EECS 16B Designing Information Devices and Systems II
Spring 2016 Anant Sahai and Michel Maharbiz Midterm 2

Exam location: 145 Dwinelle (SIDs ending in 1 and 5)

PRINT your student ID: ____

PRINT AND SIGN your name: ________________, ________________ ____________________
(last) (first) (signature)

PRINT your Unix account login: ee16b-_____________

PRINT your discussion section and GSI (the one you attend): ____

Row Number (front row is 1): __________ Seat Number (left most is 1): __________

Name and SID of the person to your left: ____

Name and SID of the person to your right: ____

Name and SID of the person in front of you: ____

Name and SID of the person behind you: ____

Section 0: Pre-exam questions (3 points)

1. **What has been the most useful concept you learned from EE16A? (1 pt)**

2. **What TV show, book or movie has given you a good laugh? (Feel free to write the title in any language.) (2 pts)**

Do not turn this page until the proctor tells you to do so. You can work on Section 0 above before time starts.

[Extra page. If you want the work on this page to be graded, make sure you tell us on the problem's main page.]

Section 1: Warm-up questions (48 points)

3. True or False (2 pts for each question) For each question below, circle **T** on the left of each statement if you think the statement is true; else circle **F** (for false).

(a) **[T / F]** An ideal capacitor dissipates energy from the circuit in the form of heat.

(b) **[T / F]** An ideal "golden rules" op-amp behaves as though it has infinite gain.

(c) **[T / F]** A series RLC circuit connected with a DC input voltage/current in a single loop cannot exhibit voltage or current oscillations in time.

(d) **[T / F]** Given an impedance Z connected across a voltage source $v(t)$, it is possible for $i(t)$ to be in-phase (no phase shift) with a sinusoidal $v(t)$.

(e) **[T / F]** Since the current across an open circuit must be zero, the voltage across the open circuit must also be zero by Ohm's law.

(f) **[T / F]** The voltage across a constant current source must be zero.

(g) **[T / F]** An electrical impedance across two terminals $Z = j\omega k$ (where ω is a positive angular frequency in rad/s and k is a positive real number) can be implemented using only capacitors.

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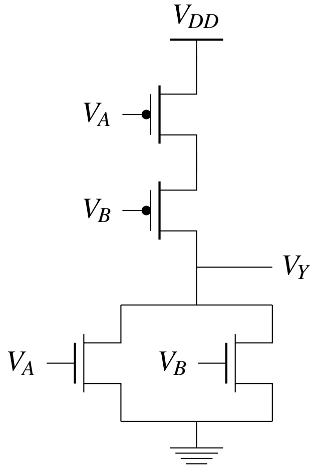
4. Digital Circuits (9 pts)

Consider the circuit below:

(a) (3 pts) The circuit below is a legal CMOS gate. A, B and Y are the Boolean values of the voltages, V_A, V_B and V_Y, respectively. Write down Y as a Boolean formula involving A and B.



Operator	Meaning
$\neg$	NOT
$\vee$	OR
$\wedge$	AND
$\oplus$	XOR

Table 1: Reminder: Logical Operators

Implement each of the following Boolean functions with a single CMOS gate (i.e. implemented using a pull-up network consisting of PMOS transistors connected to a pull-down network consisting of NMOS transistors) by drawing it, or state why the function cannot be implemented as a single CMOS gate in 1-3 sentences. You only have available V_A and V_B as inputs.

(b) (3 pts) $\neg(A \wedge B)$.

(c) (3 pts) $A \wedge B$.

5. Can you control me? (8pts)

We have a discrete time system that evolves according to $\vec{x}(t+1) = A\vec{x}(t) + B\vec{u}(t)$. For each part, **answer whether there exists a sequence of control vectors $\vec{u}(t)$ that will bring the state to the origin $\vec{0}$ in a finite number of steps no matter where it starts.**

(a) (4 pts) $A = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix}$ and $B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$.

