ECSE 323 Digital System Design

Lab #2 – g27_sine (sine function circuit)

Group 27

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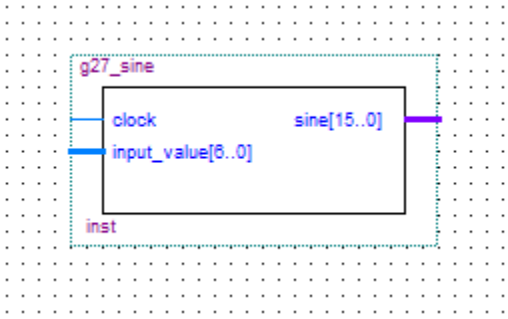


Design of a sine circuit using a Lookup Table

Since sound is periodic pressure waves, we need a periodic function to represent sounds of different periods. Writing out all 128 values of sine for inputs in degrees is tedious, so we calculated the results in Excel and put the contents of the Excel table in a .mif file to be used by the Altera SRAM.

x (degree)	x (radian)	sin(x)	sin(x) * 2^16	int [sin(x) * 2^16]
0	0	0	0	0
1	0.017453	0.017452	1143.761	1143
2	0.034907	0.034899	2287.173	2287
3	0.05236	0.052336	3429.889	3429
4	0.069813	0.069756	4571.56	4571
5	0.087266	0.087156	5711.839	5711
6	0.10472	0.104528	6850.377	6850
7	0.122173	0.121869	7986.829	7986
8	0.139626	0.139173	9120.848	9120
9	0.15708	0.156434	10252.09	10252
10	0.174533	0.173648	11380.21	11380
11	0.191986	0.190809	12504.86	12504
12	0.20944	0.207912	13625.7	13625
13	0.226893	0.224951	14742.39	14742
14	0.244346	0.241922	15854.59	15854
15	0.261799	0.258819	16961.96	16961
16	0.279253	0.275637	18064.17	18064
17	0.296706	0.292372	19160.87	19160
18	0.314159	0.309017	20251.74	20251
19	0.331613	0.325568	21336.43	21336
20	0.349066	0.34202	22414.63	22414

21	0.366519	0.358368	23486	23486
22	0.383972	0.374607	24550.22	24550
23	0.401426	0.390731	25606.96	25606
24	0.418879	0.406737	26655.89	26655
25	0.436332	0.422618	27696.71	27696
26	0.453786	0.438371	28729.09	28729
27	0.471239	0.45399	29752.72	29752
28	0.488692	0.469472	30767.29	30767
29	0.506145	0.48481	31772.48	31772
30	0.523599	0.5	32768	32768
31	0.541052	0.515038	33753.54	33753
32	0.558505	0.529919	34728.79	34728
33	0.575959	0.544639	35693.46	35693
34	0.593412	0.559193	36647.27	36647
35	0.610865	0.573576	37589.91	37589
36	0.628319	0.587785	38521.09	38521
37	0.645772	0.601815	39440.55	39440
38	0.663225	0.615661	40347.99	40347
39	0.680678	0.62932	41243.14	41243
40	0.698132	0.642788	42125.73	42125
41	0.715585	0.656059	42995.48	42995
42	0.733038	0.669131	43852.14	43852
43	0.750492	0.681998	44695.44	44695
44	0.767945	0.694658	45525.13	45525
45	0.785398	0.707107	46340.95	46340
46	0.802851	0.71934	47142.65	47142
47	0.820305	0.731354	47930	47929
48	0.837758	0.743145	48702.74	48702
49	0.855211	0.75471	49460.65	49460
50	0.872665	0.766044	50203.49	50203
51	0.890118	0.777146	50931.04	50931
52	0.907571	0.788011	51643.07	51643
53	0.925025	0.798636	52339.38	52339
54	0.942478	0.809017	53019.74	53019
55	0.959931	0.819152	53683.95	53683
56	0.977384	0.829038	54331.81	54331
57	0.994838	0.838671	54963.11	54963
58	1.012291	0.848048	55577.68	55577
59	1.029744	0.857167	56175.32	56175
60	1.047198	0.866025	56755.84	56755
61	1.064651	0.87462	57319.08	57319

