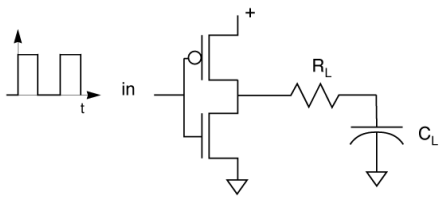
Power consumption analysis

- Almost all power consumption comes from switching behavior.
- Static power dissipation comes from leakage currents.
- Surprising result: power consumption is independent of the sizes of the pullups and pulldowns.

Power consumption circuit

- Input is square wave.



Power consumption

- A single cycle requires one charge and one discharge of capacitor: $E = C_L(V_{DD} - V_{SS})^2$.
- Clock frequency $f = 1/t$.
- Energy $E = C_L(V_{DD} - V_{SS})^2$.
- Power = E x f = $f\ C_L(V_{DD} - V_{SS})^2$.

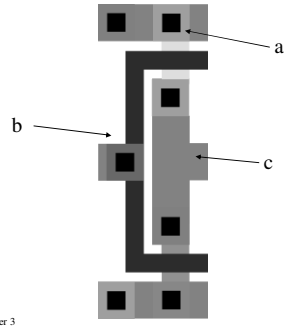
Observations on power consumption

- Resistance of pullup/pulldown drops out of energy calculation.
- Power consumption depends on operating frequency.
  - Slower-running circuits use less power (but not less energy to perform the same computation).

Speed-power product

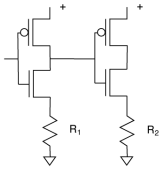
- Also known as power-delay product.
- Helps measure quality of a logic family.
- For static CMOS:
  - $SP = P/f = CV^2$.
- Static CMOS speed-power product is independent of operating frequency.
  - Voltage scaling depends on this fact.

Parasitics and performance



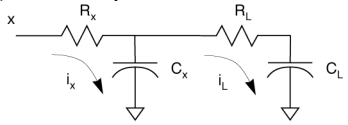
Effect of parasitics

- a: Capacitance on power supply is not bad, can be good in absence of inductance. Resistance slows down static gates, may cause pseudo-nMOS circuits to fail.



Effects of parasitics, cont'd

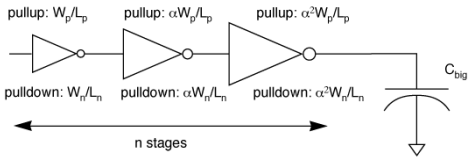
- b: Increasing capacitance/resistance reduces input slope.
- c: Similar to parasitics at b, but resistance near source is more damaging, since it must charge more capacitance.



Driving large loads

- Sometimes, large loads must be driven:
  - off-chip;
  - long wires on-chip.
- Sizing up the driver transistors only pushes back the problem—driver now presents larger capacitance to earlier stage.

Cascaded driver circuit



Optimal sizing

- Use a chain of inverters, each stage has transistors a larger than previous stage.
- Minimize total delay through driver chain:
  - $t_{tot} = n(C_{big}/C_g)^{1/n} t_{min}$.
- Optimal number of stages:
  - $n_{opt} = \ln(C_{big}/C_g)$.
- Driver sizes are exponentially tapered with size ratio α.