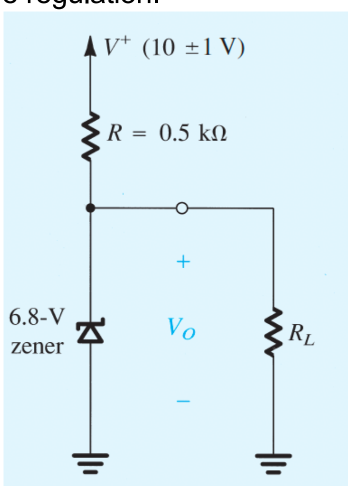
ECE 3355: Electronics

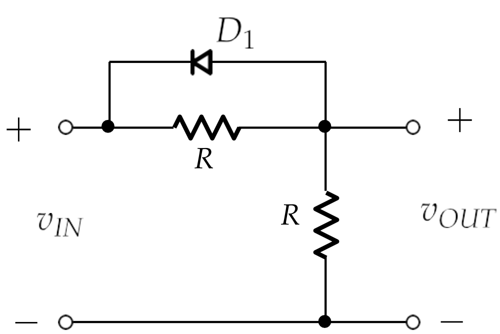
Homework 8 Topic: Diodes II + BJTs

1. Consider a half-wave peak rectifier fed with a voltage v_S having a triangular waveform with 24-V peak-to-peak amplitude, zero average, and 1-kHz frequency. Assume that the diode has a 0.7-V drop when conducting. Let the load resistance R = 100Ω and the filter capacitor C = 100 μF. Find the average dc output voltage, the time interval during which the diode conducts, the average diode current during conduction, and the maximum diode current.

2. Zener Diode Regulator: For this problem you will need the data sheet for a Zener Diode, which you can find your own or use the one Fairchild Semiconductor that is provided on Canvas. Note that the data sheet provides values for V_Z, which is measured at the current I_Z, as well as for the series resistance. We want to design a 12 V regulator using a reverse-bias Zener diode similar to the circuit below the load of 2.2 kΩ. For this design problem, the supply voltage V^+ is 25 ± 2.5 V (not 10 ± 1 V a shown in the figure below).
    - Choose one Zener diode to regulate the load voltage to approximately 12 V. Based on the information in the data sheet, find V_{Z0} for this diode.
    - If the Zener current is 25 mA, find V_Z. Then find the current through R, and from that determine a value for R. Use the nominal voltage for the power supply (i.e., 25 V).
    - Find the line regulation.



3. For the circuit below using the constant voltage drop model with $V_{D0} = 0.7$ V and $r_D = 0$:
    a. Write an expression for v_{OUT} in terms of v_{IN}.
    b. Sketch a graph of v_{OUT} vs. v_{IN}.



4. Repeat problem 3 with $r_D = R$.

5. For the circuit below using the constant voltage drop model with $V_{D0} = 0.7\,\text{V}$, $V_{Z0} = 1.4\,\text{V}$, $r_D = r_z = 0$:
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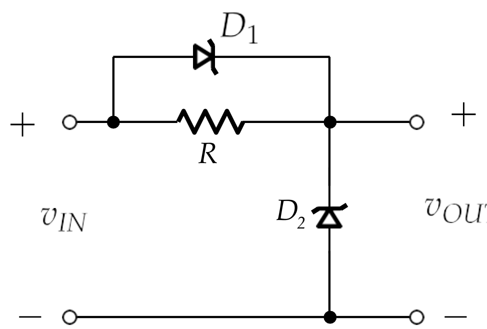
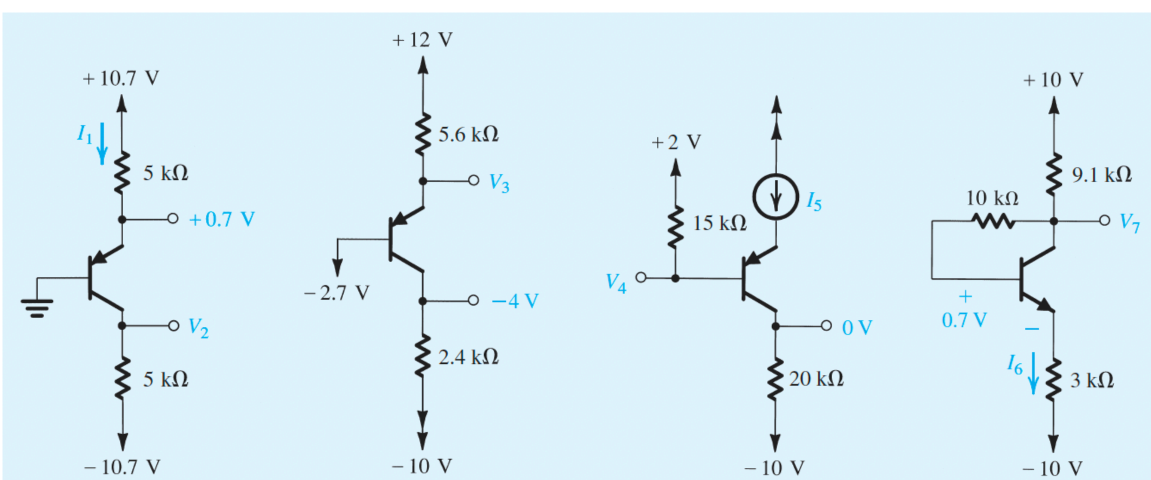


