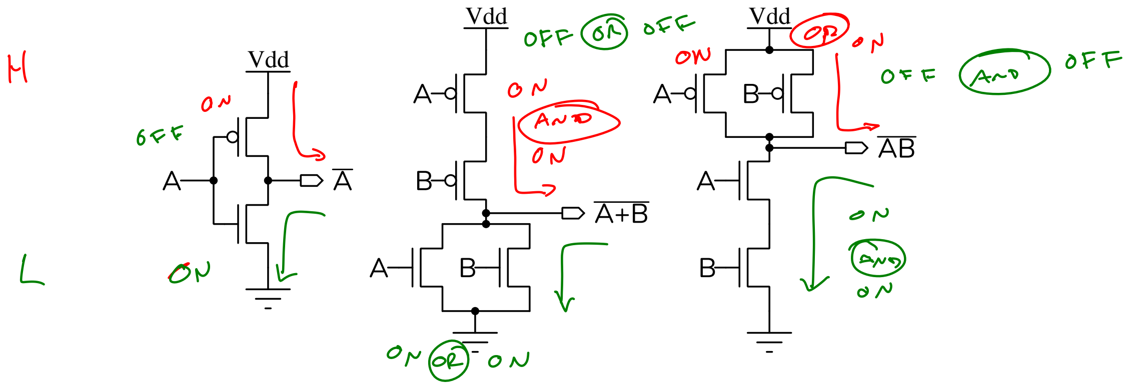
Implementation of Digital Logic Circuits

Exercise 1:



In which direction does the output current flow when the output is high? When it is low? Which transistors are on in each case?

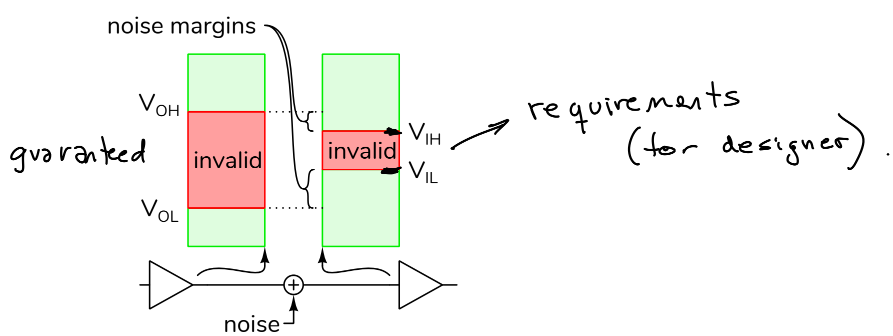
H output : current out
L output : current in

H output : top on bottom off
L output : top off bottom on

on : ALL series transistors on
ANY parallel " on

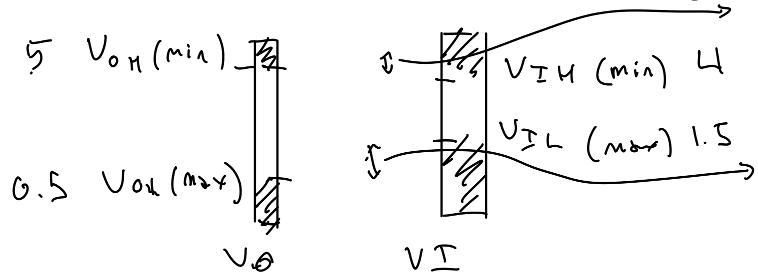
off : ANY series transistors on
ALL parallel " off

Exercise 2:



Which of these specifications does the manufacturer guarantee? Which are requirements?

Exercise 3: A logic family has V_{OH}(min) = 5 V, V_{OL}(max) = 0.5 V, V_{IH}(min) = 4 V and V_{IL}(max) = 1.5 V. What are the noise margins?



$V_{OH} - V_{IH} = 5 - 4 = 1$

$V_{IL} - V_{OL} = 1.5 - 0.5 = 1$

Exercise 4: All else being equal, by how much would we expect to decrease power consumption when reducing logic levels from 5 V to 3.3 V? What would be the effect on power consumption in reducing the clock frequency from 50 MHz to 1 MHz?

