RC Band Pass and Notch Filter

Materials:

- [2 Series Mixed Series Oscilloscope (MSO)]
- Arbitrary/Function Generator (AFG): AFG1000 or internal 2 Series AFG
- Resistors
- Capacitors
- Breadboard
- Jumper wires

Task 1: Analyzing the Band Pass Filter

Follow the steps below to observe the behavior of a RC band pass filter. Use the following components for the circuit in Figure 1.

C_1 = 0.334 uF C_2 = 0.1 uF R_1 = 200 Ω R_2 = 100 Ω

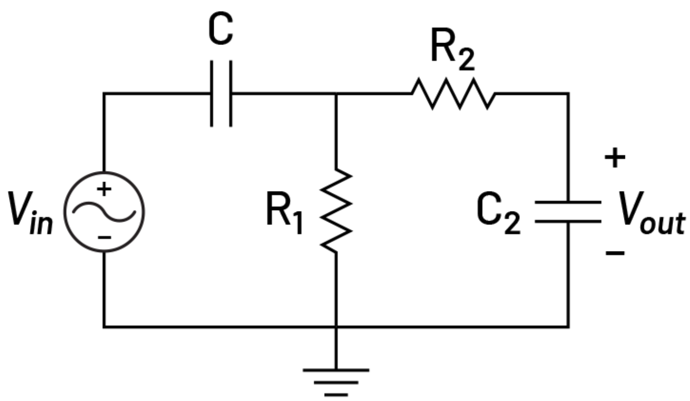

Figure 1. Band pass filter circuit diagram.

1. Construct the band pass filter circuit according to the diagram in Figure 1 using the corresponding resistor and capacitor values for R_1, R_2, C_1 and C_2. This experiment uses two input channels on the 2 Series MSO for analysis. Attach the Channel 1 probe to the input of the circuit (V_{in}) and the Channel 2 probe to the output of the circuit (V_{out}). Make sure both probes are connected to the common ground of the circuit.

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: "5 kHz"
   - Amplitude: "500 mVpp"

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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 circuit's input and output waveforms on Channels 1 and 2. Adjust the horizontal scale using the "scale" knob to see a few periods of the waveforms. Adjust the vertical scale knob to be 200mV/div for both waveforms. Use the numbered channel buttons to the right of the scale knobs to select which waveform is being affected by the vertical scaling. The vertical scale of each channel is listed on the bottom left corner of the screen.

4. The band pass filter is designed by combining a low pass and high pass filter. The band of frequencies between the two cut-off frequencies is passed through the filter. Vary the frequency to find the lower end of the band and the higher end of the band. Adding phase and amplitude measurements can help analyze when the output of the filter is beginning to cut off. Add these measurements by tapping the "measure" button on the top right of the screen and finding the correct measurement. Estimate the bandwidth of the filter by subtracting the lower frequency from the higher frequency.

5. To compare the estimated bandwidth to the actual bandwidth of the filter use the built in frequency response measurement 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 100 Hz to 100 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 frequencies. Band pass filters have a lower cut off frequency and a higher cut off frequency. After the cut off frequencies are located using the cursors and bode plot calculate the frequencies by hand using the formulas:

$$f_{high} = \frac{1}{2\pi R_2 C_2}$$
$$f_{low} = \frac{1}{2\pi R_1 C_1}$$

   Compare the cutoff frequency from the bode plot to the calculated cutoff frequency based of the circuit components. Band pass filters also have a resonant frequency which is where the filter is at its peak gain. Use the cursors to locate the resonant frequency on the bode plot. Compare the measured resonant frequency to the calculated resonant frequency using this formula:

$$f_r = \sqrt{f_{high} * f_{low}}$$

Task 2: Analyzing the Notch Filter

Follow the steps below to observe the behavior of a Twin-T Notch filter. Use the following components for the circuit in Figure 1.