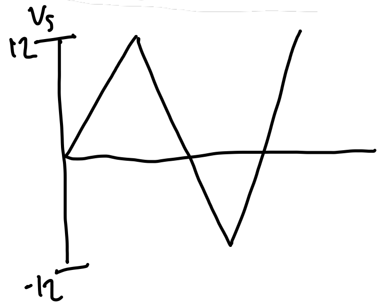
6. Measurements of V_{BE} and two terminal currents taken on a number of npn transistors operating in the active mode are tabulated below. For each, calculate the missing current value as well as α, β, and IS as indicated by the table.

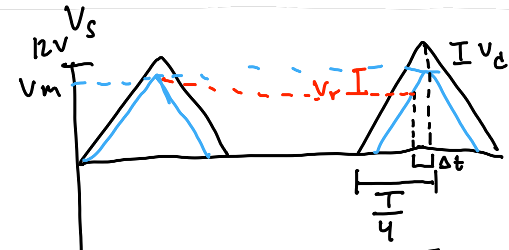
Transistor	a	b	c	d	e
V_{BE} (mV)	700	690	580	780	820
I_C (mA)	1.000	1.000		10.10	
I_B (μA)	10		5	120	1050
I_E (mA)		1.020	0.235		75.00
α					
β					
I_S					

7. For the circuits below, assume that the transistors have very large β. Some measurements have been made on these circuits, with the results indicated in the figure. Find the values of the other labeled voltages and currents.



1. Consider a half-wave peak rectifier fed with a voltage v_S having a triangular waveform with 24-V peak-to-peak amplitude, zero average, and 1-kHz frequency. Assume that the diode has a 0.7-V drop when conducting. Let the load resistance R = 100Ω and the filter capacitor C = 100 µF. Find the average dc output voltage, the time interval during which the diode conducts, the average diode current during conduction, and the maximum diode current.





