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ELEN3081
Experiment 1
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Linear Dependent Sources

The following VCVS was constructed using the instructions provided by the lab manual. It resulted in an ideal inverting amplifier with a gain of 2. As seen in *Figure 1*, this result is achieved with a voltage range from [-10V, 10V].

Current Controlled Devices

Building a current controlled device, and then altering the current through a given resistor is not difficult through the use of calculations with current dividers. The given circuit could be modified in a number of ways to produce the desired output. *Figure 2* shows this modified circuit, which resulted in a 200mV output.

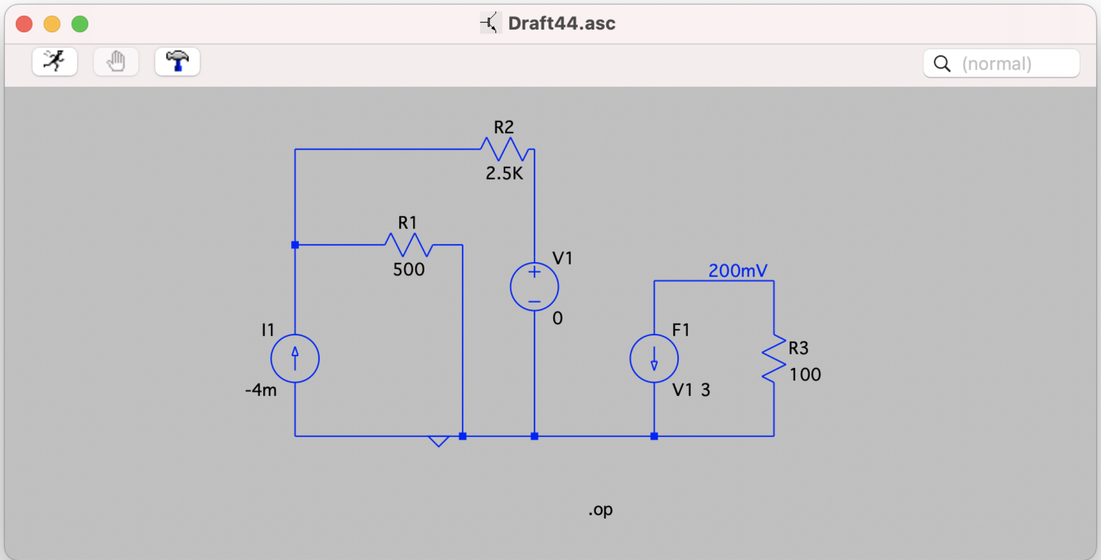

Figure 2: A Modified CCCS Circuit with Updated Outputs

Modeling opamps using LTspice

For an ideal opamp, there should be an output voltage of -2V. Using the VCVS, however, demonstrates some of the physical limitations of non-ideal limitations. Through measuring the output voltage of the VCVS with the following opamp gains, the values in *Figure 3* were observed.

Opamp Gain	Output Voltage
100	-1.9170V
1000	-1.9940V
100000	-1.9990V
Ideal	-2.0000V

Figure 3: Output Voltages seen with given Gains

This demonstrates the direct relationship that the gain of the opamp has on the output voltage of the opamp—it further demonstrates that as the $\lim_{gain \to \infty}$ the opamp becomes ideal.

Saturation in the VCVS Opamp Model

Physical opamps cannot produce infinitely large output voltages—and as a result will saturate at an output voltage. In modeling this with the VCVS opamp previously used, we can see in *Figure 4* that the opamp will output, at most ±5V.

