TOTAL IONIZING DOSE TEST REPORT

No. 10T-RTSX32SU-D1RH51
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I. Summary Table

Parameter	Tolerance
1. Gross Functionality	Passed 100 krad(SiO_2)
2. Power Supply Current (I_{CCA}/I_{CCI})	Passed 60 krad(SiO_2)
3. Input Threshold (V_{TIL}/V_{IH})	Passed 100 krad(SiO_2)
4. Output Drive (V_{OL}/V_{OH})	Passed 100 krad(SiO_2)
5. Propagation Delay	Passed 100 krad(SiO_2) per 10% degradation criterion
6. Transition Charateristics	Passed 100 krad(SiO_2)

II. Total Ionizing Dose (TID) Testing

This testing is designed on the base of an extensive database (see TID data of antifuse-based FPGA in http://www.klabs.org/ and http://www.actel.com/) accumulated from the TID testing of many generations of antifuse-based FPGAs.

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

Table 1 lists the DUT and irradiation parameters. During irradiation each input and most of the output is grounded through a 100k-ohm resistor; during annealing each input or output is tied to the ground or V_{CCI} with a 1 k ohm resistor. Appendix A and B contain the schematics of the irradiation-bias circuit.

Table 1 DUT and Irradiation Parameters

Part Number	RTSX32SU
Package	CQFP256
Foundry	United Microelectronics Corp.
Technology	0.25 µm CMOS
DUT Design	TDSX32CQFP256_2Strings
Die Lot Number	D1RH51
Quantity Tested	6
Serial Number	60 krad(SiO_2): 203, 225, 236 100 krad(SiO_2): 25, 77, 107
Radiation Facility	Defense Microelectronics Activity
Radiation Source	Co-60
Dose Rate	5 krad(SiO_2)/min (±5%)
Irradiation Temperature	Room
Irradiation and Measurement Bias (V_{CCI}/V_{CCA})	Static at 5 V/2.5 V

B. *Test Method*

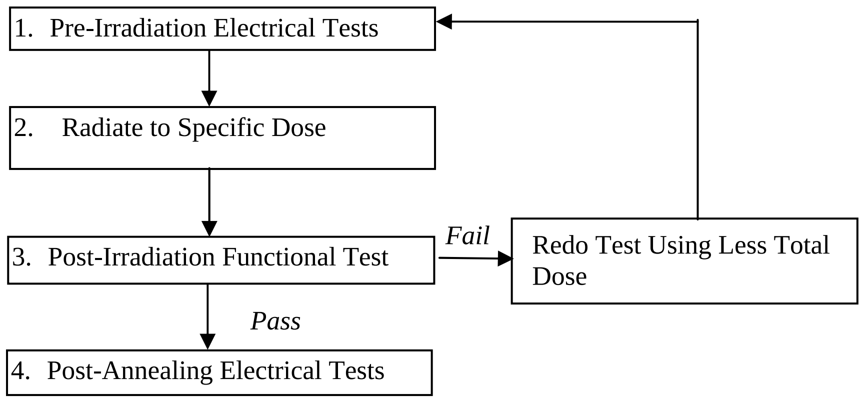


Figure 1 Parametric test flow chart

The test method generally follows the guidelines in the military standard TM1019. Figure 1 shows the flow chart describing the steps for functional and parametric tests at pre-irradiation, post-irradiation and post-annealing.

The accelerated aging, or rebound test mentioned in TM1019 is unnecessary because there is no adverse time-dependent effect (TDE) in Actel products manufactured by deep sub-micron CMOS technologies. Elevated temperature annealing basically reduces the effects originating from radiation-induced leakage currents. As indicated by test data in the following sections, the predominant radiation effects in RTSXSU family are due to radiation-induced leakage currents.

Room temperature annealing is performed for approximately 6 days.

C. *Design and Parametric Measurements*

Table 2 lists each electrical parameter and the corresponding logic design. The functionality is measured on the output pins (O_AND3 and O_AND4) of two combinational buffer-strings with 616 buffers each and output pins (O_OR4 and O_NAND4) of a shift register with 512 bits. I_{CC} is measured on the power supply of the logic-array (I_{CCA}) and I/O (I_{CCI}) respectively. The input logic thresholds (V_{TIL}/V_{IH}) are measured on twelve combinational nets listed in Table 2, and the output-drive voltages (V_{OL}/V_{OH}) are measured on the output buffers of these nets. The propagation delays are measured on the O_AND4 output of one buffer string. The delay is defined as the time delay from the time of triggering edge at the CLOCK input to the time of switching state at the output O_AND4. 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 O_AND4, are displayed as oscilloscope snapshots of the rising and falling edge during logic transitions.

Table 2 Logic Design for Parametric Measurements

Parameters	Logic Design
1. Functionality	All key architectural functions (pins O_AND3, O_AND4, O_OR3, O_OR4, and O_NAND4)
2. I_{CC} (I_{CCA}/I_{CCI})	DUT power supply
3. Input Threshold (V_{TIL}/V_{IH})	Input buffers (DA/QA0, DAH/QA0H, ENCNTR/YO0, ENCNTRH/YO0H, IDII0/IDIO0, IDII1/IDIO1, IDII2/IDIO2, IDII3/IDIO3, IDII4/IDIO4, IDII5/IDIO5, IDII6/IDIO6, IDII7/IDIO7)
4. Output Drive (V_{OL}/V_{OH})	Output buffer (DA/QA0, DAH/QA0H, ENCNTR/YO0, ENCNTRH/YO0H, IDII0/IDIO0, IDII1/IDIO1, IDII2/IDIO2, IDII3/IDIO3, IDII4/IDIO4, IDII5/IDIO5, IDII6/IDIO6, IDII7/IDIO7)
5. Propagation Delay	String of buffers (pin LOADIN to O_AND4)
6. Transition Characteristic	D flip-flop output (O_AND4)

III. TEST RESULTS

A. *Functionality*

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

B. *Power Supply Current (I_{CCA} and I_{CCI})*

Figures 2-7 plots the in-flux standby I_{CCA} and I_{CCI} versus total dose for each DUT. Table 3 summarizes the pre-irradiation, post-irradiation and post-annealing I_{CC}.

Table 3 Pre-irradiation, Post Irradiation and Post-Annealing I_{CC}

DUT	Total Dose krad(SiO_2)	I_{CCA} (mA)			I_{CCI} (mA)		
		Pre-irrad	Post-irrad	Post-ann	Pre-irrad	Post-irrad	Post-ann
25	100krad	0.35	241	85	1	171	74
77	100krad	0.35	276	89	1	187	76
107	100krad	0.42	273	84	1	184	67
203	60krad	0.4	14.2	11	1	33	19
225	60krad	0.35	13.7	11	1	30	16
236	60krad	0.35	13.5	11	1	30.2	17

In compliance with TM1019.6 subsection 3.11.2.c, the post-irradiation-parametric limit (PIPL) for the post-annealing I_{CCA}/I_{CCI} in this test is defined as the highest I_{CCA}/I_{CCI} in the RTSXSU spec sheet; they both are 25 mA.

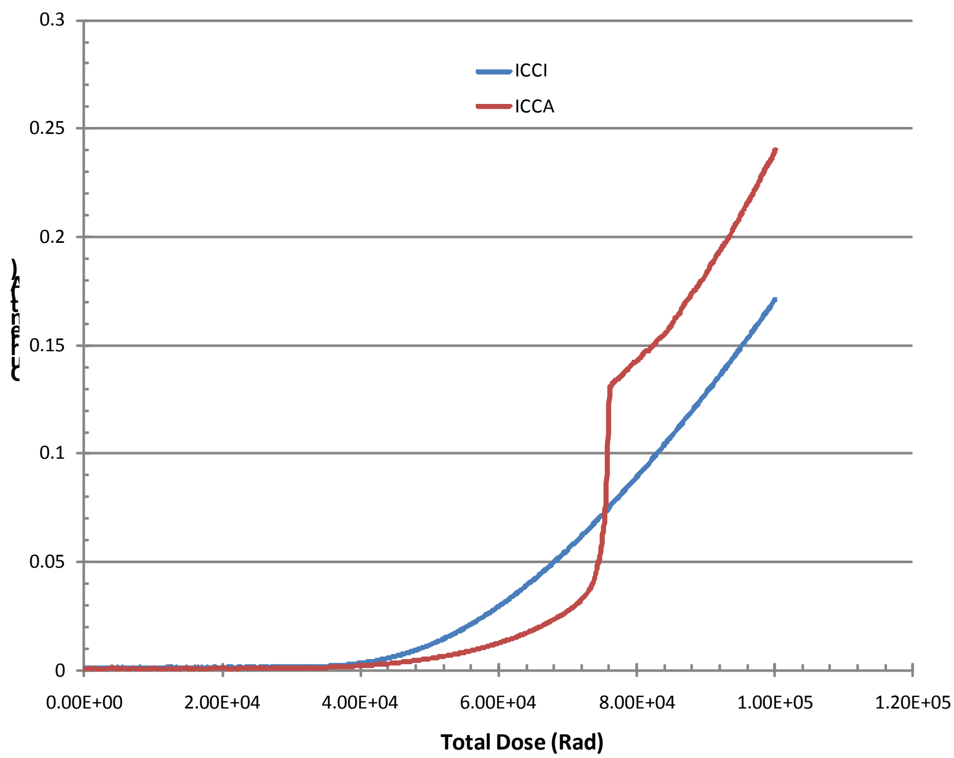


Figure 2 DUT 25 in-flux I_{CCA} and I_{CCI}

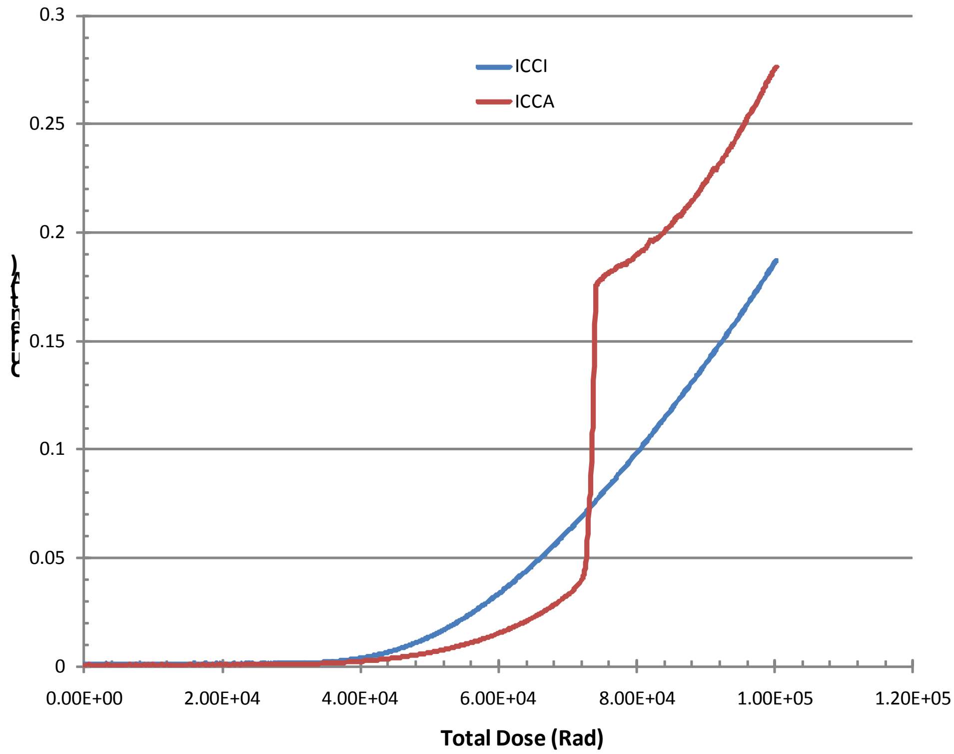


Figure 3 DUT 77 in-flux I_{CCA} and I_{CCI}

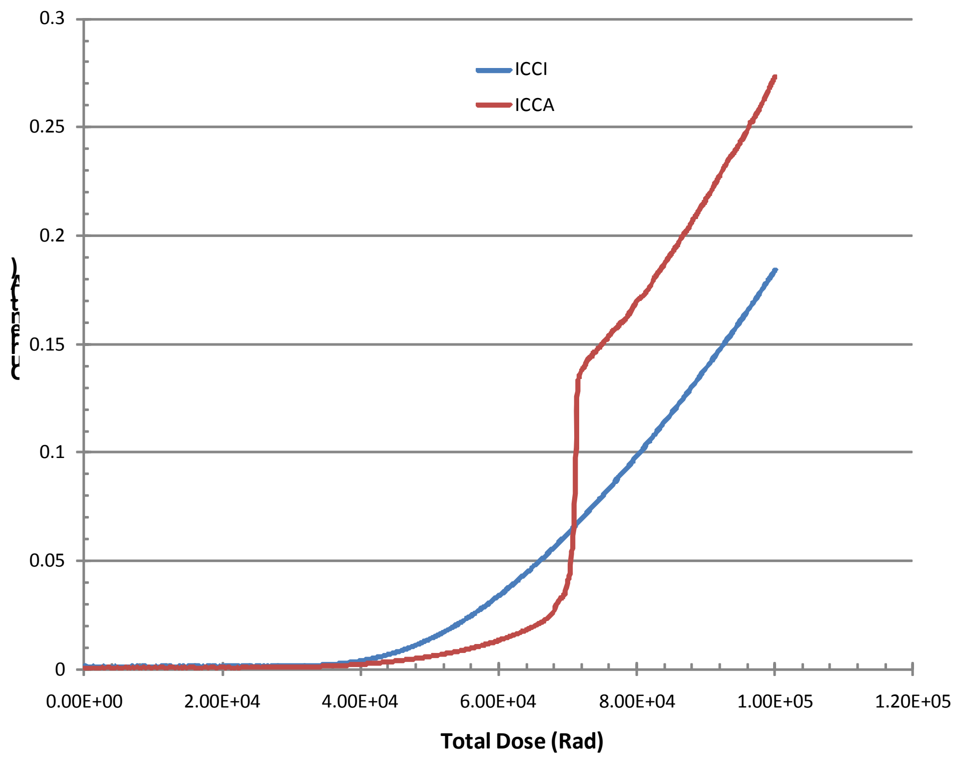


Figure 4 DUT 107 in-flux I_{CCA} and I_{CCI}

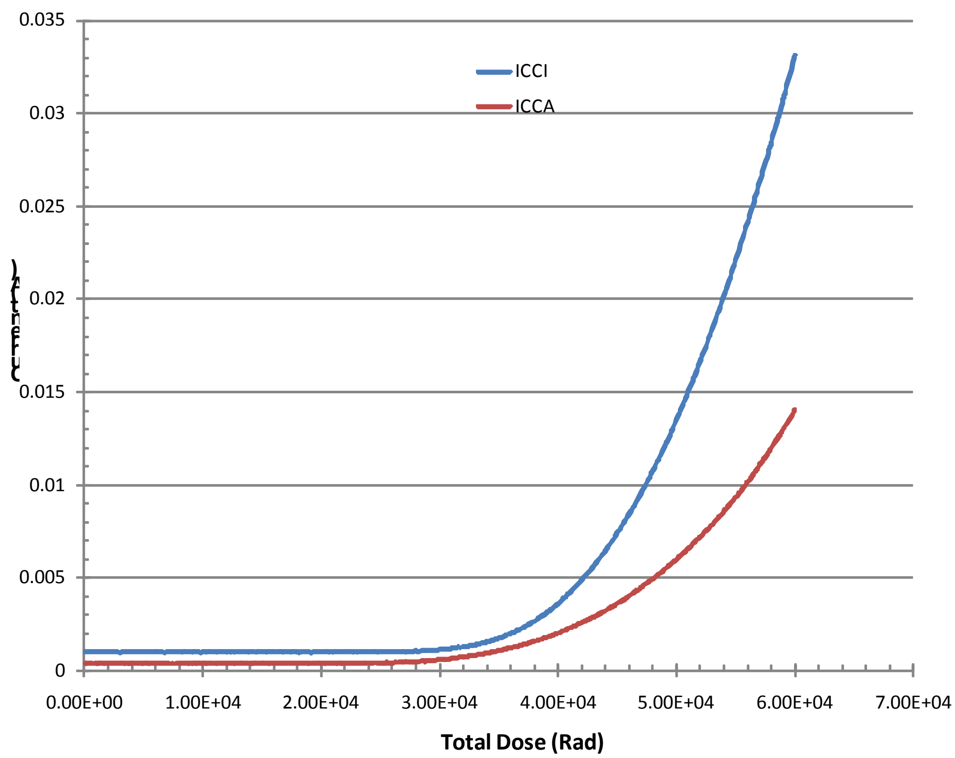


Figure 5 DUT 203 in-flux I_{CCA} and I_{CCI}

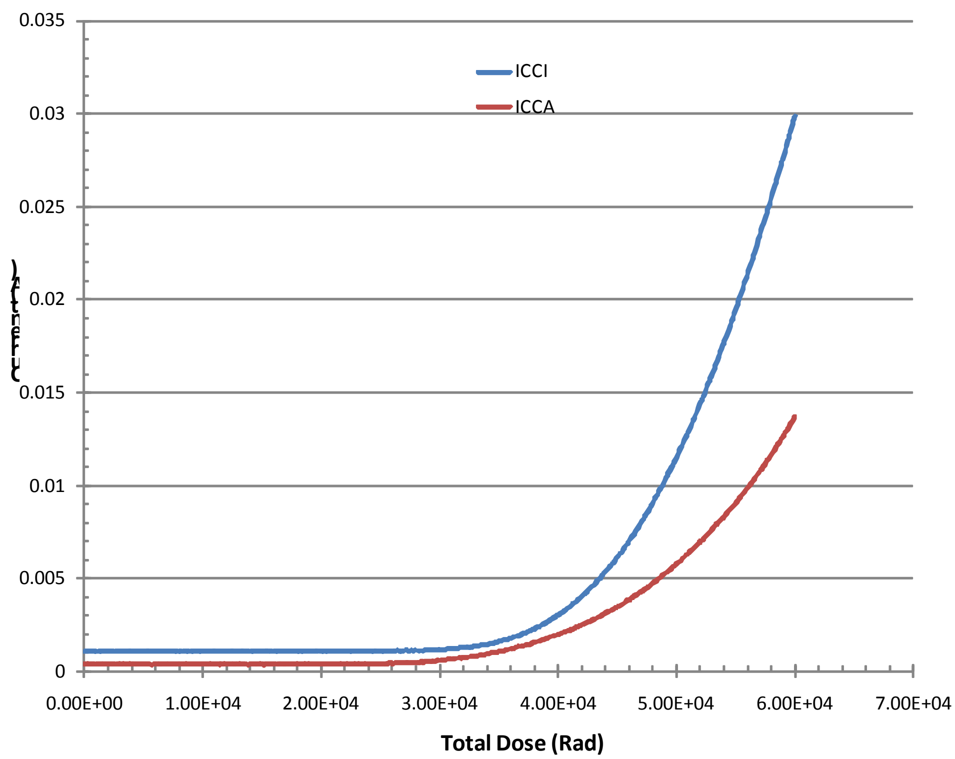


Figure 6 DUT 225 in-flux I_{CCA} and I_{CCI}

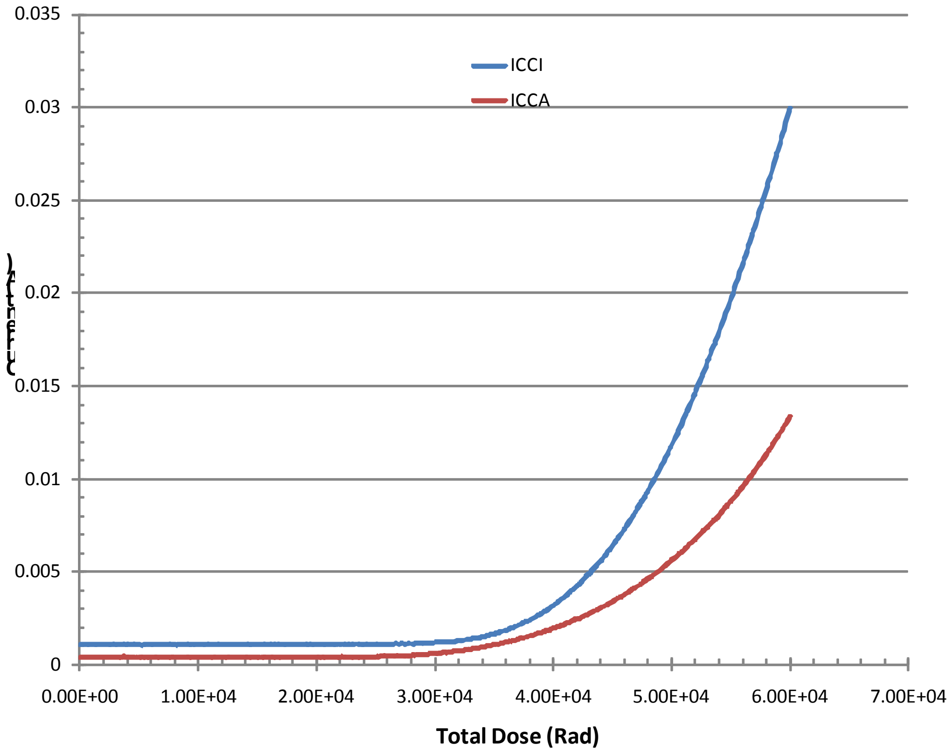


Figure 7 DUT 236 in-flux I_{CCA} and I_{CCI}

C. *Single-Ended Input Logic Threshold (V_{IL}/V_{IH})*

Table 4 lists the pre-irradiation and post-annealing single-ended input logic threshold. All data are within the spec limits. The post-annealing shift in every case is less than 10%.

