DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
OLD DOMINION UNIVERSITY
ME Comprehensive Exam
Fall 2015

ODU HONOR PLEDGE

I pledge to support the Honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism. I am aware that as a member of the academic community, it is my responsibility to turn in all suspected violators of the Honor Code. I will report to a hearing if summoned.

Student Signature: _____

Student Name (BLOCK CAPITALS): _____

UIN Number: _____

Please turn in this examination paper, with the pledge above signed with your answer books.

1. This examination contains 26 problems from the following six areas:

A.	MATH (only two from this group)	A1	A2	A3	A4		
B.	CIRCUITS & ELECTRONICS	B1	B2	B3			
C.	DSP/CONTROLS/COMMUNICATION	C1	C2	C3	C4	C5	C6
D.	EMAG/QUANTUM ELEC./LASERS OPCIAL COMMUNICATIONS	D1	D2	D3	D4		
E.	SOLID STATE/PHYS. ELEC./ PLASMA ELECTRONICS	E1	E2	E3			
F.	COMPUTER SYSTEMS	F1	F2	F3	F4	F5	F6

2. You must answer five questions (no more than two from MATH group).
3. Answer in the blue books provided. **Use a separate book for each question. Put the title and number of question on front of each book (ex. MATH A-1)**
4. Return all the 26 problems.
5. You will be graded on five questions only**.**
6. The examination is "closed-book"; only writing material and a scientific calculator are allowed. **No formula sheet is allowed**. Formulas are included where needed. No material shall be shared without prior permission of the proctor(s).
7. You have four hours to complete this examination.

PROBLEM A1 – MATH

Complex Variables and Differential Equations

EQ1:

A function f(z) is said to be analytic in a domain D if f(z) is defined and differentiable at all points of D.

If $f(z)=|z|^2$, use Cauchy-Riemann equations to show whether f(z) is analytic.

PROBLEM A2 – MATH

<u>Vector Calculus</u>

Consider the function $f(x) = x^2 - y^2$.

a) Make a sketch of f. You do not need to be numerically accurate, but you need to capture the qualitative shape of f.

b) Compute the vector field $A = grad(f)$.

c) Make a sketch of A. Again, you do not need to be numerically accurate, but capture A qualitatively.

d) Compute $curl(A)$.

e) It is possible to compute $curl(grad(f))$ even without knowing f? What is the result, and how can it be interpreted?

PROBLEM A3 – MATH

Linear Algebra

Let $A = [a_{ij}]_{1 \le i, j \le n}$ be a square matrix of dimension $n \times n$.

1. Write the equation that determines the eigenvalues and eigenvectors of matrix A and the expression of the characteristic polynomial of matrix A.

2. State Cayley-Hamilton theorem and argue that A^n is a linear combination of matrices $I, A, \ldots, A^{n-1}$.

3. Show that eigenvectors corresponding to distinct eigenvalues of matrix A are linearly independent.

4. Define similar matrices and show that, if matrix A has n distinct eigenvalues, then it is similar to a diagonal matrix. What are the elements of this diagonal matrix and how is the similarity transformation matrix obtained?

PROBLEM A4 – MATH

Probability

Suppose $s \geq 1$ is a fixed integer. Let $\boldsymbol{x}$ be a random variable with probability density function

$$f(s,x) = \frac{x^{s-1}}{(s-1)!}e^{-x}, \quad x \geq 0$$

and zero otherwise.

(a) What properties must $f(s,x)$ satisfy to be a valid density function?

(b) Define $\Gamma(s,x) = \mathrm{P}\{\boldsymbol{x} > x\}$. Determine a first-order, linear differential equation that $\mathrm{e}^x\Gamma(s,x)$ must satisfy.

(c) Find a series solution to the differential equation in part (b).

(d) Use the result from part (c) to produce an explicit formula for $\mathrm{P}\{\boldsymbol{x} > x\}$.

(e) Compute $\mathrm{P}\{\boldsymbol{x} \leq 1\}$ when $s = 5$.

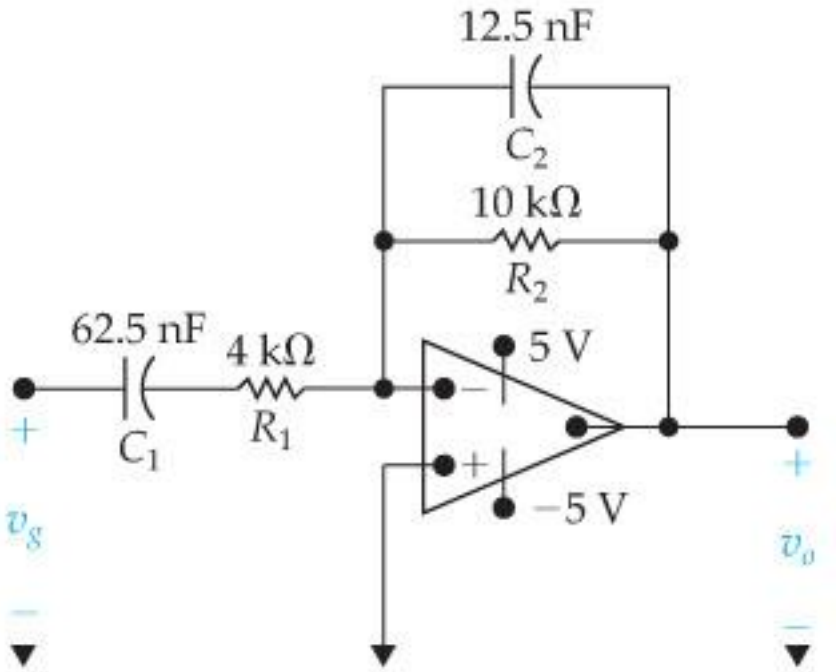
PROBLEM B1 – CIRCUITS AND ELECTRONICS

Circuits

Laplace Application to Circuit Analysis

The op amp shown in the circuit is ideal. There is no energy stored in the circuit at the time it is energized. If $v_g = 16{,}000\, u(t)\, V$, find

a. Find $V_o(s)$.
b. Find $v_o(t)$.
c. How long does it take to saturate the operational amplifier?
d. How small the rate of increase in v_g must be to prevent saturation?

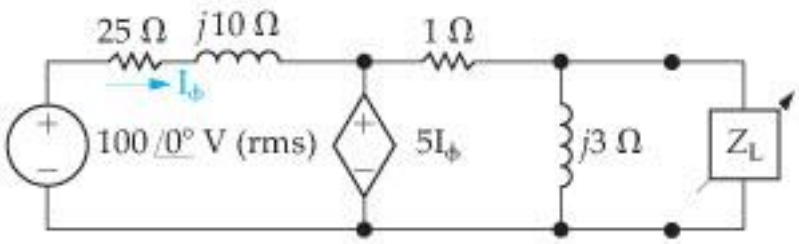


PROBLEM B2 – CIRCUITS AND ELECTRONICS

Sinusoidal Steady State Power

The load impedance Z_L for the circuit shown in the figure is adjusted until maximum average power is delivered to Z_L.

