Ph.D. Qualifying Exam

September 14th, 2017

1:00-5:00pm

Electrical Engineering

Part I

Instructions:
This is a closed-book/closed-notes exam module, four hours in duration. There are ten (10) problems in this exam, and you will have a choice of answering only eight (8). The 4 questions from EE 234 and EE310 are required. The other 4 questions can be selected from other topics. The selected eight (8) questions must be clearly marked in the selection boxes below.

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Write your name and student ID below.

Full Name:  ____________________________________________

Student ID:  ____________________________________________

Please write your student ID Number of EVERY PAGE, but DO NOT write your name on any other pages of the exam.

Blank paper is provided if you need additional space to show your work. PLEASE INDICATE THE PROBLEM NUMBER ON EACH ADDITIONAL PAGE YOU USE.

Good Luck!
Question 1, ElecEng 234

a) Consider the following nonhomogeneous ODEs, find their homogeneous solution, and give the form (no need to determine coefficients) of nonhomogeneous solution. (48 points)
   i) $y'' + 4y' + 34y = 3e^{-x} \sin(4x) + \cos(4x)$
   ii) $y'' - 4y = 2 \cosh^2(x)$

b) Find the general solution of $y'' + 20y' + 25y = e^{-2.5x}$ with following steps i) Determine homogeneous solution, ii) Find nonhomogeneous solution with coefficients determined using method undetermined coefficients and iii) Arrive at the general solution. (52 points)

Usual equations $\cosh x = (e^x + e^{-x})/2$ and $\sinh x = (e^x - e^{-x})/2$
Final grade for this question: _________ out of 10 Points

Question 2, ElecEng 234

Consider the following matrix:

\[
\begin{pmatrix}
5 & 0 & 0 \\
0 & 1 & 4 \\
0 & 4 & 1
\end{pmatrix}
\]

a) Find its characteristic equation. (10 points)
b) Find all eigenvalues and the spectral radius of the matrix. (20 points)
c) Find all eigenvectors and the geometric multiplicity of each eigenvalue. (70 points)
Question 3, ElecEng 310

(a) Using z transform, find the zero-state response of an LTI Digital system:

\[ y[n+2] + y[n+1] + 0.16y[n] = x[n+1] + 0.32x[n] \]

for the input \( x[n] = (4)^{-n}u[n] \). (10 points)

(b) Repeat (a) using time-domain method (10 points)
Question 4, ElecEng 310

For the system described by the differential equation, find the zero-state unit step response of its inverse system, so that the cascade system of the system and its inverse system is an identity system:

\[
\frac{d^2 y(t)}{dt^2} - 2\frac{dy(t)}{dt} - 8y(t) = \frac{d^2 x(t)}{dt^2} - 2\frac{dx(t)}{dt} - 3x(t)
\]
Question 5, ElecEng 301

In the circuit shown, assume $V_{s1}$ is a sinusoidal voltage source. For the dependent source, $A$ is the current (top to bottom) through the capacitor and $\alpha$ is a proportionality constant. Determine

1. the current through the voltage source $V_{s1}$ (including direction)
2. the value of $\alpha$ to make the current through the voltage source $V_{s1}$ equal to zero.
3. Find the current through the resistors for this $\alpha$ value (i.e., the $\alpha$ value from part 2).
If \( v_C(0^-) = 2V, \ i_L(0^-) = 1A \), Please determine

(a) \( i_R(0^+) \), \( V_L(0^+) \)

(b) \( \frac{dv_C(0^+)}{dt}, \frac{di_L(0^+)}{dt} \)

(c) the general solution of \( i_L(t) \) and \( i_R(t) \)
Problem 7. Please analyze the circuit shown below to determine the voltages at all marked nodes and current through all marked branches (assume $\beta = 100$, $|V_{BBQ1}| = 0.7 \, \text{V}$).
Final grade for this question: ________ out of 10 Points

Question 8, ElecEng 335

Problem 8. The differential amplifier shown below uses transistors with $\beta = 100$. Evaluate the following:

(a) The input differential resistance $R_{id}$
(b) The CMRR in dB

[Diagram of the differential amplifier with labeled components]

Student ID: _____________
Question 9, ElecEng 354

Design a combinational logic circuit with three inputs A, B, and C and one output F. The output F=1 when the value of the input in binary is less 3.

a) Give the truth table for the function F.
b) Express function F as sum of its minterms.
c) Simplify F using the Karnaugh Map and obtain minimal sum of products and minimal product of sums.
d) Draw logic circuit of F corresponding to its minimal sum of products expression using logic gates.
e) Draw logic circuit using NAND gates only.
f) Draw logic circuit using a PLA.
Question 10, ElecEng 367

A • Answer each of these questions with one or a few complete sentences.

