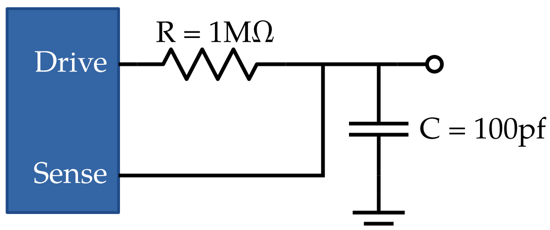
Name: ____________________ Lab section/TA: ____________________

Problem Set 4

Problem 1: Capacitive sensing

(4 Points) The fact that your body has capacitance is one of the principles that makes touchscreens work. In this problem, we'll explore out how to make a simple touch sensor, using only two digital pins on an Arduino.

Suppose we have the circuit below, where "drive" is a digital output and "sense" is a digital input. Instead of a regular capacitor, C is a long wire, or even a piece of tin foil. Assume there is no voltage on the capacitor. The sense pin will read a 1 when the voltage goes above 2.5 V.



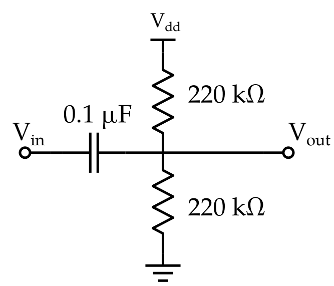
Assume there is no charge on the capacitor, and then the drive pin goes high (5 volts) at time $t = 0$. At what time will the sense pin first read a 1?

Now suppose you touch the "capacitor" wire with your finger, and the capacitance goes up to 130 pF. Now how long will it take for the sense pin to read a 1?

You can read more about this at playground.arduino.cc/Main/CapSense. Some members of the teaching staff will be excited if you use this to control your LED cube.

Problem 2: Audio biasing circuit

(6 Points) If you built the audio input circuit for the LED cube, you need to construct the circuit below. In this problem, we will analyze what this circuit does.



This circuit has two sources that behave differently (and there's no simple way to combine them), so it's appropriate to use superposition here. V_{dd} is the DC power supply, as usual, and V_{in} is the time-varying audio signal input relative to ground.

Calculate V_{out} assuming that V_{in} is off (0 V).

Calculate the transfer function (i.e., the gain $\frac{V_{out}}{V_{in}}$) assuming that V_{dd} is off (0 V). *Note that this tells you how V_{out} behaves for all possible sine wave inputs.*

For the next two questions, we'll turn both sources on and observe what happens for different inputs to V_{in}.

What is V_{out} if V_{in} is 1 V DC?

What is V_{out} if V_{in} is a 100 Hz sine wave with an amplitude of 1V_{pp}? *This will be a function of t.*

Problem 3: Some filters

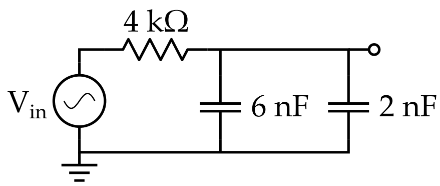
(6 Points) For each of the following circuits, write an equation for the output voltage amplitude as a function of V_{in} and the frequency f, and draw a Bode plot (a log-log plot of gain in dB vs frequency). Gain is the output voltage divided by the input:

$$\text{gain} = \frac{V_{out}}{V_{in}}$$

and can be expressed in dB as

$$\text{dB} = 20 \cdot \log_{10}(\frac{V_{out}}{V_{in}})$$

Please be sure to label the slopes of the plot and the frequencies of any break points. *Hint: You can check your work with EveryCircuit, using the frequency analysis plots.*



Problem 4: Matching

(4 Points) For each time domain waveform shown below, write the letter of the matching frequency domain representation and give a very brief (1 sentence or less) justification. Note that because we're only showing the amplitude and not the phase, multiple waveforms may share the same frequency representation. Note that the '0' frequency component is really the DC value of the signal, and the trace length is the period of a tone with frequency = '1'.

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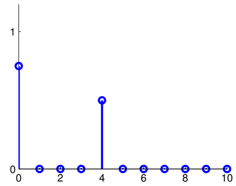

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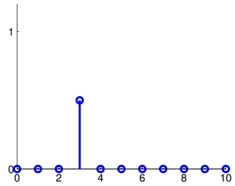

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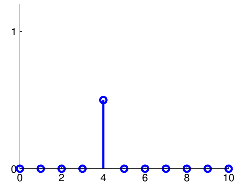

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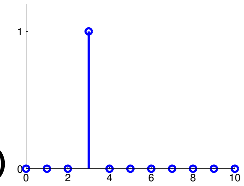

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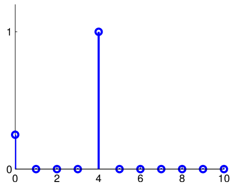