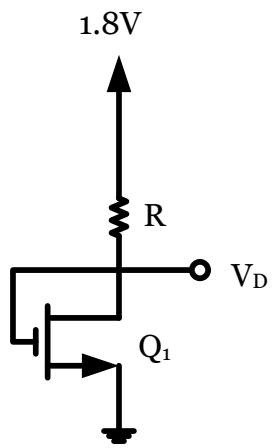
a) Find the maximum average power delivered to Z_L.
b) What percentage of the total power developed in the circuit is delivered to Z_L?



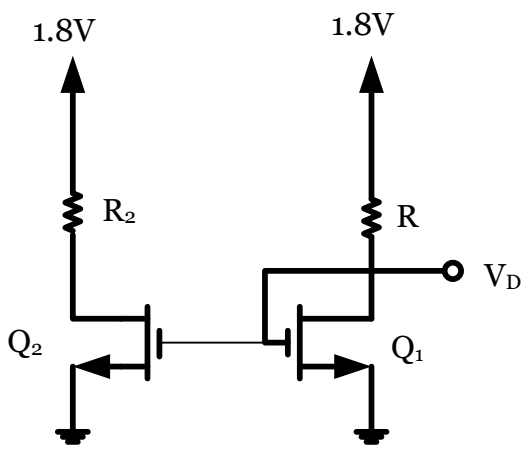
PROBLEM B3 – CIRCUITS AND ELECTRONICS

Electronics

For the circuit in below figure,
(a) find the values of R and results in V_D=0.8V. The MOSFET has V_{tn}=0.5V, $\mu_n C_{ox}$=0.4 mA/V^2, W/L=0.72μm/0.18μm, and λ=0.



Assume that the above circuit is connected to a transistor Q2 which is identical to Q1.
(b) Find the value of R2 that results in Q2 operating at the edge of the saturation region when calculated value of R and V_D=0.8V are applied.



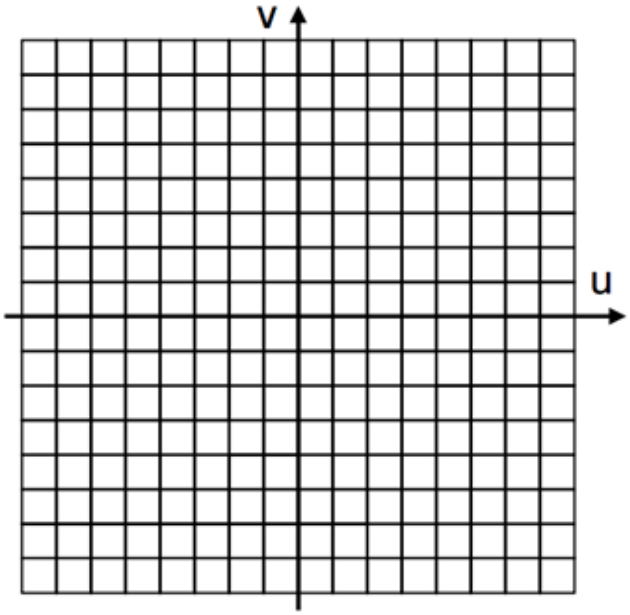
PROBLEM C1 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Image Processing

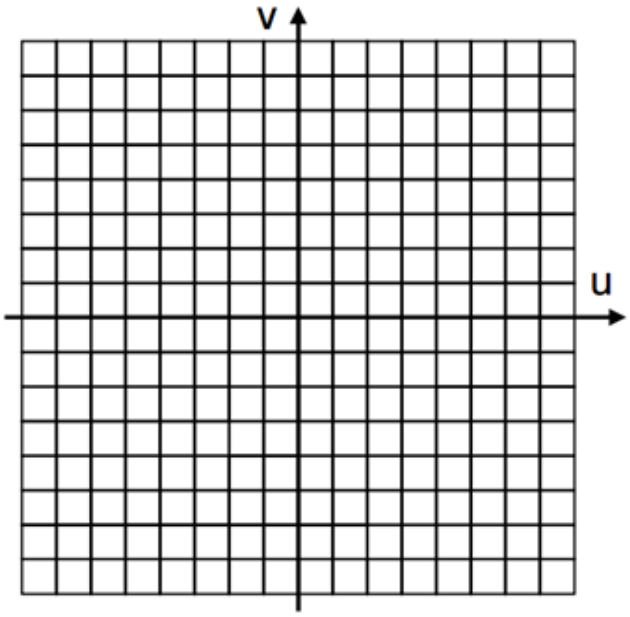
Given the 2D image **f(x,y)** below, answer the following questions.

$$f(x,y) = cos(2\pi x + 6\pi y)$$

a) Determine the Fourier transform ***F(u,v)*** of ***f(x,y)*** and sketch the spectrum below. Use circles to indicate the locations of impulses. **(4 pts)**



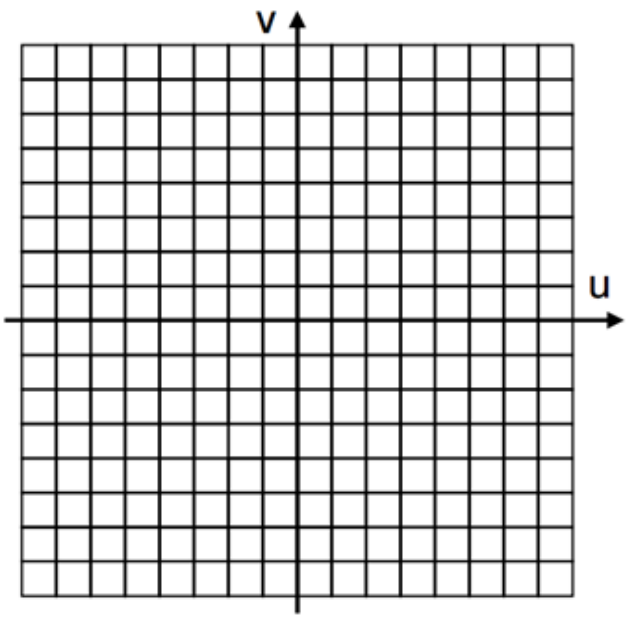
b) Suppose this signal is sampled uniformly with sampling intervals **Δx=Δy=Δ=1/4**. Sketch the spectrum of the sampled signal below. **(3 pts)**



c) If the sampled signal is filtered using an ideal low-pass filter ***h(x,y)*** with frequency response:

$$H(u,v) = \begin{cases} 1 \;\; if \;\; \sqrt{u^2+v^2} < \frac{f_s}{2} \\ 0 \qquad\qquad otherwise \end{cases}$$

where ***fs*=1**/Δ. Sketch the spectrum of the filtered signal below and provide the spatial domain expression the filtered signal $f_{filtered}$**(x,y). (3 pts)**



