Reminder:

- R_0 – equivalent resistance of minimum size ($W = L = 1$) NMOS transistor
- I_0 – equivalent I_{ds} current of minimum size ($W = L = 1$) NMOS transistor
- C_0 – gate capacitance of minimum size transistor
- $\tau = R_0 C_0$ or maybe C_0/I_0 – technology dependent delay term

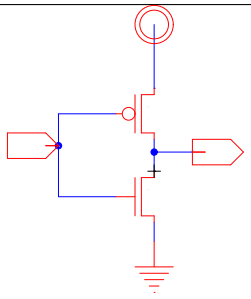
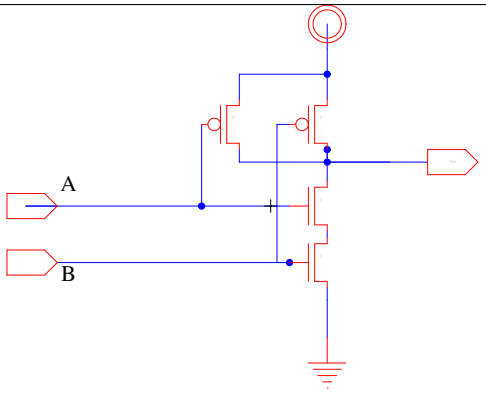
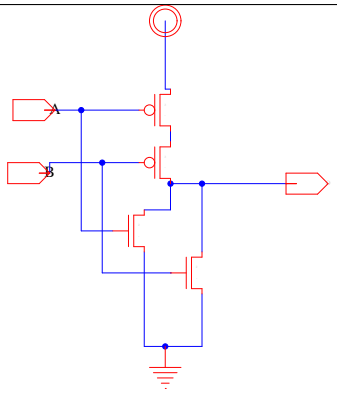
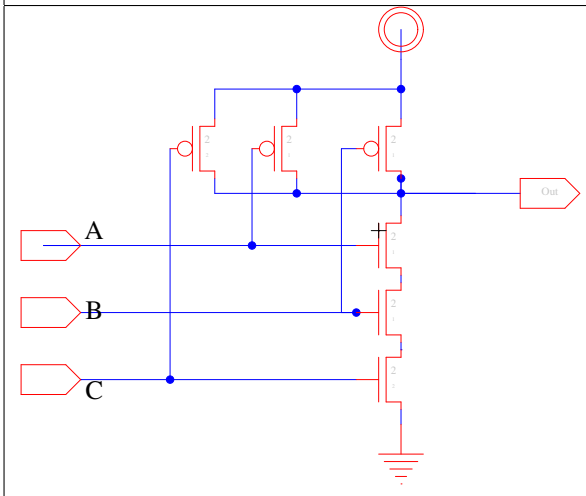
R, I, and C in terms of R_0, I_0, and C_0 for a transistor with width W:

R_{drive}	$\frac{R_0}{W}$
I_{drive}	$I_0 W$
C_{gate}	$W \cdot C_0$

We will evaluate two cases today.

1. Extreme velocity saturation where $R_{p0} = R_{n0}$ (i.e. I_{ds} at rails is same for equally sized N and P devices—simplifying assumption we made for examples from last class)
2. $R_{p0} = 2R_{n0}$ (i.e. I_{ds} PMOS at rails is half I_{ds} of NMOS)

