Elec 2210 test 1

95

Thursday, September 20, 2018 12:19 PM

Name: [redacted]

Turn in equation sheet together with test paper.

Equation sheet will not be returned.

Equation sheet can contain only equations without text, circuit, waveform drawing, sample math solutions are not allowed.

Intro (15)

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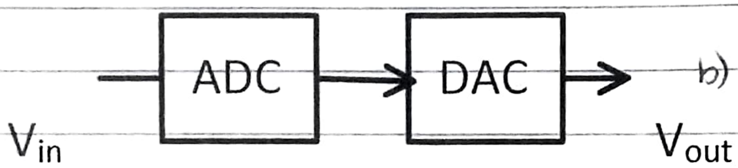
In the system below, n=4, V_{FS}=32V.

- Find V_{out} for $V_{in} = 17V$. **(4)**
- Find the interval of V_{in} for a V_{out} of 16V. **(3)**

a) $V_{LSB} = \frac{32V}{2^4} = 2V$

$\frac{Vin}{V_{LSB}} = \frac{17V}{2V} = 8.5 \approx 9.$

$Vout = 9 \cdot 2V = 18V$



b) $\frac{16V}{2V} = 8$, ~~.5V~~ $\pm \frac{1}{2} V_{LSB} = 1V.$

16

$16 - 1V \leq Vin < 16 + 1V$

$15V \leq Vin < 17V$

Find out the data rate in GBPS (giga bits per second) required to download 10 binary GB data in 10 seconds. **(8)**

$10 \text{ binary } GB = 10 \cdot GB \cdot \frac{2^{30} \text{ Bytes}}{GB} \cdot \frac{8 \text{ bits}}{1 \text{ byte}}$

$= 8.5899 \times 10^{10}$ bits $= 8.5899 \times 10^{10}$ bits $\cdot \frac{10^{-9} \text{ Gbits}}{1 \text{bits}}$ $= 85.899$ Gbits

$\text{data rate} = \frac{\cancel{8.5899 \times 10^{10} \text{ bits}}\ 85.899 \text{ Gbits}}{10 \text{ sec}} = 8.5899 \text{ GBPS}$

Solid (20)

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1. Which of the following dopants are acceptors? **(4)**
   a. B in Si
   b. As in Si
   c. Si in GaAs when Si replaces Ga
   d. Si in GaAs when Si replaces As
2. A 20nm long Si resistor is doped with $N_d=10^{17}/cm^3$. $n_i=10^{10}/cm^3$. $v_{sat}=\frac{10^7 cm}{s}$. mobility is $200\frac{cm^2}{V\cdot s}$.
   a. Should we add As or B to achieve a target n = $10^{18}/cm^3$? **(3)** At what level? **(3)**
   b. Does Ohm's law still work if we apply 0.05V? **(5)**

a) add As,

$n = N_{d\,new} = 10^{18}/cm^3$.

we should add As to $10^{18}/cm^3$, or add $\Delta N_d = 10^{18}-10^{17} = 9\times10^{17}/cm^3$

b) $v = \mu E = 200\frac{cm^2}{V.S}\cdot\frac{V}{l} = 200\frac{cm^2}{V\cdot S}\cdot\frac{0.05V}{20\times10^{-7}cm} = 5\times10^6\, cm/s$

$< V_{sat}$.

so ohm's law does work

3. The two contacts of a p-type semiconductor are biased at 1V and 5V, check all that are true **(5)**:
   a. Hole current is much higher than electron current
   b. The 1V side acts as source of holes
   c. The 5V side acts as source of holes
   d. Current flows from 5V to 1V
   e. Holes drift from 5V to 1V

PN Diodes (20)

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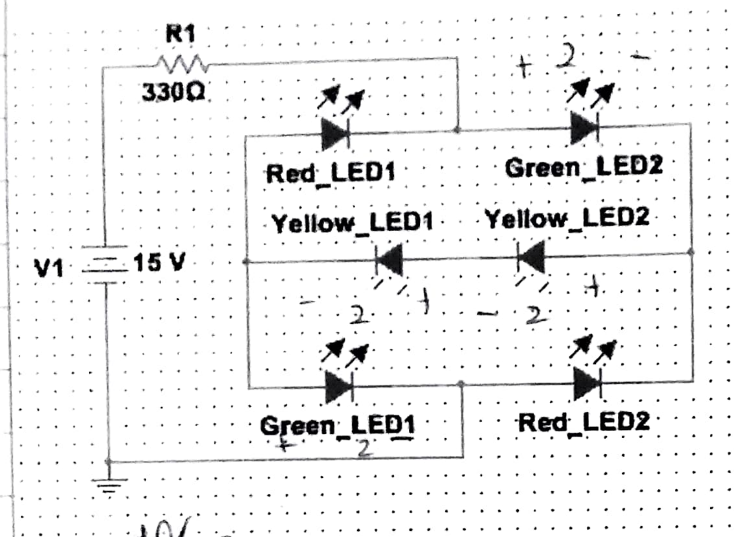


