ECE285 Electric Circuits I
Fall 2013 Nathalia Peixoto

FINAL EXAM

Dec 16th , 2013, 10:30am-1:15pm

Honor pledge: "On my honor I have neither given nor received aid on this exam."

Name:______________________________________ Signature:_________________

- **Calculators allowed.**
- **Single sided 8.5x11 sheet with formulas and circuits allowed.**
- No books, no cell phones allowed.
- Write in English. Write clearly. Write neatly.
- All your answers must be in these stapled pages. If you use the backside you need to indicate this on the front. Back of pages are usually **NOT** graded.
- Do not take the staple off.
- Do not expect the answers to be integers.

For this exam please assume, unless otherwise specified, that:

- Voltages are measured in reference to ground.
- Light bulbs are resistances.
- All switches are actuated in the direction shown by their arrows at t=0s, unless otherwise noted by the switch.
- Operational amplifiers are properly powered, so that they don't saturate.

Question	Max points	Grade
1	2	
2	2	
3	2	
4	2	
5	1	
6	1	
7	20	
8	20	
9	20	
10	20	
11	5	
12	5	
total		

Learning objectives for questions 1 through 5

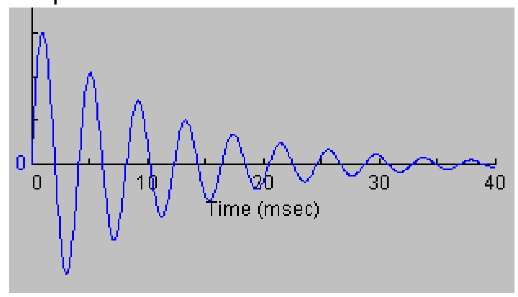
1. Students will be able to correctly identify the natural response from an RLC circuit. (Associate time contant, resonance, natural frequency concepts).
2. Student will be able to analyze any circuit containing only supplies (independent and dependent) and resistors. Students will understand series and parallel resistors.
3 and 4: (same learning objectives as in question 2 above). Students will differentiate open circuit from short circuit, and the consequences thereof.
5. Students will be able to recognize common operational amplifier circuits.

B

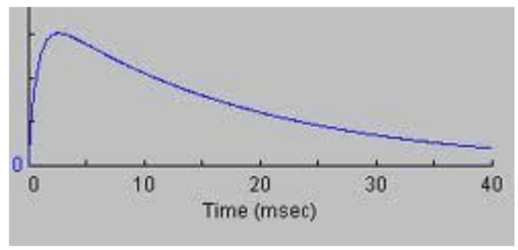
C

1. Which of the following graphs shows the natural response of an RLC circuit that is underdamped?
a) Graph 1
b) Graph 2
c) Graph 3
d) Either graph 1 or 2
e) None of the above

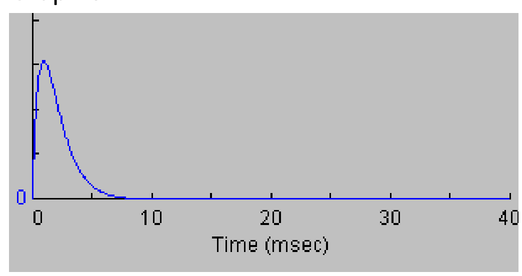
Graph 1:



Graph 2:

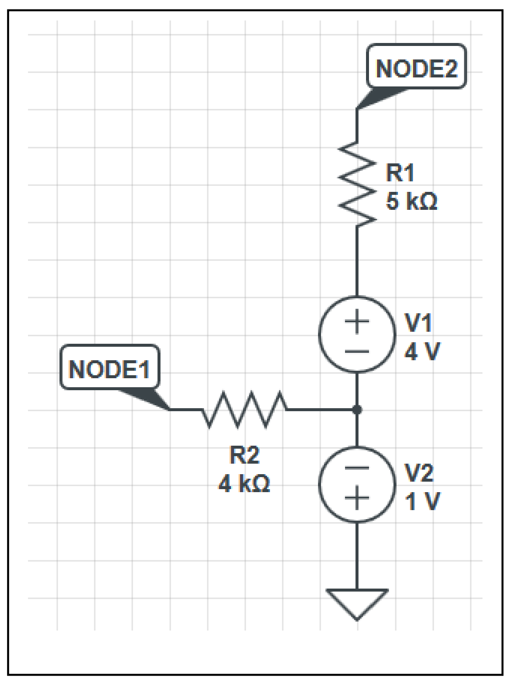


Graph 3:



