For the main control block I used the bellow table for the signals :

opcode	RegDEs	Branch	Memread	Memtoreg	Aluop	Memwrite	Alusrc	Regwrite	J	Jal	Bne
000000	1	0	0	0	010	0	0	1	0	0	0
000010	0	0	0	0	x	0	0	0	1	0	0
000011	0	0	0	0	x	0	0	0	0	1	0
000100	x	1	0	x	001	0	0	0	0	0	0
000101	x	0	0	x	001	0	0	0	0	0	1
001101	0	0	0	0	100	0	1	1	0	0	0
100011	0	0	1	1	000	0	1	1	0	0	0
101011	x	0	0	x	000	1	1	0	0	0	0
001111	0	0	0	0	011	0	1	1	0	0	0

For the Alu control :

AluOP	Funct field	Alu control	Operation
000	Xxxxxx	010	Add
001	Xxxxxx	110	Sub
010	100000	010	Add
010	100010	110	Sub
010	100100	000	And
010	100101	001	Or
011	Xxxxxx	011	Lui
100	Xxxxxx	001	Ori
010	100110	111	xor

The comparator module gets the alu result and the opcode as input ,

The output is the alu result id the instruction is ori or lui ,

Otherwise the comparator checks If the result is less ,greater or equal to zero and produce the output .

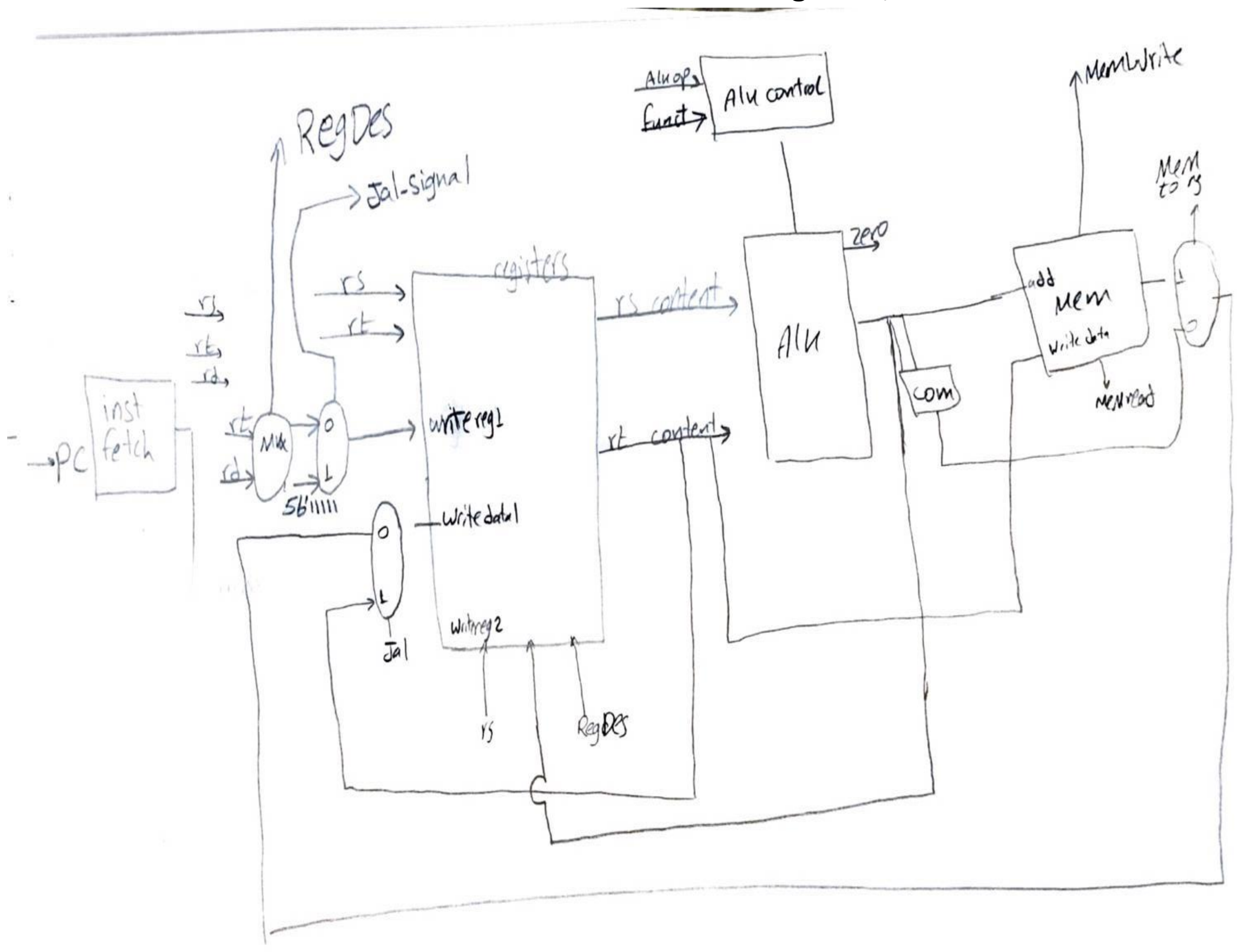
Registers module : outputs the content of RS and RT registers ,

