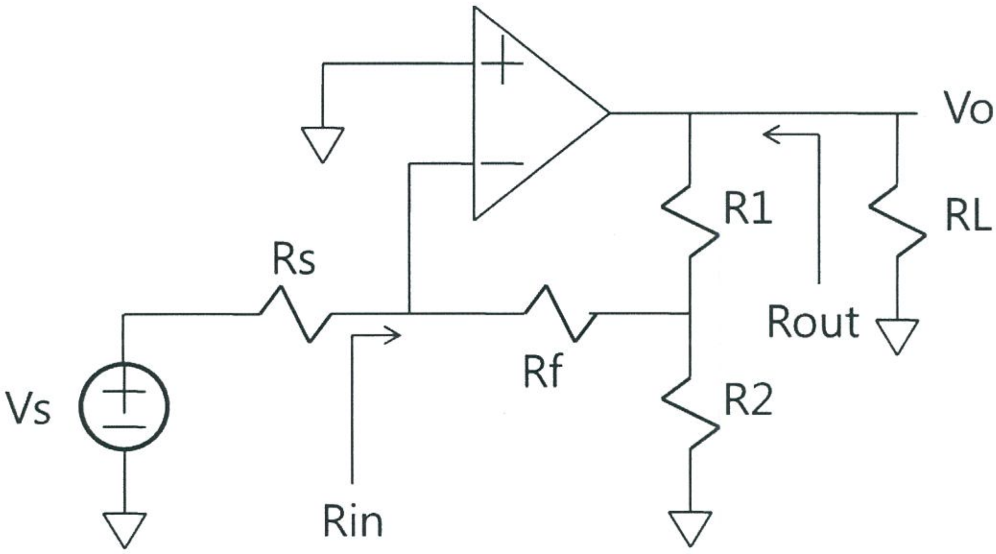
포스텍 전자전기공학과 박사자격시험 전자회로 2014년 7월 (4문제, 2페이지)

[1]. Answer following questions.

The OP amp can be modeled with an input resistance of r_{id}, an output resistance of r_o and a voltage gain of μ .



(a) What is the type of feedback (5pt)

(b) Derive Vo/Vs (20pt)

(c) Derive Rin (5pt)

(d) Derive Rout (5pt)

[2]. Assume an open-loop amplifier has two poles. When the amplifier is configured with unity-gain negative feedback configuration, the amplifier output oscillates at 1MHz. Draw Bode plot (amplitude and phase) of the open-loop amplifier. (15pt)

[3]. **간략하게 답하시오. (35점, 별도 표시없으면 각 2점)**

(1) 커패시터(C)에서 전류(I)와 전압(V) 중에서 시간에 대해 연속인 변수는 무엇인가?

(2) 다이오드의 가장 대표적인 전기적 특성 하나는 무엇인가?

(3) 오실로스코프 입력단에 AC coupling을 사용한 경우, 오실로스코프에 나타나는 파형의 평균전압(DC전압)은 얼마인가?

(4) 어떤 소자가 증폭기로 동작하려면 단자(terminal) 개수가 얼마인가?

(5) 전자회로에서 VCVS, VSCS, CCVS, CCCS와 같은 종속원(dependent source)의 역할은 무엇인가?

(6) (밑줄친 괄호 안에서 한 개씩 선택하시오. (7)~(9)) 증폭기회로(인덕터는 없음)의 전달함수에서 신호주파수가 증가할수록, 전달함수 크기(magnitude)는 대체로 (<u>증가, 감소</u>)하고 전달함수 위상(phase)는 대체로 (<u>leading, lagging</u>)한다.

(7) 전자회로의 BJT나 MOSFET의 소신호등가회로는 (<u>선형, 비선형</u>) 회로이다.

(8) Static CMOS logic gate는 (<u>NMOS,PMOS</u>) pull-up 회로와 (<u>NMOS,PMOS</u>) pull-down 회로로 구성되므로, VDD와 VSS 사이를 관통하는 steady state 전류가 (   )이다. (3점)

(9) PMOSFET에서 단자 전위(electric potential)가 더 positive인 쪽은 (<u>source, drain</u>) 단자이다.

