Exam 2

BME 301

BME 301

- There are 5 questions to be answered for the basic grade.
- Question 6 is for extra credit.
- Write **neatly** and **clearly**.

Exam 2

1. For the ECG signal

   A signal has the following characteristics:

      i. Periodic square wave
      ii. 45:55 duty cycle
      iii. Frequencies that range from 10kHz to 500kHz

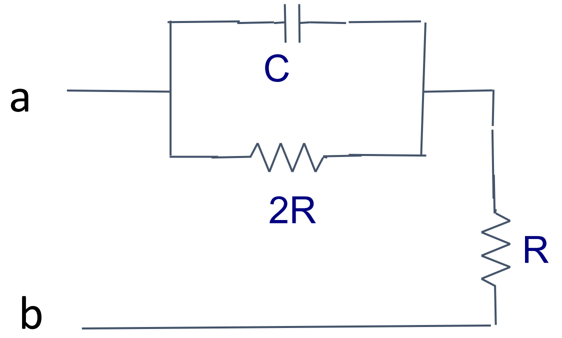
   a. Calculate the minimum sampling rate
   b. Describe the process called to assure you get a better sampling rate? What is it called?

2. What is the most important part of a how a design is carried out?

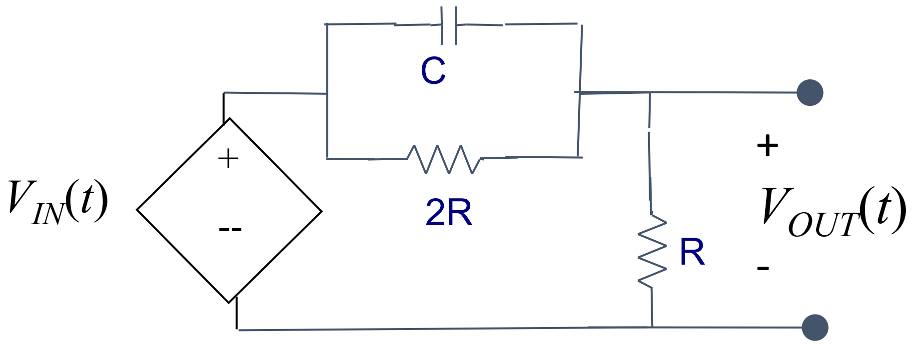
3. For an Arduino
   a) For an Arduino Sketch, fully describe PWM and state how it is initiated?
   b) What is does the IDE stand for and how used in Sketch?

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=5 and C=2

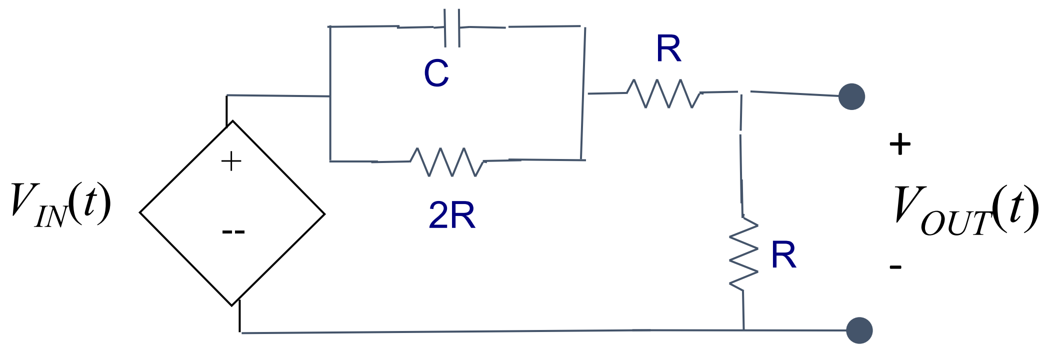


5. For the following circuit:
   a) Determine and sketch the transfer function in ***polar form.***
   b) Assume that R=5 and C=2, sketch the transfer function versus the ***frequency, f***; i.e. ***in Hertz***.
   c) What sort of circuit is this?
   d) What is its cutoff frequency?



Exam 2

6. For Honors/extra credit
   a) Determine and sketch the transfer function in ***polar form.***
   b) Assume that R=2 and C=1, sketch the transfer function versus the ***frequency, f***; i.e. ***in Hertz***.
   c) What sort of circuit is this?
   d) How would you go about finding the cutoff frequency?