62	1.082104	0.882948	57864.85	57864
63	1.099557	0.891007	58393	58393
64	1.117011	0.898794	58903.37	58903
65	1.134464	0.906308	59395.79	59395
66	1.151917	0.913545	59870.12	59870
67	1.169371	0.920505	60326.21	60326
68	1.186824	0.927184	60763.92	60763
69	1.204277	0.93358	61183.13	61183
70	1.22173	0.939693	61583.7	61583
71	1.239184	0.945519	61965.51	61965
72	1.256637	0.951057	62328.44	62328
73	1.27409	0.956305	62672.39	62672
74	1.291544	0.961262	62997.25	62997
75	1.308997	0.965926	63302.91	63302
76	1.32645	0.970296	63589.3	63589
77	1.343904	0.97437	63856.32	63856
78	1.361357	0.978148	64103.88	64103
79	1.37881	0.981627	64331.92	64331
80	1.396263	0.984808	64540.36	64540
81	1.413717	0.987688	64729.14	64729
82	1.43117	0.990268	64898.21	64898
83	1.448623	0.992546	65047.5	65047
84	1.466077	0.994522	65176.99	65176
85	1.48353	0.996195	65286.62	65286
86	1.500983	0.997564	65376.36	65376
87	1.518436	0.99863	65446.19	65446
88	1.53589	0.999391	65496.08	65496
89	1.553343	0.999848	65526.02	65526
90	**1.570796**	**1**	**65536**	**65536**

Table1. Input and output values

When x = 90, sin(x)*2^16 = 2^16 converted to binary 10000000000000000 which is a 17-bit number. We set the word size 16, it will show 0000000000000000. (Write down 0 in decimal)

For inputs greater than 90 (from 91 to 127), the output should be all ones. (**65535** in decimal)

Creating a Memory Initialization File:

g27_sine.mif*

Addr	+0	+1	+2	+3	+4	+5	+6	+7
0	0	1143	2287	3429	4571	5711	6850	7986
8	9120	10252	11380	12504	13625	14742	15854	16961
16	18064	19160	20251	21336	22414	23486	24550	25606
24	26655	27696	28729	29752	30767	31772	32768	33753
32	34728	35693	36647	37589	38521	39440	40347	41243
40	42125	42995	43852	44695	45525	46340	47142	47929
48	48702	49460	50203	50931	51643	52339	53019	53683
56	54331	54963	55577	56175	56755	57319	57864	58393
64	58903	59395	59870	60326	60763	61183	61583	61965
72	62328	62672	62997	63302	63589	63856	64103	64331
80	64540	64729	64898	65047	65176	65286	65376	65446
88	65496	65526	0	65535	65535	65535	65535	65535
96	65535	65535	65535	65535	65535	65535	65535	65535
104	65535	65535	65535	65535	65535	65535	65535	65535
112	65535	65535	65535	65535	65535	65535	65535	65535
120	65535	65535	65535	65535	65535	65535	65535	65535

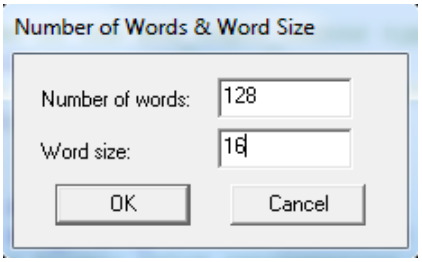


Figure1. Memory Initialization File (numbers in unsigned decimal)

Select Binary in Memory Radix (View list)