And writes into two different registers ,(RT , RD or $31 (in case of jal)) and writes into RS register in case of R type instructions

PC module : computes the next pc depending on the input signlas

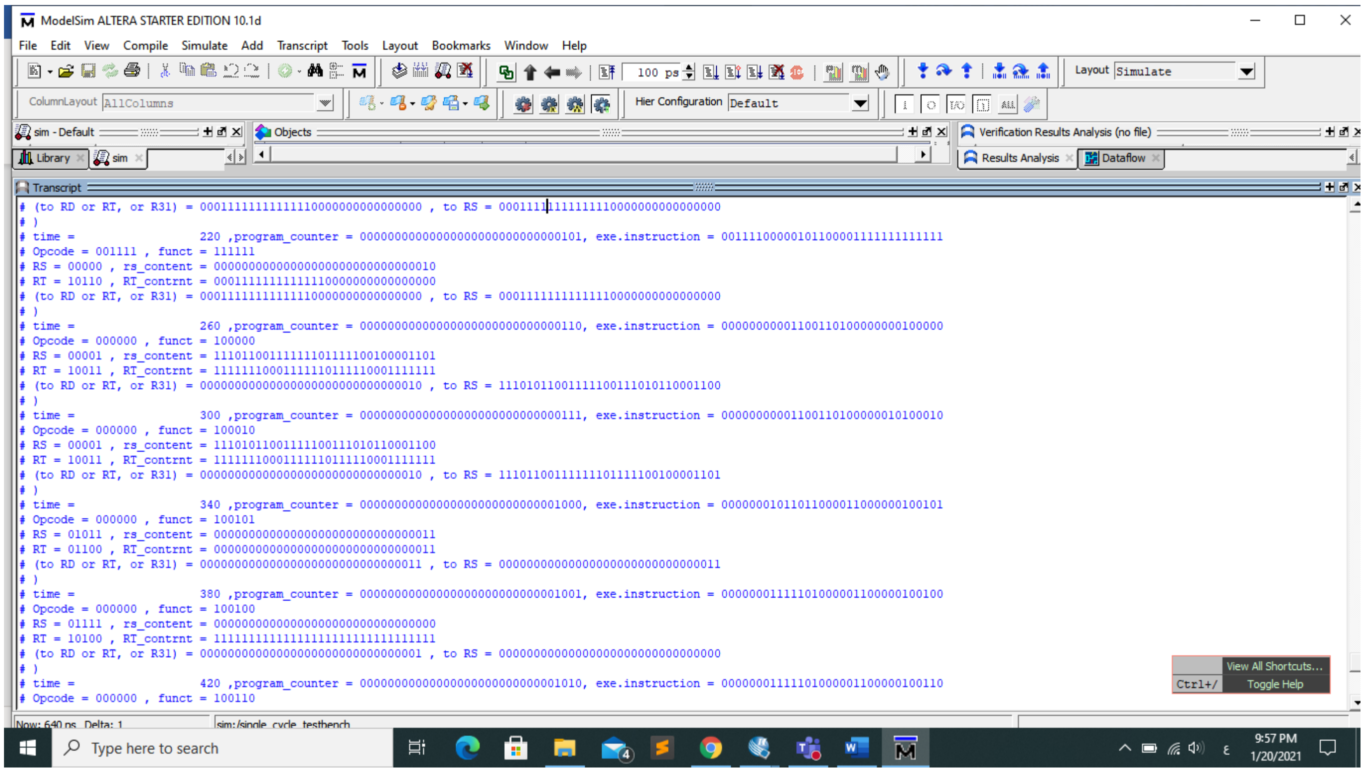
Jal, jump, (beq and zero) , (bne and not zero) and jump register ,or it adds one to the current pc .