$i_L = \frac{V_{dc}}{R}$

$i_C = C\frac{dv_c}{dt} \Rightarrow i_C \Delta t = C V_r$

$V_m = V_{s_{peak}} - V_D$

$V_m = 12 - (0.7)$

$V_m = 11.3\ [V]$

$V_m - V_r = V_m e^{-T/RC}$

$RC = .01 > T = .001$

$\therefore e^{-T/RC} \approx 1 - \frac{T}{RC}$

$V_m - V_m e^{-T/RC} = V_r$

$V_m(1-(1-\frac{T}{RC})) \approx V_r$

$V_m \frac{T}{RC} \approx V_r$

$\frac{V_m}{fRC} \approx V_r$

$\frac{11.3}{1K(100)(100\mu)} \approx V_r$

$V_r = 1.13$

$V_{dc,avg} \approx V_m - \frac{V_m}{2fRC}$

$V_{dc,avg} \approx 11.3 - \frac{11.3}{2(1K)(100)(100\mu)}$

$\boxed{V_{dc,avg} = 10.735\ [V]}$

$\frac{V_{s_{peak}}}{\frac{T}{4}} = \frac{V_r}{\Delta t}$

$4fV_{s_p} = \frac{V_r}{\Delta t}$

$\Delta t = \frac{1.13}{4(1K)(12)}$

$\Delta t = 23.5\ [\mu s]$ interval diode conducts

$i_{D_{avg}} = i_{C_{avg}} + i_L$

$i_{D_{avg}} = C\frac{dv_c}{dt} + \frac{V_{dc}}{R}$

$i_{D_{avg}} = \frac{CV_r}{\Delta t} + \frac{V_{dc}}{R}$

$i_{D_{avg}} = \frac{100\mu(1.13)}{23.5\mu} + \frac{10.735}{100}$

$i_{D_{avg}} = 4.92\ [A]$ average diode current in FB

$i_{D_{Max}} = 4.92\ [A]$

since $i_{C_{max}} \approx i_{C_{avg}}$ in Δt

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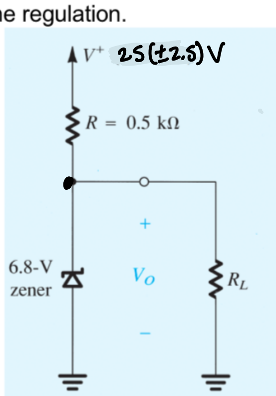


Fairchild BZX55C2V4

$V_Z(\text{nominal}) = 12\ [V]$

$I_Z = 5\ [mA]$

$Z_Z = 20\ [\Omega] = r_z$

$V_{Z0} = V_Z - I_Z \cdot Z_Z$

$V_{Z0} = 12 - (.005)(20)$

$\boxed{V_{Z0} = 11.9\ [V]}$

$V_Z(25mA) = V_{Z0} + Z_Z I_Z$

$= 11.9 + (20)(.025)$

$\boxed{V_Z(25mA) = 12.4\ [V]}$

$i_L = \frac{V_Z}{R_L} = \frac{12.4}{2.2K}$

$i_L = 5.64\ [mA]$

$i_R = i_Z + i_L$

$i_R = 25 + 5.64$

$i_R = 30.64\ [mA]$

$V^+ - V_Z = i_R \cdot R$

$R = \frac{V^+ - V_Z}{i_R}$

$R = \frac{25 - 12.4}{30.64}$

$R = 411.3 \approx 411\ [\Omega]$

line regulation:

$\Delta V_o = \Delta V^+\left(\frac{r_z \| R_L}{R + (r_z \| R_L)}\right)$

$\frac{\Delta V_O}{\Delta V^+} = \frac{20 \| 2.2K}{411 + (20 \| 2.2K)}$

$\frac{\Delta V_O}{\Delta V^+} = 0.046$

$\Delta V_o = \text{line reg.}(\Delta V^+)$

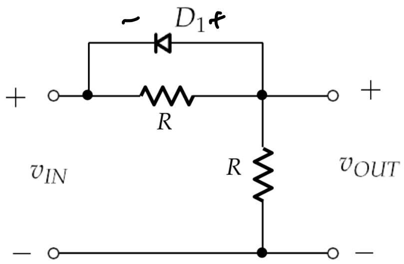
$\Delta V_o = (.046)(2.5)$

$\boxed{\Delta V_O = 0.115\ [V]}$

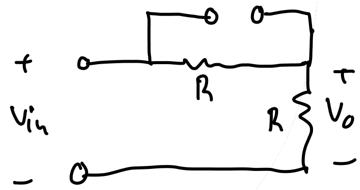
3. For the circuit below using the constant voltage drop model with $V_{D0} = 0.7$ V and $r_D = 0$:

   a. Write an expression for v_{OUT} in terms of v_{IN}.

   b. Sketch a graph of v_{OUT} vs. v_{IN}.