Table 4a Pre-Irradiation and Post-Annealing Input Thresholds

DUT	25(100krad)				77 (100krad)			
Input Pin	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
	V_{IL} (mV)		V_{IH} (V)		V_{IL} (V)		V_{IH} (V)	
DA	1390	1385	1440	1595	1385	1375	1440	1580
DAH	1340	1445	1460	1445	1335	1445	1460	1445
ENCNTR	1475	1365	1960	1920	1420	1370	1960	1920
ENCNTRH	1330	1355	1530	1475	1395	1365	1545	1545
IDII7	1395	1400	1395	1395	1400	1425	1405	1385
IDII6	1175	1245	1400	1410	1195	1235	1400	1410
IDII5	1375	1385	1435	1415	1375	1390	1435	1415
IDII4	1285	1225	1400	1395	1420	1205	1425	1390
IDII3	1170	1185	1625	1585	1150	1180	1630	1595
IDII2	1435	1445	1475	1400	1440	1445	1475	1400
IDII1	1165	1195	1385	1520	1170	1210	1395	1535
IDII0	1445	1430	1385	1400	1445	1435	1395	1400

Table 4b Pre-Irradiation and Post-Annealing Input Thresholds

DUT	107(100krad)				203 (60krad)			
Input Pin	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
	V_{IL} (mV)		V_{IH} (V)		V_{IL} (V)		V_{IH} (V)	
DA	1390	1375	1425	1595	1375	1365	1450	1615
DAH	1320	1430	1445	1430	1335	1335	1460	1445
ENCNTR	1380	1405	1960	1920	1420	1380	1945	1905
ENCNTRH	1260	1375	1555	1405	1385	1360	1540	1540
IDII7	1400	1425	1405	1390	1380	1385	1385	1370
IDII6	1185	1185	1410	1410	1245	1200	1425	1390
IDII5	1375	1390	1435	1420	1375	1375	1430	1420
IDII4	1375	1220	1390	1380	1420	1430	1395	1380
IDII3	1165	1190	1630	1600	1155	1180	1615	1595
IDII2	1445	1445	1480	1400	1430	1420	1465	1385
IDII1	1180	1210	1395	1535	1155	1165	1510	1510
IDII0	1445	1435	1385	1400	1430	1430	1380	1380

Table 4c Pre-Irradiation and Post-Annealing Input Thresholds

DUT	225(60krad)				236 (60krad)			
Input Pin	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann	Pre-Irrad	Post-Ann
	V_{IL} (mV)		V_{IH} (V)		V_{IL} (V)		V_{IH} (V)	
DA	1380	1370	1445	1440	1375	1365	1440	1440
DAH	1320	1305	1450	1450	1335	1325	1460	1450
ENCNTR	1420	1385	1960	1935	1350	1405	1945	1930
ENCNTRH	1410	1390	1545	1540	1335	1360	1540	1535
IDII7	1385	1400	1395	1405	1385	1400	1395	1395
IDII6	1170	1225	1430	1400	1170	1420	1395	1395
IDII5	1365	1370	1420	1420	1375	1375	1435	1430
IDII4	1380	1420	1425	1425	1420	1375	1430	1390
IDII3	1150	1155	1625	1610	1150	1150	1625	1615
IDII2	1435	1435	1475	1385	1435	1430	1475	1385
IDII1	1165	1170	1395	1390	1155	1165	1510	1520
IDII0	1435	1430	1450	1380	1435	1430	1385	1380

D. *Output-Drive Voltage (V_{OL}/V_{OH})*

The pre-irradiation and post-annealing V_{OL}/V_{OH} are listed in Tables 5 to 10. The post-annealing data is within the spec limit, and the radiation effect is very small in every case.

Table 5a DUT 25 Pre-Irradiation and Post-Annealing V_{OL} (mV) at Various Sinking Current

DUT	Pin	1mA		12mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
25 (100krad)	IDIO7	158.05	158.05	237.07	237.07	295.09	296.09	519.16	519.16	996.30	997.30
	IDIO6	146.87	146.87	223.80	222.80	279.75	278.75	491.56	490.56	921.17	917.17
	IDIO5	148.03	148.03	227.05	226.05	284.06	284.06	504.10	502.10	950.19	947.19
	IDIO4	151.94	150.94	231.91	231.91	290.88	290.88	516.79	515.79	976.61	974.61
	IDIO3	153.05	153.05	229.07	230.07	284.09	285.09	497.15	500.15	952.29	957.29
	IDIO2	151.92	151.92	228.89	228.89	284.86	285.86	498.75	500.75	925.54	928.54
	IDIO1	144.87	145.87	222.80	223.80	279.75	280.75	498.55	500.55	945.15	948.15
	IDIO0	149.93	149.93	225.89	225.89	281.86	282.86	493.75	495.75	932.53	936.53
	QA0	130.91	129.91	200.86	200.86	252.82	252.82	461.68	461.68	932.35	931.35
	QA0H	144.10	144.10	218.15	218.15	272.19	271.19	478.34	477.33	923.65	921.65
	YO0	151.06	151.06	230.09	230.09	288.12	287.12	507.20	506.20	936.37	934.37
	YO0H	141.10	141.10	216.15	216.15	271.19	270.19	480.34	480.34	936.66	936.66

Table 5b DUT 25 Pre-Irradiation and Post-Annealing V_{OH} (mV) at Various Sourcing Current

DUT	Pin	1mA		8mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
25 (100krad)	IDIO7	4817.88	4807.88	4732.92	4727.92	4587.98	4577.99	4013.23	3988.24	2668.83	2578.87
	IDIO6	4802.79	4797.79	4722.91	4717.91	4583.12	4573.13	4053.91	4033.94	2745.88	2666.00
	IDIO5	4802.12	4797.12	4722.17	4712.17	4572.26	4567.26	4027.58	4007.59	2693.38	2618.43
	IDIO4	4811.44	4806.44	4726.50	4721.50	4576.61	4566.62	4022.02	4002.04	2653.04	2568.10
	IDIO3	4807.88	4802.89	4732.92	4722.92	4587.98	4577.99	4033.23	4008.24	2698.81	2623.85
	IDIO2	4806.44	4801.44	4726.50	4721.50	4581.61	4571.62	4042.01	4022.02	2722.98	2643.04
	IDIO1	4807.78	4802.79	4722.91	4717.91	4578.12	4568.14	4043.93	4023.96	2705.94	2626.06
	IDIO0	4816.43	4811.44	4736.49	4731.50	4591.60	4581.61	4032.01	4007.03	2688.01	2603.07
	QA0	4832.06	4827.07	4757.19	4752.19	4612.42	4607.43	4038.37	4018.40	2715.54	2635.67
	QA0H	4833.67	4828.67	4753.61	4748.61	4608.50	4603.50	4048.07	4028.06	2742.08	2662.02
	YO0	4801.44	4791.45	4716.51	4706.52	4566.62	4556.63	4032.01	4007.03	2683.01	2603.07
	YO0H	4828.67	4823.66	4748.61	4743.60	4608.50	4598.49	4048.07	4023.06	2742.08	2662.02

Table 6a DUT 77 Pre-Irradiation and Post-Annealing V_{OL} (mV) at Various Sinking Current

DUT	Pin	1mA		12mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
77 (100krad)	IDIO7	158.05	159.05	239.07	239.07	297.09	297.09	522.16	522.16	1004.30	1004.30
	IDIO6	147.87	147.87	223.80	223.80	279.75	279.75	493.56	492.56	923.17	922.17
	IDIO5	149.03	148.03	228.05	227.05	287.06	285.06	507.10	504.10	960.19	952.19
	IDIO4	152.94	152.94	234.91	233.91	294.88	293.88	521.79	519.79	990.60	986.61
	IDIO3	154.05	154.05	231.07	231.07	287.09	288.09	502.15	504.15	964.29	966.29
	IDIO2	152.92	151.92	229.89	228.89	285.86	285.86	501.75	499.75	929.54	926.54
	IDIO1	146.87	145.87	224.80	225.80	282.75	282.75	503.55	503.55	957.14	956.14
	IDIO0	149.93	149.93	225.89	226.89	282.86	282.86	494.75	494.75	937.53	936.53
	QA0	130.91	130.91	201.86	201.86	254.82	254.82	465.67	464.68	942.34	939.34
	QA0H	145.10	145.10	220.15	219.15	274.19	274.19	482.34	482.34	933.65	930.65
	YO0	153.06	152.06	232.09	231.09	290.12	289.12	511.20	510.20	946.38	944.38
	YO0H	141.10	141.10	216.15	216.15	271.19	270.19	481.34	479.34	937.66	935.66

Table 6b DUT 77 Pre-Irradiation and Post-Annealing V_{OH} (mV) at Various Sourcing Current

DUT	Pin	1mA		8mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
77 (100krad)	IDIO7	4812.88	4807.88	4732.92	4727.92	4587.98	4572.99	4008.24	3983.25	2653.83	2573.87
	IDIO6	4807.78	4797.79	4722.91	4717.91	4583.12	4573.13	4058.90	4033.94	2745.88	2670.99
	IDIO5	4802.12	4797.12	4717.17	4712.17	4572.26	4562.26	4027.58	4007.59	2708.37	2633.42
	IDIO4	4811.44	4806.44	4726.50	4721.50	4576.61	4566.62	4017.03	3997.04	2653.04	2573.10
	IDIO3	4807.88	4802.89	4727.92	4722.92	4587.98	4577.99	4018.23	4003.24	2678.82	2603.85
	IDIO2	4806.44	4801.44	4726.50	4721.50	4576.61	4571.62	4042.01	4017.03	2722.98	2643.04
	IDIO1	4807.78	4797.79	4722.91	4717.91	4573.13	4568.14	4038.93	4013.97	2685.97	2611.08
	IDIO0	4816.43	4811.44	4736.49	4726.50	4591.60	4581.61	4032.01	4007.03	2688.01	2603.07
	QA0	4832.06	4827.07	4757.19	4752.19	4612.42	4602.44	4038.37	4013.41	2710.55	2635.67
	QA0H	4833.67	4828.67	4758.61	4748.61	4613.50	4603.50	4048.07	4028.06	2742.08	2667.03
	YO0	4796.45	4796.45	4716.51	4706.52	4566.62	4556.63	4027.02	4007.03	2683.01	2603.07
	YO0H	4828.67	4823.66	4748.61	4743.60	4608.50	4598.49	4048.07	4023.06	2752.09	2672.03

Table 7a DUT 107 Pre-Irradiation and Post-Annealing V_{OL} (mV) at Various Sinking Current

DUT	Pin	1mA		12mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
107 (100krad)	IDIO7	156.05	156.05	234.07	234.07	292.09	292.09	513.15	512.15	982.30	979.29
	IDIO6	145.87	145.87	221.80	221.80	276.75	275.75	487.56	487.56	910.18	908.18
	IDIO5	148.03	147.03	226.05	225.05	283.06	282.06	501.10	499.10	946.19	938.19
	IDIO4	150.94	149.94	230.91	228.91	289.88	287.89	512.80	510.80	968.61	962.62
	IDIO3	151.05	152.05	227.07	227.07	282.09	283.09	494.15	495.15	944.28	945.28
	IDIO2	150.93	149.93	226.89	225.89	282.86	281.86	495.75	493.75	919.54	913.54
	IDIO1	143.87	143.87	221.80	220.80	278.75	276.75	495.55	492.56	938.16	931.16
	IDIO0	147.93	147.93	223.89	223.89	278.86	278.86	488.76	488.76	922.54	920.54
	QA0	128.91	128.91	198.86	197.86	250.82	249.83	457.68	454.68	923.35	917.36
	QA0H	143.10	142.10	216.15	214.15	269.19	268.19	473.33	471.33	912.64	906.63
	YO0	150.06	149.06	228.09	227.09	285.11	284.11	501.20	500.20	926.37	920.37
	YO0H	140.10	139.10	213.15	213.15	267.19	266.19	475.33	473.33	925.65	920.64

Table 7b DUT 107 Pre-Irradiation and Post-Annealing V_{OH} (mV) at Various Sourcing Current

DUT	Pin	1mA		8mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
107 (100krad)	IDIO7	4817.88	4812.88	4732.92	4732.92	4587.98	4582.98	4018.23	3998.24	2683.82	2603.85
	IDIO6	4807.78	4802.79	4727.90	4722.91	4583.12	4573.13	4063.90	4043.93	2760.85	2700.94
	IDIO5	4802.12	4797.12	4722.17	4717.17	4577.25	4572.26	4037.58	4017.59	2728.36	2658.40
	IDIO4	4811.44	4806.44	4731.50	4721.50	4581.61	4571.62	4027.02	4012.03	2673.02	2608.07
	IDIO3	4807.88	4807.88	4732.92	4727.92	4592.98	4582.98	4033.23	4018.23	2703.81	2648.83
	IDIO2	4806.44	4801.44	4726.50	4721.50	4581.61	4576.61	4057.00	4037.01	2767.95	2698.00
	IDIO1	4807.78	4797.79	4722.91	4717.91	4578.12	4573.13	4048.92	4028.95	2720.91	2656.01
	IDIO0	4816.43	4811.44	4736.49	4731.50	4591.60	4586.60	4047.00	4022.02	2722.98	2653.04
	QA0	4832.06	4827.07	4757.19	4752.19	4617.42	4607.43	4048.35	4028.38	2725.52	2660.63
	QA0H	4833.67	4823.66	4758.61	4743.60	4613.50	4603.50	4058.08	4033.06	2767.10	2697.05
	YO0	4801.44	4796.45	4716.51	4711.51	4571.62	4561.62	4042.01	4027.02	2722.98	2658.03
	YO0H	4828.67	4823.66	4748.61	4748.61	4608.50	4603.50	4058.08	4038.07	2777.11	2707.06

Table 8a DUT 203 Pre-Irradiation and Post-Annealing V_{OL} (mV) at Various Sinking Current

DUT	Pin	1mA		12mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
203 (60krad)	IDIO7	154.05	155.05	232.07	233.07	289.09	290.09	508.15	508.15	968.29	970.29
	IDIO6	143.87	142.87	217.80	217.80	272.75	271.76	479.57	477.57	891.20	886.20
	IDIO5	145.03	144.03	222.04	221.04	279.06	277.06	493.10	490.10	928.19	920.18
	IDIO4	148.94	147.94	227.91	226.91	285.89	284.89	506.80	504.80	954.62	947.62
	IDIO3	151.05	150.05	226.07	225.07	281.08	280.08	491.15	489.15	937.28	932.28
	IDIO2	148.93	147.93	223.89	221.89	278.86	276.86	487.76	484.76	898.55	892.55
	IDIO1	142.87	141.87	219.80	218.80	275.75	274.75	490.56	488.56	926.17	919.17
	IDIO0	145.93	145.93	220.89	220.89	275.86	274.86	481.76	481.76	905.55	904.55
	QA0	127.91	127.91	197.86	196.86	248.83	247.83	452.68	450.68	912.36	906.37
	QA0H	141.10	140.10	213.15	212.15	266.19	264.19	467.33	465.33	896.63	891.62
	YO0	148.06	147.06	224.09	223.09	280.11	279.11	494.20	492.20	908.36	902.36
	YO0H	138.10	137.10	210.15	209.15	264.19	262.18	468.33	465.33	906.63	900.63

Table 8b DUT 203 Pre-Irradiation and Post-Annealing V_{OH} (mV) at Various Sourcing Current

DUT	Pin	1mA		8mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
203 (60krad)	IDIO7	4817.88	4812.88	4732.92	4732.92	4587.98	4587.98	4013.23	4003.24	2648.83	2618.85
	IDIO6	4807.78	4807.78	4727.90	4727.90	4583.12	4583.12	4068.89	4058.90	2765.85	2730.90
	IDIO5	4802.12	4802.12	4722.17	4717.17	4572.26	4572.26	4027.58	4022.59	2683.39	2653.41
	IDIO4	4811.44	4806.44	4726.50	4726.50	4576.61	4576.61	4027.02	4017.03	2658.03	2638.05
	IDIO3	4807.88	4802.89	4727.92	4727.92	4587.98	4582.98	4018.23	4013.23	2653.83	2623.85
	IDIO2	4806.44	4806.44	4726.50	4721.50	4581.61	4576.61	4052.00	4047.00	2737.97	2708.00
	IDIO1	4807.78	4802.79	4722.91	4722.91	4578.12	4578.12	4048.92	4038.93	2710.93	2680.97
	IDIO0	4816.43	4811.44	4736.49	4736.49	4591.60	4591.60	4032.01	4027.02	2688.01	2648.04
	QA0	4827.07	4832.06	4757.19	4757.19	4612.42	4612.42	4038.37	4028.38	2695.57	2670.61
	QA0H	4833.67	4833.67	4753.61	4753.61	4613.50	4608.50	4043.07	4038.07	2702.05	2677.03
	YO0	4801.44	4796.45	4716.51	4716.51	4571.62	4566.62	4042.01	4037.01	2703.00	2673.02
	YO0H	4828.67	4823.66	4748.61	4748.61	4608.50	4603.50	4043.07	4033.06	2717.06	2682.04

Table 9a DUT 225 Pre-Irradiation and Post-Annealing V_{OL} (mV) at Various Sinking Current

DUT	Pin	1mA		12mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
225 (60krad)	IDIO7	156.05	156.05	234.07	234.07	292.09	292.09	513.15	513.15	981.29	979.29
	IDIO6	144.87	144.87	220.80	219.80	274.75	274.75	485.56	483.56	905.19	900.19
	IDIO5	146.03	146.03	223.05	223.05	281.06	280.06	496.10	495.10	933.19	929.19
	IDIO4	149.94	148.94	229.91	228.91	288.88	286.89	511.80	508.80	965.61	958.62
	IDIO3	153.05	152.05	228.07	227.07	284.09	283.09	497.15	496.15	952.29	947.28
	IDIO2	148.93	147.93	224.89	223.89	280.86	279.86	490.76	488.76	907.55	902.55
	IDIO1	144.87	143.87	222.80	221.80	279.75	278.75	498.55	495.55	944.15	937.16
	IDIO0	147.93	147.93	222.89	222.89	278.86	277.86	487.76	486.76	918.54	915.54
	QA0	128.91	128.91	198.86	198.86	250.82	249.83	457.68	454.68	922.35	916.36
	QA0H	142.10	142.10	215.15	214.15	268.19	267.19	472.33	470.33	909.64	903.63
	YO0	149.06	148.06	227.09	226.09	283.11	283.11	500.20	498.20	921.37	915.37
	YO0H	139.10	138.10	212.15	211.15	266.19	265.19	472.33	470.33	917.64	912.64

Table 9b DUT 225 Pre-Irradiation and Post-Annealing V_{OH} (mV) at Various Sourcing Current

DUT	Pin	1mA		8mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
225 (60krad)	IDIO7	4817.88	4812.88	4737.91	4732.92	4587.98	4587.98	4018.23	4008.24	2683.82	2648.83
	IDIO6	4807.78	4807.78	4727.90	4722.91	4583.12	4583.12	4068.89	4058.90	2780.82	2755.86
	IDIO5	4807.11	4802.12	4722.17	4722.17	4577.25	4572.26	4042.57	4032.58	2738.36	2718.37
	IDIO4	4811.44	4811.44	4726.50	4726.50	4581.61	4576.61	4032.01	4027.02	2688.01	2658.03
	IDIO3	4807.88	4807.88	4727.92	4727.92	4587.98	4587.98	4028.23	4023.23	2693.81	2668.83
	IDIO2	4811.44	4806.44	4726.50	4726.50	4581.61	4581.61	4057.00	4047.00	2757.96	2727.98
	IDIO1	4807.78	4807.78	4722.91	4722.91	4578.12	4578.12	4053.91	4048.92	2735.89	2715.92
	IDIO0	4816.43	4816.43	4736.49	4736.49	4591.60	4591.60	4042.01	4037.01	2717.99	2688.01
	QA0	4832.06	4832.06	4757.19	4757.19	4617.42	4612.42	4048.35	4043.36	2750.48	2725.52
	QA0H	4833.67	4833.67	4753.61	4758.61	4613.50	4613.50	4058.08	4053.08	2777.11	2747.09
	YO0	4801.44	4796.45	4716.51	4716.51	4571.62	4566.62	4047.00	4037.01	2727.98	2703.00
	YO0H	4828.67	4828.67	4753.61	4748.61	4608.50	4608.50	4058.08	4048.07	2782.11	2752.09

