Test 1 (02/01/16)

Total # Pages 4
Total # Problems 4

Name SOLUTION

1. (10 points) __________
2. (25 points) __________
3. (40 points) __________
4. (25 points) __________

Total (100 points) __________

GOOD LUCK
1. A diode circuit and voltage waveform $v_s(t)$ are shown. (10 points).

![Diode Circuit Diagram]

List which diodes are ON (i.e., forward biased and conducting current) and which are OFF for $0 < t < 2$. Assume ideal diodes.

<table>
<thead>
<tr>
<th>ON Diodes:</th>
<th>OFF Diodes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_2$, $D_4$</td>
<td>$D_1$, $D_3$</td>
</tr>
</tbody>
</table>

List which diodes are ON and which are OFF for $2 < t < 4$. Assume ideal diodes.

<table>
<thead>
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<th>ON Diodes:</th>
<th>OFF Diodes:</th>
</tr>
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<tbody>
<tr>
<td>$D_1$, $D_3$</td>
<td>$D_2$, $D_4$</td>
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</table>

2. Consider the diode circuit shown below with a signal voltage waveform $v_s(t)$ as shown. Draw the specified voltage waveforms in the table below. (25 points).

![Diode Circuit Diagram]

Sketch the voltage waveform for $v_o(t)$ assuming an ideal diode. Label the time axes and the signal values.

![Voltage Waveform 1]

Sketch the voltage waveform for $v_o(t)$ assuming a constant voltage drop model for the diode (the diode voltage is at 0.5V when conducting). Label the time axes and the signal values.

![Voltage Waveform 2]
3. Answer the following questions. $|V_{BE}| = 0.7\,\text{V}$ for an ON transistor and $|V_{CE}| = 0.2\,\text{V}$ when the transistor is in saturation.

a) For the bipolar transistors and conditions shown in the following table calculate the missing entries. (15 points).

<table>
<thead>
<tr>
<th>Device</th>
<th>$I_C$ (mA)</th>
<th>$I_B$ (mA)</th>
<th>$I_E$ (mA)</th>
<th>$\alpha$</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>2</td>
<td>0.04</td>
<td>2.04</td>
<td>0.98</td>
<td>50</td>
</tr>
<tr>
<td>b</td>
<td>0.98</td>
<td>0.02</td>
<td>1</td>
<td>0.98</td>
<td>49</td>
</tr>
<tr>
<td>c</td>
<td>100</td>
<td>10</td>
<td>110</td>
<td>0.91</td>
<td>10</td>
</tr>
</tbody>
</table>

b) In the circuit shown, calculate the collector current and collector voltage assuming $\beta = 100$. (10 points).

$I_C = 1\,\text{mA}$ \hspace{1cm} V_C = 1.7\,\text{V}

$I_E = 1\,\text{mA} \Rightarrow I_C \approx 1\,\text{mA}$

$I_B = \frac{I_C}{\beta} \approx \frac{1}{100} \,\text{mA}$

$V_C = 0.7\,\text{V} + 100\,\text{k} \Omega \left( I_B \right) = 0.7 + 1 = 1.7\,\text{V}$

Active since $V_{CB} = 1\,\text{V}$ (reverse biased)

(c) For the circuit shown determine the region of operation (cutoff, active, or saturation) for the transistor with $\beta = 49$. (15 points).

Assume active

$I_B = \frac{I_E}{\beta + 1} = \frac{1\,\text{mA}}{50} = 0.02\,\text{mA}$

$\therefore \, \, V_B = 2 - 10 \times (0.02) = 1.8\,\text{V} \Rightarrow V_{BC} = 1.8\,\text{V}$

i.e. CBJ is forward biased

$\Rightarrow$ saturation
4. For the circuit shown, the emitter voltage is 4 V. Calculate the collector voltage and collector, base, and emitter currents for the transistor. Use this information to calculate $\alpha$ and $\beta$. Do not assume large $\beta$. $|V_{BE}| = 0.7$V for an ON transistor. (25 points).

\[ I_C = 0.4 \text{ mA} \quad I_B = 0.1 \text{ mA} \]
\[ I_E = 0.5 \text{ mA} \quad V_C = -1V \]
\[ \alpha = 0.8 \quad \beta = 4 \]

\[ I_E = \frac{5-4}{2} = 0.5 \text{ mA} \]
\[ V_B = 3.3 \text{ V} \]
\[ V_C = -5 + 8 \times 0.5 = -1 \text{ V} \]
\[ I_B = \frac{V_B - V_C}{43 \text{k}\Omega} = \frac{3.3 - (-1)}{43 \text{k}\Omega} = \frac{4.3}{43 \text{k}\Omega} = 0.1 \text{ mA} \]
\[ I_C = I_E - I_B = 0.5 - 0.1 = 0.4 \text{ mA} \]

\[ \beta = \frac{I_C}{I_B} = \frac{0.4}{0.1} = 4 \]

\[ \alpha = \frac{\beta}{\beta + 1} = \frac{4}{5} = 0.8 \]

Active since $V_{BC} = 4.3$V (reverse biased)