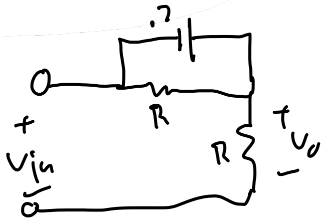
V_{in} − small



$$V_o = V_{in}\left(\frac{R}{R+R}\right)$$

$$V_o = \frac{V_{in}}{2}$$

D_1 conducts only for $V_{out} \geq V_{in} + .07$ [V]



$$V_o - V_{in} = 0.7$$

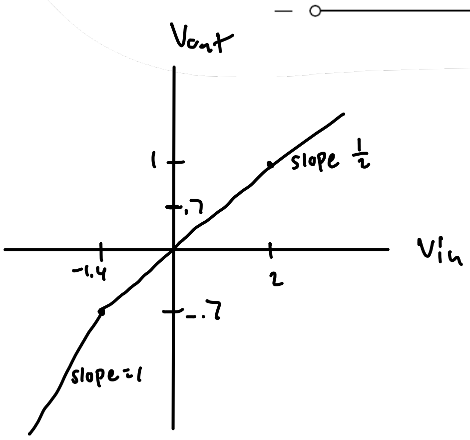
$$V_o = 0.7 + V_{in}$$

$$-0.7 \geq V_{in} - \frac{V_{in}}{2}$$

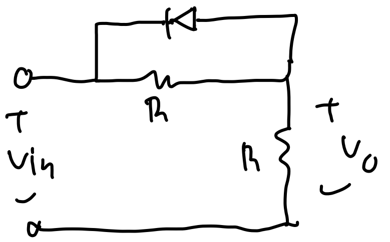
$$-0.7 \geq \frac{1}{2} V_{in}$$

$$-1.4 \geq V_{in}$$

$$V_o = \begin{cases} \frac{1}{2} V_{in}, & V_{in} \geq -1.4 \\ 0.7 + V_{in}, & V_{in} \leq -1.4 \end{cases}$$

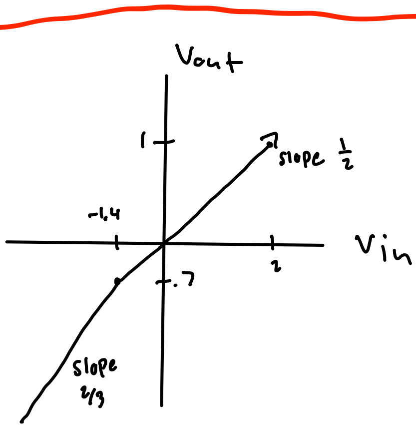


4. Repeat problem 3 with $r_D = R$.



V_{in} small $\Rightarrow$ $V_o = \frac{1}{2} V_{in}$

$$V_o = \begin{cases} \frac{1}{2} V_{in}, & V_{in} \geq -1.4 \\ \frac{7}{30} + \frac{2}{3} V_{in}, & V_{in} \leq -1.4 \end{cases}$$



conducts for $V_{out} \geq V_{in} + 0.7$

$$i_D + i_1 + i_2 = 0$$

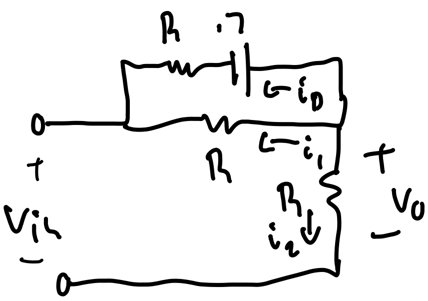
$$\frac{V_o + .7 - V_{in}}{R} + \frac{V_o - V_{in}}{R} + \frac{V_o}{R} = 0$$

$$3V_o - 2V_{in} - 0.7 = 0$$

$$3V_o = 0.7 + 2V_{in}$$

$$V_o = \frac{7}{30} + \frac{2}{3} V_{in}$$

$V_o - V_{in} = 0.7$



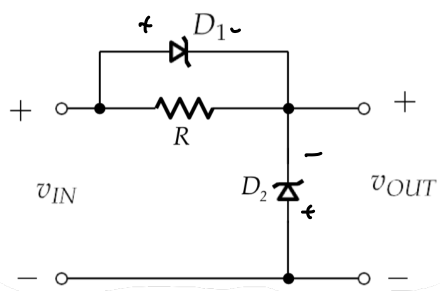
$$\frac{7}{30} + \frac{2}{3} V_{in} \geq V_{in} + 0.7$$

$$-\frac{7}{15} \geq \frac{1}{3} V_{in}$$

$$-1.4 \geq V_{in}$$

5. For the circuit below using the constant voltage drop model with $V_{D0} = 0.7\,\text{V}$, $V_{Z0} = 1.4\,\text{V}$, $r_D = r_z = 0$:

   a. Write an expression for v_{OUT} in terms of v_{IN}.
   b. Sketch a graph of v_{OUT} vs. v_{IN}.



