ECE215: Filter Lab

Today we will build and investigate filter circuits using the function generator, oscilloscope, & breadboard.

Keysight 33500B Waveform Generator

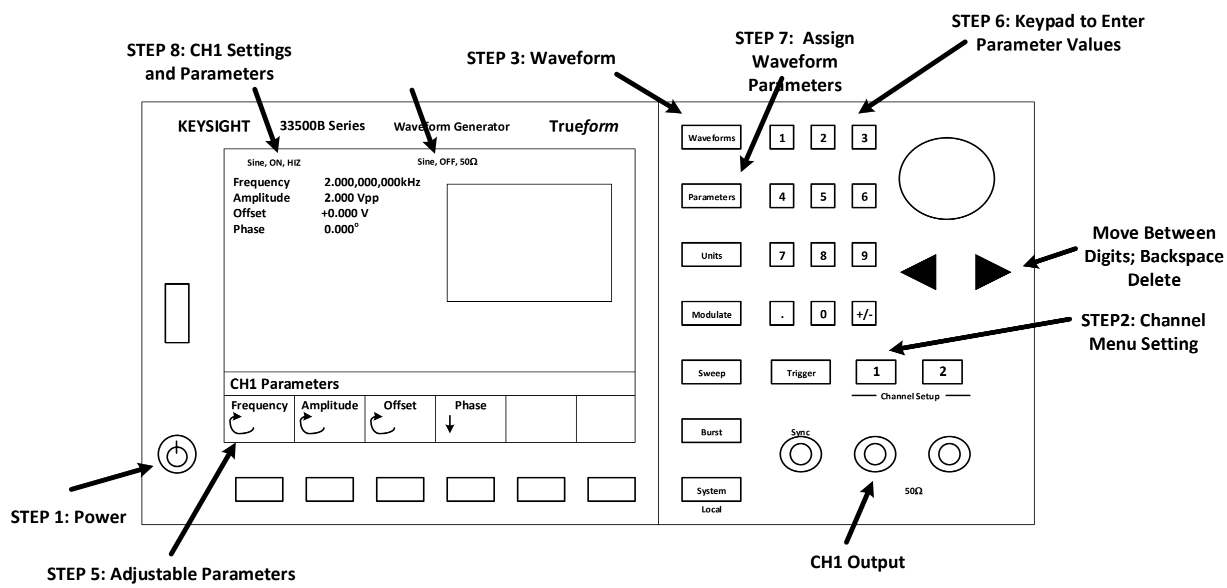
Let's program our Function Generator to produce a 4kHz, 10Vpp, sinusoidal signal

STEP 1: Turn FG ON **STEP 2:** Set Menu to CH1 (see figure below)

STEP 3: Press the "Output Load" button and set it to **High Z** on the menu at the bottom of the screen (this will ensure that the peak-to-peak amplitude we program will be what we measure!)

Output **Off On**	**Output** ↓ **Load**	**Range** **Auto**	**Polarity** **Normal**	**Voltage** ↓ **Limits**	**More** ▶▶ **1 of 2**

STEP 4: Press the Waveform Button so we can choose the type of signal



STEP 5: On the menu at the bottom of the screen, choose "Sine" (so it's highlighted)

Sine	**Square**	**Ramp**	**Pulse**	**Arb**	**More** ▶▶ **1 of 2**

STEP 6: Once you make a type selection, that menu item will be highlighted from that point forward and you will be transferred directly to its specific menu. Press the "Frequency" button (so it's highlighted)

Frequency	**Aplitude**	**Offset**	**Phase** ↓

STEP 7: Let's change the value from the default 1kHz to 4kHz. Type "4" on the numeric keypad. This will change the menu to the following where we can choose "kHz". The left-pointing arrow allows you to erase values you did not intend

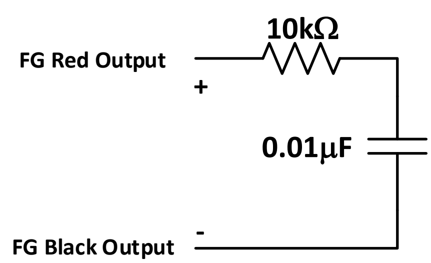
μHz	**mHz**	**Hz**	**kHz**	**MHz**	**Cancel**

STEP 8: Press the "Parameters" button on the panel to return to the sinewave parameters and choose "Amplitude". Set it to 10Vpp (where pp means peak-to-peak) using the keypad.

STEP 9: Turn ON CH1 by pressing the button for the CH1 menu and selecting Output -> ON

Output **Off On**	**Output** ↓ **Load**	**Range** **Auto**	**Polarity** **Normal**	**Voltage** ↓ **Limits**	**More** ▶▶ **1 of 2**

STEP 10: Build the following filter circuit on your breadboard (use the red mini-grabber cable to connect from the FG to the breadboard)



Predict the cutoff frequency: ___________________

STEP 11: Connect CH1 of the oscope to where the FG is connected to your circuit (so we measure the FG signal); Connect CH2 of the oscope across the capacitor. Make sure that the black connection of CH1 is connected to the bottom of the circuit.

Tektronix 2 series Oscilloscope (O-Scope)

Let's configure the scope to measure the amplitudes of the two signals and the phase difference

STEP 12: If CH1 is not ON, touch and hold the "Ch 1" box in the bottom left of the screen and select "Turn Ch 1 On". Do the same with CH2, and make sure the other channels are OFF. (Another way to do this is by pushing the buttons in the VERTICAL box to the right of the screen.)

