IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

MICROELECTRONICS: DEVICES TO CIRCUITS

Combinational Logic Design-III

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

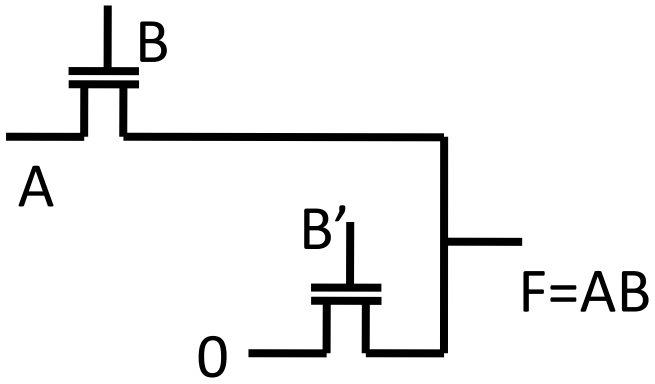


Outline

- Pass-Transistor Logic
- Voltage Swing of Pass-Transistor
- VTC of Pass-Transistor
- Differential Pass-Transistor Logic
- Properties of Differential Pass-Transistor Logic
- Robust and Efficient Pass-Transistor Design
  - Level Restoration
  - Multiple-Threshold Transistor
  - Transmission gate logic
- Performance of Pass-Transistor and Transmission-Gate
- Recapitulation

Pass-Transistor Logic

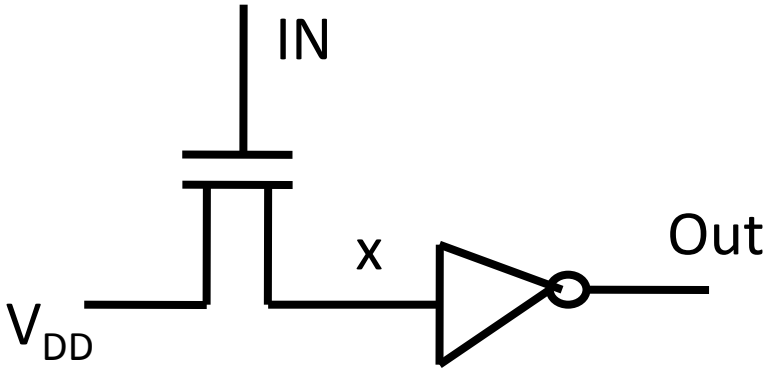
- A widely used alternative to complementary CMOS logic is pass transistor in which logic inputs are applied in gate as well as source and drain.

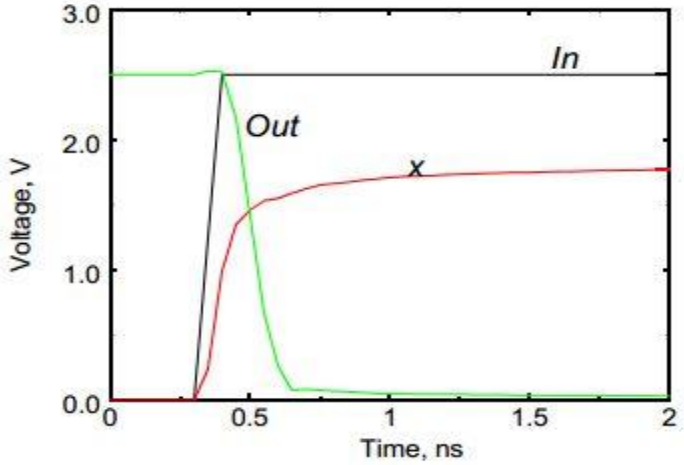


- As we know that NMOS is effective in passing 0 but poor in pulling a node to V_{DD}. Hence, in a NMOS based pass transistor the high output is V_{DD}-V_T instead of V_{DD}.

Voltage Swing for Pass-Transistor Logic

- The transient response of an NMOS charging up a capacitor.