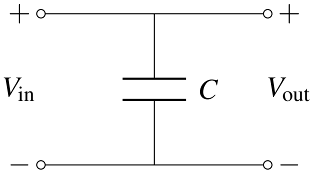
(b) (4 pts) $A = \begin{bmatrix} 1 & 2 \\ 1 & 2 \end{bmatrix}$ and $B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$.

PRINT your name and student ID: ____________________

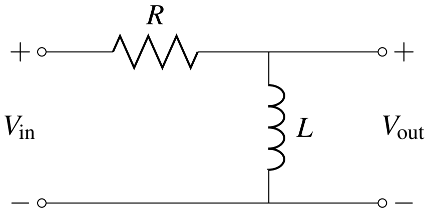
6. Transfer Functions (9 pts)

Consider the circuit diagrams below. We define $H(\omega) = V_{\text{out}}/V_{\text{in}}$ as the voltage transfer function for each circuit. Here, assume that the input is connected to an ideal voltage source that applies a sinusoidal voltage. For each circuit, **provide an expression for** $H(\omega)$ where ω is the frequency of the applied sinusoidal voltage in radians per second. Here the transfer functions should be expressed as functions of j, ω, constants and the physical constants (R, C, L) of the systems.

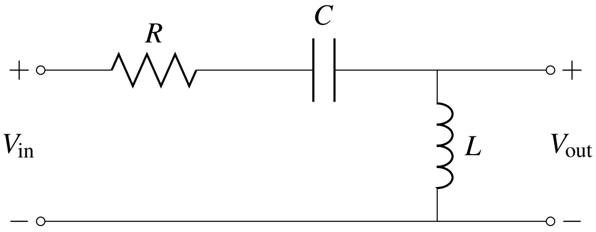
(a) (3 pts) $H(\omega) = ?$



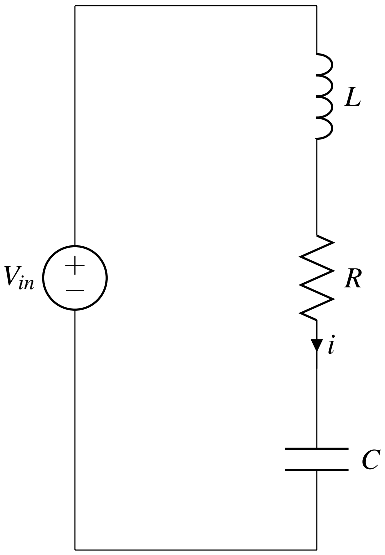
(b) (3 pts) $H(\omega) = ?$



(c) (3 pts) $H(\omega) = ?$



7. RLC Transient Matching (8pts)

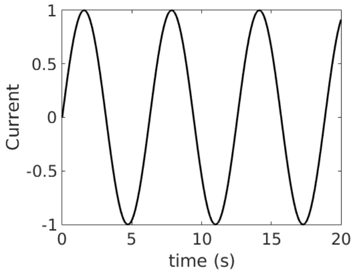


Throughout this problem, we assume $V_{in} = 1V$ for $t < 0$ and $0V$ for $t \geq 0$.

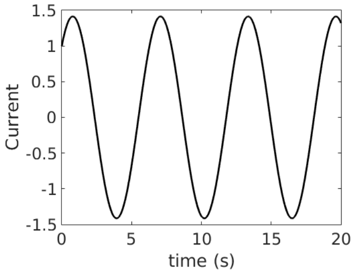
For this problem you are asked to **match** the transient behavior for **the current,** i, of the RLC circuit for various values of R, L, and C.

Circle your answer. There is no need to give any justification. However, 0 points will be awarded for an incorrect answer, 0.5 point will be awarded for leaving it blank and 4 points will be awarded for the correct answer

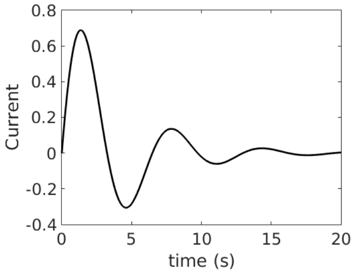
(a) (4 pts) For $R = 0\Omega$, $L = 1H$, $C = 1F$ Which one is the correct transient response of the current in the circuit?