Exam 2

1. For the ECG signal

A signal has the following characteristics:

   i. Periodic square wave
   ii. 45:55 duty cycle
   iii. Frequencies that range from 10kHz to 500kHz

a. Calculate the minimum sampling rate

Find the highest frequency and multiply it by 2. This is the minimum sampling rate. Therefore, the highest frequency is 500kHz and the minimum sampling rate is then 1,000,000 samples/second.

b) Describe the process called to assure you get a better sampling rate? What is it called?

Sample at a higher rate than the minimum sampling rate: multiply the minimum sampled rate by a number greater than zero, e.g. 10x. This is called Oversampling.

Exam 2

2. What is the most important part of a how a design is carried out?

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

Exam 2

3. For an Arduino
   a) For an Arduino Sketch, fully describe PWM and state how it is initiated?

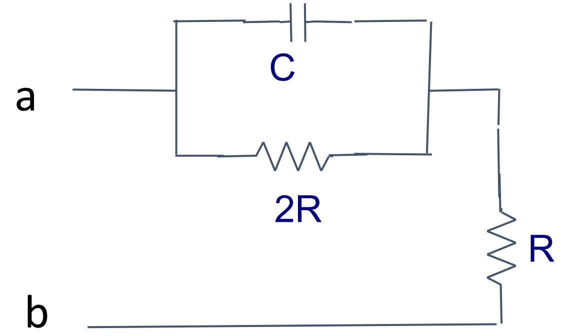
   PWM stands for Pulse Width Modulation and is a square wave with a high time and a low time. The percent of time it is high divided by the square wave total period is called the Duty Cycle. Choose a digital pin with the tilde symbol, "~" in front of the pin number and issue an analogWrite() to it. The parameter used within the analogWrite function are the pin number and a number from 0 to 255 which represents the desired Duty Cycle.

   b) What is does the IDE stand for and how used in Sketch?
      i. IDE is known 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=5 and C=2



$$a)\ Z_{in} = 2R||Z_C + \mathrm{R}$$

$$2R||Z_C = \frac{2R\ X\ \frac{1}{J\omega C}}{2R+\frac{1}{J\omega C}} = \frac{2R}{1+j\omega 2RC}$$

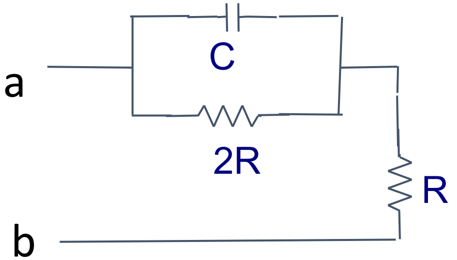
$$Z_{in} = 2R||Z_C + R = \frac{2R}{1+j\omega 2RC} + R = \frac{2R+R(1+j\omega 2RC)}{1+j\omega 2RC} = R\frac{3+j\omega 2RC}{1+j\omega 2RC}$$

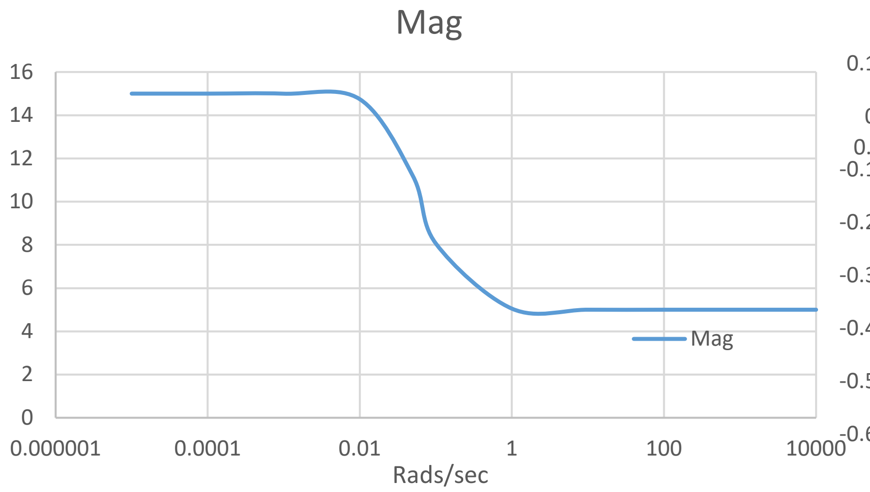
$$= R\frac{\sqrt{(3)^2+(\omega 2RC)^2}\angle tan^{-1}(\frac{\omega 2RC}{3})}{\sqrt{1+(\omega 2RC)^2}\angle tan^{-1}(\omega 2RC)} = R\frac{\sqrt{(3)^2+(\omega 2RC)^2}}{\sqrt{1+(\omega 2RC)^2}}\ \angle tan^{-1}(\frac{\omega 2RC}{3}) - tan^{-1}(\omega 2RC)$$