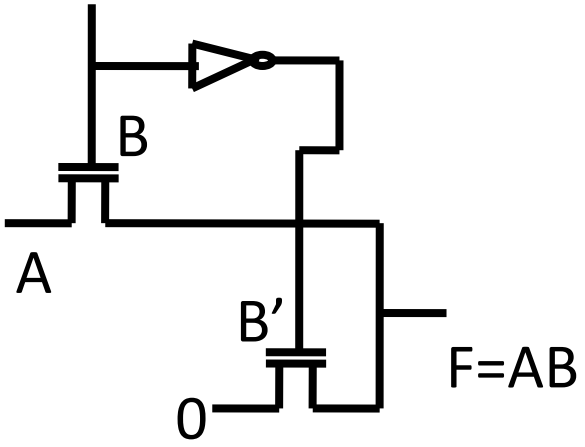


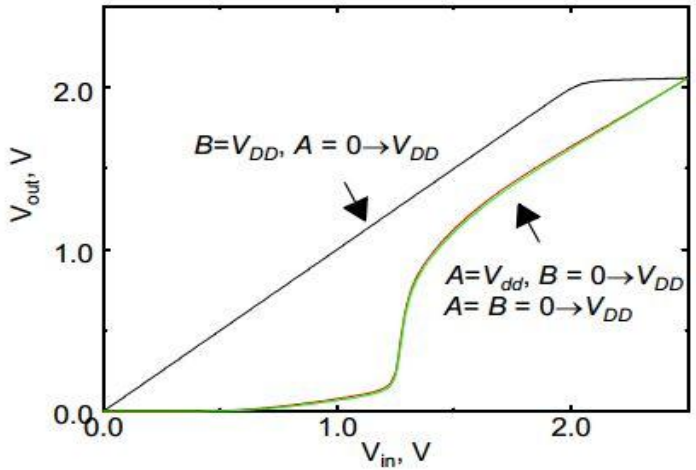
- It shows that the pass-transistor gate cannot be cascaded by connecting the output of a pass gate to gate input of a pass-transistor

Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

VTC of the Pass-Transistor AND Gate

- VTC of the pass-transistor logic depends on the data.

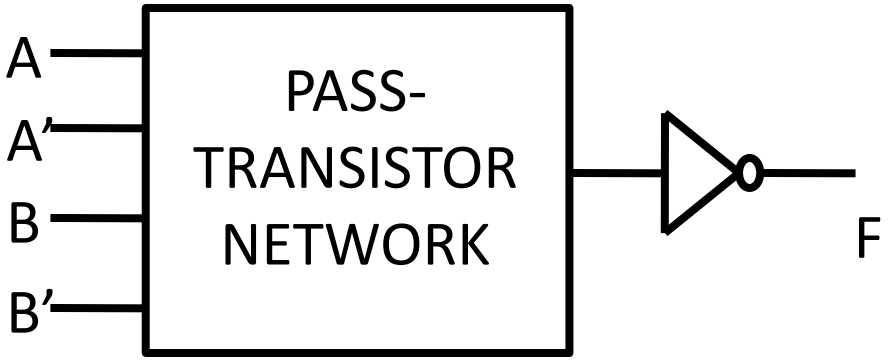


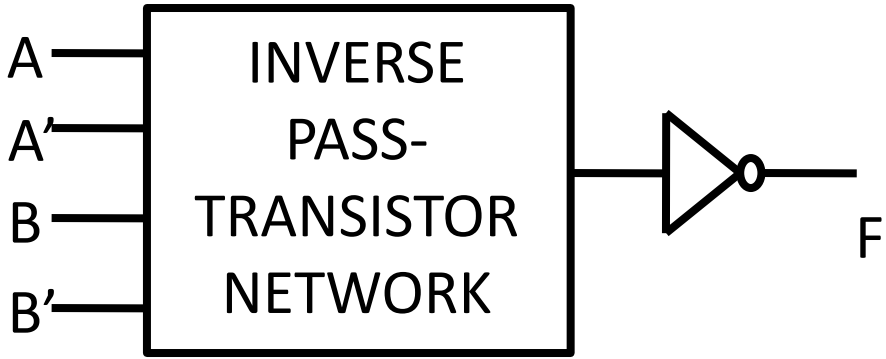


- The pure pass-transistor is not regenerative. A gradual signal degradation is observed which can be remedied by occasional insertion of a CMOS inverter.

