Exam 2

BME 301

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- There are 5 questions to be answered.
- There is a 6th question for extra credit.
- Write **<u>neatly</u>** and **<u>clearly</u>**.

Exam 2

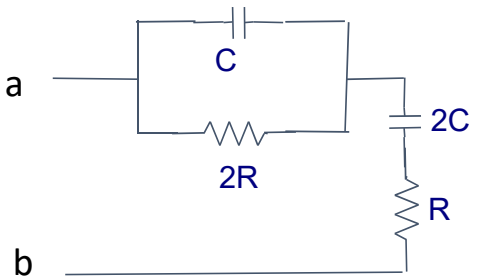
1. For the ECG signal following
   a. How would you determine the minimum sampling rate of any single?
   b. What is the process called to assure you get a better sampling rate?

2. What is the most important part of the design process?

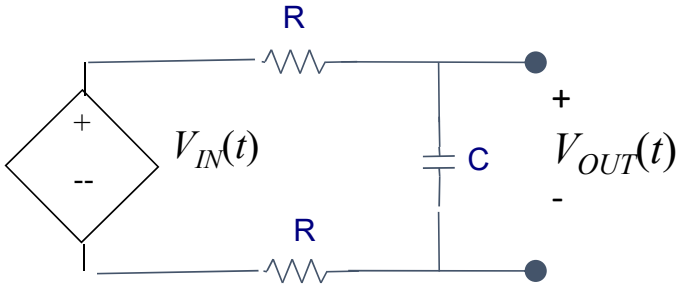
3. For an Arduino
   a) For an Arduino Sketch, what are Global Variables for and where is it defined?
   b) What is does the IDE stand for and how used in Sketch?

Exam 2

4. Impedances
   a) Find and sketch the **impedance** of the following circuit with respect to terminals a-b. in ***polar form*** and sketch the impedance as a function of ***radian frequency, ω***, i.e. ***in radians/second***. Assume R=1 and C=2



5. For the following circuit:
   a) Determine and sketch the transfer function in ***polar form.***
   b) Assume that R=1 and C=2, sketch the transfer function versus the ***frequency, f***; i.e. ***in Hertz***.
   c) What sort of circuit is this?
   d) What is its cutoff frequency?

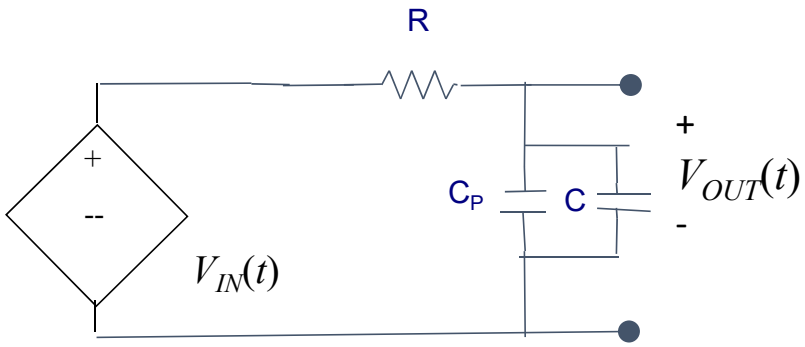


Exam 2

6. For extra credit

Repeat steps a-d of problem 5 for the following circuit.
Hint: Is there a way to simplify the circuit ?

C_P=2, C=1, R=2



Exam 2

1. For the ECG signal following
   a. How would you determine the minimum sampling rate of any single?

   To determine the minimum sampling rate you need to determine the highest frequency and then multiply it by 2 to determine the minimum sampling rate.

   b. What is the process called to assure you get a better sampling rate?

   Sample at a higher rate; say 10x the minimum sampled rate. This is called Oversampling.

Homework

2. What is the most important part of the design process?

The Customer Needs are key to the Design Process. All device decisions are made based on the Customer Needs.

