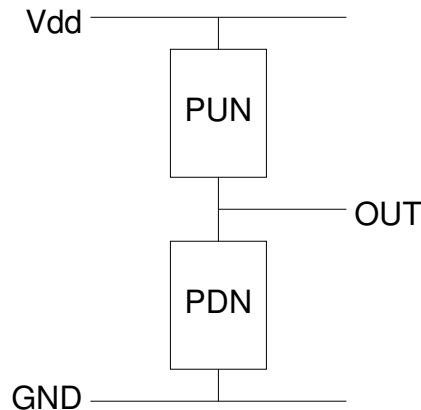


Static CMOS Complementary Gates



- **Static**

After the appropriate propagation delay the output becomes valid and remains valid.¹

- **Complementary**

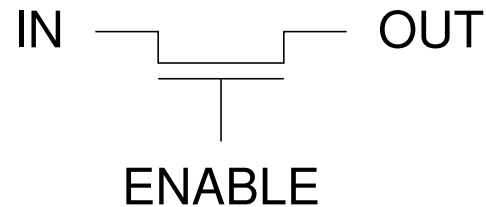
For any set of inputs there will exist either a path to Vdd or a path to GND.

Where this condition is not met we have either a high impedance output or a conflict in which the strongest path succeeds. Static CMOS **Non-complementary** gates make use of these possibilities.

¹c.f. Dynamic logic which uses circuit capacitance to store state for a short time.

Pass Transistor Circuits

- Pass Transistor



- Provides very compact circuits.
- Good transmission of logic '0'.
- Poor transmission of logic '1'.
 - - slow rise time
 - - degradation of logic value

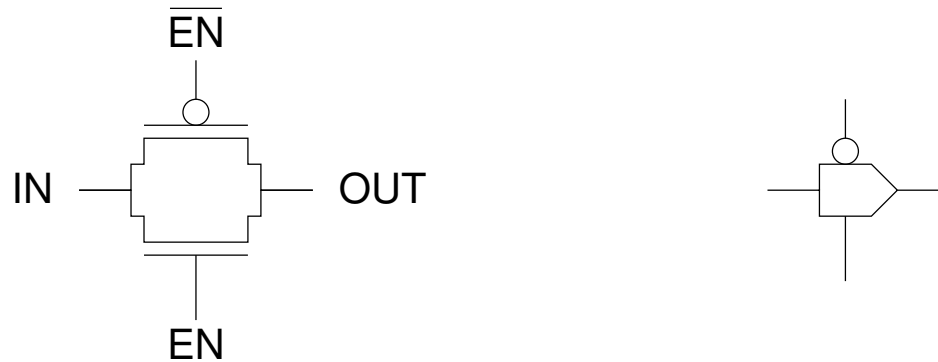
The pass transistor is used in many dynamic CMOS circuits².

²where pull-up is performed by an alternative method

Pass Transistor Circuits

- Transmission Gate

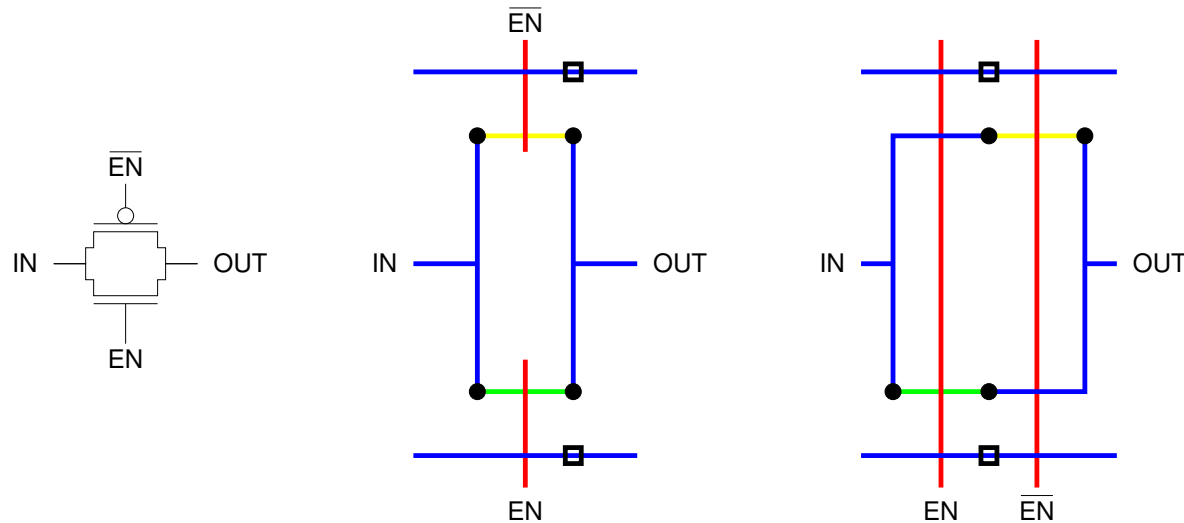
- For static circuits we would normally use a CMOS transmission gates:



