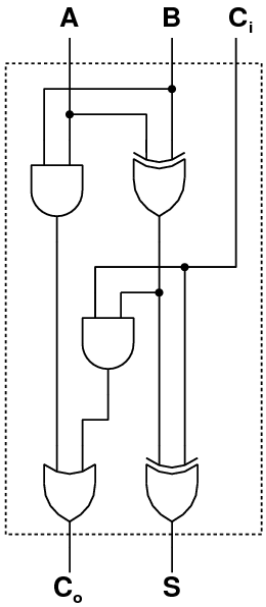
5. In this question we will compute the Area and Delay of different adder components. To calculate the Area and the Speed use the values in the following table:

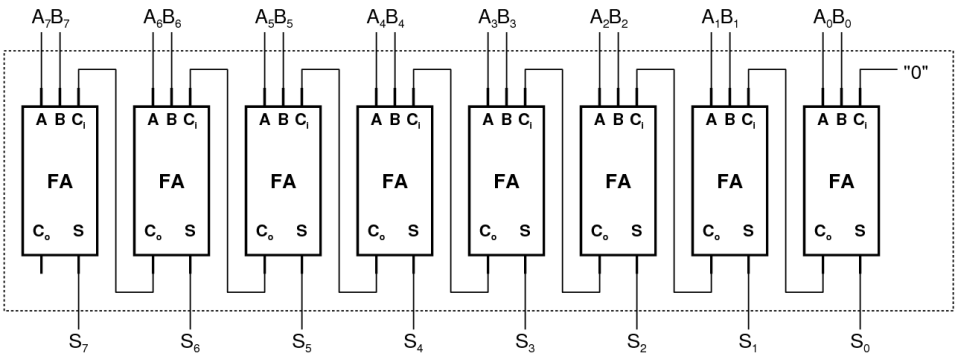
Gate	Delay (all paths)	Area
2-input AND	15ps	1.8 μm^2
2-input OR	15ps	1.8 μm^2
2-input XOR	20ps	2.3 μm^2

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} = 2.3µm^2+ 2.3µm^2 + 1.8µm^2 + 1.8µm^2 + 1.8µm^2 = 10µm^2
Critical path from A/B to Co
t_{crit}= t_{XOR} + t_{AND} +t_{OR} = 20ps + 15ps + 15ps = 50ps

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)

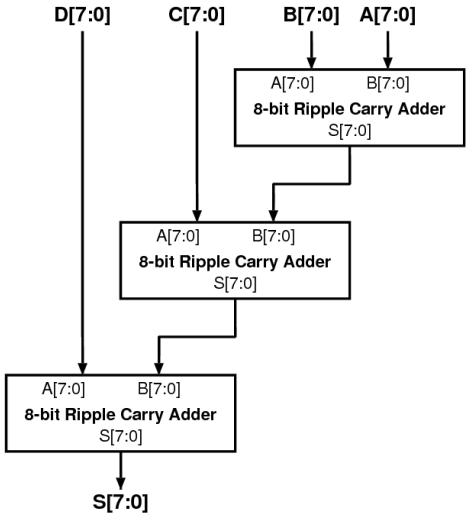


$A_{Tot} = 8 \times A_{FA} = 80\ \mu m^2$

T_{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
$T_{crit}=t_{MSB} + 6 \times t_{FA} + 1 \times t_{LSB} = 40+ 6 \times 50ps + 30ps = 370ps.$

$8 \times t_{FA} = 400ps$ 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)



Total Area = 3x Eightbit RCA = $3 \times 80\ \mu m^2 = 240\ \mu m^2$

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 $T_{crit} = t_{B,S} + t_{B,S} + T_{8bitRCA} = 40ps + 40ps + 370ps = 450ps.$

Note: $1ps = 0.000\ 000\ 000\ 001s = 1.10^{-12}s$
$1\mu m^2 = 0.000\ 000\ 000\ 001m^2 = 1.10^{-12}\ m^2$