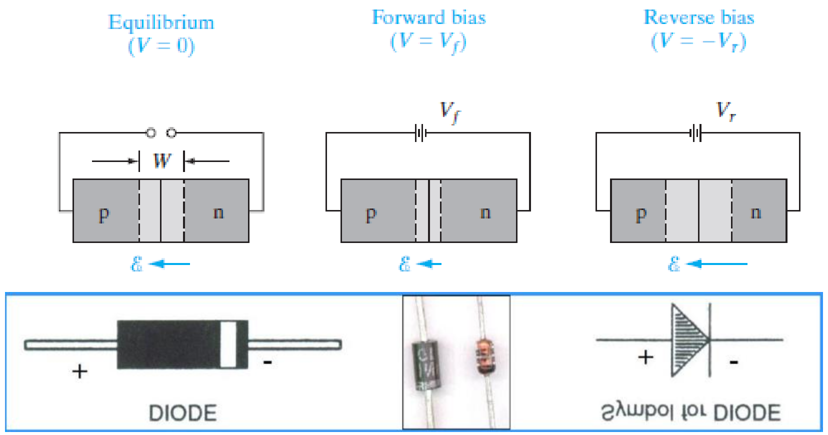
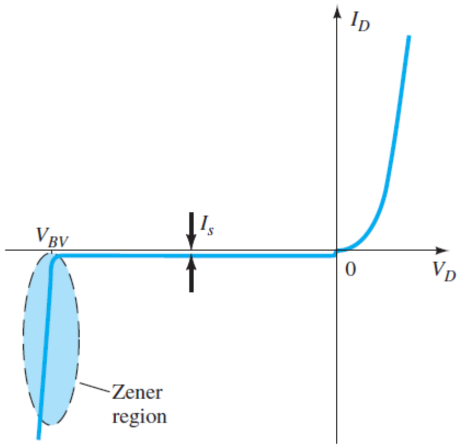
Fundamentals of Electronics

ECE 101

Summary of electronic devices

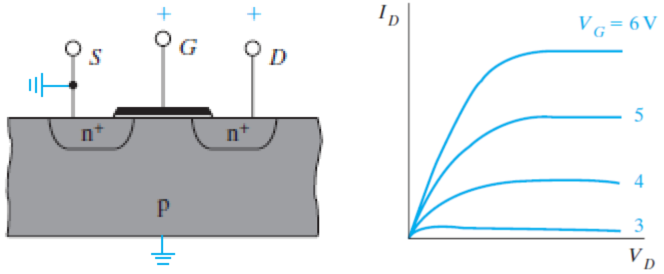
Diodes

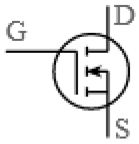


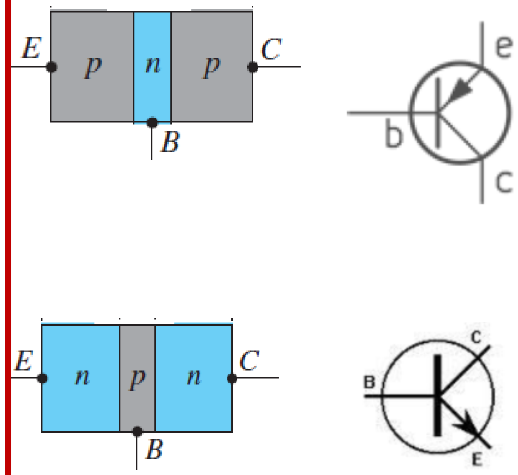


$$I_D = I_s(e^{V_D/nV_T} - 1)$$

MOSFETs







BJT Configurations

- CB
- CC
- CE

BJTs

Integration

- Integration is the process of creating an integrated circuit (IC) by combining thousands of transistors into a single chip.

SSI - Small Scale integration
less than 100 components (about 10 gates)

MSI - Medium Scale integration
less than 500 components (more than 10 but less than 100 gates)

LSI - Large Scale integration
components b/w 500 and 300000 (more than 100 gates)

VLSI - Very Large Scale integration
it contains more than 300000 components per chip

Nowadays, more than a billion transistor on a chip.

Very large-scale integration (VLSI) is the process of integrating or embedding hundreds of thousands of transistors on a single silicon semiconductor microchip.

A microprocessor is an example of VLSI circuit.

Why VLSI?

- Physically smaller size
- Integration improves the design
- Lower parasitic = higher speed
- Lower power consumption
- Integration reduces manufacturing cost - (almost) no manual assembly

A Few VLSI companies in India

1 | Texas Instruments
Corporate office – Dallas, United State | **Establishment** –1951 |

2 | Analog Device Inc.
Corporate office – Norwood, USA | **Establishment** – 1965 |

3 | Cypress Semiconductor Corporation
Corporate office – San Jose, USA | **Establishment** – 1982 |

4 | Broadcom Corporation
Corporate office – Irvine, USA | **Establishment** – 1991 |

5 | Cisco Systems
Corporate office – San Jose, USA | **Establishment** – 1984 |

6 | Bit Mapper Integration Technologies Private Limited
Corporate office – Pune, Maharashtra | **Establishment** – 1985 |

7 | Horizon Semiconductors
Corporate office – Bangalore, Karnataka | **Establishment** – 1815|

8 | Einfochips limited
Corporate office – Ahmadabad, Gujarat | **Establishment** – 1994 |

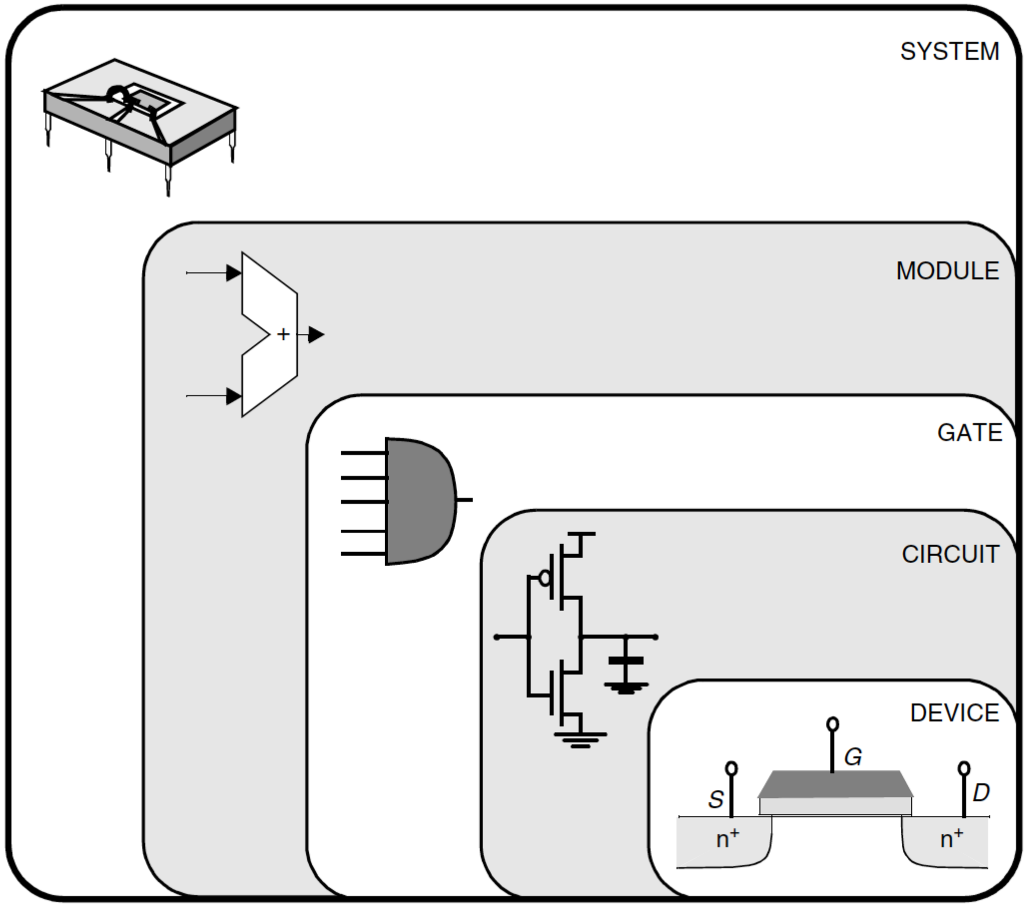
9 | Trident Tech Labs
Corporate office – New Delhi, India | **Establishment** – 2000 |

10 | HCL technologies
Corporate office – Noida, Uttar Pradesh | **Establishment** – 1991 |

