Exams Fall2015_2A

Tuesday, November 17, 2015 4:04 PM

Professors Schmitz, Varodayan, Choi, and Minin

ECE 110 November 17, 2015

Hour Examination #2

1) Write your official:
   Last Name (use capital letters): _____________________________
   First Name (use capital letters): _____________________________
   NetID: __________________________________________________
   UIN: ____________________________________________________

2) Fill in the Orange bubble sheet with all the information requested:
   a. LAST NAME, FIRST INITIAL example: SCHMITZ C
   b. STUDENT NUMBER (UIN) example: 678912345
   c. SECTION (AL1 9am enter 444, AL2 10am - 111, AL3 1pm - 222, AL4 2pm - 333)
   d. NETWORK ID (NetID) example: cdschmit
   e. Also, fill out the hand-written center of the sheet with course, instructor, section and your signature.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD

A. CALCULATORS ARE NOT ALLOWED ON THIS EXAM

B. Write or print clearly in this exam booklet for your own benefit. Circle the correct answer within the exam booklet and then mark it on the orange bubble sheet. You may not argue for points because you marked one answer in the exam and another on the bubble sheet, so be careful when marking your answers.

C. All problems are equally weighted.

D. Your grade will be determined based on the answers submitted on your bubble sheet.
   Submit both the bubble sheet AND the complete exam booklet.

Students caught cheating on this exam will earn a grade of F for the entire course. Other penalties may include suspension and/or dismissal from the university.

I have read and acknowledge the above statements. Furthermore, I promise not to give or receive help on this or any other exam.

________________________________________
Signature

Page 1 of 14
1. If a light-emitting diode (LED) has the turn on voltage $V_{ON} = 2 \, V$, what is the resistance $R$ needed to set the current through the LED to 25 mA (assuming the offset ideal model)?

- a. 40 $\Omega$
- b. 35 $\Omega$
- c. 30 $\Omega$
- d. 25 $\Omega$
- e. 20 $\Omega$

$$R = \frac{1 \, V}{25 \, mA} = \frac{1000 \, mV}{25 \, mA} = 40 \, \Omega$$

2. If a light-emitting diode (LED) has the turn on voltage $V_{ON} = 2 \, V$, what fraction of the power supplied by the 3 V source is consumed by the diode?

- a. 1/9
- b. 1/3
- c. 4/9
- d. 2/3
- e. Depends on $R$

$$P = IV \quad \text{with} \quad I \text{ same for all elements} \Rightarrow \frac{P_D}{P_R + P_D} = \frac{I(2V)}{I(3V) + I(2V)} = \frac{2}{3}$$

3. Assuming an offset ideal model, what is the current, $I$, through each of the two identical diodes if their turn on voltage is $V_{ON} = 0.7 \, V$?

- a. 10 mA
- b. 20 mA
- c. 35 mA
- d. 40 mA
- e. 55 mA

$$I_R = \frac{0.4 \, V}{10 \, \Omega} = 40 \, mA$$

$$I = \frac{I_R}{2} = 20 \, mA$$
At the required voltage $V_2$, $D_1$ is between ON & OFF

so $V_D = V_{ON}$ and $I_D = 0$

4. Assuming an ideal offset model with $V_{ON} = 0.7 \ V$ for each diode, what is the minimum voltage $V_2$ for which $D_1$ has no current flowing through it?

   a. 1.8 $V$
   b. 2.5 $V$
   c. 3.2 $V$
   d. 3.6 $V$
   ( ) 4.3 $V$

   $D_2$ is ON because current flows through that resistor
   Same $V$ as other resistor because same $I$

5. What are the minimum and maximum values of $V_{out}$ assuming the offset ideal model for the diodes with $V_{ON} = 0.7 \ V$ and the input signal given by $V_{in} = 3 \ cos(120\pi t) \ V$?

   a. minimum -3 $V$, maximum 2.2 $V$
   b. minimum -3 $V$, maximum 1.5 $V$
   c. minimum -3 $V$, maximum 0.8 $V$
   d. minimum 0.8 $V$, maximum 3 $V$
   e. minimum 2.2 $V$, maximum 3 $V$

Diode turns ON if $V_{in} > 2.2 \ V$
Then $V_{out} = 2.2 \ V$
6. What are the minimum and maximum values of $V_{\text{out}}$ assuming the offset ideal model for the diodes with $V_{\text{on}} = 0.7 \, \text{V}$ and the input signal given by $V_{\text{in}} = 2 \cos(120\pi t) \, \text{V}$?