- - balanced n and p pass transistors
 - - faster pull-up
 - - slower pull-down

Pass Transistor Circuits

- Transmission Gate Layout

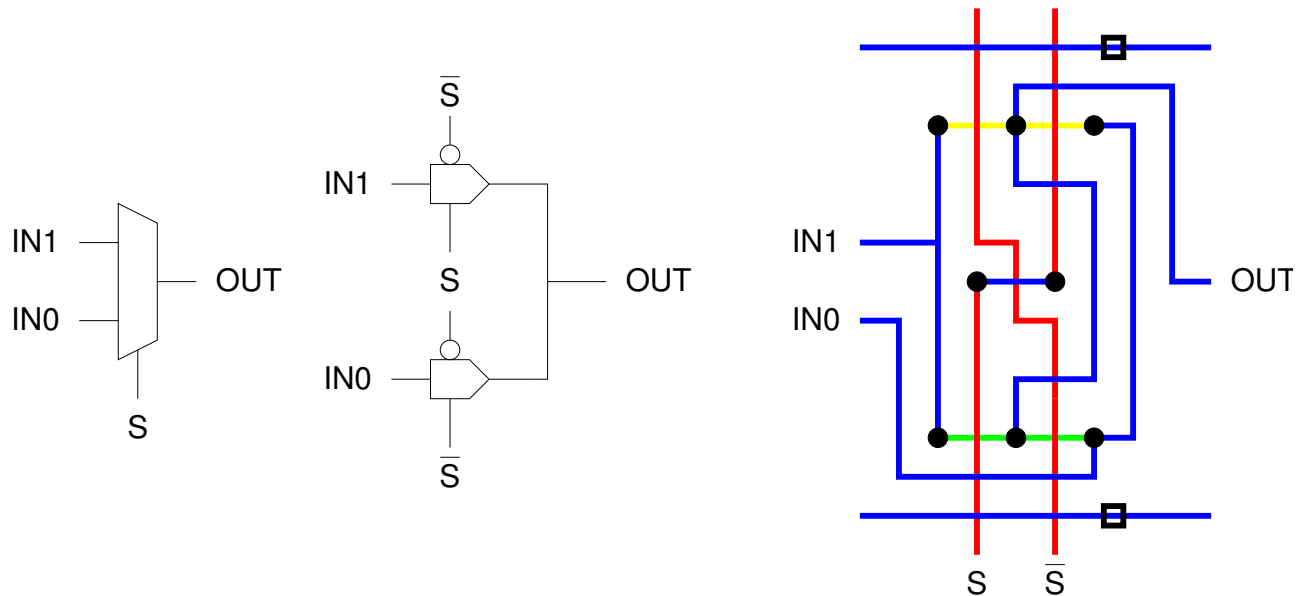


- note that these circuits are not fully complementary³ hence they do not immediately lend themselves to a *line of diffusion* implementation.

