2nd Order Filters

Materials:

- 2 Series Mixed Series Oscilloscope (MSO)
- Arbitrary/Function Generator (AFG): AFG1000 or internal 2 Series AFG
- Direct current (DC) power supply: 2230 High Power Programmable Power Supply
- Resistors (4)
- Capacitors (4)
- Operational Amplifier (Op Amp)
- Breadboard
- Jumper wires

Procedure:
Task 1: Analyzing a 2nd Order Low Pass Filter

C = 10 uF R = 1 kΩ Op Amp PN: UA741

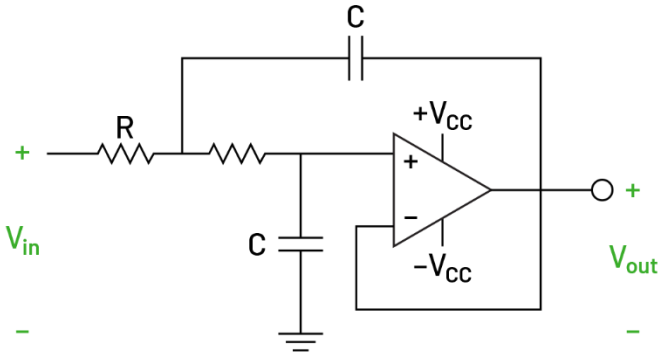

Figure 1. Low pass filter circuit diagram.

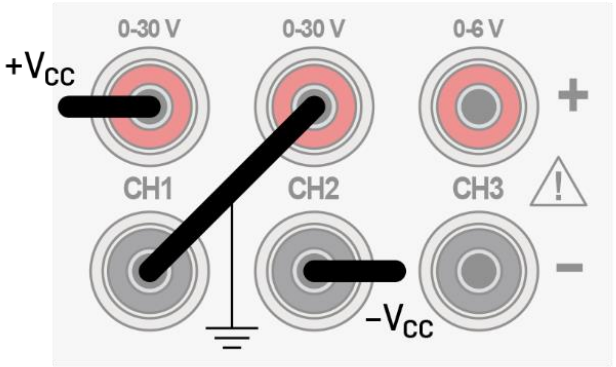

Figure 2. Wire diagram of 2230 power supply for powering op amp.

1. Build the low pass filter circuit in Figure 1. making sure to connect the correct nodes to the inverting and non-inverting inputs. To power the op amp, use the DC power supply with the configuration in Figure 2. By connecting the negative output from channel 1 and the

positive output from channel 2, the new reference ground allows the power supply to output positive and negative voltages. Connect the channel 1 probe to V_{in} and channel 2 probe to V_{out} on the 2 Series MSO.

2. To set up the input (V_{in}), the built in AFG on the 2 Series MSO or an external AFG can be used. For the built in AFG, connect the "AFG/ Aux Out" output to the input of the circuit. To configure the AFG, locate the "AFG PG" button at the bottom of the screen. Select "AFG" and configure the following settings:

    - Waveform: "sine"
    - Frequency: "60 Hz"
    - Amplitude: "1 Vpp"

    Once the settings are configured, select Output: "continuous" to turn on the AFG. For an external AFG, configure your sinusoidal input using the same parameters.

3. Observe the input and output waveforms. Using the "Measure" button on the top right corner of the screen, add an "Amplitude" measurement to channels 1 and 2 and add a "Phase" measurement which is located under the "TIME MEASUREMENTS" section. Record the input amplitude, output amplitude and phase difference in Table 1. for three difference frequencies.

Frequency	V_{in} Amplitude	V_{out} Amplitude	Phase Shift

Table 1. Low pass filter measurements.

4. To calculate the theoretical cutoff frequency of the filter, use the following formula:

$$f_c = \frac{1}{2\pi RC}$$

    Record this frequency in Table 2.

5. To measure the cutoff frequency, use the built in Bode plot analysis tool on the 2 Series MSO. Remove the phase and amplitude measurements by tapping on the measurement on the right side of the screen and deleting the measurement. Next, tap the "measure" button and select the "FRA" tab at the top of the measurement window. Tap the "control loop response (bode)" and set the input to Ch 1 and the output to Ch 2. To configure the analysis, select the frequency range to be from 10 Hz to 10 kHz with 10 points per decade. Select the generator to be "internal" and the amplitude to be 500 mVpp. Once the measurement is configured, the AFG is preset. The "run/stop" button on the top right corner of the scope will trigger the analysis.

    Once the analysis is complete, the plotted bode graph will appear on the screen. Use the cursor to locate the -3dB frequency or the cutoff frequency. This frequency is located

where the gain is equal to -3dB. Record this frequency in Table 2. Compare the observed frequency to the theoretical frequency.