(A)

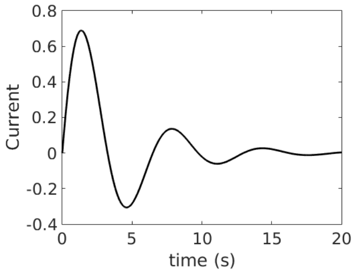


(B)

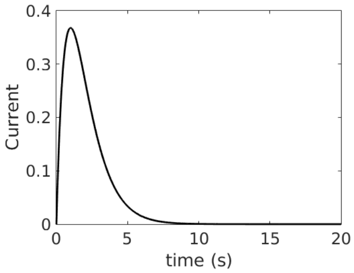


(C)

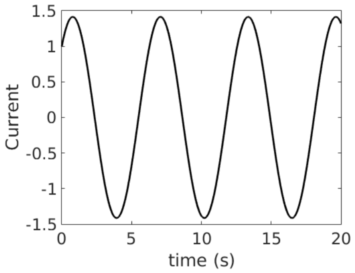
(b) (4 pts) For $R = 0.5\Omega$, $L = 1H$, $C = 1F$ Which one is the correct transient response of the current in the circuit?



(A)



(B)

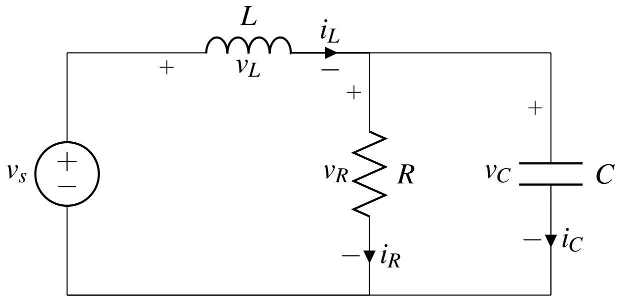


(C)

Section 2: In The Zone(59 points)

8. RLC Problem (26 pts)

Consider the circuit below: let's try to analyze it with everything you know about circuits.



(a) (3 pts) Assume $v_s = V_0$ for $t < 0$, and $v_s = 0$ for $t \geq 0$. **What is $v_C(0)$? What is $i_L(0)$?**

(b) (3 pts) If $v_s = 0$ (a constant) for any $t \geq 0$, **what is the steady state value of v_C?** (i.e. $v_C(t \rightarrow \infty)$) **What is the steady state value of i_L?**

(c) (3 pts) **Write down the KCL equation on a node connecting the three passive components in terms of i_L, i_C and i_R.**

(d) (3 pts) **Write down a KVL equation for the loop containing the voltage source, inductor and the capacitor in terms of v_s, v_L and v_C.**

(e) (6 pts) **Write down differential equations for v_C and i_L** using the relationships between the voltage across each component and the current through it, in addition to the equations obtained above. **Convert them into the following matrix form** (notice that $v_s = 0$ for any $t \geq 0$):

$$\begin{pmatrix} \frac{di_L}{dt} \\ \frac{dv_C}{dt} \end{pmatrix} = A \begin{pmatrix} i_L \\ v_C \end{pmatrix}$$

(f) (8 pts) For the differential equations above, we know the solution can be obtained from the general solutions $c_1 e^{\lambda_1 t}\vec{v}_1 + c_2 e^{\lambda_2 t}\vec{v}_2$. **What are the values of λ_1 and λ_2? Express them in terms of R, L, C and constants.**

[Extra page. If you want the work on this page to be graded, make sure you tell us on the problem's main page.]

9. Hold me and linearize me (13 pts)

Consider a non-linear two-dimensional system with states x_0 and x_1 and scalar input u that evolves according to the following coupled differential equations

$$\begin{aligned} \frac{d}{dt}x_0(t) &= \dot{x}_0 = x_1(t) \\ \frac{d}{dt}x_1(t) &= \dot{x}_1 = 4 - (\frac{u(t)}{x_0(t)})^2 \end{aligned} \tag{1}$$

(a) (5 pts) **Find an input u_e so that if the system starts in state vector $\vec{x}_e = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ and we apply the input $u(t) = u_e$, the system will always stay in that same state.**

(b) (8 pts) **Write linearized state-space equations around $\vec{x}_e$ and u_e. Convert them into the following form and find the matrices A and B.**

$$\frac{d}{dt}\vec{x}(t) = A(\vec{x} - \vec{x}_e) + B(u(t) - u_e)$$

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[Extra page. If you want the work on this page to be graded, make sure you tell us on the problem's main page.]