(10) 다음 4개 증폭기 중에서 소신호 전압이득이 양(陽)인 것을 모두 고르시오. CS(common source), SF(source follower), cascode, CB(common base), (틀리면 감점) (4점)

(11) 전압 단위인 'Volt'를 다음 네 개의 MKSA 단위(Kg, meter, sec, Amp)로 표시하시오.

(12) 어떤 비선형 인덕터의 자속(magnetic flux)이 전류의 제곱(I^2)으로 주어질때, 이 인더터의 전류가 0에서 1 Ampere까지 증가하면 저장된 에너지는 얼마나 증가하는가? (4점)

(13) 2 개의 PMOSFET, 2 개의 NMOSFET, 한 쪽 단자가 VDD에 연결된 1개의 DC 전류원을 이용하여 single-ended 출력을 가지는 차동증폭기 회로를 그리시오. 단, Vi+, Vi-, Vo를 표시하시오. (4점)

(14) (13) 회로에서 소신호 공통모드 전압이득을 감소시키는 소자는 어떤 것들인가?

[4]. 어떤 신호전압원의 소스 저항이 1k옴인데, 여기에 1k옴 저항 1개와 1uF 커패시터 두 개를 추가하여 2차 band pass filter를 구현한다. (15점)

(1) 이 회로를 그리시오. 또 입력전압 Vi와 출력전압 Vo를 표시하시오. (4점)

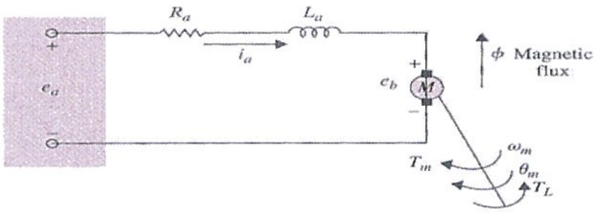
(2) 전달함수를 구하시오. (3점)

(3) Q(quality factor) 값은 얼마인가. (2점) 단, Q = 0.5/(damping factor)

(4) Vi(t) = delta(t) - u(t) 에 대한 Vo(t) 식을 구하시오. delta(t)는 impulse 함수이고 u(t)는 unit step 함수이다.(6점)

EE Automatic Control QE (Requisite) July 30, 2104

Mathematical Modeling of PM DC Motors: (50 points)



The above circuit diagram represents a PM dc motor. The armature is modeled as a circuit with resistance R_a, connected in series with the inductance L_a, and a voltage source e_b representing the back emf in the armature when the rotor rotates. The motor variables and parameters are defined as follows: $i_a(t)$ = armature current, L_a = armature inductance, R_a = armature resistance, $e_a(t)$ = applied voltage, $e_b(t)$ = back emf, K_b = back-emf constant, $T_L(t)$ = load torque, ϕ = magnetic flux in the air gap, $T_m(t)$ = motor torque, $w_m(t)$ = rotoe angular velocity, $\theta_m(t)$ = rotor displacement, J_m = rotor inertia, K_i = torque constant, B_m = viscous-friction coefficient. We assume that the torque developed by the motor is proportional to the armature current such as

$$T_m(t) = K_i i_a(t)$$

and the back emf is proportional to the rotor angular velocity such as

$$e_b(t) = K_b w_m(t).$$

(a) (20 points) Find the cause-and -effect equations for the motor circuit.

(b) (15 points) Draw the block diagram of the system.

(c) (15 points) Find the transfer function between the motor displacement $\Theta_m(s)$ and the input voltage $E_a(s)$.

제어선택 : Automatic Control Part II (Total 50 points)

1. Describe the definitions of the following terms. (20 points)

state $x(t_0)$ controllable at t_0

asymptotically stable at t_0 state transition matrix

2. $\dot{x}(t) = \begin{bmatrix} 1 & 1 & -2 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix} x + \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} u, \quad y = [2\ 0\ 0]x$. Let $u = pr - kx(t)$.

1) Find p and k so that the resulting system has eigenvalues -2 and $-1 \pm j2$ and will track asymptotically any step reference input. (20 points)

2) Find the transfer function of the resulting system from r to y. (10 points)

전력전자 선택 : Area of Power Electronics (Total 50 points)

1. Consider the buck-boost dc-to-dc converter. Its input voltage and output voltage are V_d and V_o, respectively. The duty ratio and switching period are also D and T_s. (30 points)

1) Derive the input-output voltage relation in the continuous conduction mode.