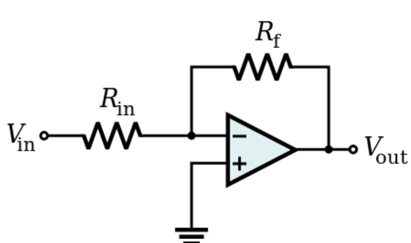
2. A light bulb is connected to a voltage supply and lights up. When a second one is connected in series to the first one:
a) Current through the first one will go up.
b) This won't work, as light bulbs need to always be connected in parallel.
c) Required power from the supply will go up.
d) Current through the first one will go down.
e) None of the above.

3. This question refers to the figure with the resistors and voltage supplies. The voltage measured by a multimeter connected to node 2, in reference to node 1, is:
a) 0V
b) 4V
c) 2V
d) -3V
e) -4V



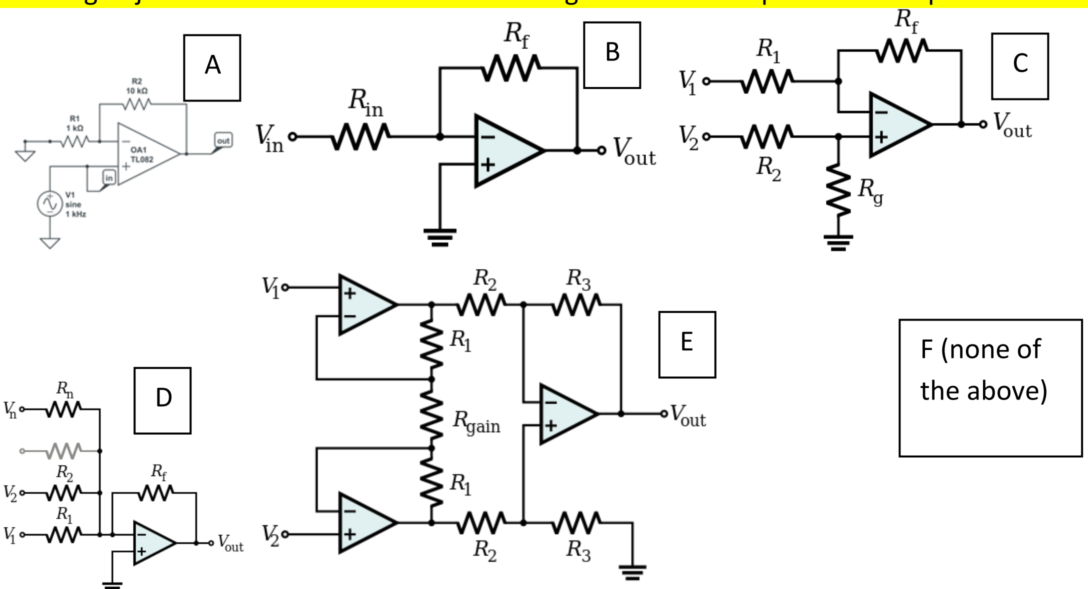
4. Referring still to the same circuit, if node 2 is shorted to ground, the voltage on node 1, in reference to ground:
a) Doesn't change.
b) Goes to zero.
c) Changes to 1V.
d) Goes to 3V.
e) None of the above.