³since there are sets of inputs for which the output is neither pulled low nor high

Pass Transistor Circuits

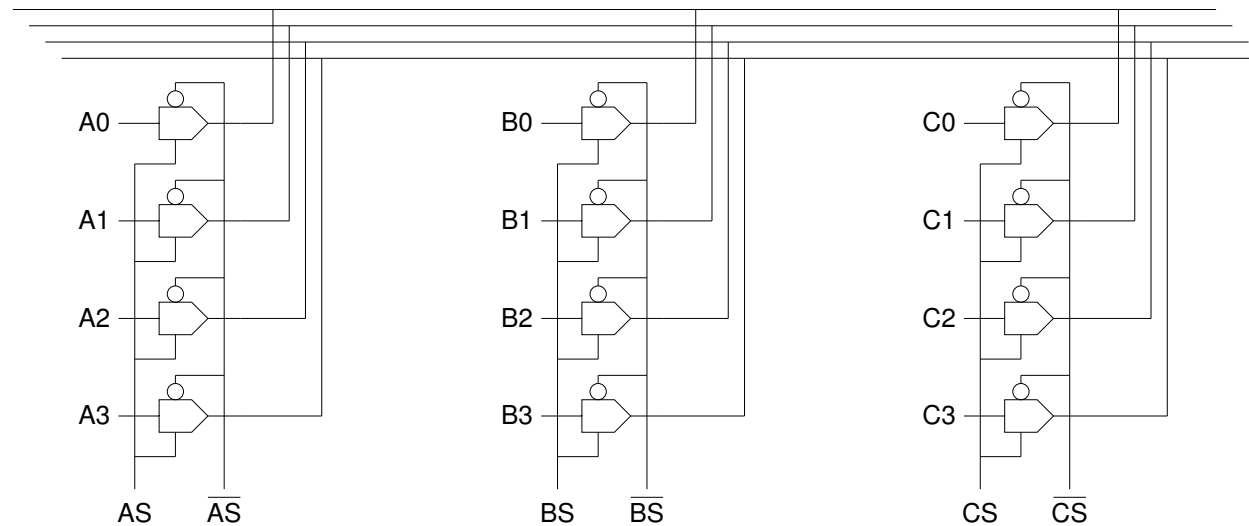
- Transmission Gate Multiplexor



- very few transistors 4 (+2 for inverter)
- difficult layout may offset this advantage
 - - prime candidate for 2 level metal