Theoretical Cutoff Frequency	Observed Cutoff Frequency

Table 2. Low pass filter theoretical and observed cutoff frequencies.

Task 2: Analyzing a 2nd Order High Pass Filter

C = 6.2 nF R = 1 kΩ Op Amp PN: UA741

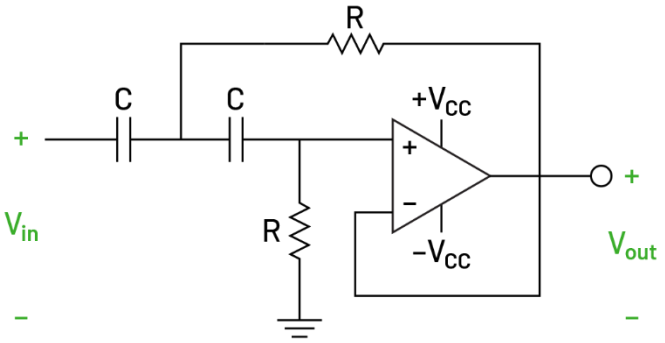

Figure 3. High pass filter circuit diagram.

1. Build the high pass filter circuit shown in Figure 3. To power the op amp, use the same power supply configuration as used in Task 1. Configure the AFG to input the following sine wave:

    - Waveform: "sine"
    - Frequency: "30 kHz"
    - Amplitude: "1 Vpp"

    Attach the input (V_{in}) to channel 1 ad the output to channel 2 like in Task 1.

2. Complete the steps 3-5 in Task 1 for the high pass filter circuit and record the data in Table 3 and 4. The theoretical cutoff frequency formula for the high pass filter circuit is the same as the low pass filter circuit because the resister and capacitor values are the same:

$$f_{c,high} = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

If $R_1 = R_2$ and $C_1 = C_2$:

$$f_c = \frac{1}{2\pi RC}$$

Frequency	V_{in} Amplitude	V_{out} Amplitude	Phase Shift

Table 3. High pass filter measurements.

Theoretical Cutoff Frequency	Observed Cutoff Frequency

Table 4. High pass filter theoretical and observed cutoff frequencies.

3. What are the benefits of using high order, active filters instead of passive filters? Were the theoretical and observed cutoff frequencies similar? Did one of the filters perform as expected more than the other?

Instructor Notes:

Figure 4. Low pass filter bode plot results. Measured cutoff frequency of 91.283 Hz.

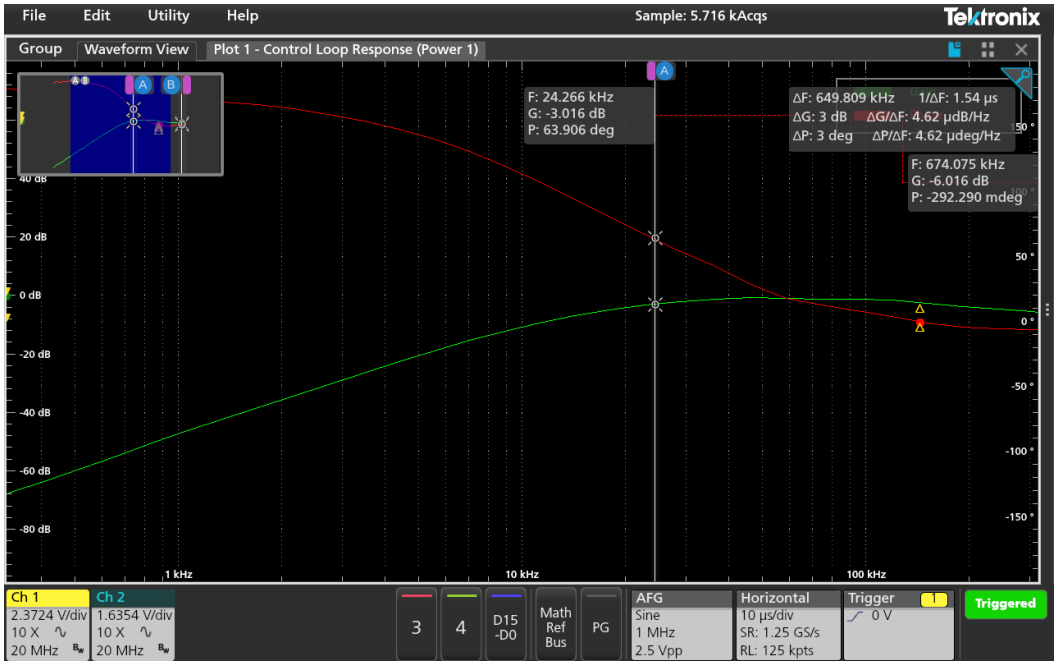

Figure 5. High pass filter bode plot results. Measure cutoff frequency of 24.266 kHz.