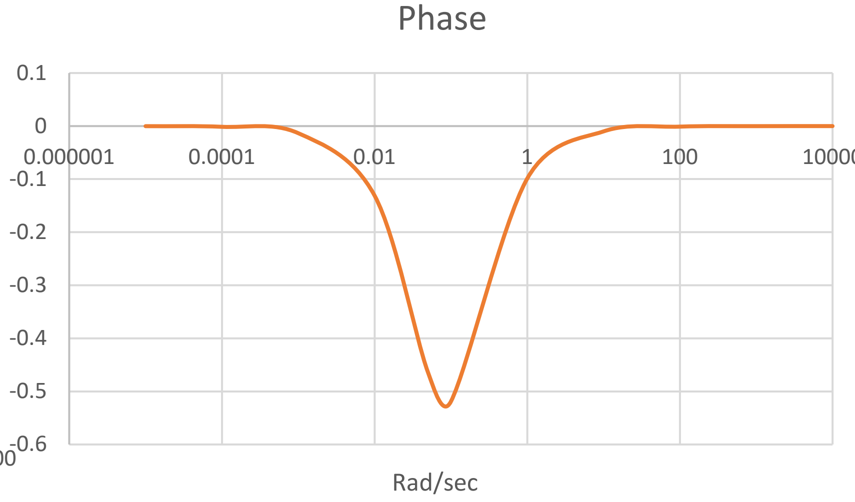
Exam 2

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=5 and C=2







$$Z_{in} = R\,\frac{3+j\omega 2RC}{1+j\omega 2RC}$$

$$Z_{in}\big|_{\omega=0} = 3R = 15\ \angle 0$$

$$Z_{in}\big|_{\omega\to\infty} \to R\,\frac{j\omega 2RC}{j\omega 2RC} \to R = 5\ \angle 0$$

$$Z_{in}\big|_{\omega=\frac{1}{2RC}} = R\,\frac{3+j\frac{1}{2RC}2RC}{1+j\frac{1}{2RC}\omega 2RC} = R\,\frac{3+j1}{1+j1} = 5\,\frac{\sqrt{10}\angle \tan^{-1}\frac{1}{3}}{\sqrt{2}\angle\frac{\pi}{4}} = 5\sqrt{5}\angle 0.32 - 0.78$$

$$= 11.18\ \angle\text{-}0.46$$

5. For the following circuit:

Exam 2

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

b) Assume that R=5 and C=2, sketch the transfer function versus the ***frequency, f***; i.e. ***in Hertz***.

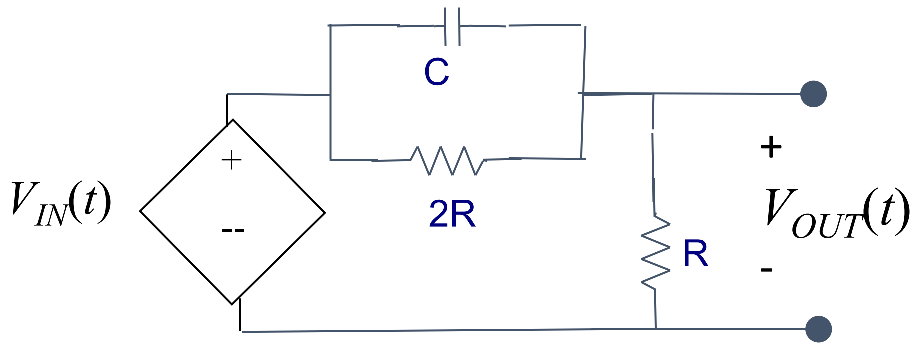
c) What sort of circuit is this?

d) What is its cutoff frequency?