Pass Transistor Circuits

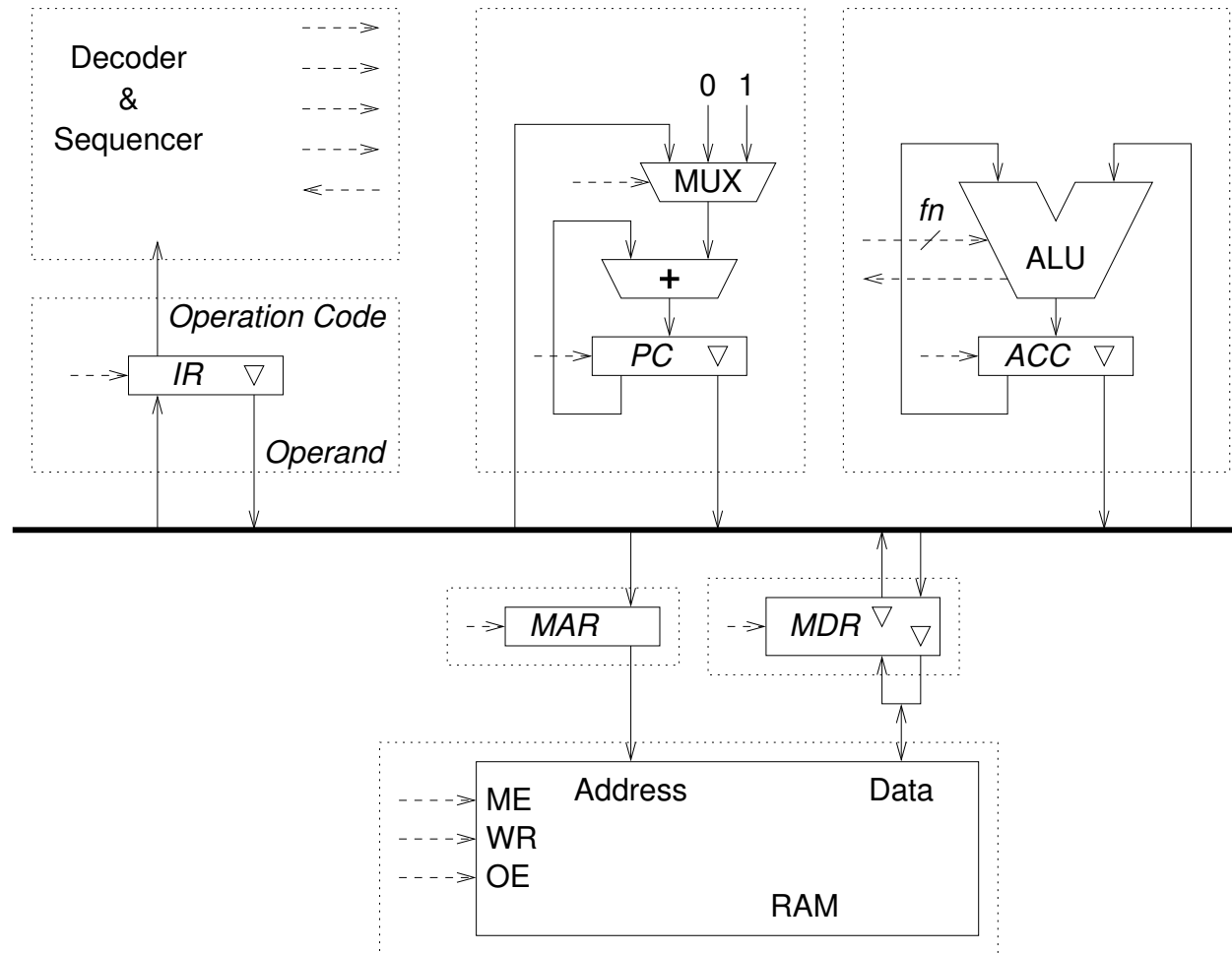
- Bus Wiring



- distributed multiplexing⁴
- only one inverter required per bank of transmission gates
- greatly simplifies global wiring

