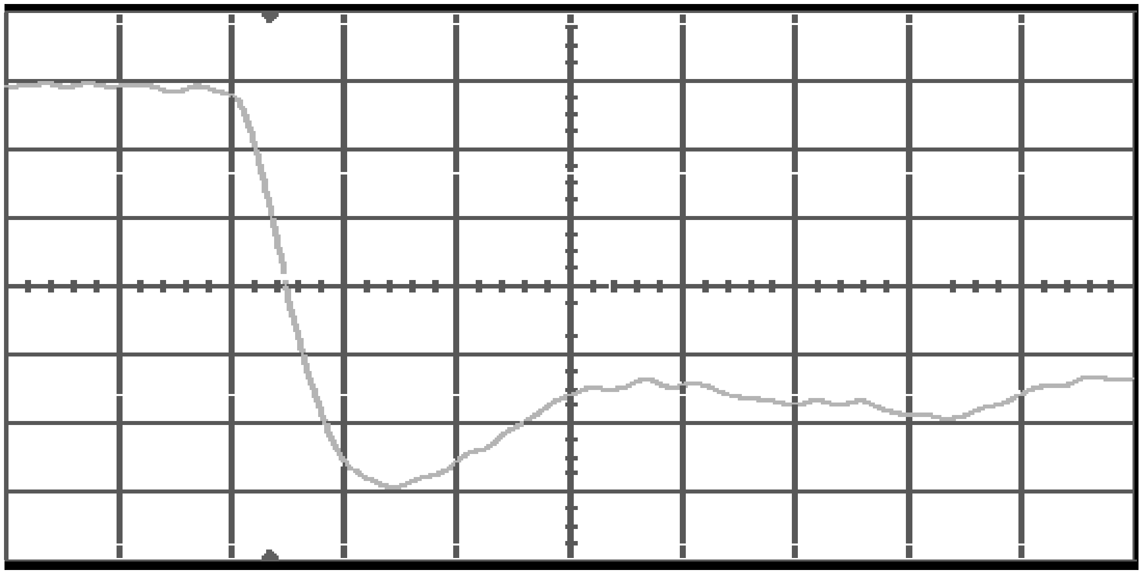

Figure 15(a) DUT 2743 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

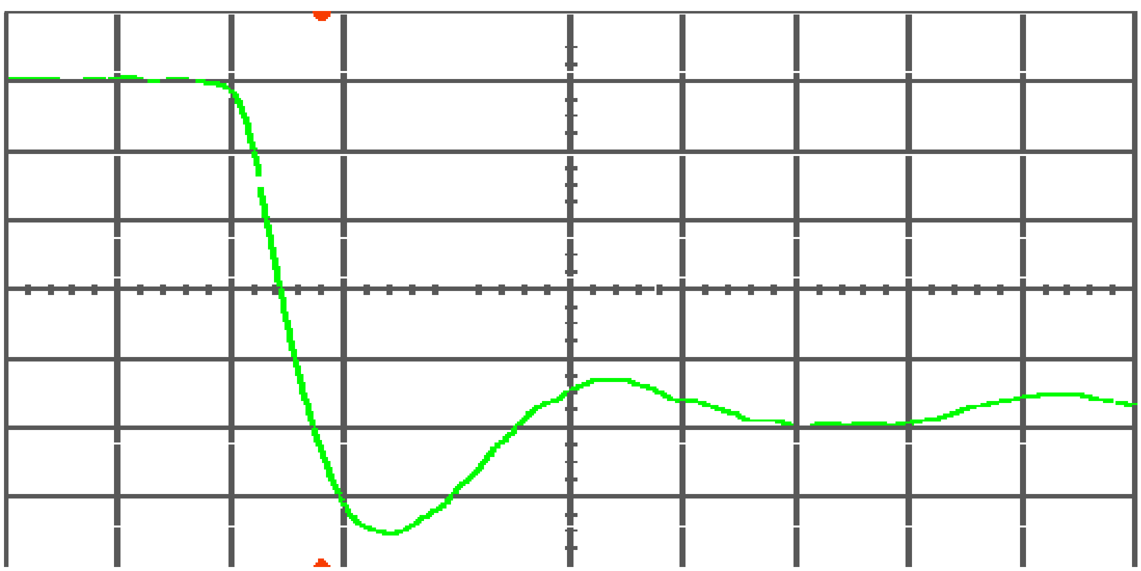

Figure 15(b) DUT 2743 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

