Gradescope Practice Test

1) $n = 3$
$V_{FS} = 8$
$V_{in} = 5.4V$
$V_{in} < V_{out}$

$V_{lsb} = \frac{8}{2^3} = 1$ $\quad \frac{V_{in}}{V_{lsb}} = 5.4 \rightarrow 5V$

$Range = V_{out} \pm \frac{1}{2} V_{lsb}$

$= 4.5 - 5.5$ but $V_{in} < V_{out}$ so

$\boxed{Range = 4.5 - 5}$

2) 10 binary GB

10 GBPS

time = ?

$10 \text{ binary GB} = 10 \cdot \frac{2^{30} \text{ byte}}{GB} \cdot \frac{8 \text{ bits}}{\text{byte}} = 8.59 \times 10^{10} \text{ bits}$

$8.59 \times 10^{10} = 85.9 \text{ Gb}$

$time = \frac{85.9 \text{ Gbits}}{10 \text{ GBPS}} = \boxed{8.59 \text{ seconds}}$

3)
a) $\boxed{\text{donor}}$

b) $L = 20nm$
$N_A = 10^{16}$
$n_i = 10^{10}$
$V_{sat} = 10^7$
$\mu_D = 200$

target $n = 10^{17}$

$pn = n_i^2 \rightarrow p = \frac{n_i^2}{n} = 1000$

$p + N_d = n + N_A \rightarrow N_d = (n + N_A) - p$

$\boxed{= 1.1e^{17}}$

c) $V_{sat} = \mu E = \mu \cdot \frac{V}{L} = \frac{\mu \cdot V}{L}$ $\quad \swarrow$ convert nm to cm

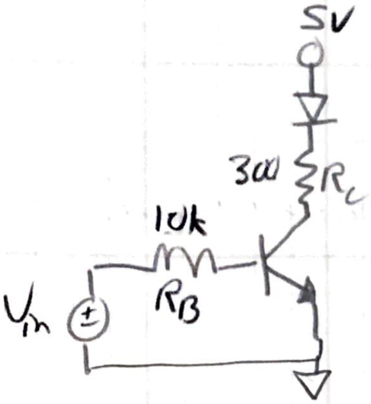
$V = \frac{L \cdot V_{sat}}{\mu} = \frac{(20 \times 10^{-7}) \cdot 10^7}{200} = \boxed{0.1 V}$

4) The two contacts of a n-type semiconductor are biased at 1V and 5V.

- The 1V side acts as the source of electrons.
- Current flows from 5V to 1V

5) NPN Switch

$\beta_F = 200$, $V_{BE,on} = 0.8\,V$, $V_{CE,sat} = 0.2\,V$, Diode turn on $= 1.8\,V$



a) At what Vin does the BE junction turn on?

$V_{BE,on} = 0.8\,V$ so Vin must equal $\boxed{0.8V}$

b) At what Vin does the transistor enter Saturation?

$$V_{in} = V_{BE,on} + \frac{(5V - V_{CE,sat} - V_{turn\,on})}{R_C} \times \frac{1}{\beta_F} \times R_B$$

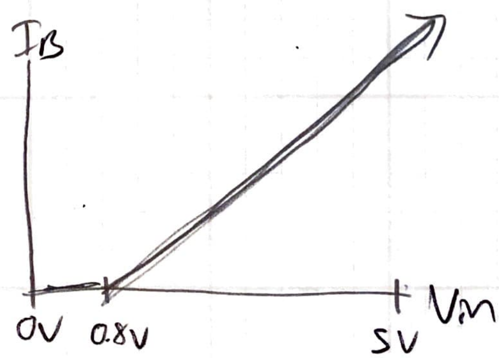
$$V_{in} = 0.8 + \frac{(5 - 0.2 - 1.8)}{300} \cdot \frac{1}{200} \times 10{,}000 = \boxed{1.3\,V}$$