   a. minimum -2 V, maximum 2 V
   b. minimum -2 V, maximum 1.4 V
   c. minimum -1.4 V, maximum 2 V
   d. minimum -0.7 V, maximum 1.4 V
   e. minimum -1.4 V, maximum 0.7 V

   $V_{\text{out}}$ range: -2 to 2 V

   **D1/D2** turn ON if $V_{\text{in}} > 1.4 \, \text{V}$; then $V_{\text{out}} = 1.4 \, \text{V}$

   **D3** turns ON if $V_{\text{in}} < -0.7 \, \text{V}$; then $V_{\text{out}} = -0.7 \, \text{V}$

7. How many of the light-emitting diodes are ON (emitting light) in the diagram below, assuming an offset ideal model with $V_{\text{on}} = 3 \, \text{V}$?

   a. 6
   b. 5
   c. 4
   d. 3
   e. none

   **At least 9 V is needed to turn on this chain.**
8. The **current source** in the model circuit below correctly represents the model of a
   a. base-emitter junction of a BJT  
   b. collector-emitter junction of a BJT  
   c. gate-body junction of an nMOS  
   d. gate-source junction of an nMOS  
   e. drain-source junction of an nMOS

![Diagram](image)

9. What is the base current, $I_B$, in the transistor circuit below?
   a. 0.18 mA  
   b. 0.09 mA  
   c. 0.04 mA  
   d. 0.02 mA  
   e. 0 mA

$$I_B = \frac{1.1 - 0.7}{20 \, \text{k}\Omega} = 0.02 \, \text{mA}$$

10. If we bias the transistor below with $R_B = 20 \, \text{k}\Omega$ and $R_C = 400 \, \Omega$ what is the output voltage, $V_{CE}$, when the input voltage, $V_{IN} = 1.7 \, \text{V}$?
   a. 6.2 V  
   b. 5.2 V  
   c. 4.2 V  
   d. 2.8 V  
   e. 0.2 V

$$I_B = \frac{1.7 - 0.7}{20 \, \text{k}\Omega} = 0.05 \, \text{mA}$$

$$I_C = \beta I_B = 5 \, \text{mA} \text{ unless SATURATED}$$

$$I_{C, \text{sat}} = \frac{6.2 - 0.2}{0.4 \, \text{k}\Omega} = 15 \, \text{mA}$$

$$V_{CE} = V_{CC} - I_C R_C = 6.2 - (5 \, \text{mA})(0.4 \, \text{k}\Omega) = 6.2 - 2 = 4.2 \, \text{V}$$
11. If we bias the transistor below with $R_B = 10 \, \text{k}\Omega$ and $R_C = 500 \, \Omega$ what is the minimum input voltage, $V_{IN}$, for which output voltage reaches saturation, i.e. $V_{CE} = 0.2 \, \text{V}$?

- a. 0.7 V
- b. 1.2 V
- c. 1.9 V
- d. 3.1 V
- e. 6.2 V

$$I_{C, sat} = \frac{6.2 - 0.2}{0.5\, \text{k}\Omega} = 12 \, \text{mA}$$

$$I_{B@active/sat} = \frac{I_{C, sat}}{\beta} = 0.12 \, \text{mA}$$

$$V_{in@active/sat} = I_{B@active/sat} \cdot R_B + V_{BE,on} = (0.12 \, \text{mA})(10 \, \text{k}\Omega) + 0.7$$

$$= 1.2 + 0.7 = 1.9 \, \text{V}$$

12. Cathy has just connected the circuit below, but cannot read the resistor code and does not know what value she used for either resistor. She measures $V_{CE}$ to be 6.2 V. What will $V_{CE}$ become if she adds a resistor identical to $R_C$ in series with $R_C$ (thereby increasing $R_C$ by a factor of two)? Note: You don’t need $V_{IN}$ to solve this.

