Lab Procedures, policies and Equipment

Spring 2015

Objectives

- To prepare materials needed for the semesters' lab assignments.
- To review techniques and procedures required for professional laboratory work.
- To gain experience using the function generator, power supply, oscilloscope and multimeter located in the ECE Circuits Lab (EL 104).

Parts and Equipment Required

Components and Materials Needed:

- 10kΩ resistor (1)
- 1kΩ resistor (1)
- 1nF capacitor (1)
- solderless breadboard/superstrip (1)

Equipment to be Used:

- Digital Multimeter (1)
- Oscilloscope (2 channels)
- Function generator (1)
- Banana-to-alligator cables (1 pair, red and black)
- BNC-to-BNC cable (2)

- BNC-to-alligator cable (1)
- Oscilloscope probe (2)

1 Pre-Lab Exercises

Exercise 1. Consider the following signal:

$$v_{\text{IN}}(t) = 1\text{V} + (2\text{V})\sin(2\pi f t),$$

for a frequency of $f = 10$kHz. Describe the magnitude spectrum, $|V_{\text{IN}}(f)|$, associated with this signal.

Exercise 2. Suppose the signal from Exercise 1 is provided as input to the circuit shown in Fig. 1. Give expressions for the output signal, $v_{\text{OUT}}(t)$.

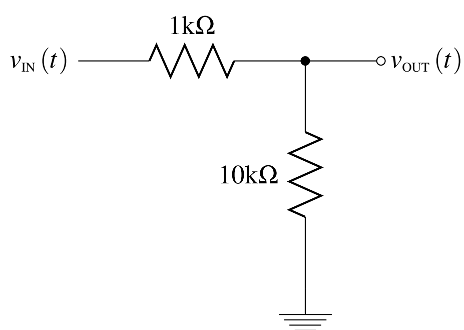

Figure 1: Circuit for Exercise 2.

Exercise 3. Suppose the signal from Exercise 1 is provided as input to the circuit shown in Fig. 2. Evaluate the gain $|H(f)|$ (in dB), the phase shift $\phi = \angle H(jf)$ (in degrees) and the output signal $v_{\text{OUT}}(t)$ (in Volts) at three frequencies, $f_1 = 1$kHz, $f_2 = 10$kHz, $f_3 = 50$kHz. What kind of filter circuit is this, and what is its 3dB cutoff frequency, in kHz? Finally, evaluate the phase ϕ at the 3dB cutoff frequency. Hint: The 3dB cutoff frequency is where the output amplitude falls to 0.707 of its maximum value. Also recall that the gain, in decibels, at specific frequency f is given by

$$\text{Gain(dB)} = 20\log_{10}\left(\frac{v_{\text{OUT}}(f)}{v_{\text{IN}}(f)}\right),$$

Exercise 4. Suppose the signal from Exercise 1 is provided as input to the circuit shown in Fig. 3. Evaluate the gain $|H(f)|$ (in dB), the phase shift $\phi = \angle H(jf)$ (in degrees) and the output signal $v_{\text{OUT}}(t)$ (in Volts) at three frequencies, $f_1 = 1$kHz, $f_2 = 10$kHz, $f_3 = 50$kHz. What kind of filter circuit is this, and what is its 3dB cutoff frequency, in kHz? Finally, evaluate the phase ϕ at the 3dB cutoff frequency.

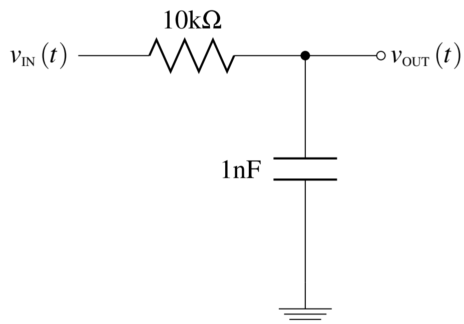

Figure 2: Circuit for Exercise 3.

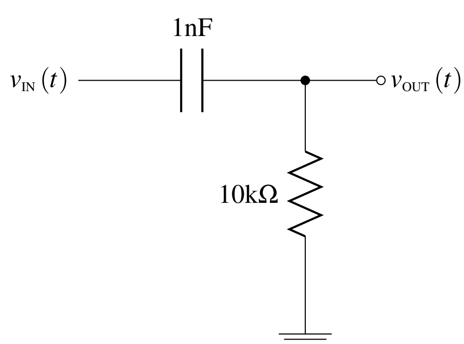

Figure 3: Circuit for Exercise 4.

2 Physical Experiments

Procedure 1. Connect the banana cables to the Digital Multimeter on your lab bench. Set the Multimeter to measure Ohms, and obtain precise measurements for the two resistors used in this lab. Record the values in your lab book.

Procedure 2. Using a BNC cable, connect the `Main` signal output from the Function Generator to the `CH 1` input on the oscilloscope. Also connect the `SYNC` output from the Function Generator to the `EXT TRIG` input on the oscilloscope. Perform the following steps:

Step A. Press the `TRIG MENU` button. Using the Menu buttons along the right side of the oscilloscope display, press the `Source` button until it displays `Ext`.

Step B. Press the `Channel 1` button. You should see the `Channel 1` Menu options appear along the right side of the scope display. Make sure that it reads `DC Coupling`, `BW Limit OFF`, `Probe 1X` and `Invert OFF`.

Step C. Adjust the `Volts/Div` and `Seconds/Div` knobs to get 1 V per division and 100 µs per division, respectively.

Step D. Adjust the `Amplitude`, `Offset` and `Frequency` knobs on the Function Generator until the settings match the waveform specified in Prelab Exercise 1. Set the Function Generator to a sine wave signal source. Use the oscilloscope display to verify your settings. <u>Note:</u> To adjust the offset voltage on the Function Generator, you will have to pull out on the knob to unlock its setting.