5. On the figure with the opamp, Rf=1k Ω and Rin=500 Ω. If Vin is 0.5V, what is Vout?
a) 2V
b) -1V
c) -2V
d) 1V
e) none of the above

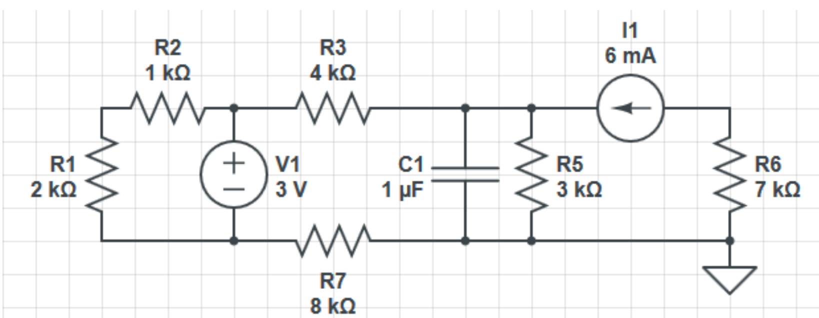


6. From the images below, select the instrumentation amplifier: E

Learning objective: students will be able to recognize common operational amplifier circuits.



7. Find the Thèvenin equivalent from the perspective of the capacitor. (Hint: source transformation won't work here.) You can use any method you would like. Consider superposition one of them.



Learning objective: students will be able to simplify circuits containing supplies and resistors; students will understand the Thevenin and Norton theorems and apply them when simplifying circuits; students will successfully leverage methods in circuits (source transformation, Kirchhoff's laws, Ohm's law, mesh analysis, nodal analysis, superposition).

Answer: Rth – to find it one would short the 3V power supply and open the 6mA current supply. Doing that, the resistance across the capacitor would be 4k+8k+3k= 15kOhms. This is the Thevenin resistance. Then one would draw two circuits: one with just the 3V , and the 6mA open. This would create a voltage drop of … across the 3kOhm resistor. 3V/15k = 0.2mA. The voltage drop is 0.6V.

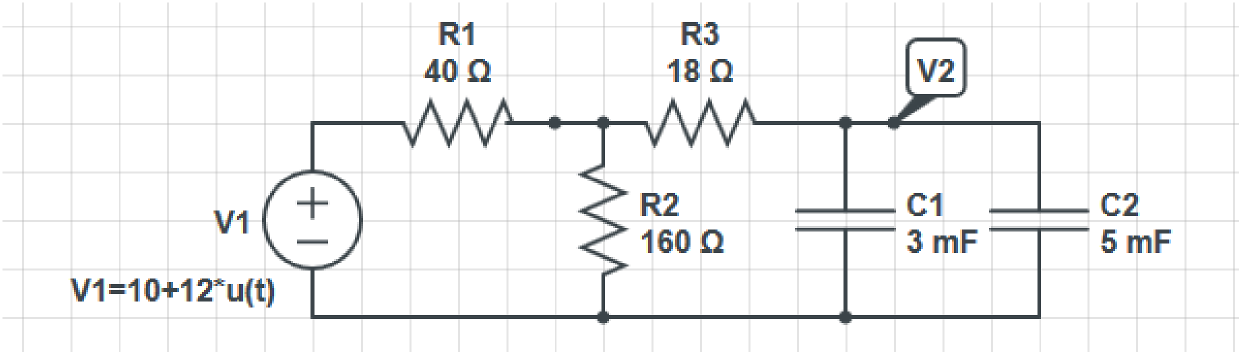
The second circuit would short the 3V and use the 6mA as the only power supply. This means the 3k would be in parallel with the 12k, giving an equivalent resistance of 2.4kOhms. The voltage drop across the 2.4kOhm resistor, assuming the 6mA current, is 14.4V.

Thevenin equivalent: Vth=15V and Rth=2.4kOhms.

TEC:

8. Find the nodal voltage V2 for t≥0.

V2 =



Learning objectives: capacitors in parallel = add the capacitances (to 8mF in this case).