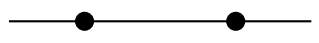
10. Circuit Design (8 pts)

In this problem, you will find a circuit where several components have been left *blank* for you to fill in.

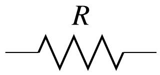
Assume the op-amp is *ideal*.

You have at your disposal *only one of each* of the following components:

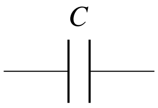
(a) an open circuit



(b) a short circuit

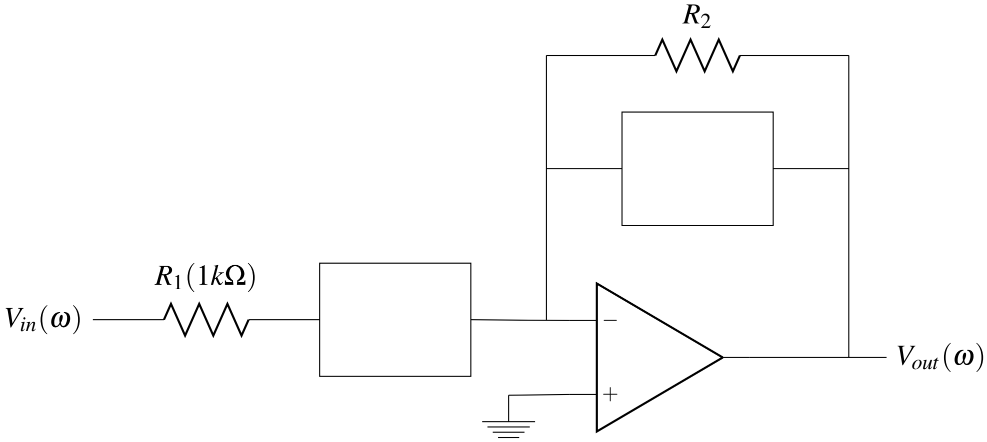


(c) a resistor (you choose from the value $R = 0.5k, 1k, 2k\Omega$)



(d) a capacitor (you choose from the value $C = 0.5\mu, 1\mu, 2\mu F$)

Consider the circuit below. The voltage source $v_{in}(t)$ has the form $v_{in}(t) = v_0 \cos(\omega t + \phi)$. The labeled voltages $V_{in}(\omega)$ and $V_{out}(\omega)$ are the phasor representation of $v_{in}(t)$ and $v_{out}(t)$. The transfer function $H(\omega)$ is defined as $H(\omega) = V_{out}(\omega)/V_{in}(\omega)$.