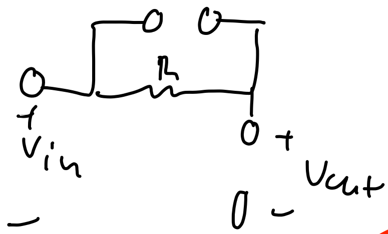
$V_{out} \le -0.7$, $D_2 \rightarrow$ FB $\therefore V_{out} = -0.7\,[V]$

$V_{out} \ge 1.4$, $D_2 \rightarrow$ rev. breakdown $\therefore V_{out} = 1.4\,[V]$

need V_{out} for $-0.7 \le V_{in} \le 1.4$

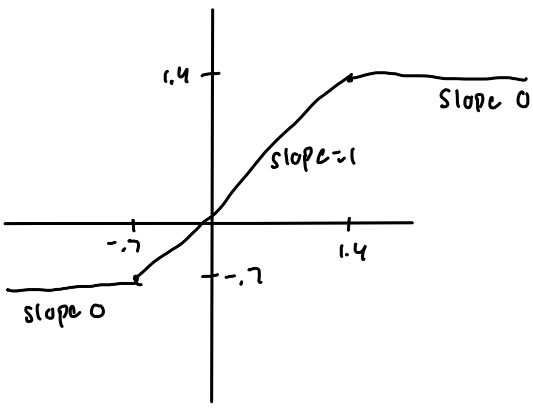
V_{in} - small : cant overcome $V_{D0} = 0.7 \therefore D_1 \rightarrow$ open

$V_{in} = 0.7$, cant overcome $V_{Z0} = 1.4$ for $D_2 \rightarrow$ open



$\therefore V_{out} = V_{in}$

$$V_{out} = \begin{cases} 1.4\,[V] & V_{in} \ge 1.4 \\ V_{in} & -0.7 \le V_{in} \le 1.4 \\ -0.7 & V_{in} \le -0.7 \end{cases}$$



6. Measurements of V_{BE} and two terminal currents taken on a number of npn transistors operating in the active mode are tabulated below. For each, calculate the missing current value as well as α, β, and IS as indicated by the table.

Transistor	a	b	c	d	e
V_{BE} (mV)	700	690	580	780	820
I_C (mA)	1.000	1.000	0.23	10.10	73.95
I_B (μA)	10	20	5	120	1050
I_E (mA)	1.01	1.020	0.235	10.22	75.00
α	0.99	0.98	0.979	0.988	0.986
β	100	50	46	84	70.43
I_S	$6.91 \cdot 10^{-16}$	$1.03 \cdot 10^{-15}$	$1.93 \cdot 10^{-14}$	$2.85 \cdot 10^{-16}$	$4.21 \cdot 10^{-16}$

$I_E = I_B + I_C$ $\quad \alpha = \frac{I_C}{I_E}$

$\beta = \frac{\alpha}{1-\alpha}$

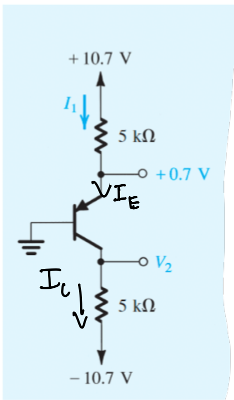
$I_c = I_s e^{\frac{V_{BE}}{V_T}}$ $\quad V_T \approx 25\,mV$

$1m = I_s e^{\frac{700m}{25m}}$

$1m\, e^{-28} = I_s$

$I_s = 6.91 \cdot 10^{-16}$

7. For the circuits below, assume that the transistors have very large β. Some measurements have been made on these circuits, with the results indicated in the figure. Find the values of the other labeled voltages and currents.



