VLSI PROJECT – MONSOON 2023

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2022102064

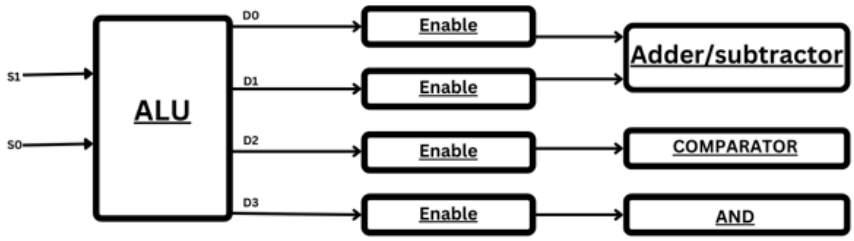
AIM: To design an ALU that performs

1. 4-bit addition
2. 4-bit subtraction
3. 4-bit comparator
4. 4-bit logical and

Procedure:

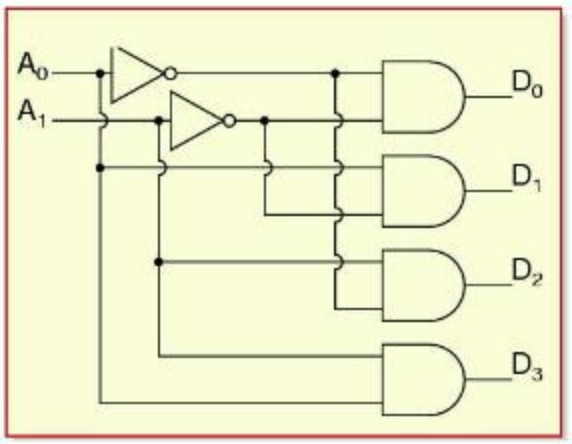
- Design a decoder that takes inputs s0 and s1.
- The outputs of the decoder should enable the input.
- If D0=1 then adder operation should work .
- If D1=1 then subtractor operation should work.
- If D2 =1 then comparator operation should work.
- If D3=1 then logical AND operation should work.

Rough sketch of the project:

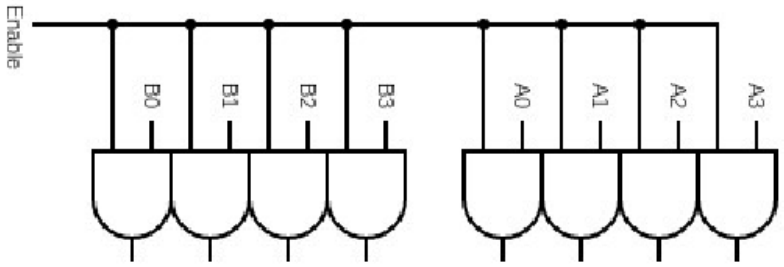


The block diagrams of the blocks used in this project are:

1) Decoder:



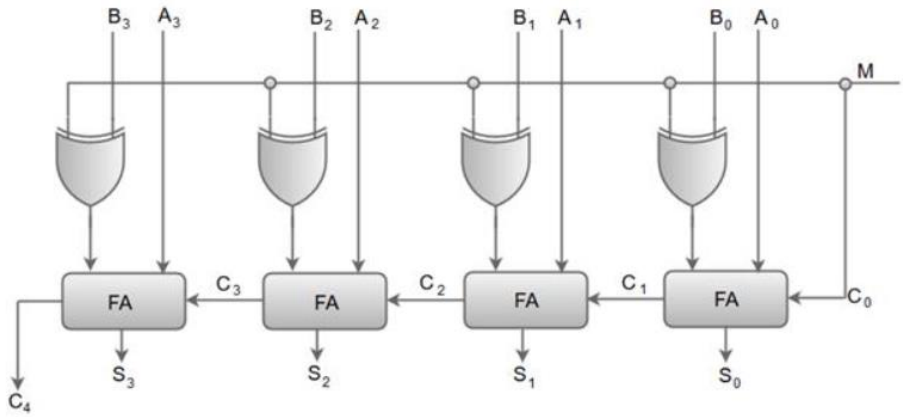
2) Enable:



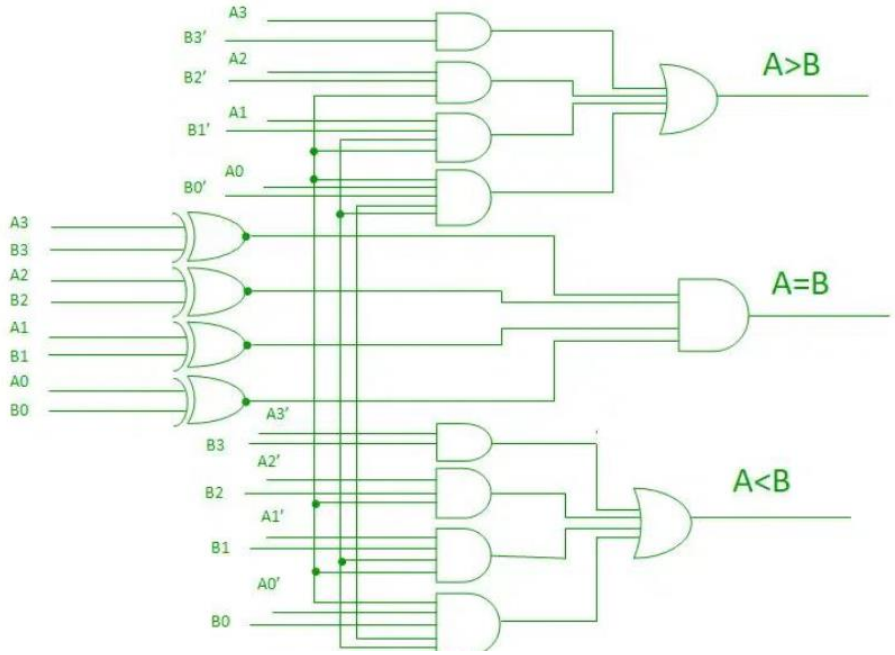
3) Adder and subtractor block:

Here when M=0 it performs addition and when M=1 it performs subtraction

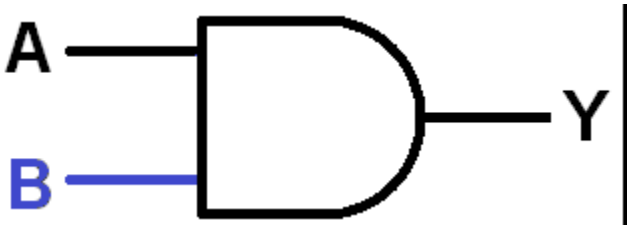
4 bit adder-subtractor:



4) Comparator:



5) AND:

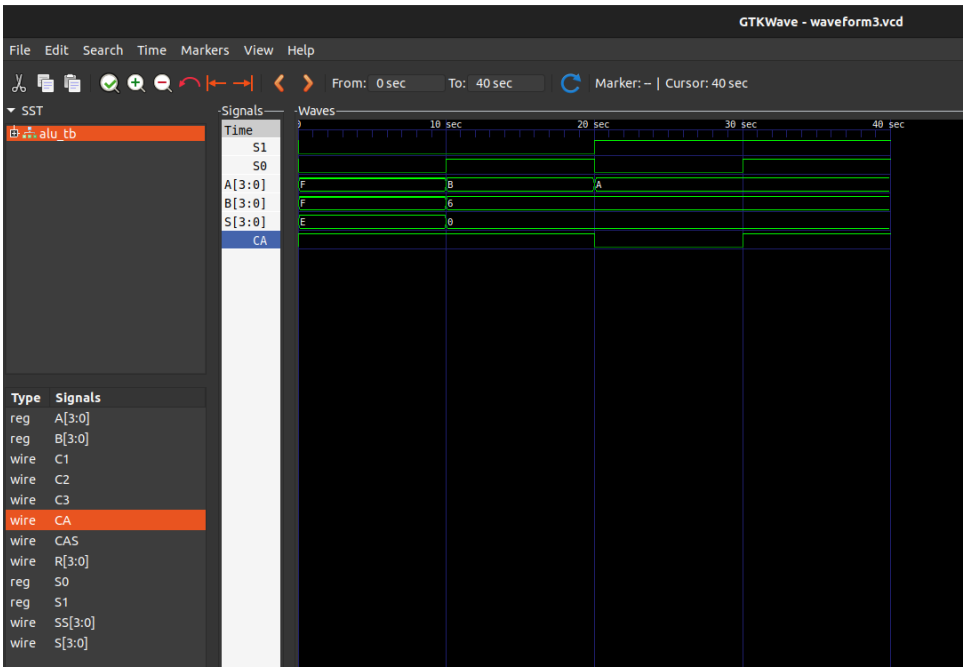


Verilog implementation:

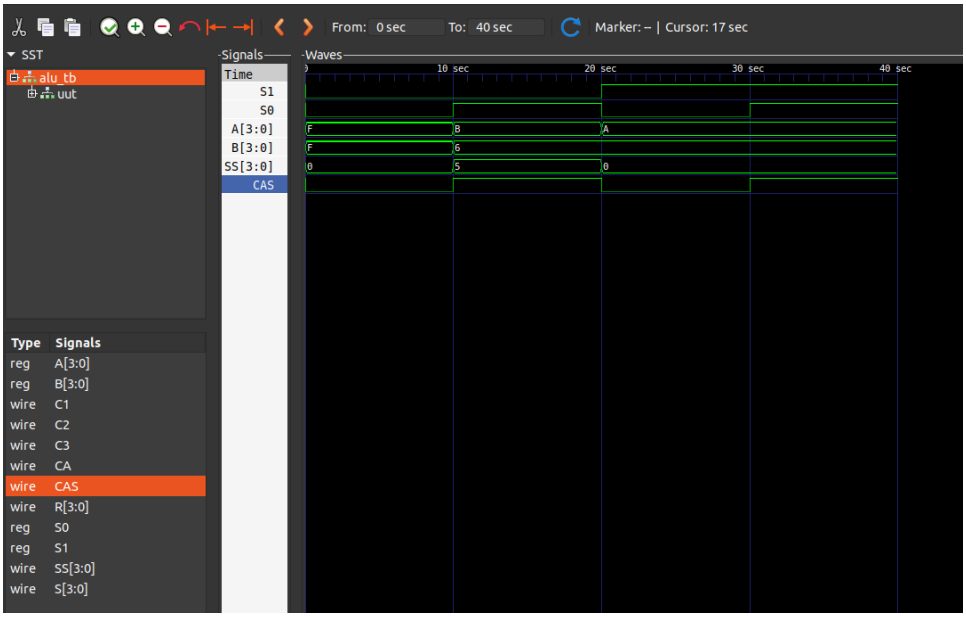
OUTPUTS:

GTK WAVE PLOTS:

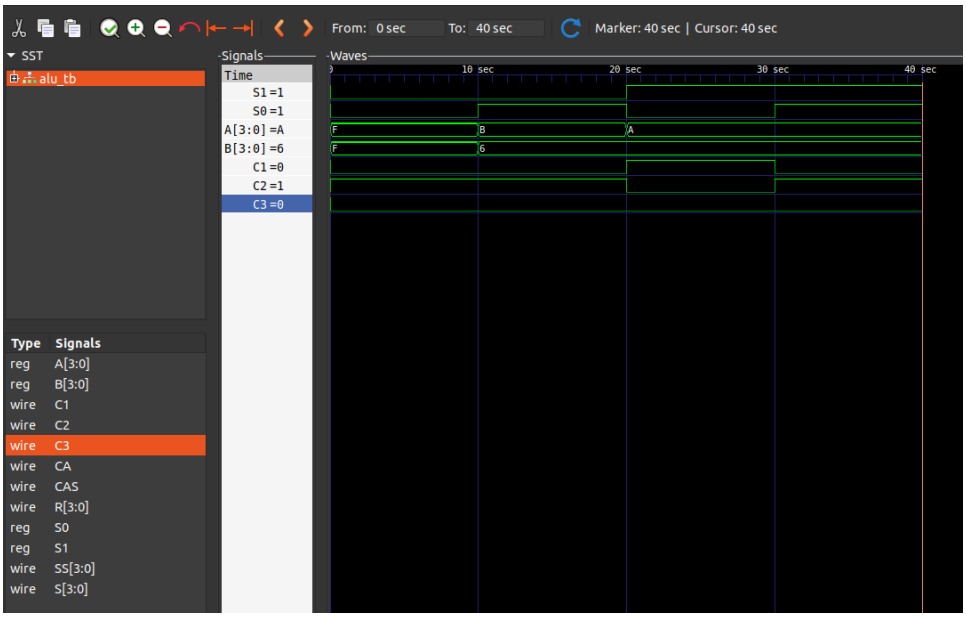
1. Adder block:



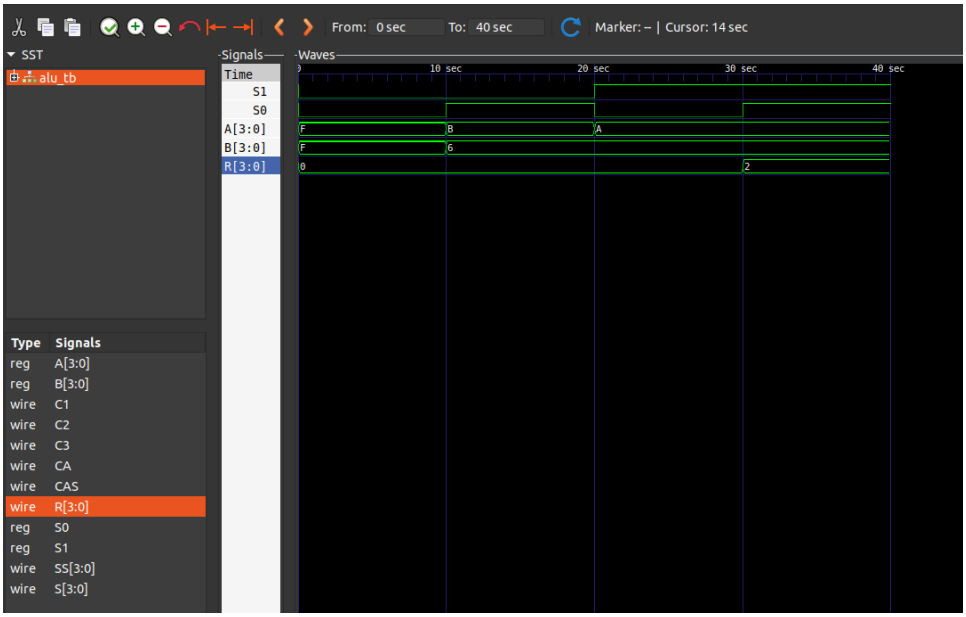
2. Subtractor block:



3. Comparator block:



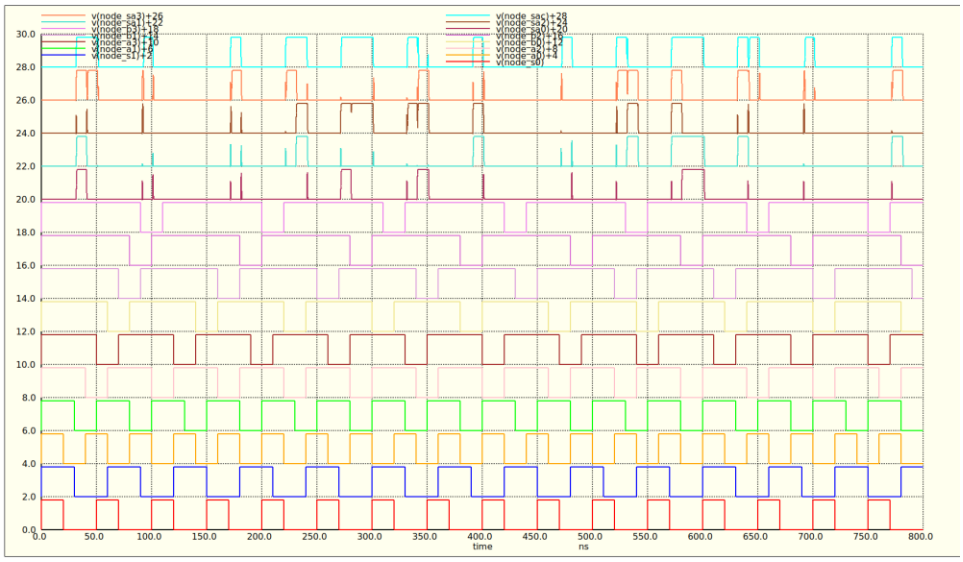
4. Logical AND:



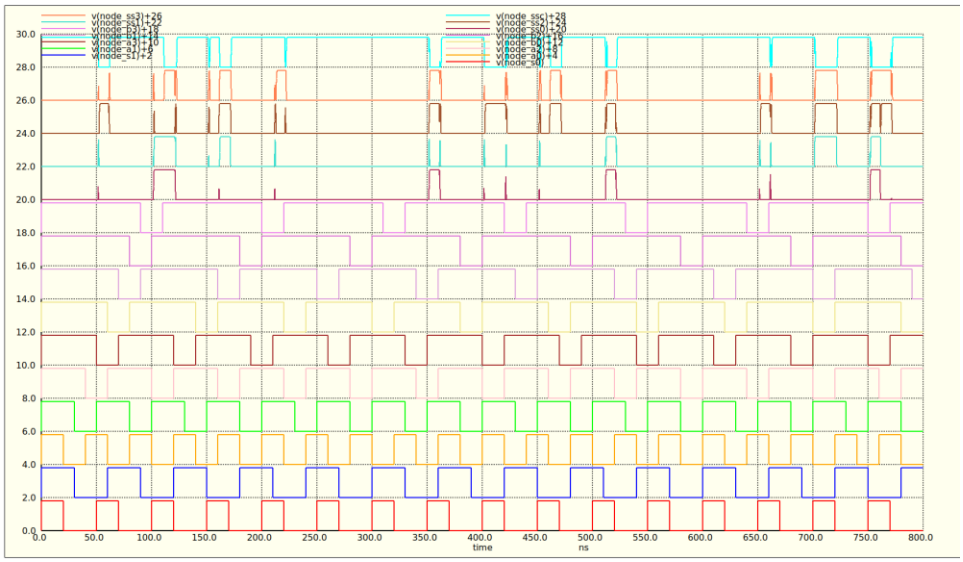
NGSPICE implementation:

OUTPUTS:

1. Adder block:

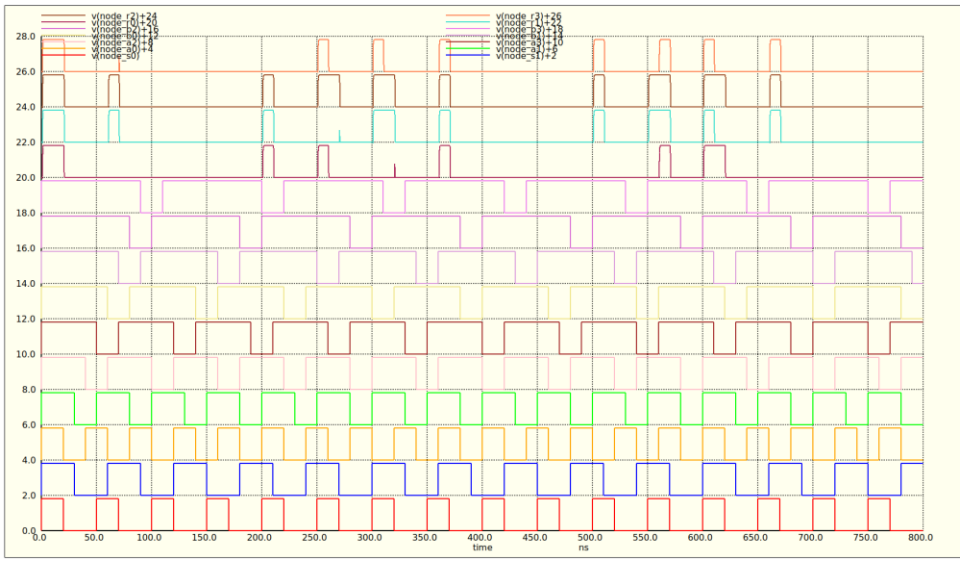


2. Subtractor block:



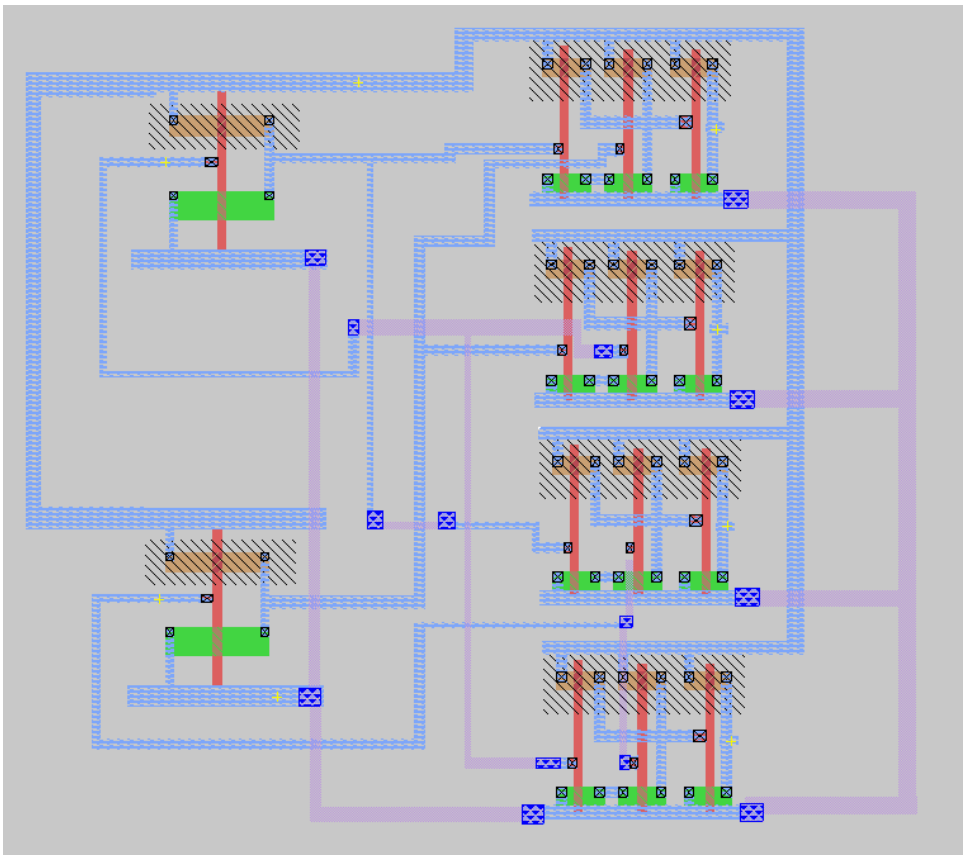
3. Comparator block:

4. And block:

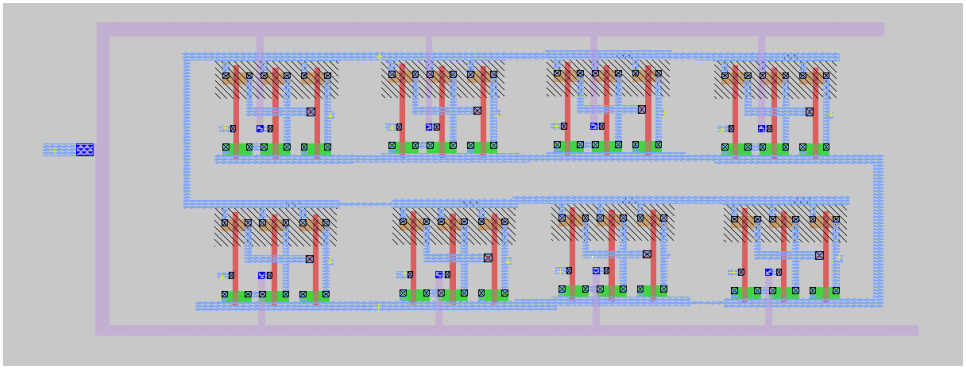


Magic implementation:

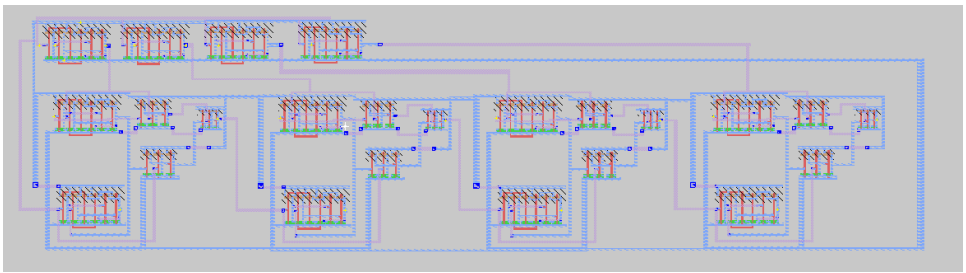
1. Decoder:



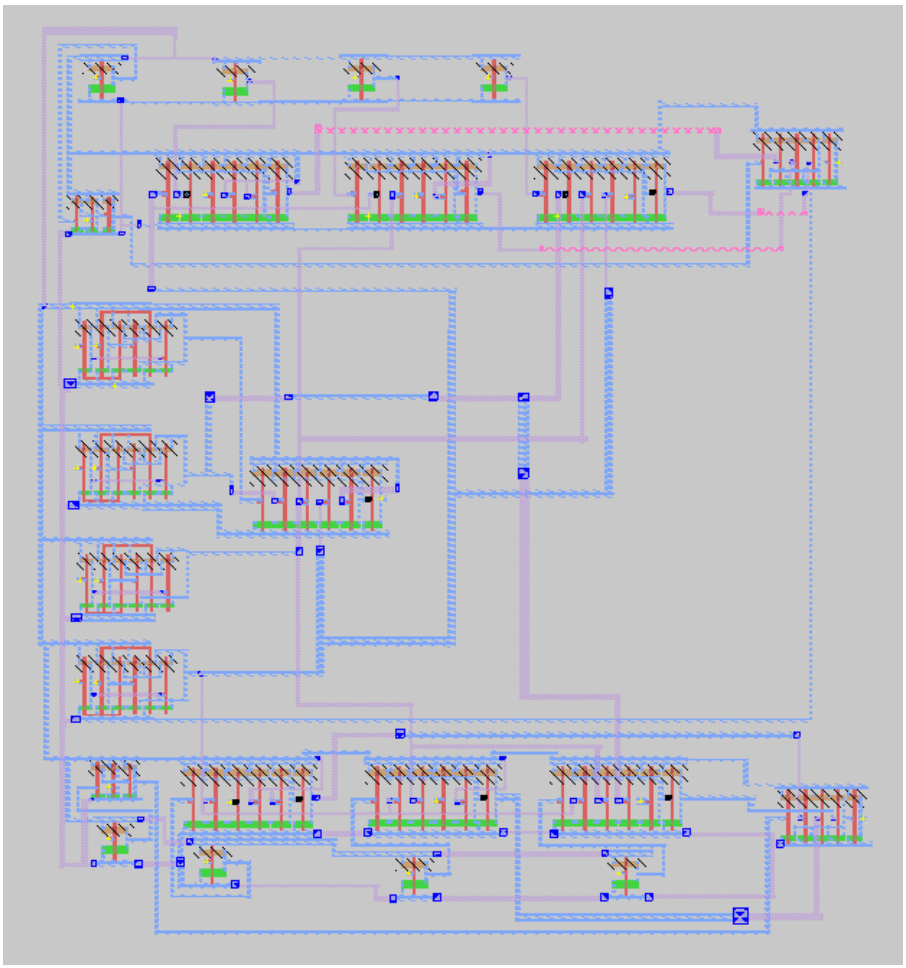
2. Enable block:



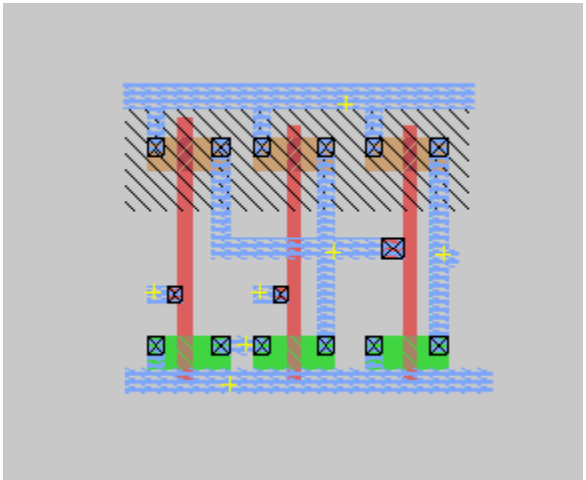
3. Adder subtractor block:



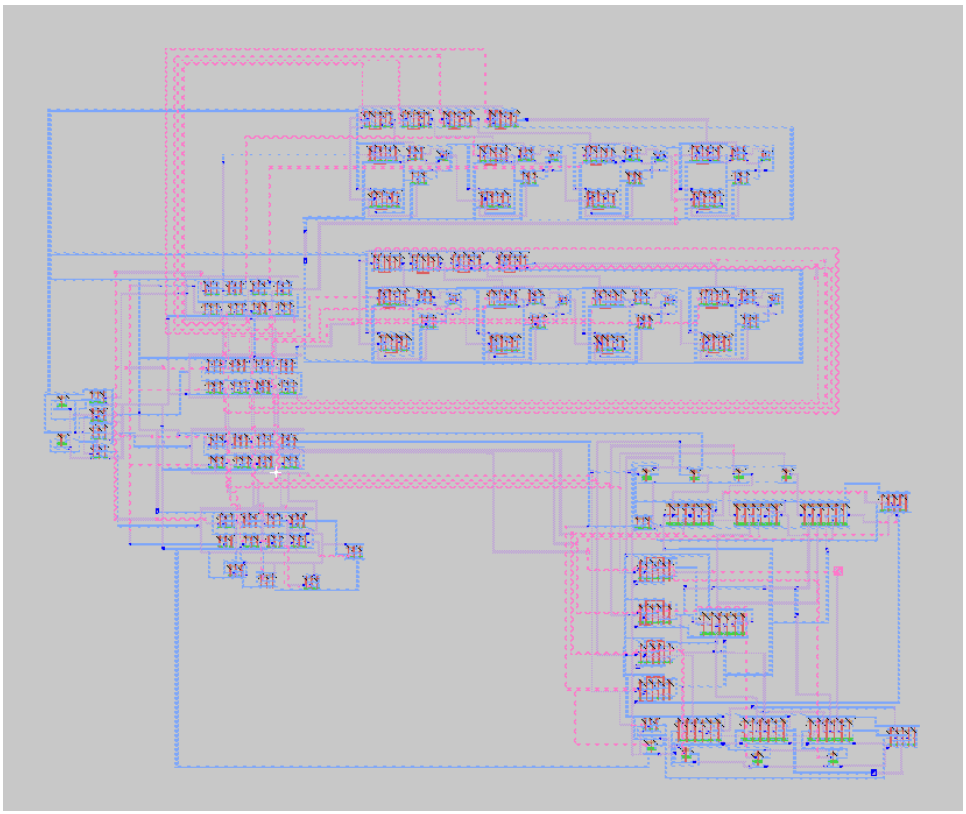
4. Comparator block:



5. AND:

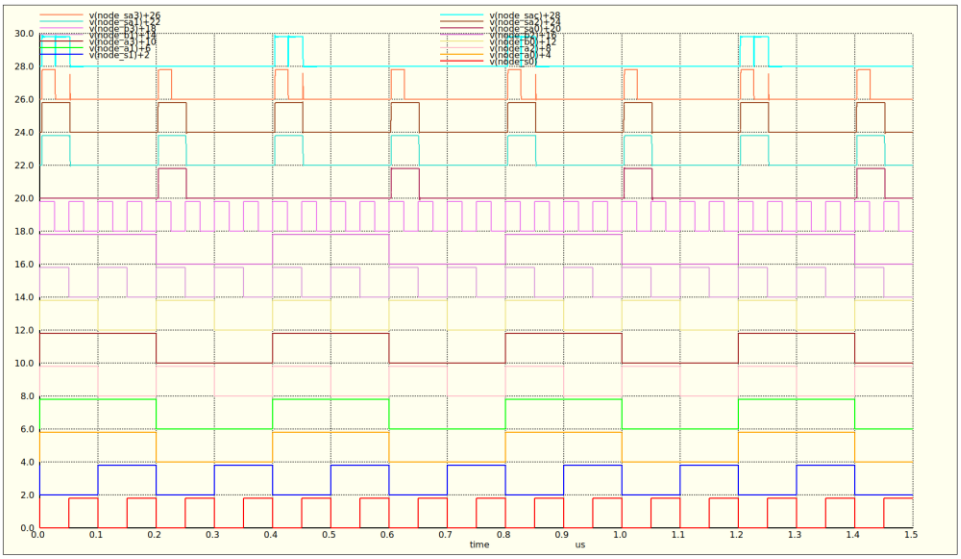


FINAL ALU BLOCK:

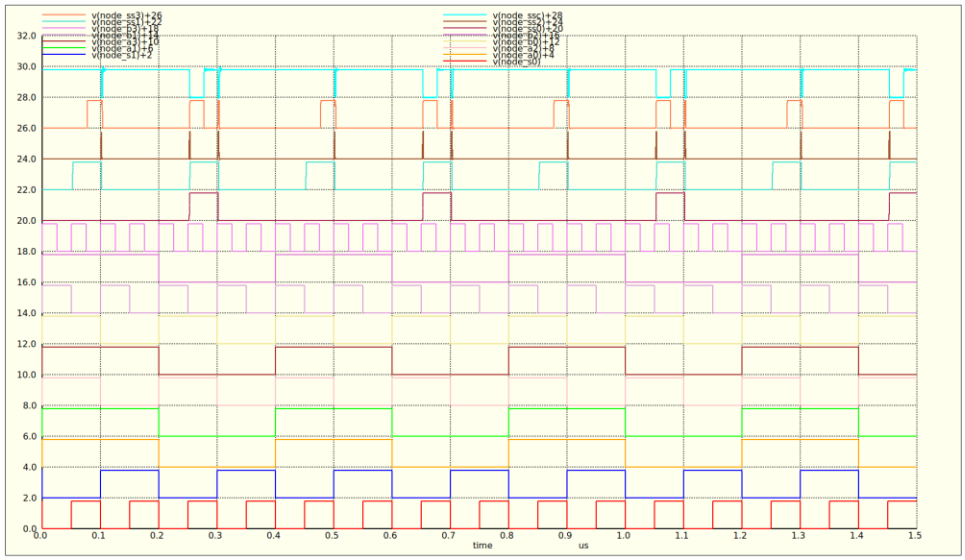


OUTPUTS:

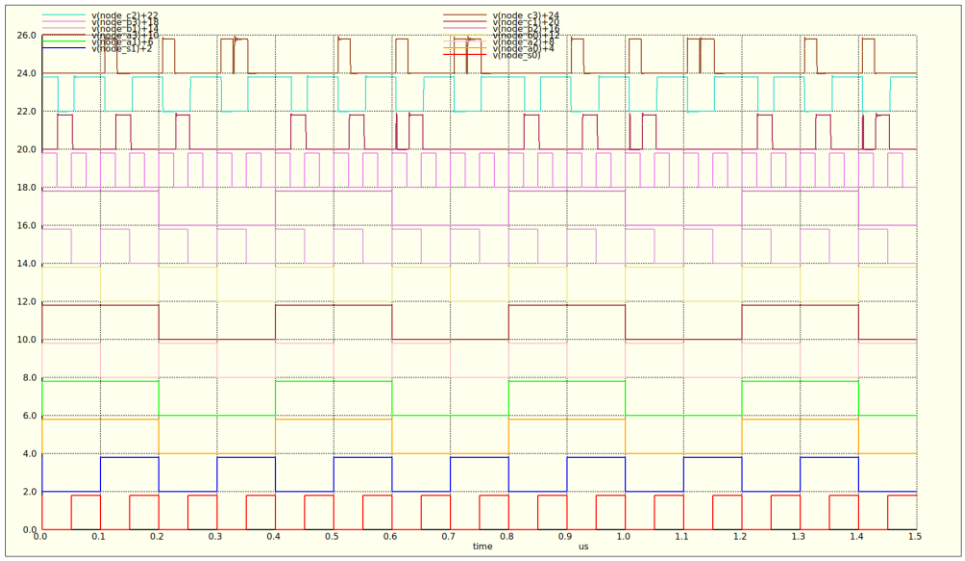
1. ADDER:



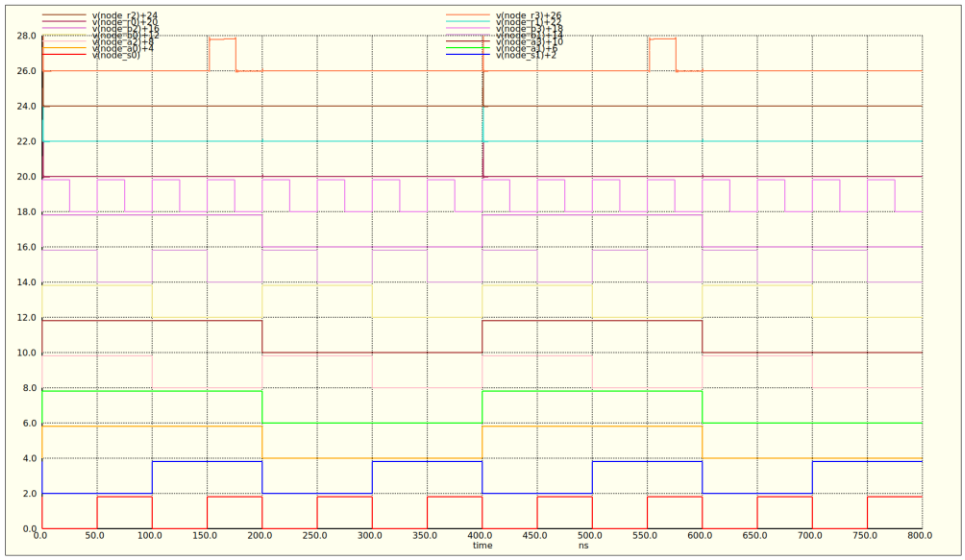
2. SUBTRACTOR:



3. COMPARATOR:



4. AND:



DELAY ANALYSIS

ADDER DELAYS:

SET THE REQUIRED INPUT AS PULSE AND REST ALL DC=0.

