ELECTRICAL AND COMPUTER ENGINEERING
PhD QUALIFYING EXAMINATION

Monday, January 11, 2010

Be sure to put your Exam Packet number on each sheet that has material to be graded. Do **not** put your name on any sheet other than at the bottom of this cover 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 Exam Packet number on the page of a question that you do not want 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

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13

14

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

STUDENT NAME: ____________________________ Exam packet number: _____

Exam packet number: _______________ Score: _______________

Problem 1: Digital Logic

Find a function to detect an error in the representation of a decimal digit in BCD. In other words, write an equation with value 1 when the inputs are any one of the six unused bit combinations in the BCD code, and value 0 otherwise. Based on your equation, please also implement it with only **NAND gates and inverters**.

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Department of EECS, The University of Tennessee

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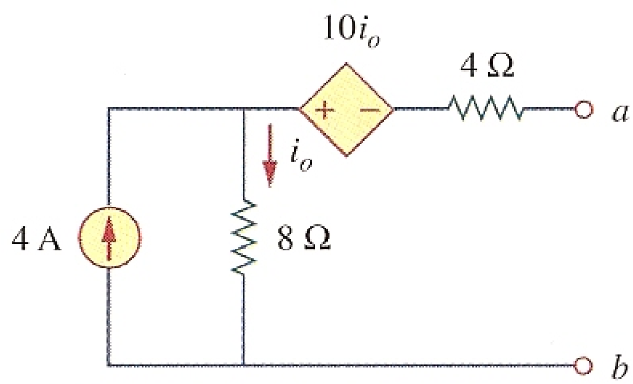
Problem 2: Basic Circuits

Determine the Norton equivalent at terminals *a*-*b* for the circuit



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Problem 3: Signals and Systems

One period of a periodic signal of period 20 ms is described by

$$\mathrm{x}(t) = \begin{cases} 1 \ , & |t| < 5 \text{ ms} \\ 0 \ , & 5 \text{ ms} < |t| < 10 \text{ ms} \end{cases} .$$

It can be represented by a Fourier series of the form

$$\mathrm{x}(t) = \sum_{k=-\infty}^{\infty} (1/2)\mathrm{sinc}(k/2) e^{j100\pi kt} .$$

(where $\mathrm{sinc}(t) = \dfrac{\sin(\pi t)}{\pi t}$). Assume that this signal can be reasonably approximated by a partial sum of the average value and the first 7 harmonics

$$\mathrm{x}_7(t) = \sum_{k=-7}^{7} (1/2)\mathrm{sinc}(k/2) e^{j100\pi kt}$$

The signal represented by this partial sum is impulse-sampled by being multiplied by a periodic impulse of period 1/60 second to produce

$$\mathrm{x}_\delta(t) = \mathrm{x}_7(t) \sum_{n=-\infty}^{\infty} \delta(t - n/60).$$

Let its continuous-time Fourier transform be defined by

$$\mathrm{X}_\delta(f) = \int_{-\infty}^{\infty} \mathrm{x}_\delta(t) e^{-j2\pi ft}\, dt .$$

At what cyclic frequencies f in the range $0 \le f \le 100$ Hz is this continuous-time Fourier transform non-zero?

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Problem 4: Calculus

Let (s_n) and (t_n) be the following sequences that repeat in cycles of four:

$$(s_n) = (0, 1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1, \cdots)$$

$$(t_n) = (2, 1, 1, 0, 2, 1, 1, 0, 2, 1, 1, 0, 2, 1, 1, 0, \cdots)$$

Find

(a) $\liminf s_n + \liminf t_n$
(b) $\liminf (s_n + t_n)$
(c) $\liminf s_n + \limsup t_n$
(d) $\limsup (s_n + t_n)$
(e) $\limsup s_n + \limsup t_n$
(f) $\liminf (s_n t_n)$
(g) $\limsup (s_n t_n)$

(Recall that $\limsup s_n = \lim_{N\to\infty} \sup\{s_n : n > N\}$ **and** $\liminf s_n = \lim_{N\to\infty} \inf\{s_n : n > N\}$ **.)**

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Problem 5: Programming

A header file already exists called Point.h that defines the Point class, which is implemented in the file Point.cpp. Objects of the Point class represent points in a 2D Cartesian coordinate system, and the class implements the binary operators + and – on Point objects, the Euclidian norm (distance from the origin) of a Point object p, p.norm(), and the inner product of two Point objects a and b, inner(a,b). The x and y coordinates of a Point object p are doubles and can be queried or set using the notation p.h() and p.v(), respectively.