$$I_1 = \frac{10.7 - 0.7}{5K}$$

$$\boxed{I_1 = 2\,[mA]} = I_E$$

$$V_2 - (-10.7) = I_c \cdot 5K$$

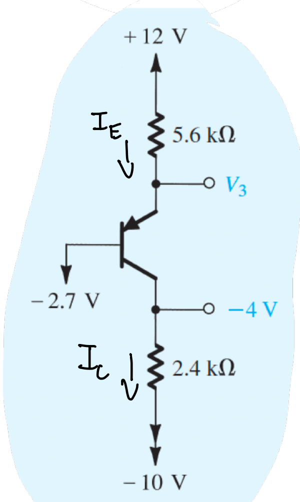
$$V_2 = I_c(5K) - 10.7$$

$$\boxed{V_2 = -0.7\,[V]}$$

$$I_c = \beta I_B \Rightarrow I_B = \frac{I_c}{\beta}$$

$$I_E = I_c + I_B \Rightarrow I_c + \frac{I_c}{\beta}$$

$$I_E = I_c\left(1 + \frac{1}{\beta}\right) \quad \beta \to \infty \Rightarrow I_E \approx I_c \therefore I_c \approx 2[mA]$$



$I_c \approx I_E$ since $\beta \to \infty$

$$I_E \approx I_c = \frac{-4 - (-10)}{2.4K} = 2.5\,[mA]$$

$$\frac{12 - V_3}{5.6K} = I_E$$

$$12 - I_E(5.6K) = V_3$$

$$\boxed{V_3 = -2\,[V]}$$

$I_c \approx I_E,\ I_B \approx 0$

$$I_c + I_B = I_E$$

$$I_c = I_E = I_6$$

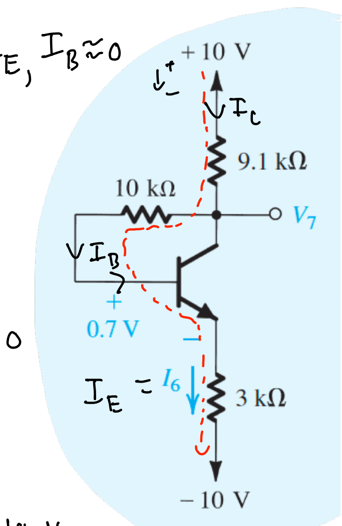
KVL:

$$10 + I_6 9.1K + \cancel{I_B}^{0} 10K + .7 + I_6 3K - (-10) = 0$$

$$I_6(9.1K + 3K) = 20 - .7$$

$$I_6 = \frac{19.3}{12.1K}$$

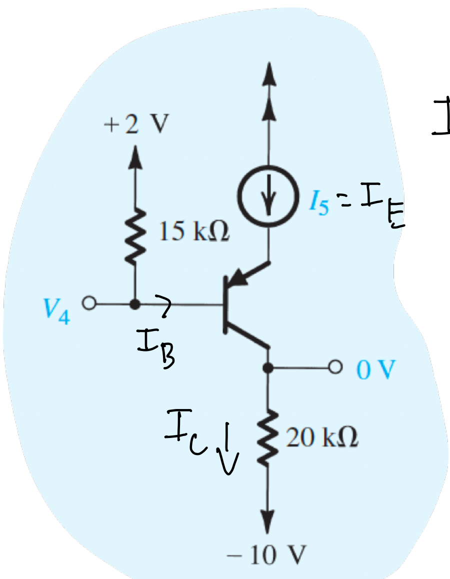
$$\boxed{I_6 = 1.595\,[mA]}$$



$$\frac{10 - V_7}{9.1K} = I_c$$

$$10 - I_c(9.1K) = V_7$$

$$\boxed{V_7 = -4.515}$$



$$I_E \approx I_c = \frac{0 - (-10)}{20K} = \boxed{0.5\,[mA]} = I_5$$

$$I_B = \frac{I_c}{\beta}, \quad \beta \to \infty \Rightarrow I_B = 0$$

$$\frac{2 - V_4}{15K} = 0$$

$$\boxed{V_4 = 2\,[V]}$$