# Shifters & Multipliers

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CECS 361 - Digital Design Techniques and Verification

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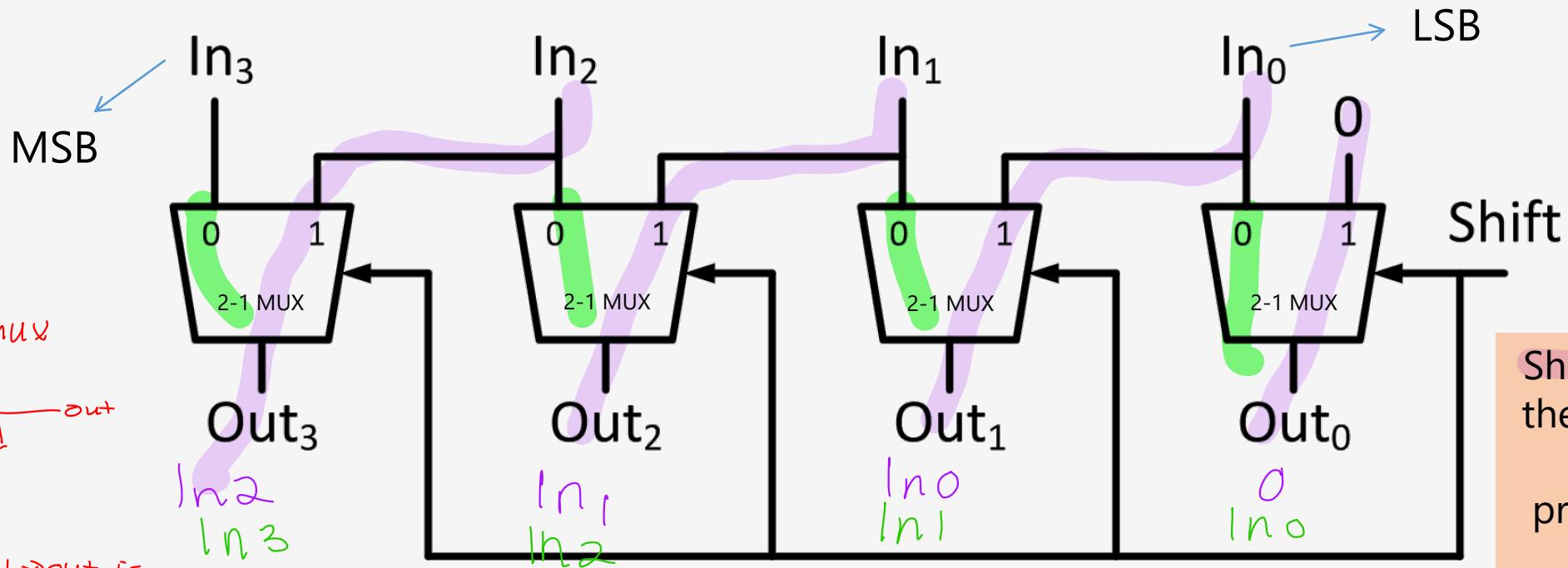
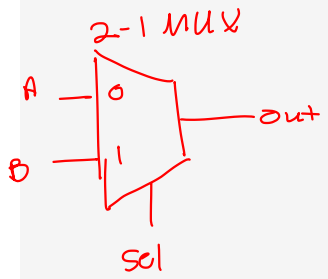
# Linear Shifter

Linear shifter shifts its inputs by a number of bits to the right or to the left, and routes the result to its output.




4-Bit Linear Shifter




if sel = 1 → out is whatever is at terminal 1.