Given two Point objects, write a new member function for the Point class whose prototype is

```
bool Point::above (Point &, Point &);
```

Where x.above(y,z) returns true if and only if the Point object x is located above (has vertical coordinate v greater than) the line that passes through Point objects y and z.

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Problem 6: Probability and Statistics

An unbiased coin is tossed repeatedly until a "tail" is observed for the second time. Find the probability that it would require k tosses to achieve that.

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Problem 7: Communications

A. Consider a superhetrodyne receiver that is supposed to pick up signals at $f_c = 30$ MHz, where the intermediate frequency is $f_{IF} = 5$ MHz, and the local oscillator frequency is below the incoming carrier frequency (i.e. $f_{LO} < f_c$). What is the image frequency? Show your work.

B. Consider a $f_c = 5$ MHz bandpass signal that is digitally modulated whereby the 0 and 1 message digits are the generated by turning the carrier on and off (on-off keying). Let's assume the on-off rate is $f_d = 100$ Hz. Sketch and label the output signal's power spectral density and determine its approximate null-to-null bandwidth (i.e. distance between the spectrum's first set of zero crossings).

C. Define or explain the following:

a. What is a double conversion superhetrodyne receiver?

b. How does a direct conversion receiver differ from a superhetrohetrodyne?

c. List at least 2 primary technical reasons why wireless phones use the UHF band.

d. Which type of detector (envelope or product) is preferred for weak signal reception?

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Problem 8: Computer Architecture

You are the lead designer of a new processor. The processor design and compiler are complete, and now you must decide whether to produce the current design as it stands or spend additional time to improve it. You discuss this problem with your hardware engineering team and arrive at the following options:

a. *Leave the design as it stands.* Call this base computer *Mbase*. It has a clock rate of 800 MHz, and the following measurements have been made using a simulator:

Instruction Class	CPI	Frequency
A	2	40%
B	3	25%
C	3	25%
D	5	10%

b. *Optimize the hardware.* The hardware team claims that it can improve the processor design to give it a clock rate of 950 MHz. Call this computer *Mopt*. The following measurements were made using a simulator for *Mopt*:

Instruction Class	CPI	Frequency
A	2	40%
B	2	25%
C	3	25%
D	4	10%

What is the CPI for each computer? What are the native MIPS ratings for Mbase and Mopt? How much faster is Mopt than Mbase?

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Problem 9: Operating Systems

The producer-consumer problem illustrates the need for synchronization in systems where many processes share a resource. In the problem, two processes share a fixed-size buffer. One process produces information and puts it in the buffer, while the other process consumes information from the buffer. These processes do not take turns accessing the buffer, they both work concurrently. Herein lies the problem. What happens if the producer tries to put an item into a full buffer? What happens if the consumer tries to take an item from an empty buffer? Complete the following pseduocode to implement producer and consumer functions, respectively.

```
BufferSize = 3;
count = 0;

Producer()
{

}

Consumer()
{

 }
```

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Problem 10: Algorithms and Data Structures