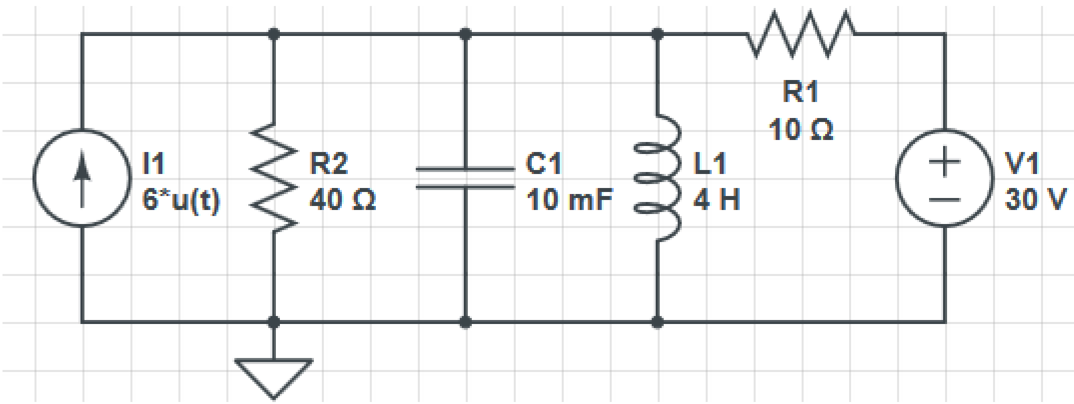
Recognize there is no voltage drop across the 18 Ohm resistor for t<0 (when the voltage applied is just 10V, the voltage across the capacitors, V2, is 8V).

Recognize that the Vinf, with the V1=22V, is similar (17.6V) – again, learning objective for series resistors (voltage division) as well as an open circuit because of the capacitors and the 18 Ohm resistor doesn't have any current flowing through it.

Final answer of the kind: v(t)=Vinf+ (V(0)-Vinf)*e^(-t/tau), where tau is the time constant.

Answer: 17.6-9.6*e^(-2.5*t) V

9. a) Find the current through the inductor for t≥0. (8pts)
b) Find the voltage across the capacitor for t≥0. (7 pts)
c) Find the energy stored in both (L and C) at t=100ms. (5 pts)



Learning objectives:

- Recognize a characteristic equation from an RLC circuit.
- Source transformation allows for simplification of circuit (in this case, for t>0, if the 30V is transformed into a current source, that 3A source can be added to the 6A source).
- Student will be able to simplify circuits, leveraging previously learned circuits techniques.
- Recognize the natural response of an RLC circuit:
- (This circuit is overdamped (the characteristic equation is the simple s^2+2*alpha*s+w_o^2=0;)
-