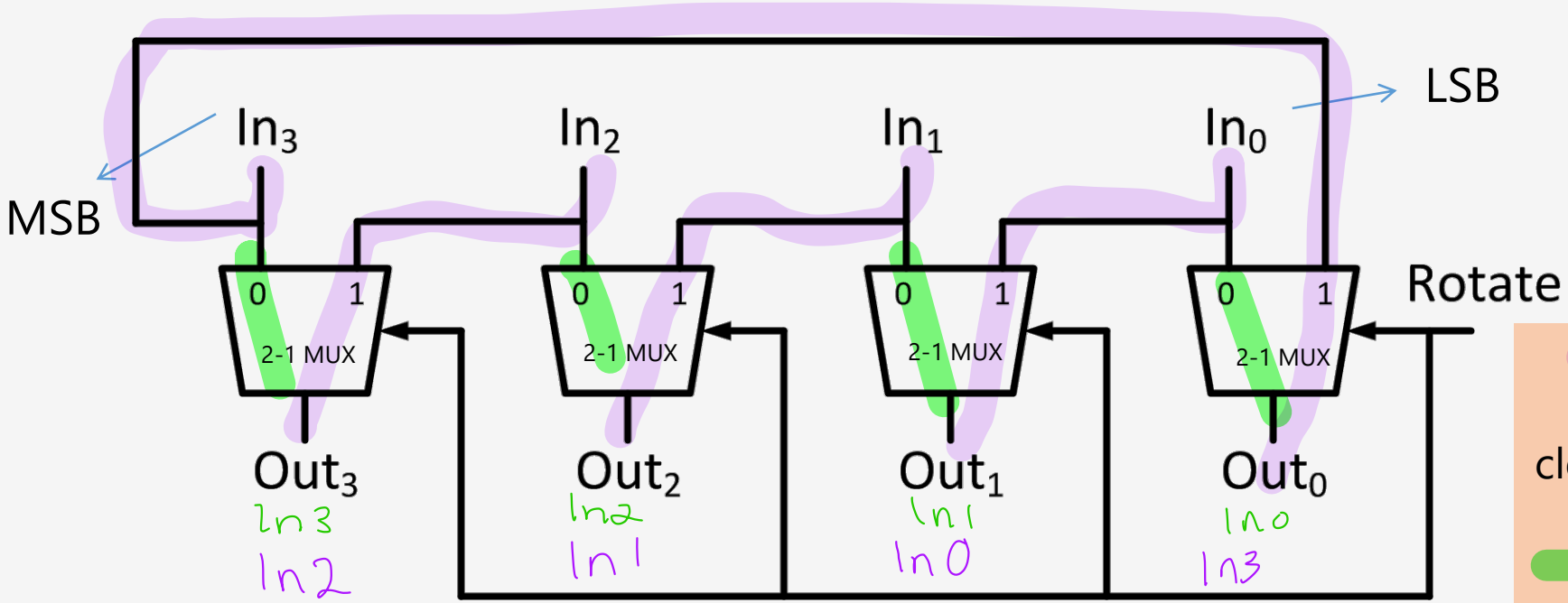
if sel = 0 → out is whatever is at terminal 0.

Shift = 1 → It shifts the input to the left by one bit and produces 0 at LSB.

Shift = 0 → No shift.

# Barrel Shifter

Barrel shifter rotates its inputs in either clockwise or counterclockwise direction by a number of bits and propagate them to their outputs.