Binary

g27_sine.mif*

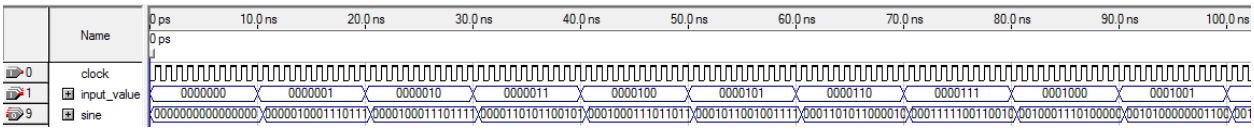
Addr	+0	+1	+2	+3	+4	+5	+6	+7
0	0000000000000000	0000010001110111	0000100011101111	0000110101100101	0001000111011011	0001011001001111	0001101011000010	0001111100110010
8	0010001110100000	0010100000001100	0010110001110100	0011000011011000	0011010100111001	0011100110010110	0011110111101110	0100001001000001
16	0100011010010000	0100101011011000	0100111100011011	0101001101011000	0101011110001110	0101101110111110	0101111111100110	0110010000000110
24	0110100000011111	0110110000110000	0111000000111001	0111010000111000	0111100000101111	0111110000011100	1000000000000000	1000001111011001
32	1000011110101000	1000101101101101	1000111100100111	1001001011010101	1001011001111001	1001101000010000	1001110110011011	1010000100011011
40	1010010010001101	1010011111110011	1010101101001100	1010111010010111	1011000111010101	1011010100000100	1011100000100110	1011101100111001
48	1011111000111110	1100000100110100	1100010000011011	1100011011110011	1100100110111011	1100110001110011	1100111100011011	1101000110110011
56	1101010000111011	1101011010110011	1101100100011001	1101101101101111	1101110110110011	1101111111100111	1110001000001000	1110010000011001
64	1110011000010111	1110100000000011	1110100111011110	1110101110100110	1110110101011011	1110111011111111	1111000010001111	1111001000001101
72	1111001101111000	1111010011010000	1111011000010101	1111011101000110	1111100001100101	1111100101110000	1111101001100111	1111101101001011
80	1111110000011100	1111110011011001	1111111011000010	1111111000010111	1111111010011000	1111111100000110	1111111101100000	1111111110100110
88	1111111111011000	1111111111110110	0000000000000000	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111
96	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111
104	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111
112	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111
120	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111	1111111111111111

Figure1. Memory Initialization File (numbers in binary)

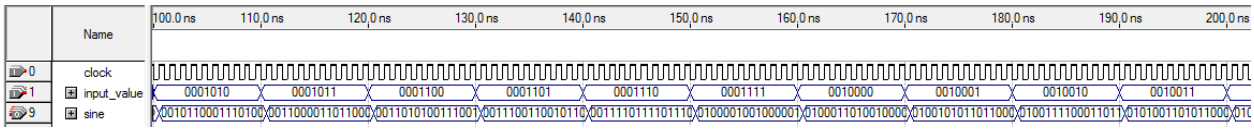
Input_value starts at 0000000, ends at 1111110, and is incremented by 1. Note_number is counted every 10 ns and the end time is **1270ns**, testing all 128 possible input patterns. The testing results are shown below.

Functional Simulation Results:

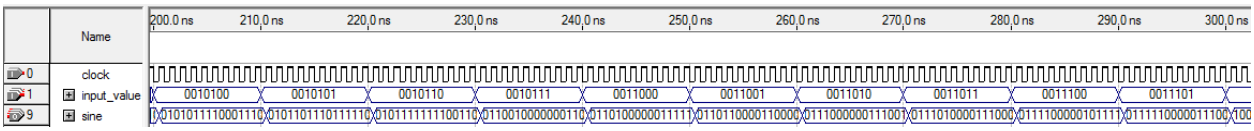
- t = 0 – 100ns



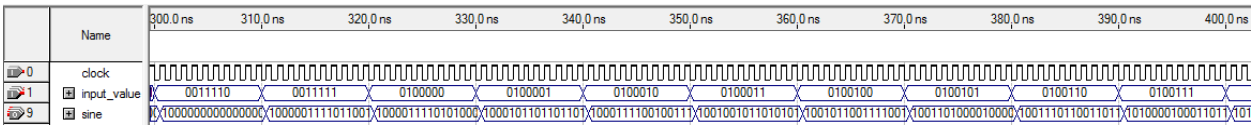
- t = 100 – 200ns



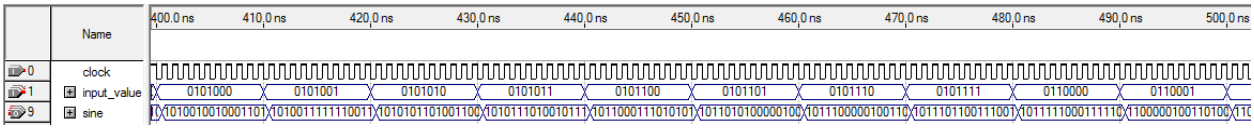
- t = 200 – 300ns



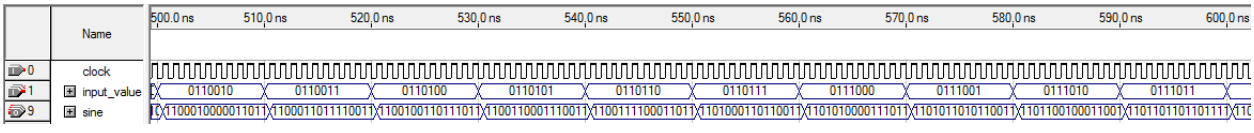
- t = 300 – 400ns



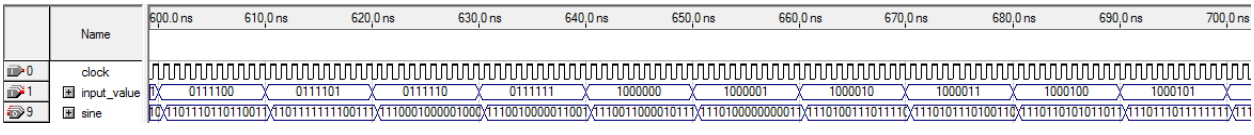
- t = 400 – 500ns



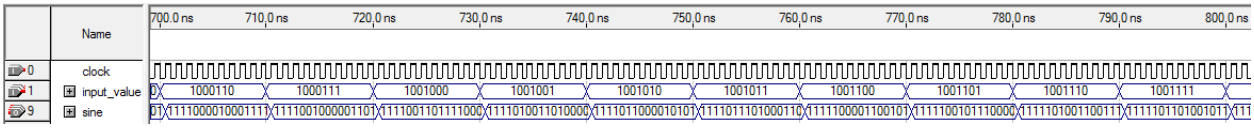
- t = 500 – 600ns



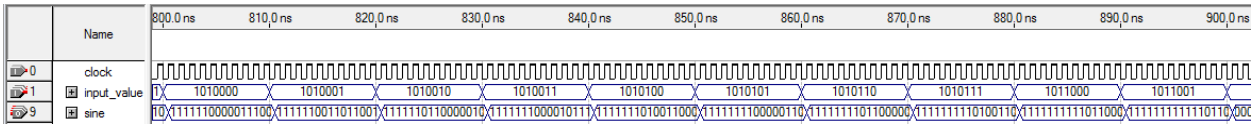
- t = 600 – 700ns



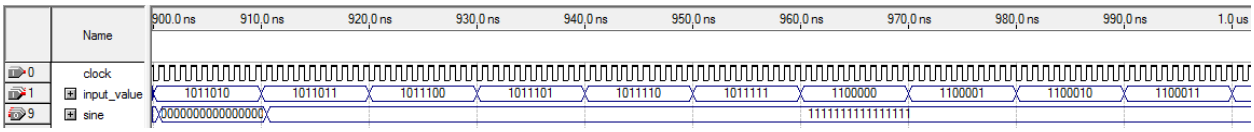
- t = 700 – 800ns