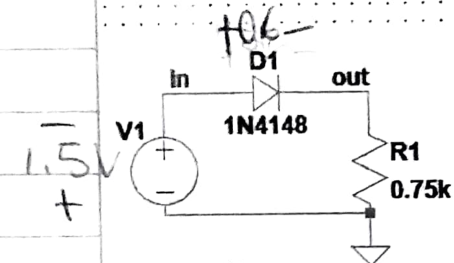
1. Turn on voltage is 2V. Green Led 1,2, and
1) Which LEDs are lighting up? **(4)** Yellow-led 1,2.
~~2) Which LEDs light up when V1 is changed from 15V to -15V?~~ **(4)**
3) What value of R1 should we use to ~~flow 7 mA of current?~~ **(4)**

1) Green led 1,2 and Yellow led 1,2

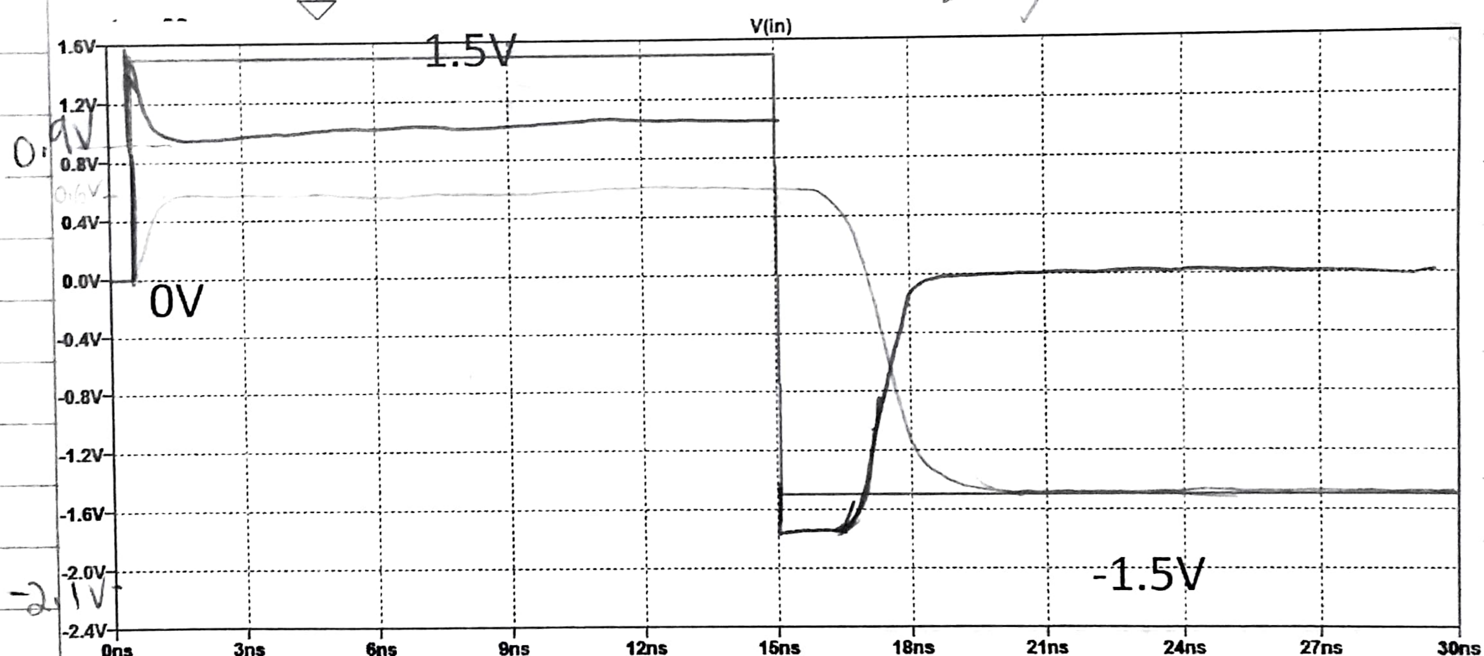
2) Red led 1,2 and Yellow led 1,2

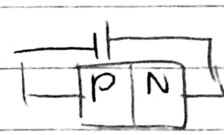
3) $V_R = 15V - 4\times 2V = 7V$

$R_1 = \frac{V_R}{I} = \frac{7V}{7mA} = 1K\Omega$



2. For the V(in) given, draw V(out) considering the charge ~~storage (capacitances) of the diode. Turn-on voltage is 0.6V.~~ (5)