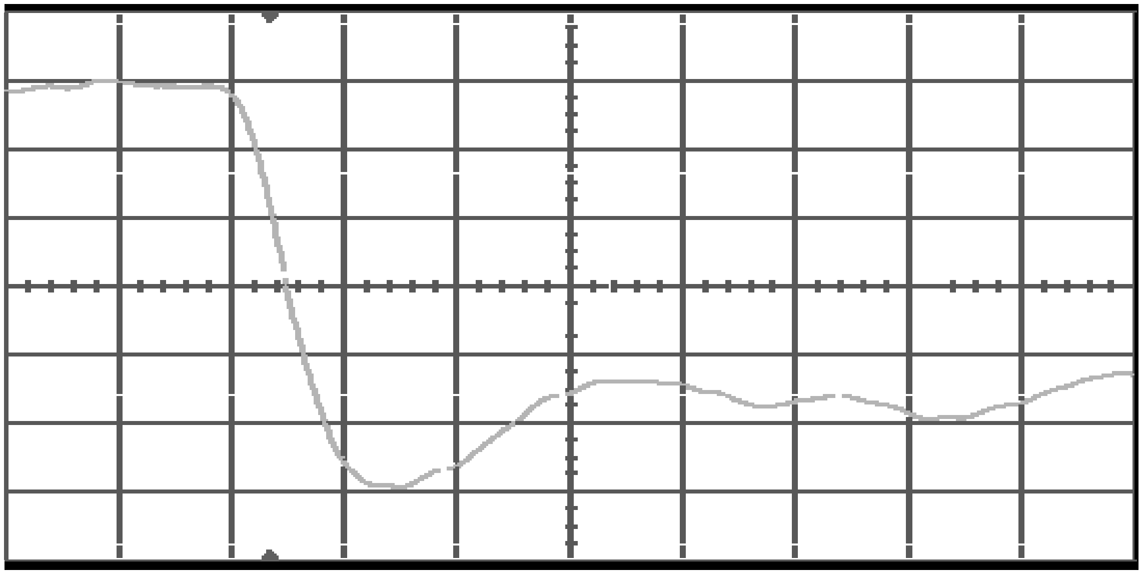

Figure 16(a) DUT 2756 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

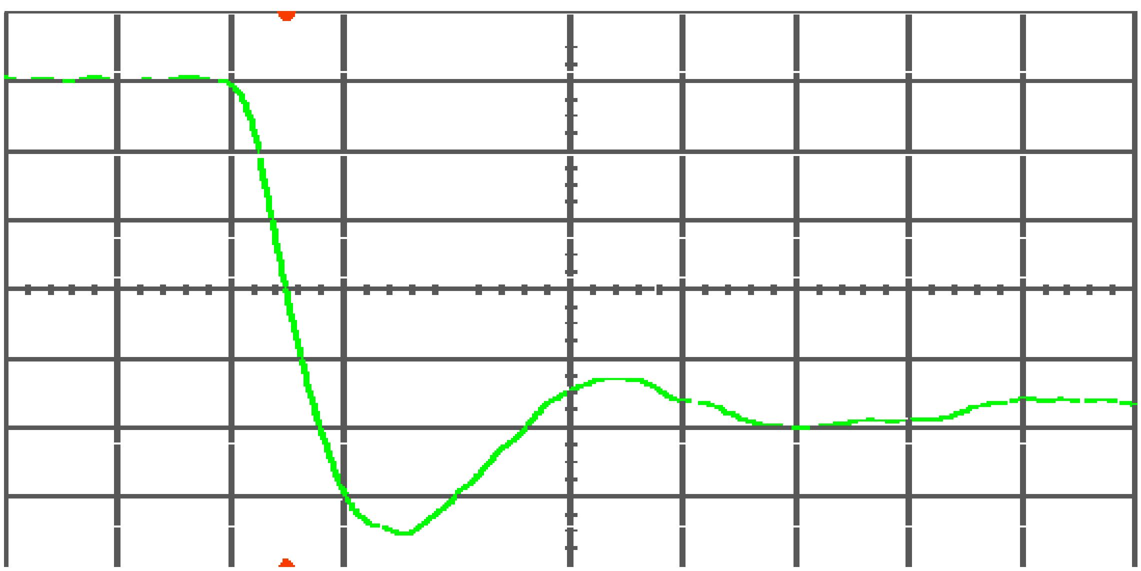

Figure 16(b) DUT 2756 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