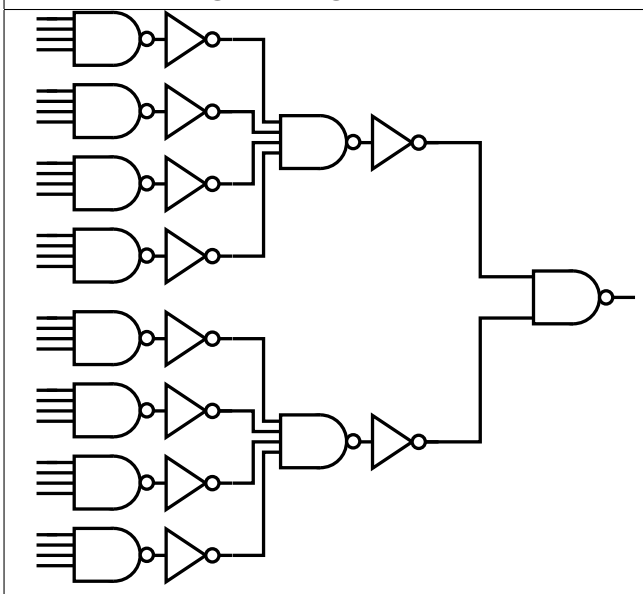
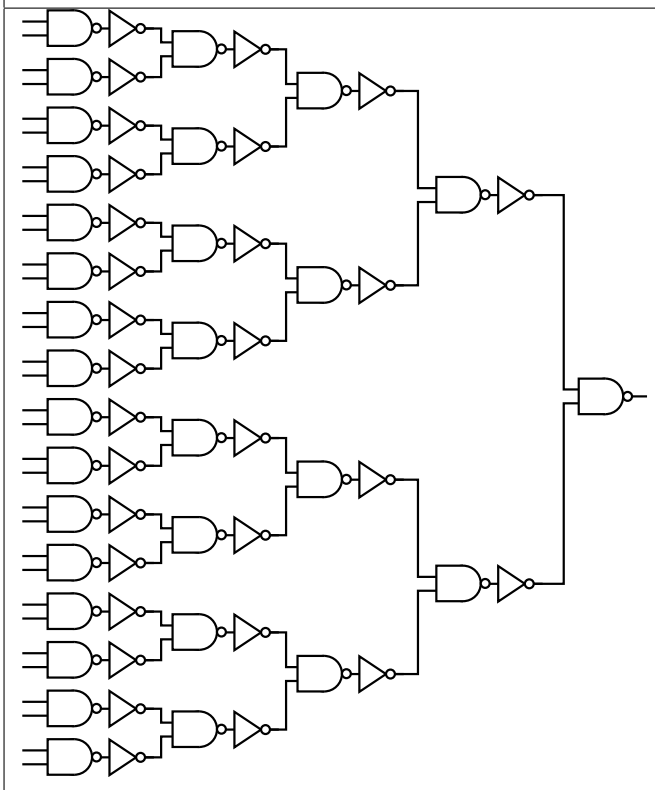
1. How can you size for equal, worst-case rise/fall times assuming targeting $R_{drive} = \frac{R_0}{2}$ for the two cases above? C_a is the capacitance of the A input.

	$R_{p0} = R_{n0}$			$R_{p0} = 2R_{n0}$		
	W_p	W_n	C_a	W_p	W_n	C_a
	2	2	$4C_0$	4	2	$6C_0$
						
						
						

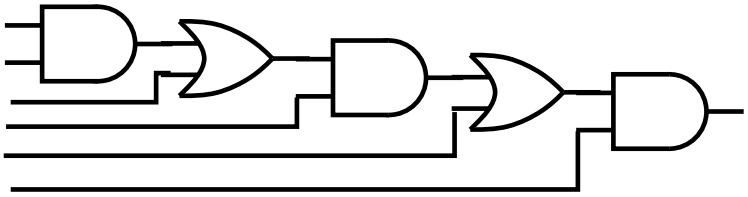
2. For a k-input NAND gate, sized for equal, worst-case rise/fall times and targeting $R_{drive} = \frac{R_0}{2}$:

	$R_{p0} = R_{n0}$	$R_{p0} = 2R_{n0}$
What is C_{in} as a function of k?		

3. Assuming sized for $\frac{R_0}{2}$ drive as above, and input also driven by $R_{drive} = \frac{R_0}{2}$, compare the delay of the following three nand32 implementations for the $R_{p0} = R_{n0}$ case. Include the delay of driving the input and assume each implementation has an output load of $4C_0$.

Organization	**Delay**
single-stage nand32	
	
	

4. What is the delay for each of the two implementations below for this logical computaiton:



Assume $R_{drive} = \frac{R_0}{2}$ sizing of gates from previous page, and input also driven by $R_{drive} = \frac{R_0}{2}$. Assume each implementation has an output load of $2C_0$.

	Delay	
	$R_{p0} = R_{n0}$	$R_{p0} = 2R_{n0}$