Differential Pass-Transistor Logic

- For high performance design, a differential pass-transistor logic family called CPL or DPL, is commonly used.

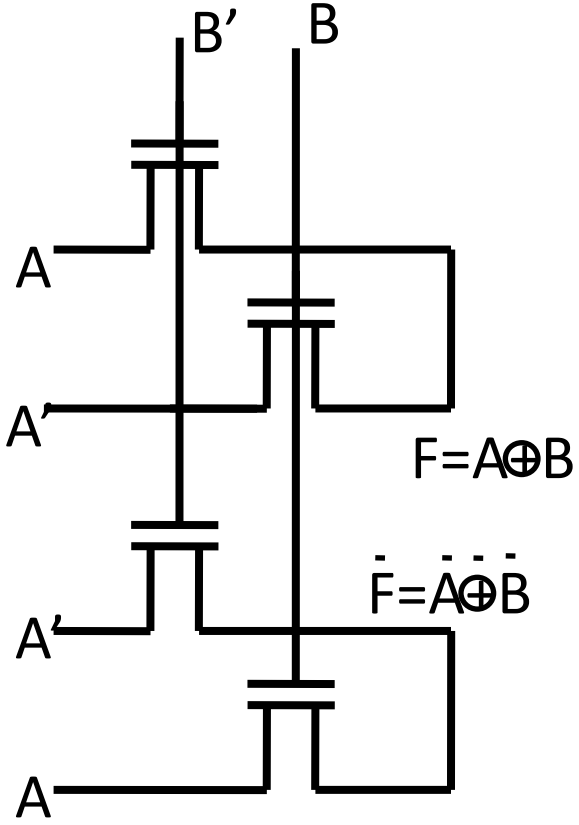




- The basic idea is to accept input in both true and complementary forms and produce true and complementary outputs.

Properties of Differential Pass-Transistor Logic

- Since both true and complementary inputs are required, so an extra circuit is needed.
- XORs and Adders can be realized with a small number of transistors.
- CPL belongs to the class of a static gates, because output nodes are always connected to either V_{DD} or ground.
- This design is very modular. In effect, all gates use exactly the same topology. Only the inputs are permutated.