2) Derive the critical inductor value for the critical conduction mode.

3) Derive and draw its switch utilization factor (SUF) with respect to the duty ratio D.

2. Consider the flyback converter. Its input voltage and output voltage are V_d and V_o, respectively. (20 points)

1) Explain the operation principle of the flyback converter and derive its voltage transfer ratio in the continuous conduction mode.

2) Derive the voltage stress across the switch of the flyback convert- ter during the off interval.

[QE - Communications]

Consider the binary signal set $\{s_1(t), s_2(t)\}$ given by

$$s_1(t) = -s_2(t) = \begin{cases} +A & \text{if } 0 \le t < T/2 \\ -A & \text{if } T/2 \le t < T \\ 0 & \text{elsewhere} \end{cases}$$

where $A > 0$ is a real number and T is the symbol duration. Assume that each signal is transmitted equally likely over an AWGN channel with mean zero and double-sided power spectral density $N_0/2$.

(a) (6 points) Plot the signal constellation and the decision region for each signal in terms of the average signal energy E and N_0.

(b) (7 points) Sketch the optimum receiver structure based on the matched filter.

(c) (7 points) Derive the conditional PDF of the matched filter output in terms of E and N_0, given that $s_1(t)$ was transmitted.

(d) (10 points) Derive the average probability in terms of E and N_0.

(e) (10 points) Consider the quaternary signal set $\{s_1(t), s_2(t), s_3(t), s_4(t)\}$ given by

$$s_3(t) = -s_4(t) = \begin{cases} +A & \text{if } 0 \le t < T/4 \text{ or } T/2 \le t < 3T/4 \\ -A & \text{if } T/4 \le t < T/2 \text{ or } 3T/4 \le t < T \\ 0 & \text{elsewhere.} \end{cases}$$

Plot the signal constellation and the decision region for each signal in terms of E and N_0. Identify the employed basis signals of unit energy.

(f) (10 points) Assuming that the signals in (e) are equally likely, derive the union bound on the average error probability.

Consider a uniformly distributed random variable Z, defined by

$$f_z(z) = \begin{cases} \dfrac{1}{2\pi}, 0 \le z \le 2\pi \\ 0, otherwise \end{cases}$$

The two random variables X and Y are related to Z by $X = \sin(Z)$ and $Y = \cos(Z)$.

(a) Determine the probability density function of X and Y.
(b) Show that X and Y are uncorrelated random variables
(c) Are X and Y statistically independent? Why?

(50 점).

전자기학/초고주파 분야

박사과정자격시험 (2014. 7. 30)

1. **(15 점)** (a) Briefly explain how the electric field intensity $\overline{E}$ is defined.

(b) Using Gauss's law, find $\overline{E}$ due to an infinite uniform sheet of charge ρ_s (C/m^2) located in free space.

(c) Using Gauss's law, find $\overline{E}$ due to an infinite line charge of ρ_l (C/m) located in free space.

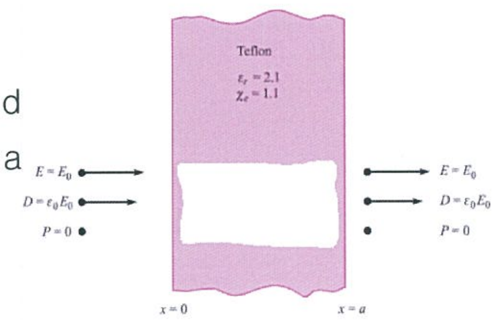
2. **(15 점)** If we take the zero reference for potential at infinity, find the potential at (0,0,2) caused by the following charge configuration in free space. (use $\displaystyle\int \frac{dx}{\sqrt{x^2+a^2}} = \ln\left(x+\sqrt{x^2+a^2}\right)$)

(a) ρ_l=12 nC/m on the circular line $\rho = 2.5,\ z = 0$

(b) ρ_l=12 nC/m on the linear line $y = 2.5,\ z = 0,\ -1.0 < x < 1.0$.