$$a)\ \frac{V_{out}}{V_{in}} = \frac{R}{Z_{in}};\ where\ Z_{in} = 2R||C + R = R\,\frac{3+j\omega 2RC}{1+j\omega 2RC}$$

$$\frac{V_{out}}{V_{in}} = \frac{R}{\mathrm{R}\,\frac{3+j\omega 2RC}{1+j\omega 2RC}} = \frac{1+j\omega 2RC}{3+j\omega 2RC}$$

$$Let\ \omega = 2\pi f\ and\ f_0 = \frac{1}{2\pi 2RC} = 0.008\ Hz$$



$$\frac{V_{out}}{V_{in}} = \frac{1 + j\frac{f}{f_0}}{3 + j\frac{f}{f_0}} = \frac{\sqrt{1 + (\frac{f}{f_0})^2}\angle tan^{-1}\frac{f}{f_0}}{\sqrt{3 + (\frac{f}{f_0})^2}\angle tan^{-1}\frac{f}{3f_0}}$$

Exam 2

5. For the following circuit:

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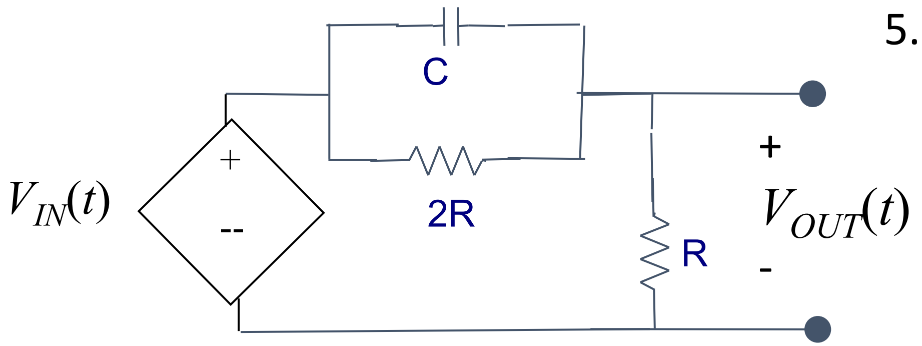


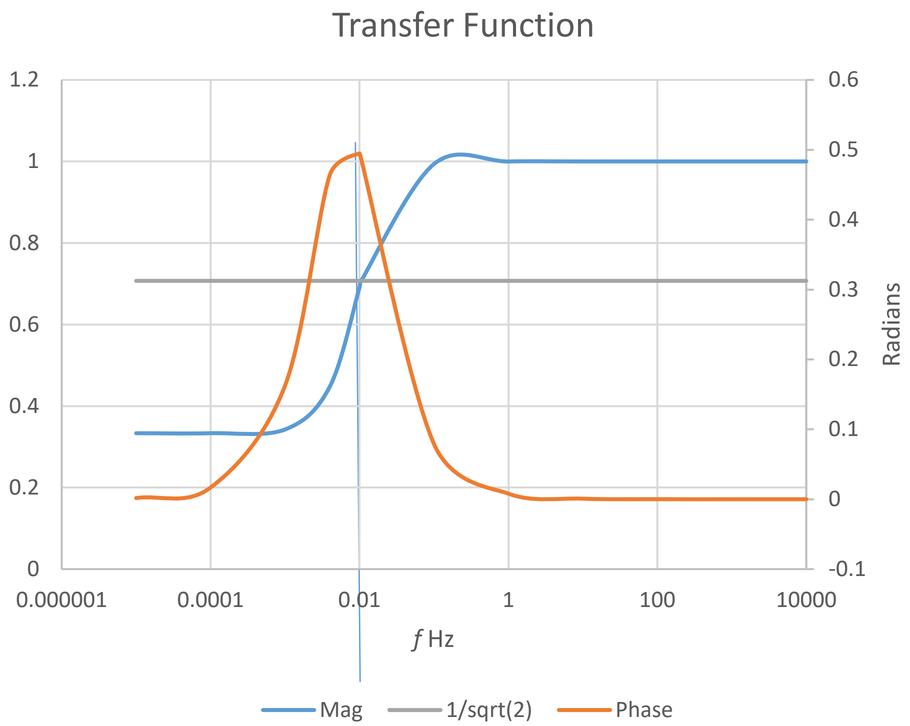
$$b)\ \frac{V_{out}}{V_{in}} = \frac{1+j\frac{f}{f_0}}{3+j\frac{f}{f_0}}$$

$$\frac{V_{out}}{V_{in}}\Big|_{f=0} = \frac{1}{3}\angle 0$$

$$\frac{V_{out}}{V_{in}}\Big|_{f\to\infty} \to \frac{j\frac{f}{f_0}}{j\frac{f}{f_0}} = 1\ \angle 0$$