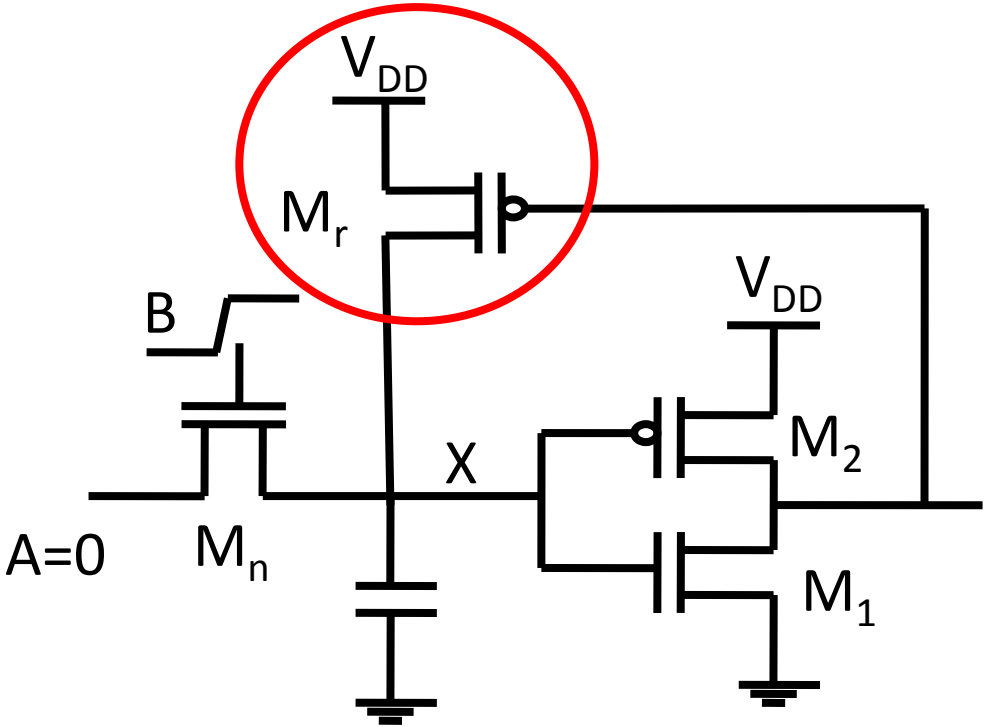


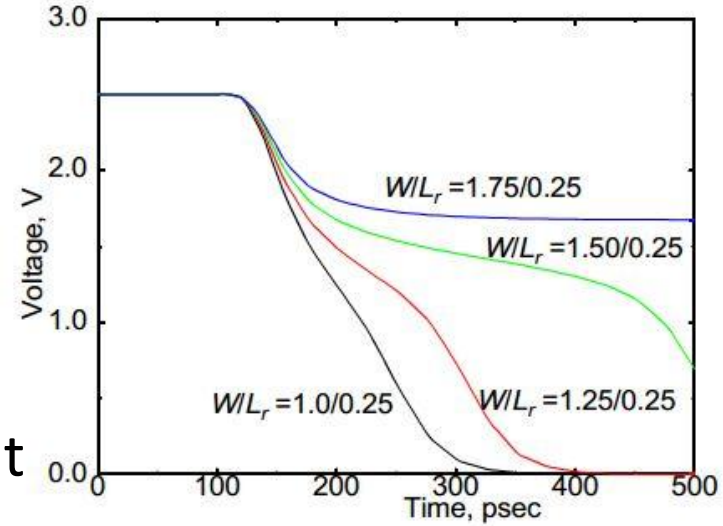
Robust and Efficient Pass-Transistor Design

- As differential pass-transistor logic suffers from the problem of static power dissipation and reduced noise margin.
- There are several solutions are proposed to deal with such problems-

1. **Level Restoration**
2. **Multiple-Threshold Transistor**
3. **Transmission gate logic**