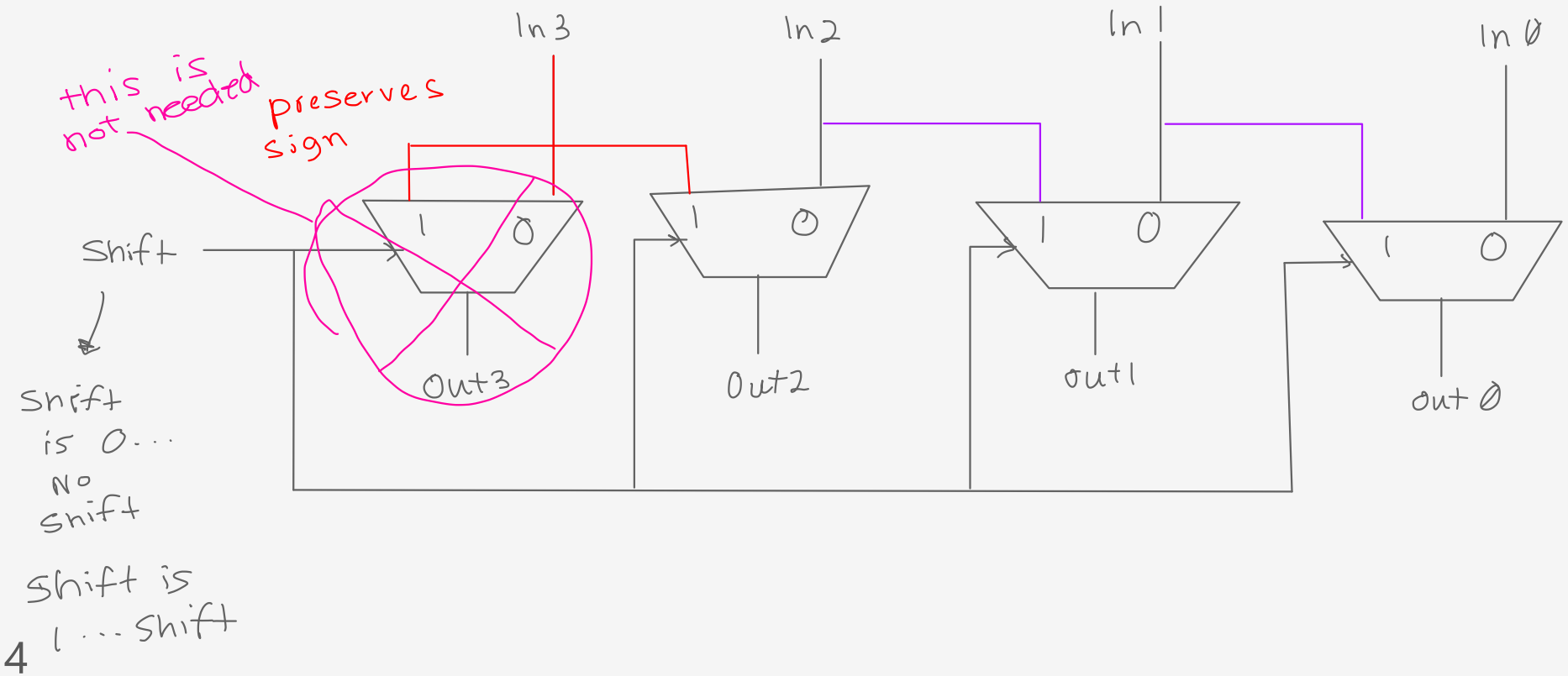

4-Bit Barrel Shifter

Rotate = 1 → It rotates the input clockwise by one bit

Rotate = 0 → No rotate.

# Shifter - Sample Question

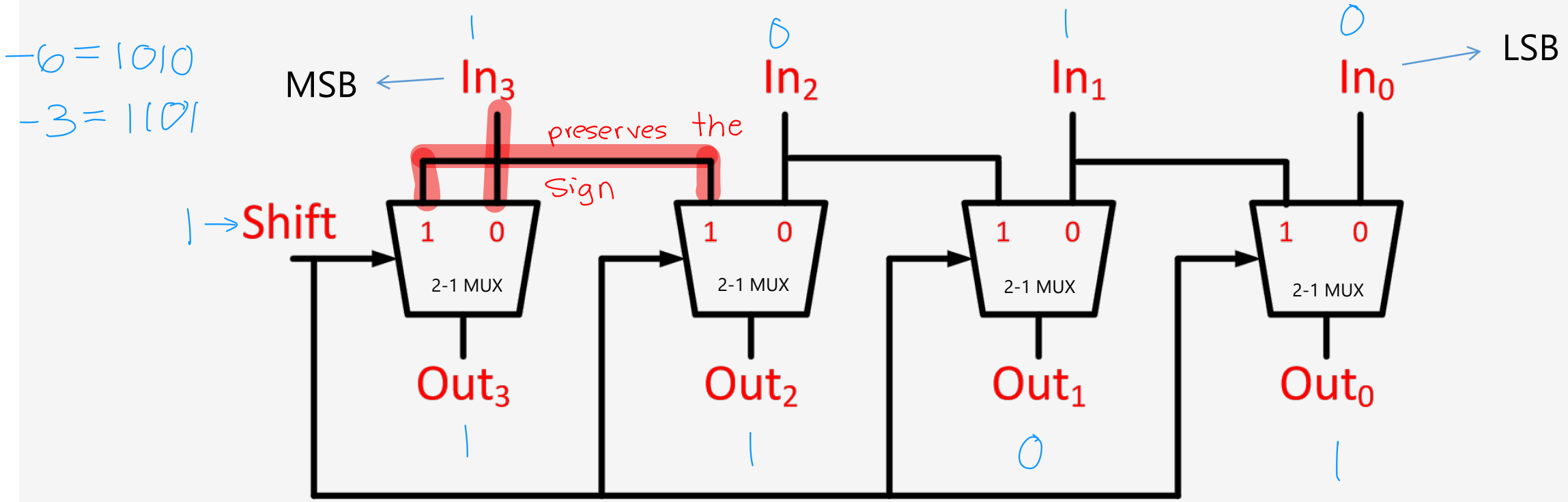
Design a 4-bit arithmetic linear shifter that shifts its inputs to the right by one bit and keep the sign bit.