3. Consider increasing reverse bias of a PN junction:
- ~~Does the depletion width increase or decrease? (1)~~ increase
- Does the depletion capacitance increase or decrease? **(1)** decrease
- ~~Does the peak electric field increase or decrease? (1)~~ increase

Rectifiers (10)

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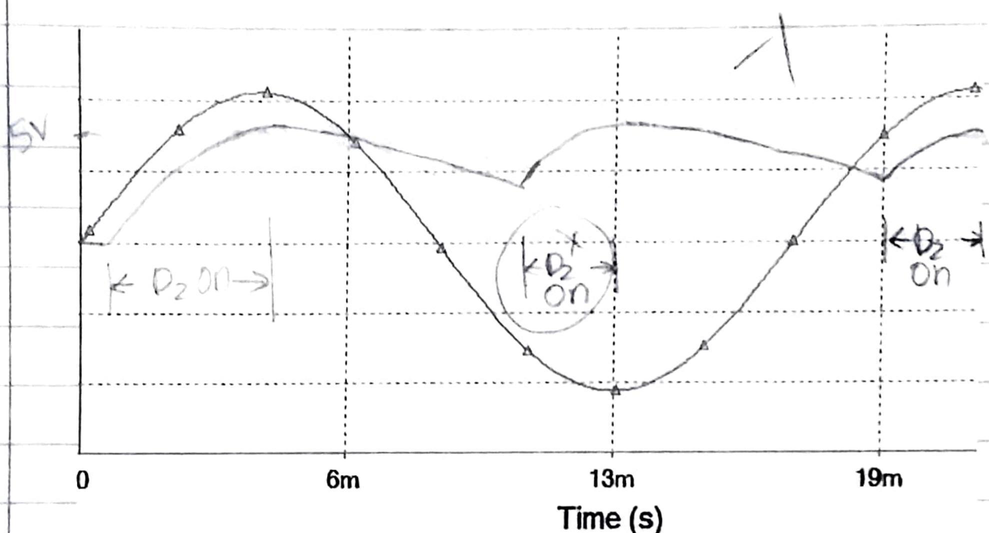
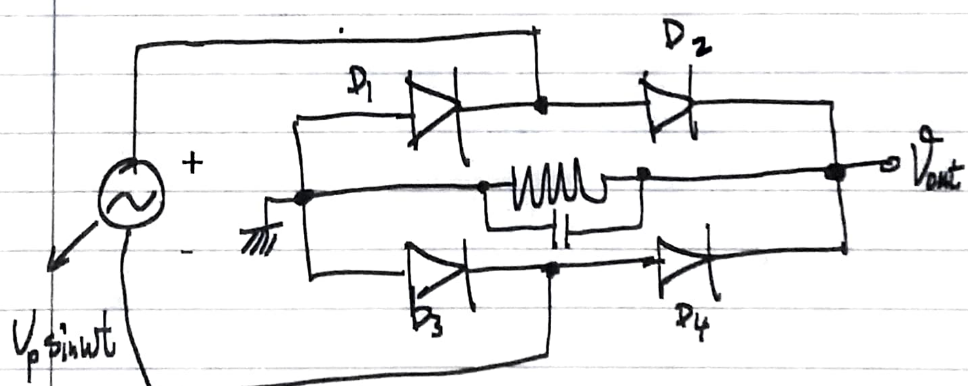
Design a 5V, 1A full wave bridge rectifier with a V_r no more than 10 mV. Von=0.7V. Frequency of ac source is 60Hz. $V_{in} = V_p \sin(\omega t)$. $\omega = 2\pi f$.

a) Find V_p required **(3)**. $V_p = 5V + 2\times0.7V = 6.4V$
b) For the Vin=$V_p \sin \omega t$ below, sketch Vout **(4)**.
c) Mark the time intervals during which D2 is on **(3)**





Bjt (20)

