Student Number & Name: ____________________

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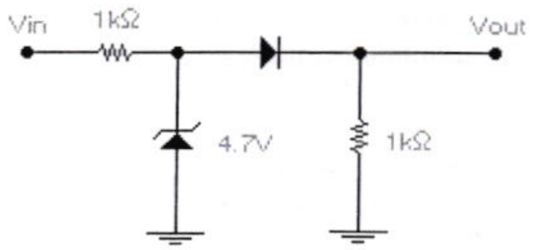
ES232 Midterm Make-up Exam

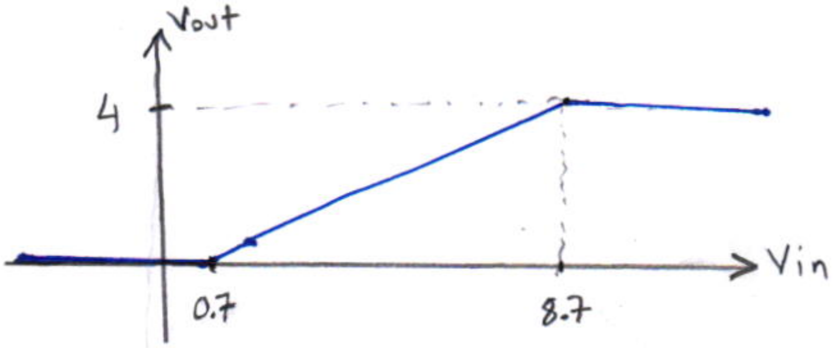
May 3, 2019

1) For the circuit in the figure, assume the diode is (0.7 Volt) ideal. Obtain and draw input-output voltage relationship.

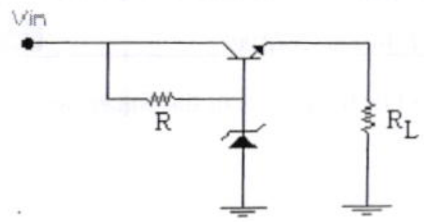


- if $V_{in} < 0.7$, the diode is off $\Rightarrow V_{out} = 0$.
- if $V_{in} > 0.7$, the diode is on:
  - if the zener off, $I_d = \frac{V_{in} - 0.7}{2K}$, $V_{out} = \frac{V_{in} - 0.7}{2}$

    the voltage on the zener: $\frac{V_{in} + 0.7}{2}$
  - if $V_{in} > 8.7$, the zener is on, $V_{out} = 4$



2) The voltage regulator circuit given has to produce 5V on R_L. The transistor has β=100 and V_{be}=0.7V (assume working in active region). R_L = 10 Ω.



a) What is the suitable Vz value?
b) If V_{in}=10V what should be the maximum value of R?
c) If R=100Ω, what should be the minimum value V_{in}?

a) $V_z = 5 + 0.7 = \underline{5.7\ V.}$

b) $I_E = \frac{5}{R_L} = 0.5\ A$, $I_B = \frac{I_E}{\beta+1} \cong 5mA$, $I_R > I_B$

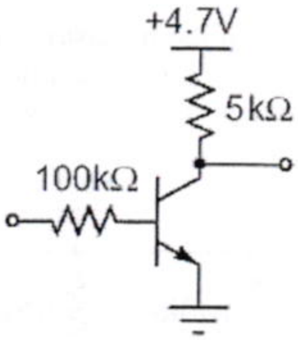
$\Rightarrow R < \frac{V_{in} - 5.7}{5mA} = \underline{860\ \Omega}$

c) $\frac{V_{in} - 5.7}{R} > 5mA$, $V_{in} > 5.7 + 5mA \cdot R$, $\underline{V_{in} > 6.2\ V}$

3) A simple logical inverter is shown in the figure.

a) When the input goes high (4.7V), the transistor should saturate as to have the minimum possible output voltage (V_{CEsat}=0.2 V). What is the minimal β the transistor must have to saturate at an input voltage of 4.7V given the resistors as shown?