R = 1 kΩ   C = 10 nF

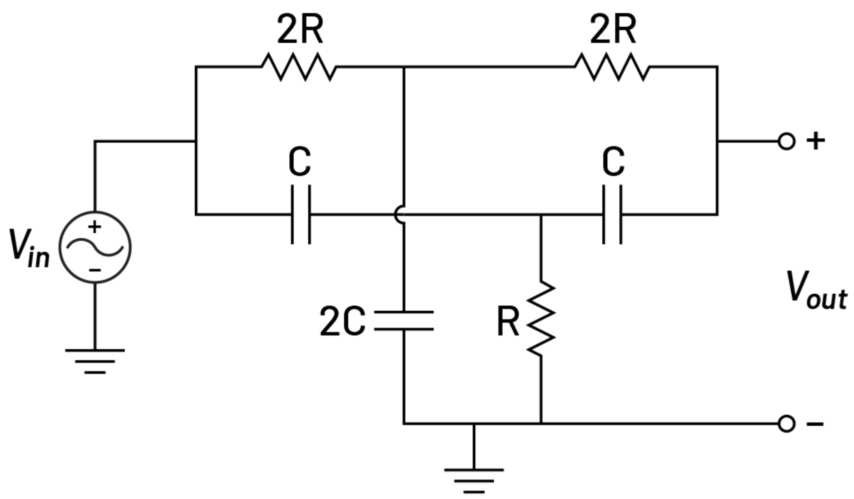

Figure 2. Diagram of Twin-T notch filter circuit.

1. Construct the notch filter circuit according to the diagram in Figure 1 using the corresponding resistor and capacitor values for R and C. Attach the Channel 1 probe to the input of the circuit (V_{in}) and the Channel 2 probe to the output of the circuit (V_{out}). Make sure both probes are connected to the common ground of the circuit. Tip: capacitor values are added together when placed in parallel. Two C capacitors in parallel will work the same as a singular 2C capacitor.

2. Set up the input (V_{in}) with either the internal AFG or an external AFG as done in Task 1. Configure AFG to the following settings:

    - Waveform: "sine"
    - Frequency: "5 kHz"
    - Amplitude: "500 mVpp"

    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. Adjust the vertical and horizontal scales as done in Task 1 to observe the waveforms. The notch filter is designed to suppress a single frequency. Try to manually sweep through frequencies from 5k Hz to 10 kHz and locate the targeted frequency. Feel free to add phase and amplitude measurements to help analyze the input and output waveforms.

4. Follow similar steps in Task 1, step 5 to create a frequency analysis of the notch filter. Use the bode plot cursors to find the suppressed or "notch" frequency and the -3dB frequencies. The notch frequency can also be hand calculated using the formula below:

$$f_N = \frac{1}{4\pi RC}$$

Compare the estimated notch frequency in Step 3 to the bode plot measured and the hand calculated frequencies.

Instructor Notes:

Band pass Filter Results:

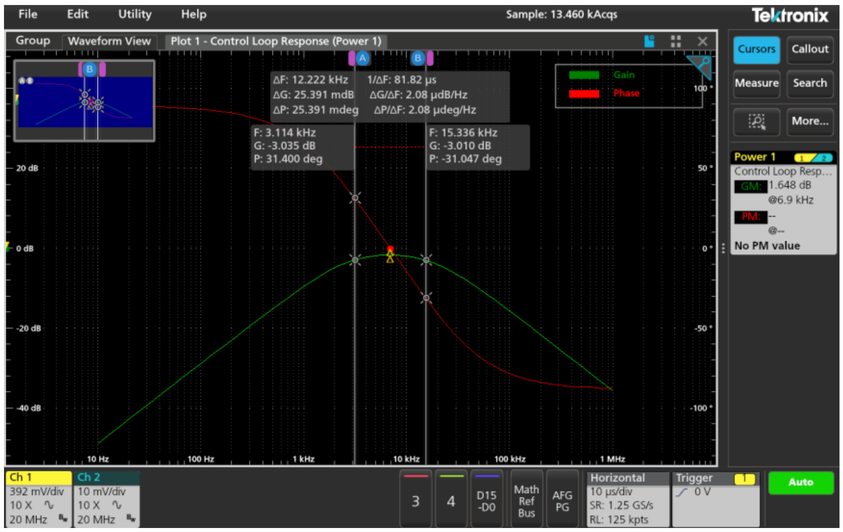

Figure 3. Band pass filter bode plot.

Cut off frequencies:

F_L = 3.114 kHz F_H = 15.914 kHz

Notch Filter Results:

F_N = 8.084 kHz

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