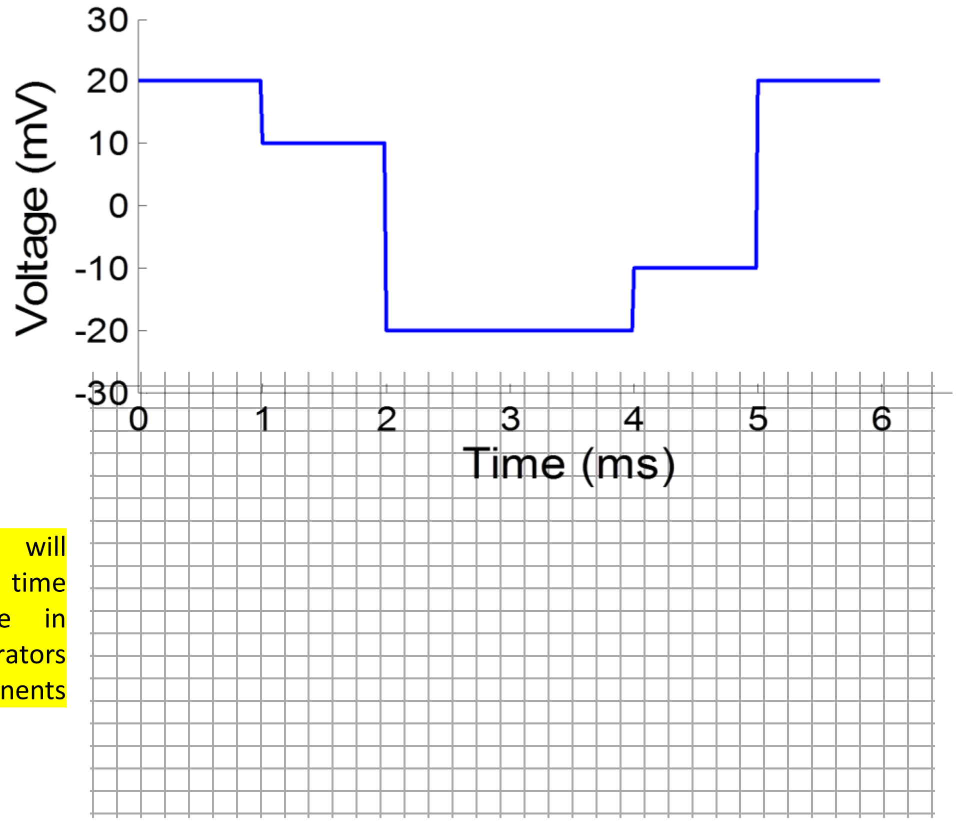
i(t) =

v(t)=

w1=

w2=

10. (a) An op amp integrator with R=4MΩ and C=1 μF is properly powered so that it doesn't saturate for the input given below. Sketch the output. (10 pts)



Learning objective: student will understand the concept of time constant and its relevance in differentiators and integrators utilizing active components (operational amplifiers).

Answer to question 10a:

$$RC = 4 \times 10^6 \times 1 \times 10^{-6} = 4$$

$$v_o = -\frac{1}{RC}\int v_i dt = -\frac{1}{4}\int v_i dt$$

For $0 < t < 1$, $v_i = 20$, $v_o = -\frac{1}{4}\int_0^t 20dt = -5t$ mV

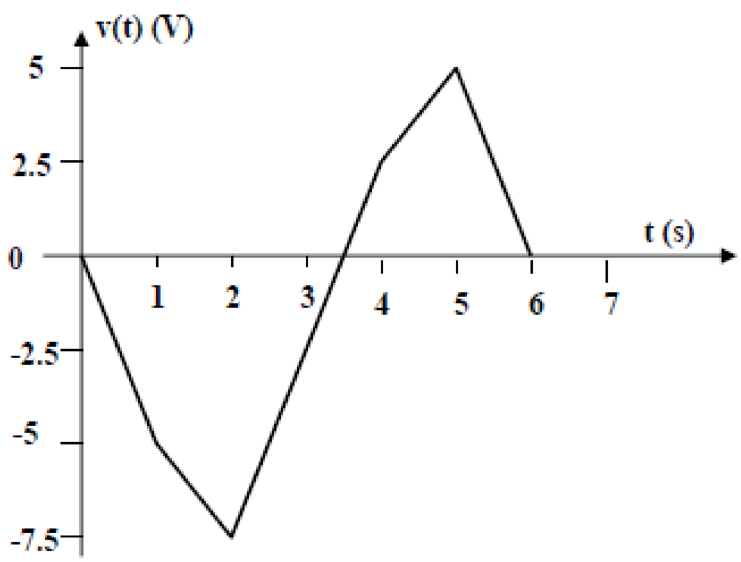
For $1 < t < 2$, $v_i = 10$, $v_o = -\frac{1}{4}\int_1^t 10dt + v(1) = -2.5(t-1) - 5$
$= -2.5t - 2.5$mV

For $2 < t < 4$, $v_i = -20$, $v_o = +\frac{1}{4}\int_2^t 20dt + v(2) = 5(t-2) - 7.5$
$= 5t - 17.5$ mV