PROBLEM C2 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Digital Signal Processing

1. (10 points) For an LTID system, the impulse response of the system is known as $h[n]$. If we denote the zero-state response of the system for $u[n]$ as $g[n]$, prove

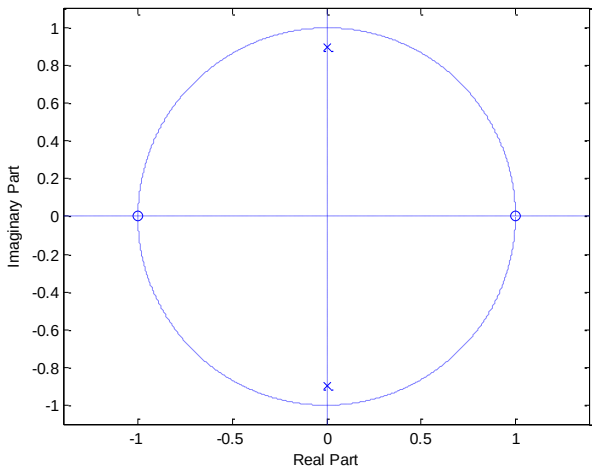
$$g[n] = \sum_{k=-\infty}^{n} h[k]$$

PROBLEM C3 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

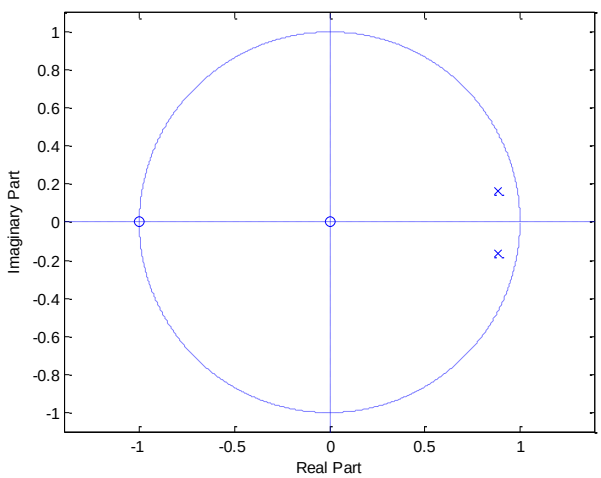
Digital Signal Processing

2. (10 points) Based on the pole-zero location of the systems, roughly sketch the amplitude response of these filters (from 0 to π).

(a) (4 points)



(b) (4 points)



(c) (2 points) What kind of filter is it in (a) and (b) (low-pass, high-ass or band-pass)?

PROBLEM C4 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Control Systems

The simplified heading control system for an aircraft is represented by the block diagram in Figure 1.

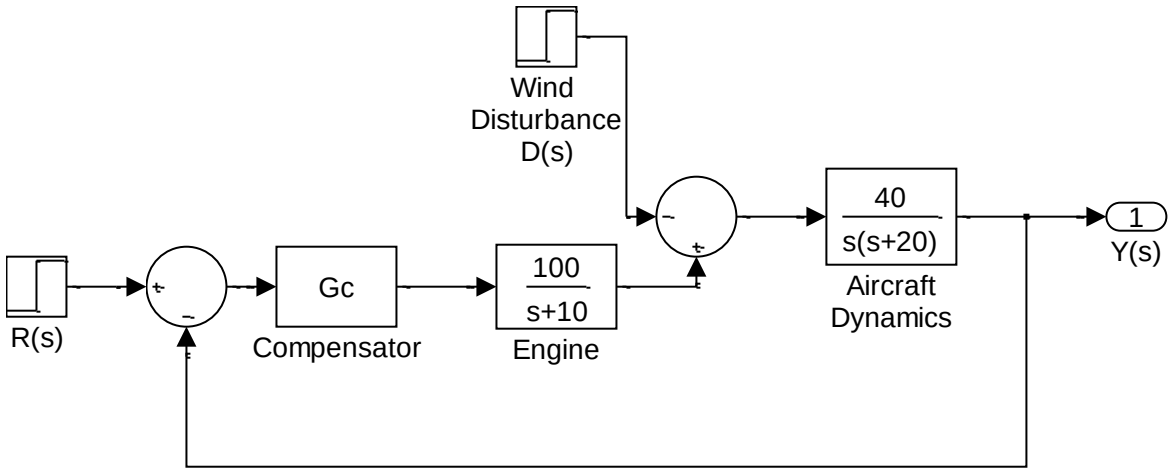


Figure 1. Block diagram of the heading control systemft.

Suppose that in order to meet the following control specifications:

Percent Overshoot $\leq 12\%$
Settling Time ≤ 0.5 sec.

that a lead controller is to be designed with pole at s=-60 and a zero at s=-10, that is, the lead compensator is of the form Gc(s) = Kc (s+10)/(s+60). The root locus for Kc > 0 is given in Figure 2.

a) Derive the range of values of Kc so that all the design specifications are met. Explain.

b) Select the value of Kc from the range determined in part (a) that gives the smallest steady state error to unit steps in r(t) and wind disturbance, d(t). What is this error?

c) For this value of Kc, approximately what are the gain and phase margins? Are the margins better than when Kc=1 (see Figure 3)? Explain why or why not. REMEMBER TO INCLUDE ALL YOUR WORK IN YOUR SOLUTIONS BOOKLET.

REVIEW

For a prototype second order open-loop transfer function $G(s) = \omega_n^2/(s^2 + 2\varsigma\omega_n s + \omega_n^2)$ the following unit step response relations are useful:

- percent overshoot = 100 exp($-\varsigma\pi$ / sqrt($1 - \varsigma^2$))
- 2% settling time $\approx 4 / (\varsigma\omega_n)$

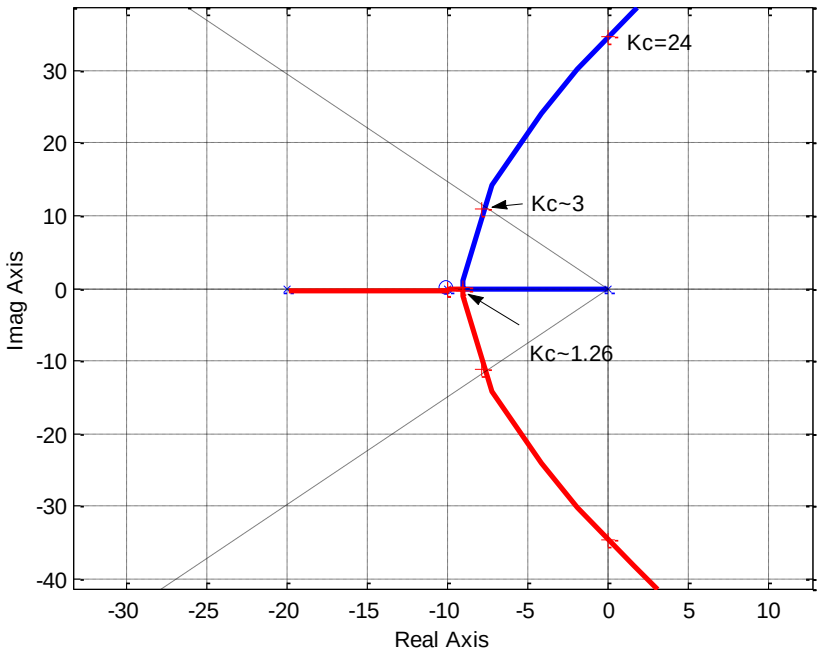


Figure 2. Root locus for closed-loop poles with a lead compensator.