- a. 0.2 V
- b. 3.1 V
- c. 4.2 V
- d. 5.5 V
- e. 7.2 V

At beginning, BJT is ACTIVE because $V_{CE} > V_{CE,sat}$ & $V_{CE} < V_{CC}$

After $R_C$ doubles

- Assuming BJT stays in ACTIVE mode,
  $$I_C = \beta I_B$$
  and is unchanged from before

- $I_C \cdot R_C$ doubles relative to old value of $8.2 \, \text{V} = 6.2 \, \text{V}$

- new $I_C \cdot R_C = 4 \, \text{V}$

- new $V_{CE} = 8.2 - 4 = 4.2 \, \text{V}$ ⇒ ACTIVE is correct
13. If we double the base current to 2 mA, the power dissipated by the transistor approximately

   a. goes up by a factor of 4
   b. goes up by a factor of 2
   c. remains the same
   d. goes down by a factor of 2
   e. goes down by a factor of 4

<table>
<thead>
<tr>
<th>( I_B (mA) )</th>
<th>( V_{BE} (V) )</th>
<th>( I_C (mA) )</th>
<th>( V_{CE} (V) )</th>
<th>( P (mW) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.7</td>
<td>100</td>
<td>2</td>
<td>200.7</td>
</tr>
<tr>
<td>2</td>
<td>0.7</td>
<td>200</td>
<td>1</td>
<td>201.4</td>
</tr>
</tbody>
</table>

14. Given the BJT IV characteristic with the load line provided, and assuming \( V_{BE, on} = 0.7V \), what is the output voltage, \( V_o \), when \( V_i = 1.1V \) in the circuit below?

   **HINT:** \( R_B \approx 40 \text{ k}\Omega \), while \( V_{CC} \) and \( R_C \) can be found from the load line.

\[ I_B = \frac{(1.1 - 0.7)V}{40 \text{ k}\Omega} = \frac{400 \text{ mV}}{40 \text{ k}\Omega} = 10 \text{ mA} \]
15. Given the BJT below biased with $V_{CC} = 5.2\, V$, $R_C = 200\, \Omega$, $R_B = 4\, k\Omega$, what is/are the regime(s) of operation of the BJT if the input voltage is given by

$$V_i(t) = 1.5 + 0.6\cos(200\pi t)?$$

- a. Active only
- b. Cut-off (Off) and Active
- c. Cut-off (Off) and Saturation
- d. Active and Saturation
- e. Cut-off (Off), Active, and Saturation

- \[ V_{BE, on} = 0.7\, V \]

- \[ V_{BE, on} + \frac{R_B}{\beta R_C} (V_{CE, sat} - V_{BE, on}) = 0.7 + \frac{4}{100 \times 0.2} (0.2 - 0.7) = 0.7 + \frac{0.8}{20} = 1.7\, V \]

16. If the BJT below is biased with $V_{CC} = 12\, V$ and $R_C = 200\, \Omega$, what should be the value of $R_B$ in order to set the magnitude of amplifier “gain” to ten, i.e. $G = \frac{V_{out} - V_{in}}{V_{in}} = -10$?

- a. 500\, \Omega
- b. 1\, k\Omega
- c. 1.5\, k\Omega
- d. 2\, k\Omega
- e. 5\, k\Omega

- \[ G = \frac{\beta R_C}{R_B} \]

- \[ -10 = -100 \frac{0.2\, k\Omega}{R_B} \]

- \[ R_B = \frac{100 \times 0.2}{10} = 2\, k\Omega \]
17. The drain-source junction of an nMOS with a grounded source, operating in the active region, can be modeled as a
   a. voltage source
   b. current source
   c. resistor
   d. diode
   e. capacitor

In the active region, the I-V curve is drawn as a horizontal line.

18. Consider the graph and the nMOS circuit below.
   If $I_1 = 5 \text{ mA}$, $V_{TH} = 2 \text{ V}$, $V_{GS} = 6 \text{ V}$, and $V_{DD} = 8 \text{ V}$ what is the value of $R_D$ which would result in $V_{DS} = 4 \text{ V}$?

   **Graph:**
   - $I_D = 16I_1$
   - $V_{DS} = 4 \text{ V}$
   - $V_{GS} - V_{TH} = 6 - 2 = 4$

   **Circuit:**
   - $V_{DD} = 8 \text{ V}$
   - $V_R = 4 \text{ V}$

   **Options:**
   a. 25 Ω
   b. 50 Ω
   c. 75 Ω
   d. 100 Ω
   e. 125 Ω

   $R_D = \frac{V_R}{I_D} = \frac{4000 \text{ mV}}{80 \text{ mA}} = 50 \Omega$
19. Which of the following output columns correctly represents the output of the logic gate circuit below for inputs A and B?

