Frequency Dependent Op Amp Behavior

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Overview:
This investigation is intended to help you better understand how bandwidth is influenced by the gain of an op amp circuit and how the frequency of an input signal or loads may influence the slew rate. Single op amps, such as the 411 or 741 should be used. Part 1 investigates changes in bandwidth and Part 2 investigates slew rate and part 2 investigates slew rate.

Pre-lab:

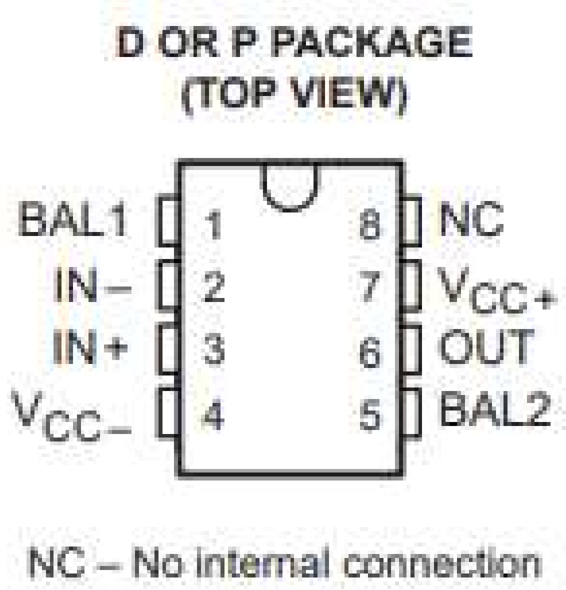

Figure 1: LF411 Op Amp diagram

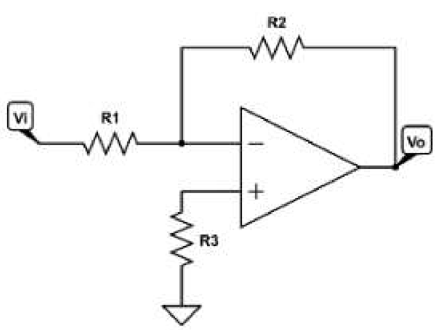

Figure 2: Recommended layout of test circuit

Procedure:
Step 1:

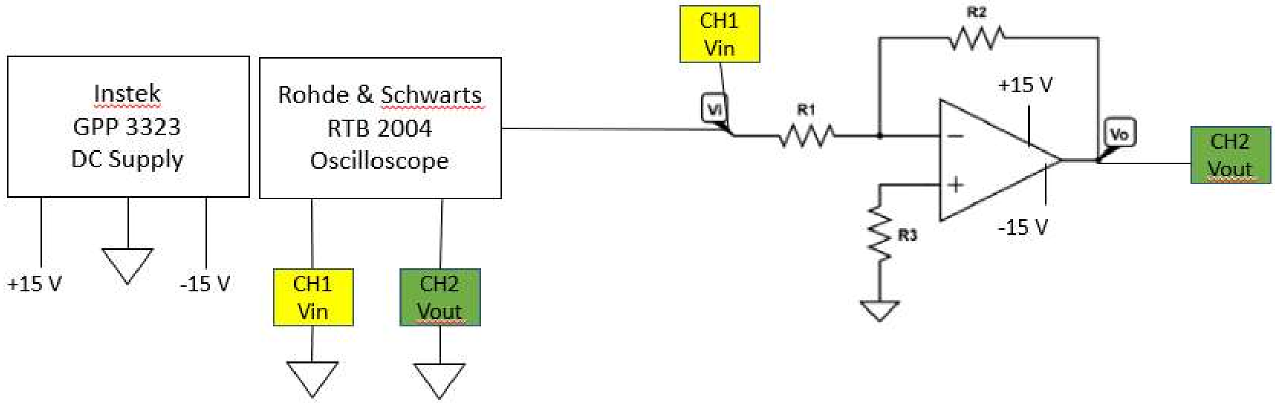

Figure 3: Circuit schematic based off design layout in Figure 2

Part 1:

Step 2-3:

Table 1: Gain and corner frequency at component values based on circuit in Figure 3

R1 [ohms]	R2 [kohms]	R3 [ohms]	Gain [V/V]	Gain [dB]	Corner Frequency [kHz]
98.97	9.89	98.60	72.36	37.19	28.18

