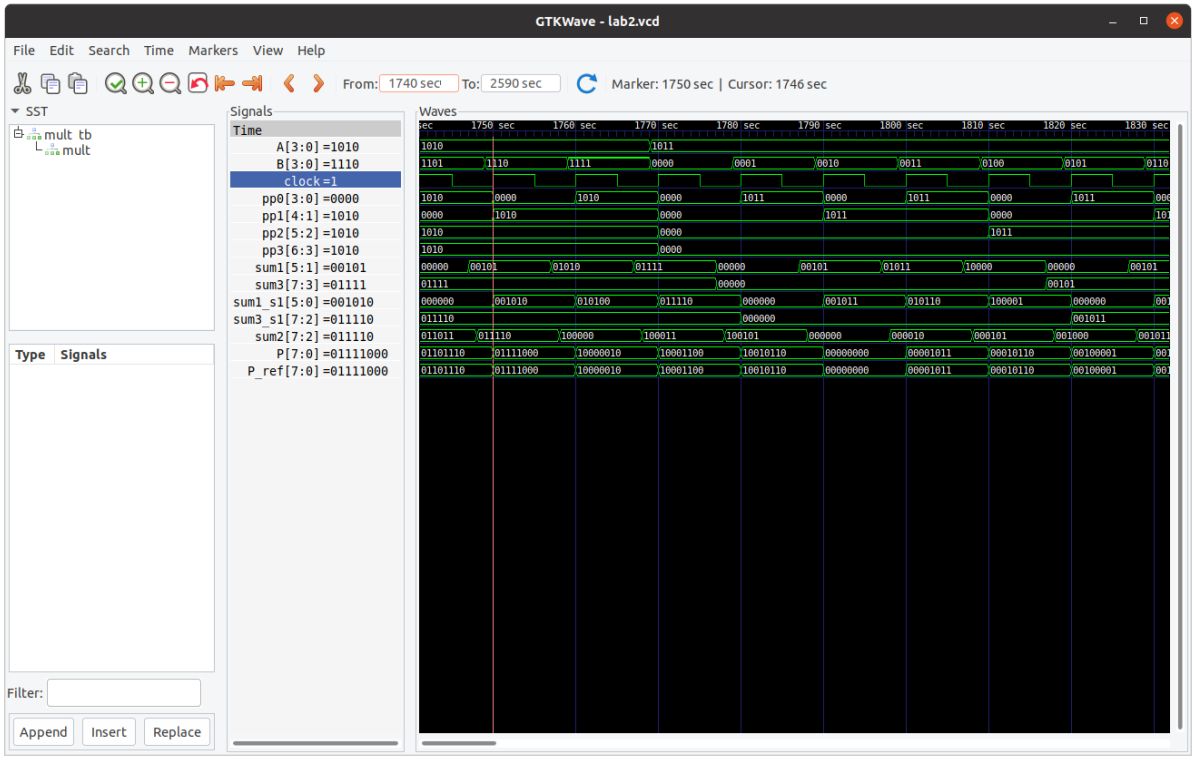
Lab 2

Lab 2: Part 1

1. `mult_fast` code

```
module mult_fast(
  output reg[7:0] P,  // product
  input[3:0] A, B,    // multiplicand and multiplier
  input clk       // clock (posedge)
  );
  // stage 0 (input)
  reg[3:0] a_s0, b_s0;
  always @(posedge clk) begin
    a_s0 <= A;
    b_s0 <= B;
  end
  // stage 1
  wire[3:0] pp0 = a_s0 & {4{b_s0[0]}}; // ignore the delays of AND gates
  wire[4:1] pp1 = a_s0 & {4{b_s0[1]}}; // ignore the delays of AND gates
  wire[5:2] pp2 = a_s0 & {4{b_s0[2]}}; // ignore the delays of AND gates
  wire[6:3] pp3 = a_s0 & {4{b_s0[3]}}; // ignore the delays of AND gates
  reg[5:1] sum1;
  always @(pp0, pp1)
    sum1[5:1] <= #7 pp0[3:1] + pp1[4:1]; // delay of the 4-bit adder
  reg[7:3] sum3;
  always @(pp2, pp3)
    sum3[7:3] <= #7 pp2[5:3] + pp3[6:3]; // delay of the 4-bit adder
  reg[5:0] sum1_s1;
  reg[7:2] sum3_s1;
  always @(posedge clk) begin
    sum1_s1 <= {sum1, pp0[0]};
    sum3_s1 <= {sum3, pp2[2]};
  end
  // stage 2 (output)
  reg[7:2] sum2;
  always @(sum1_s1, sum3_s1)
    sum2[7:2] <= #8 sum1_s1[5:2] + sum3_s1[7:2]; // delay of the 6-bit adder
  always @(posedge clk) begin
    P <= {sum2, sum1_s1[1:0]};
  end
endmodule
```