# Shifter - Sample Question - Solution

Divider by 2.

Design a 4-bit arithmetic linear shifter that shifts its inputs to the right by one bit and keep the sign bit.



# Array Multiplier

Array multiplier generates all partial products before summing each column in the partial product tree to obtain the result.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $A_3$ | $A_2$ | $A_1$ | $A_0$ | Multiplicand |
| | | | | $B_3$ | $B_2$ | $B_1$ | $B_0$ | Multiplier |
| | | | x | | | | | |
| | | | | $B_0.A_3$ | $B_0.A_2$ | $B_0.A_1$ | $B_0.A_0$ | Partial Product 0th |
| | | | $B_1.A_3$ | $B_1.A_2$ | $B_1.A_1$ | $B_1.A_0$ | | Partial Product 1th |
| | | $B_2.A_3$ | $B_2.A_2$ | $B_2.A_1$ | $B_2.A_0$ | | | Partial Product 2nd |
| | $B_3.A_3$ | $B_3.A_2$ | $B_3.A_1$ | $B_3.A_0$ | | | | Partial Product 3rd |
| + | | | | | | | | |
| $Sum_7$ | $Sum_6$ | $Sum_5$ | $Sum_4$ | $Sum_3$ | $Sum_2$ | $Sum_1$ | $Sum_0$ | Sum Output |

4-Bit Array Multiplier Algorithm

# Array Multiplier - Sample Question 1

Unsigned

Multiply 13 and 9 according to the rules of array multiplication.

$13 = (1101)_2$

$9 = (1001)_2$

$13(9) = 117 = (1110101)_2$

```
          1 1 0 1
        x 1 0 0 1
        ---------
          1 1 0 1
        0 0 0 0 0
      0 0 0 0 0 0
+ 0 1 1 0 1 0 0 0
-----------------
  0 1 1 1 0 1 0 1
128 64 32 16 8 4 2 1
```

64 + 32 + 16 + 4 + 1

96 20 21

117

# Array Multiplier - Sample Question 1 - Solution

Multiply 13 and 9 according to the rules of array multiplication.

$13 = (1101)_b$

$9 = (1001)_b$

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 1 | 0 | 1 | | Multiplicand |
| | | | | 1 | 0 | 0 | 1 | | Multiplier |
| | | | x | | | | | | |
| | | | | 1 | 1 | 0 | 1 | | Partial Product 0th |
| | | | 0 | 0 | 0 | 0 | | | Partial Product 1th |
| | | 0 | 0 | 0 | 0 | | | | Partial Product 2nd |
| | 1 | 1 | 0 | 1 | | | | | Partial Product 3rd |
| + | | | | | | | | | |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | | Sum Output |

$(01110101)_b = 117$

# Array Multiplier - Sample Question 2

Design the partial product tree for 4-bit array multiplier.