Table 10a DUT 236 Pre-Irradiation and Post-Annealing V_{OL} (mV) at Various Sinking Current

DUT	Pin	1mA		12mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
236 (60krad)	IDIO7	156.05	156.05	234.07	234.07	292.09	292.09	513.15	513.15	981.29	981.29
	IDIO6	144.87	144.87	219.80	219.80	274.75	274.75	484.56	483.56	902.19	900.19
	IDIO5	146.03	145.03	223.05	222.04	280.06	278.06	495.10	493.10	930.19	925.19
	IDIO4	149.94	148.94	229.91	228.91	287.89	286.89	509.80	507.80	961.62	957.62
	IDIO3	152.05	152.05	227.07	226.07	283.09	282.09	494.15	493.15	944.28	941.28
	IDIO2	149.93	149.93	226.89	225.89	281.86	281.86	494.75	493.75	914.54	911.54
	IDIO1	142.87	142.87	221.80	219.80	277.75	276.75	494.56	492.56	933.16	929.16
	IDIO0	148.93	148.93	223.89	224.89	279.86	279.86	490.76	490.76	927.54	926.54
	QA0	128.91	127.91	198.86	197.86	249.83	248.83	454.68	453.68	916.36	913.36
	QA0H	143.10	142.10	215.15	215.15	268.19	268.19	473.33	471.33	911.64	907.64
	YO0	149.06	149.06	227.09	227.09	284.11	283.11	500.20	499.20	921.37	918.37
	YO0H	140.10	139.10	214.15	213.15	268.19	267.19	475.33	474.33	924.65	921.65

Table 10b DUT 236 Pre-Irradiation and Post-Annealing V_{OH} (mV) at Various Sourcing Current

DUT	Pin	1mA		8mA		20mA		50mA		100mA	
		Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an	Pre-rad	Post-an
236 (60krad)	IDIO7	4817.88	4812.88	4732.92	4732.92	4587.98	4582.98	4013.23	4003.24	2673.82	2628.84
	IDIO6	4807.78	4802.79	4727.90	4722.91	4583.12	4583.12	4068.89	4058.90	2780.82	2740.88
	IDIO5	4802.12	4802.12	4722.17	4717.17	4577.25	4572.26	4037.58	4027.58	2718.37	2678.39
	IDIO4	4811.44	4806.44	4726.50	4726.50	4576.61	4576.61	4032.01	4022.02	2683.01	2648.04
	IDIO3	4807.88	4807.88	4732.92	4727.92	4587.98	4582.98	4028.23	4018.23	2683.82	2643.84
	IDIO2	4806.44	4806.44	4726.50	4726.50	4581.61	4576.61	4052.00	4042.01	2752.96	2717.99
	IDIO1	4802.79	4802.79	4727.90	4722.91	4578.12	4573.13	4048.92	4038.93	2725.91	2695.95
	IDIO0	4816.43	4816.43	4736.49	4731.50	4591.60	4586.60	4037.01	4027.02	2708.00	2668.02
	QA0	4832.06	4827.07	4757.19	4752.19	4617.42	4612.42	4043.36	4038.37	2720.53	2685.59
	QA0H	4833.67	4833.67	4758.61	4753.61	4613.50	4608.50	4053.08	4043.07	2742.08	2707.06
	YO0	4801.44	4796.45	4716.51	4716.51	4571.62	4566.62	4047.00	4032.01	2732.98	2693.01
	YO0H	4828.67	4828.67	4748.61	4748.61	4608.50	4608.50	4053.08	4043.07	2757.09	2717.06

E. Propagation Delay

The propagation delay was measured pre-irradiation and post-annealing. As shown in Table 11, the radiation delta in every case is well within the 10% degradation criterion.

Table 11 Radiation-Induced Propagation-Delay Degradations

DUT	Total Dose	Pre-Irradiation (ns)	Post-Annealing (ns)	Degradation
25	100 krad	522	540	3.45%
77	100 krad	516	535	3.68%
107	100 krad	511	520	1.76%
203	60 krad	521	523	0.38%
225	60 krad	517	520	0.58%
236	60 krad	525	528	0.57%

F. Transition Characteristics

Figures 8 to 19 show the pre-irradiation and post-annealing transition edges. In each case, the radiation effect on transition-time is insignificant.

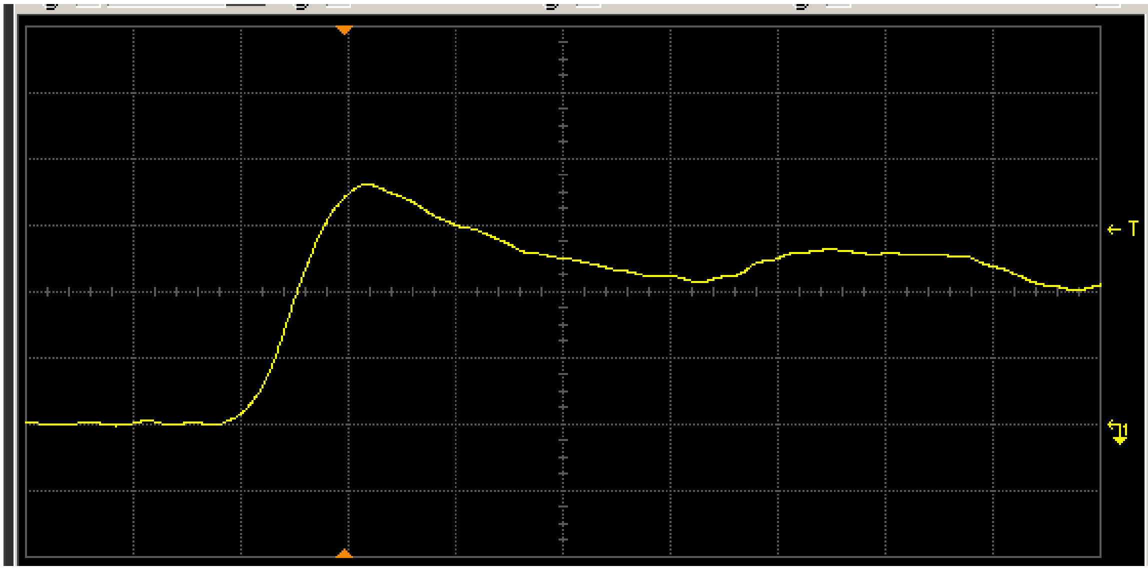


Figure 8(a) DUT 25 pre-irradiation rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

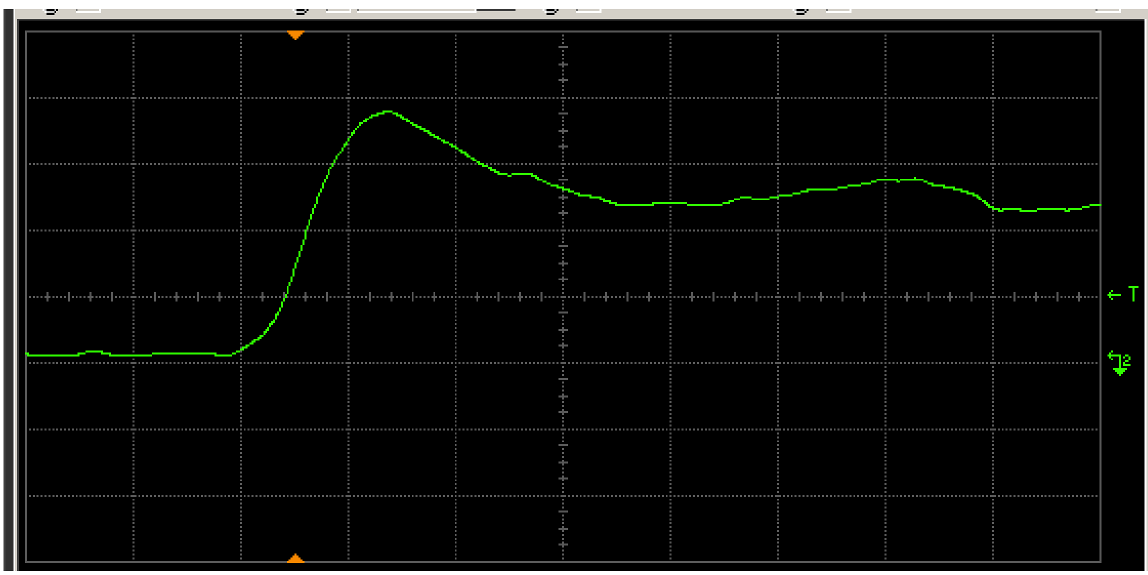


Figure 8(b) DUT 25 post-annealing rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

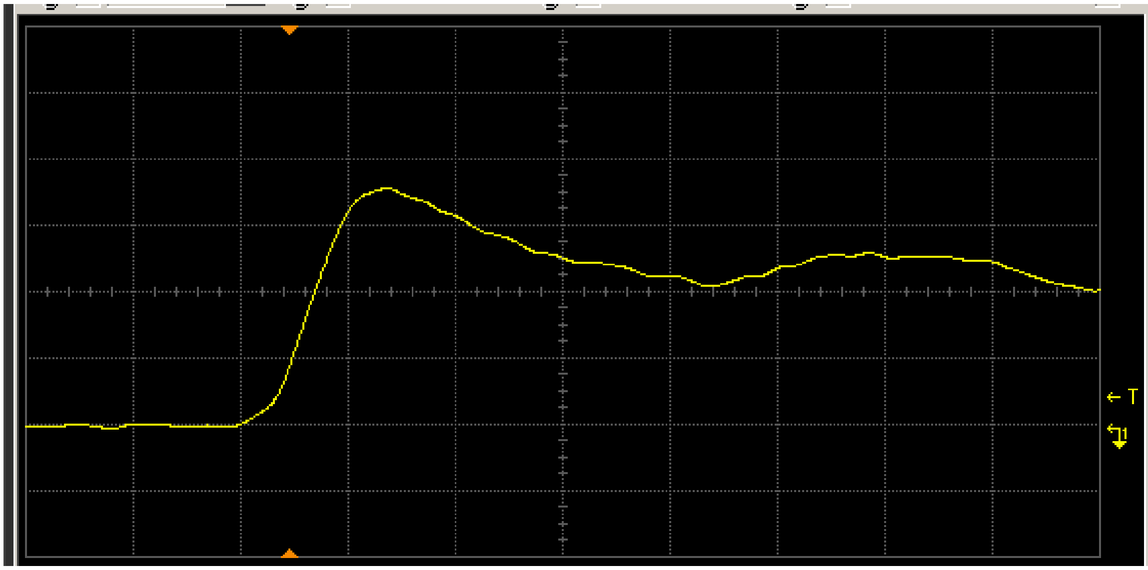


Figure 9(a) DUT 77 pre-irradiation rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

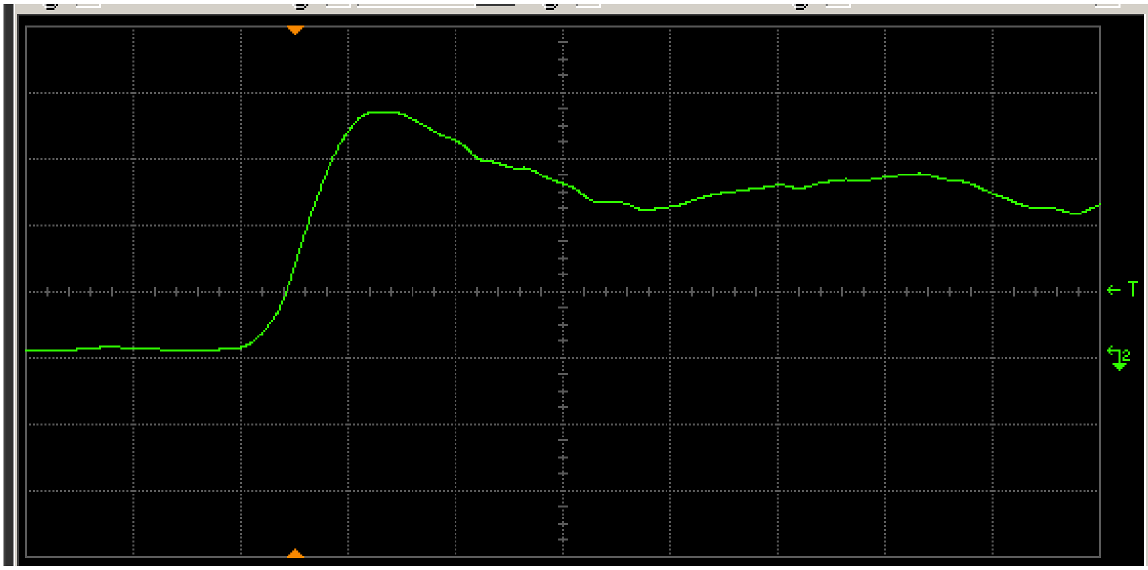


Figure 9(b) DUT 77 post-annealing rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

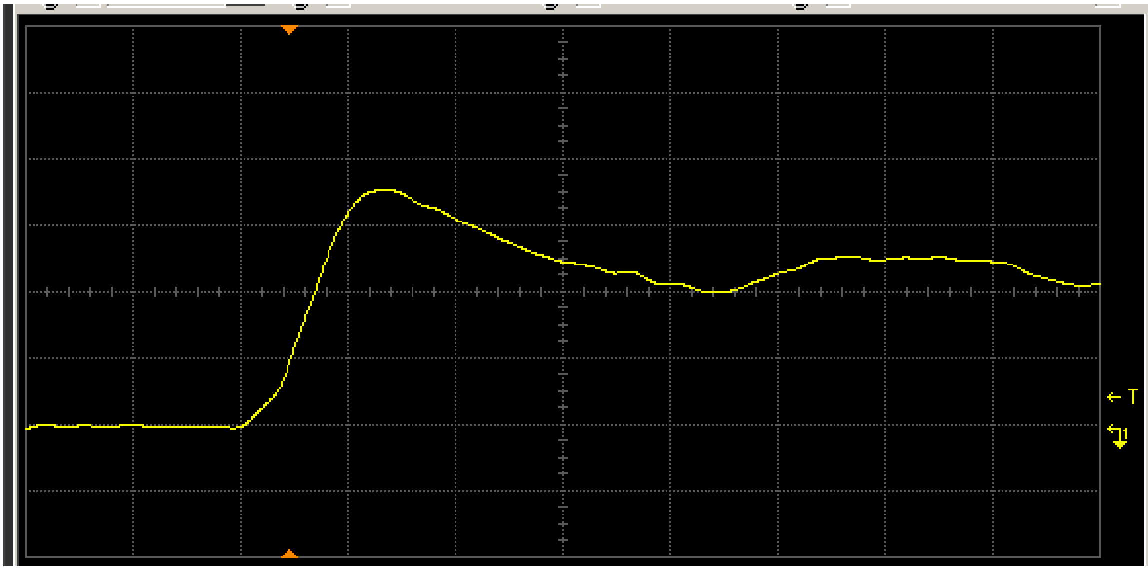


Figure 10(a) DUT 107 pre-radiation rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

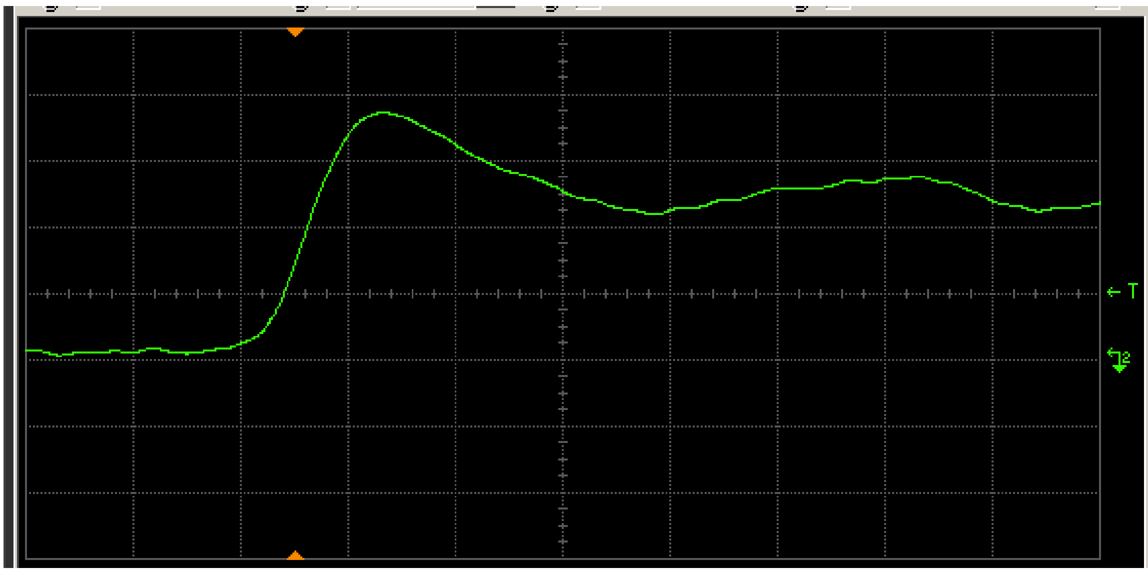


Figure 10(b) DUT 107 post-annealing rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

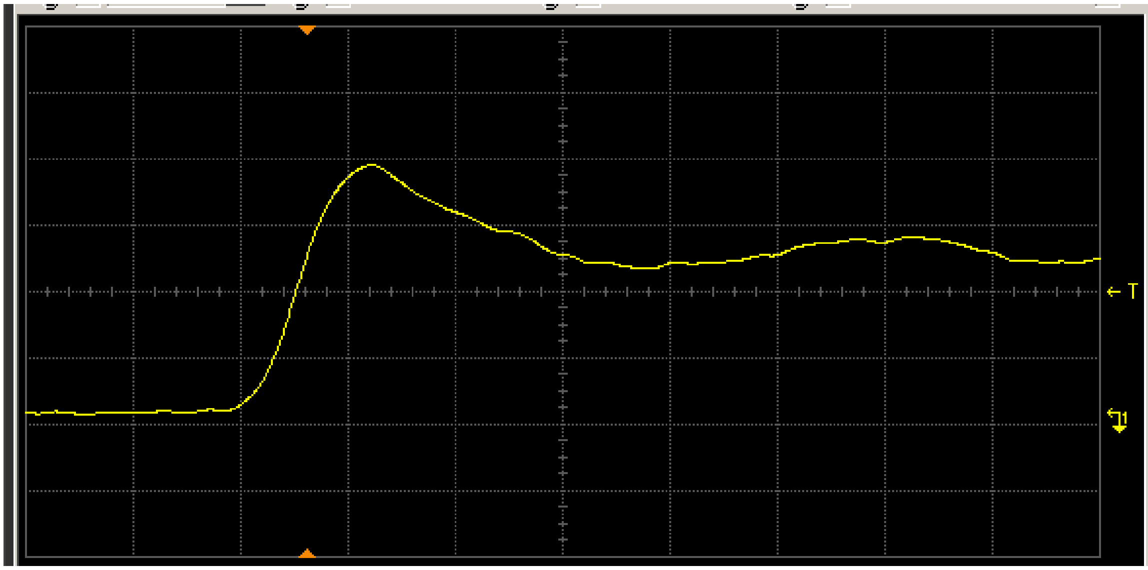


Figure 11(a) DUT 203 pre-irradiation rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

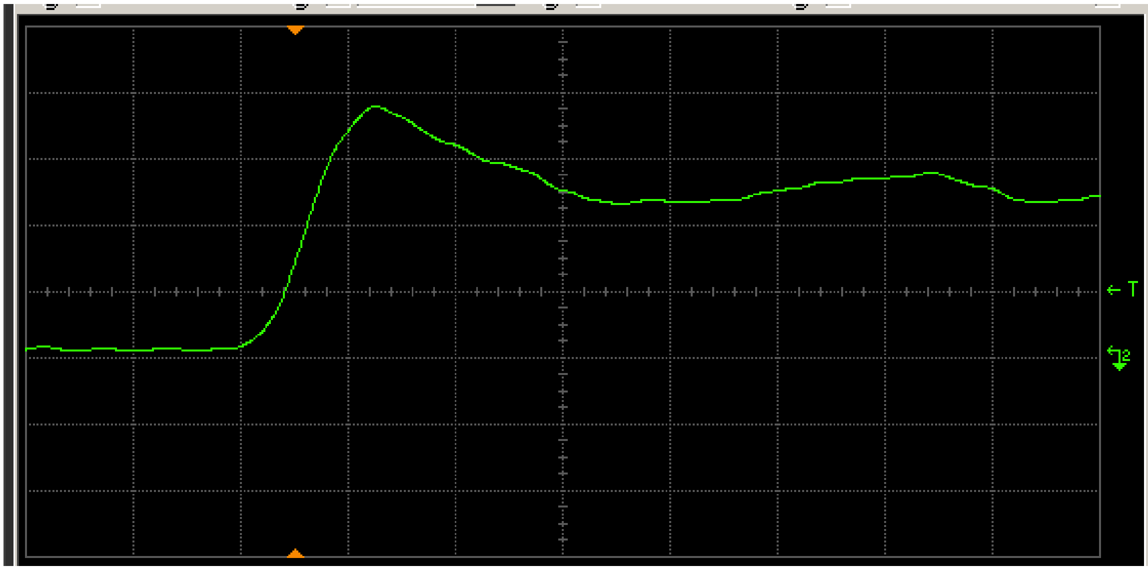


Figure 11(b) DUT 203 post-annealing rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