2. Show the waveform with the settings in `lab2.sav`, (should include 1750 to 1800 sec)



3. What is the latency (worst case waiting time from the input becomes steady to the register of the last stage refreshes)?

   感覺是20秒(ticks)，觀察$P = A \times B$的結果 (have to wait for the rising or falling edge, hence 20 instead of 21)

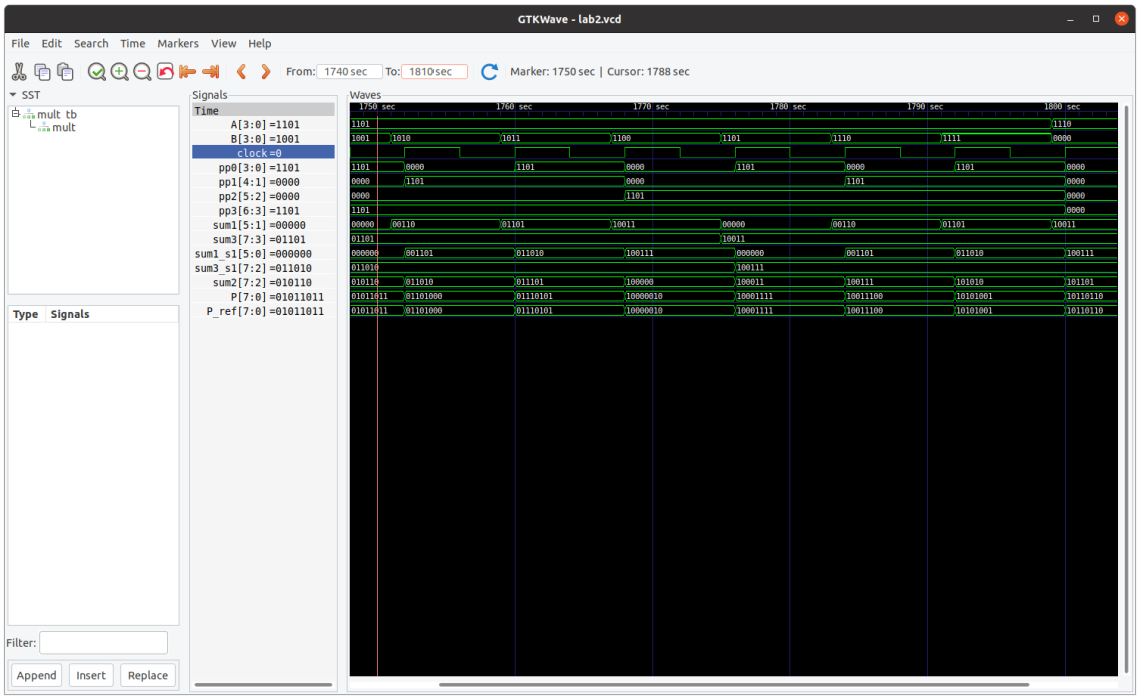
Lab 2: Part 2

Minimize the clock cycle by changing the delays in the module multtb.

1. What is the minimum clock cycle?

   8 ticks

2. screenshot


GTKWave - lab2.vcd
File Edit Search Time Markers View Help
From: 1740 sec To: 1810 sec
Marker: 1750 sec | Cursor: 1788 sec
SST
mult tb
mult
Type Signals
Filter:
Append Insert Replace
Signals
Time
A[3:0] =1101
B[3:0] =1001
clock =0
pp0[3:0] =1101
pp1[4:1] =0000
pp2[5:2] =0000
pp3[6:3] =1101
sum1[5:1] =00000
sum3[7:3] =01101
sum1_s1[5:0] =000000
sum3_s1[7:2] =011010
sum2[7:2] =010110
P[7:0] =01011011
P_ref[7:0] =01011011
Waves
1750 sec
1760 sec
1770 sec
1780 sec
1790 sec
1800 sec