All the modules have testbench to check if it is working well ,



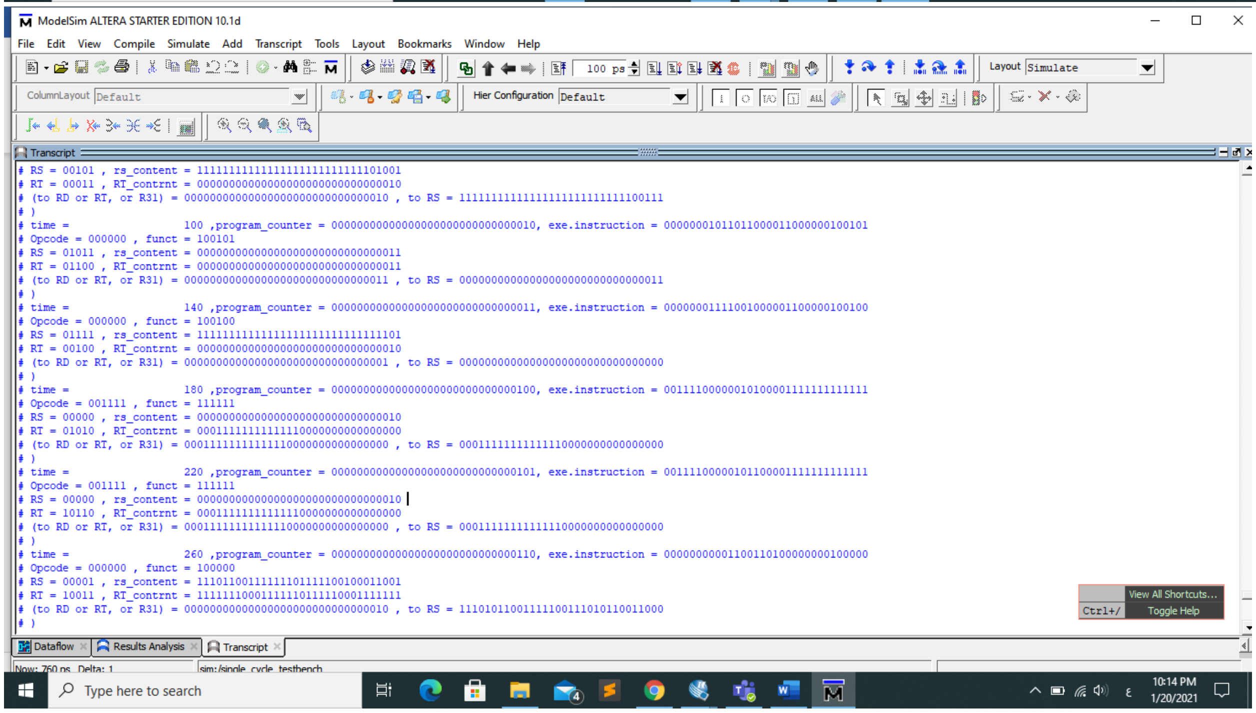
All the fignals come from the control unit in the above picture

Some test cases :


ModelSim ALTERA STARTER EDITION 10.1d
File Edit View Compile Simulate Add Transcript Tools Layout Bookmarks Window Help
Layout Simulate
ColumnLayout AllColumns
Hier Configuration Default
sim - Default
Objects
Verification Results Analysis (no file)
Library
sim
Results Analysis
Dataflow
Transcript
View All Shortcuts...
Ctrl+/ Toggle Help
Type here to search
9:57 PM
1/20/2021

