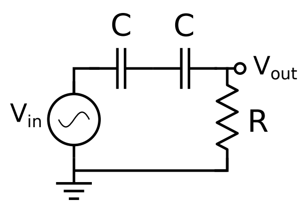
Name: ______________________ Lab section/TA: ______________________

Homework 5

Problem 1: Some more filters

R = 1 kΩ and C = 2 nF

(a) Find an expression for the transfer function $\frac{V_{out}}{V_{in}}$ as a function of frequency variable f.



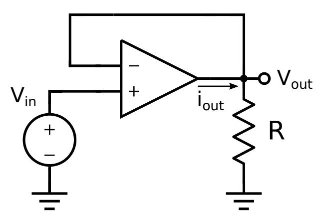
(b) Sketch a Bode plot of the transfer function $\frac{V_{out}}{V_{in}}$. Be sure to specify any cutoff frequencies and non-zero slopes.

(c) V_{in} is described by the time function $10\sin(2\pi ft)$V. Find the amplitude of V_{out} for the following three values of f : $\frac{1}{2\pi}$ kHz, $\frac{10}{2\pi}$ kHz, and $\frac{100}{2\pi}$ MHz. What kind of filter is this?

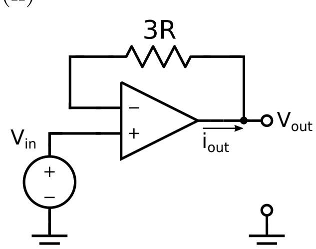
Problem 2: Operational Amplifiers

The following circuits use ideal operational amplifiers. R = 100 Ω.
(a) Find an expression for the gain $\frac{V_{out}}{V_{in}}$
(b) Determine i_{out} when $V_{in} = 2\,\mathrm{V}$

(i)



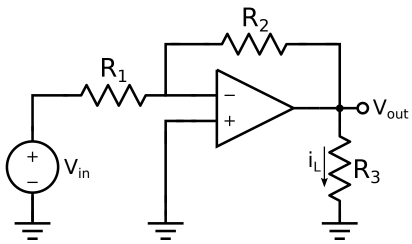
(ii)



Problem 3: More Op-Amp Circuits

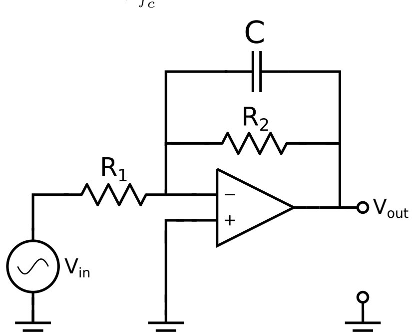
The following circuits use ideal operational amplifiers.

(a) Find the gain $\frac{V_{out}}{V_{in}}$ of the following circuit



(b) Now just for (b), let $R_1 = 100\,\Omega$, $R_2 = 2\,\text{k}\Omega$, $R_3 = 1\,\text{k}\Omega$, $i_L = 10\,\text{mA}$. Calculate V_{out} and V_{in}.

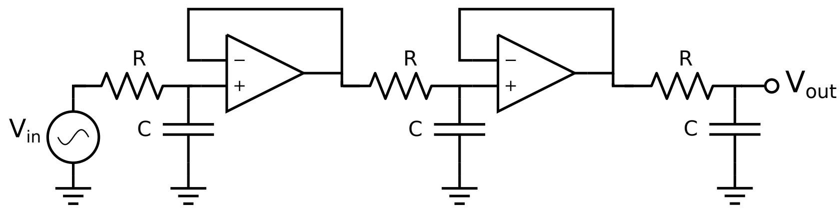
(c) Find the gain $\frac{V_{out}}{V_{in}}$ as a function of frequency f in the following circuit. Your expression should be in the form $\frac{A}{1+\frac{f}{f_c}}$ where A and f_c are constants.



(d) Compare the gain expressions of the two circuits.

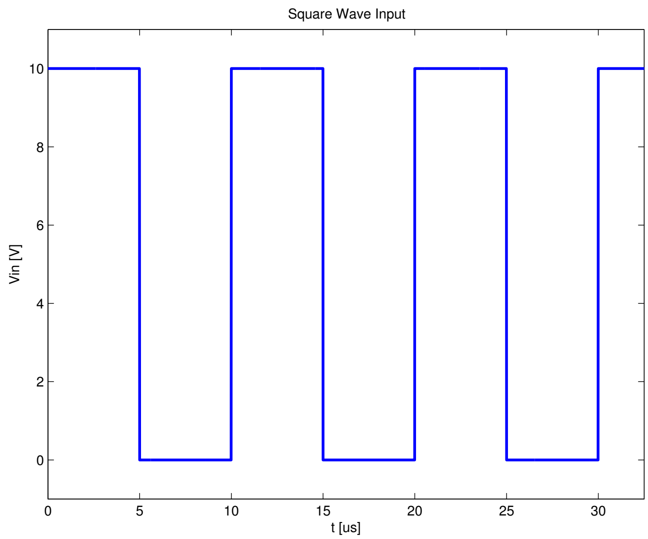
Problem 4: Cascaded Filters

Find an expression for the gain $\frac{V_{out}}{V_{in}}$ in terms of R, C, and f



Problem 5: Switch Mode Power Supplies

(6 Points) In lecture, we have discussed the concept of switching mode power supplies. They operate under the premise of creating a square wave and then filtering that square wave to transform one DC voltage to another. The following waveform was created from a 10 V supply that was switched on/off at 50% duty cycle.

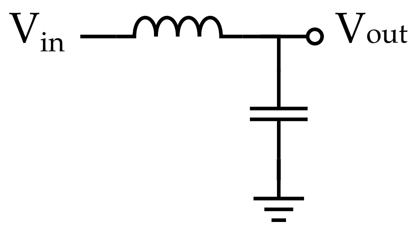


Any square wave can be represented by a Fourier series. To keep things simple, rather than find the entire Fourier series, we'll just decompose it into two parts: the DC component, and the square wave excluding the DC component.

What is the DC component in the Fourier series of this square wave?

What is the amplitude of the square wave, *excluding* the DC component?

This square wave is far from the DC output voltage we desire. In order to filter this signal, we input the square wave into the following output filter with inductance 50 µH and capacitance 500 µF.



Write an equation for the output voltage amplitude as a function of V_{in} and the frequency f, and draw a Bode plot (a log-log plot of gain in dB vs frequency).

For simplicity, we will consider just the DC component and fundamental frequency of the Fourier series of the input square wave. Furthermore, assume that the amplitude of the fundamental frequency of the input waveform is equal to the amplitude of the square wave you found in the second part of this problem, above.[1]

What are the amplitudes of the DC component and the fundamental frequency at the *output*?

[1] The amplitude of the fundamental frequency of a square wave is actually a factor of $4/\pi$ bigger than the amplitude of the square wave itself, but for this problem we'll pretend they're the same.

Problem 6: Reflection

How long did you spend on this homework assignment?
Which problem did you find most difficult?