ELECTRICAL AND COMPUTER ENGINEERING

PhD QUALIFYING EXAMINATION

Session 2

August 23, 2005

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 13 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 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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12
13

Do all work on the paper supplied to you. Do not write on the back of any page.
Problem 1-2

Consider the following Finite State Machine circuit.

1. Find the state table of this FSM circuit. *(Show all the steps of your analysis).*
2. Find the output sequence and the function of this FSM circuit.
Find the value of the maximum average power that can be transferred to the load $Z_L$, if that complex load impedance can be made any value we wish.
Problem 3-2

A periodic rectangular-wave signal, \( x(t) \), with a period of 1 ms, is the excitation of a single-pole, lowpass filter with a transfer function of

\[
H(s) = \frac{1}{1 + \tau s}
\]

where \( \tau = 1 \text{ ms} \). One period of \( x(t) \) is described by

\[
x(t) = \begin{cases} 1, & 0 < t < 0.1 \text{ ms} \\ 0, & 0.1 \text{ ms} < t < 1 \text{ ms} \end{cases}
\]

The response of the filter is \( y(t) \). Find the minimum and maximum values of \( y(t) \), \( y_{\text{min}} \) and \( y_{\text{max}} \), over all time.
Find the general solution of the second order equation

\[ x \frac{d^2y}{dx^2} + \frac{dy}{dx} = x^3 \]

where \( x \) is the independent variable.
The $n+1$ coefficients of an $n$-th degree polynomial are stored in the C++ array of doubles named `coeffs`, and a floating point value is stored in the C++ double named `x`. The C++ `int` named `n` holds the degree of the polynomial. Write a loop using C++ to evaluate the polynomial at the value stored in `x`, assuming that the coefficient for the term of greatest power of `x` is stored first in the array. Store the result in the C++ double named `z`. You can assume that `z` is initialized to zero.

All of your code must be written in C or C++. 
It is possible to create a processor capable of running all programs using a single
instruction type (but you must be clever). It is even easier to create a universal processor
using two instruction types. Give two instruction types that will allow you to execute any
program. (To clarify – your processor only has two machine code instruction types/legal
opcodes.) You may assume your processor is a load/store architecture, memory-memory
architecture, accumulator, or stack-based (but be sure to state this!). Also, you may
assume the processor includes a condition code register with typical condition codes
recorded. Explain your choice and give simple examples such as how common control
structures are implemented, arithmetic, branching, logical instructions, etc.
A cyclic sorted list is one type of list data structure where $x_1 < x_2, \ldots < x_n$, but $x_1$ (starting point) and $x_n$ (ending point) are "connected" to form a cycle. For example, in the following list, 56 is the starting point and 100 is the ending point.

80 85 90 95 100 56 78

Design an algorithm to identify the "ending point". Hint: the easiest algorithm can accomplish the task with linear time; but you can also do so in logarithmic time.
Recall the classic dining philosopher's problem:
Five philosophers sit around a circular table. Each of the five philosophers leads a simple
life alternating between thinking and eating spaghetti. In front of each philosopher is a
dish of spaghetti that is constantly replenished by a dedicated server. There are exactly
five forks on the table, one between each adjacent pair of philosophers. Eating spaghetti
requires that a philosopher use both forks (simultaneously) which are adjacent to his
plate. You have been tasked with finding an algorithm that allows the philosophers to eat
and think without deadlock or starvation. Note that two philosophers cannot use the
same fork at once. You have been given the following pseudo-code, but there is one or
more errors in the code. You must identify the errors and fix them. Discussion: why is
this problem considered relevant to the field of operating systems?

procedure philosopher
    begin
        while true do
            begin
                thinkforawhile;
                pickupleftfork;
                pickuprightfork;
                eatforawhile;
                putdownleftfork;
                putdownrightfork;
            end
        end;
Problem 9-2

Determine whether each of the vectors

\[ x = \begin{bmatrix} 0 \\ 2 \\ 1 \end{bmatrix} \quad \text{and} \quad y = \begin{bmatrix} 0 \\ 1 \\ 2 \end{bmatrix} \]

are a linear combination of \( \mathbf{v}_1, \mathbf{v}_2, \) and \( \mathbf{v}_3, \) where

\[ \mathbf{v}_1 = \begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix}, \quad \mathbf{v}_2 = \begin{bmatrix} 2 \\ 0 \\ 1 \end{bmatrix}, \quad \mathbf{v}_3 = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \]
Problem 10-2

For the transistor in the figure below, find the Q-point if $V_{TO} = +4$ V, $\gamma = 0$, $K_p' = 10 \mu A/V^2$, $2\phi_p = 0.6$ V, and $W/L = 10/1$. 

![Diagram of the transistor circuit with a +15 V source, a 10 k\Omega resistor, and a grounded node.]
A balanced, three-phase, 60 Hz voltage is applied to a three-phase, 4-pole induction motor. When the motor delivers rated output horsepower, the slip is found to be 0.05. Determine the following:

a) The speed of the revolving field relative to the stator structure.
b) The frequency of the rotor currents.
c) The speed of the rotor mmf relative to the rotor structure.
d) The speed of the rotor mmf relative to the stator structure.
e) The speed of the rotor mmf relative to the stator field distribution.
Problem 12-2

Determine the electric field intensity of a finite length straight line charge of a uniform density $\rho_l$ in air, then find the field for an infinite length.
Problem 13-2

a. You have an AM signal that consists of \( x_c(t) = [1 + x(t)] \cos 2\pi 1000t \) and an adjacent interfering signal described as

\[
x_f(t) = 0.1 \cos 2\pi 1010t = 0.1 \cos 2\pi (1000 + 10)t
\]

Thus the signal coming into the receiver is \( v(t) = x_c(t) + x_f(t) \)

(1) Express \( v(t) \) as a bandpass signal in quadrature carrier form such that the carrier frequency is 1000 Hz. What is the expression for the quadrature components \( v_q(t) \) and \( v_i(t) \)?

(2) If \( v(t) \) was described in envelope phase form what would be the expressions for \( A(t) \) and \( \phi(t) \)?

b. You have a DSB transmitter that has an output power of 100 watts and a message power of 0.8. What would be the output power required for an A.M. transmitter if the modulation index was 0.9 and you wanted to maintain the same level of sideband power (i.e. the received message will have the same strength)?