⁴internal chip bus should never be allowed to float high impedance

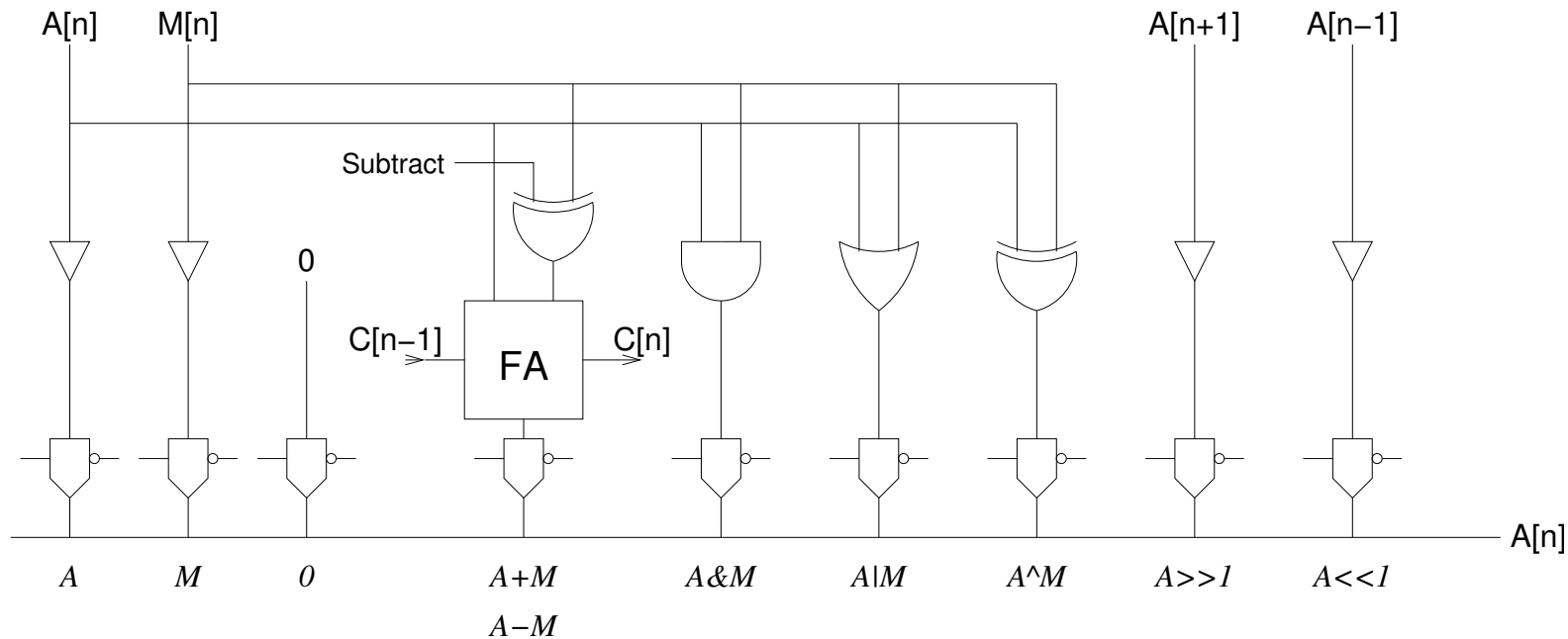
Bus Distributed Multiplexing



Ideal for signals with many drivers from different modules.

Bus Distributed Multiplexing

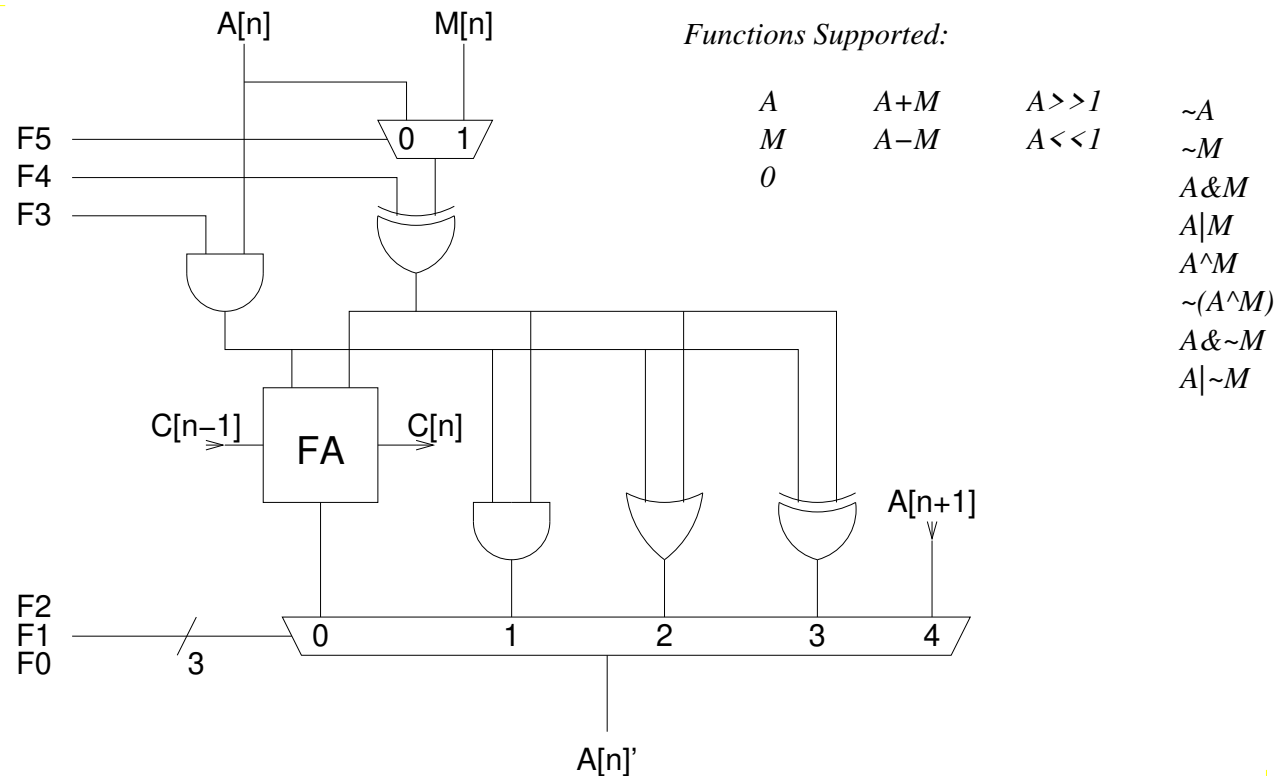
Implementation of bitslice ALU:⁵



- Separate circuit for each function
- Connected via distributed multiplexor

⁵Note that transmission gates have no drive capability in themselves. Here a good drive is ensured by providing buffers.

