Basic Electronics

Assessed Problems 3

Hand in before your week 4 deadline.

APS3.1 The diagram shows an ideal AC voltage source connected to a series RC circuit which is to be used as a filter.

(a) Find an expression for the magnitude of the *gain* of the filter circuit. [1 mark]

(b) Is this a low-pass or high-pass filter? Justify your answer. [1 mark]

(c) Show that the cut-off frequency for the filter is given by [1 mark]

$$\omega_c = \frac{1}{RC}$$

For the rest of the question, assume $R = 120\,\Omega$, $C = 15.625\,\mu\text{F}$ and the AC voltage source has an amplitude $10\,\text{V}$, frequency $200/\pi\,\text{Hz}$, and is a maximum at time $t = 0$.

(d) Express the circuit's impedance in both complex cartesian and polar form. [1 mark]

(e) Find the amplitudes of

i. the circuit current.

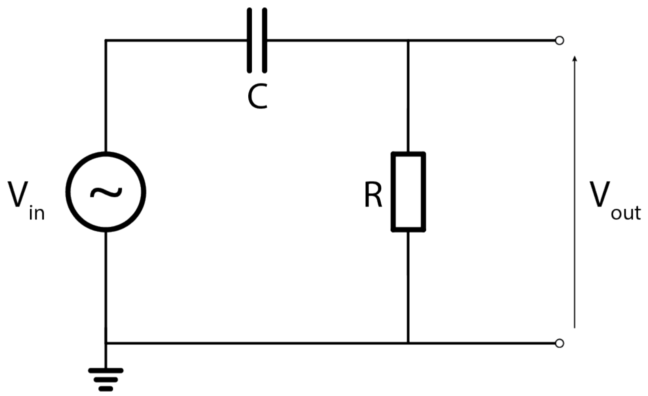
ii. the voltage across the resistor.

iii. the voltage across the capacitor. [3 marks]

(f) Draw the capacitor and resistor voltages on a phasor diagram. Add a phasor representing the applied voltage. [1 mark]

(g) Hence show that Kirchhoff's voltage law holds. [1 mark]

(h) Does the output signal lead or lag the input? Explain your answer. [1 mark]



Hint: It can be useful to represent the three voltages (input, capacitor and resistor) as functions of time and then plot these using Python. You can then check your answers against a simulation of the circuit in LTSpice. This is **not** *required to be given as part of your answer, however.*

CC
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Basic Electronics

Tutorial Problems 3

These problems are for your week 4 tutorial

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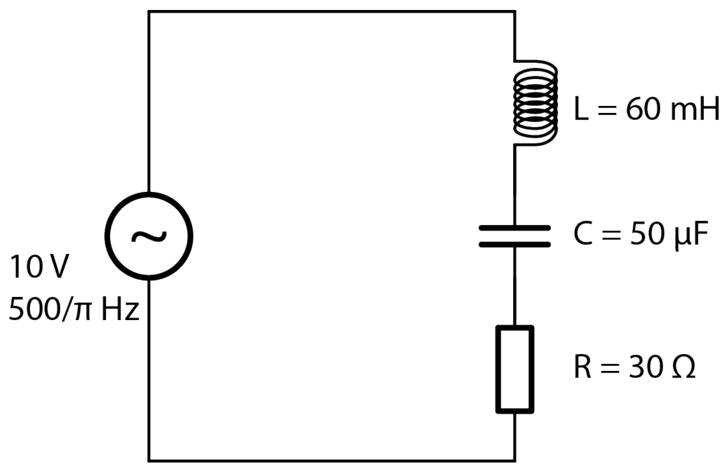
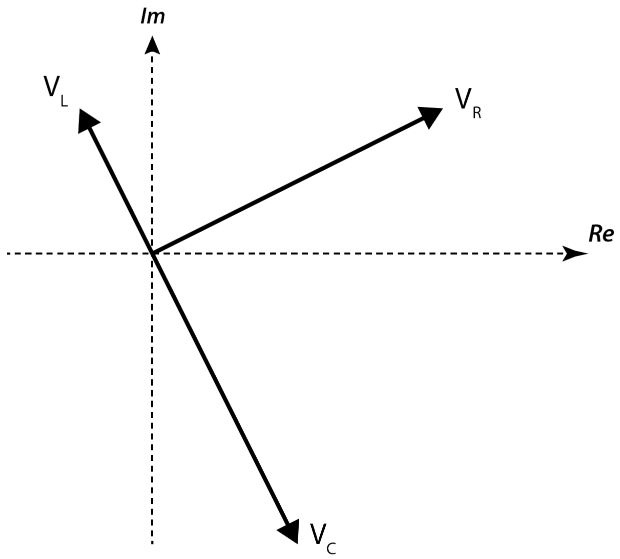
1. A series LCR circuit comprising a $30\,\Omega$ resistor, $50\,\mu$F capacitor and $60\,$mH inductor is connected to an ideal $10\,$V sinusoidal source operating at a frequency of $500/\pi\,$Hz.
   (a) Write an expression for the complex impedance of the LCR circuit.
   (b) Find the amplitude of the potential difference across
      i. the resistor,
      ii. the capacitor,
      iii. the inductor.
   (c) Sketch these three as phasors in the complex plane.
   (d) What is the average power delivered by the source?
   (e) Find the peak energy stored by
      i. the capacitor,
      ii. the inductor.