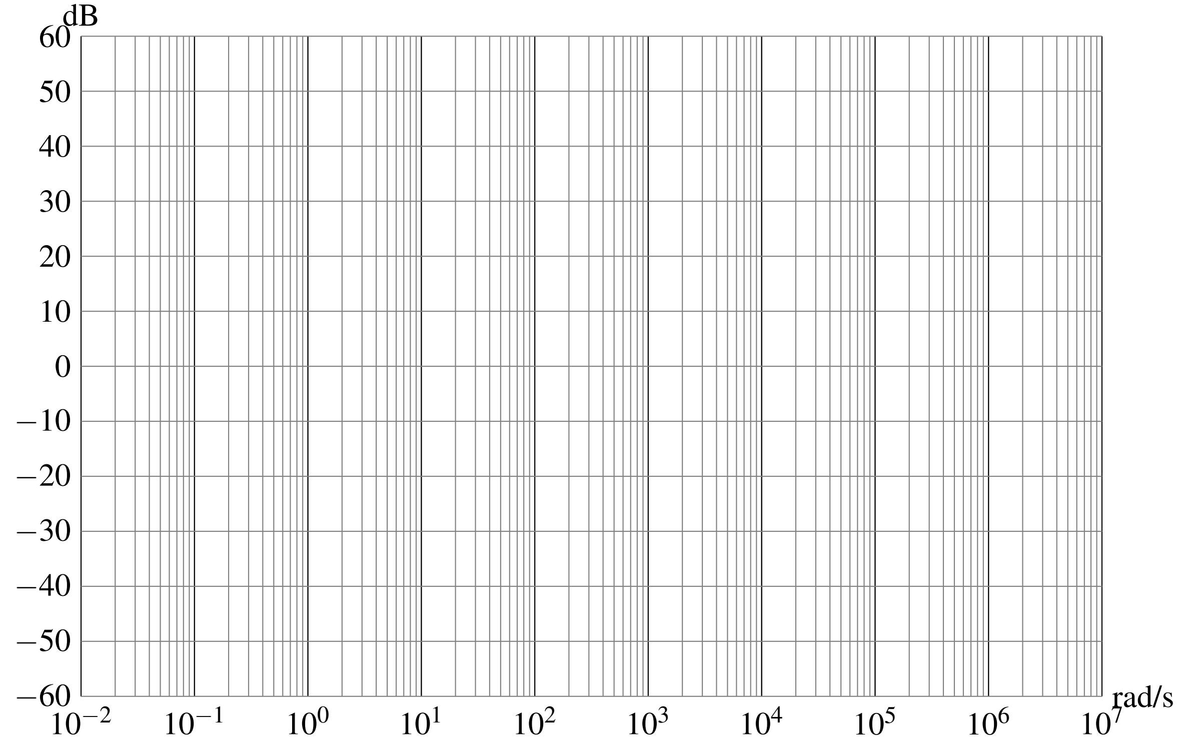


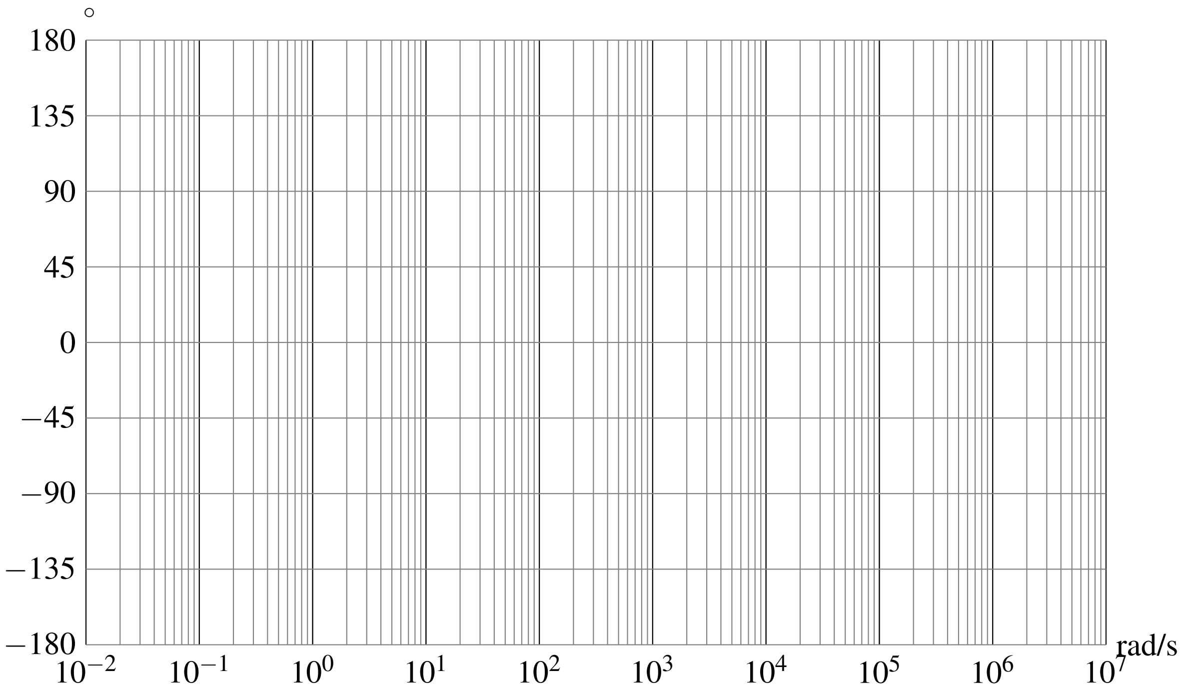
Let R_1 be $1k\Omega$. **Fill in the boxes and determine the value of** R_2 so that

