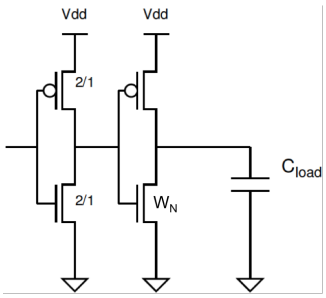
Today's Question: How do we drive a large load ($e.g.\ C_{load} = 4 \times 10^4 C_0$) with minimum delay? Detail buffer count and sizing.

Assume:

- velocity saturated sizing for gate drive; inverter sizing is: W_n=2, W_p=2
- Start with $C_{diff} = 0$ case (for simplicity)

1. If we had one inverter stage to size, how should it be sized?

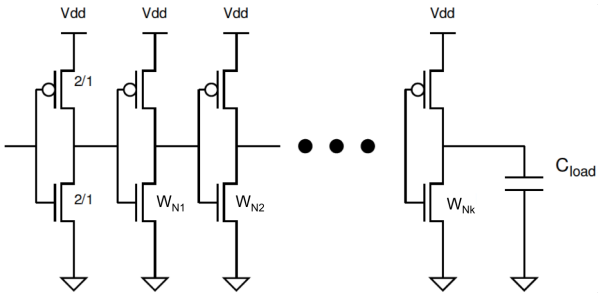


   (a) Write delay equation from $R_0/2$ drive through driving C_{load}.

   (b) Symbolic expression for delay-minimizing W_N.

   (c) Concrete size, W_N, for $C_{load} = 4 \times 10^4 C_0$.

2. If we had k inverter stages to size, how should the each be sized?

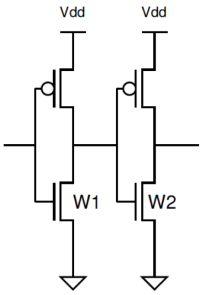


   (a) Write delay equation.

   (b) Symbolic expression for delay-minimizing W_{Ni}.

   (c) Symbolic expression for total delay using solution above.

3. If $C_{diff} = \gamma C_{gate}$, what is the stage delay for a $W1$ inverter driving a $W2$ inverter?



4. How does optimal stages and buffering change if we include $C_{diff} = \gamma C_{gate}$?

   (a) Write delay equation.

   (b) Symbolic expression for delay-minimizing W_{Ni}.

   (c) Compare with $C_{diff} = 0$ ($\gamma = 0$) case above.

   (d) Symbolic expression for total delay.

   (e) What is the optimal stage size relation when $\gamma \geq 0$?

   (f) For what γ are the following the optimal ρ?

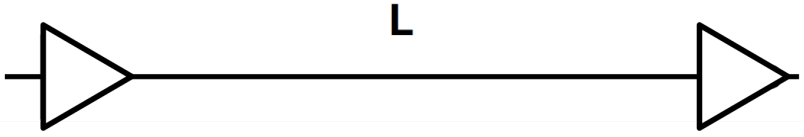
   (**Hint:** solve for γ in terms of ρ)

ρ	γ
3	
4	

Assume:

- R_u=60KΩ per 1mm length of wire; C_u=0.16pF per 1mm length of wire
- $R_{wire} = L \times R_u$; $C_{wire} = L \times C_u$;
- R_0=25KΩ; C_0=0.01fF
- velocity saturated; $\gamma = C_{diff}/C_{gate} = 1$
- initial, minimum size buffer has $W_p = W_n = 1$

5. What is the delay of an unbuffered wire of length L=1mm driven and loaded by a minimum size buffer ($W_p = 1$, $W_n = 1$)? Draw the equivalent RC network and write a symbolic equation.



- Symbolic Equation:

6. What is the delay of a length $L = 1mm$, when we add N evenly spaced buffers to the wire.

Wire of Length	**Delay (ns)**	**Number in 1mm**	**Total Delay for 1mm** (ns)
1mm		1	
0.5mm		2	
0.1mm		10	
0.01mm		100	
0.001mm		1000	

7. What is the delay of a length L, when we add N evenly spaced buffers to the wire.
   - Symbolic Equation:
8. How many buffers do we use to minimize delay?
   - Symbolic Equation:
   - Number of buffers to minimize delay on 1mm wire:
   - Delay at this buffer count:
   - Optimum segment length between buffers:
9. How should we size the buffers?
   - Symbolic Equation:
   - W to minimize delay:
   - Delay of 1mm wire at optimal buffer size: