ELE 312
Digital Electronics

http://www.ee.hacettepe.edu.tr/~usezen/ele312/

Textbooks

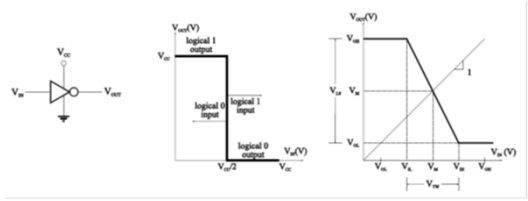
- DeMassa and Ciccone, ***Digital Integrated Circuits***, John Wiley & Sons.
- Taub and Schilling, ***Digital Integrated Electronics***, McGraw-Hill

Contents

Properties of Digital Integrated Circuits

Most important elements: Inverter and Noninverter

Idealized Inverter and Voltage Transfer Characteristics (VTCs)



Noise Margins

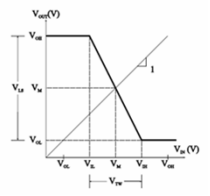
High noise margin (for logical level 1) $V_{NMH} = V_{OH} - V_{IH}$

Low noise margin (for logical level 0) $V_{NML} = V_{IL} - V_{OL}$

Noise Sensitivities

(For logical level 1) $V_{NSH} = V_{OH} - V_M$

(For logical level 0) $V_{NSL} = V_M - V_{OL}$



Noise Immunities

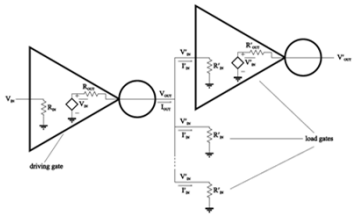
(For logical level 1) $V_{NIH} = \frac{V_{NSH}}{V_{LS}}$

(For logical level 0) $V_{NIL} = \frac{V_{NSL}}{V_{LS}}$

FAN-IN and FAN-OUT

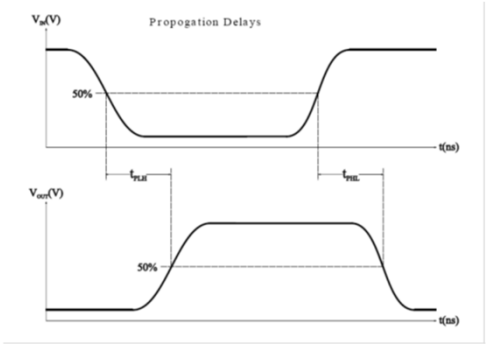
$N_{high} = \left\lfloor \frac{I_{OUT(high)}}{I_{IN(high)}} \right\rfloor$

$N_{low} = \left\lfloor \frac{I_{OUT(low)}}{I_{IN(low)}} \right\rfloor$

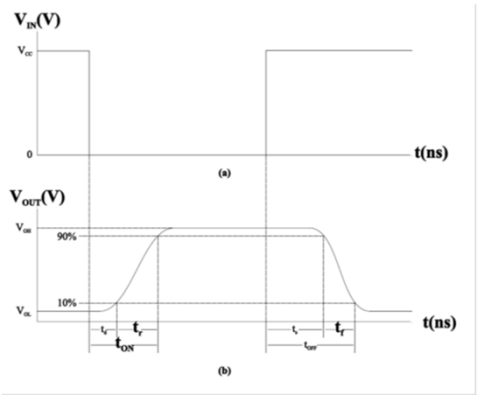


Maximum fan-out: $N_{max} = \min\left(N_{high(max)}, N_{low(max)}\right)$

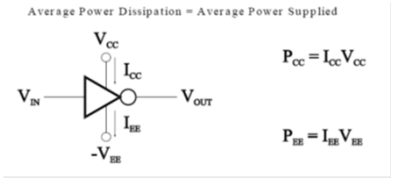
Propagation Delays



Rise and fall times and turn-on and turn-off times



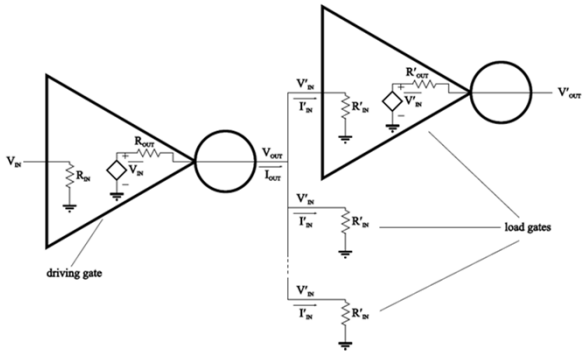
Power dissipation



$$P_{CC\,(avg)} = \frac{P_{CC\,(OH)} + P_{CC(OL)}}{2}$$

$$\boxed{P_{CC\,(avg)} = \frac{I_{CC\,(OH)} + I_{CC(OL)}}{2} V_{CC}}$$

Logic Element Equivalent Circuit and Fan-out



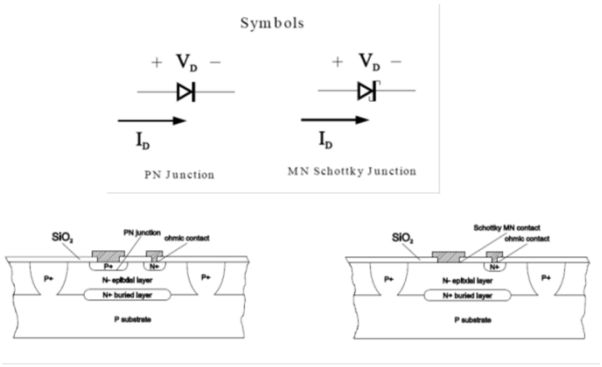
Power - Delay Product:

Speed-power product = (Average Power Diss) x (Propagation Delay)

$PD = P_{DISS(avg)} \times t_{P(avg)}$

Diode Digital Circuits

Diodes



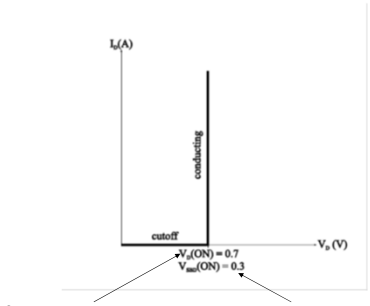
Shockleys Eq

$I_D = I_S(e^{V_D/\eta_T} - 1)$ where $V_T = \frac{kT}{q}$

for Forward Bias

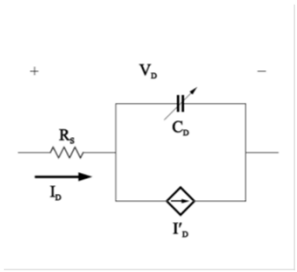
$V_D \cong V_0 = 0.7$ V

IV Characteristics



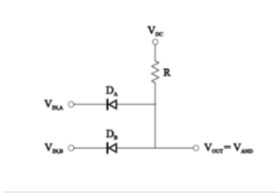
for PN Junction diodes for MN Schottky diodes

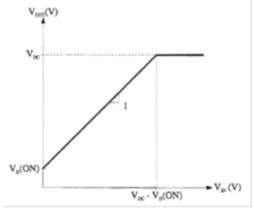
SPICE model



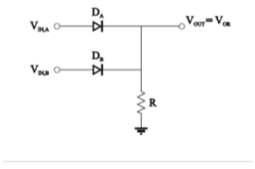
$$I'_D = I_S(e^{V_D/V_T} - 1)$$

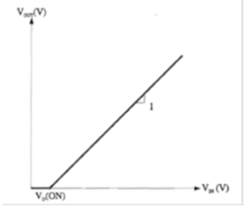
Basic Logic Gates: AND



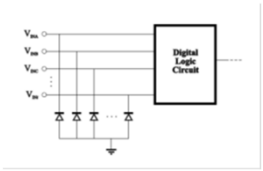


Basic Logic Gates: OR

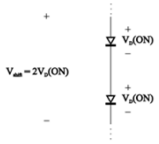




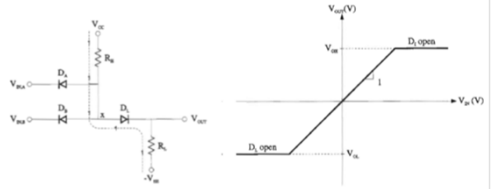
Clamping Diodes



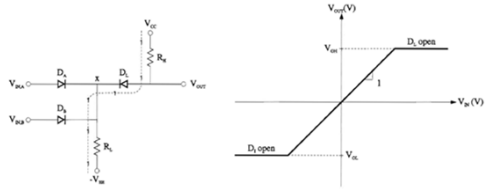
Level shifting diodes

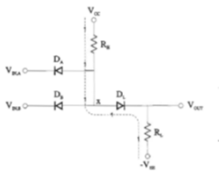


Level Shifting Diode AND Gate



Level Shifting Diode OR Gate





Ex. Find the output low and high voltages for the circuit shown above, where $V_{CC} = V_{EE} = 4V$, $V_{D(ON)} = 0.7V$, $R_H = 1k\Omega$, $R_L = 2k\Omega$.