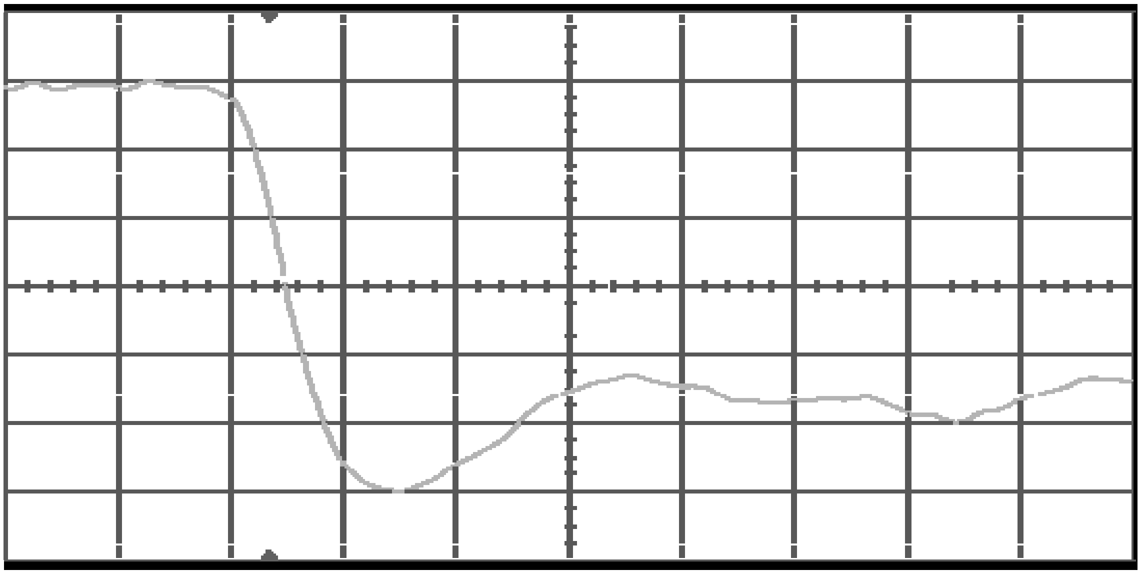
Figure 17(a) DUT 2757 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

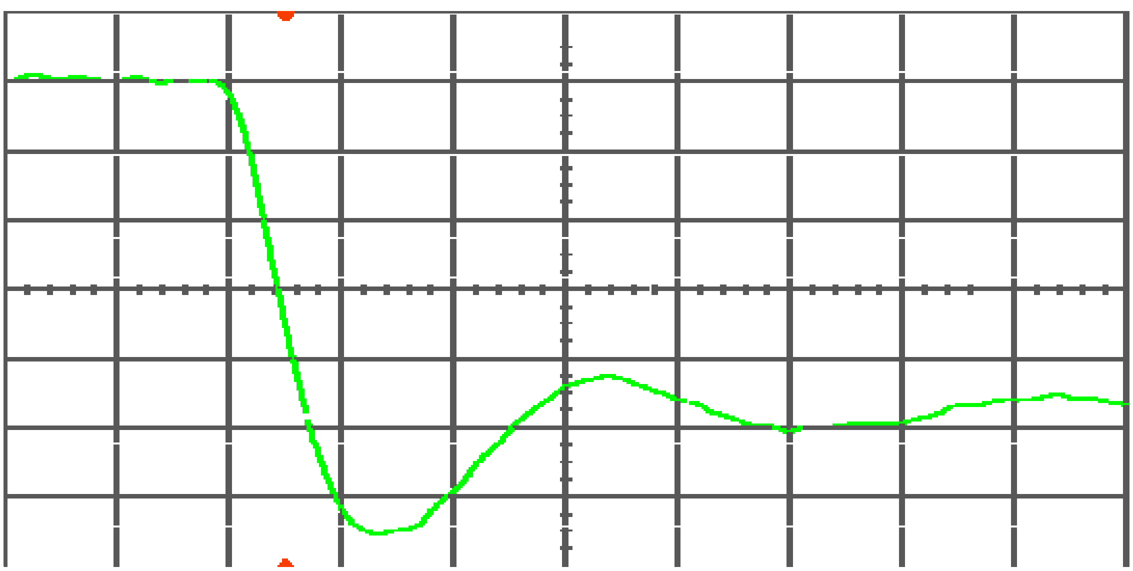
Figure 17(b) DUT 2757 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