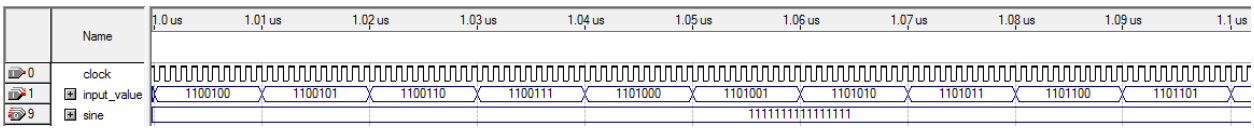
- t = 800 – 900ns



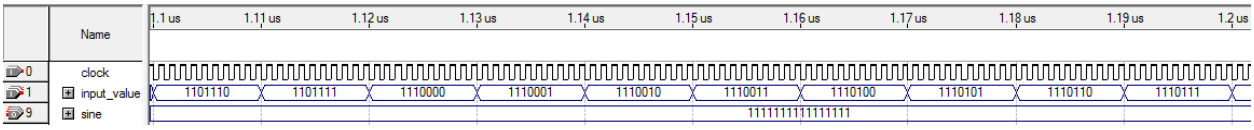
- t = 900 – 1000ns



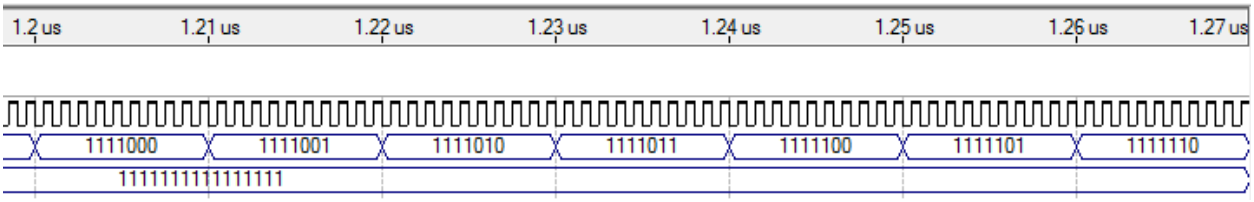
- t = 1000 – 1100ns



- t = 1100 – 1200ns

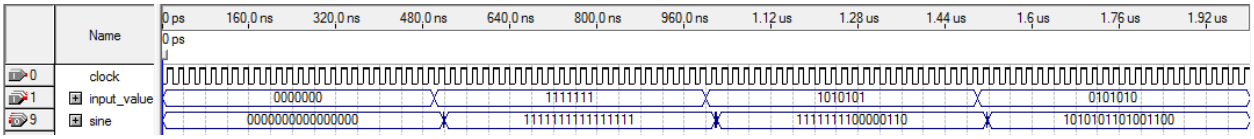


- t = 1200 – 1270ns



Timing Simulation Result:

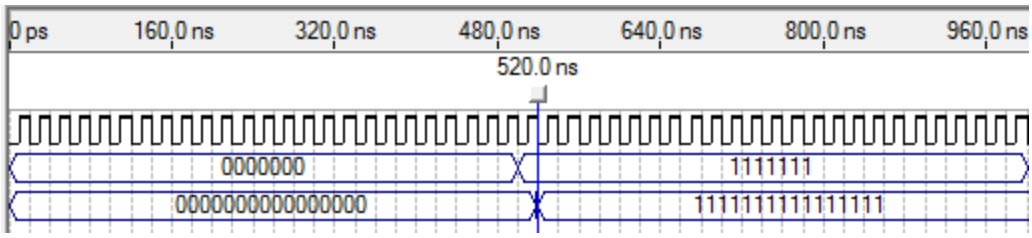
Using an end time of 2usec and a clock signal with a period of 20nsec.



The output values are correct.

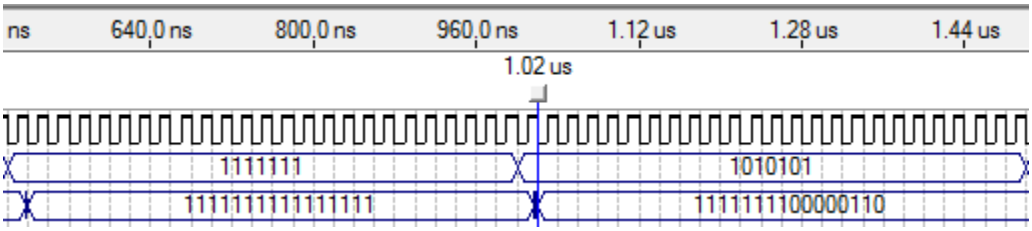
Setting time for different transition:

- Transition from 0000000 to 1111111



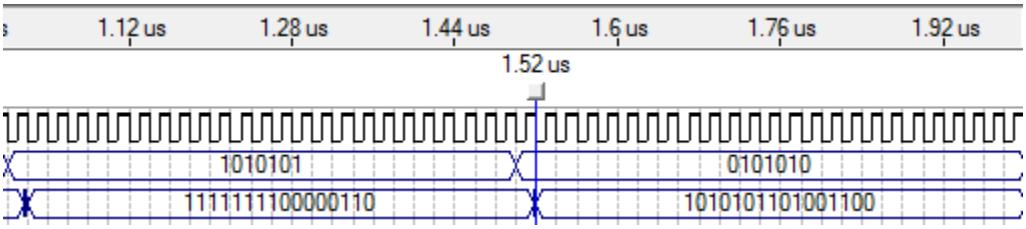
Settling time = 520 – 500ns = 20ns

- Transition from 1111111 to 1010101



Settling time = 1.02us – 1.0us = 0.02us

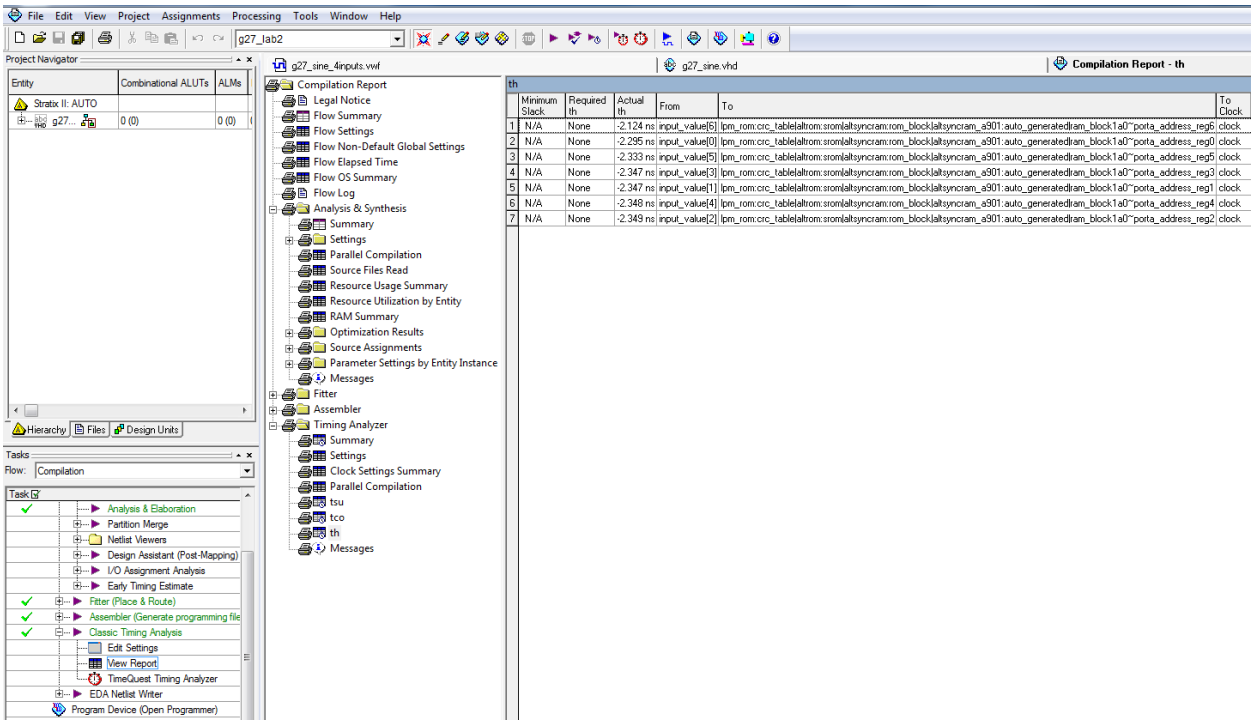
- Transition from 1010101 to 0101010



Settling time = 1.52us – 1.5us = 0.02us

The settling time is the same for every transition.

The compilation report gives us some interesting information about the efficiency of our hardware usage.



Analysis & Synthesis Resource Usage Summary

	Resource	Usage
1	Estimated ALUTs Used	0
2	Dedicated logic registers	0
3		
4	Estimated ALUTs Unavailable	0
5		
6	Total combinational functions	0
7	⊟ Combinational ALUT usage by number of inputs	
8	-- 7 input functions	0
9	-- 6 input functions	0
10	-- 5 input functions	0
11	-- 4 input functions	0
12	-- <=3 input functions	0
13		
14	⊟ Combinational ALUTs by mode	
15	-- normal mode	0
16	-- extended LUT mode	0
17	-- arithmetic mode	0
18	-- shared arithmetic mode	0
19		
20	Estimated ALUT/register pairs used	0
21		
22	⊟ Total registers	0
23	-- Dedicated logic registers	0
24	-- I/O registers	0
25		
26		
27	I/O pins	24
28	Total block memory bits	2048
29	Maximum fan-out node	clock
30	Maximum fan-out	16
31	Total fan-out	144
32	Average fan-out	3.60

