THE MIN H. KAO DEPARTMENT
OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

PhD QUALIFYING EXAMINATION FOR THE ELECTRICAL ENGINEERING AND COMPUTER ENGINEERING PROGRAMS

Monday, August 17, 2009
FERRIS HALL

Be sure to put your ID number on each sheet that has material to be graded. Do not put your name on any sheet.

There are 14 equally weighted problems. You are to SELECT ANY EIGHT of these to answer. You must make it very clear which eight that you choose. (If it is not clear, then the first eight problems that you attempt will be graded.) Indicate your selections in two ways:

1. Circle below which eight problems that you want graded.

2. If you write anything other than your ID number on the page of a question that you do not graded, then cross out that page with a large X from corner to corner.

Circle the eight questions that you want graded:

1
2
3
4
5
6
7
8
9
10
11
12
13
14

Do all work on the paper supplied to you. Do not write on the back of any page.

STUDENT NAME: _____ STUDENT ID# XXX-XX- _ _ _ _

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Problem 1: Digital Logic

Given the following function of four inputs:

$$F(A,B,C,D) = \overline{A}\ B\ C + A\ D + A\ C$$

(a) Implement the function using an 8:1 Multiplexor.
(b) Implement the function using a 4:16 decoder and a single OR gate.

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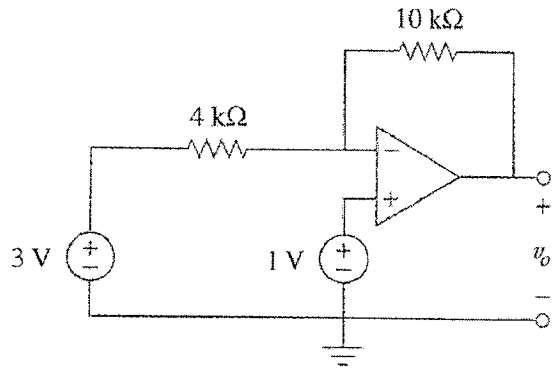
Problem 2: Basic Circuits

Calculate v_o in the op amp circuit



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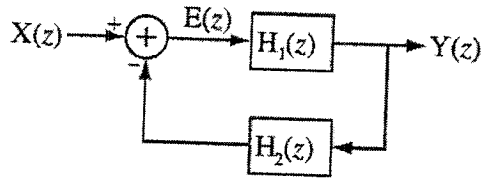
Problem 3: Signals and Systems

A discrete-time feedback system (see diagram below) has a forward-path transfer function $H_1(z)=\frac{Kz}{z-0.5}$ and a feedback-path transfer function $H_2(z)=1+z^{-1}$. For what range of real values of K is this system stable?



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Problem 4: Calculus

1) Show that the function $f(x)=\frac{1}{x^2}$ is not uniformly continuous on $(0, 1)$.

2) Show that $\sum_{n=1}^{\infty} 2^{-n} x^n$ represents a function f on $(-2,2)$, but that the convergence is not uniform.

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Problem 5: Programming

Write a C++ function whose header is

```
int eval (unsigned n, int * v);
```

where v is a pointer to the first element of an array of n values. The function is to find the largest value in the array and return the number of times this value occurs in the array. The function can make only one pass through the array. In other words, the algorithm must have complexity O(n).

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Department of EECS, University of Tennessee

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Problem 6: Probability and Statistics

The number X is randomly (and uniformly) selected between [-1,1]. Let A denote the event $\{|X-0.5|<1\}$ and B the event $\{X>3/4\}$. Find $P(A|B)$ and $P(B|A)$.

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Department of EECS, University of Tennessee

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Problem 7: Communications

1A. Define, answer or explain the following:

a. List at least 1 source of multipath interference

b. What is the implication of the *threshold effect* in FM communication?

c. Under what circumstances do the envelope and product detectors have the same signal-to-noise (SNR) performance?

d. Given a long coax cable between an antenna and receiver. If it is desired to add a preamplifier, should it go near the antenna, or can it be put next to the receiver? Justify your answer.

e. List at least 2 sources of noise in wireless communications (do not include interference).

f. Describe why FM is superior to linear modulation systems with respect to battery life and power efficiency.

g. List the primary characteristics of a channel that limit the bit rate (baud) of a signal transmission.

1B. Consider a DSB signal where the transmitter power output is $S_T = 100$ watts and the message power is $S_x = 0.75$. The signal is received at a $(S/N)_D = 40$ dB. What is the new transmitter power output if the modulation scheme is changed to 100% AM with the goal of maintaining the same value of $(S/N)_D = 40$ dB?

Student ID: _____ Score: _____

Problem 8: Computer Architecture

Here is a series of address references given as word addresses: 1,4,8,5,20,17,19,56,9,11,4,43,5,6,9,17,21,12

Assuming a direct mapped cache with 8 two-word blocks that is initially empty, label each reference in the list as a hit or a miss and show the final contents of the cache.