- a) \( Z_1 \)
- b) \( Z_2 \)
- c) \( Z_3 \)
- d) \( Z_4 \)
- e) \( Z_5 \)

\[
\begin{array}{cccc}
\text{Inputs} & A & B & Z_1 & Z_2 & Z_3 & Z_4 & Z_5 \\
\hline
0 & 0 & 1 & 0 & 1 & 0 & 0 \\
0 & 1 & 0 & 1 & 1 & 0 & 1 \\
1 & 0 & 1 & 0 & 0 & 1 & 1 \\
1 & 1 & 0 & 0 & 1 & 0 & 0 \\
\end{array}
\]

20. For which set of inputs below is this MOS logic circuit’s output \( Z \) simultaneously connected to both \( V_{dd} \) and ground?

- a) \( A = 0, B = 0, C = 0 \)
- b) \( A = 0, B = 0, C = 1 \)
- c) \( A = 1, B = 0, C = 0 \)
- d) \( A = 0, B = 1, C = 1 \)
- e) \( A = 1, B = 1, C = 1 \)
21. Jack’s integrated CMOS circuit consumes 2 W when powered with $V_{DD}$ of 6 V and running with the switching rate of 200 MHz and 5% activity factor. Jack can **triple the switching rate** to 600 MHz AND **triple activity factor** to 15% while consuming the **same power** if the circuit can operate with the $V_{DD}$ of

(Hint: 1 MHz = 1,000,000 Hz, but you don’t need it)

a. 12 V  

b. 6 V  

c. 3 V  

d. 2 V  

e. 1.5 V

22. If the average noise power in a 500 $\Omega$ resistor is 0.02 mW, what is the RMS signal voltage required to achieve the signal-to-noise power ratio of 16?

a. 140 mV  

b. 200 mV  

c. 280 mV  

d. 400 mV  

e. 640 mV

23. What is the frequency NOT present in the signal given by the equation below, where $t$ is in seconds?

$$v(t) = \cos(220\pi t) + 2 \cos(440\pi t) - \sin(740\pi t) + 3 \cos(880\pi t)$$

a. 740 Hz  

b. 440 Hz  

c. 370 Hz  

d. 220 Hz  

e. 110 Hz
24. If a sampling period is 0.25 s, what is the sample \( v[3] \) (for \( n = 3 \)) for the signal given below, where \( t \) is in seconds? (Note: trigonometric function reference is given below)

\[ v(t) = \cos(\pi t) - 2 \sin(2\pi t) \]

<table>
<thead>
<tr>
<th>( x )</th>
<th>( \pi/4 )</th>
<th>( \pi/2 )</th>
<th>( 3\pi/4 )</th>
<th>( \pi )</th>
<th>( 5\pi/4 )</th>
<th>( 3\pi/2 )</th>
<th>( 7\pi/4 )</th>
<th>( 2\pi )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sin(x) )</td>
<td>0</td>
<td>0.7</td>
<td>1</td>
<td>0.7</td>
<td>0</td>
<td>-0.7</td>
<td>-1</td>
<td>-0.7</td>
</tr>
<tr>
<td>( \cos(x) )</td>
<td>1</td>
<td>0.7</td>
<td>0</td>
<td>0.7</td>
<td>-1</td>
<td>-0.7</td>
<td>0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

\[ v[3] = \sqrt{\left( 3T_s \right)^2} = \sqrt{\left( \frac{\pi}{4} \right)^2} \]

\[ = \cos\left( \frac{\pi}{4} \right) - 2 \sin\left( \frac{\pi}{2} \right) \]

\[ = (0.7) - 2(-1) \]

\[ = 0.7 + 2 \]

25. What is the sampling period if 5000 samples are taken each second?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>4 ms</td>
</tr>
<tr>
<td>b.</td>
<td>2 ms</td>
</tr>
<tr>
<td>c.</td>
<td>1 ms</td>
</tr>
<tr>
<td>d.</td>
<td>0.5 ms</td>
</tr>
<tr>
<td>e.</td>
<td>0.2 ms</td>
</tr>
</tbody>
</table>

\[ f = \frac{5000}{H/s} \]

\[ T_s = \frac{1}{f} = \frac{1}{5000} = 0.0002 \text{ s} = 0.2 \text{ ms} \]