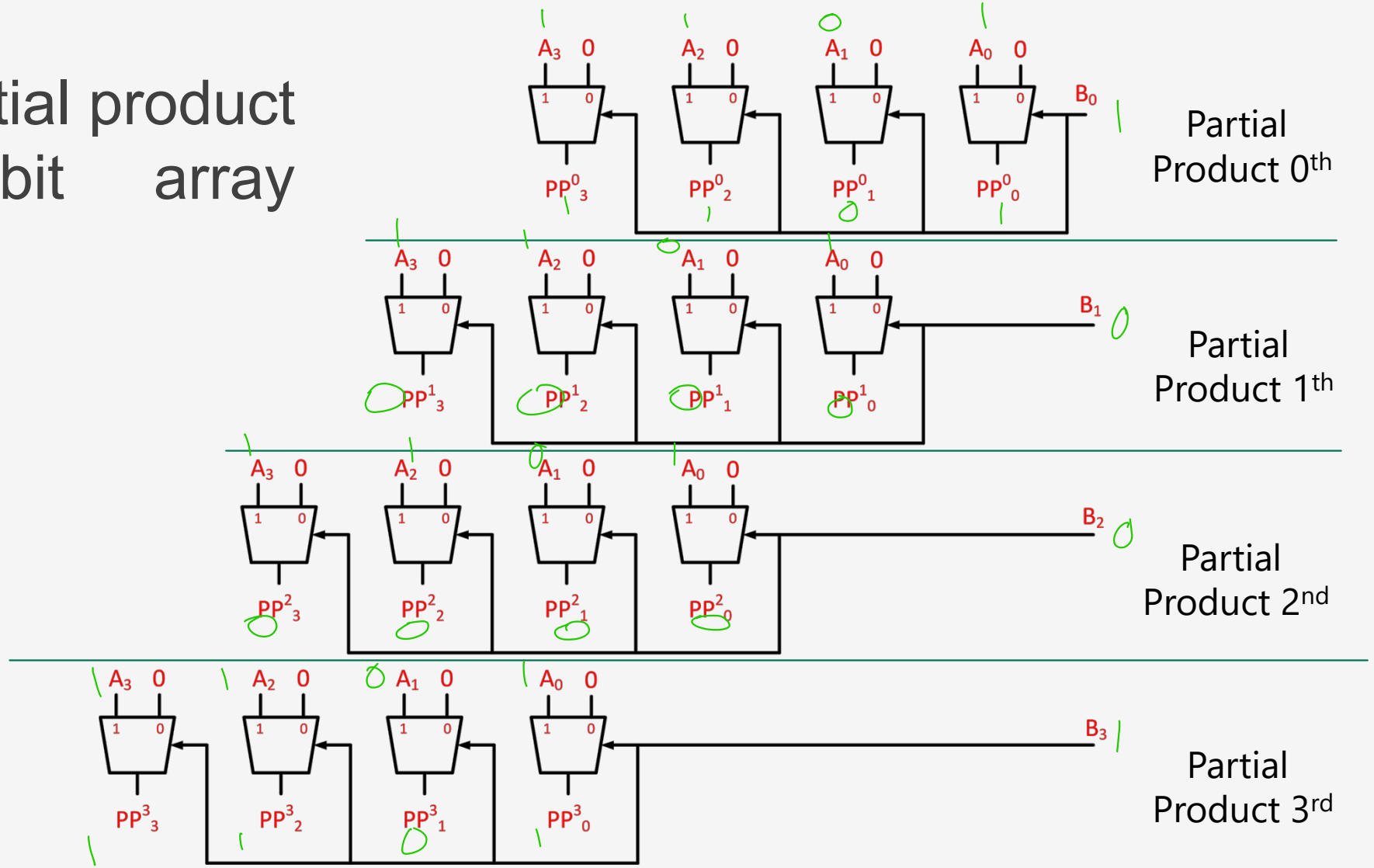
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $A_3$ | $A_2$ | $A_1$ | $A_0$ | Multiplicand |
| | | | | $B_3$ | $B_2$ | $B_1$ | $B_0$ | Multiplier |
| | | | x | | | | | |
| | | | | $B_0.A_3$ | $B_0.A_2$ | $B_0.A_1$ | $B_0.A_0$ | Partial Product 0th |
| | | | $B_1.A_3$ | $B_1.A_2$ | $B_1.A_1$ | $B_1.A_0$ | | Partial Product 1th |
| | | $B_2.A_3$ | $B_2.A_2$ | $B_2.A_1$ | $B_2.A_0$ | | | Partial Product 2nd |
| | $B_3.A_3$ | $B_3.A_2$ | $B_3.A_1$ | $B_3.A_0$ | | | | Partial Product 3rd |
| + | | | | | | | | |
| $Sum_7$ | $Sum_6$ | $Sum_5$ | $Sum_4$ | $Sum_3$ | $Sum_2$ | $Sum_1$ | $Sum_0$ | Sum Output |