System Level Electronics

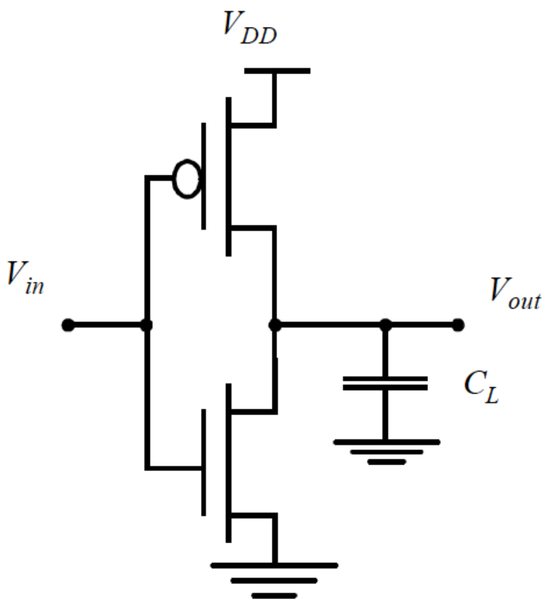
Abstraction

Design abstraction in digital electronics

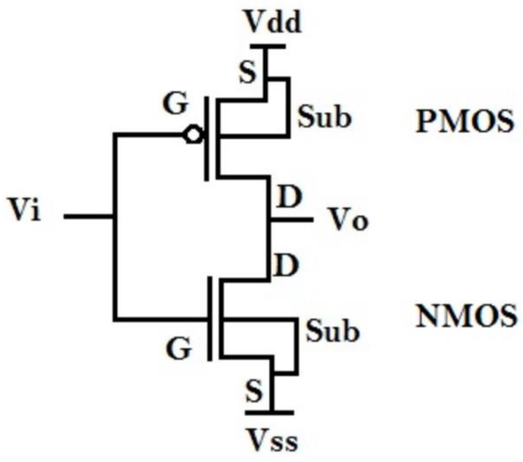


Digital Integrated Circuits by Rabaey et al

Logic gate implementation – CMOS Inverter

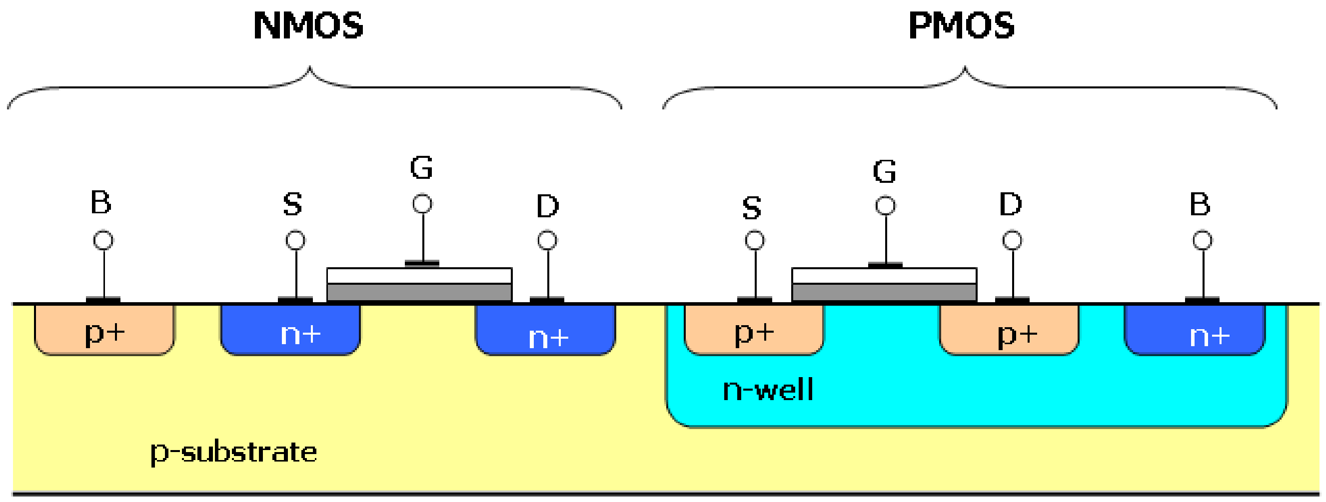


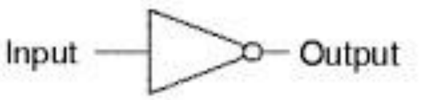
CMOS Inverter



- G = Gate Terminal
- S = Source Terminal
- D = Drain Terminal
- Sub = Substrate Terminal