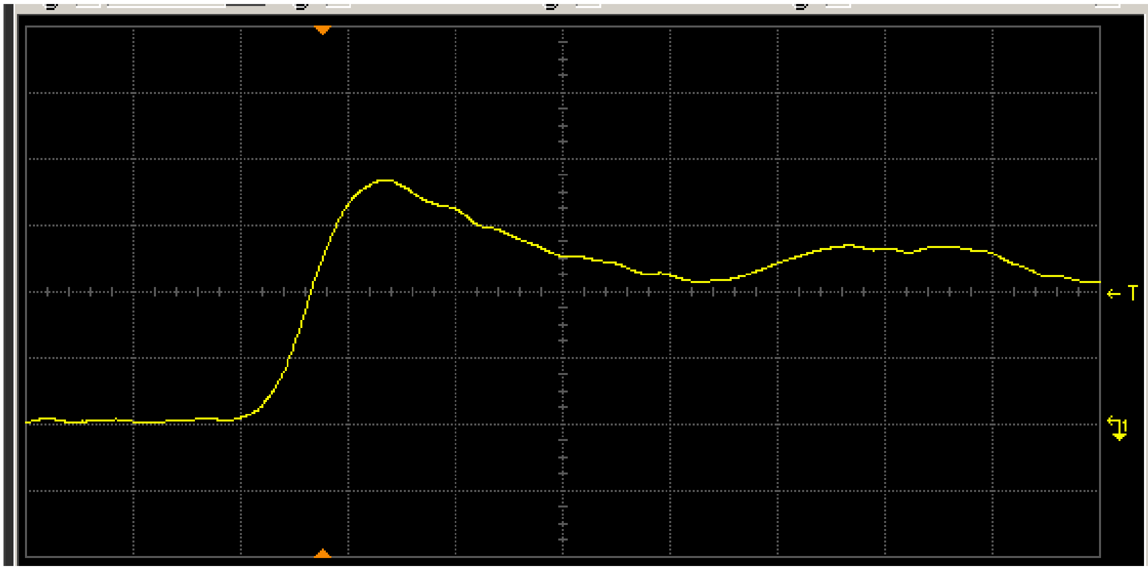


Figure 12(a) DUT 225 pre-irradiation rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

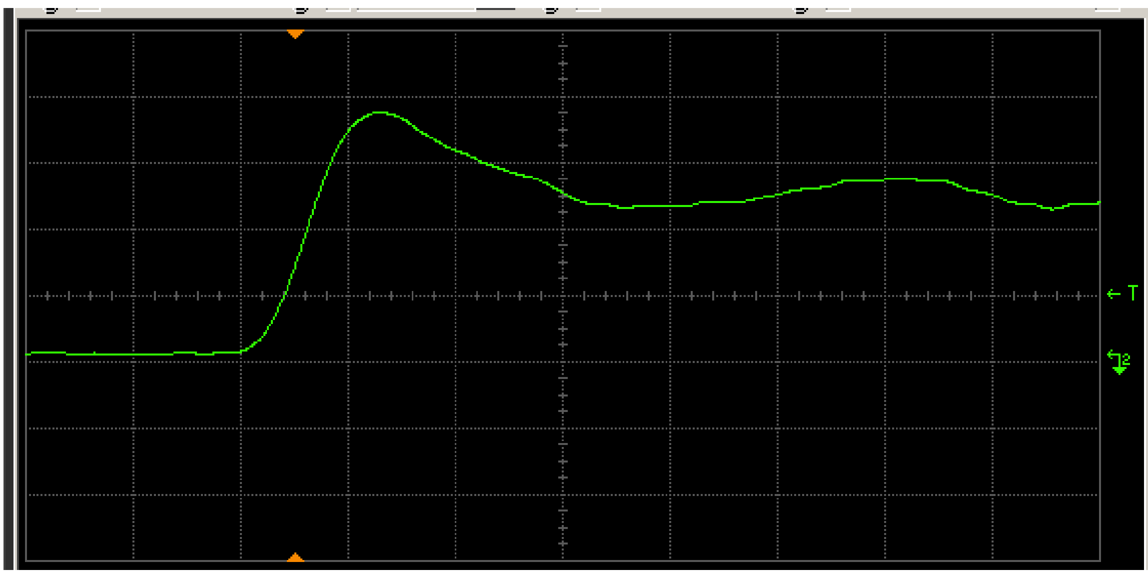


Figure 12(b) DUT 225 post-annealing rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

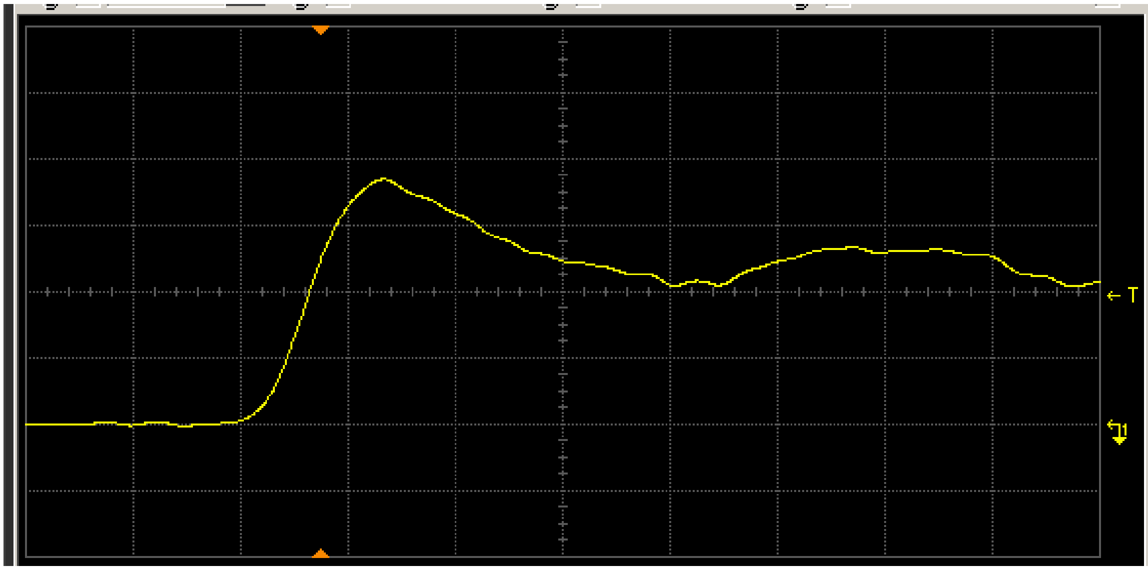


Figure 13(a) DUT 236 pre-irradiation rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

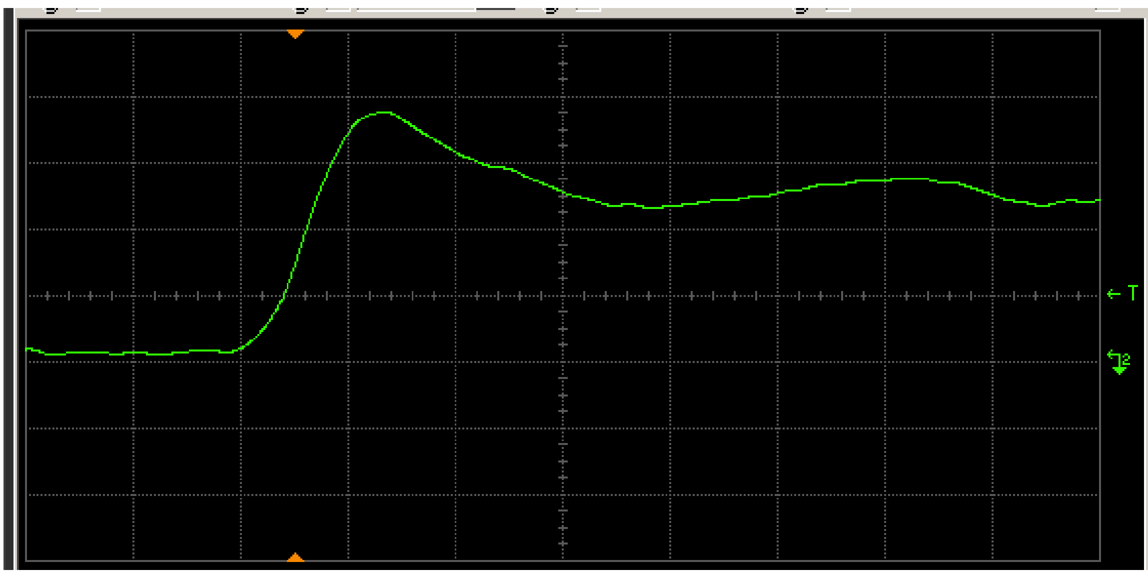


Figure 13(b) DUT 236 post-annealing rising edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

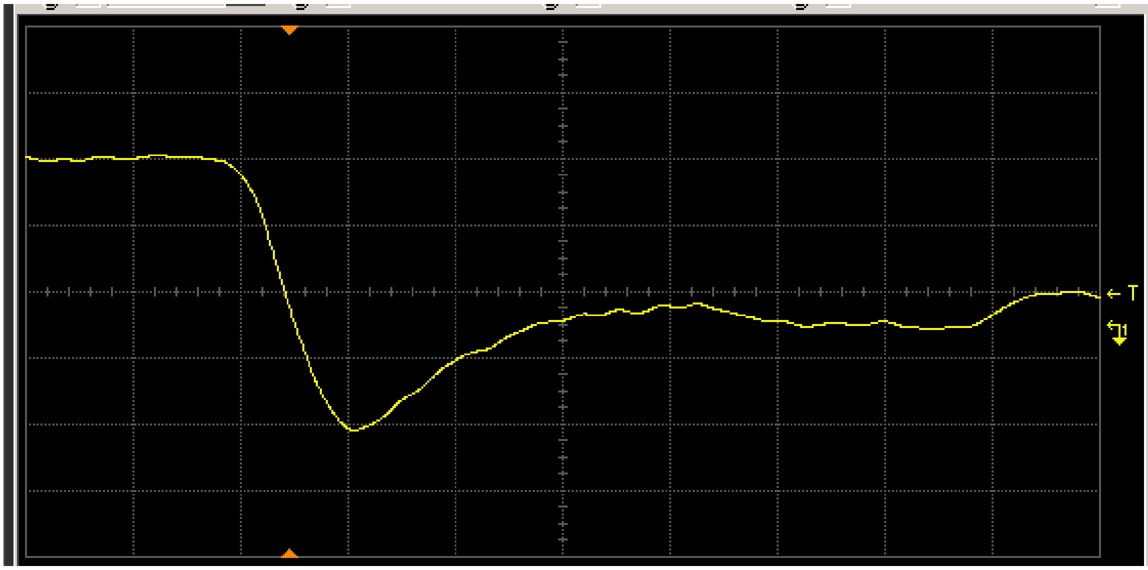


Figure 14(a) DUT 25 pre-irradiation falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

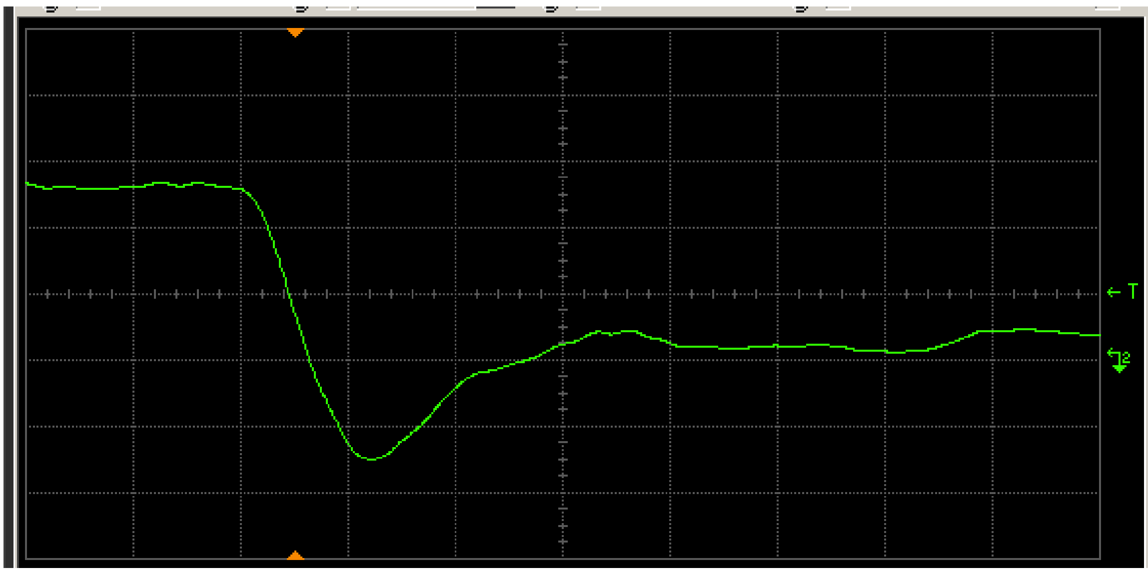


Figure 14(b) DUT 25 post-annealing falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

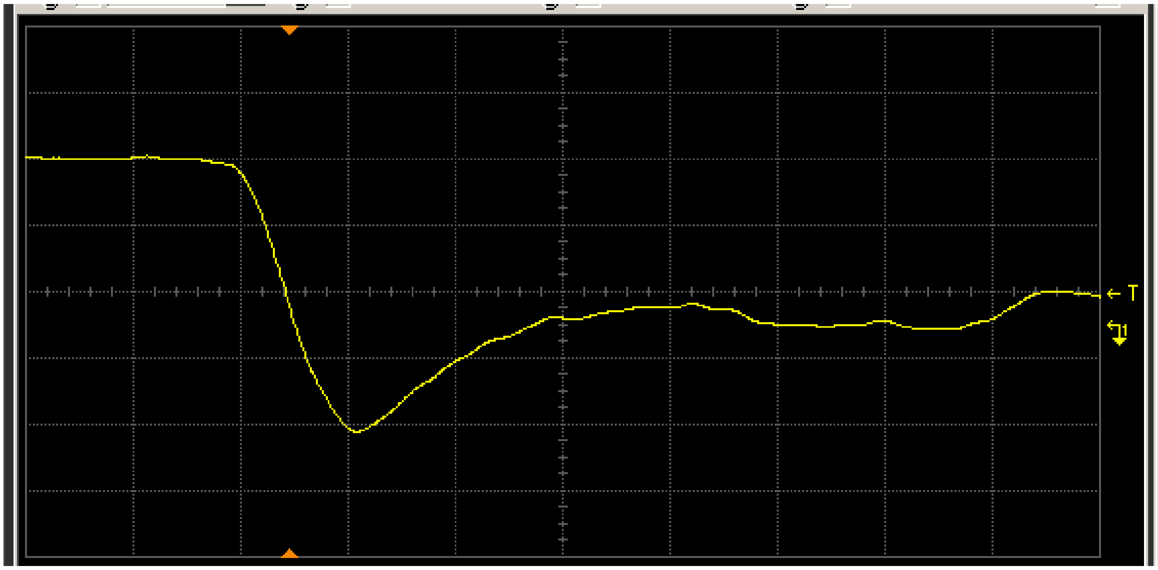


Figure 15(a) DUT 77 pre-irradiation falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

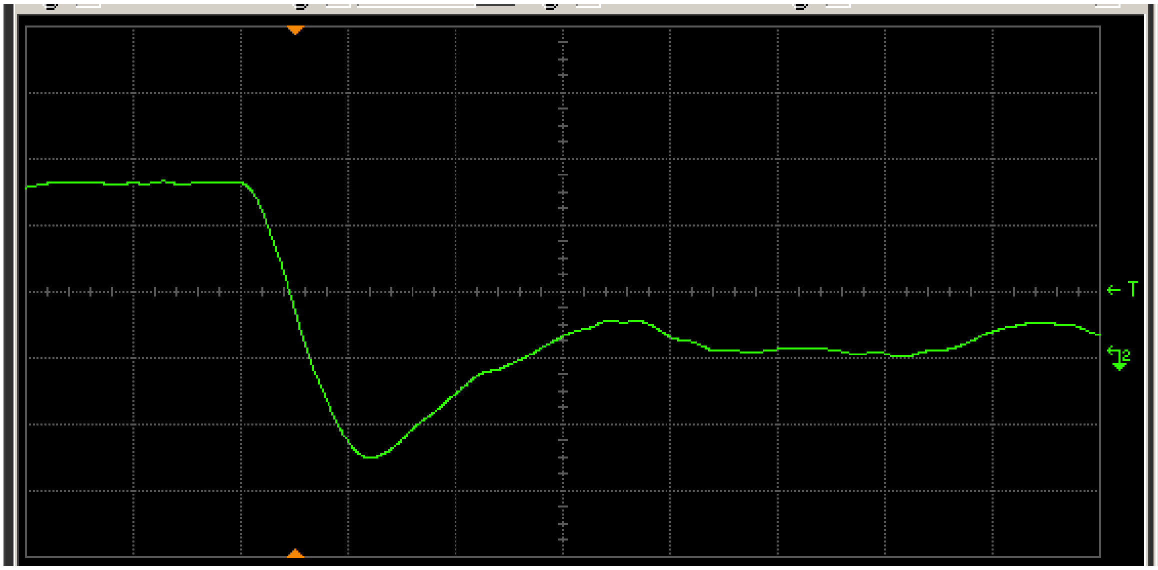


Figure 15(b) DUT 77 post-annealing falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

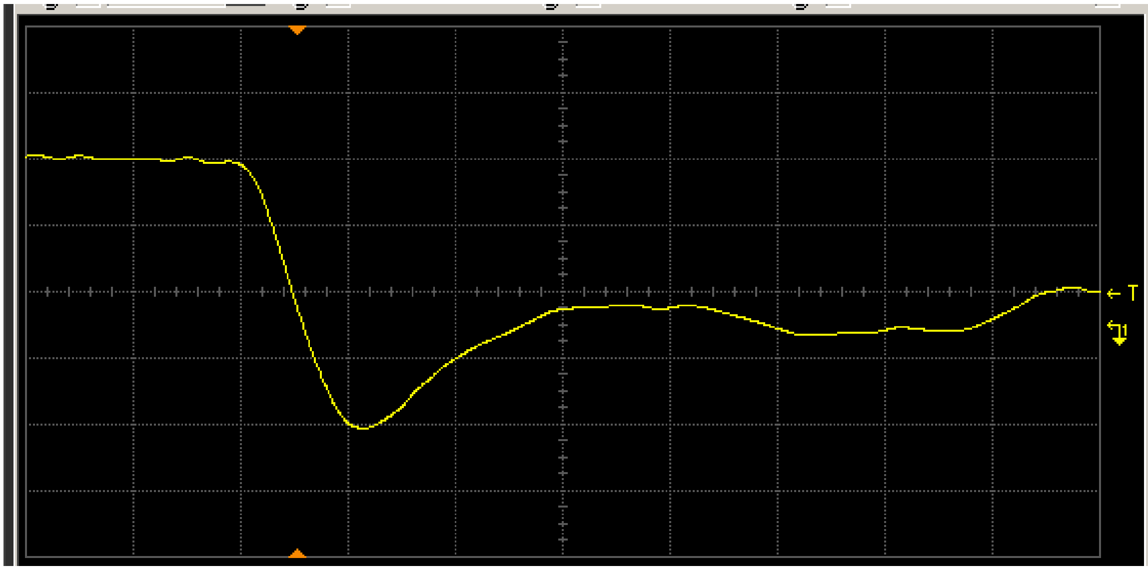


Figure 16(a) DUT 107 pre-radiation falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