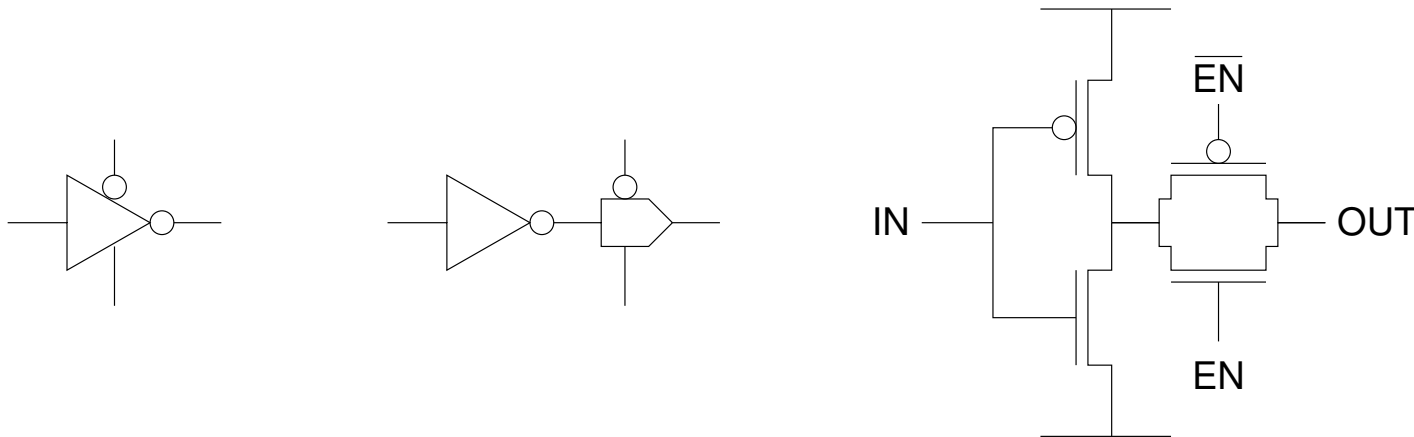
Bus Distributed Multiplexing



- Single optimized ALU module
- Multiplexing is not distributed
- Multiplexor implementation may use transmission gates

Pass Transistor Circuits

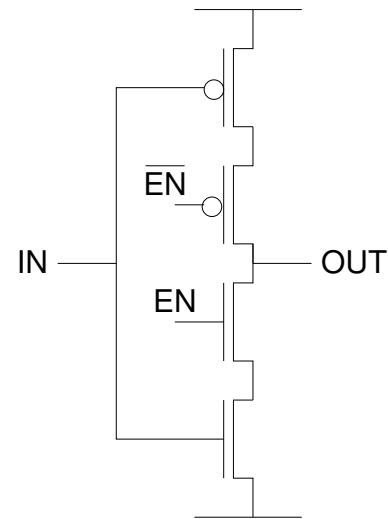
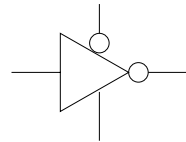
- Tristate Inverter



- Any gate may have a tri-state output by combining it with a transmission gate.