tco

	Slack	Required tco	Actual tco
1	N/A	None	8.628 ns
2	N/A	None	7.514 ns
3	N/A	None	7.292 ns
4	N/A	None	7.236 ns
5	N/A	None	7.230 ns
6	N/A	None	7.219 ns
7	N/A	None	7.175 ns
8	N/A	None	6.989 ns
9	N/A	None	6.985 ns
10	N/A	None	6.952 ns
11	N/A	None	6.952 ns
12	N/A	None	6.950 ns
13	N/A	None	6.939 ns
14	N/A	None	6.934 ns
15	N/A	None	6.895 ns
16	N/A	None	6.889 ns
17	N/A	None	8.628 ns
18	N/A	None	7.514 ns
19	N/A	None	7.292 ns
20	N/A	None	7.236 ns
21	N/A	None	7.230 ns
22	N/A	None	7.219 ns
23	N/A	None	7.175 ns
24	N/A	None	6.989 ns
25	N/A	None	6.985 ns
26	N/A	None	6.952 ns
27	N/A	None	6.952 ns
28	N/A	None	6.950 ns
29	N/A	None	6.939 ns
30	N/A	None	6.934 ns
31	N/A	None	6.895 ns
32	N/A	None	6.889 ns
33	N/A	None	8.628 ns
34	N/A	None	7.514 ns
35	N/A	None	7.292 ns
36	N/A	None	7.236 ns
37	N/A	None	7.230 ns
38	N/A	None	7.219 ns
39	N/A	None	7.175 ns
40	N/A	None	6.989 ns
41	N/A	None	6.985 ns
42	N/A	None	6.952 ns
43	N/A	None	6.952 ns
44	N/A	None	6.950 ns

tco

	Slack	Required tco	Actual tco
45	N/A	None	6.939 ns
46	N/A	None	6.934 ns
47	N/A	None	6.895 ns
48	N/A	None	6.889 ns
49	N/A	None	8.628 ns
50	N/A	None	7.514 ns
51	N/A	None	7.292 ns
52	N/A	None	7.236 ns
53	N/A	None	7.230 ns
54	N/A	None	7.219 ns
55	N/A	None	7.175 ns
56	N/A	None	6.989 ns
57	N/A	None	6.985 ns
58	N/A	None	6.952 ns
59	N/A	None	6.952 ns
60	N/A	None	6.950 ns
61	N/A	None	6.939 ns
62	N/A	None	6.934 ns
63	N/A	None	6.895 ns
64	N/A	None	6.889 ns
65	N/A	None	8.628 ns
66	N/A	None	7.514 ns
67	N/A	None	7.292 ns
68	N/A	None	7.236 ns
69	N/A	None	7.230 ns
70	N/A	None	7.219 ns
71	N/A	None	7.175 ns
72	N/A	None	6.989 ns
73	N/A	None	6.985 ns
74	N/A	None	6.952 ns
75	N/A	None	6.952 ns
76	N/A	None	6.950 ns
77	N/A	None	6.939 ns
78	N/A	None	6.934 ns
79	N/A	None	6.895 ns
80	N/A	None	6.889 ns
81	N/A	None	8.628 ns
82	N/A	None	7.514 ns
83	N/A	None	7.292 ns
84	N/A	None	7.236 ns
85	N/A	None	7.230 ns
86	N/A	None	7.219 ns
87	N/A	None	7.175 ns
88	N/A	None	6.989 ns

Timing Analyzer Summary

	Type	Slack	Required Time	Actual Time
1	Worst-case tsu	N/A	None	2.574 ns
2	Worst-case tco	N/A	None	8.628 ns
3	Worst-case th	N/A	None	-2.124 ns

th

	Minimum Slack	Required th	Actual th
1	N/A	None	-2.124 ns
2	N/A	None	-2.295 ns
3	N/A	None	-2.333 ns
4	N/A	None	-2.347 ns
5	N/A	None	-2.347 ns
6	N/A	None	-2.348 ns
7	N/A	None	-2.349 ns

tsu

	Slack	Required tsu	Actual tsu
1	N/A	None	2.574 ns
2	N/A	None	2.573 ns
3	N/A	None	2.572 ns
4	N/A	None	2.572 ns
5	N/A	None	2.558 ns
6	N/A	None	2.520 ns
7	N/A	None	2.349 ns

89	N/A	None	6.985 ns
90	N/A	None	6.952 ns
91	N/A	None	6.952 ns
92	N/A	None	6.950 ns
93	N/A	None	6.939 ns
94	N/A	None	6.934 ns
95	N/A	None	6.895 ns
96	N/A	None	6.889 ns
97	N/A	None	8.628 ns
98	N/A	None	7.514 ns
99	N/A	None	7.292 ns
100	N/A	None	7.236 ns
101	N/A	None	7.230 ns
102	N/A	None	7.219 ns
103	N/A	None	7.175 ns
104	N/A	None	6.989 ns
105	N/A	None	6.985 ns
106	N/A	None	6.952 ns
107	N/A	None	6.952 ns
108	N/A	None	6.950 ns
109	N/A	None	6.939 ns
110	N/A	None	6.934 ns
111	N/A	None	6.895 ns
112	N/A	None	6.889 ns