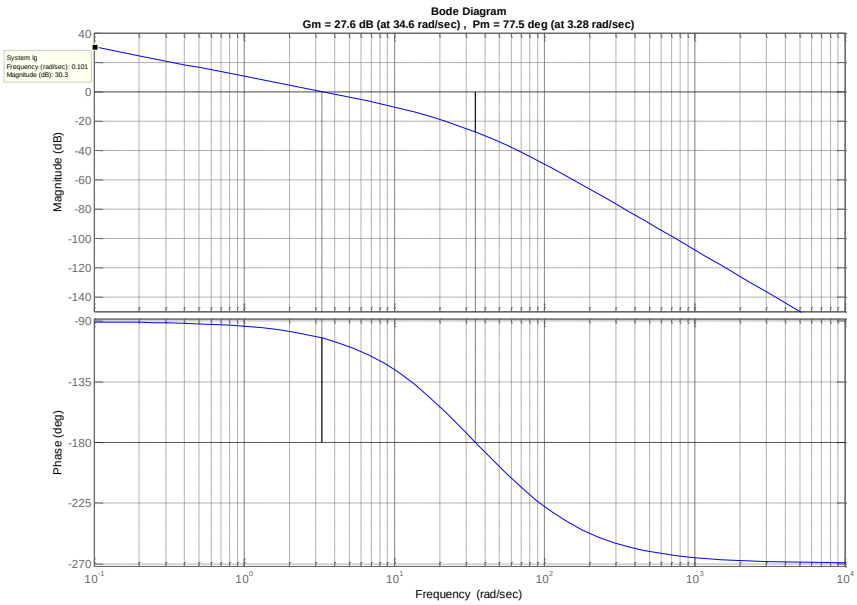


Figure 3. Bode plots of loop gain when Kc=1. The magnitude plot crosses the w=0.1 rad/sec line with a magnitude of 30.3 dB.

PROBLEM C5 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Communication systems

Consider a sinusoidal carrier signal $c(t) = A_c \cos(2\pi f_c t)$ modulating the information-bearing signal $m(t) = a\cos(2\pi f_m t)$, where $f_c >> f_m$.

1. Write the expression of the modulated signal $u_{\mathrm{AM}}(t)$ when conventional amplitude modulation is used, define the modulation index, and state what condition is required to prevent overmodulation.
2. Write the expressions of the pre-envelope signal $u_+^{\mathrm{AM}}(t)$ and of the complex envelope $\tilde{u}_{\mathrm{AM}}(t)$ for signal $u_{\mathrm{AM}}(t)$ in Part 1, and determine its corresponding in-phase and quadrature components $u_I^{\mathrm{AM}}(t)$ and $u_Q^{\mathrm{AM}}(t)$.
3. Write the expression of the modulated signal $u_{\mathrm{PM}}(t)$ when phase modulation is used, define the modulation index β_{P}, and state the condition required for narrowband phase modulation.
4. Write the expressions of the pre-envelope signal $u_+^{\mathrm{PM}}(t)$ and of the complex envelope $\tilde{u}_{\mathrm{PM}}(t)$ for signal $u_{\mathrm{PM}}(t)$ in Part 3, and determine its corresponding in-phase and quadrature components $u_I^{\mathrm{PM}}(t)$ and $u_Q^{\mathrm{PM}}(t)$.
5. Assuming that the condition required for narrowband phase modulation in Part 3 is satisfied, write an approximate expression for $u_{\mathrm{PM}}(t)$ that is similar to that of $u_{\mathrm{AM}}(t)$ in Part 1. Comment on the similarities/differences between the two modulated signals (the narrowband phase modulated signal and the conventional amplitude modulated signal).

USEFUL MATHEMATICAL FORMULAS

Trigonometric identities:

$$\sin(x \pm y) = \sin x \cos y \pm \sin y \cos x$$

$$\cos(x \pm y) = \cos x \cos y \mp \sin x \sin y$$

$$\cos(x)\cos(y) = \frac{\cos(x-y) + \cos(x+y)}{2}$$

$$\sin(x)\sin(y) = \frac{\cos(x-y) - \cos(x+y)}{2}$$

$$\sin(x)\cos(y) = \frac{\sin(x-y) + \sin(x+y)}{2}$$

Euler's formula

$$e^{jx} = \cos(x) + j\sin(x)$$

Hilbert transform pairs

$$\mathcal{H}\{\cos 2\pi f_c t\} = \sin 2\pi f_c t$$

$$\mathcal{H}\{\sin 2\pi f_c t\} = -\cos 2\pi f_c t$$

PROBLEM C6 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Communication Networks

1. (5 pts) The channel bandwidth is 6 MHz. There are four levels of symbols.

(a) If the channel is noiseless, what is the maximum achievable rate?

(b) If the channel has noise and the SNR is 10 dB, what is the maximum achievable rate now?

2. (5 pts) Consider a network where node C is connected to nodes B, D, E. Distance vector routing is used. The following vectors just come to node C: (5, 0, 8, 12, 6, 2) from B, (16, 12, 6, 0, 9, 10) from D, and (7, 6, 3, 9, 0, 4) from E. The cost of the links from C to B, D, and E, are 6, 3, 5, respectively. Please compute the new routing table for node C. Give both the next-hop and the cost.

PROBLEM D1 – PHYSICAL ELECTRONICS I

Electromagnetics

A microwave oven typically operates at 2.45 GHz. A bottom round steak has a relative permittivity of 40 (or $\varepsilon' = 40\varepsilon_0$, $\varepsilon_0 = 8.8542 \times 10^{-12}$ F/m, $\mu = \mu_0 = 4\pi \times 10^{-7}$ H/m) and a loss tangent $\tan\delta = 0.3$ at the operating frequency.

(a) Calculate the complex wavenumber $\underline{k}$.

(b) Calculate the penetration depth d_p in steak.