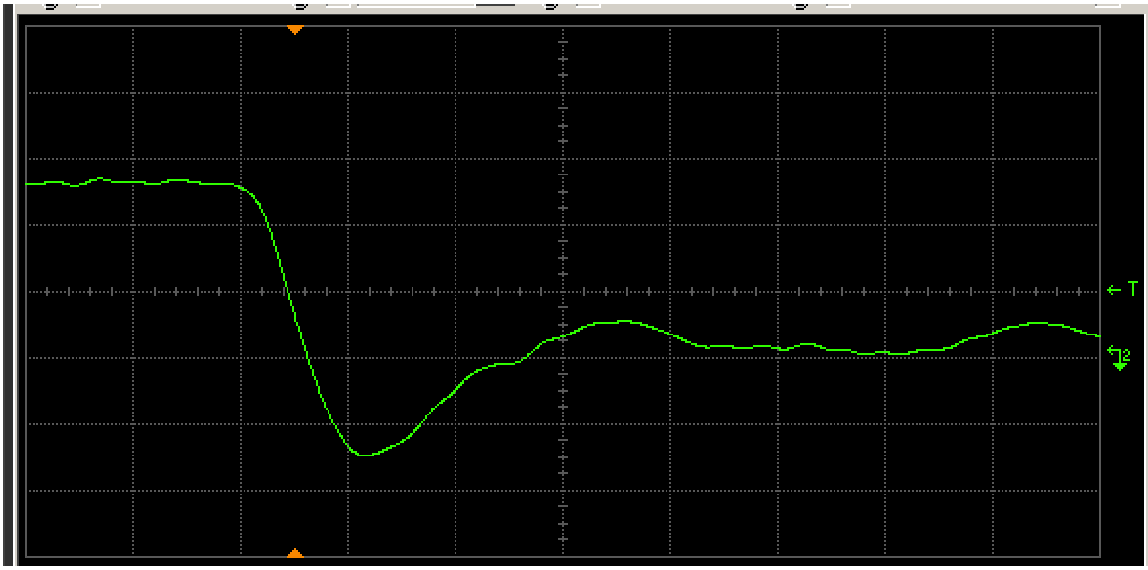


Figure 16(b) DUT 107 post-annealing falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

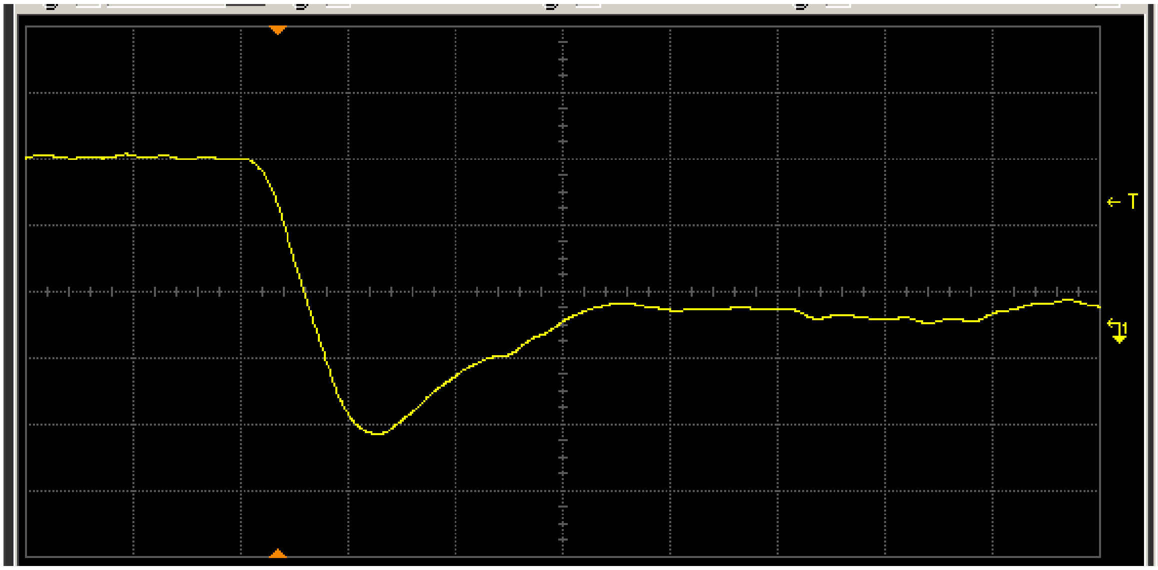


Figure 17(a) DUT 203 pre-irradiation falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

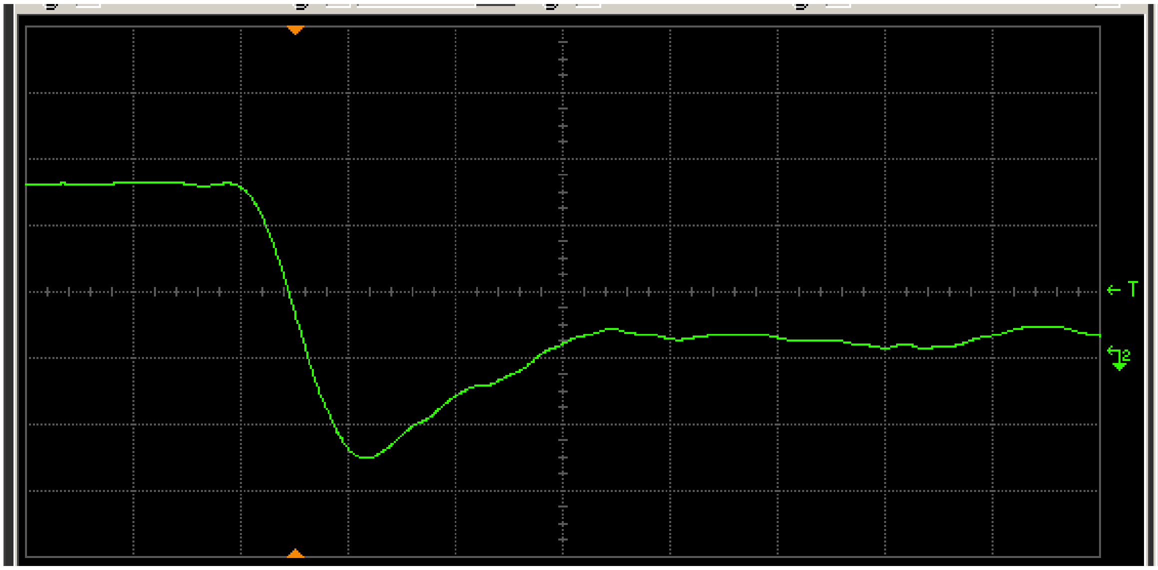


Figure 17(b) DUT 203 post-annealing falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

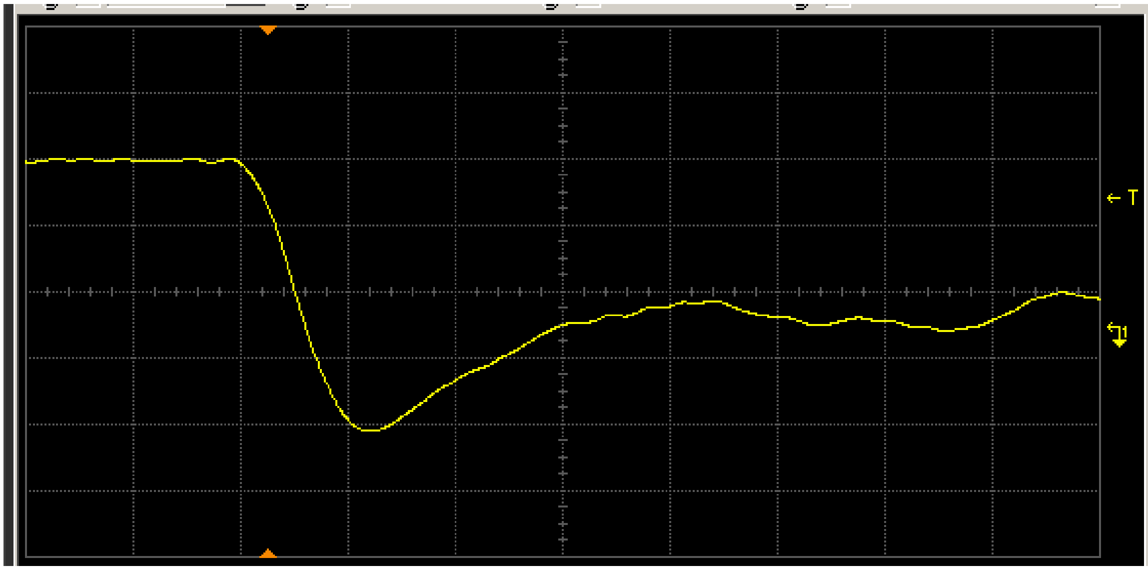


Figure 18(a) DUT 225 pre-irradiation falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

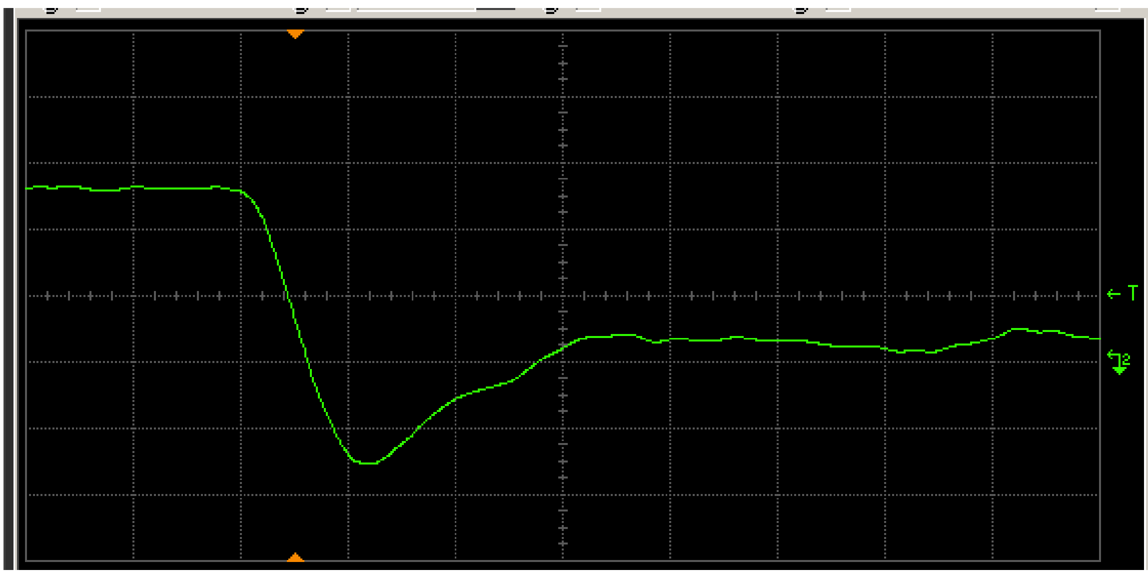


Figure 18(b) DUT 225 post-annealing falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

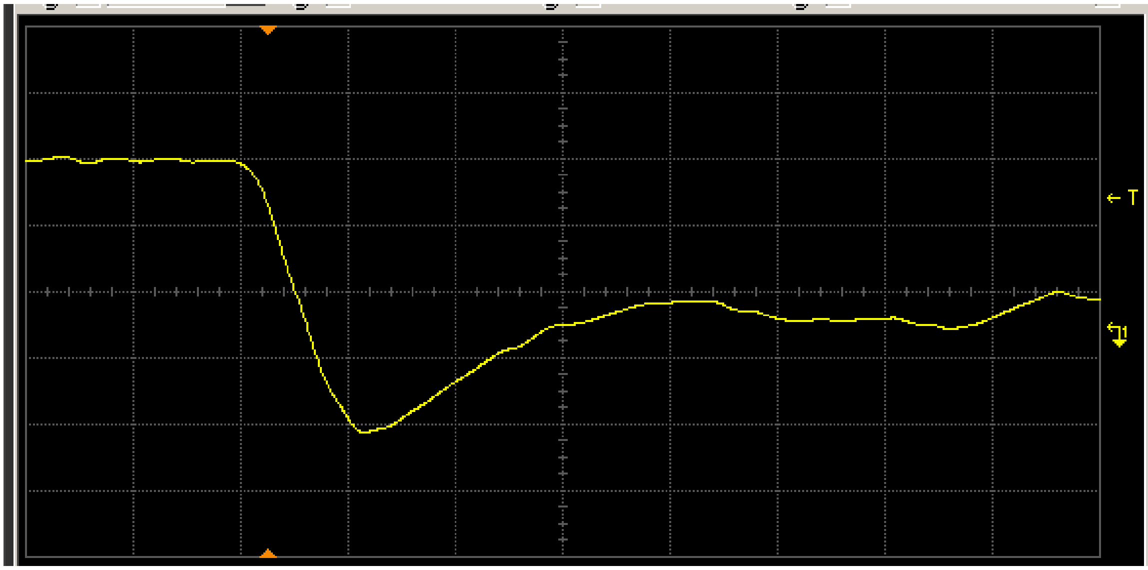


Figure 19(a) DUT 236 pre-irradiation falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

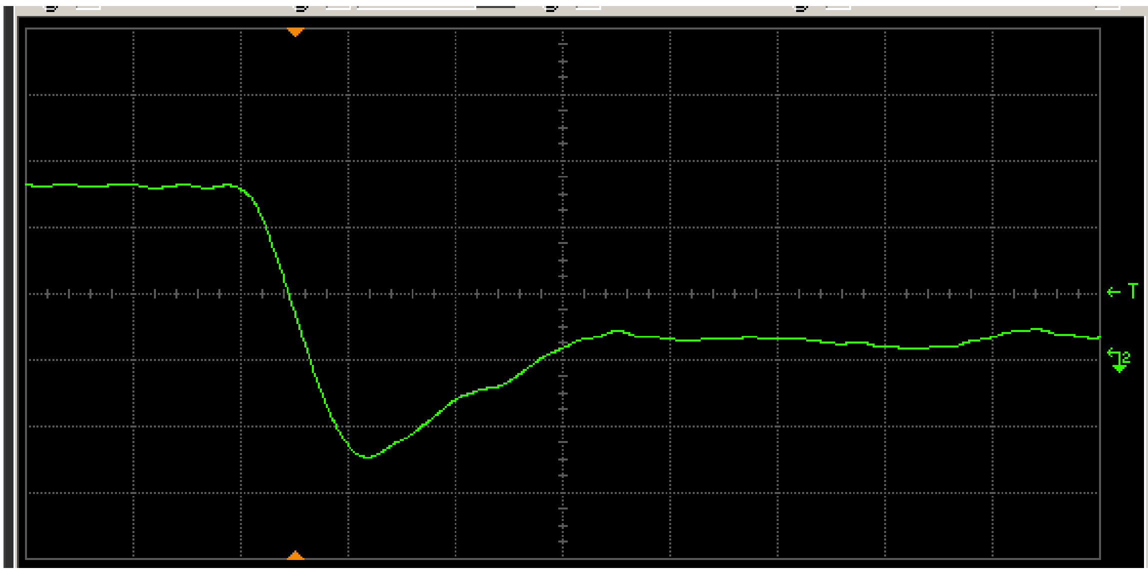


Figure 19(b) DUT 236 post-annealing falling edge. The ordinate is 2 V/div, and abscissa 2 ns/div.

APPENDIX A DUT BIAS

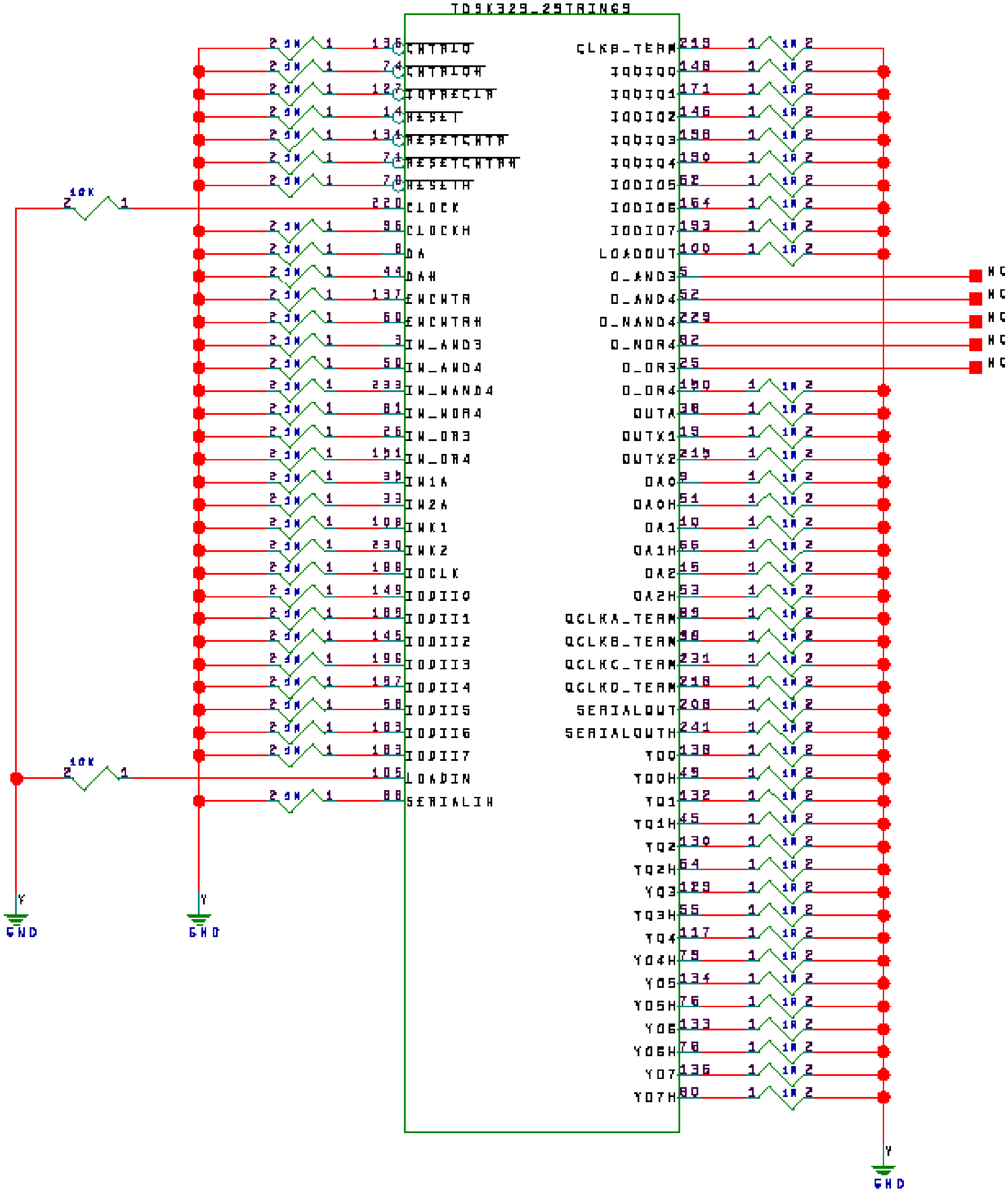
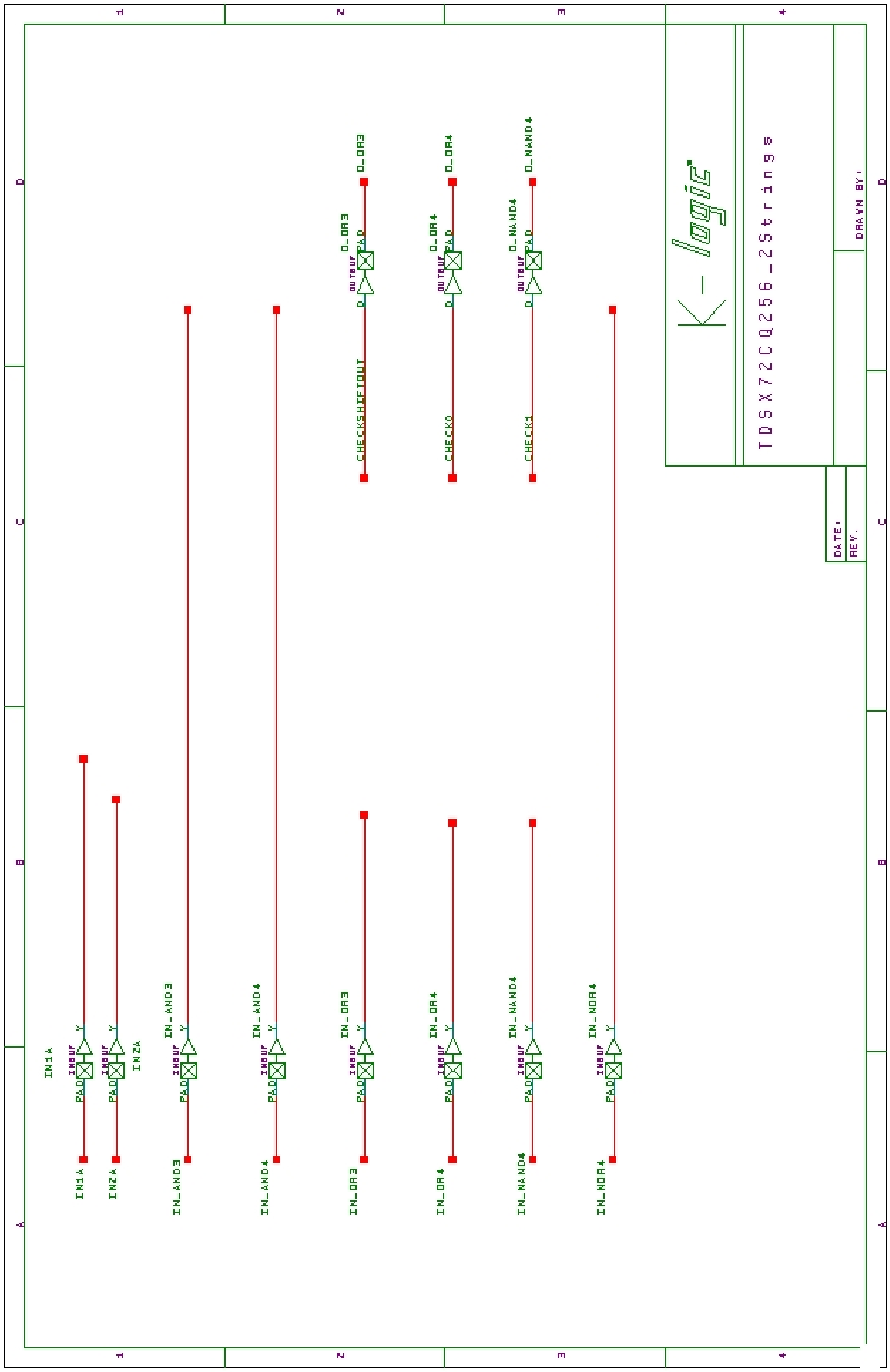
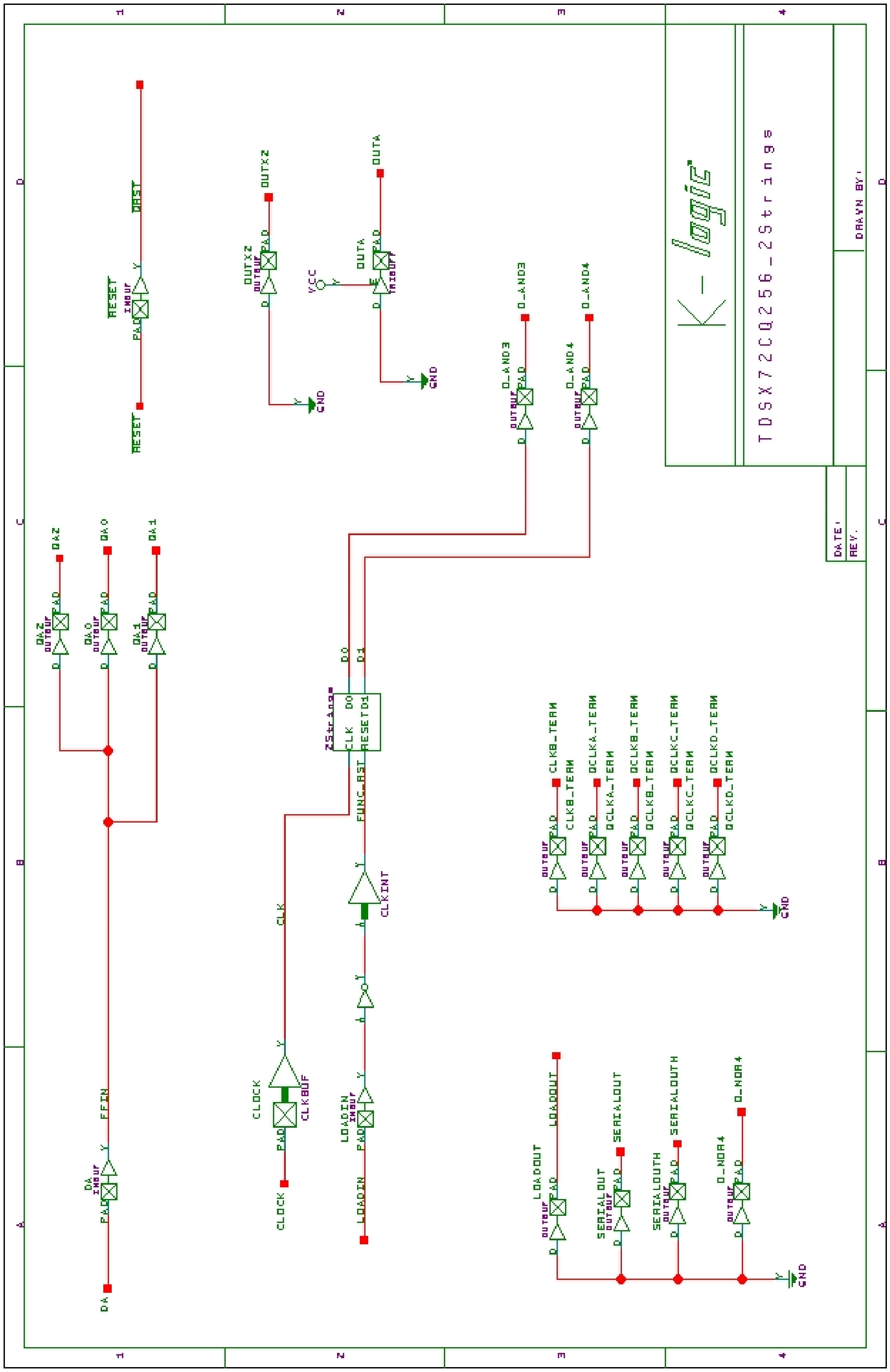