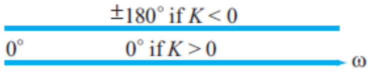
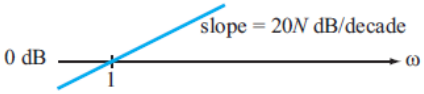
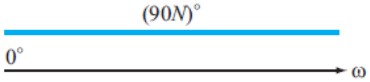
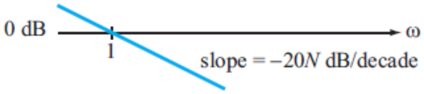
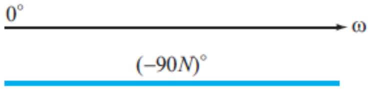
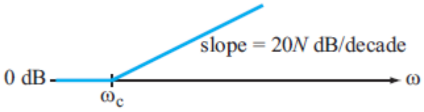
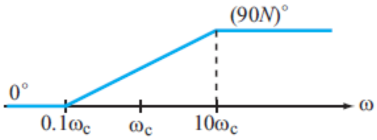
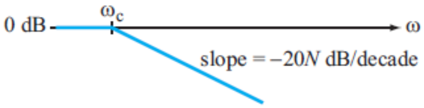
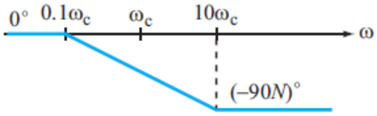
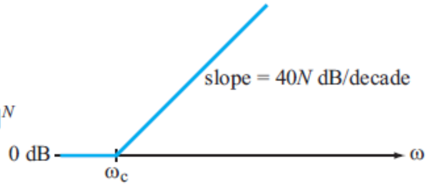
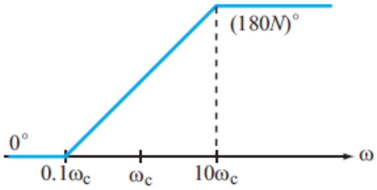
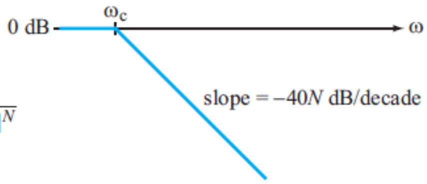
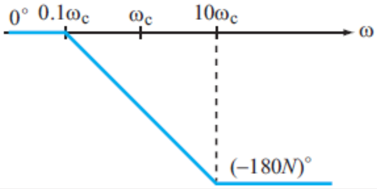
- It is a high-pass filter.
- $|H(\infty)| = 2$.
- $|H(10^3)| = \sqrt{2}$.

11. Bode plot (12 pts)

Draw the Bode plot for the transfer function $H(\omega) = \frac{(j\omega\times 10)(10+j\omega\times 10^{-3})}{(100+j\omega\times 10)}$ Remember you have the Bode plot table in the next page!





Factor	**Bode Magnitude**	**Bode Phase**
Constant K		
Zero @ Origin $(j\omega)^N$		
Pole @ Origin $(j\omega)^{-N}$		
Simple Zero $(1 + j\omega/\omega_c)^N$		
Simple Pole $\left(\frac{1}{1 + j\omega/\omega_c}\right)^N$		
Quadratic Zero $[1 + j2\xi\omega/\omega_c + (j\omega/\omega_c)^2]^N$		
Quadratic Pole $\frac{1}{[1 + j2\xi\omega/\omega_c + (j\omega/\omega_c)^2]^N}$		

[Doodle page! Draw us something if you want or give us suggestions or complaints. You can also use this page to report anything suspicious that you might have noticed.]