Pass Transistor Circuits

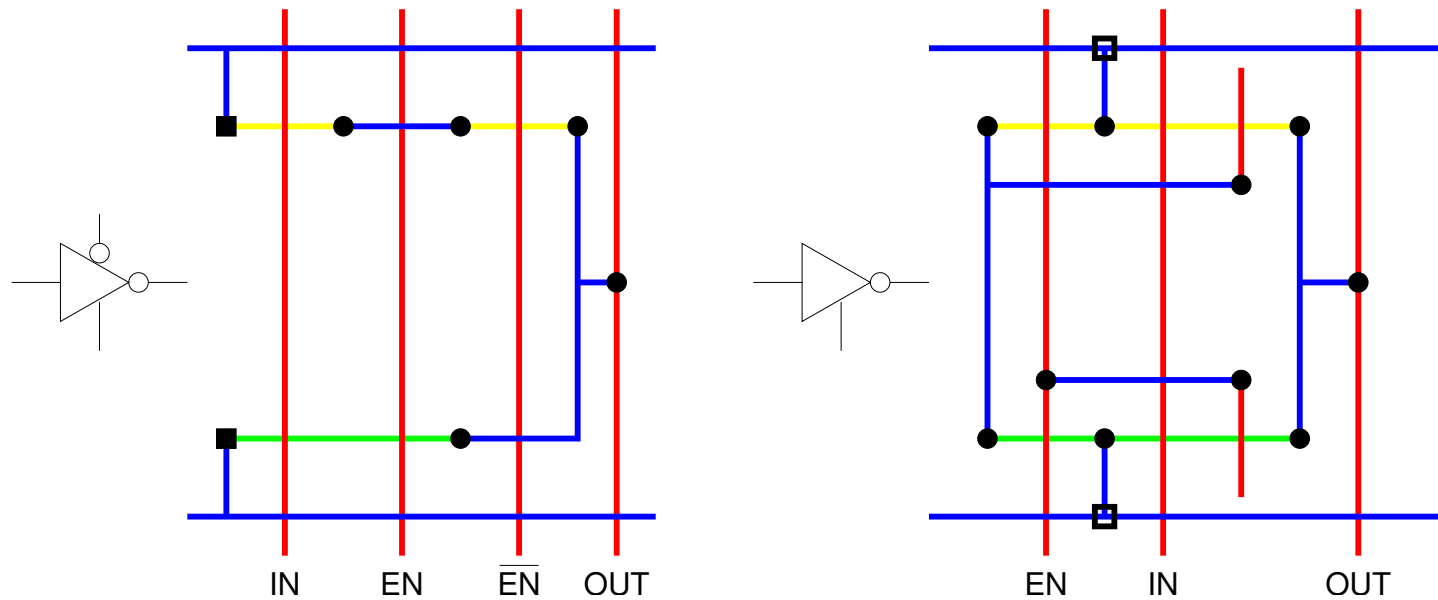
- Tristate Inverter



- Alternatively the transmission gate may be incorporated into the gate.
 - - one connection is removed - easier to layout
 - - also easier to simulate!