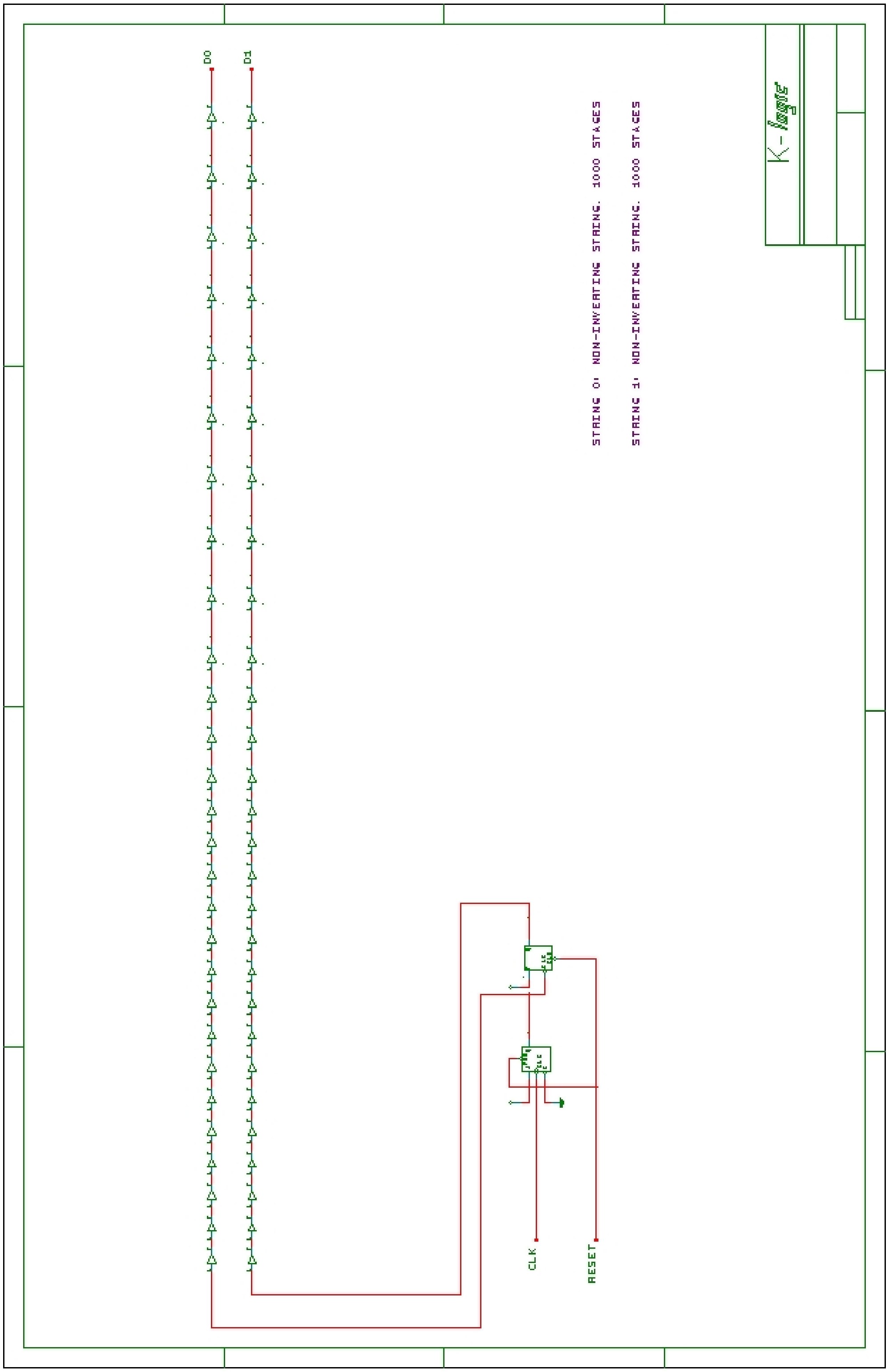
Figure A1 DUT bias during irradiation

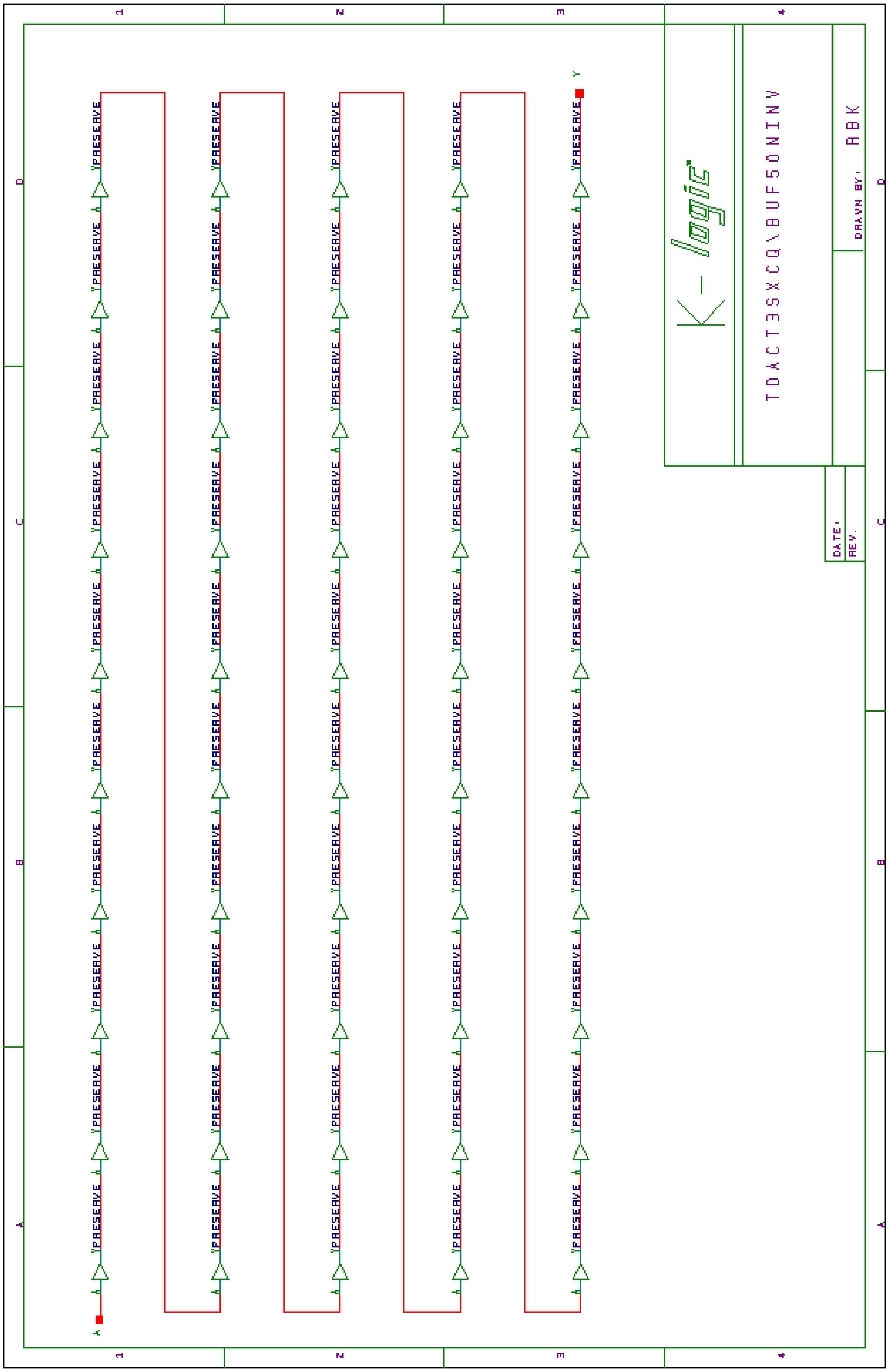
APPENDIX B DUT DESIGN SCHEMATICS (Note that TDSX32CQ256_2STRINGS, in fact, is the same as TDSX72CQ256_2STRINGS except the sizes of buffer strings and shift registers)

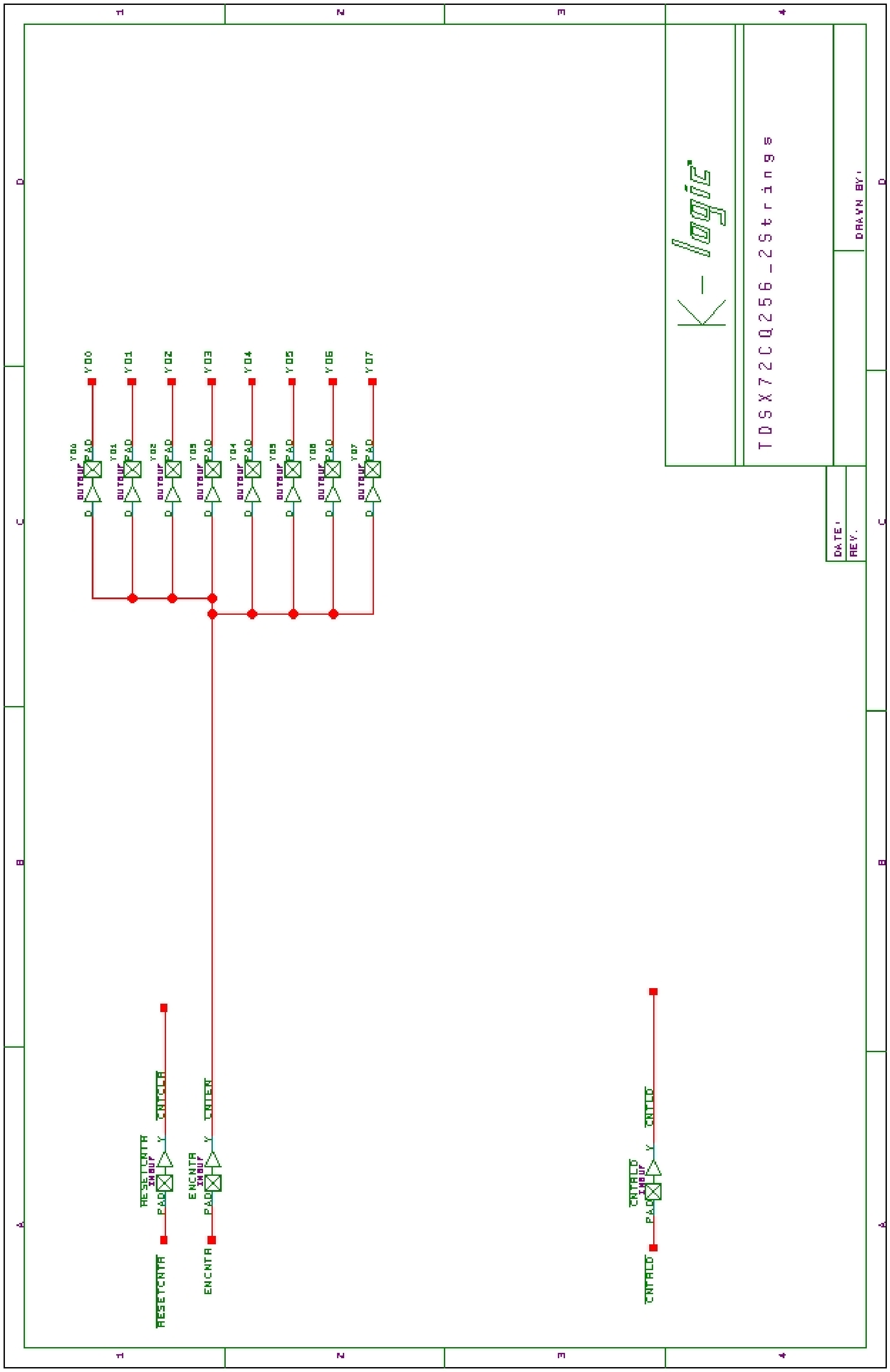


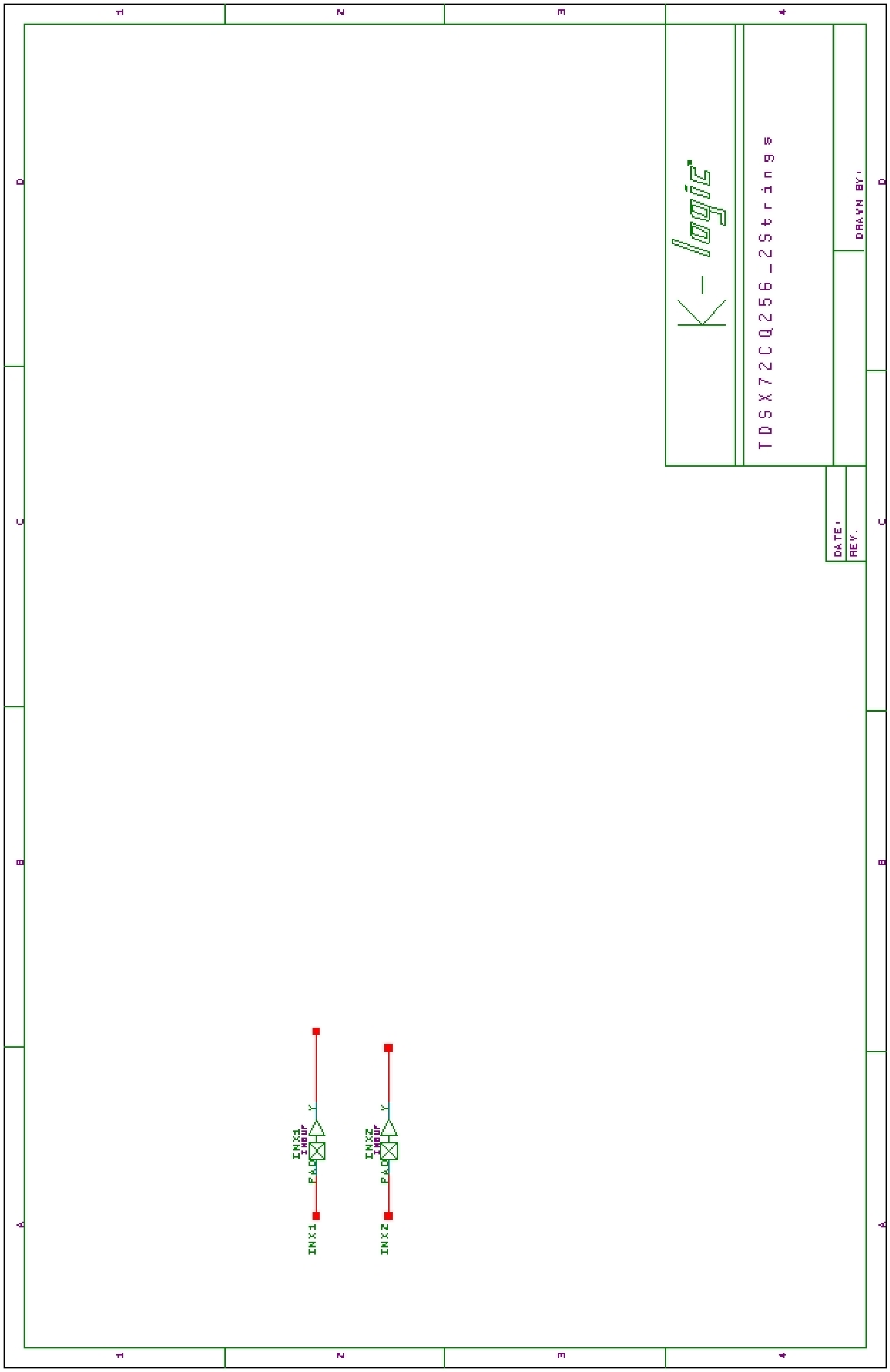
TDSX72CQ256_2Strings
DRAWN BY:
DATE:
REV.
IN1A
IN2A
IN_AND3
IN_AND4
IN_OR3
IN_OR4
IN_NAND4
IN_NOR4
INBUF
PAD
Y
O_OR3
O_OR4
O_NAND4
OUTBUF
D
CHECKSHIFTOUT
CHECK0
CHECK1