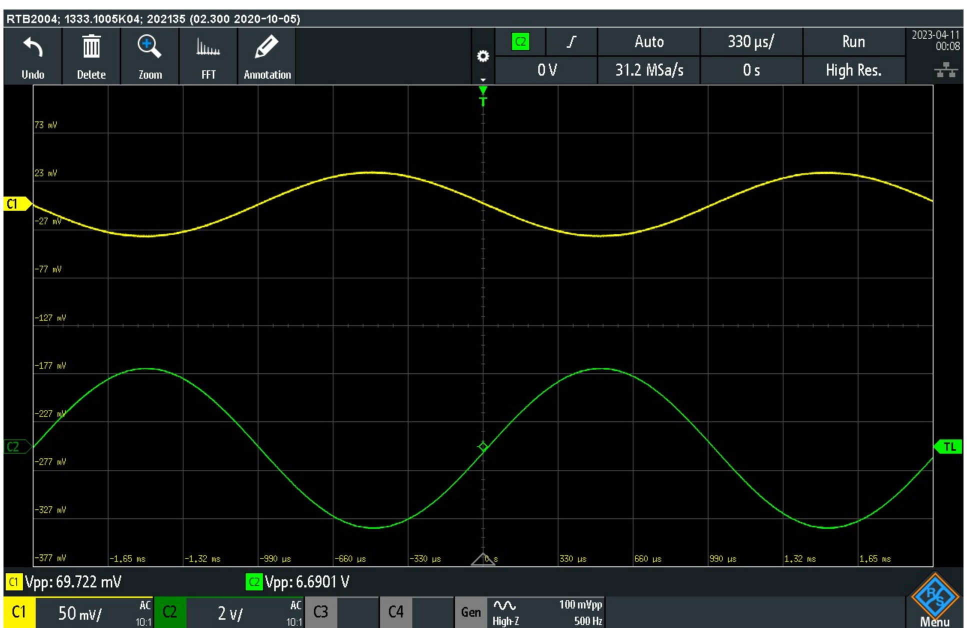

Figure 4: Waveform of circuit from Figure 3 at 100 mVpp sinusoid at 500 Hz with impedance values corresponding to Table 1

Figure 5: Frequency sweep of circuit from Figure 3 at 100 mVpp with impedance values corresponding to Table 1

Step 4:

Table 2: Gain and corner frequency at component values based on circuit in Figure 3

R1 [ohms]	R2 [ohms]	R3 [ohms]	Gain [V/V]	Gain [dB]	Corner Frequency [kHz]
98.97	98.90	98.60	10.15	20.13	19

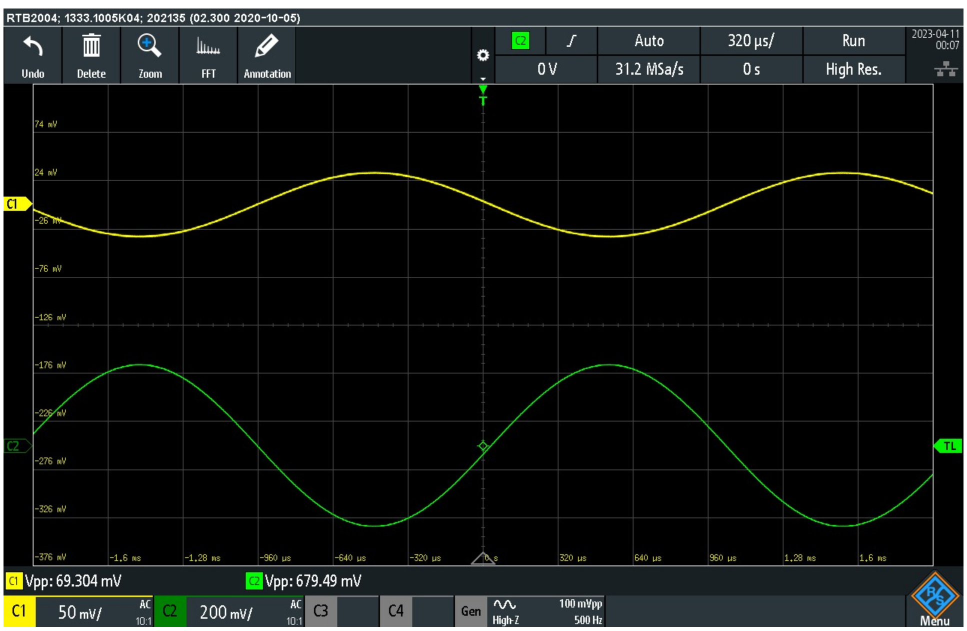

Figure 6: Waveform of circuit from Figure 3 at 100 mVpp sinusoid at 500 Hz with impedance values corresponding to Table 2