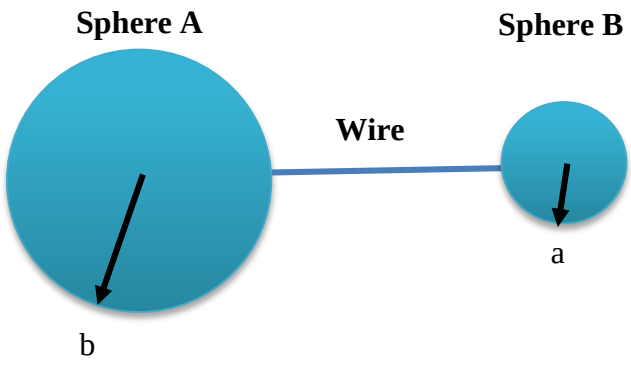
(c) Calculate the intrinsic impedance $\underline{\eta}$.

(d) Let the microwave be represented by a time-harmonic uniform plane wave: $\underline{\vec{E}} = \hat{x}E_0 exp(-j\underline{k}z)$ and $\underline{\vec{H}} = \hat{y}(E_0/|\underline{\eta}|)\ exp(-j\underline{k}z - j\phi)$, where $\underline{k}$ is the complex wavenumber, and $\underline{\eta} = |\underline{\eta}|exp(-j\phi)$ is the complex intrinsic impedance. Given the electric-field intensity just beneath the surface of the steak, $|\underline{\vec{E}}|_{z=0}$ =1 MV/m, find the time-average power density *just beneath the surface* and that *inside the steak for a depth of* d_p. (Hint: Calculate the time-average Poynting vectors at $z = 0$, and $z = d_p$, respectively.)

PROBLEM D2 – PHYSICAL ELECTRONICS I

<u>Electromagnetics</u>

Two conducting spheres of radii *a* and *b* are connected by a long and thin conducting wire as shown in below figure. A charge of q is placed on this structure, i.e. $q_a+q_b=q$. Find the charge on each sphere and calculate the **E** field on the surface of each sphere.



PROBLEM D3 – PHYSICAL ELECTRONICS I

Lasers

A diode laser has the following characteristics:

Optical cavity of length 250 μm
Peak radiation at 1550 nm
Refractive index of semiconductor diode material 4
Optical gain bandwidth 2 nm.

(a) What is the laser mode spacing in nm? (3 points)

(b) How many modes can lase and what are their wavelengths in nm? (4 points)

(d) What is the reflection coefficient at each face of the semiconductor surface/air interface? (3 points)

PROBLEM D4 – PHYSICAL ELECTRONICS I

<u>Optical Fiber Communications</u>

Find the external quantum efficiency for a $Ga_{1-x}Al_xAs$ laser diode with (x = 0.03) which has an optical-power-versus-drive-current relationship as shown in the following figure (use the 20° C curve.)

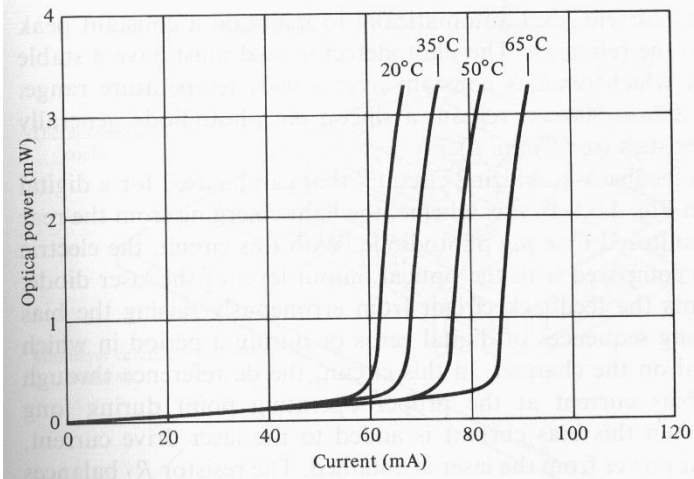


FIGURE 4-31
Temperature-dependent behavior of the optical output power as a function of the bias current for a particular laser diode.

PROBLEM E1 - PHYSICAL ELECTRONICS II

Solid State Electronics

D1) A Boron Diffusion is used to form the base of a npn transistor in a 0.18 Ohm cm n-type Si wafer. A solid solubility limited Boron Pre-deposition is performed at 900 C for 15 min followed by a 5 hour drive-in at 1100 C.

a) Find the boron surface concentration graphically from Fig. 4.6 and calculate the B impurity dose after the pre-deposition step. Use $D_1 = 1.45 \times 10^{-15}$ cm^2/ sec for Boron diffusivity at 900 C.

b) Calculate the B surface concentration and the junction depth following the 5 hour drive-in step. Apply Fig. 4.8 to obtain the n-type background dopant concentration. Use $D_2 = 2.96 \times 10^{-13}$ cm^2/ sec for Boron diffusivity at 1100 C.