c) Vin sweeps from 0V to 5V, sketch I_B

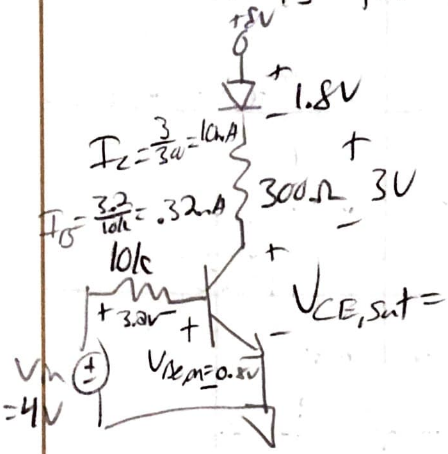
$$I_B = \frac{V_{in} - V_{BE,on}}{10k}$$

$V_{BE,on} = 0.8\,V$

Linear relationship

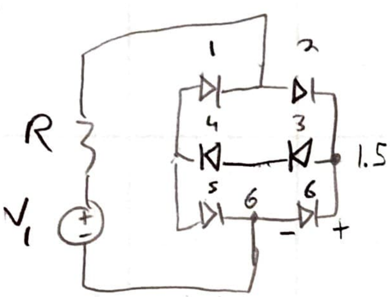


d) What is the transistor current gain at $V_{in} = 4V$?



$$\beta_F = \frac{I_C}{I_B} = \frac{10mA}{.32mA} = \boxed{31.25}$$

6)



Turn on = 1.5V

a) Find forward voltage accross D6 for $V_1 = 15V$

$1.5 - 6 = \boxed{-4.5V}$

b) Why is R a few hundred Ω instead of a few Ω?

A: Limit current to a mA range typical for LEDs

c) Forward Voltage of D4 when $V_1 = 15V$

$\boxed{+1.5V}$

d) Forward Voltage of D3 when $V_1 = -15V$

$\boxed{+1.5V}$

7)

Turn-on = 0.7 V
Switching from 5V to −10V

a) Vout before switching

$V_{in} - V_{on} = 5 - 0.7 = \boxed{4.3\,V}$

b) Vout after switching

$V_{in} - V_{on} = -10 - 0.7 = \boxed{-10.7\,V}$

c) Diode current after switching

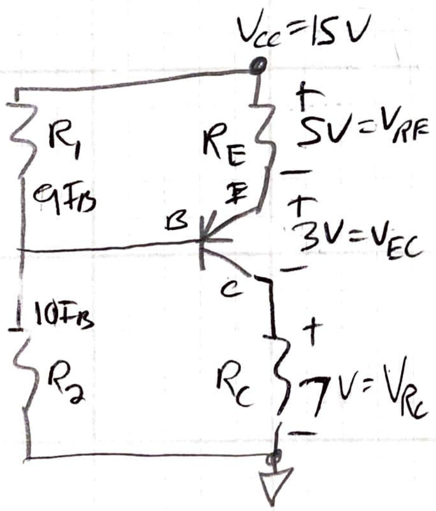
$I = \frac{V}{R} = \frac{-10.7}{750} = \boxed{-14.26\,mA}$

8)

a) $\beta_F = \frac{I_C}{I_B} = \boxed{100}$

b) $\beta_R = \frac{I_C}{I_B} = \boxed{2}$

a) Design a 4-resistor PNP circuit to achieve:
$V_{EC} = 3V$, $I_C = 5mA$, $\beta_F = 100$, $V_{CC} = 15V$, $\phi_t = 0.0258$, $I_S = 10^{-15}$.
Make feedback resistor drop 5V.