Level Restoration

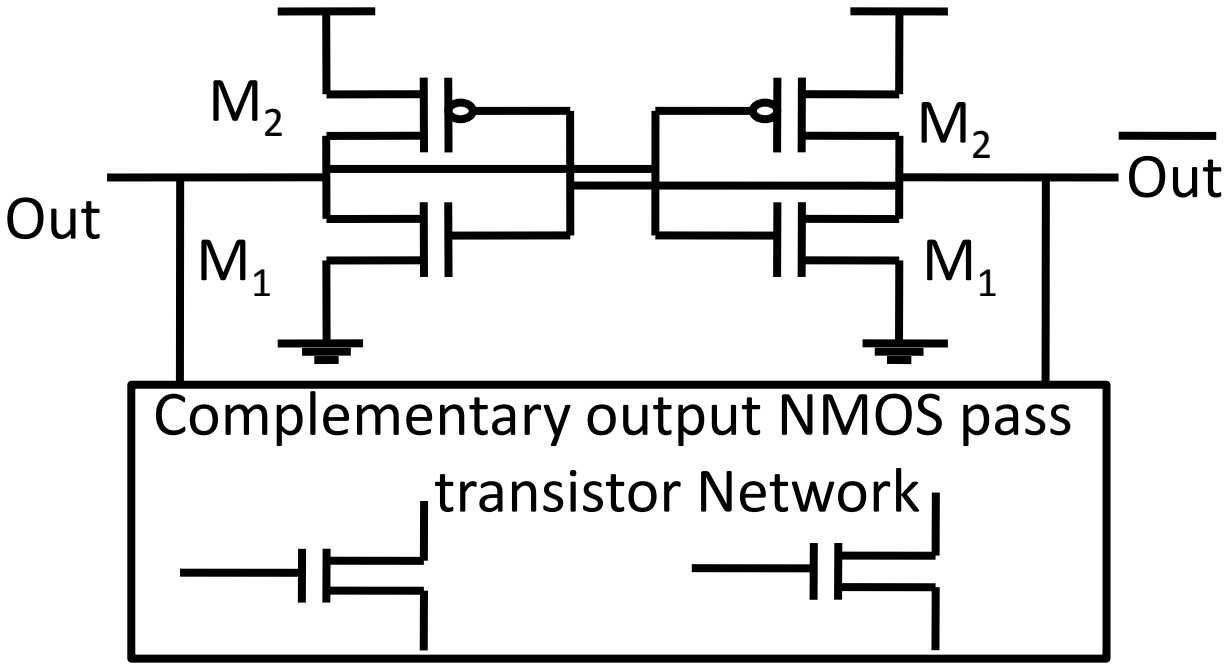




Transient Response of the circuit

Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

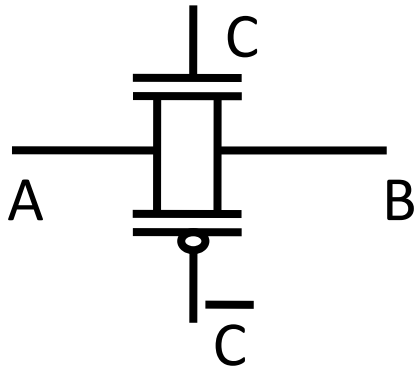
Multiple-Threshold Transistors

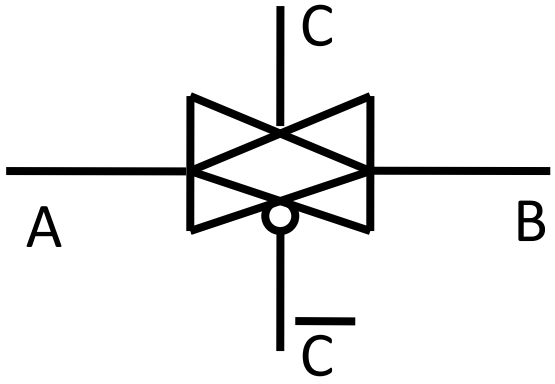


Complementary inputs to gate and source-drain terminals

Transmission Gate Logic

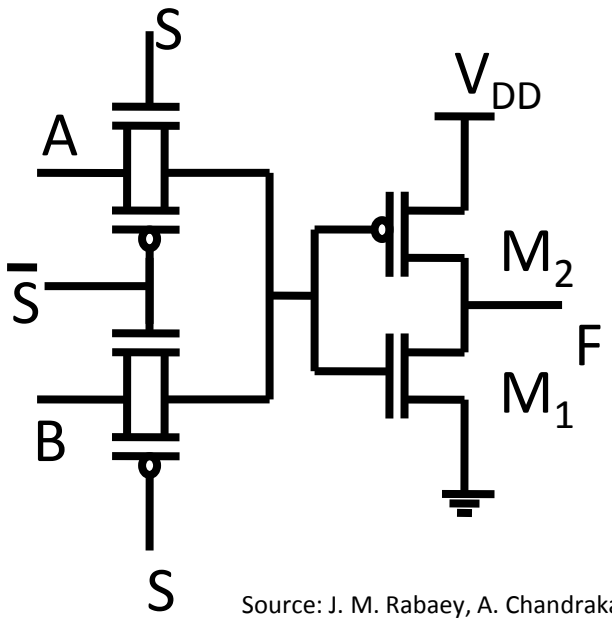
- To use the properties of both NMOS and PMOS of passing strong 0 and 1 respectively are merged in a single device.
- NMOS and PMOS are connected in parallel.