STEP 13: Adjust the vertical scale by selecting channel (1 or 2) in the VERTICAL box to the right of the screen and turning the "Scale" knob. Ensure both channels' max and min are shown on the screen.

STEP 14: Adjust the horizontal scale by turning the "Scale" knob in the HORIZONTAL box. Adjust it so you see about two cycles or periods displayed. You may also use the touch screen and pinch it.

STEP 15: Our scope also has the built-in ability to measure a whole host of waveform quantities. To do this, press the "Measure" button near the top right of the touch screen.

STEP 16: Add the "Peak-to-Peak" measurement for both CH1 and CH2. You should see the measurements show up in the window to the right of the main scope display. Note, if you see other measurements there you don't want, you can swipe them off the screen to the right to delete them.

STEP 17: Finally, let's measure the phase angle. Press "Measure", and then select the TIME MEASUREMENTS menu. Select "Phase." We need to tell the scope which channels to use. Set Source 1 to CH2 and Source 2 to CH1. Finally press "Add."

STEP 18: Complete the following table by going back and adjusting the FG settings (always make sure that the input and output waveforms fit within the scope window and that the output signal is large enough so the scope can measure the phase angle. Adjust the Volt/div as necessary to ensure this). **For the measurements between 1-2kHz, find the frequency that results in a gain of 0.7071 (or an output of 0.7071 times the input amplitude). This is your measured cutoff frequency.**

Frequency	**Input Amplitude (Vpp)**	**Output Amplitude (Vpp)**	**Phase Difference (degrees)**	**Ratio of Amplitudes (Gain)**
100 Hz				
200Hz				
400Hz				
1kHz				
????kHz				0.7071
2kHz				
4kHz				
10kHz				
20kHz				
40kHz				

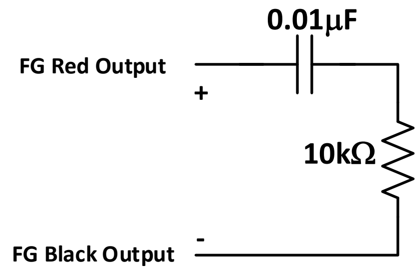
What type of filter do we have? ____________________

What is its measured cutoff frequency? ___________________

Why is the measured cutoff frequency not exactly what you predicted?

____

<u>STEP 19</u>: Flip the positions of the filter resistor and capacitor and take the output across the resistor.



<u>STEP 20</u>: Now, let's get a "feel" for what type of filter this is by sweeping through frequencies from 100Hz-10kHz. Choose "Parameters" on the FG, select Frequency, and use the left and right-pointing arrows below the main control knob to choose the left-most digit. Then use the control knob to sweep the frequency up and down. Move the control digit down if you need to. Note what type of filter you have. Find the measured cutoff frequency like you did for the previous filter.

Frequency	Input Amplitude	Output Amplitude	Phase Difference	Ratio of Amplitudes (Gain)
????kHz				0.7071

What type of filter do we have? ___________________

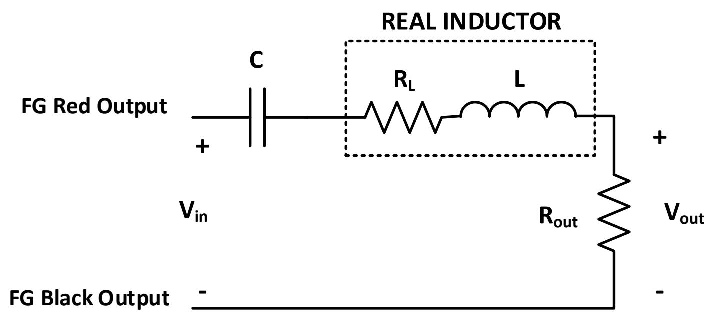
What is its measured cutoff frequency? ______________________

<u>STEP 21:</u> With the components out of the breadboard, use the ZLCR meter to measure the actual component values.

Measured R: _______________ Measured C: ____________________

Recalculate your filter cutoff frequency using the measured R and C values. Is this cutoff frequency closer to what you measured the cutoff frequency to be? ____ _______________

STEP 22: Now you will build and investigate another filter circuit using the function generator, oscilloscope, & breadboard. Hypothesize which type of filter it is (LPF, HPF, BPF, BRF).



FILTER TYPE: _______________

As we did before, we will prototype the circuit and confirm our hypothesis above by applying various input frequencies and measuring the input and output amplitudes using the oscilloscope.

STEP 23: Build the above filter circuit on your breadboard (use the mini-grabber cable to connect from the FG to the breadboard). The capacitor will be 0.01μF, the inductor is 500mH, and the output resistor will be $R_{out} = 10k\Omega$. Note the resistor R_L is part of a real inductor and **does not need to be separately added**.

STEP 24: Connect the input voltage to CH1 and the output resistor voltage to CH2 of the o-scope.

STEP 25: Using the control knob on the FG, sweep through 100Hz-10kHz. Can you estimate approximately where the peak gain occurs [Note, this value should occur between 1-5kHz]?

Frequency for Peak Gain: ______________________

You will find that the gain at the "center frequency" will not quite be equal to 1 because of the inductor internal resistance. Use the frequency that gets you closest to 1 as your center frequency.

Were you able to confirm your filter analysis hypothesis? ____________

STEP 26: If you have extra time, try to find the cutoff frequencies of your filter and estimate the bandwidth. Otherwise, please power off and put away all equipment. You can leave the circuit components on top of the breadboard.