$V_1 = 5$
$V_2 = 3.3$

$$\frac{P_2}{P_1} = \left(\frac{3.3}{5}\right)^2 \simeq 0.44$$

$P_2 = 0.44 P_1$

reduction $= P_1 - P_2$
$= (1 - 0.44) P_1 = 0.56 P_1$
$= 56\%$ of P_1

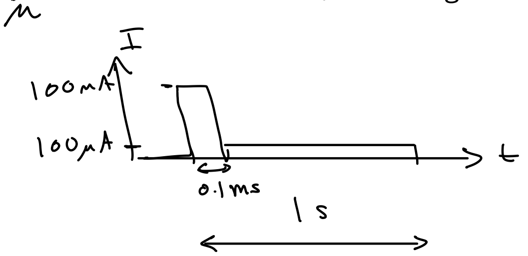
$f_1 = 50$
$f_2 = 1$

$$\frac{P_2}{P_1} = \frac{1}{50} = 0.02$$

$P_2 = 0.62 P_1$

reduction $= P_1 - P_2$
$= (1 - 0.02) P_1 = 0.98 P_1$
$= 98\%$ of P_1

Exercise 5: The energy stored in a battery (its "capacity") is measured in Watt-hours. If a circuit draws 100 mA for 100 μs per second and draws 100 ~~m~~A μ the rest of the time, how long will a 1000 mAh battery last?



$$\text{average current} = \frac{0.1 \times 10^{-3}}{1} 100 + \frac{(1 - 0.1 \times 10^{-3})}{1} \cdot 100 \times 10^{-3} \quad \text{mA}$$

$$= 10 \times 10^{-3} + 100 \times 10^{-3} - 10 \times 10^{-6}$$

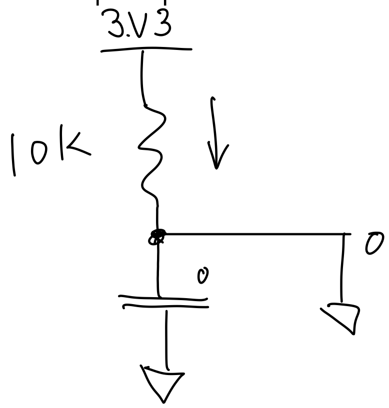
$$\approx 110 \times 10^{-3} \text{ mA} \approx 110 \mu A$$

$$1000 \text{mA} \cdot \text{h} \cdot 3600 \text{ s/h} = 3.6 \times 10^6 \text{ mA} \cdot \text{s}$$

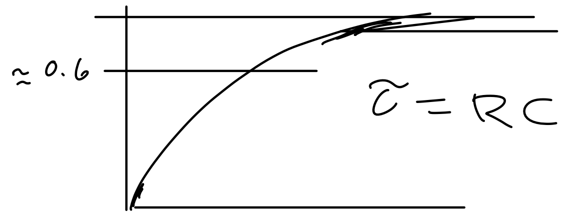
$$\text{time} = \frac{3.6 \times 10^6 \text{ mA} \cdot \text{s}}{0.110 \text{ mA}} \approx 32.7 \times 10^6 \text{ s} \approx 9000 \text{ hours}$$

($\simeq$ 1 year)

Exercise 6: What are the active-state current and the RC time constant for a wired-or interrupt-request line using a 10kΩ resistor pulling up a circuit with 50 pF capacitance to 3.3 V?



$$i = \frac{V}{R} = \frac{3.3}{10{,}000} = 0.33\,\text{mA}$$



$\tau = RC$

$R = 10\,k\Omega$

$C = 50\,pF$

$$\tau = RC = 10 \times 10^{3} \times 50 \times 10^{-12}$$

$$= 500 \times 10^{-9} = 0.5\,\mu s.$$

Exercise 7: How many square mm of PCB area does each package require? Which packages have their pins accessible when the package is placed on the PCB?

$$\text{area} = \begin{cases} (22)^2 = 484 \\ (3.5)^2 = 12.25 \end{cases} \approx 40\times$$