Discussion Problems

2. The figure below shows the phasor diagram for a series LCR circuit. We **don't** know the component values or the driving frequency.
   (a) Is the driving frequency above, below or at the resonant frequency?
   (b) Add a phasor representing the amplitude of the applied voltage.



3. Consider a circuit similar to question 1 but where there resistor, capacitor and inductor are in **parallel**. At $\omega = \omega_0 = 1/\sqrt{LC}$, will the magnitude of the impedance be a maximum or a minimum? Contrast this with the series LCR circuit.

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Basic Electronics

Further Problems 3

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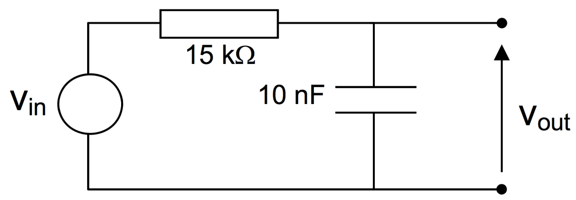
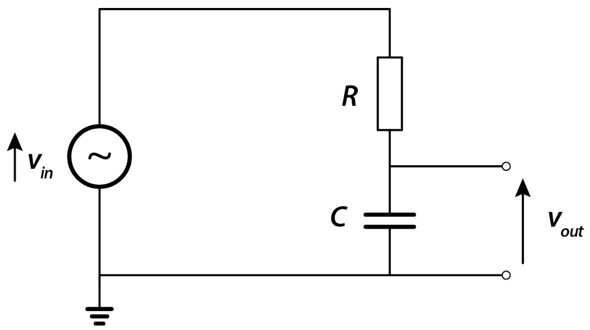
1. The ideal source V_{in} applies a sine wave voltage of amplitude 3 V and angular frequency 12566 rad/s to the the RC filter shown below. What is the magnitude of the output voltage and what is its phase angle relative to the input?



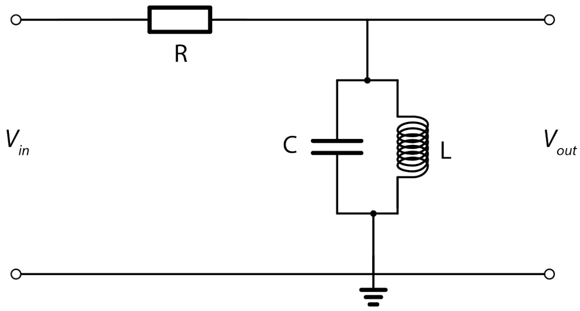
2. A low-pass filter is formed from a 100 kΩ resistor in series with a 100 pF capacitor. The RMS voltage across the capacitor is found to be 2 V and lags the input voltage V_{in} by $\pi/4$ rad. Which of the following statements about V_{in} is true?
   (a) $V_{in} = 2\sqrt{2}\,\mathrm{V_{RMS}}$ and $f = 10^5$ Hz
   (b) $V_{in} = 2\sqrt{2}\,\mathrm{V_{RMS}}$ and $f = 6.28$ MHz
   (c) V_{in} has an amplitude of 4 V and $\omega = 10^5$ rad/s
   (d) V_{in} has a peak-to-peak amplitude of $4\sqrt{2}$ V and $\omega = 10^5$ rad/s
   (e) V_{in} has a peak-to-peak amplitude of 8 V and $\omega = 100$ rad/s

3. The figure below shows a RC filter circuit. The sinusoidal input waveform has an amplitude of 2 volts and a phase angle zero at time $t = 0$. Assume the same angular frequency $\omega = 1/RC$ for all parts of this question.



   (a) Show that the output amplitude is $\sqrt{2}$ volts.
   (b) Calculate the phase difference, in radians, between the output waveform and the input. Does the output lead or lag the input?
   (c) Sketch the input and output phasors on a phasor diagram.
   (d) The capacitor is replaced by an inductor. Find an expression for the inductance L which will result in the same output amplitude.

4. The figure below shows a LCR filter circuit.
   (a) Find an expression for the magnitude of the filter's gain.
   (b) What is the gain for very low and very high frequencies? For the natural frequency $\omega = \omega_0$?
   (c) Explain this behaviour, in terms of the individual component impedances at these frequencies.
   (d) Hence describe what type of filter this is.
   (e) Find an expression for the bandwidth of the filter.
   (f) For $C = 1000\,\mu\text{F}$, $L = 1\,\text{mH}$ and $R = 10\,\Omega$, find the natural frequency and the bandwidth.
   (g) Describe how to double the bandwidth without changing the natural frequency.



Numerical solutions and hints

1. Amplitude 1.41 V Phase -1.08 rad.
2. (c)
3. (b) $-\frac{\pi}{4}$ rad, (d) $L = R^2C$
4. (b) Zero and 1, (f) 1000 and 100 rad/s.

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