$$\frac{V_{out}}{V_{in}}\Big|_{f=f_0} = \frac{1+j1}{3+j1} = \frac{\sqrt{2}\angle\frac{\pi}{4}}{\sqrt{10}\angle tan^{-1}\frac{1}{3}} = \frac{1}{\sqrt{5}}\angle 0.78 - 0.32$$

$$=0.47\ \angle 0.465$$



Exam 2

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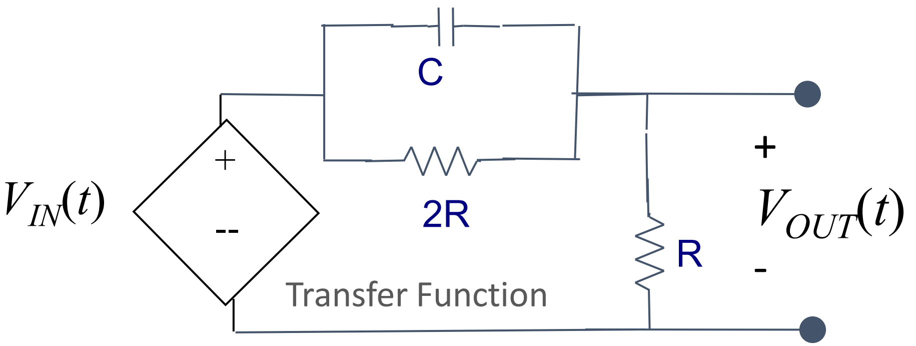
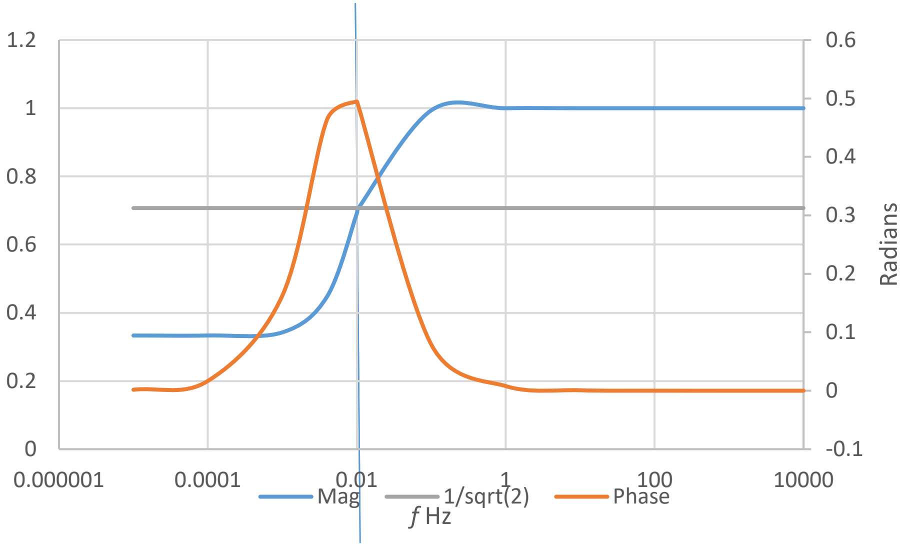


c) It may look like a HPF; however, it is not a filter since there is no stop band. That is there is no section of the transfer function where it has a value of zero.

d) From the chart, if this was a filter then the cutoff frequency would be $\sqrt{7}f_0 = 0.0105\ Hz$.



$$d)\ \left|\frac{V_{out}}{V_{in}}\right| = \frac{\sqrt{1+(\frac{f_{co}}{f_0})^2}}{\sqrt{9+(\frac{f_{co}}{f_0})^2}} = \frac{1}{\sqrt{2}}$$

$$\frac{1+(\frac{f_{co}}{f_0})^2}{9+(\frac{f_{co}}{f_0})^2} = \frac{1}{2}\ \ OR\ 2 + 2(\frac{f_{co}}{f_0})^2 = 9 + (\frac{f_{co}}{f_0})^2$$