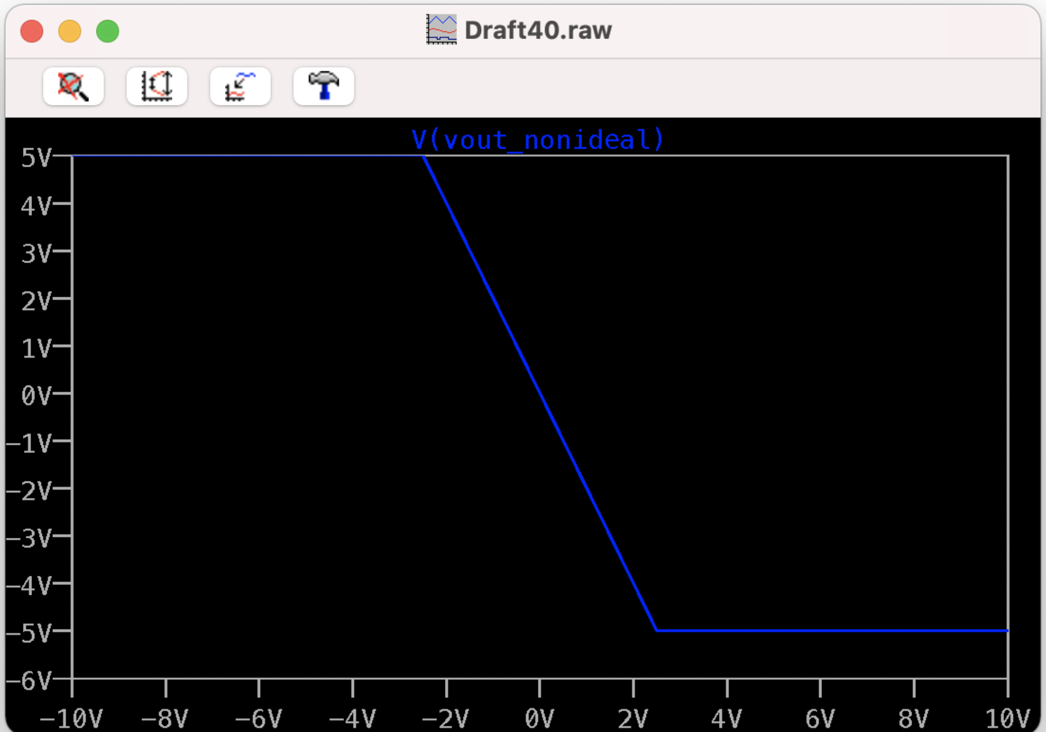

Figure 4: Voltage saturation occurs at ±5V.

Modeling Commercial Opamps

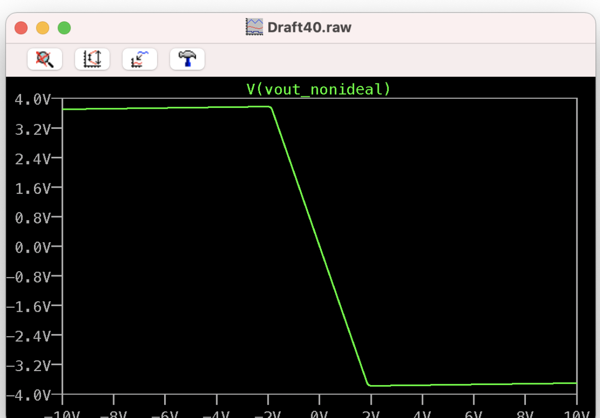

Figure 5: Output Voltage for Texas Instruments LM741

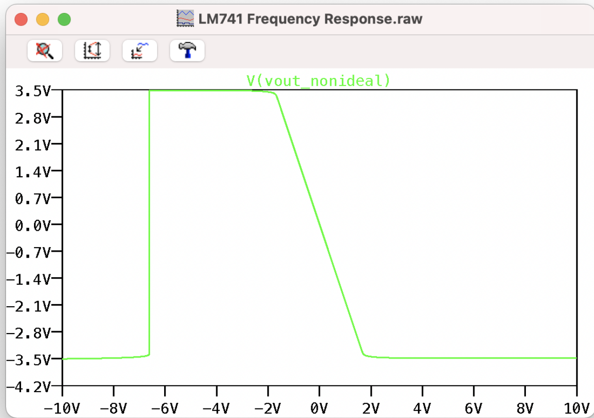

Figure 6: Output Voltage for Texas Instruments LF411

Figure 7: Output Voltage for Texas Instruments LF356

We can see that each opamp, well an opamp nonetheless, has a different output. Both the LF356 and the LF411 have identical gains of -2, while the LM741 has a gain of approximately -1.875. Despite a smaller gain, the LM741 has the widest output range before saturation, having outputs from [-2V, 2V]. The LF356 and LF411 have output ranges before saturation of [-1.5V, 1.5V] and [-1.75V, 1.75V], respectively.

