2013 EECE 2410 – Circuits and Signals: Biomedical Applications

Final Exam

Modified Slightly for 2014 EECE 2150 Fall Semester Practice Final

Name:

Instructions:

- Closed book, closed notes,
- Computers, cell phones, scientific calculators are NOT allowed
- Complete all 5 problems
- Show all work and **place a box around all your final answers**
- Write your name on all pages
- You may write on both sides of the pages

Question 1 (20 Points) **Name:**

1A) For the following time-dependent signals (4pts)

i) re-write them in **complex exponential** notation, and

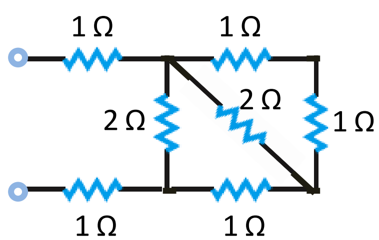
ii) what is the associated **phasor** values?

(**Answer both parts!**)

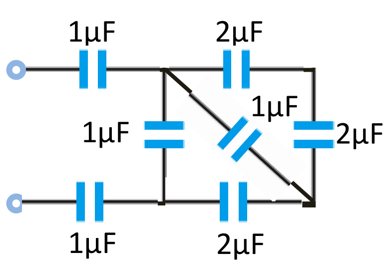
$v(t) = 6\cos(227t + 20^{o})$

$i(t) = 3\sin(1000t + 130^{o})$

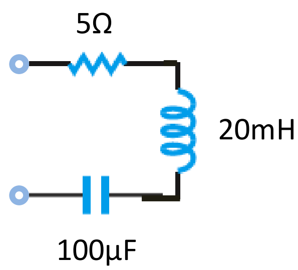
1B) What is the equivalent Resistance ($\boldsymbol{R_{eq}}$) of the following resistor network? (4pts)



1C) What is the equivalent Capacitance ($\boldsymbol{C_{eq}}$) of the following capacitor network. (4pts)



1D) What is the equivalent Impedance (***Z_{eq}***) of the following network if the source has an angular frequency of **1000 rad/s** (4pts)



1E) True of False. In data acquisition, all else being equal, (4pts)

T F Use of an analog-to-digital converter with a higher sampling rate will reduce quantization noise

T F Use of an analog-to-digital converter with a greater number of bits will reduce quantization noise

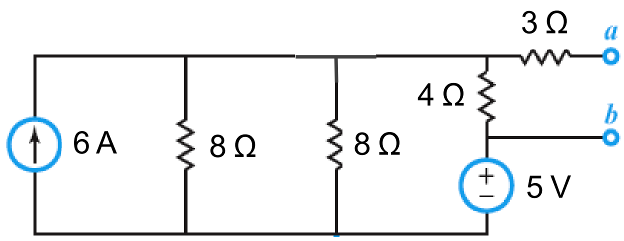
T F Use of an analog-to-digital converter with a higher sampling rate will reduce any aliasing that may occur

T F Use of an analog-to-digital converter with a greater number of bits will reduce aliasing that may occur

Question 2 (10 Points) **Name:**

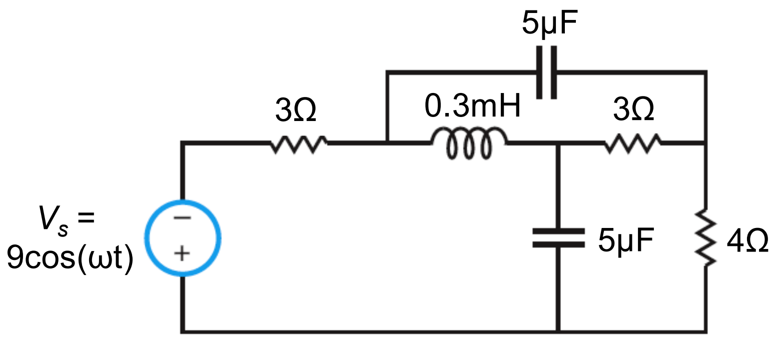
2A) Find the Thevenin and Norton equivalent circuits for the following circuit at terminals (a,b). You may use any method you wish. (7pts)

3B) Now assume a 7.5Ω resistor is connected across terminals (a,b). What is the **power** dissipated across this resistor? (3pts)



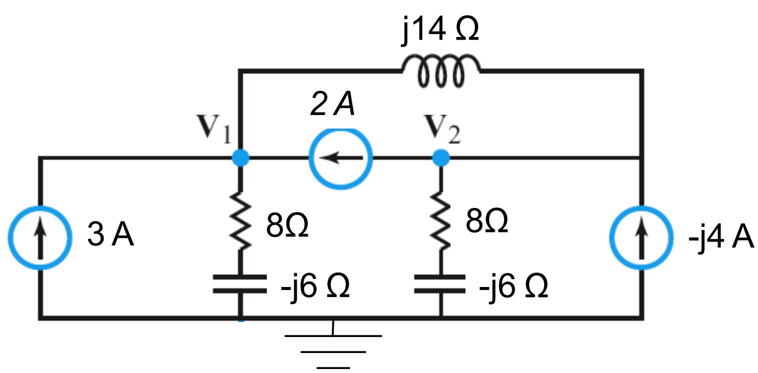
Question 3 (30 Points) **Name:**

3A) For the circuit below, calculate the impedances of the **capacitors** and the **inductor** for an angular frequency of **20,000 rad/s** (6pts)



3B) Application of the **mesh-current** method in phasor domain will yield a system of three equations for three unknown phasor currents. **Write** and s**implify** these equations and then put the system of equations in **matrix** form. **You do not need to solve for the values of the three currents.** (14pts)

3C) Now consider the circuit below. Application of the **node-voltage** method in phasor domain will yield two systems of equations and two unknown phasor node voltages at nodes $\mathbf{V_1}$ and $\mathbf{V_2}$. **Write** and simplify these equations and put the system of equations in **matrix** form. As above you do not need to solve $\mathbf{V_1}$ and $\mathbf{V_2}$ (10pts)

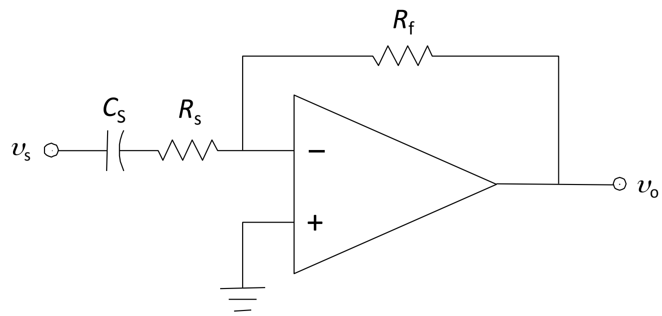


Question 4 (28 Points) **Name:**

4A) For the circuit below, assume **ideal op-amp** characteristics

i) Derive and expression for $v_o(t)$ if $v_s(t)$ = cos(ω*t***)**. Show your work.. (10 pts)

ii) What is the output voltage $v_o(t)$ if $v_s(t)$ = 1 V? (3pts)



4B) Assume the electrocardiogram signal of a certain type of bird has an angular frequency range from **0 rad/s to 1000 rad/s**:

i) **Sketch** a circuit with a small modification to the circuit above to isolate this frequency range. (3pts)

ii) Choose appropriate **Resistor and Capacitor** values. Explain your rationale for your choices. (3pts)

iii) What is the *approximate* gain of the circuit at **500 rad/s**? (3pts)

iv) If you were going to set up an analog-to-digital converter to acquire this signal, what is the **minimum sampling** rate you would use? Explain your rationale. (3pts)

v) If the voltage range of the signal after amplification was 0 to 3 V, and you were going to set up an analog-to-digital converter to acquire this signal, what is the minimum number of bits you would need to ensure that the resolution of the quantization was less than 0.03V? Explain your rationale. (3pts)

Question 5 (15 Points) **Name:**

This problem is on material not covered in our course this semester.

Consider the bandpass filter you designed in (4B) with passband [1,1000]rad/s. In this question, use F (Hz) and W (rad/s) to denote CT frequencies (as in H(jW) for a CT Fourier Transform); and f (1/sample) and w (rad/sample) to denote DT frequencies (as in $H(e^{jw})$ for a DT Fourier Transform (DTFT)).

Assume $v_s(t) = A_1 cos(W_1 t + \emptyset_1) + A_2 cos(W_2 t + \emptyset_2) + A_3 cos(W_3 t + \emptyset_3)$.

5A) For $w_1 = 0$ rad/s and $w_2 = 500$ rad/s and $w_3 = 5000$ rad/s (approximately) determine $v_o(t)$.

Hint: You can consider frequencies deep into the stop band to be eliminated by the filter if you can justify this approximation mathematically. This helps simplify the remaining sections of this question.

5B) Assume that the output signal $v_o(t)$ (in (5A) is sampled at a rate of $F_s = \frac{2000}{2\pi}$ to yield $v_{o,DT}[n] = v_o(nT_s)$ where the sampling period is the inverse of the sampling rate. Sketch the DTFT of $v_{o,DT}[n]$ for $w \in [-2\pi, 2\pi)$.

5C) Repeat (5B) for $F_s = \frac{1000}{2\pi}$.

Hint: In (5B) and (5C) do not forget to indicate both magnitude and phase for the DTFT as appropriate.

Useful Formula: $V_{o,DT}(e^{jw}) = \frac{1}{T}\sum_{k=-\infty}^{\infty} V_o\left(j\frac{w-2\pi k}{T_s}\right)$

Euler's Identity: $e^{jx} = \cos(x) + j sin(x)$