Written exam
IE1206 Embedded Electronics
IF1330 Electrical principles
Friday 17/8 2018 08.00-12.00

General Information
Examiner: Carl-Mikael Zetterling
Responsible teacher at exam: Per-Erik Hellström 08-790 43 25

All sheets that are handed in need your name and personal number written on them.
Mark every sheet with the problem it deals with.
You cannot have more than one problem per sheet.

Aids: Calculator
The exam consists of 8 problems (5 points each) distributed over the 4 modules in the course:
Module 1: problem 1 and 2
Module 2: problem 3 and 4
Module 3: problem 5 and 6
Module 4: problem 7 and 8

To pass the exam requires at least 2 points from each module and preliminary 20 points in total.
Grades are given as follows:

<table>
<thead>
<tr>
<th>Points</th>
<th>&lt;20</th>
<th>20-23</th>
<th>24-27</th>
<th>28-31</th>
<th>32-35</th>
<th>36-40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grades</td>
<td>F</td>
<td>E</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
</tbody>
</table>
1. Determine the electrical power consumed in $R_3$.
   $R_1=10 \, \text{k}\Omega$, $R_2=0.4 \, \text{k}\Omega$, $R_3=2 \, \text{k}\Omega$, $V_1=3.2 \, \text{V}$, $I_0=7 \, \text{mA}$.

2. Determine the Thevenin equivalent circuit seen at A-B.
   $V_1=6 \, \text{V}$, $R_1=1.5 \, \text{k}\Omega$, $R_2=4 \, \text{k}\Omega$.

3. The light emitting diode (LED) has a threshold voltage $V_T=2.0 \, \text{V}$, $R_1=1 \, \text{k}\Omega$ and $R_2=2 \, \text{k}\Omega$. Determine the current $I_o$ needed to have a current of $1 \, \text{mA}$ flowing through the LED so that it emits light brightly.
4. Assume the operational amplifier is ideal.

(A) Assuming operation in the linear region, derive an expression for $V_{out}$ as a function of $V_{in}$, $R_1$ and $R_2$.

(B) Within what voltage range must $V_{in}$ be to assure that the operational amplifier operates in the linear region? $R_1=1 \, \text{k} \Omega$ and $R_2=4 \, \text{k} \Omega$.

5. In the circuit below $V_o = 3 \, \text{V}$, $R_1=1 \, \text{k} \Omega$, $R_2=2 \, \text{k} \Omega$, $R_3=3 \, \text{k} \Omega$ and $C=10 \, \text{nF}$.

(A) The switch has been open for a long time. Calculate the RC time constant for charging up ($\tau_{up}$) the capacitor when the switch closes.

(B) The switch has been closed for a long time. Calculate the RC time constant for discharging ($\tau_{down}$) the capacitor when the switch opens.

6. The current source in the circuit generates the current pulse shown in the figure below.

(A) Derive a numerical expression for the voltage over the inductor, $V_L(t)$, in the interval $0<t<25 \, \mu\text{s}$.

(B) What is the energy stored in the inductor at $t=25 \, \mu\text{s}$?
7. (A) Derive an expression for the impedance \( Z \) as a function of the angular frequency \( \omega \) seen by the voltage source \( v_s \).

(B) Determine \( i(t) \) when the steady-state voltage source

\[ v_s = \sqrt{2}\cos(\omega t) \]

\( L=1 \) \( \text{H} \),
\( \omega=1000 \) \( \text{rad/s} \), \( R=1 \) \( \text{k}\Omega \) and \( C=1 \) \( \mu\text{F} \).

8. \( v_{in}(t) \) is a steady-state cosine voltage source with amplitude \( A \) and frequency \( \omega \).

(A) Derive a complex expression for \( \frac{v_{out}}{v_{in}} \) that include \( \omega \), \( R \) and \( L \).

(B) What type of filter function does the circuit perform? Motivate your answer.
Answers to written exam 17/8 2018

1. 12.5 mW of power is consumed in R3
2. VTH= 4 V, RTH=1.33 kΩ
3. Io=2.5 mA
4. A) \( V_{\text{out}} = -\frac{R_2}{R_1}V_{\text{in}} \)  B) -3.75 <V<3.75 V
5. A) \( \tau_{\text{up}}=5.5 \mu s \)  B) \( \tau_{\text{down}}=30 \mu s \)
6. A) \( V_L(t) = 100e^{-\frac{t}{25 \mu s}} \)  B) 25 µJ
7. A) \( Z = j\omega L + \frac{R}{1+j\omega RC} \)  B) \( i(t)=2\cos(\omega t-45) \) mA
8. A) \( \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{1}{1+j\omega \frac{L}{R}} \)

B) \( \omega \to 0 \) then \( \frac{V_{\text{out}}}{V_{\text{in}}} \to 1 \), \( \omega \to \infty \) then \( \frac{V_{\text{out}}}{V_{\text{in}}} \to 0 \)

This is an low pass filter