CMOS Technology



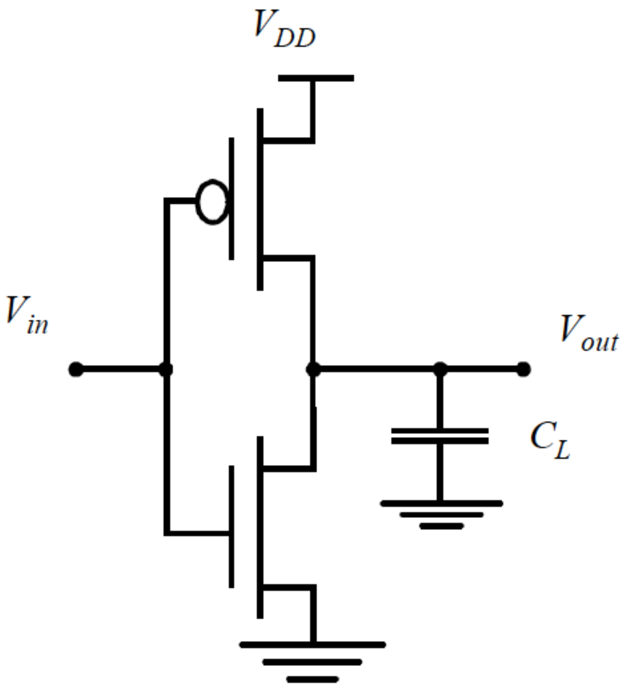


Input	Output
1	0
0	1

CMOS Inverter

Pull Up

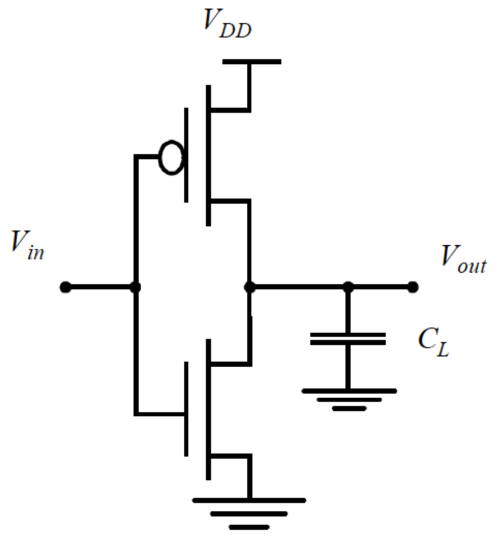
Pull Down

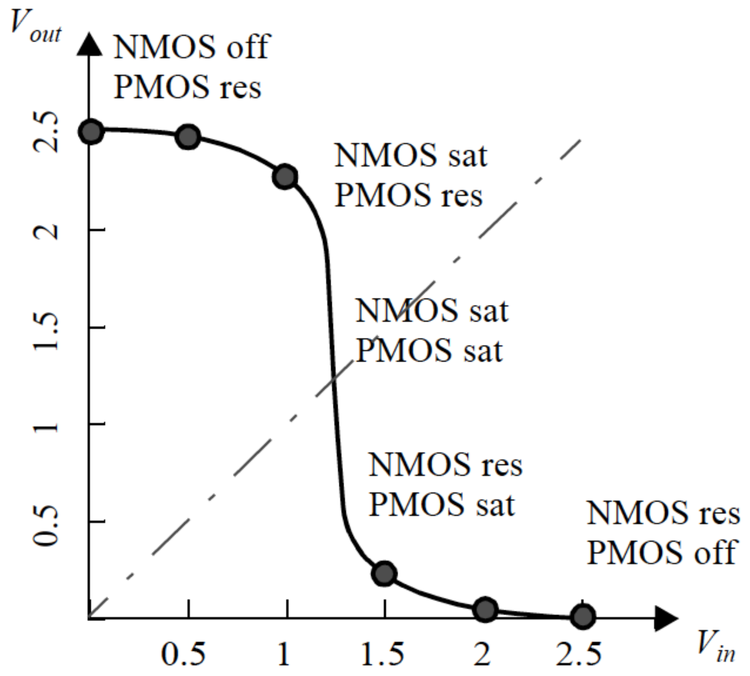


CMOS Inverter

- Cost
- Static behavior
- Dynamic behavior/performance
- Energy efficiency

CMOS Inverter – Static behavior

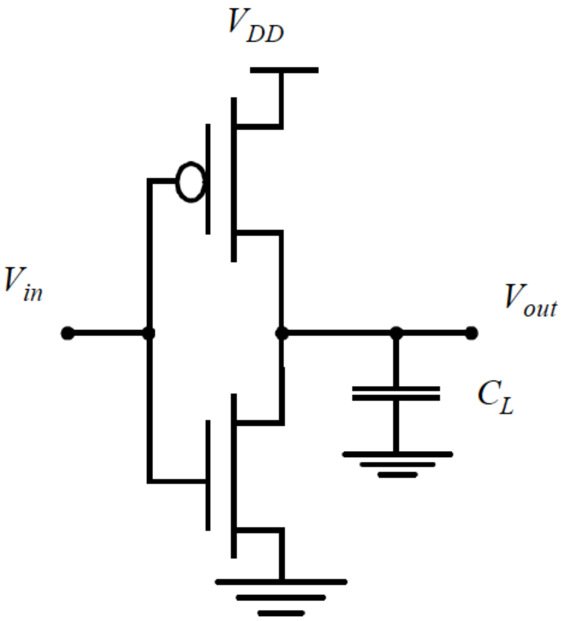


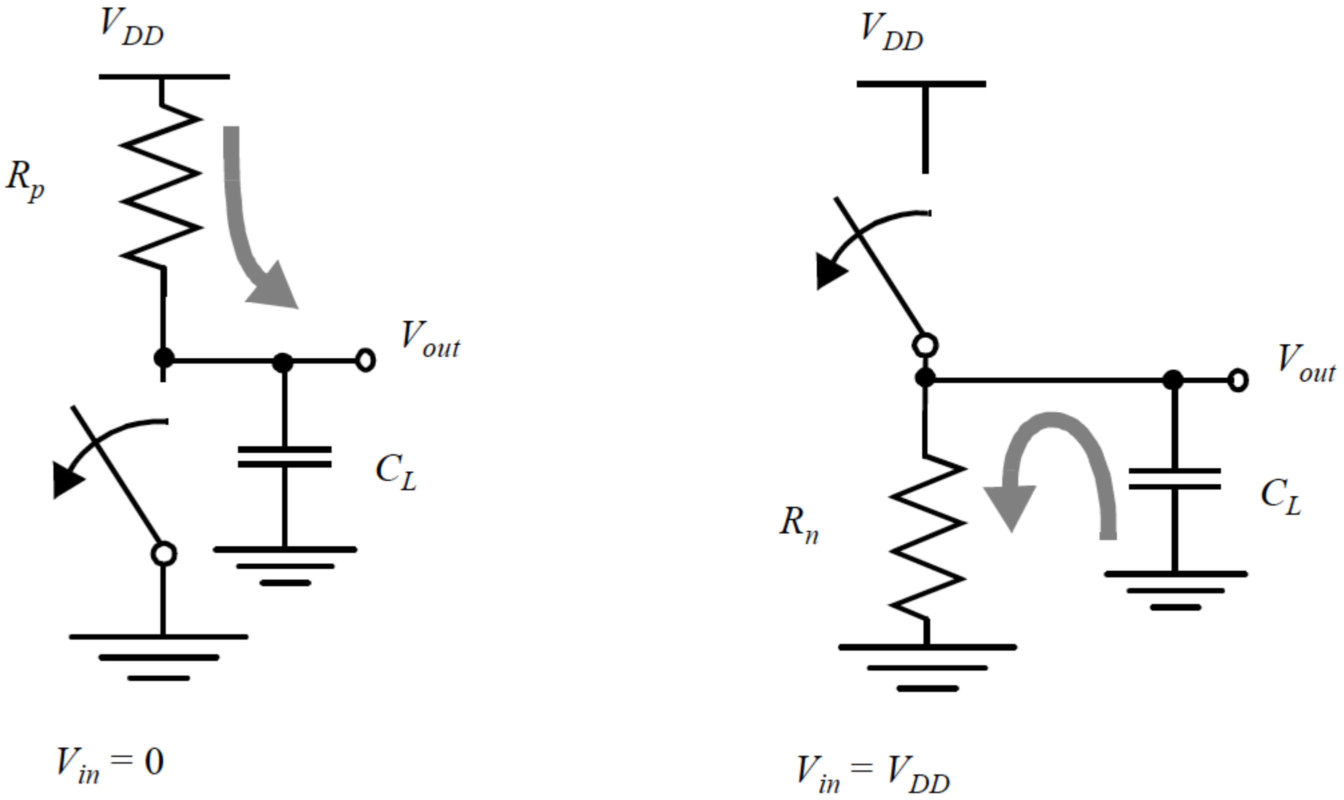


CMOS Inverter

- The high and low output levels equal VDD and GND, respectively; in other words, the voltage swing is equal to the supply voltage. This results in high noise margins.