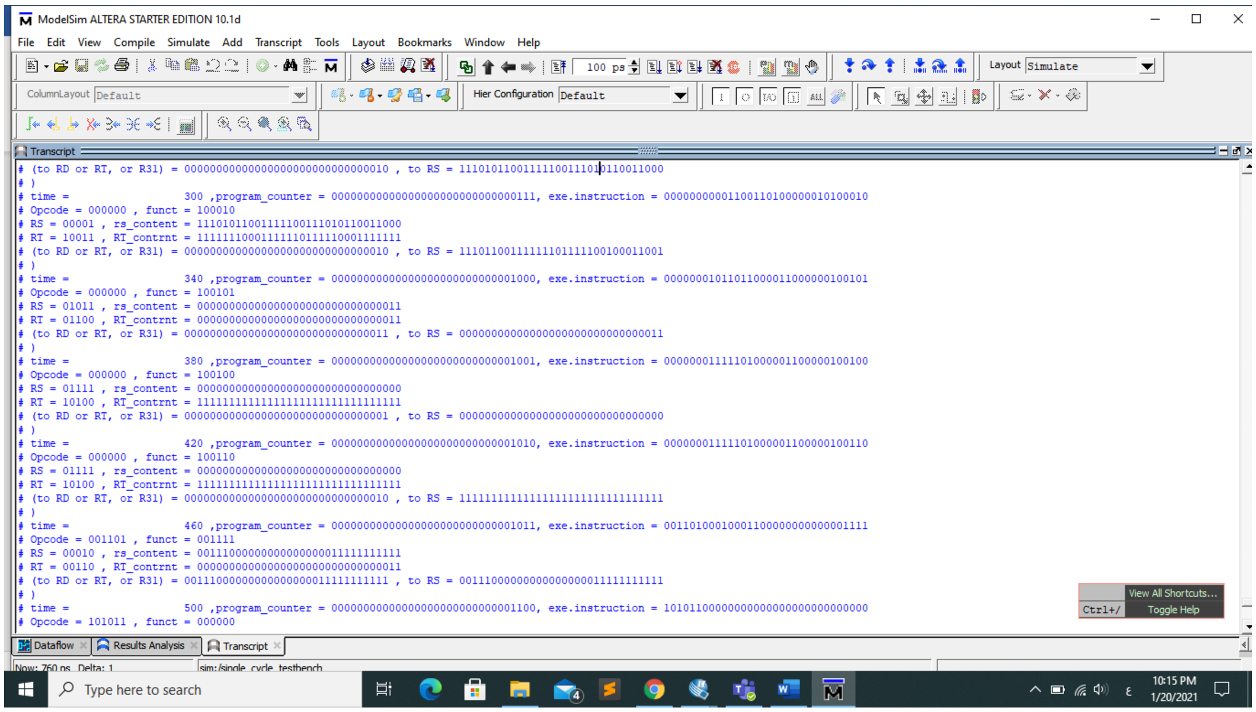
```
# (to RD or RT, or R31) = 00011111111111110000000000000000 , to RS = 00011111111111110000000000000000
# )
# time =                 220 ,program_counter = 00000000000000000000000000000101, exe.instruction = 00111100000101100001111111111111
# Opcode = 001111 , funct = 111111
# RS = 00000 , rs_content = 00000000000000000000000000000010
# RT = 10110 , RT_contrnt = 00011111111111110000000000000000
# (to RD or RT, or R31) = 00011111111111110000000000000000 , to RS = 00011111111111110000000000000000
# )
# time =                 260 ,program_counter = 00000000000000000000000000000110, exe.instruction = 00000000001100110100000000100000
# Opcode = 000000 , funct = 100000
# RS = 00001 , rs_content = 11101100111111011111001000011101
# RT = 10011 , RT_contrnt = 11111110001111110111110001111111
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11101011001111100111010110001100
# )
# time =                 300 ,program_counter = 00000000000000000000000000000111, exe.instruction = 00000000001100110100000010100010
# Opcode = 000000 , funct = 100010
# RS = 00001 , rs_content = 11101011001111100111010110001100
# RT = 10011 , RT_contrnt = 11111110001111110111110001111111
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11101100111111011111001000011101
# )
# time =                 340 ,program_counter = 00000000000000000000000000001000, exe.instruction = 00000001011011000011000000100101
# Opcode = 000000 , funct = 100101
# RS = 01011 , rs_content = 00000000000000000000000000000011
# RT = 01100 , RT_contrnt = 00000000000000000000000000000011
# (to RD or RT, or R31) = 00000000000000000000000000000011 , to RS = 00000000000000000000000000000011
# )
# time =                 380 ,program_counter = 00000000000000000000000000001001, exe.instruction = 00000001111101000001100000100100
# Opcode = 000000 , funct = 100100
# RS = 01111 , rs_content = 00000000000000000000000000000000
# RT = 10100 , RT_contrnt = 11111111111111111111111111111111
# (to RD or RT, or R31) = 00000000000000000000000000000001 , to RS = 00000000000000000000000000000000
# )
# time =                 420 ,program_counter = 00000000000000000000000000001010, exe.instruction = 00000001111101000001100000100110
# Opcode = 000000 , funct = 100110
```

```
Now: 640 ps  Delta: 1        sim:/single_cycle_testbench
```