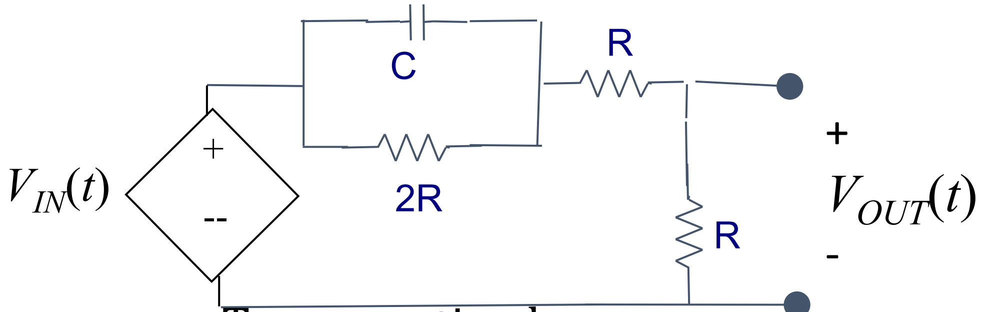
$$(\frac{f_{co}}{f_0})^2 = 7\ OR\ f_{co} = \sqrt{7}f_0 = 0.0211\ Hz$$

Exam 2

6. For HONORS and extra credit

a) Determine and sketch the transfer function in ***polar form.***

C=2, R=1



Type equation here.

$$a)\ \frac{V_{out}}{V_{in}} = \frac{R}{Z_{in}}; where\ Z_{in} = 2R||C + R + R$$

$$Z_{in} = 2R||Z_C + 2R = \frac{2R\times\frac{1}{j\omega C}}{2R+\frac{1}{j\omega C}} + 2R$$

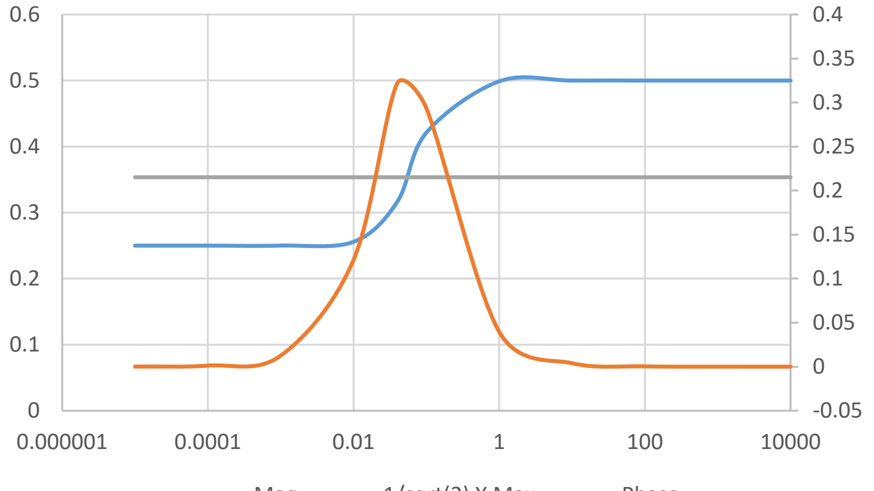
$$= \frac{2R}{1+j\omega 2RC} + 2R = \frac{2R+2R(1+j\omega 2RC)}{1+j\omega 2RC} = R\frac{4+j\omega 4RC}{1+j\omega 2RC}$$

$$\frac{V_{out}}{V_{in}} = \frac{R}{Z_{in}} = \frac{R}{R\frac{4+j\omega 4RC}{1+j\omega 2RC}} = \frac{1+j\omega 2RC}{4+j\omega 4RC}$$

$$Let\ \omega = 2\pi f\ and\ f_0 = \frac{1}{2\pi 2RC} = 0.04Hz$$

$$\frac{V_{out}}{V_{in}} = \frac{1+j\frac{f}{f_0}}{4+j2\frac{f}{f_0}} = \frac{\sqrt{1+(\frac{f}{f_0})^2}\angle tan^{-1}\frac{f}{f_0}}{\sqrt{16+4(\frac{f}{f_0})^2}\angle tan^{-1}\frac{f}{2f_0}}$$

$$= \frac{\sqrt{1+(\frac{f}{f_0})^2}}{\sqrt{16+4(\frac{f}{f_0})^2}}\angle tan^{-1}\frac{f}{f_0} - \angle tan^{-1}\frac{f}{2f_0}$$



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$$b)\ \frac{V_{out}}{V_{in}} = \frac{1+j\frac{f}{f_0}}{4+j2\frac{f}{f_0}}$$

$$\frac{V_{out}}{V_{in}}|_{f=0} = \frac{1}{4} = 0.25\ \angle 0$$

$$\frac{V_{out}}{V_{in}}|_{f\to\infty} \to \frac{j\frac{f}{f_0}}{j2\frac{f}{f_0}} = 0.5\angle 0$$