1. Describe the main functions of registers in a microprocessor.

2. Describe the main functions of buses in a microprocessor.

3. Describe the main functions of logic in a microprocessor.
4. Write one or two paragraphs comparing and contrasting the use of static memory and stack memory in a microprocessor.

5. Describe the important element of the way microprocessors were used that would not be possible without stack memory.
B. The PIC 18 is an 8-bit microcontroller. A simplified block diagram of the PIC18 is seen in figure 1. Considering PIC18 block diagram, answer each of these questions.

![Figure 1: PIC18 block diagram (simplified).](image)

1. Name four buses in the microprocessor, and give the number of bits in each

   - 
   - 
   - 
   - 

2. The instruction

   ```
   MOVLW 0x25 ;; 0x25 -> [W]
   ```

   moves the literal value 0x25 into the W register. It is indicated to the processor by the machine code $0E25

3. Where in the block diagram does the $0E25 reside before this instruction is executed?

   (a) Where in the block diagram is the $0E25 machine code transferred at the time it is executed?

   (b) Does execution of this instruction activate the “Data Address” seen in the upper right?

   (c) Describe the path taken by the literal value 0x25 the through the PIC18 processor as the instruction `MOVLW 0x25` is executed, that is, list the points the data passes as it is moved.
Question 11, ElecEng 481

For a non-degenerate semiconductor uniformly doped to \( N_D \) and \( N_A \),

a) derive general formula for free electron density, \( n(N_D,N_A) \) and discuss key cases.

b) using the obtained expression for the electron density, \( n(N_D,N_A) \) show that when \( N_A >> N_D >> n_i \), the electron density becomes

\[
  n \approx \frac{n_i^2}{N_A}
\]
Question 12, ElecEng 481

Explain how the free electron density, n(T) changes as a function of temperature in a non-degenerate n-type semiconductor with the band gap of $E_g$ doped to $N_D$. Consider the full temperature range: $0 \leq T < +\infty$.

If you are to build a free-electron based T-sensor from n-Si which is to be used for high T ($T \to +\infty$) monitoring. Investigate and plot the sensor relative sensitivity defined as $\frac{1}{n} \frac{dn}{dT}$ as a function of T. Recall, that the intrinsic electron density is given by $n_i = AT^{1.5}e^{-E_g/2KT}$, where A is some constant.
Question 13, ElecEng 362

A three-phase, 500kVA, 13000/4000 V, 60Hz, transformer with Δ-Y winding is supplying a three-phase 500kVA, 4000V, 0.8 PF (lagging) load. The equivalent line-neutral impedance of the transformer winding referred to the primary (high voltage side) is 0.05+j0.15 Ω.

(a) Determine the transformer winding currents
(b) Determine the line to line input bus voltage at the transformer primary terminals
(c) Determine the line input current to the transformer primary terminals
(d) Determine the efficiency of the system
Question 14, ElecEng 362

Consider the ferrite bead (toroid) through which the supply current, \( i_1 \), and return current, \( i_2 \), to and from an active electronic circuit are routed (note that the arrows denote the directions in which the amplitudes of the currents are positive). The electronic circuit is generating a common mode current, defined by the following relationship, which will result in a total core flux \( \Phi_c \) flowing in the direction shown because \( |i_1| > |i_2| \) and, hence, \( i_{cm} \neq 0 \).

\[
i_{cm} = i_1 - i_2
\]

If the permeability in the core is \( \mu_c \) and the cross-sectional area of the core is \( A_c \) then

(a) Use Ampere’s law and Gauss’s Law to find an expression for the flux in the core due to the common mode current (expressed in terms of \( i_1 \) and \( i_2 \)). \( \text{(Hint: remember the relationship between the current enclosed and the applied MMF in a magnetic circuit)} \)

(b) Find the self inductances due to the supply line \( (i_1) \) and return line \( (i_2) \) and the mutual inductances. \( \text{(Hint: one way to do this is to find the flux linkages first)} \)