Topics

- Combinational logic functions.
- Static complementary logic gate structures.

Combinational Logic Expressions

- Combinational logic: function value is a combination of function arguments.
- A logic gate implements a particular logic function.
- Both specification (logic equations) and implementation (logic gate networks) are written in Boolean logic.

Gate Design

Why designing gates for logic functions is non-trivial:

- May not have logic gates in the library for all logic expressions;
- A logic expression may map into gates that consume a lot of area, delay, or power.

Boolean Algebra Terminology

- Function:
  f = a'b + ab'
- a is a variable; a and a' are literals.
- ab' is a term.
- A function is irredundant if no literal can be removed without changing its truth value.

Completeness

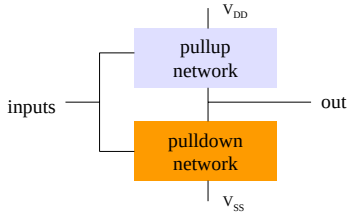
- A set of functions f1, f2, ... is complete iff every Boolean function can be generated by a combination of the functions.
- NAND is a complete set; NOR is a complete set; {AND, OR} is not complete.
- Transmission gates are not complete.
- If your set of logic gates is not complete, you can't design arbitrary logic.

Static Complementary Gates

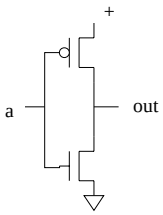
- Complementary: have complementary pullup (p-type) and pulldown (n-type) networks.
- Static: do not rely on stored charge.
- Simple, effective, reliable; hence ubiquitous.

Static Complementary Gate structure

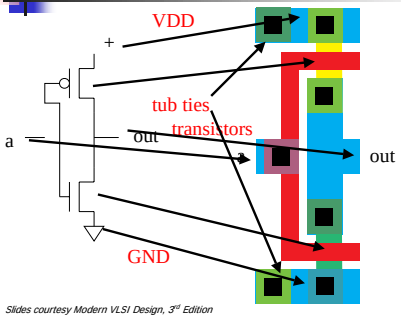
Pullup and pulldown networks:



Inverter

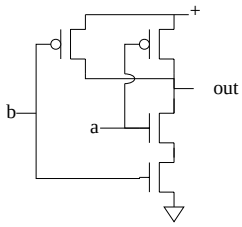


Inverter Layout

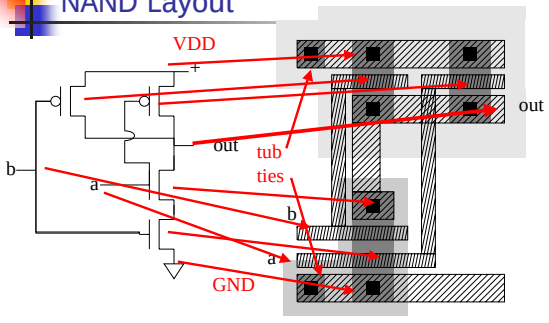


(tubs not shown)

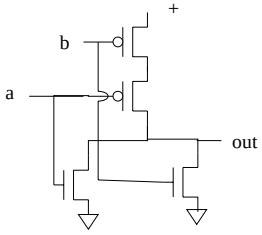
NAND Gate



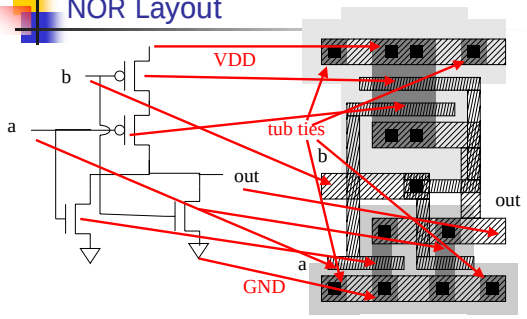
NAND Layout



NOR Gate



NOR Layout

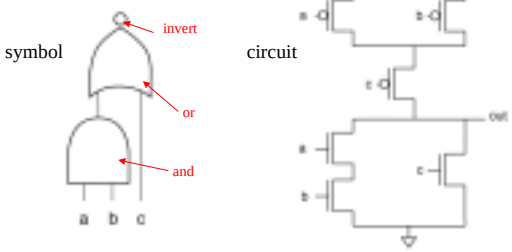


AOI/OAI Gates

- AOI = and/or/invert; OAI = or/and/invert.
- Implement larger functions.
- Pullup and pulldown networks are compact: smaller area, higher speed than NAND/NOR network equivalents.
- AOI312: and 3 inputs, and 1 input (dummy), and 2 inputs; or together these terms; then invert.

AOI Example

out = [ab+c]':



Pullup/Pulldown Network Design

- Pullup and pulldown networks are duals.
- To design one gate, first design one network, then compute dual to get other network.
- Example: design network which pulls down when output should be 0, then find dual to get pullup network.

Dual Network Construction