3. **(10 점)** Teflon slab in the region $0 \le x \le a$, and free space elsewhere. Outside teflon, there is a uniform field of $\overrightarrow{E_{out}} = \hat{x}E_0$.

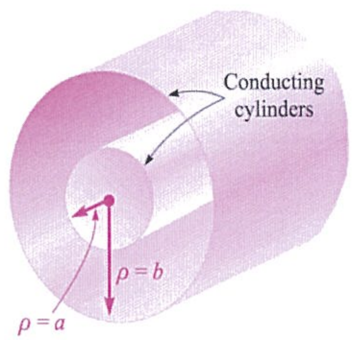
Find $\overrightarrow{D}, \overrightarrow{E}$, and $\overrightarrow{P}$ inside teflon.



4. **(10 점)** For the air coaxial line of length d shown, find (a) $\overline{B}$ for $\cancel{b}\,a < \rho < \cancel{a}\,b$,

(b) the total magnetic flux contained between the conductors of length d, and

(c) the external inductance of the line of length d.



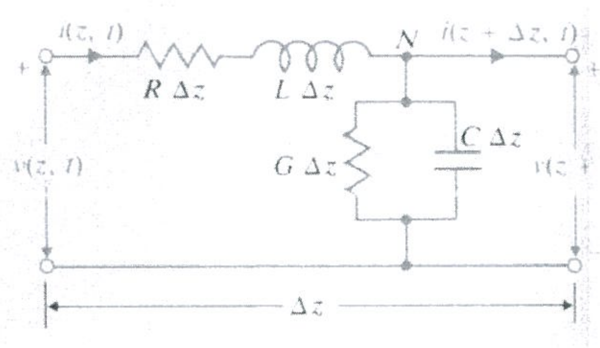
5. [25점] A right-hand circularly polarized plane wave represented by the phasor $E(z) = E_0(\hat{x} - j\hat{y})e^{-j\beta z}$ impinges normally on a perfectly conducting wall at $z = 0$.

(a) [5점] Determine the polarization of the reflected wave.

(b) [10점] Find the induced current on the conducting wall.

(c) [10점] Obtain the instantaneous expression of the total electric intensity (based on a cosine time reference).

6. [15점] The following is the equivalent circuit of a differential length Δz of a transmission line:

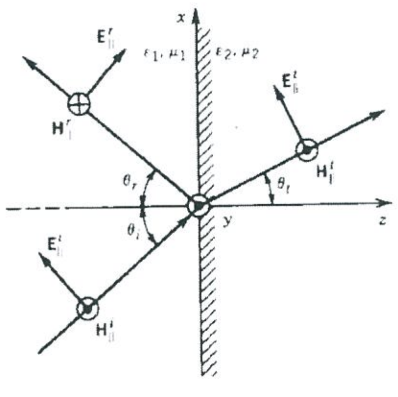


(a) [5점] Derive the general transmission-line equations using Kirchhoff's voltage law and Kirchhoff's current law as $\Delta z \to 0$.

(b) [5점] Using the results in (a) and assuming $e^{j\omega t}$ dependency of voltage and current's time behaviour, derive the time-harmonic transmission line equations.

(c) [5점] Using the results in (b), derive the propagation constant γ of a transmission line.

7. [10점] A parallel polarized plane wave traveling in a dielectric medium with ϵ_1, μ_1 is incident obliquely on a planar interface formed by the dielectric medium with ϵ_2, μ_2.



(a) [5점] Derive the expression for the reflection coefficient $\Gamma_{\parallel}^{b}$

(b) [5점] Derive the expression for the transmission coefficient $T_{\parallel}^{b}$.