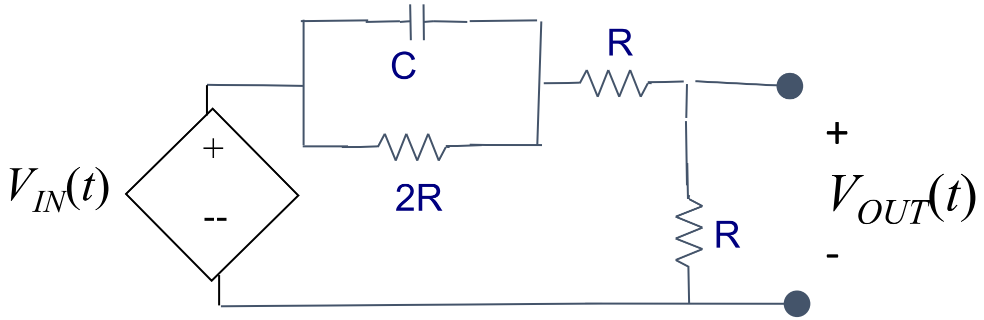
$$\frac{V_{out}}{V_{in}}|_{f=f_0} = \frac{1+j1}{4+j2} = = \frac{\sqrt{2}\angle\frac{\pi}{4}}{\sqrt{20}\angle tan^{-1}\frac{1}{2}} =$$

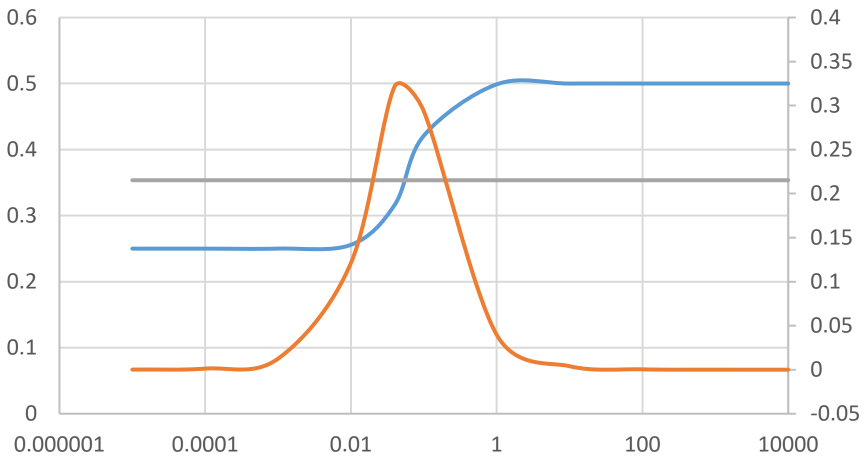
$$= \frac{\sqrt{2}}{\sqrt{20}}\angle\frac{\pi}{4} - tan^{-1}\frac{1}{2} = 0.32\ \angle 0.32$$