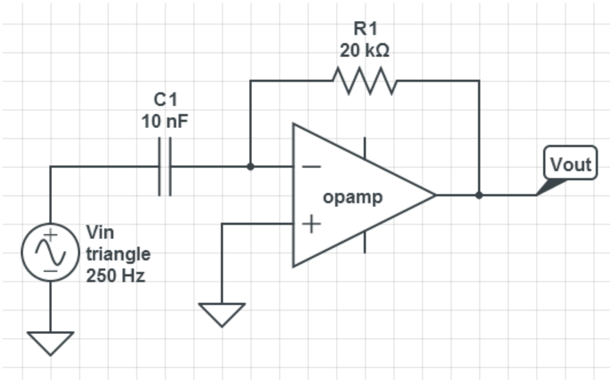
For $4 < t < 5$m, $v_i = -10$, $v_o = \frac{1}{4}\int_4^t 10dt + v(4) = 2.5(t-4) + 2.5$
$= 2.5t - 7.5$ mV

For $5 < t < 6$, $v_i = 20$, $v_o = -\frac{1}{4}\int_5^t 20dt + v(5) = -5(t-5) + 5$
$= -5t + 30$ mV

Thus $v_o(t)$ is as shown below:



10 (b) Plot the output of the circuit below, given the input is a triangular wave with amplitude 10V (20V peak-to-peak) and frequency 250Hz. Draw both the input and output. (10 pts)



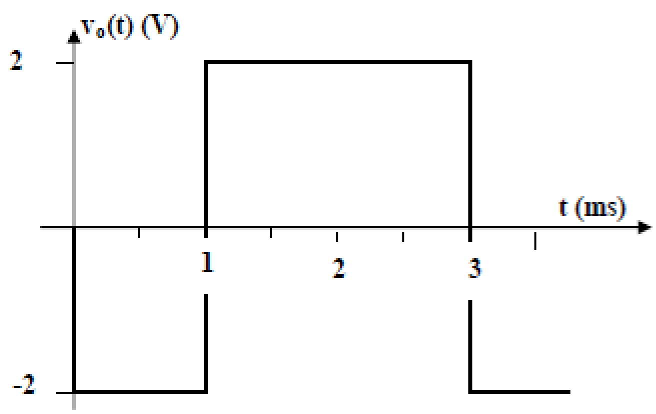
RC = 0.01 x 20 x 10^{-3} sec

$$v_o = -RC\frac{dv_i}{dt} = -0.2\frac{dv}{dt}\,\text{msec}$$

(Obs. Students need to also draw a triangular wave with a 4ms period)

$$v_o = \begin{cases} -2V, & 0 < t < 1 \\ 2V, & 1 < t < 3 \\ -2V, & 3 < t < 4 \end{cases}$$

Thus $v_o(t)$ is as sketched below:



11. Explain in one paragraph how you would solve a circuit with sequential switches. What would be a characteristic of the answer that would indicate the "sequence"?

Solution of sequential switching involves separating the circuit into subsets (depending on when switches are on or off) and solving those many circuits separately, one at a time. The solution then comes with the exponents shifted in time. For example, if part of the circuit starts at t=20ms, then the exponent of that part of the circuit, instead of t, would be (t-0.02).
It is critical that the student understands the difference between a circuit with no sequence and a circuit with sequential switching (several exponentials for example). Graphs allowed here.

12. Describe the main technical challenge you encountered during ECP2 (Electric Circuits Project 2), and how you tackled it. The technical challenge needs to be focused around circuits.

Learning objective: students will gain experience in real life applications of circuits, in building circuits, and in troubleshooting projects.

Answer: it is expected that each student gives a different answer in terms of their challenge (encountered throughout the semester).
The ones to avoid are: soldering; problems finding parts, ordering components, team member did not come to meetings. These are reasonable, non-technical, challenges. They should have been ironed out in ECP1 (first project).
Challenges expected: circuit found online did not work – we had to redesign the filter so that it passed everything above a certain frequency. We learned that ½*pi*f=w and that the RC (time constant) had a huge impact on our circuit. We chose to change the resistor to select which frequency we needed (heuristic method) as we didn't have many capacitors available;
We had many problems with the FM transmitter until the RF teacher said it would never work on a breadboard. We soldered the transmitter and kept the amplifier on the breadboard until we had it all working. We learned how to use a spectrum analyzer (make/model ETC) and are not confident that any radio can be made to work with those tools (multimeter, oscilloscope, spectrum analyzer).