b) Draw the input-output voltage transfer characteristics if the transistor has β=100. (Use the horizontal axis for the input voltage in the range of 0 to 4.7 volts. Use the vertical axis for the output voltage.)



a) $I_B = \dfrac{4.7 - 0.7}{100K} = 40\,\mu A$, $I_C = \dfrac{4.7 - 0.2}{5K} = 0.9\,mA$

$\Rightarrow \beta > \dfrac{0.9\,mA}{40\,\mu A} = \underline{\underline{22.5}}$

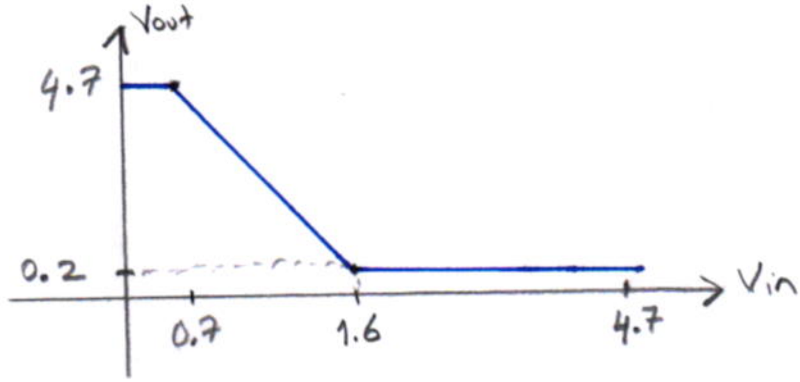
b) if $V_{in} < 0.7$, the transistor is off, $V_{out} = 4.7\,V$

if in active region:

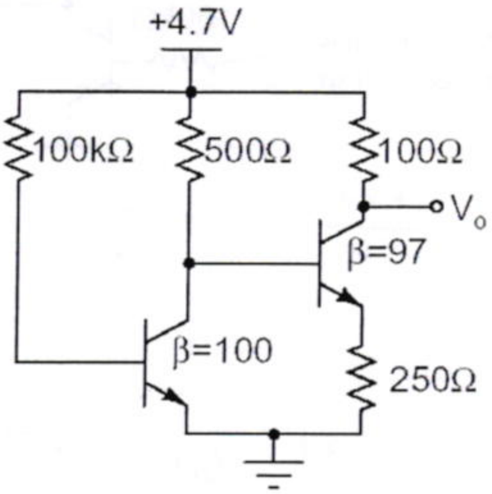
$I_B = \dfrac{V_{in} - 0.7}{100K}$, $V_{out} = 4.7 - 5K \cdot I_B \cdot \beta$

$\Rightarrow V_{out} = 4.7 - 5(V_{in} - 0.7) = 8.2 - 5 \cdot V_{in}$

if in saturation, $V_{out} = 0.2$, $V_{in} > \dfrac{8.2 - 0.2}{5} = 1.6\,V.$



4) In the transistor circuit shown below, assume that both transistors are biased in the active region. Use the index 1 for quantities pertaining to the transistor with $\beta = 100$ and the index 2 for those pertaining to the transistor with $\beta = 97$. Determine i_{b1}, i_{b2}, v_{ce1}, v_{ce2}, and the output voltage V_o.



$$i_{b1} = \frac{4.7 - 0.7}{100\,k} = 40\,\mu A$$

$$i_{c1} = 4\,mA$$

$$4.7 = 500\cdot(4mA + i_{b2}) + 0.7 + 250\cdot 98\cdot i_{b2}$$

$$\Rightarrow i_{b2} = 80\,\mu A$$

$$i_{c2} = 7.76\,mA$$

$$i_{e2} = 7.84\,mA$$

$$V_{ce1} = 4.7 - 500\cdot(4mA + 80\mu A) = 2.66\,V$$

$$V_{CE2} = 4.7 - 100\cdot i_{c2} - 250\cdot i_{e2} = 1.96\,V$$

$$V_o = 4.7 - 100\cdot i_{c2} = 3.92\,V$$