AND

# Array Multiplier - Sample Question 2 - Solution

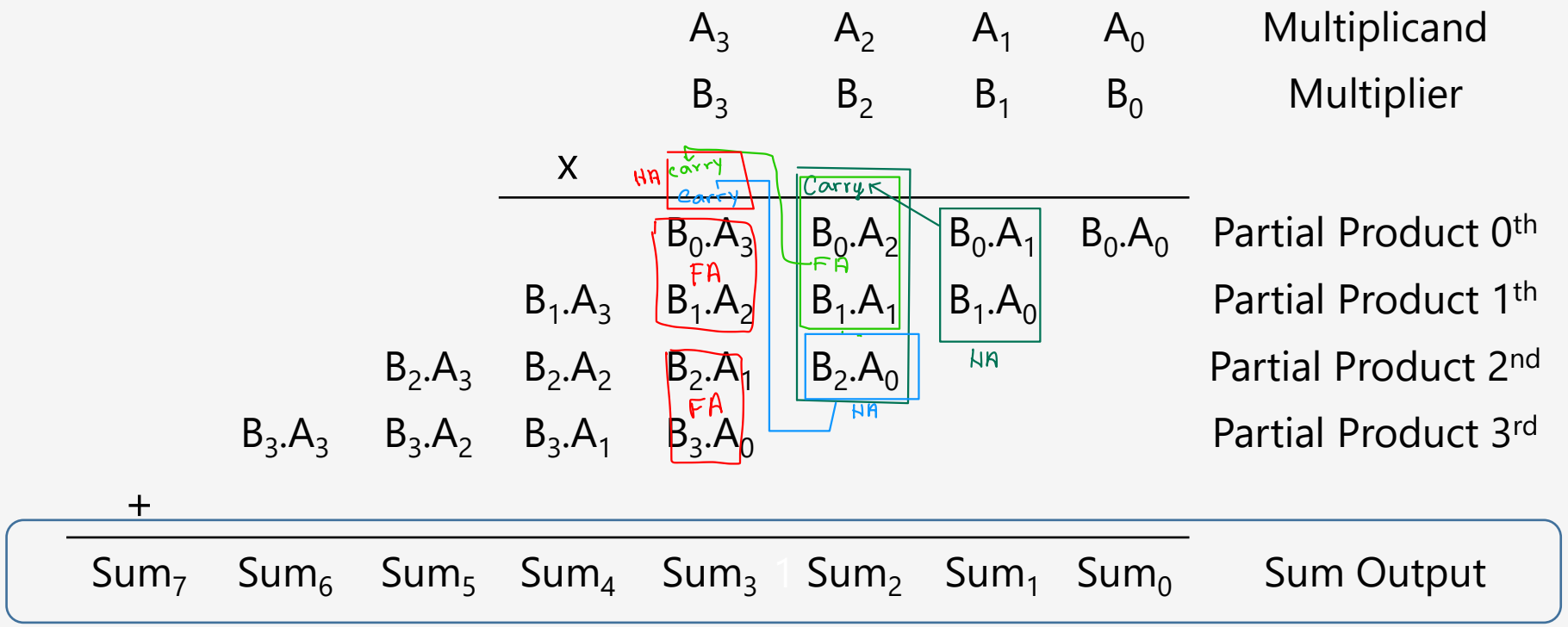
Design the partial product tree for 4-bit array multiplier.