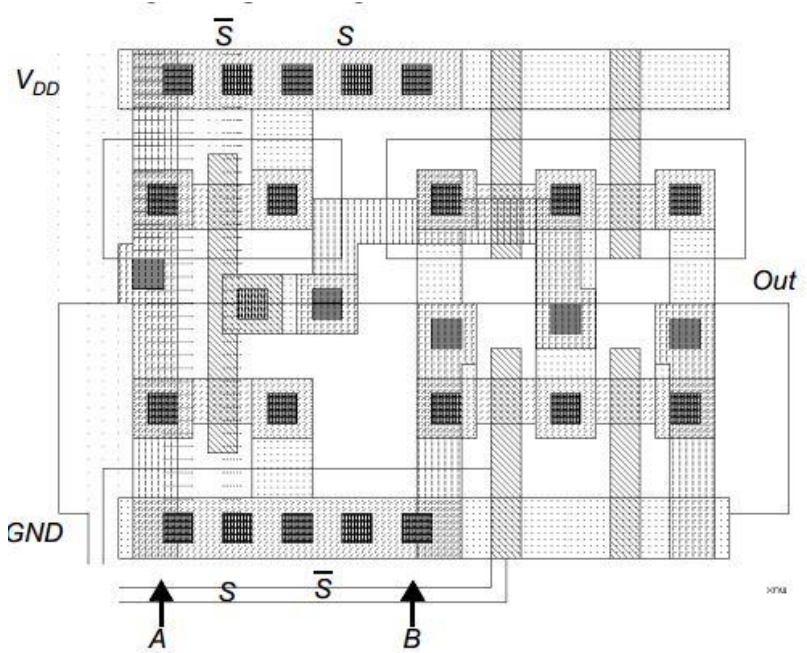




Transmission Gate Multiplexer and its layout

- Transmission gate can be used to implement some complex gates very efficiently.





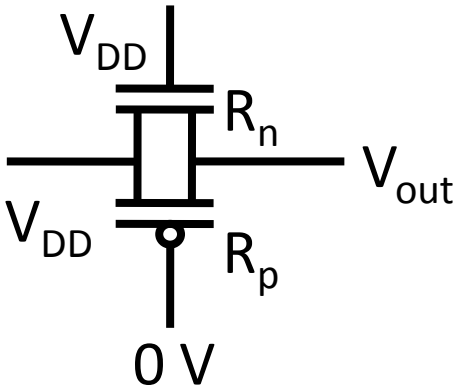
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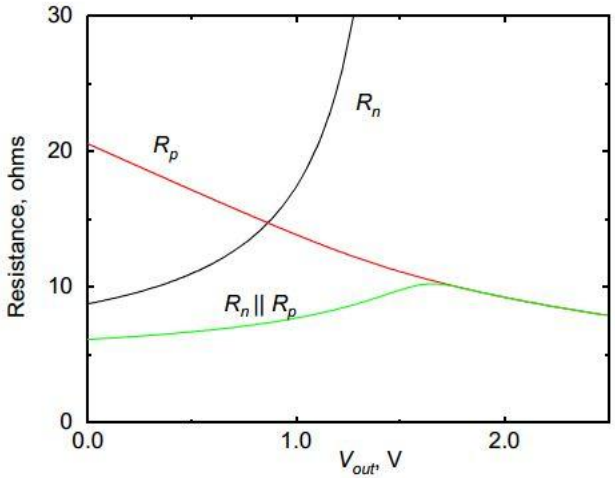
Performance of Pass-Transistor and Transmission-Gate

- Transmission gate and Pass-Transistors are non-ideal switches, so they have a series resistance associated with them.
- The effective resistance is modeled as a parallel connection of R_n and R_p

$$R_p = \frac{V_{DD} - V_{out}}{I_{Dp}} \approx \frac{1}{k_p\left(V_{DD} - |V_{Tp}|\right)}$$

$$R_n \approx \frac{V_{DD} - V_{out}}{k_n\left(V_{DD} - V_{out} - V_{Tn}\right)V_{DSAT}}$$





Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

Recapitulation

- To reduce the transistor count, we prefer pass-transistors but they are not capable to drive next state properly, if connected in cascaded.
- In differential pass-transistor logic both true and complementary inputs are accepted and both type of outputs are produced.
- A common voltage drop problem of pass transistor logic can be solved by using Level Restoration, Multiple-Threshold Transistors or Transmission Gates.
- Although these designs are beneficial over CMOS design but these techniques are not robust, so always complementary CMOS design techniques are preferable.

Thank You