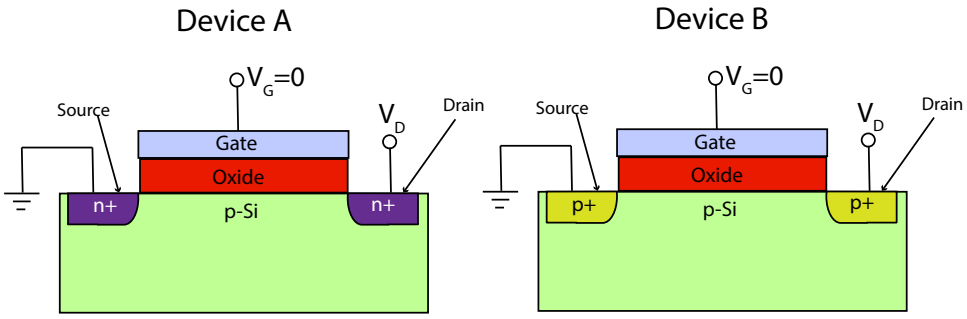
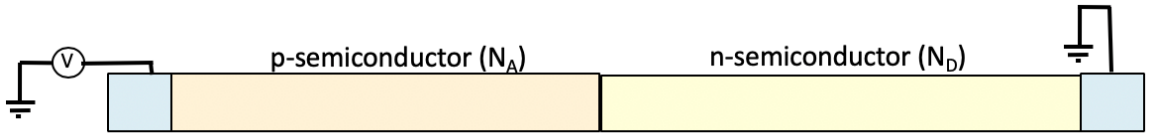
ECE 3030: Physical Foundations of Computer Engineering
Fall 2022
Homework 12—Total points 100
Due on 12/6/2022 at 11.59am. (No late submission/Strictly enforced.)

Q1 Consider the two devices shown in the following figure. Device A is the MOSFET structure that we discussed in the class and in which the source and drain are n^+-type (heavily doped n-type). On the other hand, in device B source and drain are p^+-type (heavily doped p-type). Based on what we discussed in class, do you think device B will behave like a switch–*i.e.* will device B be able to block current from flowing between the drain and the source terminal when the gate voltage V_G is zero (or less than the threshold voltage)? Provide justification for your answer. [Total 5 pts]



Q2 **p-n junction:** Draw the band diagram of the p-n junction when V=0 and when $V > 0$. Clearly indicate the relation between Fermi levels of the two sides. [Total 10 pts]



Q3 **Dynamic Voltage and Frequency Scaling (DVFS):** Consider the logic blocks shown in figure 1. Logic block 2 and 3 receives input from logic block 1 at the same time. Logic block 5 needs inputs from blocks 3 and 4 for generate the final output. Logic block 3 receives input from logic block 2. Logic block 2, 3 and 4 requires 50, 10, and 30 cycles, respectively, to generate the respective output.

Based on what you have learned in class, how will you apply DVFS in these system? For which logic block(s), will you increase or decrease the power supply voltage and by how much? How much energy will you save in your prescribed process? Explain your answer. Make necessary and simplest possible reasonable assumptions. [Total 35 pts]

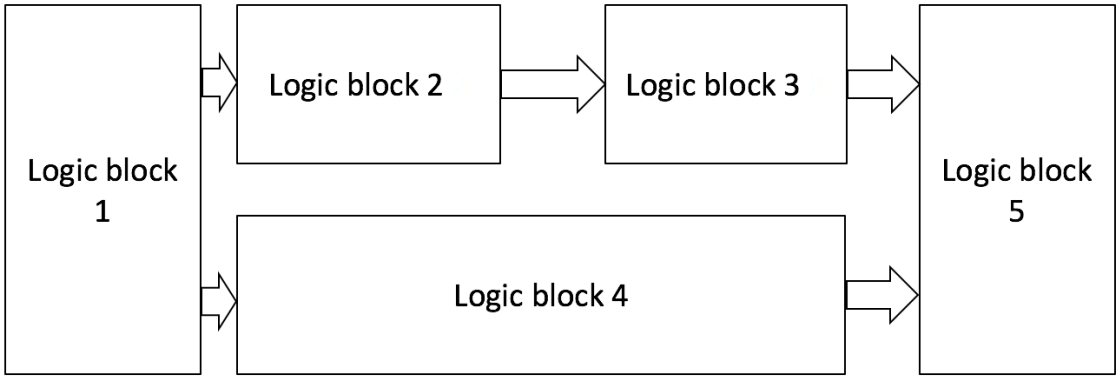


Figure 1: Dynamic Voltage and Frequency Scaling (DVFS).

Q4 **Energy, Power, and Heat** As we know in Moore's law, the transistor density of devices increases at an exponential rate. However, the power supply voltage, V_{DD}, did not decrease until after 1999. Provide a few reasons why modern semiconductors face these limitations.