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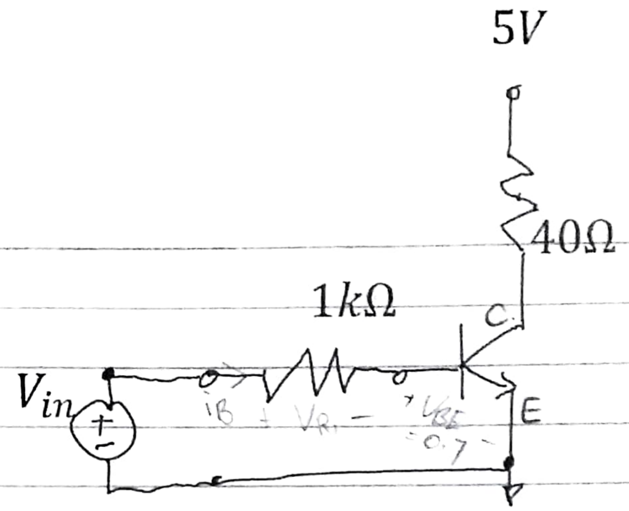


1. β_F=100. $V_{BE,on} = 0.7V$, $V_{ce,sat} = 0.2V$.
   a. At what V_{in} does the transistor turn on and enter forward opeartion? **(3)**
   b. Find I_C at $V_{in} = 1.7V$. Verify operation region assumption. **(5)**
   c. At what V_{in} does the transitor enter saturation operation. **(5)**

a) Vin = 0.7V

b) assume fwd mode, then $V_{BE} = 0.7V$

$i_B = \frac{V_{in} - V_{BE}}{1k\Omega} = \frac{1.7 - 0.7V}{1k\Omega} = 1mA$

$i_C = \beta_F \cdot i_B = 0.1A \Rightarrow V_{CE} = 5V - 40\Omega \times 0.1A = 1V > V_{cesat}$

assumption is self-consistent, and $i_C = 0.1A$

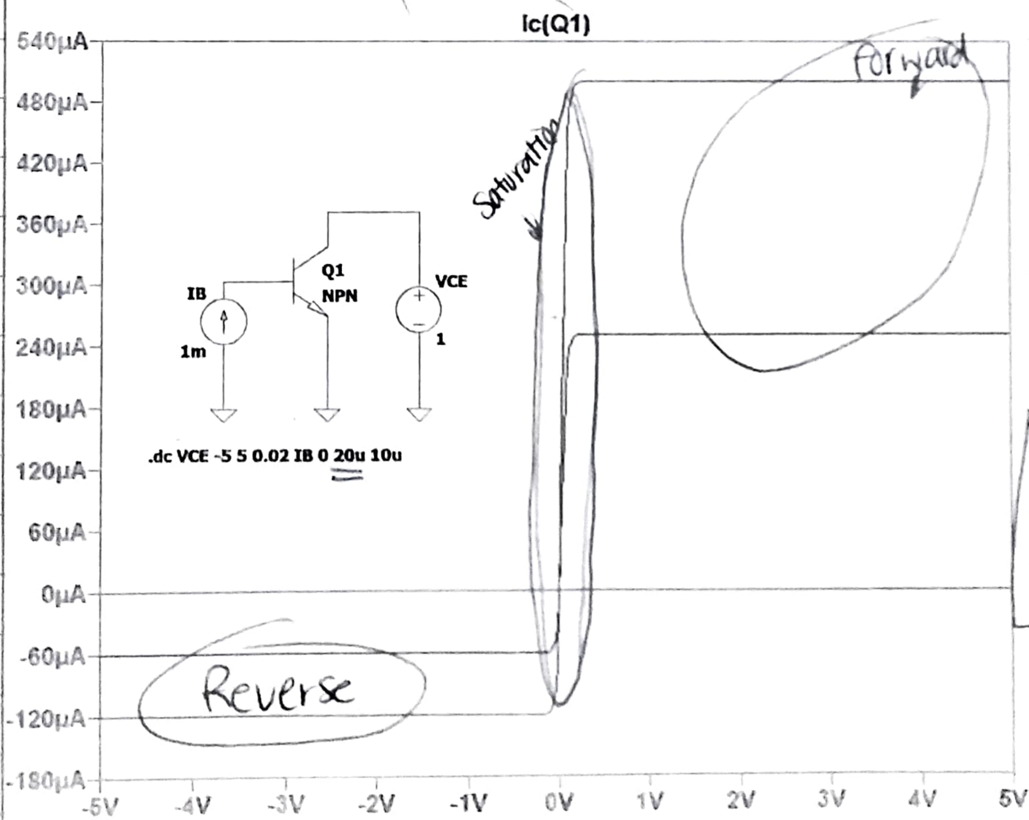
c) when $i_C = \frac{5V - 0.2V}{40\Omega} = 0.12A$, $i_B = \frac{i_C}{\beta_F} = \frac{0.12A}{100} = 1.2mA \Rightarrow$ $V_{in} = V_{BE} + i_B \cdot 1k\Omega$