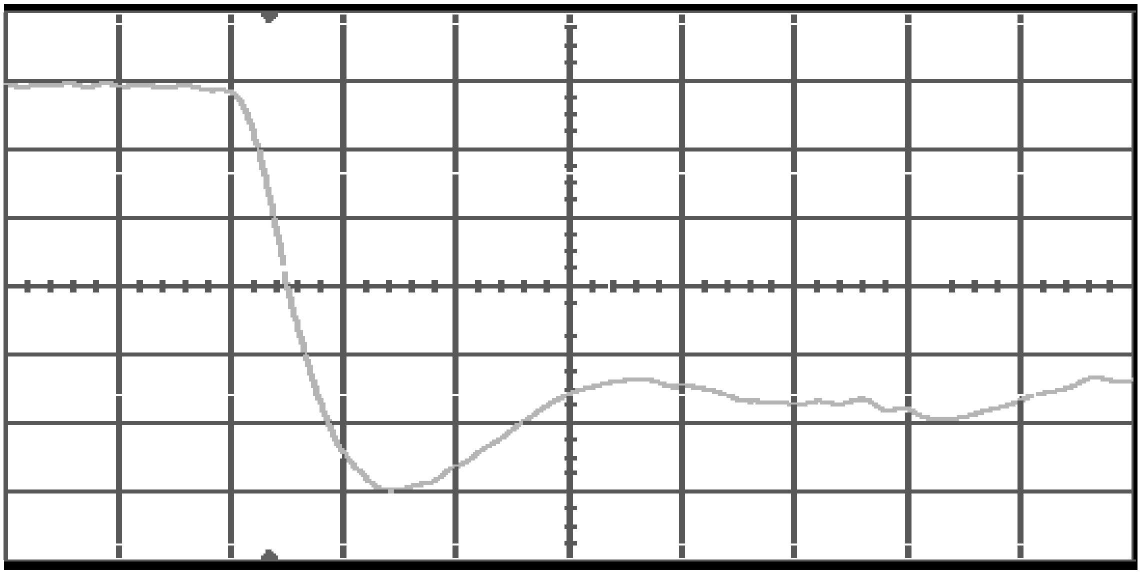

Figure 18(a) DUT 2767 pre-irradiation falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.

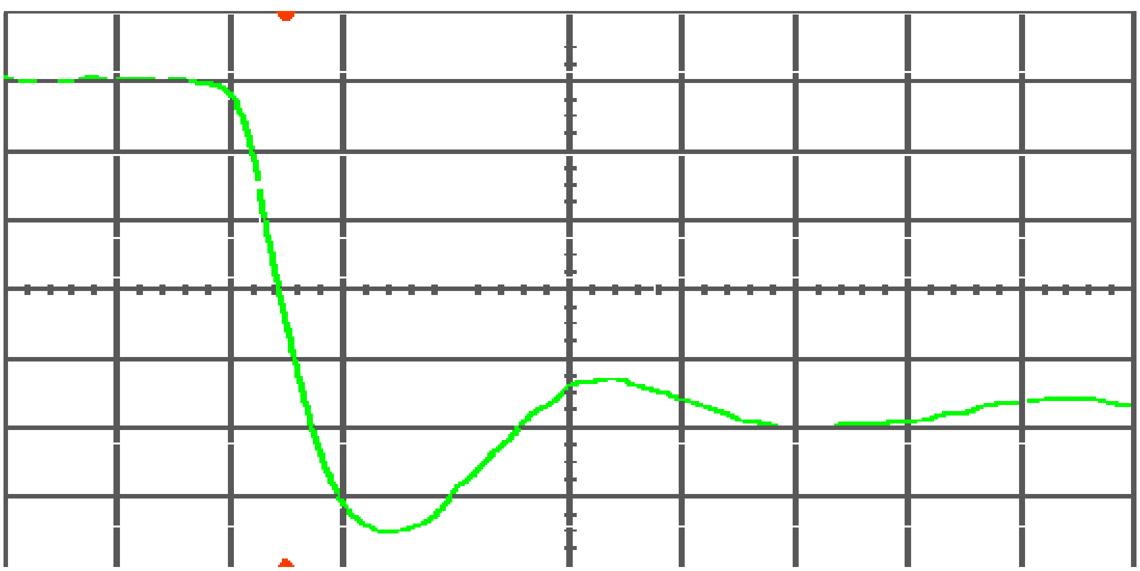

Figure 18(b) DUT 2767 post-annealing falling edge, abscissa scale is 1 V/div and ordinate scale is 2 ns/div.