Step E. Press the `Measure` button on the oscilloscope. Set the `Source` to be `Channel 1` using the Menu buttons on the side of the scope. Using the measurement options, obtain precise measurements for the signal's *frequency*, its *peak-to-peak amplitude*, and it *average value* (i.e. the offset voltage). Record these values in your lab book.

Procedure 3. Press the `Math` button on the oscilloscope. Perform the following steps:

Step A. Using the Menu buttons along the right side of the oscilloscope, set the Math operation to `FFT`. Adjust the `Seconds/Div` and `Volts/Div` knobs to read 50 kS/s and 10 dB per division, respectively.

Step B. Record the spectrum displayed on the oscilloscope. Does it match your expectations? Take note of any anomalies, and offer hypotheses to explain them.

Step C. On the Function Generator, change the signal type to a square wave. How does this change the magnitude spectrum?

Step D. Now change the signal type to a triangle wave. How does this change the magnitude spectrum?

Procedure 4. Using your breadboard, connect a circuit to match the schematic in Fig. 1. Perform the following steps:

Step A. Set the Function Generator to produce a sine wave. Press `CH 1 Menu` to turn off the FFT display on the oscilloscope. Verify that the Function Generator settings still match the waveform specified in Exercise 1.

Step B. Using a BNC-to-alligator cable, connect the Function Generator to your circuit. The alligator clips should connect to v_{IN} (red) and ground (black).

Step C. Connect the two probes to the oscilloscope. Connect both of the probes' black alligator clips to ground on your circuit board. Then connect the Channel 1 probe to v_{IN}, and the Channel 2 probe to v_{OUT}.

Step D. Adjust the oscilloscope so that both signals are visible. Adjust both Channels to display 1 V per division. Using the `Vertical Position` knobs, position the signals so that their reference points match (look for the little arrow on the left side of the scope display).

Step E. Using the `Measure` key, obtain precise measurements for the peak-to-peak amplitude and average value of each signal. Do the measurements match your expectation? Explain any difference.

Procedure 5. Change the circuit on your breadboard to match the one shown in Fig. 2, and perform the following steps:

Step A. Connect the Channel 1 probe to v_{IN} and the Channel 2 probe to v_{OUT}. Set the input frequency to a low value of $f_1 = 1\text{kHz}$.

Step B. Press the `Math` button and activate the `FFT` function. Set the `Source` to be `CH 2`. Adjust the

`VOLTS/DIV` and `SEC/DIV` knobs so that the display reads 10 dB per division and 50 kS/s, respectively.

Step C. You should see a peak at 1 kHz. Adjust the `Horizontal Position` knob so that the peak is centered on the oscilloscope display, then zoom in by pressing the `FFT Zoom` button. Zoom in on the magnitude display by adjusting the `Vertical Position` knob above `CH 2`. Change the `VOLTS/DIV` setting to 2dB per division and locate the peak on the display.

Step D. Press the `CURSOR` button and set the `Type` to `Magnitude`. Position `Cursor 1` at the top of the peak, and position `Cursor 2` 3dB below the magnitude of `Cursor 1` (watch the `Delta` measurement on the right side of the display to see when you reach 3dB).

Step E. Now change the `FFT Zoom` to `X1` and slowly increase the frequency on the Function Generator until the peak precisely touches `Cursor 2`.

Step F. Re-center the peak on the display by adjusting the `Horizontal Position` knob, and change the `FFT Zoom` to `X10`. Change the cursor `Type` to `Frequency`. Adjust one of the cursors to align with the new peak on the FFT display. This is the 3dB cutoff frequency for the circuit. Record this frequency in your lab book. Does it match your expectation from Prelab Exercise 3? Explain any differences.

Procedure 6. Change the circuit on your breadboard to match the one shown in Fig. 3, and perform the following steps:

Step A. Repeat the steps from Procedure 5. This time, you will sweep from a high frequency to a lower frequency.

Step B. Adjust the `SEC/DIV` so that the display reads 100 kS/s.

Step C. Set the Function Generator to 40kHz. As before, locate the peak magnitude with `Cursor 1`, and position `Cursor 2` to a point 3dB below `Cursor 1`.

Step D. Slowly *decrease* the frequency on the Function Generator until the peak precisely touches `Cursor 2`.

Step E. Switch the cursors to `Type Frequency`, and align one of the cursors with the peak. This is the 3dB cutoff frequency of your high-pass circuit. Record this value in your lab book. Does it meet your expectations? Offer a hypothesis for any deviation.

Procedure 7. A digital oscilloscope takes discrete samples.When the sample rate is lower than double the frequency you are looking at, the apparent frequency will be lower than actual frequency. To observe this phenomenon,leave your circuit in the configuration of Procedure 6 Increase the frequency beyond the right edge of the FFT display. Continue increasing the frequency, up to 200kHz, and observe the FFT display. What happens as you increase the frequency? Explain what you observe, and comment on how this phenomenon may affect future lab experiments.

3 Post-Lab

In your lab book, write a summary of your findings. In particular, comment on the measured behavior of the voltage divider, low-pass and high-pass circuits. Can your measurements be precisely predicted by using formulas and your measured resistor values? In your opinion, how precise is your measurement of the cutoff frequencies for the low-pass and high-pass circuits? What steps could be taken to improve the precision? Also, comment on the effect observed in Procedure 7. What problems could this cause for future experiments, and how can you avoid those problems?

Finally, write a brief report describing your objectives, methods and major findings. Submit this report to the TA or Instructor along with your Lab Book.