(11.1) (a) Derive equation (11.28) by taking the integral and limit of equation (11.27). (b) Show that equation (11.29) follows.

(11.2) What is the expected occupancy of a state at the conduction band edge for Ge, Si, and diamond at room temperature (300 K)?

$$f(E) = \frac{1}{1 + e^{(E-u)/kT}} =$$

Ge=0.67eV=> .037

Si=1.11eV=> .022

Diamond = 5eV => .005

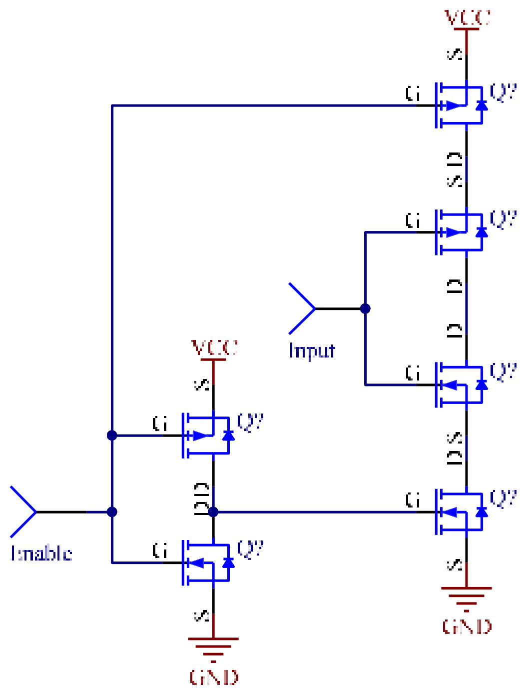
(11.3) Consider Si doped with 10^17 As atoms/cm3 .

(a) What is the equilibrium hole concentration at 300 K?

$$p_o = \frac{n_i^2}{n_0} = \frac{(1.45E^{10})^2}{10^{17}} = 2E^3$$

(b) How much does this move EF relative to its intrinsic value?

(11.4) Design a tristate CMOS inverter by adding a control input to a conventional inverter that can force the output to a high impedance (disconnected) state. These are useful for allowing multiple gates to share a single wire.




(11.5) Let the output of a logic circuit be connected by a wire of resistance R to a load of capacitance C (i.e., the gate of the next FET). The load capacitor is initially discharged, then when the gate is turned on it is charged up to the supply voltage V . Assume that the output is turned on instantly, and take the supply voltage to be 5 V and the gate capacitance to be 10 fF.

(a) How much energy is stored in the capacitor?

$$\frac{1}{2}CV^2 = 125fJ$$

(b) How much energy was dissipated in the wire?

$$\frac{1}{2}CV^2 = 125fJ$$

(c) Approximately how much energy is dissipated in the wire if the supply voltage is linearly ramped from 0 to 5 V during a long time τ ?

$$i = 5C/\tau$$

$$P = i^2R = (5C/\tau)^2R = \frac{V_A^2C^2R}{\tau}$$

$$J = \int_0^{\tau} \frac{V_A^2 C^2 R}{\tau} =$$

$$\frac{dV_C}{dt} = \frac{V_A(t) - V_C}{RC} = \frac{5(t/\tau) - V_C}{RC}$$

$$V_C(t) = 5\frac{t}{\tau} + \frac{5RC}{\tau}\left(e^{-\frac{t}{RC}} - 1\right)$$

$$V_C'(t) = 5/\tau + 5/\tau\left(e^{-\frac{t}{RC}}\right)$$

$$J = \int_o^{\tau} \left(5C/\tau + 5C/\tau\left(e^{-\frac{t}{RC}}\right)\right)^2 R\,dt$$

(d) How often must the capacitor be charged and discharged for it to draw 1 W from the power supply?

$$\frac{1W}{2 * 125fJ} = 4THz$$

(e) If an IC has $10^6$ transistors, each dissipating this charging energy once every cycle of a 100 MHz clock, how much power would be consumed in this worstcase estimate?

$$250fJ * 100MHz * 10^6 = 25\,W$$

(f) How many electrons are stored in the capacitor?

$$(5V)(10fF) = 5E^{-14}Coulombs = 312075\,Electrons$$