Homework

3. For an Arduino
   a) For an Arduino Sketch, what are Global Variables for and where isit be defined?

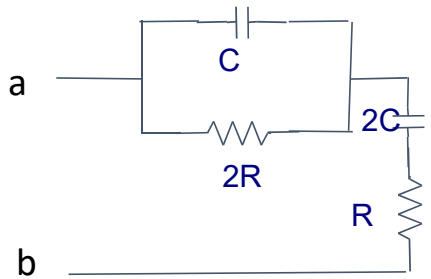
Global Variables are defined in the Global Section just before the Setup section and the Loop section is there is no Setup section.

   a) What is does the IDE stand for and how used in Sketch?
      i. IDE is know as the Integrated Development Environment (IDE).
      ii. It supports program program development, verification, and downloading to the Arduino board.
      iii. IDE support a serial monitor to allow users to interface with the program running on the Arduino board.
      iv. An Arduino program is called a Sketch and is written in **C/C++**.

Exam 2

4. Impedances

a) Find the **impedance** of the following circuit with respect to terminals a-b. in ***polar form*** and sketch the impedance as a function of ***radian frequency, ω***, i.e. ***in radians/second***. Assume R=1 and C=2



$$Z_{ab} = 2R \,||\, C + 2C + R$$

$$2R \,||\, C = \frac{2R \times \frac{1}{j\omega C}}{2R + \frac{1}{j\omega C}} = \frac{2R}{1 + j\omega 2RC}$$

$$2C + R = \frac{1}{j\omega 2C} + R = \frac{1 + j\omega 2RC}{j\omega 2C}$$

$$Z_{ab} = \frac{2R}{1 + j\omega 2RC} + \frac{1 + j\omega 2RC}{j\omega 2C} = \frac{j\omega 4RC + (1 + j\omega 2RC)^2}{j\omega 2C(1 + j\omega 2RC)}$$

$$= \frac{j\omega 4RC + 1 + j\omega 4RC + (j\omega 2RC)^2}{j\omega 2C(j\omega 2RC) + j\omega 2C} = \frac{1 - (\omega 2RC)^2 + j\omega 8RC}{-4R(\omega C)^2 + j\omega 2C}$$

$$= \frac{\sqrt{(1 - (\omega 2RC)^2)^2 + (\omega 8RC)^2}\angle \tan^{-1}\left(\frac{\omega 8RC}{1 - (\omega 2RC)^2}\right)}{\sqrt{(4R(\omega C)^2)^2 + (2\omega C)^2}\angle \tan^{-1}\left(\frac{2\omega C}{-4R(\omega C)^2}\right)} = \frac{\sqrt{(1 - (\omega 2RC)^2)^2 + (\omega 8RC)^2}}{\sqrt{(4R(\omega C)^2)^2 + (\omega 2C)^2}}\angle \tan^{-1}\left(\frac{\omega 8RC}{1 - (\omega 2RC)^2}\right) - \tan^{-1}\left(\frac{\omega 2C}{-4R(\omega C)^2}\right)$$

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4. Impedances

a) Find the **impedance** of the following circuit with respect to terminals a-b. in ***polar form*** and sketch the impedance as a function of ***radian frequency, ω***, i.e. ***in radians/second***. Assume R=1 and C=2

$$Z_{ab} = \frac{1-(\omega 2RC)^2 + j\omega 8RC}{-4R(\omega C)^2 + j\omega 2C}$$

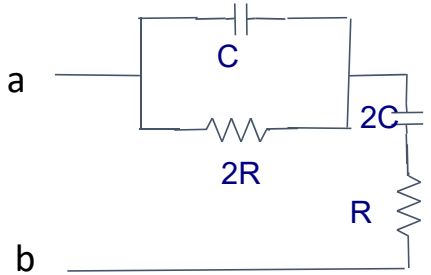
$$= \frac{\sqrt{(1-(\omega 2RC)^2)^2 + (\omega 8RC)^2}}{\sqrt{(4R(\omega C)^2)^2 + (\omega 2C)^2}} \angle \tan^{-1}\left(\frac{\omega 8RC}{1-(\omega 2RC)^2}\right) - \tan^{-1}\left(\frac{\omega 2C}{-4R(\omega C)^2}\right)$$