$R_C = \frac{V_{RC}}{I_C} = \boxed{1.4k\Omega}$

$I_B = \frac{I_C}{\beta_F} = \frac{5mA}{100} = 50\mu A$

$I_E = I_B + I_C = 5mA + 50\mu A = 5.05\,mA$

$R_E = \frac{V_{RE}}{I_E} = \frac{5V}{5.05mA} = \boxed{990\,\Omega}$

$V_{EB} = \phi_t \ln\left(\frac{I_C}{I_S}\right) = 0.0258 \ln\left(\frac{5mA}{10^{-15}}\right)$
$= 0.75V$

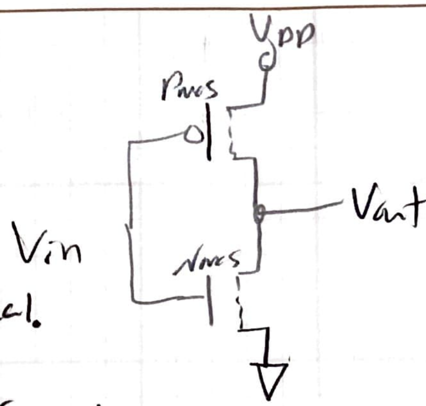
$V_B = V_{CC} - V_{RE} - V_{EB} = 15 - 5 - 0.75 = 9.246V$

$R_2 = \frac{V_B}{10I_B} = \boxed{18.49k\Omega}$ $R_1 = \frac{V_B}{9I_B} = \boxed{12.78\,k\Omega}$

10) NMOS = $W/L = 2/1$, $V_{TO} = 1V$, $KP = 50$

PMOS = $W/L = 4/1$, $V_{TO} = -1V$, $KP = 25$

$V_{DD} = 5V$



a) $V_{in} = 0V$ determine V_{out} so NMOS and PMOS currents are equal. Explain.

A: If $V_{in} = 0V$ then NMOS is off, making Nmos current $\emptyset$. For PMOS current to be $\emptyset$, V_{DD} and V_{out} must be equal.

So $V_{out} = V_{DD} = 5V$

PMOS and NMOS current $= \emptyset$

b) $V_{in} = 5V$, determine V_{out} so that NMOS and PMOS current are equal

PMOS is off so current $\emptyset$

NMOS current is $\emptyset$ only when $V_{out} = 0V$

c) Calculate on-resistance of Nmos when $V_{in} = V_{DD}$

$$R_{on} = \frac{1}{KP \cdot \frac{W}{L}(V_{in} - V_{TO})} = \boxed{2.5k\Omega}$$

11) a) Out of the intrinsic C_{GS}, C_{GD}, which is larger when $V_{GS} = V_{DS} = V_{DD}$? Is the transistor in saturation or linear?

A: When $V_{GS} = V_{DS} = V_{DD}$ the transistor is in saturation

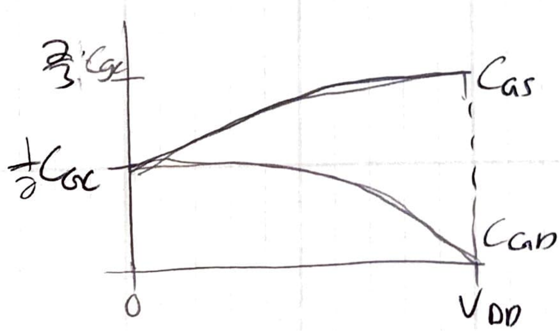
In saturation: $C_{GS} = \frac{3}{2} C_{GC}$ and $C_{GD} = \varnothing$ so $C_{GS} > C_{GD}$

b) Out of the extrinsic C_{GS}, C_{GD}, and C_{GB}, which ones are proportional to channel width? And which to length?

C_{GS} and C_{GD} are W

C_{GB} is L

c) How do the transistor intrinsic channel C_{GS} and C_{GD} vary with increasing V_{DS} from 0V to V_{DD}? Assume V_{GS} is well above threshold. Sketch the curves. At what biasing condition is $C_{GS} = \frac{1}{2} C_{ox}'' WL$?



Forward bias mode yeilds $C_{GS} = \frac{1}{2} C_{ox}'' WL$ when $V_{DS} = 0V$