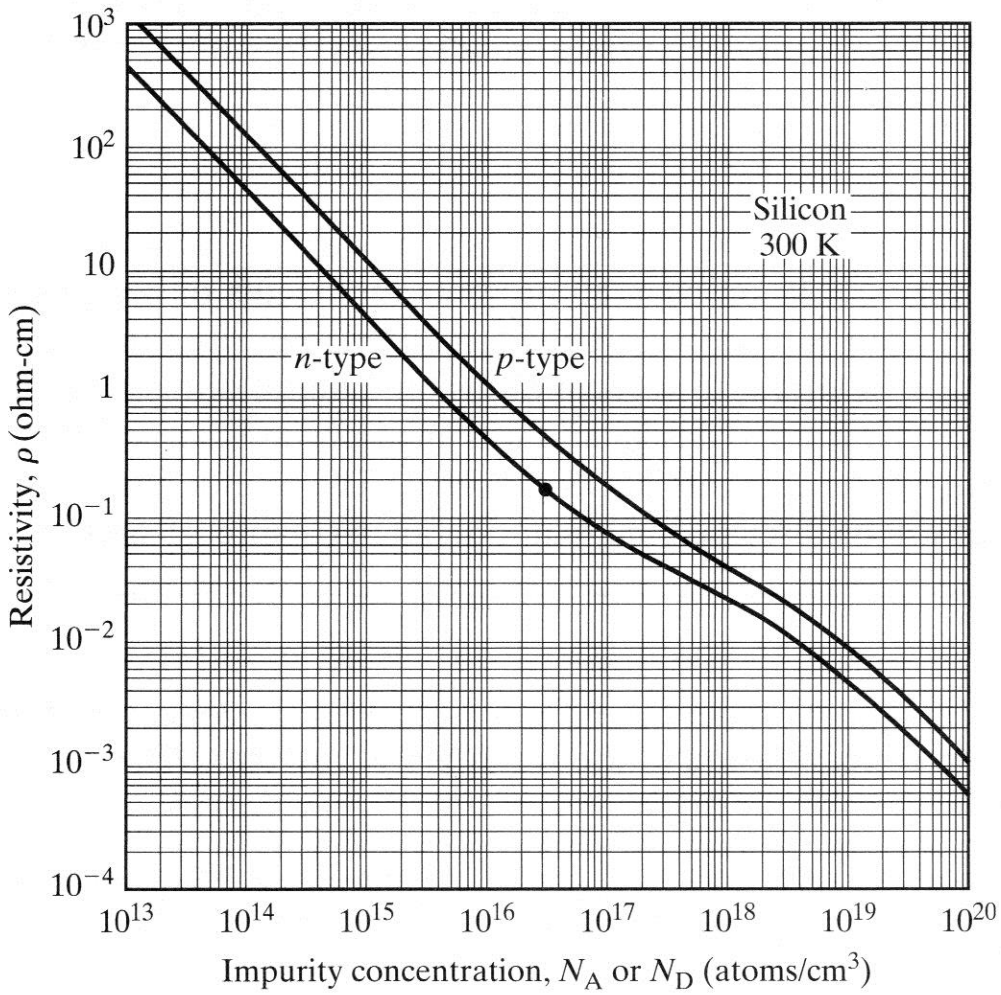


Figure 4.8: Room temperature resistivity in n- and p-type Silicon as a function of impurity concentration.

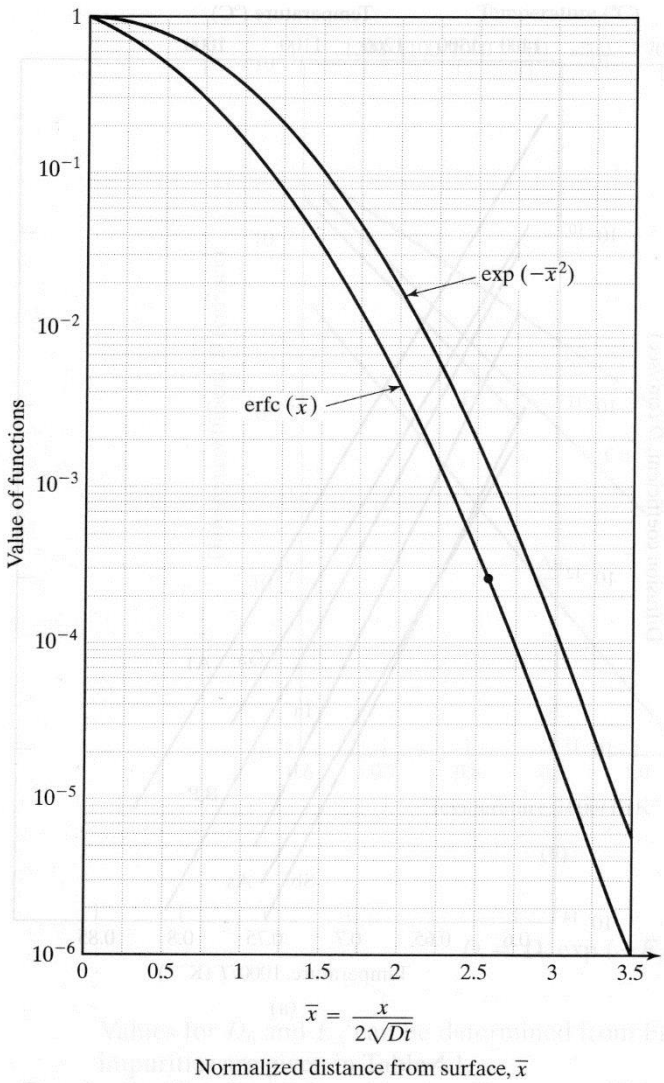


Fig. 4.4: Graphical comparison of Gaussian and complementary error function(erfc) profiles.

PROBLEM E2 – PHYSICAL ELECTRONICS II

Physical Electronics

Question 1

For a silicon abrupt junction with $N_A = 10^{18}$ cm^{-3}, $\varepsilon_{max} = 4 \times 10^5$ V/cm at reverse bias $V_R = 30$V (T = 300K), calculate the n- type doping concentration.

Question 2

Calculate the theoretical saturation current, I_S of an ideal silicon p-n junction having following specifications: $N_D = 10^{18}$ cm^{-3}, $N_A = 5\times10^{16}$ cm^{-3}, $\tau_p = \tau_n = 5 \times 10^{-7}$s, $D_p = 10$ cm^2/s, $D_n = 21$ cm^2/s and a device area of 2×10^{-4} cm^2. Also calculate the forward current at 0.5 V.

$$J_p = q\mu_p p\left(\frac{1}{q}\frac{dE_i}{dx}\right) - kT\mu_p\frac{dp}{dx} \qquad \frac{d^2\psi}{dx^2} \equiv -\frac{d\mathscr{E}}{dx} = -\frac{\rho_s}{\varepsilon_s} = -\frac{q}{\varepsilon_s}\left(N_D - N_A + p - n\right).$$

$$V_{bi} = \psi_n - \psi_p = \frac{kT}{q}\ln\left(\frac{N_A N_D}{n_i^2}\right). \qquad N_A x_p = N_D x_n. \qquad W = x_p + x_n. \qquad \mathscr{E}_m = \frac{qN_D x_n}{\varepsilon_s} = \frac{qN_A x_p}{\varepsilon_s}.$$

$$V_{bi} = \frac{1}{2}\mathscr{E}_m W. \qquad W = \sqrt{\frac{2\varepsilon_s}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)V_{bi}}. \qquad \mathscr{E}(x) = -\mathscr{E}_m + \frac{qN_B x}{\varepsilon_s}, \qquad \mathscr{E}_m = \frac{qN_B W}{\varepsilon_s}$$

$$C_j = \frac{\varepsilon_s}{W} = \sqrt{\frac{q\varepsilon_s N_B}{2(V_{bi} - V)}} \qquad V_{bi} = \frac{kT}{q}\ln\frac{p_{po}n_{no}}{n_i^2} = \frac{kT}{q}\ln\frac{n_{no}}{n_{po}}, \qquad n_{no} = n_{po}e^{qV_{bi}/kT}.$$

$$p_{po} = p_{no}e^{qV_{bi}/kT}. \qquad n_n = n_p e^{q(V_{bi} - V)/kT}, \qquad n_p = n_{po}e^{qV/kT}$$

$$J = J_p(x_n) + J_n(-x_p) = J_s\left(e^{qV/kT} - 1\right), \qquad J_s \equiv \frac{qD_p p_{no}}{L_p} + \frac{qD_n n_{po}}{L_n},$$