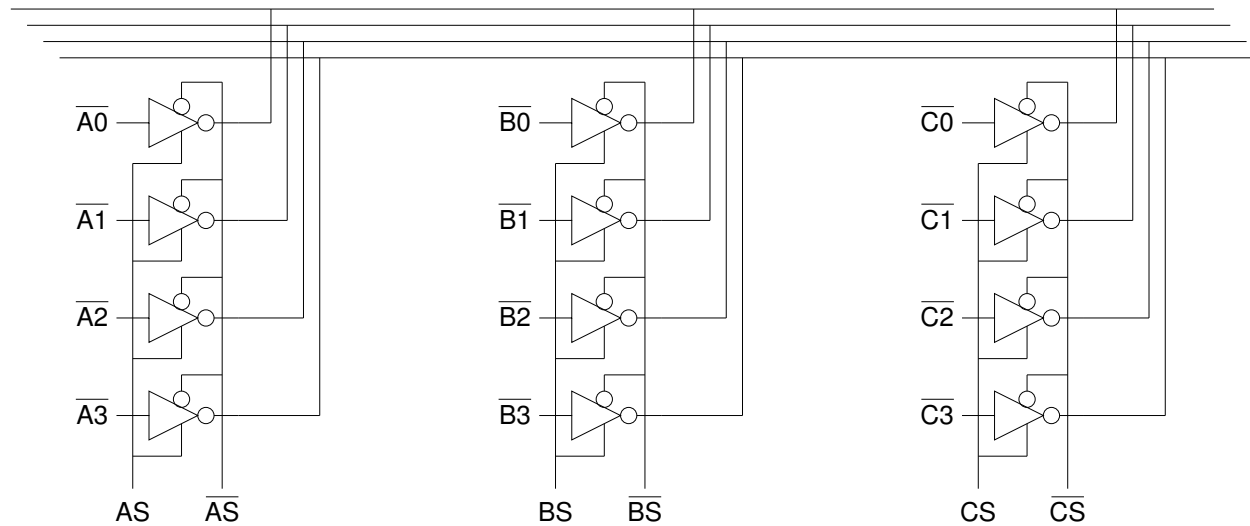
Pass Transistor Circuits

- Tristate Inverter Layout



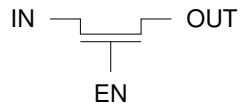
Pass Transistor Circuits

- Tristate Inverter Bus Driver

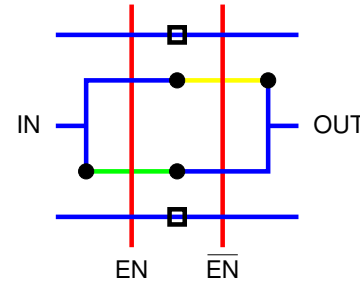
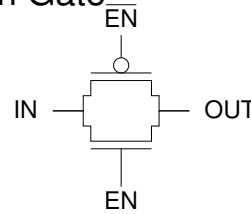
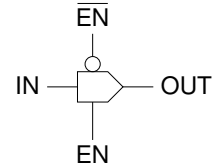


- a tristate inverting buffer is often used to drive high capacitance bus signals
- transistors may be sized as required

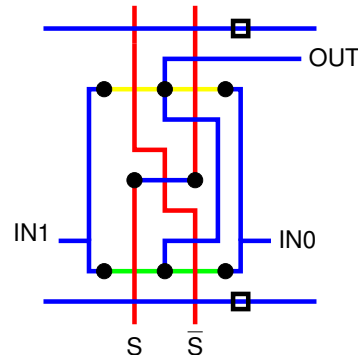
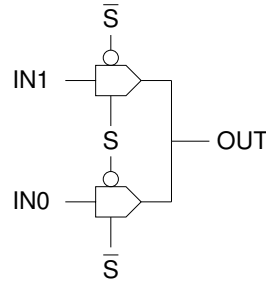
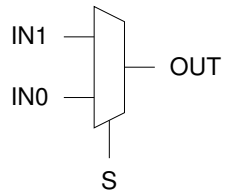
Pass Transistor



CMOS Transmission Gate



Transmission Gate Multiplexor

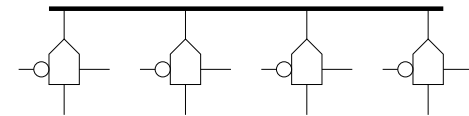


*note distinctive polysilicon crossover

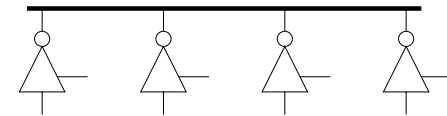
Tri-state gates are used for Multiplexing

Distributed Multiplexing

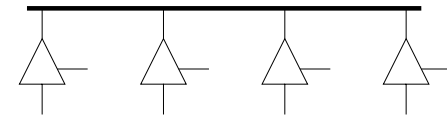
using transmission gates



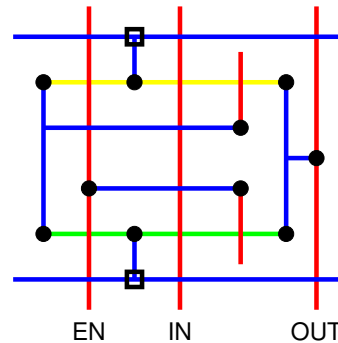
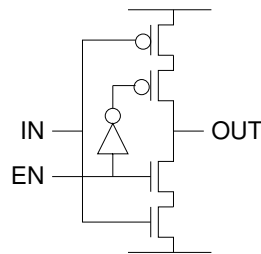
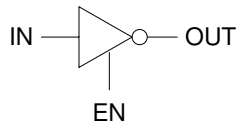
using tri-state inverters



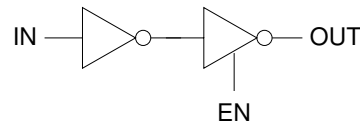
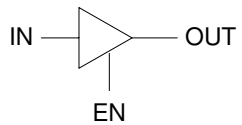
using tri-state buffers



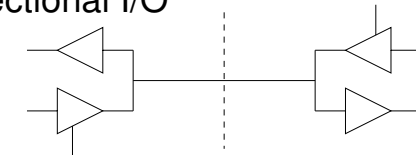
Tri-state Inverter



Tri-state Buffer



Bi-directional I/O



*this is another form of multiplexing