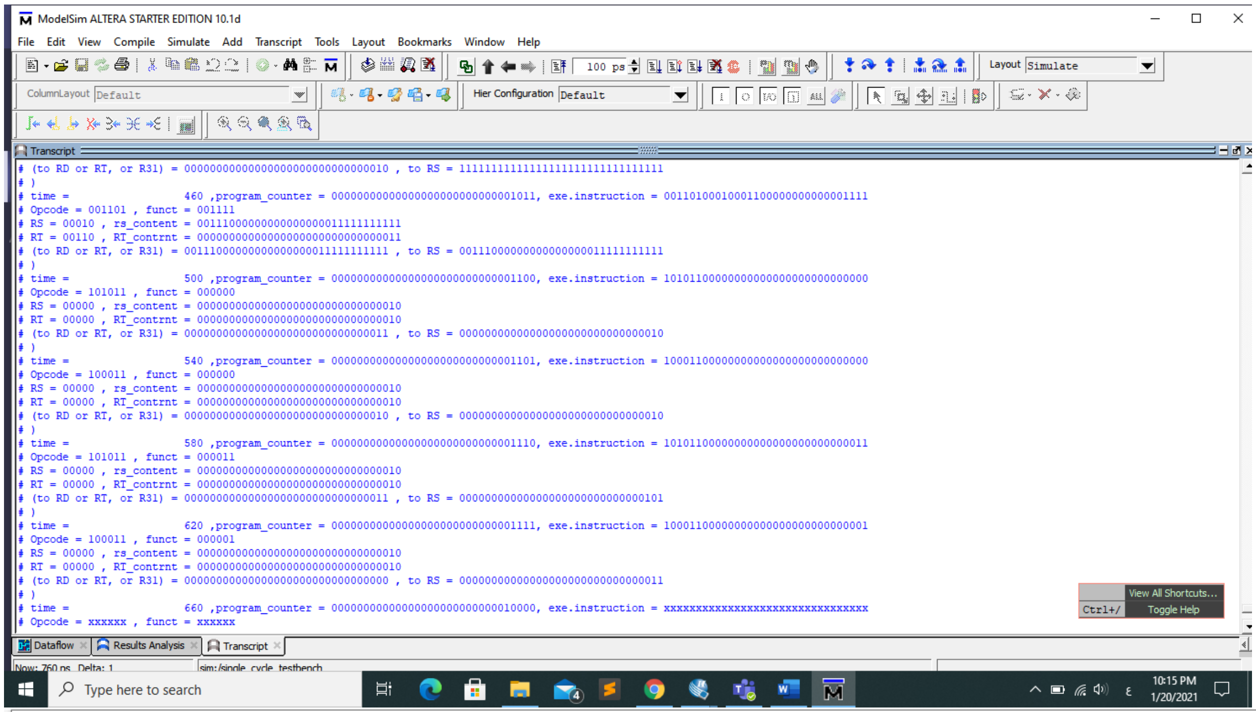


```
# RS = 00101 , rs_content = 11111111111111111111111111101001
# RT = 00011 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11111111111111111111111111100111
# )
# time =                 100 ,program_counter = 00000000000000000000000000000010, exe.instruction = 00000001011011000011000000100101
# Opcode = 000000 , funct = 100101
# RS = 01011 , rs_content = 00000000000000000000000000000011
# RT = 01100 , RT_contrnt = 00000000000000000000000000000011
# (to RD or RT, or R31) = 00000000000000000000000000000011 , to RS = 00000000000000000000000000000011
# )
# time =                 140 ,program_counter = 00000000000000000000000000000011, exe.instruction = 00000001111001000001100000100100
# Opcode = 000000 , funct = 100100
# RS = 01111 , rs_content = 11111111111111111111111111111101
# RT = 00100 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000001 , to RS = 00000000000000000000000000000000
# )
# time =                 180 ,program_counter = 00000000000000000000000000000100, exe.instruction = 00111100000101000011111111111111
# Opcode = 001111 , funct = 111111
# RS = 00000 , rs_content = 00000000000000000000000000000010
# RT = 01010 , RT_contrnt = 00011111111111110000000000000000
# (to RD or RT, or R31) = 00011111111111110000000000000000 , to RS = 00011111111111110000000000000000
# )
# time =                 220 ,program_counter = 00000000000000000000000000000101, exe.instruction = 00111100000101100001111111111111
# Opcode = 001111 , funct = 111111
# RS = 00000 , rs_content = 00000000000000000000000000000010
# RT = 10110 , RT_contrnt = 00011111111111110000000000000000
# (to RD or RT, or R31) = 00011111111111110000000000000000 , to RS = 00011111111111110000000000000000
# )
# time =                 260 ,program_counter = 00000000000000000000000000000110, exe.instruction = 00000000001100110100000000100000
# Opcode = 000000 , funct = 100000
# RS = 00001 , rs_content = 11101100111111011111001000011001
# RT = 10011 , RT_contrnt = 11111110001111110111110001111111
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11101011001111100111010110011000
# )
```

```
Now: 760 ps  Delta: 1        sim:/single_cycle_testbench
```