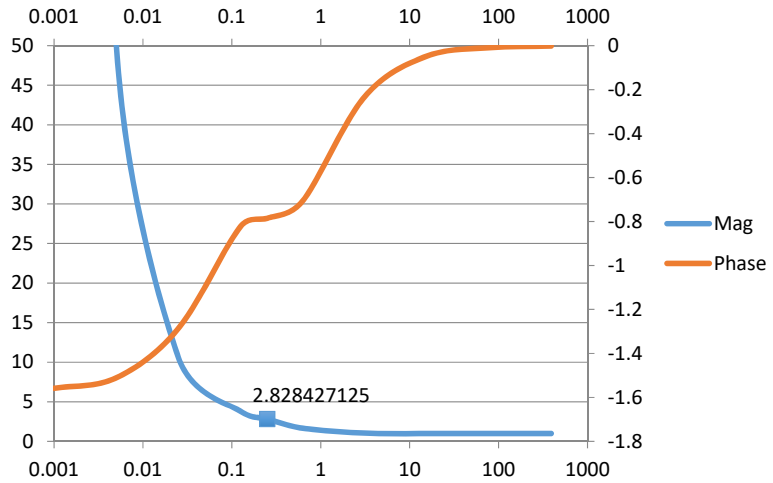
$$Z_{ab}\Big|_{\omega=0} = \frac{1-(02RC)^2 + j08RC}{-4R(0C)^2 + j04C} = \frac{1}{j0} \to \infty \angle -\frac{\pi}{2}$$

$$Z_{ab}\Big|_{\omega\to\infty} \to \frac{-(\omega 2RC)^2}{-4R(\omega C)^2} = R\angle 0 = 1\angle 0$$

$$Z_{ab}\Big|_{\omega=\frac{1}{2RC}} = \frac{1-(\frac{1}{2RC}2RC)^2 + j\frac{1}{2RC}8RC}{-4R(\frac{1}{2RC}C)^2 + j\frac{1}{2RC}2C} = \frac{1-(1)^2 + j4}{-\frac{1}{R} + j\frac{1}{R}} = \frac{j4}{-\frac{1}{R} + j\frac{1}{R}}$$

$$= \frac{j4R}{-1+j1} = \frac{4R\angle\frac{\pi}{2}}{\sqrt{2}\angle\frac{3\pi}{2}} = \frac{4R}{\sqrt{2}}\angle -\frac{\pi}{4} = \frac{4}{\sqrt{2}}\angle -\frac{\pi}{4} = 2.8\angle -0.78$$





Exam 2

5. For the following circuit:

a) Determine the transfer function in ***polar form***

b) Assume that R=1 and C=2, sketch the transfer function versus the ***frequency, f***; i.e. ***in Hertz***.

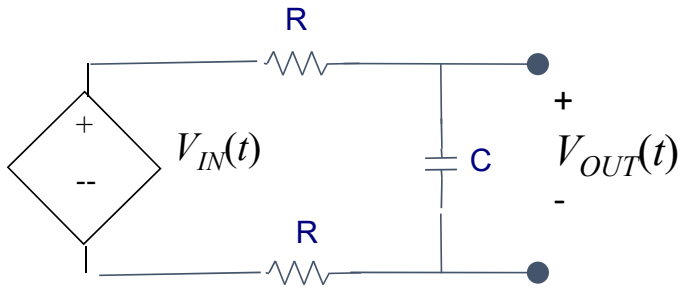
c) What sort of circuit is this?

d) What is its cutoff frequency?

$$a)\ \frac{V_{out}}{V_{in}} = \frac{\frac{1}{j\omega C}}{R+R+\frac{1}{j\omega C}} = \frac{1}{1+j\omega 2RC}$$

Let $\omega = 2\pi f$ and $f_o = \frac{1}{2\pi 2RC}$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1+j2\pi f\frac{1}{2\pi f_o}} = \frac{1}{1+j(\frac{f}{f_o})} = \frac{1}{\sqrt{1+(\frac{f}{f_o})^2}} \angle -\tan^{-1}(\frac{f}{f_o})$$