Basic understanding

a. General-purpose data structures include arrays, linked lists, trees, and hash tables. Try to comment on their differences. Under what situations would you use which data structure?
b. Stacks, queues, priority queues, and graphs are examples of specialized data structures. Try to comment on their differences. Under what situations would you use which structure?
c. For each of the following program fragments, give the Big-Oh analysis of the running time. Order the fragments by growth rate.

```
// Fragment #1
for (int i=0; i<n; i++)
  sum++;

// Fragment #2
for (int i=0; i<n; i+=2)
  sum++;

// Fragment #3
for (int i=0; i<n; i++)
  for (int j=0; j<n; j++)
    sum++;

// Fragment #4
for (int i=0; i<n; i++)
  sum++;
for (int j=0; j<n; j++)
  sum++;

// Fragment #5
for (int i=0; i<n; i++)
  for (int j=0; j<n*n; j++)
    sum++;

// Fragment #6
for (int i=0; i<n; i++)
  for (int j=0; j<i; j++)
    sum++;
```

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Problem 11: Electromagnetics

A multi layer structure is comprised of three layers: the first is air, the second has ε_{r2} = 9, and the third has ε_{r3} =4. The thickness of the second layer is 1.2m. What is:

a) the reflection coefficient at 50 MHz
b) the transmission coefficient at 50 MHz.
c) the fraction of incident average power density reflected by the structure

if

1) A normal plane wave incidence
2) A Plane wave incident with a 30 degrees (parallel incidence)

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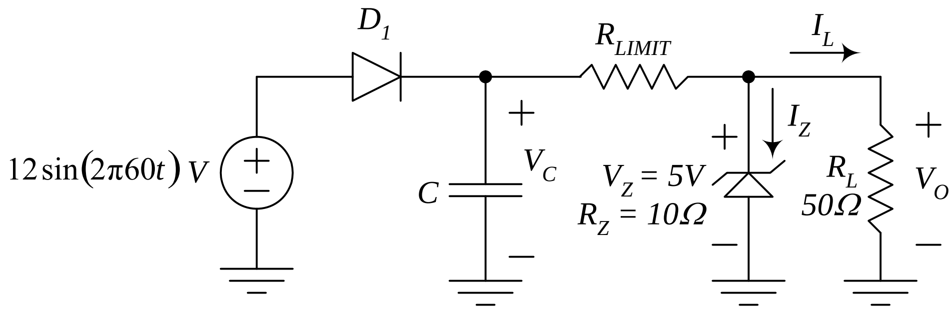
Problem 12: Advanced Circuits

Consider the Zener-regulated power supply circuit shown below. For diode D_1 you may assume $V_{ON} = 0.7$ V.



a) Is this a half-wave or full-wave rectifier? ____________________________

b) What is the nominal DC output voltage V_O? V_O = ____________________

c) What is the maximum voltage across C? V_{Cmax} = __________________

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Problem 13: Linear Algebra

Suppose that real symmetric matrices A and B are positive definite. Is their product AB still positive definite? If not, please give a counter example. How about their sum A+B and difference A-B?

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Problem 14: Power

A three-phase, balanced induction machine is connected to rated supply. The synchronous speed of this machine is 1800 rpm. The parameters of its Thevenin equivalent circuit (for one-phase) under rated supply is given as:

V_{th}=250V, R_{th}=0.06 Ω, X_{th}=0.20 Ω, R'_2=0.05 Ω, X'_2=0.25 Ω

Determine:

1) Draw the Thevenin equivalent circuit (for one-phase).
2) The maximum torque the machine can develop.
3) The speed at which the maximum torque is developed.
4) The startup torque.
5) The external resistance required in each rotor phase, if the maximum torque is to occur at start. Assume a turns ratio (stator to rotor) of 2.0.

Needed equations (for one-phase):

$$\omega_{syn} = n_s \frac{2\pi}{60}$$

$$T_{mech} = \frac{1}{\omega_{syn}} \frac{V_{th}^2}{\left(R_{th} + R_2'/s\right)^2 + \left(X_{th} + X_2'\right)^2} \frac{R_2'}{s}$$

$$s_{T_{\max}} = \frac{R_2'}{\sqrt{R_{th}^2 + \left(X_{th} + X_2'\right)^2}}$$

$$T_{\max} = \frac{1}{2\omega_{syn}} \cdot \frac{V_{th}^2}{R_{th} + \sqrt{R_{th}^2 + \left(X_{th} + X_2'\right)^2}}$$