Assuming a two-way set-associative cache with two-word blocks and a total size of 16 words that is initially empty, label each reference in the list as a hit or a miss and show the final contents of the cache. Assume LRU for the replacement policy.

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Problem 9: Operating Systems

One of the most studied problems in process synchronization and communication is the readers and writers problem. Let $R = \{r_1 \ldots r_m\}$ be a set of processes that read from a database. Let $W = \{w_1 \ldots w_k\}$ be a set of processes that write values to the same database. The system is subject to the following constraints:

1. Readers and writers can never access the database simultaneously;
2. Only a single writer at a time is allowed in the database;
3. Multiple readers may access the database simultaneously;

A semaphore *db* is used to prevent simultaneous access to the database from the readers and writers. An *int* variable *readcount* is used to count how many readers are there and the semaphore *mutex* is used for exclusive access to *readcount*. You can use P/V operations for the two standard atomic operations: wait and signal. For example, *db.P()* is equivalent to *wait(db)* or *down(&db)* used in some textbooks;

Please complete the following pesudocode to implement the reader and writer functions.

```
//shared variables
Semaphore mutex(1), db(1);
int readcount = 0;              //number of processes reading or wanting to read

  writer()
  {




  }

  reader()
  {




}
```

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Department of EECS, University of Tennessee

Student ID: _____ Score: _____

Problem 10: Algorithms and Data Structures

An array contains N numbers, and you want to determine whether two of the numbers sum to a given number K. For instance, if the input is 8, 4, 1, 6 and K is 10, the answer is yes (4 and 6). A number maybe used twice. Do the following.

a. Give an $O(N^2)$ algorithm to solve this problem.
b. Give an O(NlogN) algorithm to solve this problem. (Hint: Sort the items first. After doing so, you can solve the problem in linear time.)

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Student ID: _____ Score: _____

Problem 11: Electromagnetics

Allow the use of Smith Chart

A 1.05 GHz generator circuit with series impedance Z_g= 10Ω and voltage source given by

$$v_g(t) = 10\sin(\omega t + 30^o)$$

Is connected to a load Z_L=(100+ j50)Ω through a 50-Ω, 67 cm-long (i.e. l=67 cm) lossless transmission line. The phase velocity is 0.7c, where c is the speed of light in a vacuum. Find:

a) The wavelength λ
b) The reflection coefficient at the load Γ_L, and the voltage standing wave ratio VSWR
c) The reflection coefficient at the generator side $\Gamma_{inp}(z=-l)$.
d) The input impedance at the generator side $Z_{in}(z=-l)$
e) The phasor voltage representation of the generator voltage V_g
f) The phasor voltage on the line (i.e. at the input of the line), and its instantaneous value, i.e. function of z and t.
g) The incident phasor voltage V_o^+
h) The power delivered to the load.
i) Use single stub matching to match this load.

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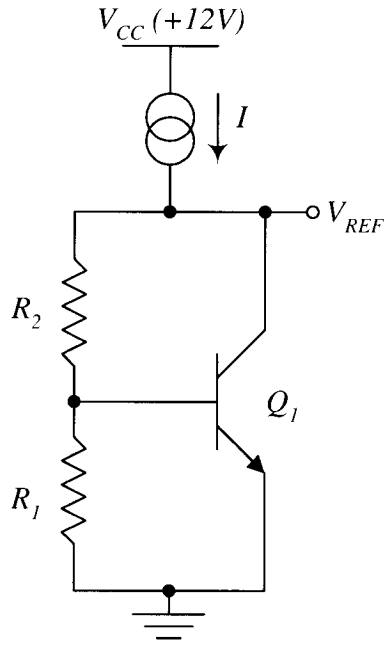
Student ID #: _____ **Score:** _____

Problem 12: Advanced Circuits

Find voltage V_{REF} and current I for the circuit provided below. Assume that Q_1 is operating in forward-active mode with $V_{BE} = 0.7$ V, and use $I_S = 10^{-16}$ A, $\beta_F = 300$, $V_T = kT/q = 25$ mV. You may neglect Early effect. Resistors $R_1 = 1$ KΩ and $R_2 = 3$ KΩ.



V_{REF} =

I =

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Problem 13: Linear Algebra

Please judge whether the following statements are correct. If not, please give a counter example (we assume that A, B and C are all square matrices, det(A) means the determinant of matrix A, rank(A) means the rank of matrix A):

- AB=BA
- A(B+C)=AB+AC
- (AB)C=A(BC)
- det(AB) = det(BA)
- rank(AB) = rank(A)rank(B)

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Problem 14: Power

A single phase transformer with rating 5kVA, 600V/120V, 60Hz has the following test data:

Short Circuit test (LV side shorted): V=65 volts, I=7.5 amps, P=175 watts
Open Circuit test (HV side open): V=120.0 volts, I=2.0 amps, P=150 watts

1) What are the winding resistance (R_{eq}) and leakage reactance (X_{eq}) parameters referred to the low voltage side?
2) What are the core impedance parameters R_c and X_m referred to the high voltage side?