Silicon (300 K): $N_C = 2.86\ 10^{19}$ cm^{-3} ; $N_V = 2.66\ 10^{19}$ cm^{-3} ; $n_i = 9.65\ 10^9$ cm^{-3}

$m_p = 1\ m_0$; $m_n = 0.19\ m_0$; $m_0 = 0.91\ 10^{-30}$ kg; $k = 1.38\ 10^{-23}$ J/K ; $q = 1.6\ 10^{-19}$ C

$$k_o = \frac{C_s}{C_l} \qquad k_e = \frac{C_s}{C_l} = \frac{k_o}{k_o + (1 - k_o)e^{-v\delta/D}} \qquad C_s = C_0[1 - (1 - k_e)^{-k_e x/L}]$$

$$C_s = k_o C_o\left(1 - \frac{M}{M_o}\right)^{k_o - 1} \qquad C_s = k_e C_l e^{-k_e x/L}$$

$$F = \frac{DC_0}{x + (D/\kappa)}. \qquad x^2 + Ax = B(t + \tau). \qquad A = 2D/\kappa,\ B = 2DC_0/C_1$$

$$B/A = \kappa C_0/C_1. \qquad \tau = (d_0^2 + 2Dd_0/\kappa)C_1/2DC_0$$

PROBLEM E3 – PHYSICAL ELECTRONICS II

Plasma Science and Discharges

A mercury vapor plasma column fills a tube of 3 cm in diameter and 3 m in length. The average energy of the electrons in the plasma is 2 eV. The tube dissipates 100 Watts of heat evenly over its surface (neglect the ends). Assume that the only source of heat is the inelastic electron-neutral collisions, where the electron loses its average energy in each collision.

a./ How many electron-neutral collisions occur per unit volume, per second?
(hint: compare total dissipated energy to electron energy)

b./ Calculate the mean electron velocity (hint: three degrees of freedom, 3/2 KT)

c./ If the effective diameter of the mercury atom is $4.\ 10^{-10}$ m and the electron number density is $n_e = 10^{16}\ m^{-3}$, calculate the density of neutral atoms and the pressure of the mercury gas in the tube.

d./ What is the mean free path of the electrons in the plasma?

e./ Calculate the electron diffusion coefficient.

PROBLEM F1 - Computer Systems

Microprocessors

Write a subroutine that calculates the nth number in the Fibonacci series in a Motorola 6811 microprocessor based system. The Fibonacci series is defined as follows. Given that $F_1 = 1$, $F_2 = 1$, then the nth Fibonacci number $F_n = F_{n-1} + F_{n-2}$, $n>2$.
The value of n is an 8-bit value found in memory location $0000. Upon completion the nth Fibonacci number should be stored in memory location $1000.
You may safely use memory locations $0001 to $00FF for storage of any temporary variables.

Details:	Style - Write your code in a three column format, i.e.:			
	LABEL:*	**MNEMONIC**	**OPERAND***	(* use only when required / needed)
Example:	***LOOP:***	***BRA***	***LOOP***	

Symbols: The use of a # sign before an operand designates immediate addressing mode, $ - hexadecimal, % - binary.
Example: LDAA #$F0 – The value F0 hexadecimal is loaded into AccA.
Addressing modes: Immediate example: LDAA #$F0 (A← $F0)
Direct example: LDAA $F0 (A← M[$00F0])
Extended example: LDAA $00F0 (A← M[$00F0])
Indexed example: LDAA 0, X (A ← M[X+0])

Available instructions:

LDAA / STAA : Load / Store Accumulator A (one byte)
LDAB / STAB : Load / Store Accumulator B (one byte)
LDD/STD : Load / Store Accumulator D (A + B, double byte)
LDX / STX : Load / Store index register X (double byte)
LDY / STY : Load / Store index register Y (double byte)
LDS/STS : Load/Store Stack Pointer (double byte)
TSX / TXS : Transfer SP in X / Transfer X in SP

ABA : Add Accumulators A + B → A
ABX/ABY : Add B to X/Y, IX/IY + 00:B → IX/IY
ADCA/ADCB : Add with Carry to A/B, A/B + M + C → A/B
ADDA/ADDB : Add Memory to A/B, A/B + M → A/B

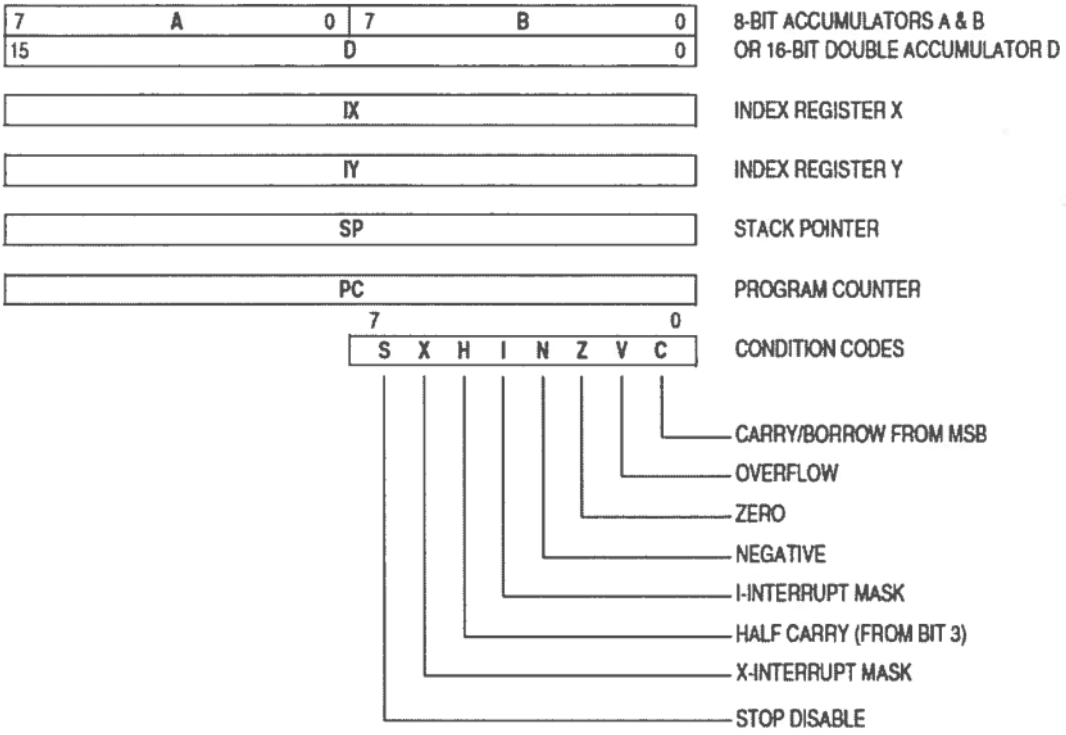
PSHA / PULA : Push / Pull Acc. A on / from the stack
PSHB / PULB : Push / Pull Acc. B on / from the stack
PSHX / PULX : Push / Pull index register X on / from the stack
PSHY / PULY : Push / Pull index register Y on / from the stack