2014 QE problems of semiconductor   Part 1 Physical Properties and Diode

1. Physical Properties of Semiconductor (30 points)
   a) What is the effective mass?
   b) What is the mean free path?
   c) Why is the electron velocity proportional to the electric field, instead of acceleration?
   d) Describe the temperature dependency of the mobility.
   e) Why is Fermi-Dirac distribution employed in semiconductor?
   f) Equations for electron and hole concentrations n & p using effective density of state, E_F, E_C and E_V
   g) Approximate the equations for the low doping case.
   h) We can approximate the equation only for the low doping case. Why? Describe the physical difference between the low doping and high doping cases?
2. NP Junction Diode (30 points)

   n-type $5*10^{18}$ /cm^3, 1um thick, L_D=0.1um, u_p=$6*10^2$ cm^2/V-s

   p-type $5*10^{16}$ /cm^3, 0.2um thick, L_D=1um, u_n=$3*10^3$$cm^2$/V-s

   kT=0.026eV

   a) Calculate electron and hole currents at V_d= 0.8V,
   b) Calculate electron and hole currents at V_d= 0.3V
   c) Calculate electron and hole currents at V_d= 1.0V.
   d) Explain the physical behaviors of the three cases in a~c
   e) Describe the current behavior for the reverse bias V_d<0

QE Semiconductor : Electronic devices (40 points)

Physical Constants

Electronic charge, $q=1.6\times10^{-19}C$ $\varepsilon_0 = 8.85\times10^{-14} F/cm$

Relative Dielectric constant of Si $\varepsilon_{r.Si} = 11.8$ Relative Dielectric constant of SiO_2 $\varepsilon_{r.SiO2} = 3.9$

1. (MOSFET) an nMOSFET is made on a p-substrate ($N_a = 5 \times 10^{16}$ cm^{-3}) with a 10 nm-thick SiO_2 as a gate insulator.
   a) (10 pts) Sketch the energy band diagram from source to drain along the interface between the SiO_2 and the substrate at the equilibrium condition (i.e., all terminals go to the ground).
   b) (15 pts) if the effective interface charge, Qi of the SiO^2 is 4×10^{10} qC/cm^2 and $\phi_{ms} = -0.95$ V, calculate the maximum depletion width(Wm), Flatband voltage(V_{FB}), and threshold voltage(V_T).
2. (BJT) Consider a p^+np BJT
   a) (5 pts) sketch the excess hole distribution, δp in the base region under the cutoff regime.
   b) (5 pts) Sketch the δp in the base region under the saturation condition.
   c) (5 pts) suggest any method to improve the switching speed.

QE 2014 반도체 광전자

1. Dielectric waveguide에서 photon의 <u>guided mode</u>와 semiconductor quantum well에서 electron의 <u>bound state</u>를 구하기 위한 wave equation을 각각의 경우에 대해 기술하고 boundary condition에 대해서 논하시오.
   (20점)

2. 길이가 L이고 반사율이 R_1과 R_2인 resonator로 이루어진 single transverse mode semiconductor laser가 있다. active region의 mode confinement factor가 Γ이고 cladding을 포함한 나머지 영역에서의 internal loss coefficient가 α일 때 주어진 active region의 material threshold gain G_{th}를 구하시오.
   (20점)

EE Math Qualifying Exam. (Math A)   July 30, 2104

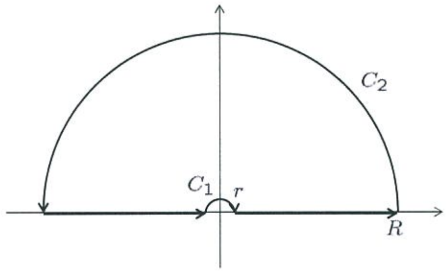
Caution!!! Use separate answer books for Problems 0.1-0.5 (Math A) and for 6-8 (Math B).

Problem 0.1 (10pt) Show that for complex variable z

$$\sinh^{-1}(z) = \ln(z + \sqrt{z^2 + 1})$$

Problem 0.2 (10pt) Evaluate the integral using the following hint and the Residue theorem:

$$I = \int_0^\infty \frac{\sin x}{x} dx = \text{Imaginary part of } \left\{ \frac{1}{2} \int_\infty^\infty \frac{e^{iz}}{z} dz \right\}$$



Problem 0.3 (10pt) (a) If a vector is a gradient of a scalar (smooth) function, i.e., $\mathbf{H} = \nabla\varphi$, then show that $\nabla \times \mathbf{H} = \mathbf{0}$.
(b) When the vector potential is equal to $\mathbf{A} = \frac{\mu_0 I}{4\pi} \ln(x^2 + y^2)\mathbf{i}_z$, find the magnetic field density given as $\mathbf{B} = \nabla \times \mathbf{A}$.