- In steady state, there always exists a path with finite resistance between the output and either VDD or GND.
- A well-designed CMOS inverter, therefore, has a low output impedance, which makes it less sensitive to noise and disturbances. Typical values of the output resistance are in k-ohm range.
- The input resistance of the CMOS inverter is extremely high, as the gate of an MOS transistor is a virtually perfect insulator and draws no dc input current
- No direct path exists between the supply and ground rails under steady-state operating conditions (this is, when the input and outputs remain constant). The absence of current flow (ignoring leakage currents) means that the gate does not consume any static power.

CMOS Inverter – Switching behavior

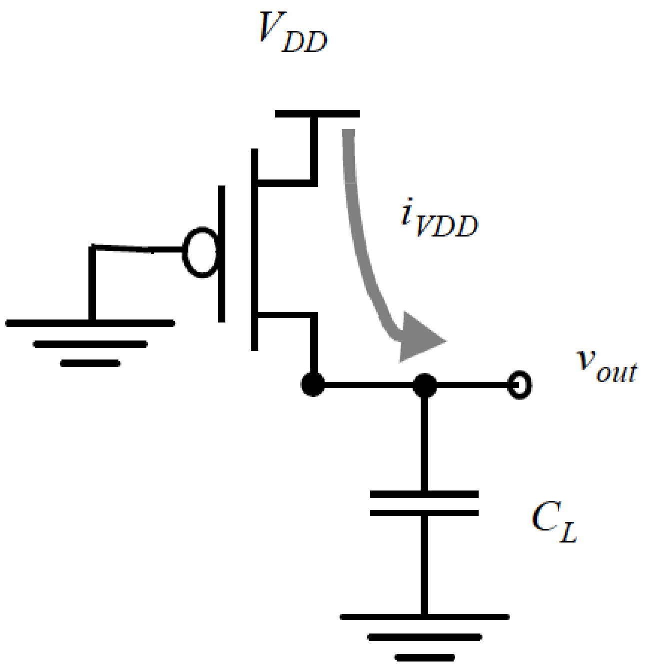




(a) Low-to-high (b) High-to-low

Getting C_L as small as possible is important for realizing fast switches

CMOS Inverter – Power Consumption



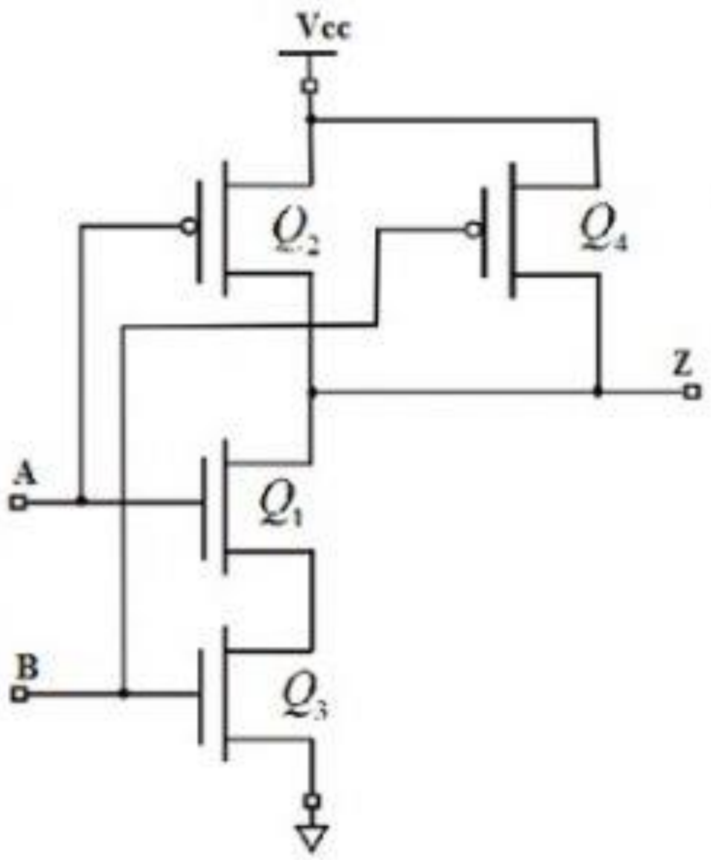
Equivalent circuit during the low-to-high transition.