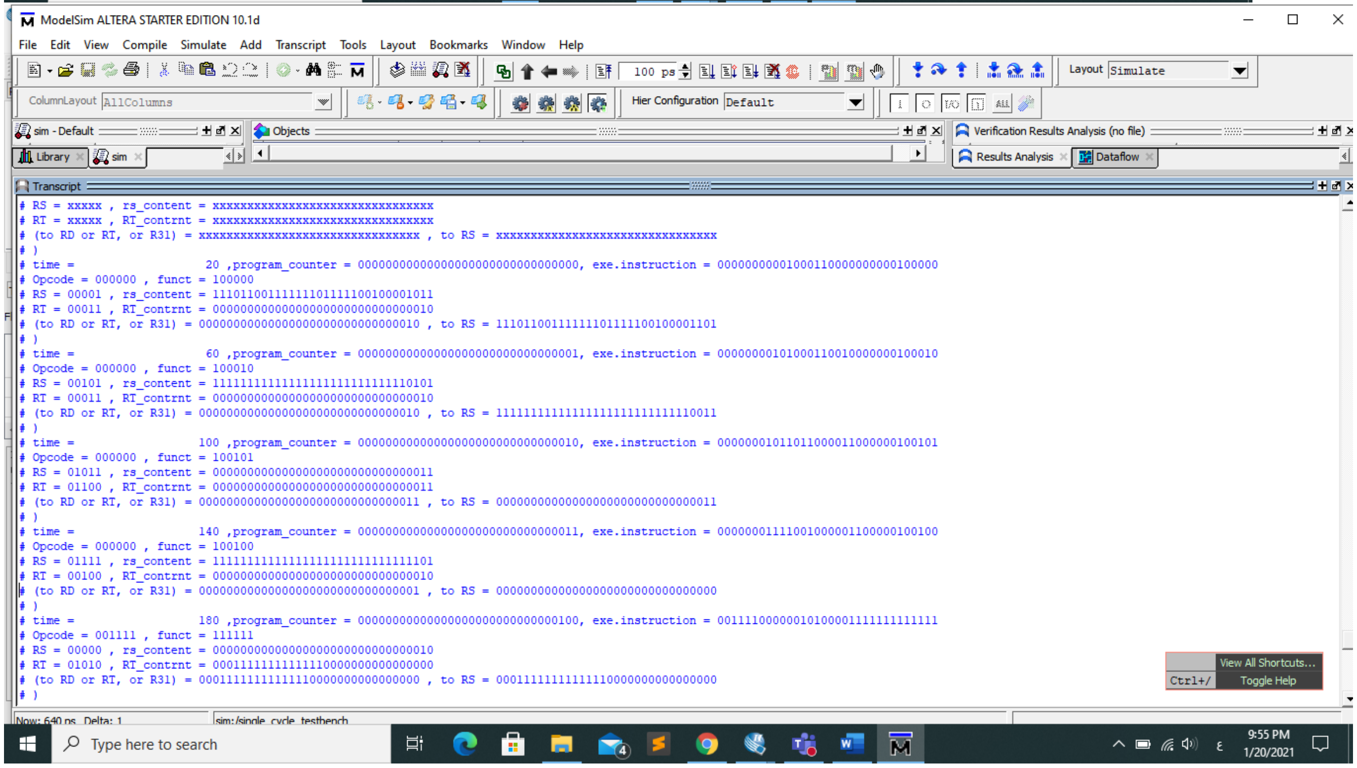
```
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11101011001111100111010110011000
# )
# time =                 300 ,program_counter = 00000000000000000000000000000111, exe.instruction = 00000000011001101000000010100010
# Opcode = 000000 , funct = 100010
# RS = 00001 , rs_content = 11101011001111100111010110011000
# RT = 10011 , RT_contrnt = 11111110001111110111110001111111
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11101100111111011111001000011001
# )
# time =                 340 ,program_counter = 00000000000000000000000000001000, exe.instruction = 00000001011011000011000000100101
# Opcode = 000000 , funct = 100101
# RS = 01011 , rs_content = 00000000000000000000000000000011
# RT = 01100 , RT_contrnt = 00000000000000000000000000000011
# (to RD or RT, or R31) = 00000000000000000000000000000011 , to RS = 00000000000000000000000000000011
# )
# time =                 380 ,program_counter = 00000000000000000000000000001001, exe.instruction = 00000001111101000011000000100100
# Opcode = 000000 , funct = 100100
# RS = 01111 , rs_content = 00000000000000000000000000000000
# RT = 10100 , RT_contrnt = 11111111111111111111111111111111
# (to RD or RT, or R31) = 00000000000000000000000000000001 , to RS = 00000000000000000000000000000000
# )
# time =                 420 ,program_counter = 00000000000000000000000000001010, exe.instruction = 00000001111101000011000000100110
# Opcode = 000000 , funct = 100110
# RS = 01111 , rs_content = 00000000000000000000000000000000
# RT = 10100 , RT_contrnt = 11111111111111111111111111111111
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11111111111111111111111111111111
# )
# time =                 460 ,program_counter = 00000000000000000000000000001011, exe.instruction = 00110100010001100000000000001111
# Opcode = 001101 , funct = 001111
# RS = 00010 , rs_content = 00111000000000000000001111111111
# RT = 00110 , RT_contrnt = 00000000000000000000000000000011
# (to RD or RT, or R31) = 00111000000000000000001111111111 , to RS = 00111000000000000000001111111111
# )
# time =                 500 ,program_counter = 00000000000000000000000000001100, exe.instruction = 10101100000000000000000000000000
# Opcode = 101011 , funct = 000000
```