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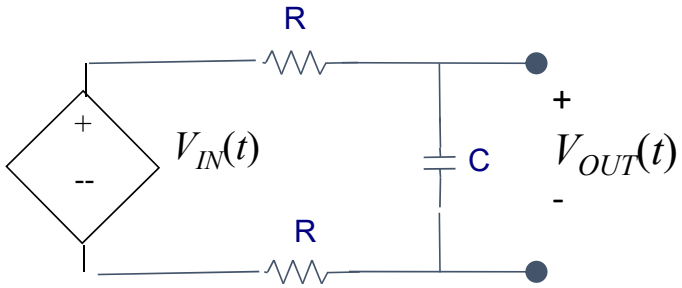


$c)$ LPF

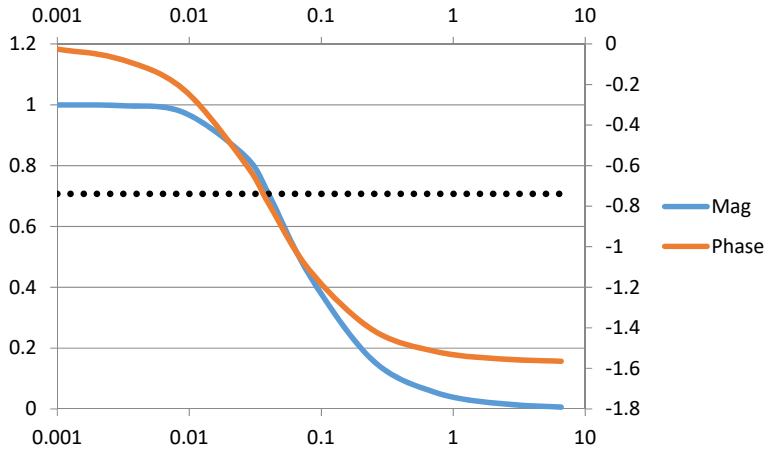
$$b)\ \frac{V_{out}}{V_{in}} = \frac{1}{1+j\frac{f}{f_o}}$$

$$d)\ f_o = \frac{1}{2\pi 2RC} = \frac{1}{4\pi} = 0.04$$

$$\frac{V_{out}}{V_{in}}\Big|_{f=0} = \frac{1}{1+j\frac{0}{f_o}} = 1\angle 0$$

$$\frac{V_{out}}{V_{in}}\Big|_{f\to\infty} \to \frac{1}{j\frac{f}{f_o}} \to \frac{1}{\frac{0}{f_{o\,1}}}\angle -\frac{\pi}{2} \to \infty\angle -\frac{\pi}{2}$$

$$\frac{V_{out}}{V_{in}}\Big|_{f=f_o} = \frac{1}{1+j\frac{f_o}{f_o}} = \frac{1}{1+j} = \frac{1}{\sqrt{2}}\angle -\frac{\pi}{4}$$



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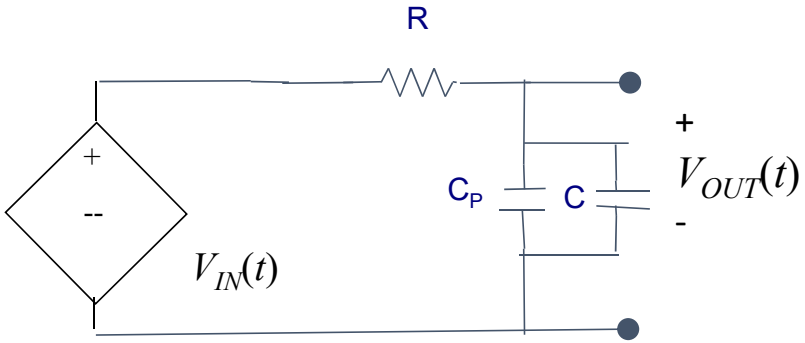
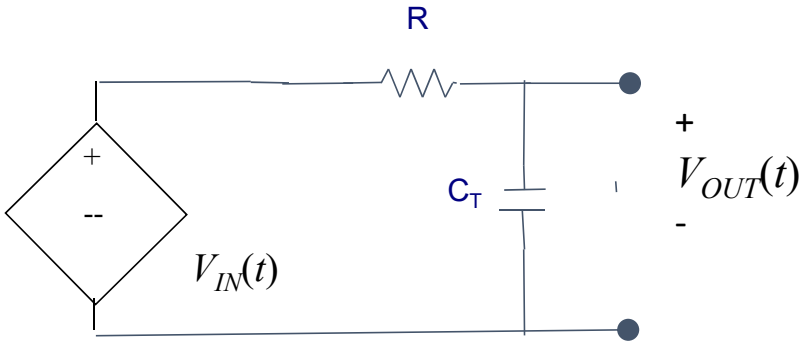
6. For HONORS and extra credit

Repeat steps a-d of problem 5 for the following circuit. Hint: Is there a way to simplify the circuit ?