Problem 0.4 (10pt) Consider a system with the transfer function $H(s) = \frac{10s}{(s+2)(s+8)}$. Determine the impulse response and sketch it. (Should consider the causality issue.)
When the input function is $x(t) = e^{-2t}u_s(t)$,
find the output $y(t) = \mathcal{L}^{-1}\{H(s)X(s)\}$, where $u_s(t)$ is a unit step function.

Problem 0.5 (10pt) In the real analysis, the analytic function is defined as a function that can be expressed as a Taylor series, i.e., the corresponding Taylor series is convergent. Indicate whether the following following function is analytic or not. Mark 'O' if it is analytic, and mark 'X' else.
Also check the continuity at $x = 0$ for each function.

(a)

$$f_a(x) = e^x \sin x$$

(b)

$$f_b(x) = f_b(x + 2\pi) \text{ and } f_b(x) = \begin{cases} x, & -\pi < x < 0 \\ -x, & 0 \geq x < \pi \end{cases}$$

(c)

$$f_c(x) = \begin{cases} x \sin\frac{1}{x}, & x \neq 0 \\ 0, & x = 0 \end{cases}$$

(d)

$$f_d(x) = \begin{cases} 0, & x < 0 \\ 1 - e^{-x^2}, & x \geq 0 \end{cases}$$

EE Math Qualifying Exam. (Math B) July 30, 2104

Caution!!! Use separate answer books for Problems 0.1-0.5 (Math A) and for 6-8 (Math B).

6. (20 points) Say **True** or **False** for each sub-problem. You don't need to justify your answer. (+1 points for the correct answer, 0 for no answer, and -1 for an incorrect answer)

(01) If λ is an eigenvalue of $\mathbf{A}$, then it is also an eigenvalue of $\mathbf{T}^{-1}\mathbf{AT}$, where $\mathbf{T}$ is any non-singular matrix.

(02) If n_+ is the number of positive eigenvalues of a symmetric matrix $\mathbf{A}$, then it is also that of positive eigenvalues of a symmetric matrix $\mathbf{T^TAT}$, where $\mathbf{T}$ is any non-singular matrix.

(03) The eigenvalues of $\mathbf{A}+\mathbf{B}$ are equal to the sum of eigenvalues of $\mathbf{A}$ and $\mathbf{B}$.

(04) Even though the columns of a square matrix are linearly independent, the rows might be linearly dependent.

(05) If a matrix $\mathbf{A}$ is positive definite, then the inverse of $\mathbf{A}$ is also positive definite.

(06) The determinant of $\mathbf{I}+\mathbf{AB}$ is equal to that of $\mathbf{I}+\mathbf{BA}$, where $\mathbf{A}\in\mathbf{R}^{m\times n}$, $\mathbf{B}\in\mathbf{R}^{n\times m}$, and $\mathbf{I}$ denotes an identity matrix with proper size.

(07) If the matrices $\mathbf{A}$ and $\mathbf{B}$ are similar, then the matrices $\mathbf{A}$ and $\mathbf{B}$ always have the same eigenvalues.

(08) The determinant of $\mathbf{AB}$ is equal to that of $\mathbf{BA}$.

(09) The determinant of $a\mathbf{A}$ is equal to a times the determinant of $\mathbf{A}$.

(10) The row spaces of $\mathbf{A}^T\mathbf{B}$ and $\mathbf{B}^T\mathbf{A}$ have the same dimension.

(11) All the eigenvalues of a symmetric matrix $\mathbf{A}$ are real.

(12) The trace of $\mathbf{AB}$ is equal to that of $\mathbf{BA}$.

(13) If $\mathbf{A}$ and $\mathbf{B}$ are both $N\times N$ square matrices, then $\mathbf{AB}=\mathbf{0}$ implies $\mathbf{A}=\mathbf{0}$ or $\mathbf{B}=\mathbf{0}$.

(14) If the only eigenvectors of $\mathbf{A}$ are multiples of a nonzero vector $\underline{x}_0$, $\mathbf{A}$ is singular.

(15) If the only eigenvectors of $\mathbf{A}$ are multiples of a nonzero vector $\underline{x}_0$, $\mathbf{A}$ has a repeated eigenvalue.