$= 0.7 + 1.2mA \cdot 1k\Omega$

$= \boxed{1.9V}$

2. IB is stepped from 0 to 6 uA in 1uA step in the ltspice simulation below:
   a. Identify forward, reverse and saturation operation region **(3)**
   b. Find β_F and β_R **(4)**

$I_C = (\beta_R + 1) I_B$



$500\mu A \begin{cases} \beta_F = \frac{500}{20} = 25 \\ \beta_R = \frac{120}{20} = 6 \end{cases}$

$250\mu A \begin{cases} \beta_F = \frac{250}{10} = 25 \\ \beta_R = \frac{60}{10} = 6 \end{cases}$

$\boxed{\begin{cases} \beta_F = 25 \\ \beta_R = 6 \end{cases}}$ $-1 = 5$

4R circuit (15)

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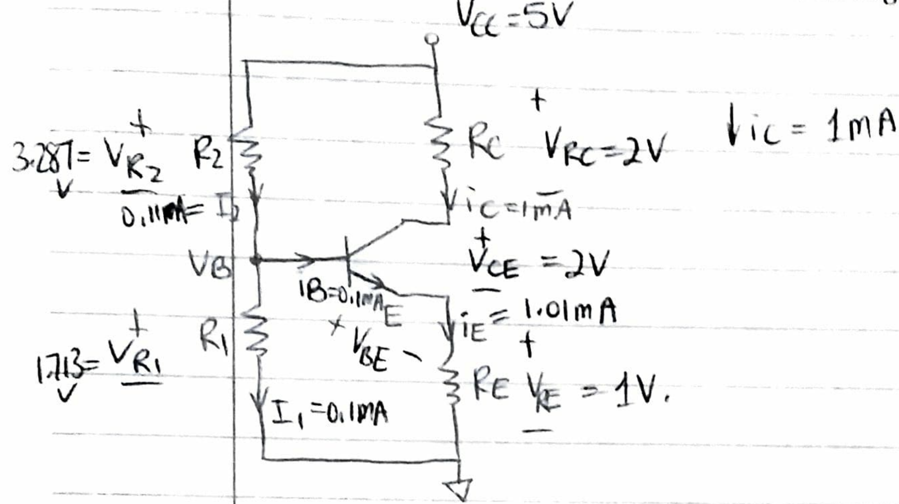
1. Design a 4-resistor NPN biasing circuit to achieve: $V_{RE} = 1V$, $V_{CE} = 2V$, $I_C = 1\ mA$, $\beta_F = 100$, $V_{CC} = 5V$, $\phi_t = 0.0258\ V$, $I_S = 10^{-15} A$.
   - Include a schematic of your circuit,
   - label the voltage across and the current through all 4 resistors on the schematic.



$$R_C = \frac{V_{CC} - V_{CE} - V_{RE}}{I_C} = \frac{5V - 2V - 1V}{1mA} = 2K\Omega, \quad V_{RC} = V_{CC} - V_{CE} - V_{RE} = 2V$$

$$i_B = \frac{i_C}{\beta_F} = \frac{1mA}{100} = 0.01\,mA$$

$$i_E = i_B + i_C = 0.01mA + 1mA = 1.01mA$$

$$\Rightarrow R_E = \frac{V_E}{i_E} = \frac{1V}{1.01mA} = 990.099\,\Omega$$

$\cancel{V_B = V_{BE} + V_{RE} = 0.7V + 1V}$ since infnd, $I_C = I_S \cdot e^{\frac{V_{BE}}{\phi_t}}$

$$V_{BE} = \phi_t \ln\left(\frac{I_C}{I_S}\right) = 25.8mV \cdot \ln\left(\frac{1mA}{10^{-15}A}\right) = 25.8mV \cdot \ln(10^{12}) = 0.713\,V$$

$$\Rightarrow V_B = V_{BE} + V_{RE} = 0.713V + 1V = 1.713\,V. \Rightarrow V_{R1} = V_B = 1.713V$$

choose $I_1 = 10 I_B = 0.1mA \Rightarrow R_1 = \frac{V_{R1}}{I_1} = \frac{1.713V}{0.1mA} = 17.13K\Omega$

then $I_2 = 11 I_B = 0.11mA$; $V_{R_2} = V_{CC} - V_B = 5V - 1.713V = 3.287V$

$$\Rightarrow R_2 = \frac{V_{R_2}}{I_2} = \frac{3.287V}{0.11mA} = 29.88\,K\Omega.$$