A0 VS S0 :

```
  Measurements for Transient Analysis

trise1              =  1.428818e-09 targ=  1.478818e-09 trig=  5.000000e-11
tfall1              =  1.003990e-09 targ=  2.011540e-07 trig=  2.001500e-07
tpd1                =  1.21640e-09
```

B0 VS S0:

```
  Measurements for Transient Analysis

trise1              =  1.899663e-09 targ=  1.949663e-09 trig=  5.000000e-11
tfall1              =  1.185044e-09 targ=  2.013350e-07 trig=  2.001500e-07
tpd1                =  1.54235e-09
```

A1 VS S1:

```
  Measurements for Transient Analysis

trise1              =  1.432543e-09 targ=  1.482543e-09 trig=  5.000000e-11
tfall1              =  9.979176e-10 targ=  2.011479e-07 trig=  2.001500e-07
tpd1                =  1.21523e-09
```

B1 VS S1:

```
  Measurements for Transient Analysis

trise1              =  1.958620e-09 targ=  2.008620e-09 trig=  5.000000e-11
tfall1              =  1.215933e-09 targ=  2.013659e-07 trig=  2.001500e-07
tpd1                =  1.58728e-09
```

A2 VS S2:

```
  Measurements for Transient Analysis

trise1             =  1.403797e-09 targ=  1.453797e-09 trig=  5.000000e-11
tfall1             =  1.033774e-09 targ=  2.011838e-07 trig=  2.001500e-07
tpd1               =  1.21879e-09
```

B2 VS S2:

```
  Measurements for Transient Analysis

trise1             =  2.019543e-09 targ=  2.069543e-09 trig=  5.000000e-11
tfall1             =  1.267025e-09 targ=  2.014170e-07 trig=  2.001500e-07
tpd1               =  1.64328e-09
```

A3 VS S3:

```
  Measurements for Transient Analysis

trise1             =  1.674680e-09 targ=  1.724680e-09 trig=  5.000000e-11
tfall1             =  1.147476e-09 targ=  2.012975e-07 trig=  2.001500e-07
tpd1               =  1.41108e-09
```

B3 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.101218e-09 targ=  2.151218e-09 trig=  5.000000e-11
tfall1             =  1.290119e-09 targ=  2.014401e-07 trig=  2.001500e-07
tpd1               =  1.69567e-09
```

A0 VS S1 :

```
  Measurements for Transient Analysis

trise1             =  1.514462e-09 targ=  1.564462e-09 trig=  5.000000e-11
tfall1             =  1.359911e-09 targ=  2.015099e-07 trig=  2.001500e-07
tpd1               =  1.43719e-09
```

A0 VS S2 :

```
  Measurements for Transient Analysis

trise1             =  2.185185e-09 targ=  2.235185e-09 trig=  5.000000e-11
tfall1             =  1.994881e-09 targ=  2.021449e-07 trig=  2.001500e-07
tpd1               =  2.09003e-09
```

A0 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.811372e-09 targ=  2.861372e-09 trig=  5.000000e-11
tfall1             =  2.611482e-09 targ=  2.027615e-07 trig=  2.001500e-07
tpd1               =  2.71143e-09
```

A1 VS S2 :

```
  Measurements for Transient Analysis

trise1             =  1.469422e-09 targ=  1.519422e-09 trig=  5.000000e-11
tfall1             =  1.377822e-09 targ=  2.015278e-07 trig=  2.001500e-07
tpd1               =  1.42362e-09
```

A1 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.107952e-09 targ=  2.157952e-09 trig=  5.000000e-11
tfall1             =  1.990894e-09 targ=  2.021409e-07 trig=  2.001500e-07
tpd1               =  2.04942e-09
```

A2 VS S3:

```
  Measurements for Transient Analysis

trise1             =  1.474578e-09 targ=  1.524578e-09 trig=  5.000000e-11
tfall1             =  1.413247e-09 targ=  2.015632e-07 trig=  2.001500e-07
tpd1               =  1.44391e-09
```

B0 VS S1:

```
  Measurements for Transient Analysis

trise1             =  2.129628e-09 targ=  2.179628e-09 trig=  5.000000e-11
tfall1             =  1.632457e-09 targ=  2.017825e-07 trig=  2.001500e-07
tpd1               =  1.88104e-09
```

B0 VS S2:

```
  Measurements for Transient Analysis

trise1             =  2.808925e-09 targ=  2.858925e-09 trig=  5.000000e-11
tfall1             =  2.286933e-09 targ=  2.024369e-07 trig=  2.001500e-07
tpd1               =  2.54793e-09
```

B0 VS S3:

```
  Measurements for Transient Analysis

trise1             =  3.497155e-09 targ=  3.547155e-09 trig=  5.000000e-11
tfall1             =  2.895356e-09 targ=  2.030454e-07 trig=  2.001500e-07
tpd1               =  3.19626e-09
```

B1 VS S2:

```
  Measurements for Transient Analysis

trise1             =  2.208063e-09 targ=  2.258063e-09 trig=  5.000000e-11
tfall1             =  1.652224e-09 targ=  2.018022e-07 trig=  2.001500e-07
tpd1               =  1.93014e-09
```

B1 VS S3:

```
   Measurements for Transient Analysis

trise1             =  2.904697e-09 targ=  2.954697e-09 trig=  5.000000e-11
tfall1             =  2.294638e-09 targ=  2.024446e-07 trig=  2.001500e-07
tpd1               =  2.59967e-09
```

B2 VS S3:

```
   Measurements for Transient Analysis

trise1             =  2.165666e-09 targ=  2.215666e-09 trig=  5.000000e-11
tfall1             =  1.653076e-09 targ=  2.018031e-07 trig=  2.001500e-07
tpd1               =  1.90937e-09
```

CRITICAL PATH : (MAX DELAY) :

```
   Measurements for Transient Analysis

trise1             =  3.497155e-09 targ=  3.547155e-09 trig=  5.000000e-11
tfall1             =  2.895356e-09 targ=  2.030454e-07 trig=  2.001500e-07
tpd1               =  3.19626e-09
```

SUBTRACTION DELAYS

A0 VS S0 :

```
   Measurements for Transient Analysis

trise1             =  1.036408e-09 targ=  1.086408e-09 trig=  5.000000e-11
tfall1             =  1.206230e-09 targ=  2.013562e-07 trig=  2.001500e-07
tpd1               =  1.12132e-09
```

A1 VS S1:

```
   Measurements for Transient Analysis

trise1             =  1.040807e-09 targ=  1.090807e-09 trig=  5.000000e-11
tfall1             =  1.210267e-09 targ=  2.013603e-07 trig=  2.001500e-07
tpd1               =  1.12554e-09
```

A2 VS S2:

```
   Measurements for Transient Analysis

trise1             =  1.101597e-09 targ=  1.151597e-09 trig=  5.000000e-11
tfall1             =  1.200815e-09 targ=  2.013508e-07 trig=  2.001500e-07
tpd1               =  1.15121e-09
```

A3 VS S3:

```
  Measurements for Transient Analysis

trise1             =  1.130888e-09 targ=  1.180888e-09 trig=  5.000000e-11
tfall1             =  1.242275e-09 targ=  2.013923e-07 trig=  2.001500e-07
tpd1               =  1.18658e-09
```

B0 VS S0:

```
  Measurements for Transient Analysis

trise1             =  2.017101e-07 targ=  2.017601e-07 trig=  5.000000e-11
tfall1             =  -1.985840e-07 targ=  1.566012e-09 trig=  2.001500e-07
tpd1               =  1.56306e-09
```

B1 VS S1:

```
  Measurements for Transient Analysis

trise1             =  2.018343e-07 targ=  2.018843e-07 trig=  5.000000e-11
tfall1             =  -1.984936e-07 targ=  1.656425e-09 trig=  2.001500e-07
tpd1               =  1.67039e-09
```

B2 VS S2:

```
  Measurements for Transient Analysis

trise1             =  2.019641e-07 targ=  2.020141e-07 trig=  5.000000e-11
tfall1             =  -1.983270e-07 targ=  1.822976e-09 trig=  2.001500e-07
tpd1               =  1.81854e-09
```

B3 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.021385e-07 targ=  2.021885e-07 trig=  5.000000e-11
tfall1             =  -1.982147e-07 targ=  1.935264e-09 trig=  2.001500e-07
tpd1               =  1.96188e-09
```

A0 VS S1:

```
  Measurements for Transient Analysis

trise1             =  2.019546e-07 targ=  2.020046e-07 trig=  5.000000e-11
tfall1             =  -1.982299e-07 targ=  1.920100e-09 trig=  2.001500e-07
tpd1               =  1.86237e-09
```

A0 VS S2:

```
  Measurements for Transient Analysis

trise1             =  2.756173e-09 targ=  2.806173e-09 trig=  5.000000e-11
tfall1             =  2.433584e-09 targ=  2.025836e-07 trig=  2.001500e-07
tpd1               =  2.59488e-09
```

A0 VS S3:

```
  Measurements for Transient Analysis

trise1             =  3.425801e-09 targ=  3.475801e-09 trig=  5.000000e-11
tfall1             =  3.075383e-09 targ=  2.032254e-07 trig=  2.001500e-07
tpd1               =  3.25059e-09
```

A1 VS S2:

```
  Measurements for Transient Analysis

trise1             =  2.071869e-09 targ=  2.121869e-09 trig=  5.000000e-11
tfall1             =  1.755573e-09 targ=  2.019056e-07 trig=  2.001500e-07
tpd1               =  1.91372e-09
```

A1 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.712607e-09 targ=  2.762607e-09 trig=  5.000000e-11
tfall1             =  2.394570e-09 targ=  2.025446e-07 trig=  2.001500e-07
tpd1               =  2.55359e-09
```

A2 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.121687e-09 targ=  2.171687e-09 trig=  5.000000e-11
tfall1             =  1.806641e-09 targ=  2.019566e-07 trig=  2.001500e-07
tpd1               =  1.96416e-09
```

B0 VS S1:

```
  Measurements for Transient Analysis

trise1             =  2.116856e-09 targ=  2.166856e-09 trig=  5.000000e-11
tfall1             =  2.339844e-09 targ=  2.024898e-07 trig=  2.001500e-07
tpd1               =  2.22835e-09
```

B0 VS S2:

```
  Measurements for Transient Analysis

trise1             =  2.745820e-09 targ=  2.795820e-09 trig=  5.000000e-11
tfall1             =  2.973995e-09 targ=  2.031240e-07 trig=  2.001500e-07
tpd1               =  2.85991e-09
```

B0 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.039923e-07 targ=  2.040423e-07 trig=  5.000000e-11
tfall1             =  -1.967759e-07 targ=  3.374110e-09 trig=  2.001500e-07
tpd1               =  3.60818e-09
```

B1 VS S2:

```
  Measurements for Transient Analysis

trise1             =  2.142211e-09 targ=  2.192211e-09 trig=  5.000000e-11
tfall1             =  2.406353e-09 targ=  2.025564e-07 trig=  2.001500e-07
tpd1               =  2.27428e-09
```

B1 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.033742e-07 targ=  2.034242e-07 trig=  5.000000e-11
tfall1             =  -1.973901e-07 targ=  2.759864e-09 trig=  2.001500e-07
tpd1               =  2.99203e-09
```

B2 VS S3:

```
  Measurements for Transient Analysis

trise1             =  2.029281e-07 targ=  2.029781e-07 trig=  5.000000e-11
tfall1             =  -1.978281e-07 targ=  2.321884e-09 trig=  2.001500e-07
tpd1               =  2.54999e-09
```

CRITICAL PATH: (MAX DELAY):

```
  Measurements for Transient Analysis

trise1             =  2.039923e-07 targ=  2.040423e-07 trig=  5.000000e-11
tfall1             =  -1.967759e-07 targ=  3.374110e-09 trig=  2.001500e-07
tpd1               =  3.60818e-09
```

COMPARATOR DELAYS:

LESSER DELAYS:

A0 vs C3:

```
  Measurements for Transient Analysis

trise1             =  2.458773e-09 targ=  2.508773e-09 trig=  5.000000e-11
tfall1             =  1.944208e-09 targ=  2.020942e-07 trig=  2.001500e-07
tpd1               =  2.20149e-09
```

A1 VS C3:

```
  Measurements for Transient Analysis

trise1             =  2.730291e-09 targ=  2.780291e-09 trig=  5.000000e-11
tfall1             =  2.028524e-09 targ=  2.021785e-07 trig=  2.001500e-07
tpd1               =  2.37941e-09
```

A2 VS C3 :

```
  Measurements for Transient Analysis

trise1             =  2.633064e-09 targ=  2.683064e-09 trig=  5.000000e-11
tfall1             =  1.965589e-09 targ=  2.021156e-07 trig=  2.001500e-07
tpd1               =  2.29933e-09
```

A3 VS C3:

```
  Measurements for Transient Analysis

trise1             =  2.342931e-09 targ=  2.392931e-09 trig=  5.000000e-11
tfall1             =  1.422136e-09 targ=  2.015721e-07 trig=  2.001500e-07
tpd1               =  1.88253e-09
```

B0 VS C3 :

```
  Measurements for Transient Analysis

trise1             =  2.019061e-07 targ=  2.019561e-07 trig=  5.000000e-11
tfall1             =  -1.981385e-07 targ=  2.011465e-09 trig=  2.001500e-07
tpd1               =  1.88379e-09
```

B1 VS C3:

```
  Measurements for Transient Analysis

trise1             =  2.022178e-07 targ=  2.022678e-07 trig=  5.000000e-11
tfall1             =  -1.979570e-07 targ=  2.192972e-09 trig=  2.001500e-07
tpd1               =  2.13040e-09
```

B2 VS C3 :

```
  Measurements for Transient Analysis

trise1             =  2.023366e-07 targ=  2.023866e-07 trig=  5.000000e-11
tfall1             =  -1.980500e-07 targ=  2.100028e-09 trig=  2.001500e-07
tpd1               =  2.14329e-09
```

B3 VS C3:

```
  Measurements for Transient Analysis

trise1             =  2.021064e-07 targ=  2.021564e-07 trig=  5.000000e-11
tfall1             =  -1.987462e-07 targ=  1.403754e-09 trig=  2.001500e-07
tpd1               =  1.68009e-09
```

EQUAL DELAYS

A0 VS C2:

```
  Measurements for Transient Analysis

trise1             =  1.904116e-09 targ=  1.954116e-09 trig=  5.000000e-11
tfall1             =  1.869650e-09 targ=  2.020197e-07 trig=  2.001500e-07
tpd1               =  1.88688e-09
```