PP(#)(#) — row/upper index; position



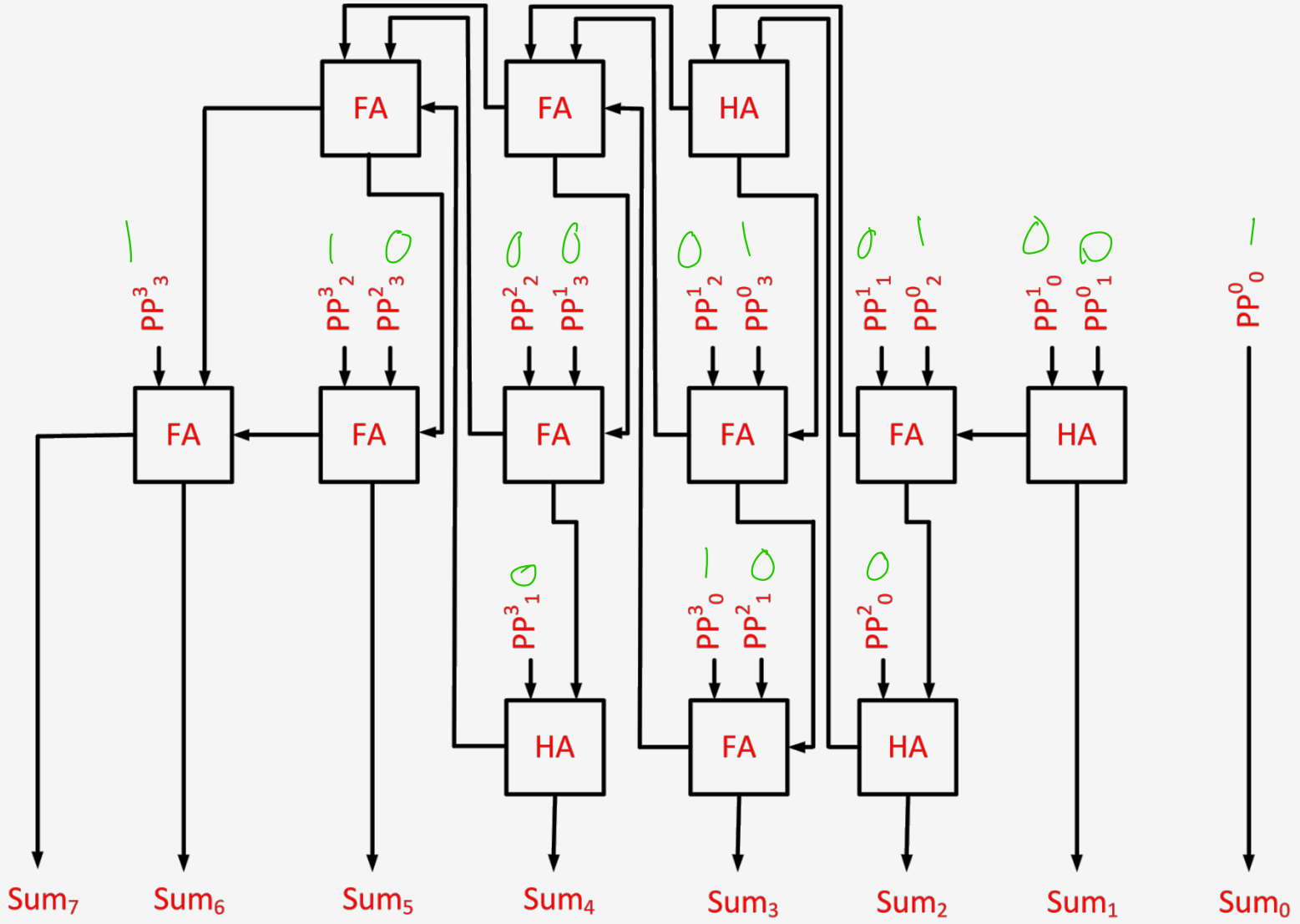
# Array Multiplier - Sample Question 3

Design full adder tree responsible for adding every partial product in the partial product tree for 4-bit array multiplier.



# Array Multiplier - Sample Question 3 - Solution

Design full adder tree responsible for adding every partial product in the partial product tree for 4-bit array multiplier.



# Homework Assignment 1

**Due Date:** Check Canvas. Sep 16.

**Late Submission Policy:**

One day delay: 25% deduction

Two days delay: 50% deduction

More than two days delay: No credit

**Academic Integrity:** There is zero tolerance for cheating, plagiarism, or any other act of violation of Academic Integrity.