- Each time the capacitor CL gets charged through the PMOS transistor, its voltage rises from 0 to VDD, and a certain amount of energy is drawn from the power supply.
- Part of this energy is dissipated in the PMOS device, while the remainder is stored on the load capacitor.
- During the high-to-low transition, this capacitor is discharged, and the stored energy is dissipated in the NMOS transistor
- The values of the energy EVDD, taken from the supply during the transition, as well as the energy EC, stored on the capacitor at the end of the transition,

$$E_{VDD} = \int_0^\infty i_{VDD}(t) V_{DD} dt = V_{DD} \int_0^\infty C_L \frac{dv_{out}}{dt} dt = C_L V_{DD} \int_0^{V_{DD}} dv_{out} = C_L V_{DD}^2$$

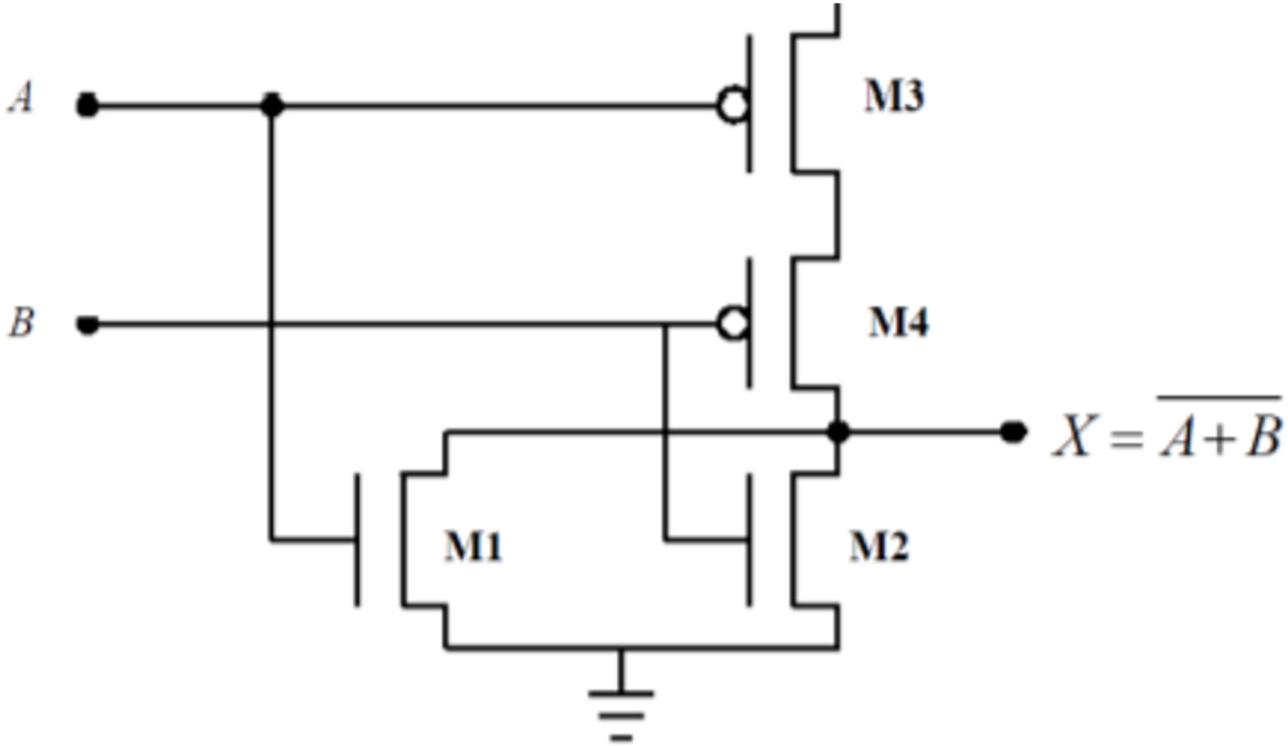
$$E_C = \int_0^\infty i_{VDD}(t) v_{out} dt = \int_0^\infty C_L \frac{dv_{out}}{dt} v_{out} dt = C_L \int_0^{V_{DD}} v_{out} dv_{out} = \frac{C_L V_{DD}^2}{2}$$