INCA / DECA : Increment / Decrement AccA – Inherent addressing
INCB / DECB : Increment / Decrement AccB
INC / DEC : Increment / Decrement memory location contents
INX / DEX : Increment / Decrement index register X
INY / DEY : Increment / Decrement index register Y
INS / DES : Increment / Decrement stack pointer

BRA : Branch always - Relative addressing
BEQ : Branch if equal to zero
BNE : Branch if not equal to zero
BGT : Branch if greater than zero
BLT : Branch if less than zero
BGE : Branch if greater than or equal to zero
BLE : Branch if less than or equal to zero
BMI : Branch if minus
BPL : Branch is plus
JMP : Jump to the given address – Absolute addressing
RTS : Return from subroutine

CLRA : Clear contents of AccA (A ← $00)
CLRB : Clear contents of AccB (B ← $00)
CLR : Clear memory location contents (M ←$00)

CMPA : Compare AccA to memory (A – M)
CMPB : Compare AccB to memory (B – M)
CBA : Compare AccB to AccA (A-B)
CPX : Compare index register X to memory (X – MM)
CPY : Compare index register Y to memory (Y – MM)


7 A 0 7 B 0
15 D 0
8-BIT ACCUMULATORS A & B
OR 16-BIT DOUBLE ACCUMULATOR D
IX
INDEX REGISTER X
IY
INDEX REGISTER Y
SP
STACK POINTER
PC
PROGRAM COUNTER
7 0
S X H I N Z V C
CONDITION CODES
CARRY/BORROW FROM MSB
OVERFLOW
ZERO
NEGATIVE
I-INTERRUPT MASK
HALF CARRY (FROM BIT 3)
X-INTERRUPT MASK
STOP DISABLE

PROBLEM F2 – COMPUTER SYSTEMS

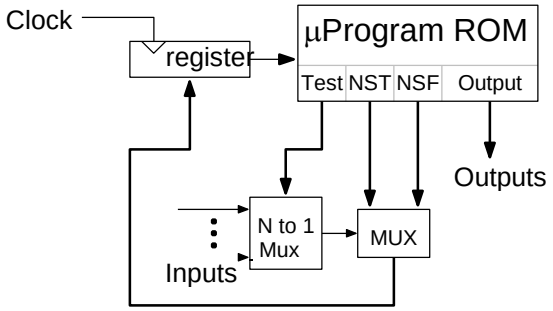
Digital System Design

You are to design a state machine that inputs a six bit binary number, and outputs a binary number whose value is 5 more than the input. Note that the binary numbers are input/output in the order of LSB to MSB. In the event of overflow, your state machine should assert an error signal.

1. (1 point) List the inputs and outputs for the state machine.

2. (5 points) Give the state machine chart and state machine table for a Moore style state machine that implements the function above.

3. (4 points) Give the implementation for the state machine given the state machine table you provided in the previous problem using a two-address microcoded controller. The figure shows the organization of a two-address microcoded controller.



PROBLEM F3 – COMPUTER SYSTEMS

Computer Architecture

1. What is the range of addresses in the instruction memory for a MIPS jump instruction (e.g., j: exit)? You need to explain why.

2. Assume that there are no pipeline (a single cycle datapath) and that the breakdown of executed instructions is as follows:

add	Sub	beq	lw	sw	j
20%	10%	25%	25%	10%	10%

In what fraction of all cycles in the input of the sign-extended circuit needed? Why?

PROBLEM F4 – COMPUTER SYSTEMS

Algorithms

Herding cats problem. You have a collection of intelligent agents (autonomous entities are simulation entities that interact with their simulation environment according to some set of rules and are designed to achieve some goal. Source: Wikipedia). Each computer has two states that are designated by the colors green and red. In this problem, two agents can exist: "cats" and "herders".

Cats interact with their environment which is a networked collection of computers whose interconnection structure is defined by a graph. In addition, cats try to avoid herders. The cat interacts in the following way:

A. It "eats" by changing the state of a computer from green to red with probability κ_c for a computer not occupied by a herder.

B. A cat can replicate itself after consuming some number of meals ρ. The replicant moves to an adjacent green computer.

C. The cat will move to a green computer not already occupied by a cat

   (i) if it detects a herder agent on the same computer. Cats can detect a herder with a probability α_h

   (ii) at random with probability ν_c

D. The cat ceases to exist after making some number of moves μ.

Herders search for cats and try to contain them to a minimum number of computers. Herders interact in the following ways:

A. Herders move through the network under the following circumstances

   (i) at random with a probability ν_h where $\nu_h > \nu_c$ to a computer that is colored red

   (ii) toward a computer occupied by a cat with α^d_h where d is the distance (hops) between the herder and the cat.

B. Herders can change the color of a computer not occupied by a cat from red to green with probability κ_h.

If a cat and a herder reside on the same computer:

A. The cat goes to sleep with probability γ_c.

B. The herder to goes to sleep with probability γ_h.

C. If a cat and a herder reside on the same computer, the cat purr can cause the herder to go to sleep with probability γ_h.

Answer the following questions based on the rules described above:

1. (6 points) Assume there is one cat and one herder and $\rho = 0$, $\gamma_c = 1$, $\gamma_h = 0$, $\alpha^d_h = 1$,

   $\kappa_c = \kappa_h = 1$, $\rho = \infty$, $\alpha_h = 0.5$. Give the pseudocode or flow chart for an algorithm the herder can use to make a cat go to sleep and also to change all computers to the color green. Note any additional assumptions you have to make for your algorithm to work.

2. (4 points) Give the time complexity for your algorithm. Be sure to show all steps in your analysis and justify any assumptions you make.

PROBLEM F5 – COMPUTER SYSTEMS

Data Structures

1. A stack `bStack` contains the following items

$$\begin{array}{c} 7 \\ 8 \\ -3 \\ 14 \\ 5 \end{array}$$

What is the output to the screen of the following code?

```
int x;
while (!bStack.isEmpty()){
  bStack.pop(x);
  if (x>0 && !bStack.isEmpty())
    bStack.pop();
  cout << x << endl;
}
```

2. Please provide pseudo code or diagram (explanations) for following questions

Given the input A (2, 8, 7, 2, 0, 1, 1, 6),

2.1 Construct a binary search tree according to the input A sequence.

2.2 Add a node, 5, into this binary search tree?

2.3 Delete a node, 0, from this binary search tree?

PROBLEM F6 – COMPUTER SYSTEMS

Logic/Digital Circuits

1. Given the following truth table,

A	B	C	Y (output)
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

(a) (5 pts) write the Boolean equation in sum-of-products form.

(b) (5 pts) Simplify the Boolean equation using Karnaugh map.