ModelSim ALTERA STARTER EDITION 10.1d

```
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11111111111111111111111111111111
# )
# time =                 460 ,program_counter = 00000000000000000000000000001011, exe.instruction = 00110100010001100000000000001111
# Opcode = 001101 , funct = 001111
# RS = 00010 , rs_content = 00111000000000000000001111111111
# RT = 00110 , RT_contrnt = 00000000000000000000000000000011
# (to RD or RT, or R31) = 00111000000000000000001111111111 , to RS = 00111000000000000000001111111111
# )
# time =                 500 ,program_counter = 00000000000000000000000000001100, exe.instruction = 10101100000000000000000000000000
# Opcode = 101011 , funct = 000000
# RS = 00000 , rs_content = 00000000000000000000000000000010
# RT = 00000 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000011 , to RS = 00000000000000000000000000000010
# )
# time =                 540 ,program_counter = 00000000000000000000000000001101, exe.instruction = 10001100000000000000000000000000
# Opcode = 100011 , funct = 000000
# RS = 00000 , rs_content = 00000000000000000000000000000010
# RT = 00000 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 00000000000000000000000000000010
# )
# time =                 580 ,program_counter = 00000000000000000000000000001110, exe.instruction = 10101100000000000000000000000011
# Opcode = 101011 , funct = 000011
# RS = 00000 , rs_content = 00000000000000000000000000000010
# RT = 00000 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000011 , to RS = 00000000000000000000000000000101
# )
# time =                 620 ,program_counter = 00000000000000000000000000001111, exe.instruction = 10001100000000000000000000000001
# Opcode = 100011 , funct = 000001
# RS = 00000 , rs_content = 00000000000000000000000000000010
# RT = 00000 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000000 , to RS = 00000000000000000000000000000011
# )
# time =                 660 ,program_counter = 00000000000000000000000000010000, exe.instruction = xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
# Opcode = xxxxxx , funct = xxxxxx
```