Figure 7: Frequency sweep of circuit from Figure 3 at 100 mVpp with impedance values corresponding to Table 2

Step 5:

Table 3: Gain and corner frequency at component values based on circuit in Figure 3

R1 [ohms]	R2 [nF + kohm]	R3 [ohms]	Gain [V/V]	Gain [dB]	Corner Frequency [kHz]
98.97	2.1 + 9.89	98.60	10.35	20.3	63

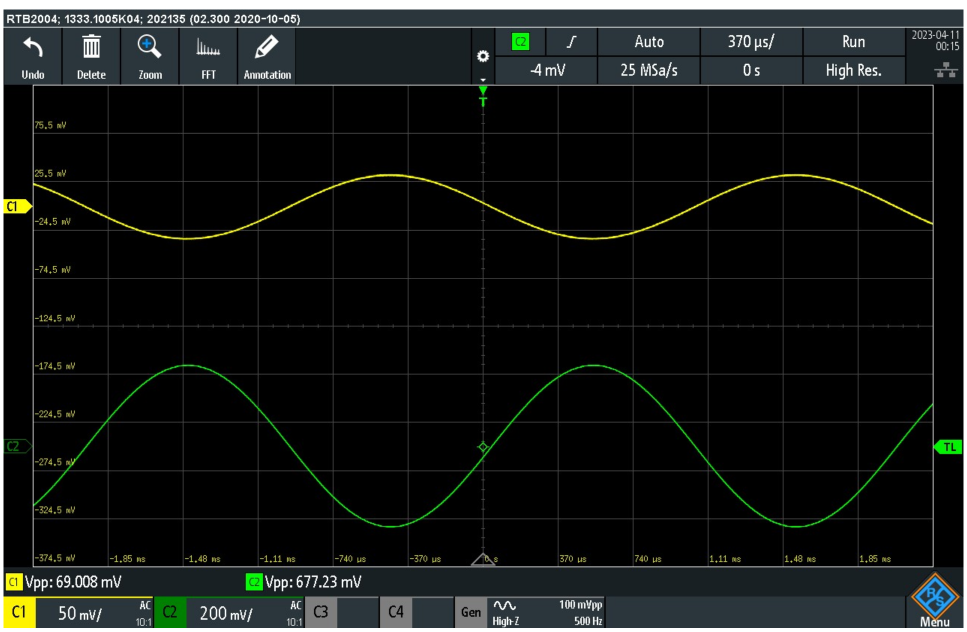

Figure 8: Waveform of circuit from Figure 3 at 100 mVpp sinusoid at 500 Hz with impedance values corresponding to Table 3

Figure 9: Frequency sweep of circuit from Figure 3 at 100 mVpp with impedance values corresponding to Table 3

Part 2:

Step 7:

R1 [ohms]	R2 [kohms]	R3 [ohms]	Delta V [Vpp]	Delta t [us]	Slew Rate [V/us]
98.97	9.89	98.60	5.48	7.5	0.73

Figure 10: Waveform of circuit from Figure 3 at 100 mVpp rectangular at 5 kHz with impedance values corresponding to Table 4

Step 8:

R1 [ohms]	R2 [kohms]	R3 [ohms]	ZL [nF]	Delta V [Vpp]	Delta t [us]	Slew Rate [V/us]
98.97	9.89	98.60	9.4	5.7	5.5	1.04

Figure 11: Waveform of circuit from Figure 3 at 100 mVpp rectangular at 5 kHz with impedance values corresponding to Table 5

Step 9:

R1 [ohms]	R2 [nF+kohms]	R3 [ohms]	Gain [V/V]	Delta V [Vpp]	Delta t [us]	Slew Rate [V/us]
98.97	4.7 + 9.89	98.60	0.156	0.705	0.245	2.88

Figure 12: Waveform of circuit from Figure 3 at 100 mVpp rectangular at 5 kHz with impedance values corresponding to Table 6

Step 11:
The 3 following figures are from the same circuit configuration as the circuit in step 7 (refer to Table 4 for component values)

	Frequency [Hz]	Delta V [mVpp]	Delta t [us]	Slew rate [V/us]
Passband	100	80.87	2.01	0.04
Corner	35.48k	91.1	0.0495	1.84

Fast	1M	90.6	0.0205	4.42

Figure 13: Output from circuit schematic in step 7 at 100 mVpp rectangular at a passband frequency of 100 Hz