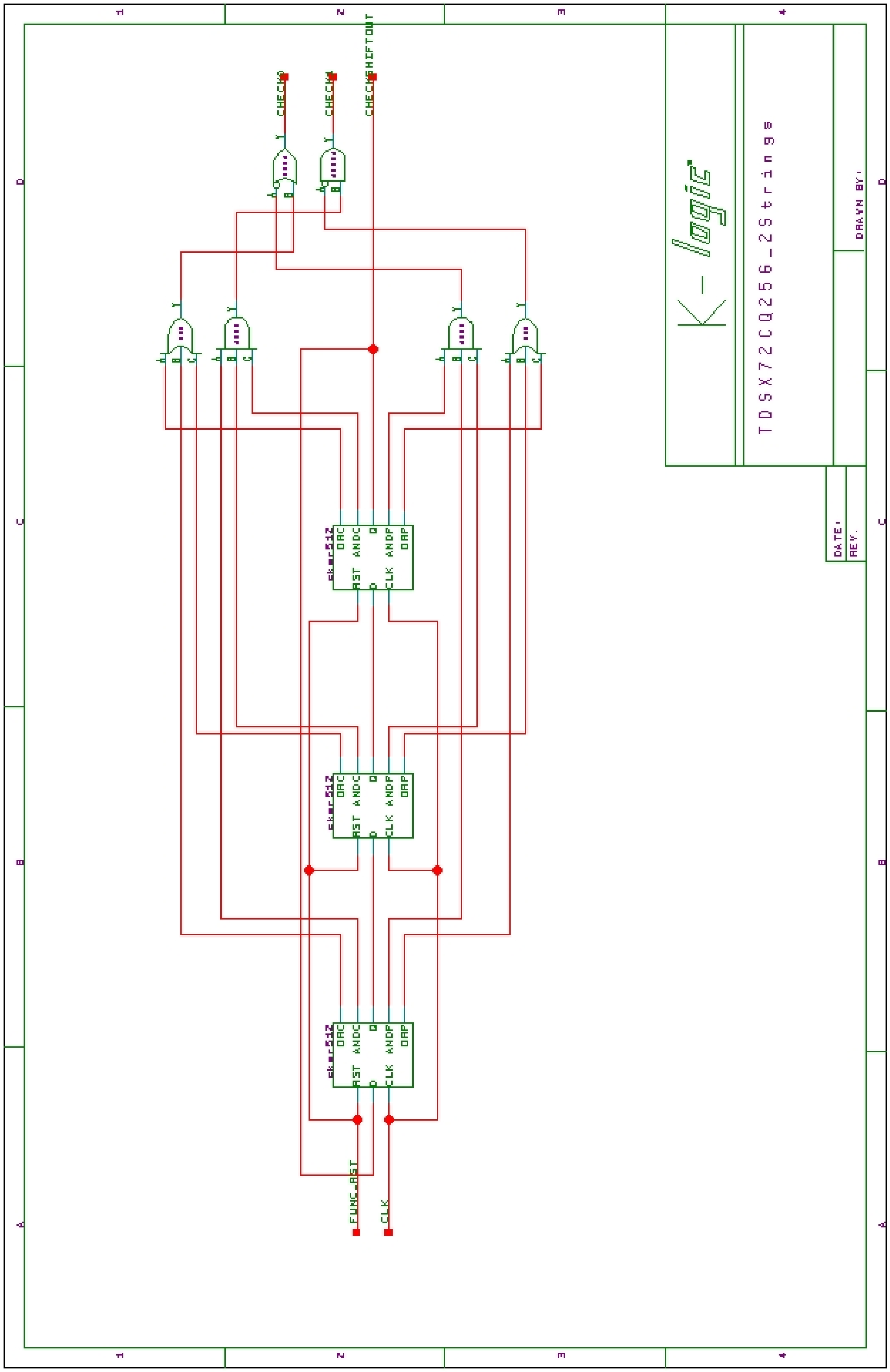

K-logic
TDSX72CQ256_2Strings
DRAWN BY:
DATE:
REV.
2Strings
CLK
RESET
D0
D1
FUNC_RST
CLKINT
CLOCK
CLKBUF
LOADIN
INBUF
OUTBUF
TRIBUF
VCC
GND

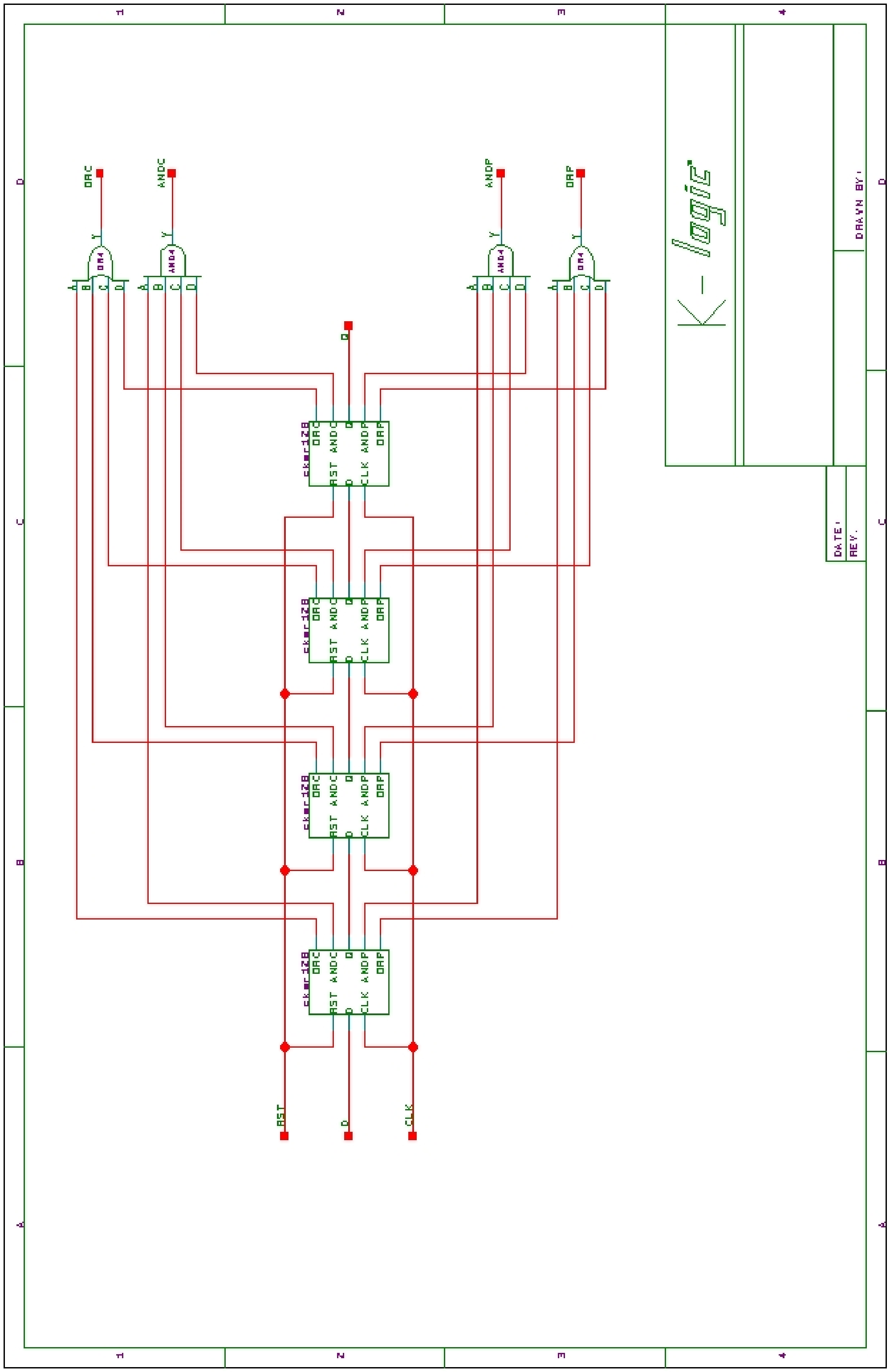

D0
D1
STRING 0: NON-INVERTING STRING, 1000 STAGES
STRING 1: NON-INVERTING STRING, 1000 STAGES
CLK
RESET

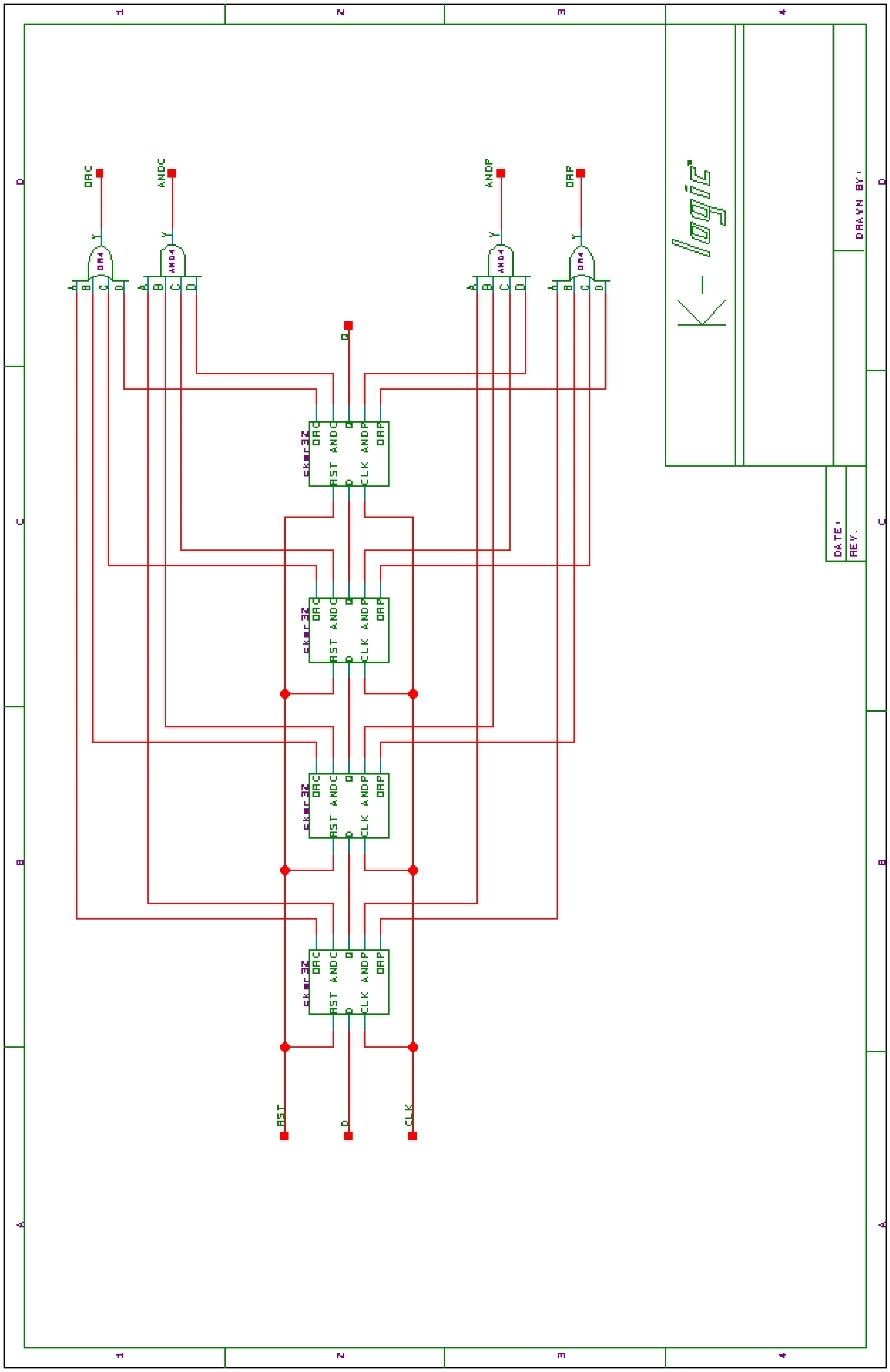

K-logic
TDACT3SXCQ\BUF50NINV
DRAWN BY: ABK
DATE:
REV.
PRESERVE

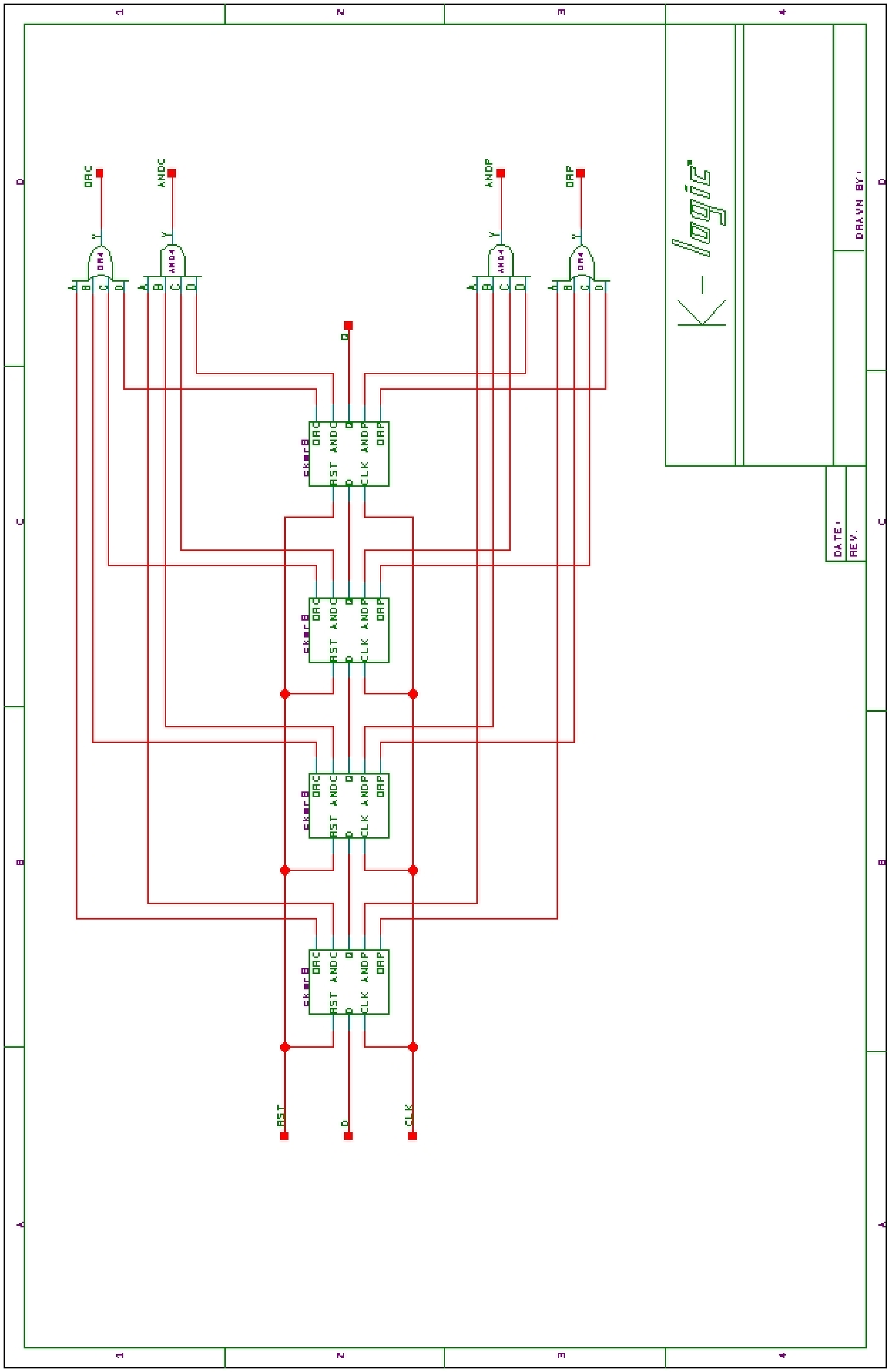

K-logic
TDSX72CQ256_2Strings
DRAWN BY:
DATE:
REV.
Y00
Y01
Y02
Y03
Y04
Y05
Y06
Y07
RESETCNTA
CNTCLR
ENCNTA
CNTEN
CNTALD
CNTLD