Now: 760 ns Delta: 1   sim:/single_cycle_testbench

10:15 PM 1/20/2021


ModelSim ALTERA STARTER EDITION 10.1d

```
# RS = xxxxx , rs_content = xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
# RT = xxxxx , RT_contrnt = xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
# (to RD or RT, or R31) = xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx , to RS = xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
# )
# time =                  20 ,program_counter = 00000000000000000000000000000000, exe.instruction = 00000000001000110000000000100000
# Opcode = 000000 , funct = 100000
# RS = 00001 , rs_content = 11101100111111101111100100001011
# RT = 00011 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11101100111111101111100100001101
# )
# time =                  60 ,program_counter = 00000000000000000000000000000001, exe.instruction = 00000000101000110000000000100010
# Opcode = 000000 , funct = 100010
# RS = 00101 , rs_content = 11111111111111111111111111110101
# RT = 00011 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000010 , to RS = 11111111111111111111111111110011
# )
# time =                 100 ,program_counter = 00000000000000000000000000000010, exe.instruction = 00000001011011000000000000100101
# Opcode = 000000 , funct = 100101
# RS = 01011 , rs_content = 00000000000000000000000000000011
# RT = 01100 , RT_contrnt = 00000000000000000000000000000011
# (to RD or RT, or R31) = 00000000000000000000000000000011 , to RS = 00000000000000000000000000000011
# )
# time =                 140 ,program_counter = 00000000000000000000000000000011, exe.instruction = 00000001111001000000000000100100
# Opcode = 000000 , funct = 100100
# RS = 01111 , rs_content = 11111111111111111111111111111101
# RT = 00100 , RT_contrnt = 00000000000000000000000000000010
# (to RD or RT, or R31) = 00000000000000000000000000000001 , to RS = 00000000000000000000000000000000
# )
# time =                 180 ,program_counter = 00000000000000000000000000000100, exe.instruction = 00111100000010101111111111111111
# Opcode = 001111 , funct = 111111
# RS = 00000 , rs_content = 00000000000000000000000000000010
# RT = 01010 , RT_contrnt = 00011111111111111000000000000000
# (to RD or RT, or R31) = 00011111111111111000000000000000 , to RS = 00011111111111111000000000000000
# )
```

Now: 640 ns Delta: 1   sim:/single_cycle_testbench

9:55 PM 1/20/2021