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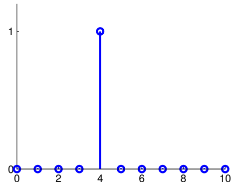

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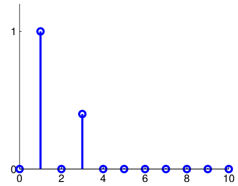

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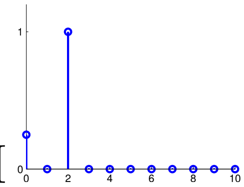
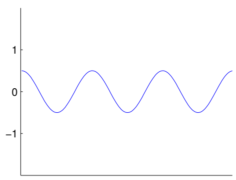
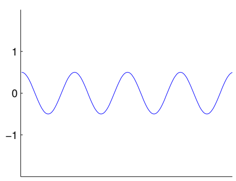
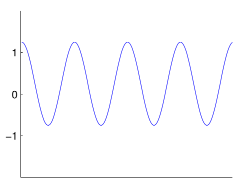
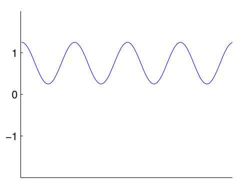
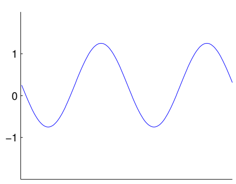


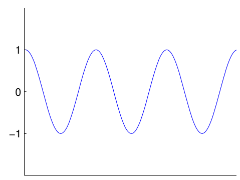


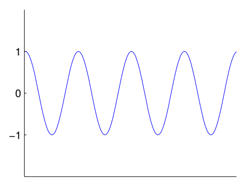


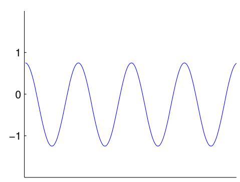


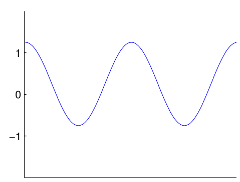






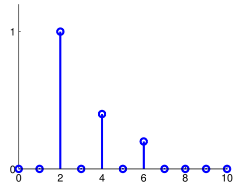
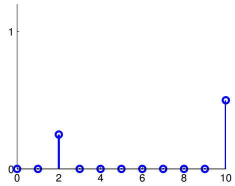
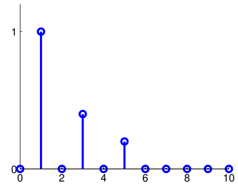
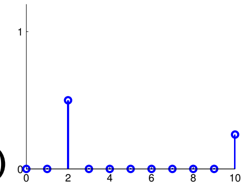


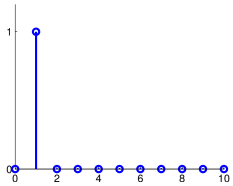
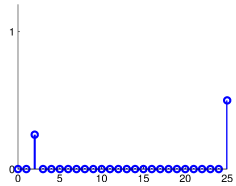
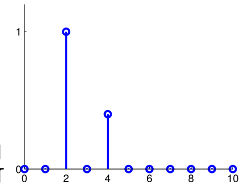
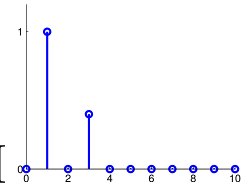


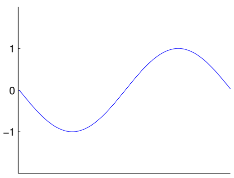
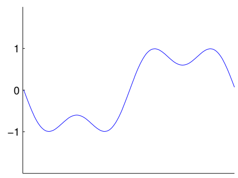


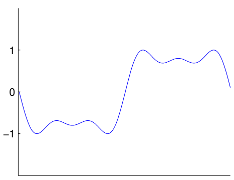
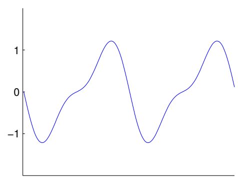
Problem 5: More matching

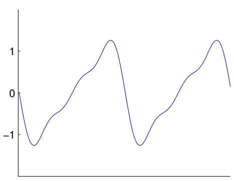
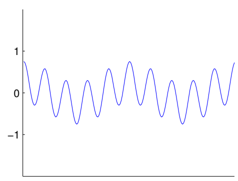
(4 Points) Same as the previous problem, but these are a bit trickier.

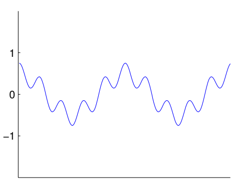
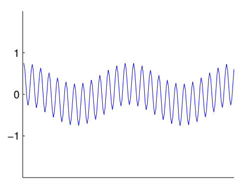
A 
B 
C 
D 

E 
F 
G 
H 

Problem 6: Reflection

(1 Points) How long did you spend on this assignment?