A1 VS C2:

```
  Measurements for Transient Analysis

trise1             =  2.363849e-09 targ=  2.413849e-09 trig=  5.000000e-11
tfall1             =  2.854944e-09 targ=  2.030049e-07 trig=  2.001500e-07
tpd1               =  2.60940e-09
```

A2 VS C2:

```
  Measurements for Transient Analysis

trise1             =  2.365385e-09 targ=  2.415385e-09 trig=  5.000000e-11
tfall1             =  3.462232e-09 targ=  2.036122e-07 trig=  2.001500e-07
tpd1               =  2.91381e-09
```

A3 VS C2 :

```
  Measurements for Transient Analysis

trise1             =  2.262452e-09 targ=  2.312452e-09 trig=  5.000000e-11
tfall1             =  3.687912e-09 targ=  2.038379e-07 trig=  2.001500e-07
tpd1               =  2.97518e-09
```

B0 VS C2:

```
  Measurements for Transient Analysis

trise1             =  1.752824e-09 targ=  1.802824e-09 trig=  5.000000e-11
tfall1             =  1.716627e-09 targ=  2.018666e-07 trig=  2.001500e-07
tpd1               =  1.73473e-09
```

B1 VS C2:

```
  Measurements for Transient Analysis

trise1             =  2.279988e-09 targ=  2.329988e-09 trig=  5.000000e-11
tfall1             =  2.560371e-09 targ=  2.027104e-07 trig=  2.001500e-07
tpd1               =  2.42018e-09
```

B2 VS C2 :

```
  Measurements for Transient Analysis

trise1             =  2.395052e-09 targ=  2.445052e-09 trig=  5.000000e-11
tfall1             =  3.099039e-09 targ=  2.032490e-07 trig=  2.001500e-07
tpd1               =  2.74705e-09
```

B3 VS C2:

```
  Measurements for Transient Analysis

trise1             =  2.208064e-09 targ=  2.258064e-09 trig=  5.000000e-11
tfall1             =  3.269721e-09 targ=  2.034197e-07 trig=  2.001500e-07
tpd1               =  2.73889e-09
```

<u>GREATER DELAYS</u>

A0 VS C1:

```
  Measurements for Transient Analysis

trise1             =  2.019151e-07 targ=  2.019651e-07 trig=  5.000000e-11
tfall1             =  -1.980829e-07 targ=  2.067130e-09 trig=  2.001500e-07
tpd1               =  1.91609e-09
```

A1 VS C1:

```
  Measurements for Transient Analysis

trise1             =  2.021697e-07 targ=  2.022197e-07 trig=  5.000000e-11
tfall1             =  -1.979530e-07 targ=  2.196957e-09 trig=  2.001500e-07
tpd1               =  2.10833e-09
```

A2 VS C1:

```
  Measurements for Transient Analysis

trise1             =  2.023859e-07 targ=  2.024359e-07 trig=  5.000000e-11
tfall1             =  -1.982672e-07 targ=  1.882835e-09 trig=  2.001500e-07
tpd1               =  2.05936e-09
```

A3 VS C1:

```
  Measurements for Transient Analysis

trise1             =  2.021104e-07 targ=  2.021604e-07 trig=  5.000000e-11
tfall1             =  -1.987713e-07 targ=  1.378722e-09 trig=  2.001500e-07
tpd1               =  1.66957e-09
```

B0 VS C1 :

```
  Measurements for Transient Analysis

trise1             =  2.438753e-09 targ=  2.488753e-09 trig=  5.000000e-11
tfall1             =  1.969273e-09 targ=  2.021193e-07 trig=  2.001500e-07
tpd1               =  2.20401e-09
```

B1 VS C1:

```
  Measurements for Transient Analysis

trise1             =  2.690640e-09 targ=  2.740640e-09 trig=  5.000000e-11
tfall1             =  2.032591e-09 targ=  2.021826e-07 trig=  2.001500e-07
tpd1               =  2.36162e-09
```

B2 VS C1:

```
  Measurements for Transient Analysis

trise1             =  2.737497e-09 targ=  2.787497e-09 trig=  5.000000e-11
tfall1             =  1.967900e-09 targ=  2.021179e-07 trig=  2.001500e-07
tpd1               =  2.35270e-09
```

B3 VS C1:

```
  Measurements for Transient Analysis

trise1             =  2.307239e-09 targ=  2.357239e-09 trig=  5.000000e-11
tfall1             =  1.480695e-09 targ=  2.016307e-07 trig=  2.001500e-07
tpd1               =  1.89397e-09
```

CRITICAL PATH: (MAX DELAY):

```
  Measurements for Transient Analysis

trise1             =  2.262452e-09 targ=  2.312452e-09 trig=  5.000000e-11
tfall1             =  3.687912e-09 targ=  2.038379e-07 trig=  2.001500e-07
tpd1               =  2.97518e-09
```

AND DELAYS:

Here we obtain 8 delays, and they are

A0 vs R0:

```
  Measurements for Transient Analysis

trise1             =  5.564904e-10 targ=  6.064904e-10 trig=  5.000000e-11
tfall1             =  6.782832e-10 targ=  2.008283e-07 trig=  2.001500e-07
tpd1               =  6.17387e-10
```

B0 VS R0:

```
  Measurements for Transient Analysis

trise1             =  5.459937e-10 targ=  5.959937e-10 trig=  5.000000e-11
tfall1             =  6.026950e-10 targ=  2.007527e-07 trig=  2.001500e-07
tpd1               =  5.74344e-10
```

A1 VS R1:

```
  Measurements for Transient Analysis

trise1             =  5.629671e-10 targ=  6.129671e-10 trig=  5.000000e-11
tfall1             =  6.819627e-10 targ=  2.008320e-07 trig=  2.001500e-07
tpd1               =  6.22465e-10
```

B1 VS R1:

```
  Measurements for Transient Analysis

trise1             =  5.402984e-10 targ=  5.902984e-10 trig=  5.000000e-11
tfall1             =  5.715189e-10 targ=  2.007215e-07 trig=  2.001500e-07
tpd1               =  5.55909e-10
```

A2 VS R2:

```
  Measurements for Transient Analysis

trise1             =  5.793566e-10 targ=  6.293566e-10 trig=  5.000000e-11
tfall1             =  6.613617e-10 targ=  2.008114e-07 trig=  2.001500e-07
tpd1               =  6.20359e-10
```

B2 VS R2:

```
  Measurements for Transient Analysis

trise1             =  5.427070e-10 targ=  5.927070e-10 trig=  5.000000e-11
tfall1             =  6.045308e-10 targ=  2.007545e-07 trig=  2.001500e-07
tpd1               =  5.73619e-10
```

A3 VS R3:

```
  Measurements for Transient Analysis

trise1             =  5.477720e-10 targ=  5.977720e-10 trig=  5.000000e-11
tfall1             =  6.532083e-10 targ=  2.008032e-07 trig=  2.001500e-07
tpd1               =  6.00490e-10
```

B3 VS R3:

```
  Measurements for Transient Analysis

trise1             =  5.260864e-10 targ=  5.760864e-10 trig=  5.000000e-11
tfall1             =  5.771735e-10 targ=  2.007272e-07 trig=  2.001500e-07
tpd1               =  5.51630e-10
```

CRITICAL PATH : (MAX DELAY) :

```
  Measurements for Transient Analysis

trise1             =  5.629671e-10 targ=  6.129671e-10 trig=  5.000000e-11
tfall1             =  6.819627e-10 targ=  2.008320e-07 trig=  2.001500e-07
tpd1               =  6.22465e-10
```