C_P=2, C=1, R=2





Since C and C_p are in parallel, let's replace it by C_T for the total Capacitance and work with this circuit. Note that C_T is equal to 3f.

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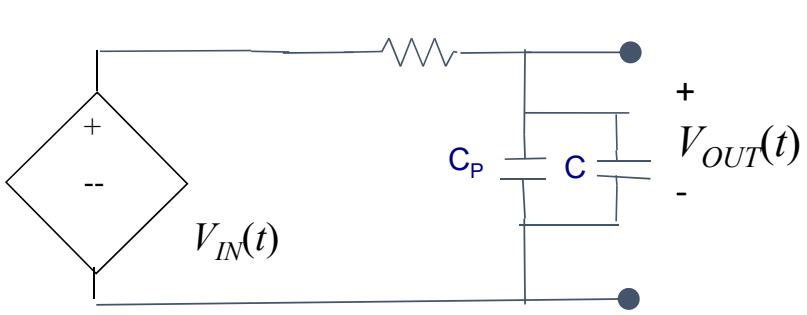


$$a)\ \frac{V_{out}}{V_{in}} = \frac{\frac{1}{j\omega C_T}}{R+\frac{1}{j\omega C_T}} = \frac{1}{1+j\omega RC_T}$$

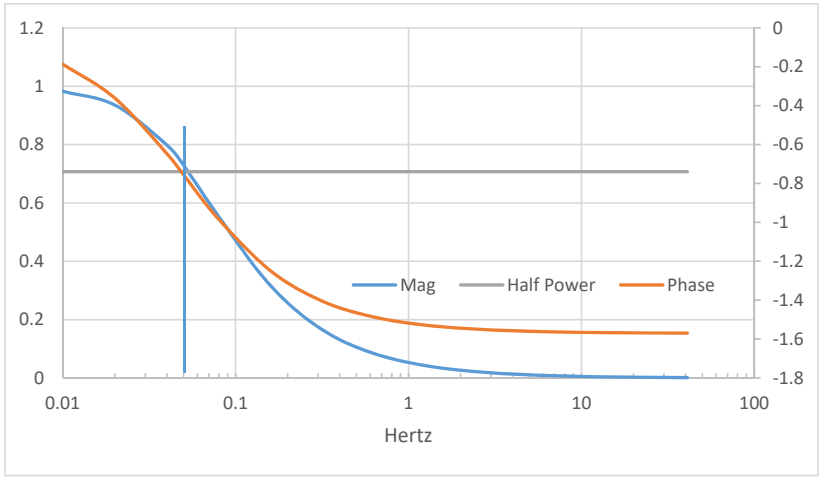
Let $\omega = 2\pi f$ and $f_o = \frac{1}{2\pi RC_T}$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1+j\omega RC_T} = \frac{1}{1+j\frac{f}{f_o}} = \frac{1_T}{\sqrt{1+(\frac{f}{f_{o\,T}})^2}} \angle -\tan^{-1}(\frac{f}{f_o})$$

$$b)\ \frac{V_{out}}{V_{in}}|_{f=0} = \frac{1}{1+j\frac{0}{f_o}} = 1\angle 0$$

$$\frac{V_{out}}{V_{in}}|_{f\to\infty} \to \frac{1}{j\frac{f}{f_o}} \to \infty\angle -\frac{\pi}{2}$$

$$\frac{V_{out}}{V_{in}}|_{f=f_o} = \frac{1}{1+j1} = \frac{1}{\sqrt{2}}\angle -\frac{\pi}{4}$$

$c)$ LPF

$$d)\ f_o = \frac{1}{2\pi RC_T} = 0.013Hz$$