CMOS based NAND Gate



Input		Output
A	B	Y= $\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

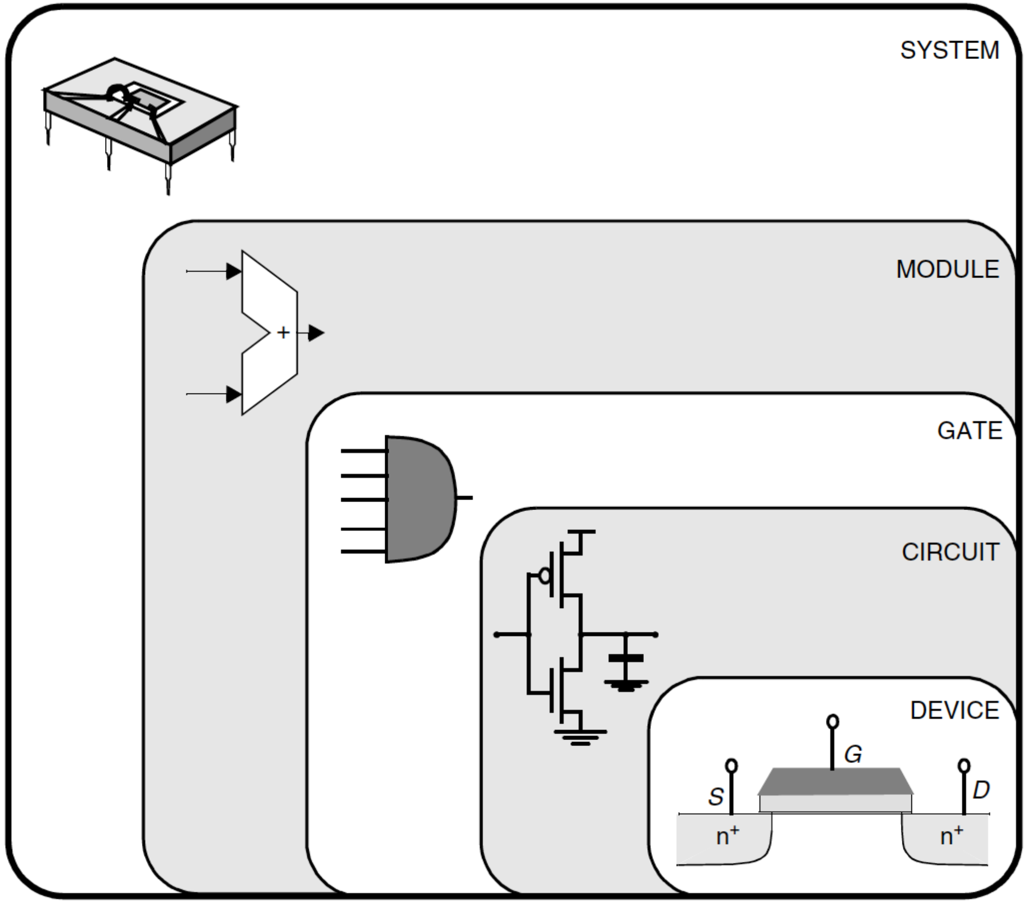
CMOS based NOR Gate



Input		Output
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

System Level Electronics

Abstraction



Digital Integrated Circuits by Rabaey et al

Operational Amplifier

- An Operational Amplifier (Op-Amp) is an integrated circuit that uses external voltage to amplify the input with a very high gain.

- The term “operational” was used as a descriptor early-on because this form of amplifier can perform operations of
  - Adding signals
  - Subtracting signals
  - Integrating signals

- The applications of Op-Amps have grown beyond those listed above.

- Therefore, Op-Amp is an active circuit element designated to perform mathematical operations of addition, subtraction, multiplication, division, differentiation and integration.

- Examples:
  - LM 111
  - LM 324
  - LM 741

LM stands for linear monolithic.

Thank you