Figure 14: Output from circuit schematic in step 7 at 100 mVpp rectangular at the center frequency of 35.48 kHz

Figure 15: Output from circuit schematic in step 7 at 100 mVpp rectangular at a "too fast" frequency of 1 MHz

The 3 following figures are from the same circuit configuration as the circuit in step 9 (refer to Table 6 for component values)

	Frequency [Hz]	Delta V [mVpp]	Delta t [us]	Slew rate [V/us]
Passband	100	66.04	0.068	0.97
Corner	3.55 k	81.11	0.029	2.79
Fast	1 M	71.1	0.014	5.08

Figure 16: Output from circuit schematic in step 9 at 100 mVpp rectangular at a bandpass frequency of 100 Hz

Figure 17: Output from circuit schematic in step 9 at 100 mVpp rectangular at the corner frequency of 3.55 kHz

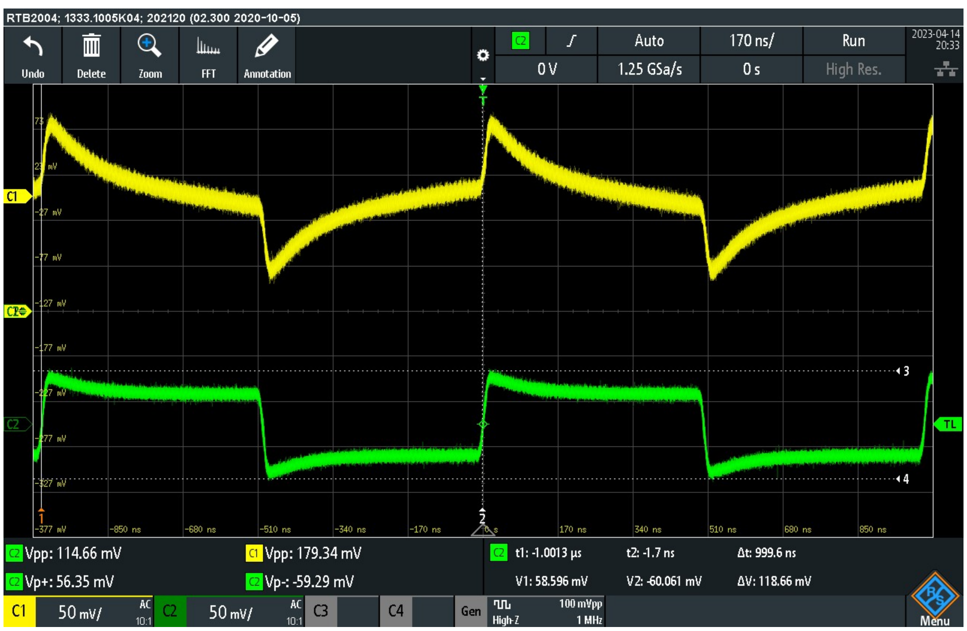

Figure 18: Output from circuit schematic in step 9 at 100 mVpp rectangular at a "too fast" frequency of 1 MHz

Questions:

1. What conclusions can you draw from varied parameter values in Part 1?
   - With a sinusoidal input, when R2 is varied with a 10x smaller resistor, the corner frequency does not change drastically but the overall gain is halved. When a capacitor is added in parallel with R2, it doubles the corner frequency but halves the gain.
2. What effect do you think differences in measured R values from theoretical values have on your findings?
   - The biggest effect in the differences between measured and theoretical values of R was the voltage gain
3. What happens when capacitance is added to the feedback loop (aka in parallel with R2)? To support your answer, find a reference and describe why this may be recommended.
   - In part 2 with the square wave, the output wave with the capacitor in series with R2 experiences decreased overshoot compared to the input wave

- https://northcoastsynthesis.com/news/understanding-stabilization-capacitors/

4. What conclusions can you draw about slew rate? For full credit, give an example of what you think would happen to the shape of a waveform if the slew rate was insufficient.

- Slew rate determines the rate or sample at which a signal can be fed through the op amp. This means that the slower the signal (or the smaller the frequency compared to the slew rate of the component), the more consistent and clean an output signal is. Therefore, if there is an input signal with an insufficient slew rate, the output signals waveform would be noisy and inconsistent compared to the waveforms of lower frequencies. For example, looking at Figures 13-15, the output signal in Figure 13 looks precise, clean and accurate in showing the rectangular function as well as the overshooting that is occurring. In Figure 15, the output signal resembles more of a trapezoid and the overshooting is not shown.