(16) If the only eigenvectors of $\mathbf{A}$ are multiples of a nonzero vector $\underline{x}_0$, $\mathbf{A}$ is diagonalizable.

(17) The projection of a vector $\underline{a}$ in the direction of a unit vector $\underline{b}(\neq\underline{0})$ is $\underline{a}^T\underline{b}$.

(18) If the absolute value of the detreminant of $\mathbf{A}$ is 1, then such a matrix $\mathbf{A}$ is unitary.

(19) If a matrix $\mathbf{A}$ is unitary, then the detreminant of $\mathbf{A}$ must be 1 or -1.

(20) $e^{\mathbf{A}+\mathbf{B}}=e^{\mathbf{A}}e^{\mathbf{B}}$ if $\mathbf{AB}=\mathbf{BA}$.

7. (15 points)

$$\mathbf{A} = \begin{bmatrix} 4 & 1 \\ -1 & 2 \end{bmatrix}$$

(a) (5 points) Find the eigenvalues of $\mathbf{A}$.

(b) (5 points) Find and verify the minimal polynomial of $\mathbf{A}$.

(c) (5 points) Find the minimum and the maximum values of

$$f(\underline{x}) = \frac{\underline{x}^T \mathbf{A} \underline{x}}{\underline{x}^T \underline{x}},$$

where $\underline{x} \neq \underline{0}$.

8. (15 points)

(a) (5 points) Show that $y(t)$ is periodic if $x(t)$ is periodic and

$$y(t) = \int_{-\infty}^{\infty} h(t-\tau)x(\tau)d\tau$$

with $\int_{-\infty}^{\infty} |h(t)| d\tau < \infty$.

(b) (5 points) Show that

$$\int_{-\infty}^{\infty} x(t)y^*(t)dt = \int_{-\infty}^{\infty} X(f)Y^*(f)df,$$

where

$$X(f) = \int_{-\infty}^{\infty} x(t)e^{-\mathrm{j}2\pi\mathrm{f}\mathrm{t}}dt, \quad Y(f) = \int_{-\infty}^{\infty} y(t)e^{-\mathrm{j}2\pi\mathrm{f}\mathrm{t}}dt$$

are the Fourier transforms of $x(t)$ and $y(t)$, respectively.

(c) (5 points) When

$$x(t) \triangleq \begin{cases} -1, & \text{for } -T/2 \leq x < 0 \\ 1, & \text{for } 0 \leq x < T/2 \\ 0, & \text{elsewhere,} \end{cases}$$

for some $T > 0$, find the Fourier transform of $x(t)$.

2014 QE (Microprocessors and Digital Logic)

1. (20 points) Use the Finite State Machine (FSM) design method to design a complete FSM circuit for an even parity checker. There are 1-bit RESET, CLK, and DATA inputs, and a single EVEN output that is 1 whenever the number of 1 bits in the serial DATA input is an even number.

2. (15 points) Consider a combinational logic subsystem that determines if a 4-bit binary quantity A,B,C,D in the range of 0000 (0) through 1011 (11 in base 10) is divisible by the decimal numbers two, three, or six. That is, the function is true if the input can be divided by the indicated amount with no remainder (e.g., By2(0110), By3(0110), and By6(0110) are all true). Assume that the binary patterns 1100 (12) through 1111 (15) are "don't cares."
   (a) Draw the truth tables for By2(A,B,C,D), By3(A,B,C,D), By6(A,B,C,D).
   (b) Minimize the functions using 4-variable K-maps to derive minimized sum-of-products forms.

3. (15 points) What is a *metastable* signal? Describe a situation in which such a signal can be produced. Show the design for a simple D flip-flop-based circuit that can be used to reduce the probability of the occurrence of a metastable signal. Now, how can this circuit be modified to *further* reduce this probability?

1. (10 points) What are the major differences between microprocessor, DSP, embedded processor, FPGA, and GPU?

2. (10 points) What are the differences between CISC and RISC?

3. (10 points) Explain three differences between real mode and protection mode in microprocessor and explain them.

4. (10 points) Explain the differences between process and thread.

5. (10 points) Draw a simple microprocessor system and explain the operation, using addressing modes with simple assembly codes.