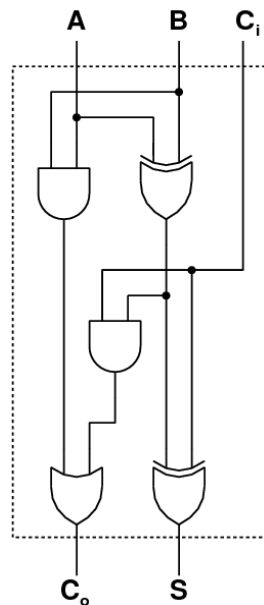


5. In this question we will compute the Area and Delay of different adder components. To calculate the Area and the Speed use the values in the following table:

Gate	Delay (all paths)	Area
2-input AND	15ps	$1.8 \mu\text{m}^2$
2-input OR	15ps	$1.8 \mu\text{m}^2$
2-input XOR	20ps	$2.3 \mu\text{m}^2$

- a) The figure below is a gate level schematic of a 1-bit full adder. Using the table above: Determine the total area of the 1-bit full adder, identify the critical path in this circuit by drawing on the schematic, and calculate the critical path using the table. (3 points)

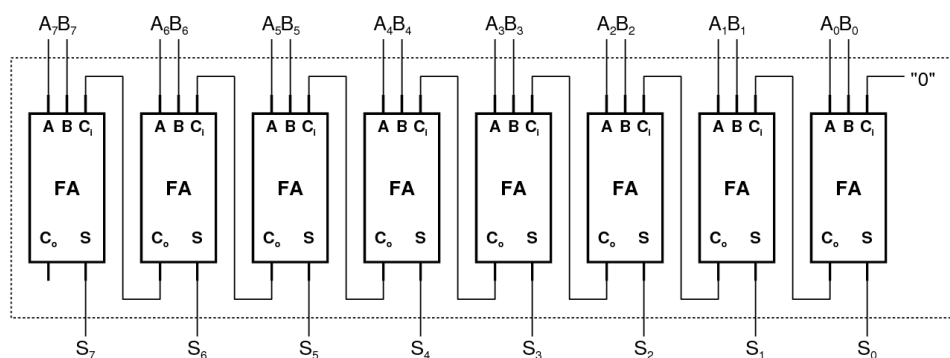


$$A_{FA} = 2.3\mu\text{m}^2 + 2.3\mu\text{m}^2 + 1.8\mu\text{m}^2 + 1.8\mu\text{m}^2 + 1.8\mu\text{m}^2 = 10\mu\text{m}^2$$

Critical path from A/B to Co

$$t_{crit} = t_{XOR} + t_{AND} + t_{OR} = 20\text{ps} + 15\text{ps} + 15\text{ps} = 50\text{ps}$$

- b) An 8-bit Ripple Carry Adder is generated from the 1-bit Full Adder from the previous question 5a. If this adder is used to add 8-bit two's complement numbers, what is the total area and the critical path of this 8-bit adder? (3 points)

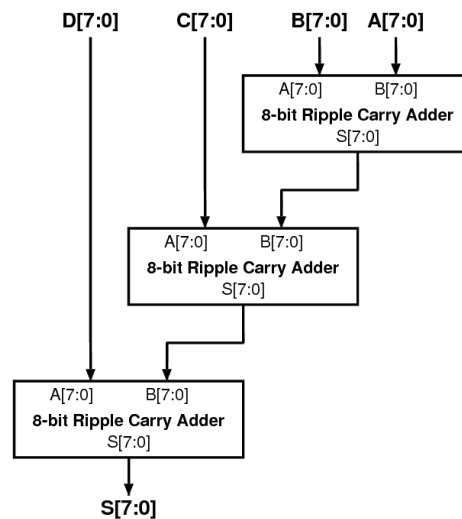


$$A_{\text{Tot}} = 8 \times A_{\text{FA}} = 80 \mu\text{m}^2$$

$T_{\text{crit}}$  is a little tricky. The  $C_i$  for the LSB is 0. So the signal there propagates through a shorter path (One AND and one OR gate = 30ps),  
 Since only Two's complement numbers are used, the carry out S8 is not used, For the MSB, only A/B to S delay is relevant = 40ps  
 $T_{\text{crit}} = t_{\text{MSB}} + 6 \times t_{\text{FA}} + 1 \times t_{\text{LSB}} = 40 + 6 \times 50\text{ps} + 30\text{ps} = 370\text{ps}$ .

$8 \times t_{\text{FA}} = 400\text{ps}$  is also acceptable should give them -1 point

- c) A multi-operand adder to add four 8-bit two's complement numbers is constructed using the 8-bit ripple carry adder structure from the question 5b as shown in the figure below. What is the total area and the critical path of this multi-operand adder? (4 points)



$$\text{Total Area} = 3 \times \text{Eightbit RCA} = 3 \times 80 \mu\text{m}^2 = 240 \mu\text{m}^2$$

The timing is trickier. The critical path goes through the LSB of the first adder, and then the second LSB to the  $S_0$  outputs (40ps each). Then you have the normal critical path of the eight-bit RCA calculated in the previous question (370ps). Together it is  
 $T_{\text{crit}} = t_{\text{B,S}} + t_{\text{B,S}} + T_{\text{8bitRCA}} = 40\text{ps} + 40\text{ps} + 370\text{ps} = 450\text{ps}$ .

Note:

1ps	= 0.000 000 000 001s	= $1 \cdot 10^{-12}\text{s}$
$1\mu\text{m}^2$	= 0.000 000 000 001 $\text{m}^2$	= $1 \cdot 10^{-12} \text{m}^2$