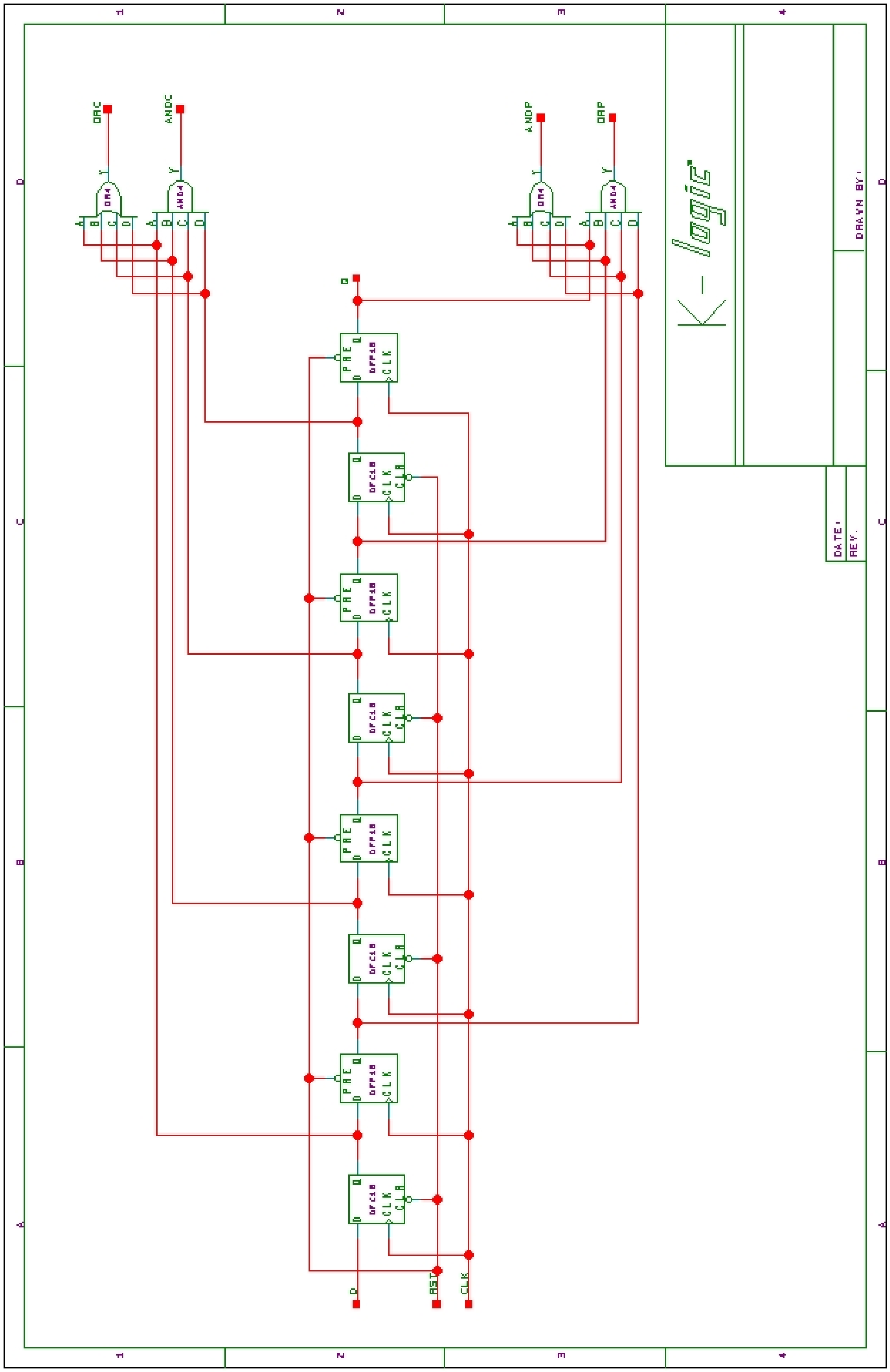

TDSX72CQ256_2Strings
DRAWN BY:
DATE:
REV.
INX1
INX2
INBUF
PAD
Y

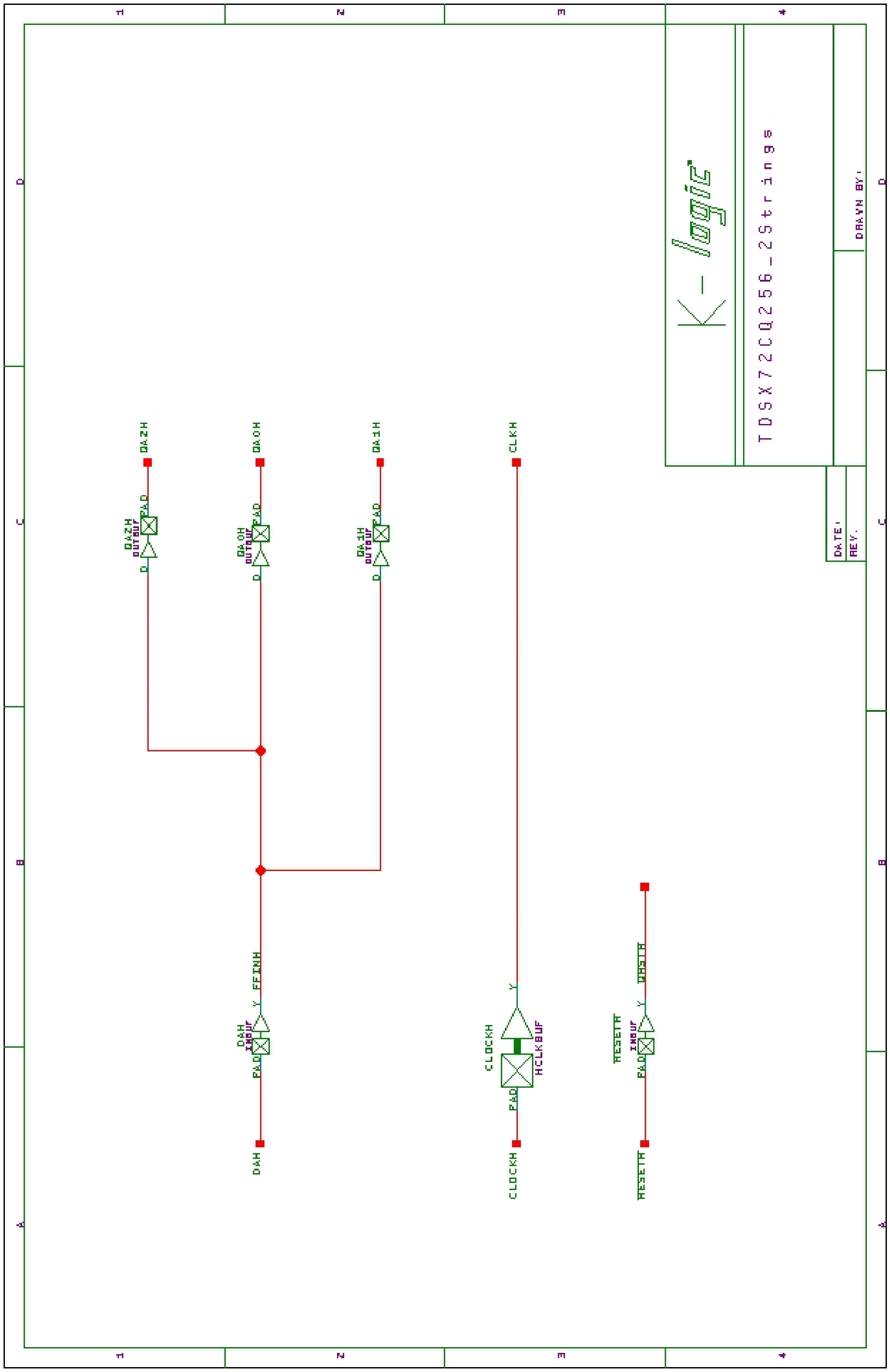

CHECK0
CHECK1
CHECKSHIFTOUT
FUNC_RST
CLK
ORC
ANDC
RST
D
Q
CLK
ANDP
ORP
T D S X 7 2 C Q 2 5 6 _ 2 S t r i n g s
DRAWN BY:
DATE:
REV.

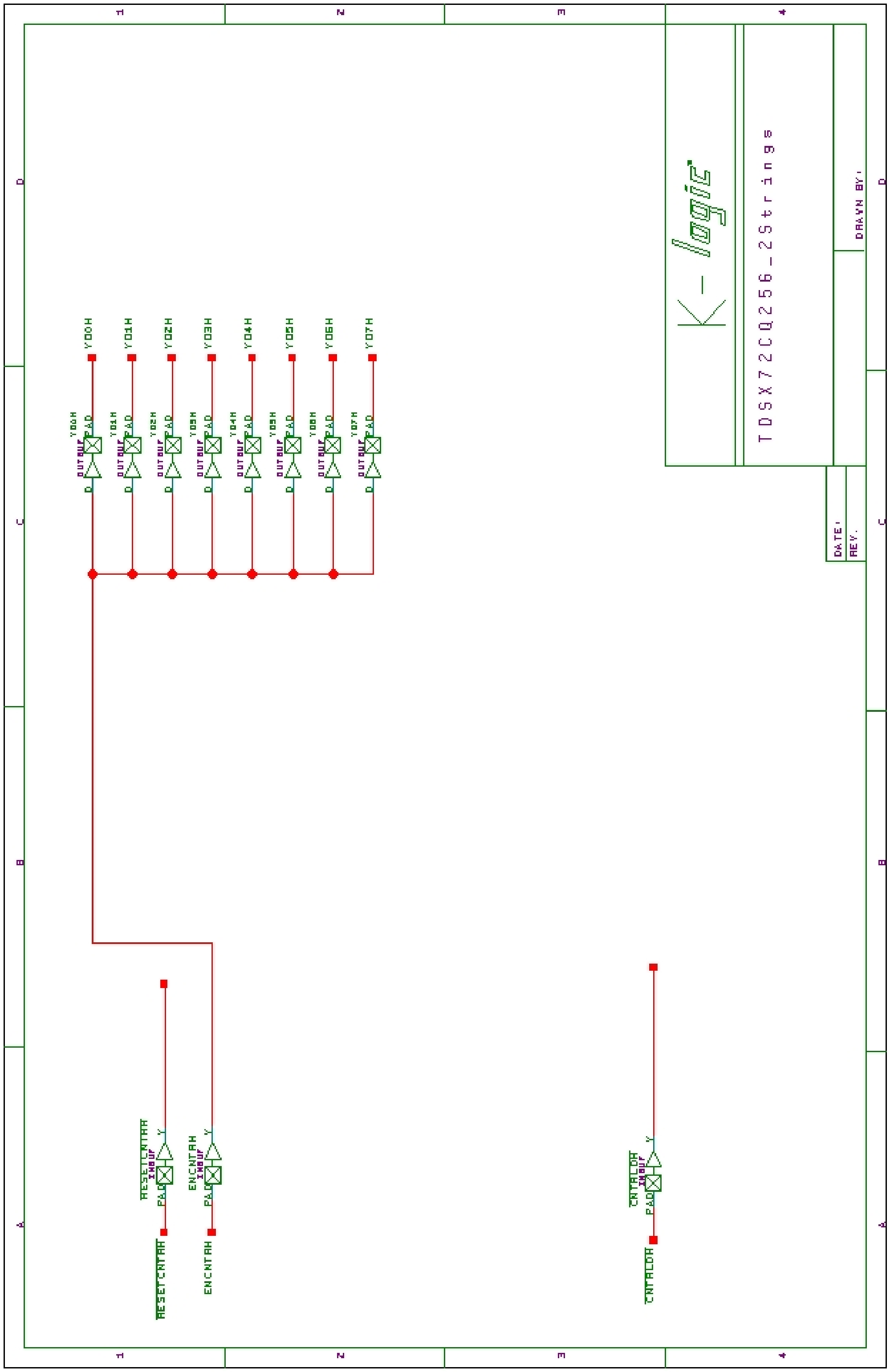

ORC
ANDC
ANDP
ORP
Q
ckmr128
RST
D
CLK
DRAWN BY:
DATE:
REV.


ORC
ANDC
ANDP
ORP
Q
ckmr32
RST
D
CLK
K-logic
DRAWN BY:
DATE:
REV.

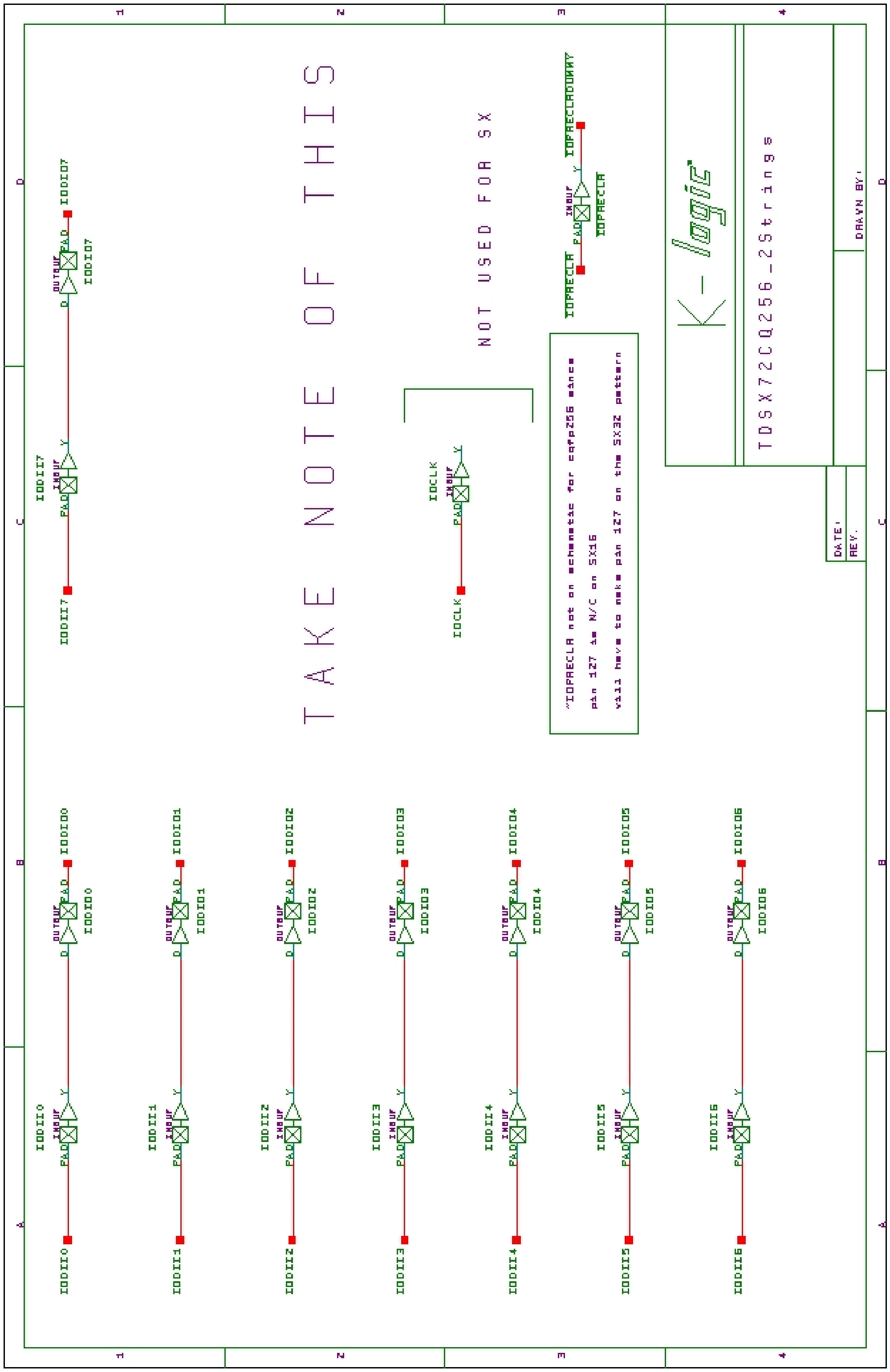

ORC
ANDC
ANDP
ORP
Q
ckmrB
RST
D
CLK
DATE:
REV.
DRAWN BY:

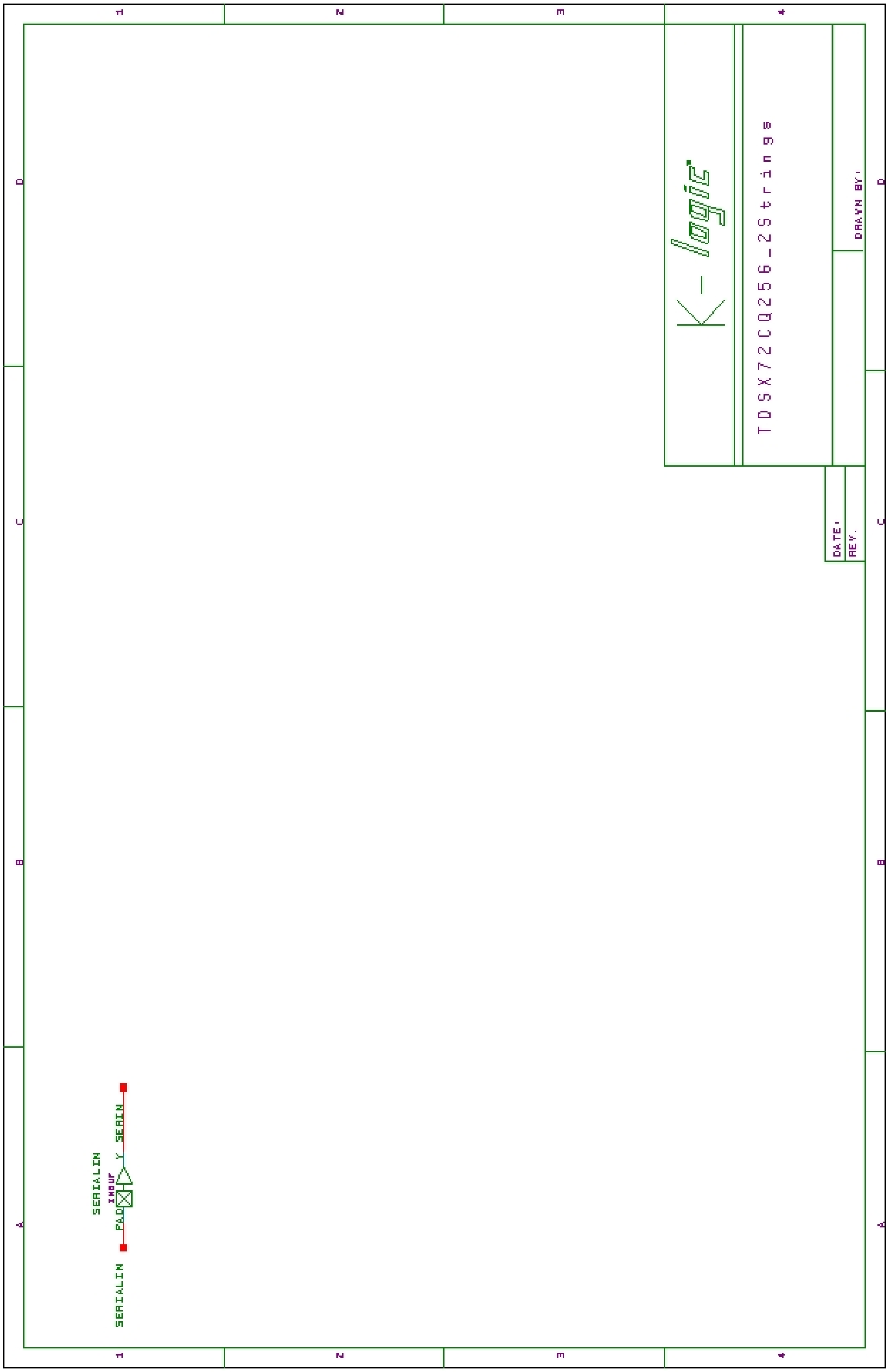

ORC
ANDC
ANDP
ORP
OR4
AND4
Q
D
RST
CLK
DFF1B
DFC1B
PRE
CLR
K-logic
DRAWN BY:
DATE:
REV.

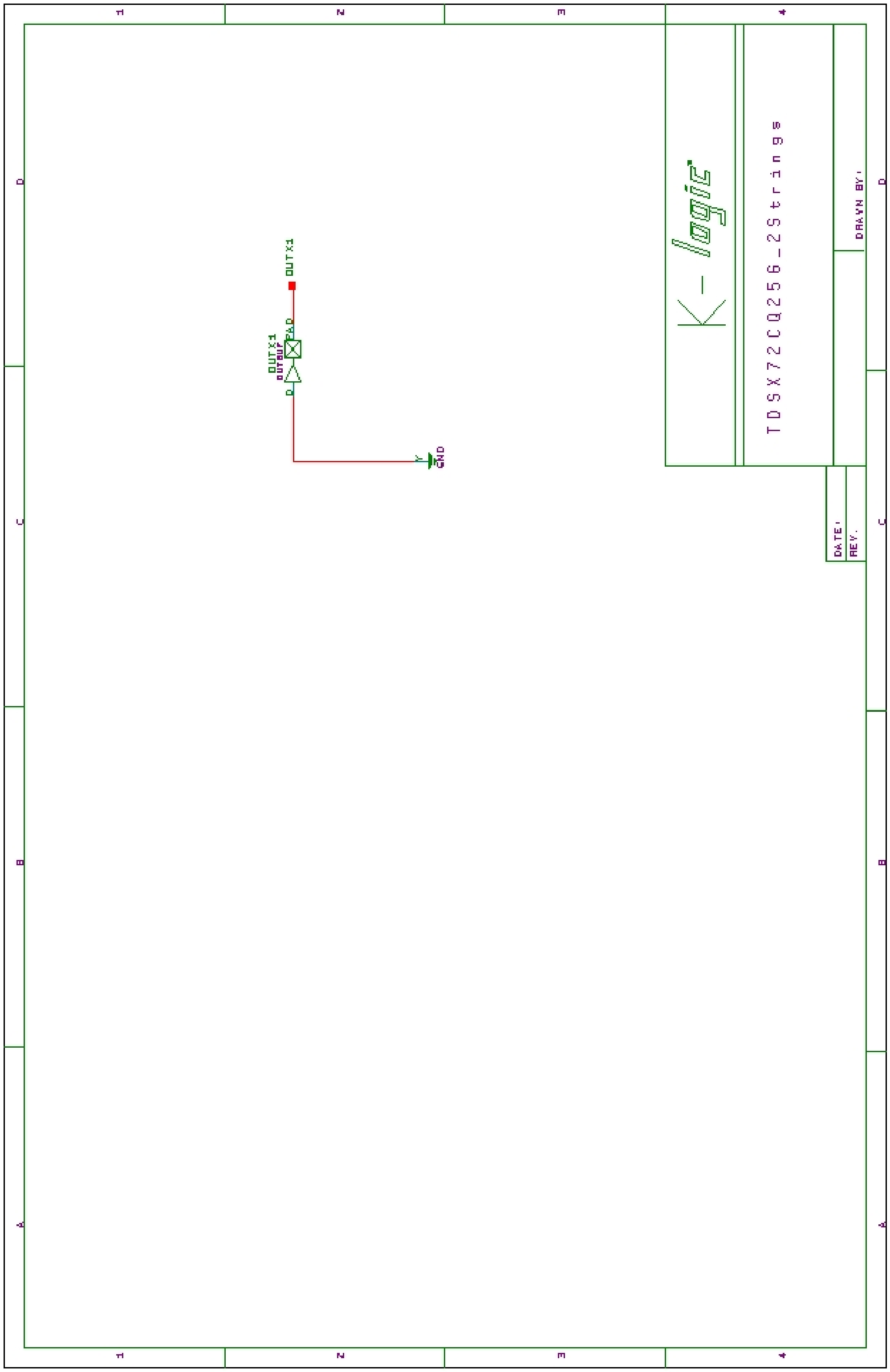

DA2H
DA0H
DA1H
CLKH
OUTBUF
PAD
D
DAH
INBUF
Y
FFINH
CLOCKH
HCLKBUF
RESETH
K-logic
TDSX72CQ256_2Strings
DRAWN BY:
DATE:
REV.



TDSX72CQ256_2Strings
DRAWN BY:
DATE:
REV.
Y00H
Y01H
Y02H
Y03H
Y04H
Y05H
Y06H
Y07H
OUTBUF
PAD
INBUF
RESETCNTAH
ENCNTAH
CNTALDH


TAKE NOTE OF THIS
NOT USED FOR SX
*IOPRECLR not on schematic for cqfp256 since
pin 127 is N/C on SX16
will have to make pin 127 on the SX32 pattern
IOPRECLR
IOPRECLRDUMMY
IOCLK
IODII0
IODII1
IODII2
IODII3
IODII4
IODII5
IODII6
IODII7
IODIO0
IODIO1
IODIO2
IODIO3
IODIO4
IODIO5
IODIO6
IODIO7
INBUF
OUTBUF
PAD
K-logic
TDSX72CQ256_2Strings
DATE:
REV.
DRAWN BY:


SERIALIN
SERIALIN
PAD
IBUF
Y
SERIN
TDSX72CQ256_2Strings
DATE:
REV.
DRAWN BY:


OUTX1
PAD
OUTBUF
GND
TDSX72CQ256_2Strings
DRAWN BY:
DATE:
REV.