6. For HONORS and extra credit

a) Determine and sketch the transfer function in ***polar form.***

C=2, R=1

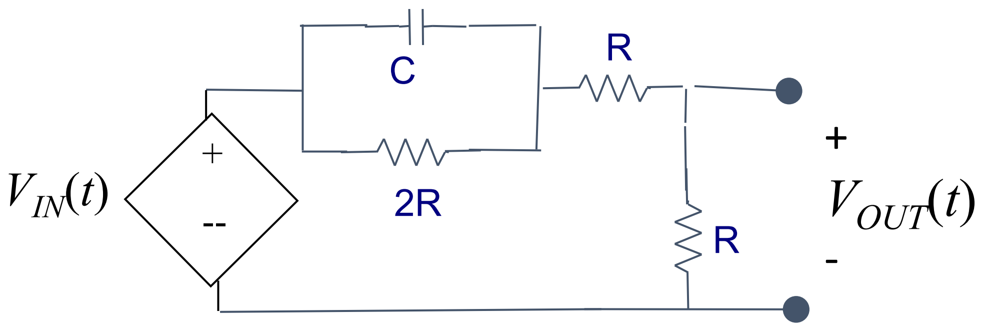


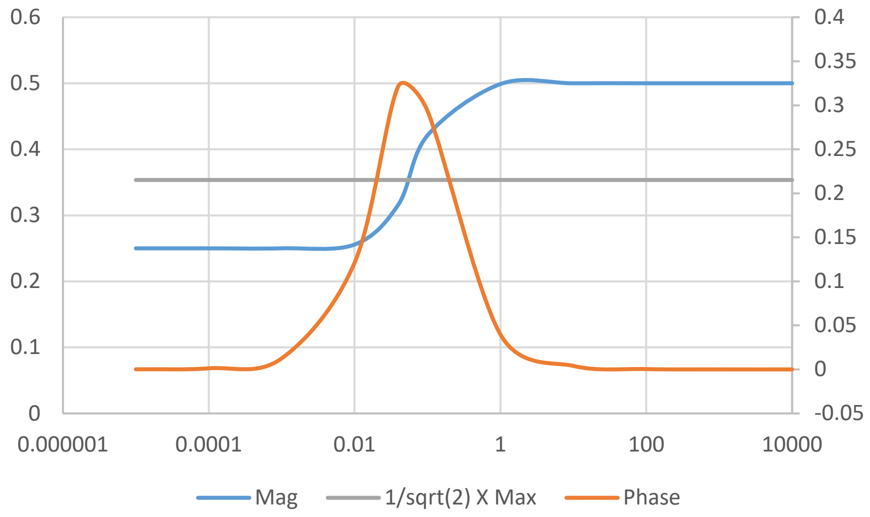


Exam 2

6. For HONORS and extra credit

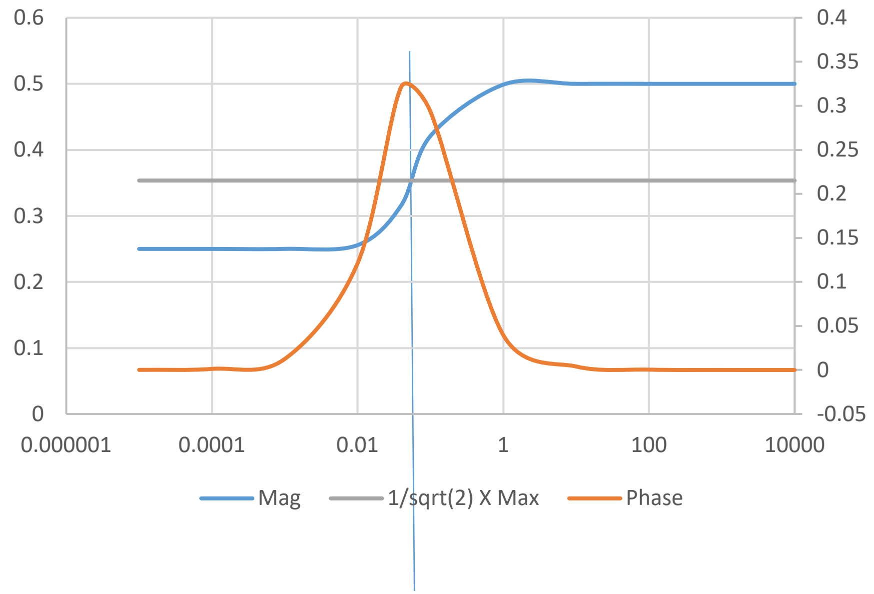
   c) What sort of circuit is this?





c) It may look like a HPF; however, it is not a filter since there is no stop band. That is there is no section of the transfer function where it has a value of zero.

Exam 2



6. For HONORS and extra credit

d) How would you go about finding the cutoff frequency?

$$d)\ \left|\frac{V_{out}}{V_{in}}\right| = \frac{\sqrt{1+(\frac{f_{co}}{f_0})^2}}{\sqrt{16+4(\frac{f_{co}}{f_0})^2}} = \frac{1}{\sqrt{2}} MAX = \frac{1}{\sqrt{2}} 0.5 = 0.35$$

$$\frac{1+(\frac{f_{co}}{f_0})^2}{16+4(\frac{f_{co}}{f_0})^2} = (0.35)^2 \quad OR \quad 1+(\frac{f_{co}}{f_0})^2 = 0.125 \times (16+4(\frac{f_{co}}{f_0})^2)$$

$$1+(\frac{f_{co}}{f_0})^2 = 2 + 0.5\,(\frac{f_{co}}{f_0})^2$$

$$0.5(\frac{f_{co}}{f_0})^2 = 1$$

$$(\frac{f_{co}}{f_0})^2 = \frac{1}{0.5} = 2 \quad OR \quad \frac{f_{co}}{f_0} = \sqrt{2}$$

$$f_{co} = \sqrt{2} f_o = \sqrt{2} \times 0.04 = 0.056\text{Hz}$$