Frequency Limitations of Commercial and Ideal Opamps

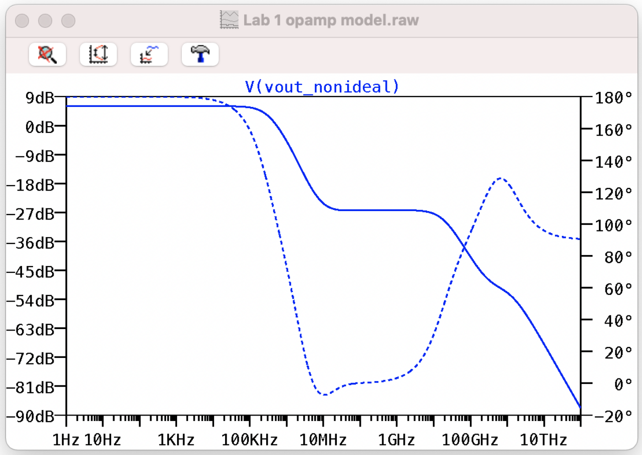

Figure 8: Frequency Response for Texas Instruments LM741

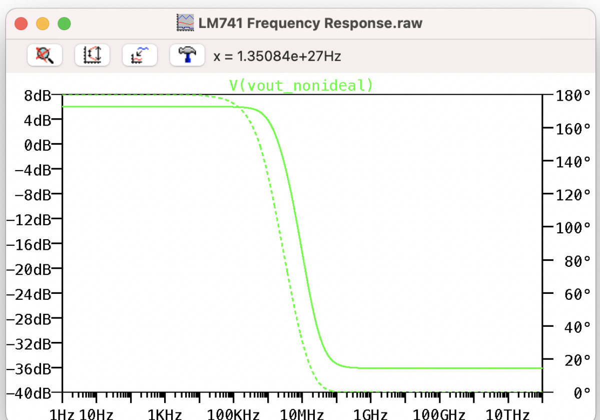

Figure 9: Frequency Response for Texas Instruments LF411

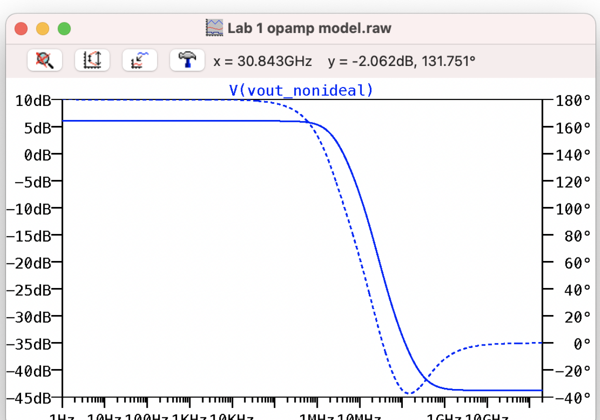

Figure 10: Frequency Response for Texas Instruments LF356

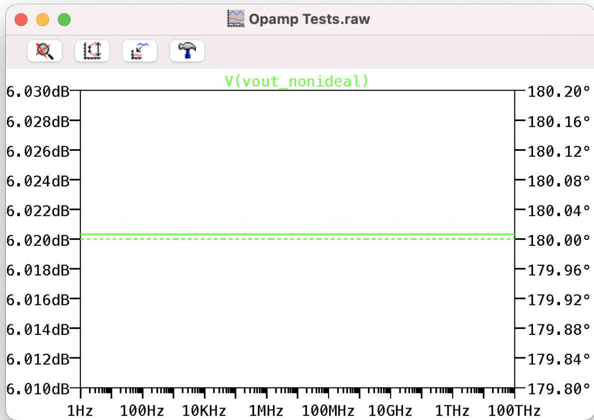

Figure 11: Frequency Response for Ideal Opamp

Each of these opamps, both commercial and ideal, have a frequency response that further demonstrates the implications of the saturation voltage in real opamps. *Figure 12* shows the range of the input frequencies that yield a response. We can observe that the LF411 has the widest frequency response, with a value of 999.9MHz. The LF356 and the LM741 each have a frequency response range of 999MHz and 99.9MHz, respectively. Naturally, the ideal opamp will have an infinite frequency response, as seen in *Figure 11*.

Opamp	Frequency Response
LM741	[100kHz, 100MHz]
LM411	[100kHz, 1GHz]
LF356	[1MHz, 1GHz]
Ideal	$[-\infty, \infty]$

Figure 12: Opamps and their Frequency Response

Creating Subcircuits of Components

By creating subcircuits of components, we can easily place and test these components in a number of different schematics. By recreating the circuit from the **Saturation in the VCVS Opamp Model** section, we can see that the same output is received, allowing for a much cleaner schematic.

Figure 13: Output of Hyperbolic Tangent model of Opamp Saturation

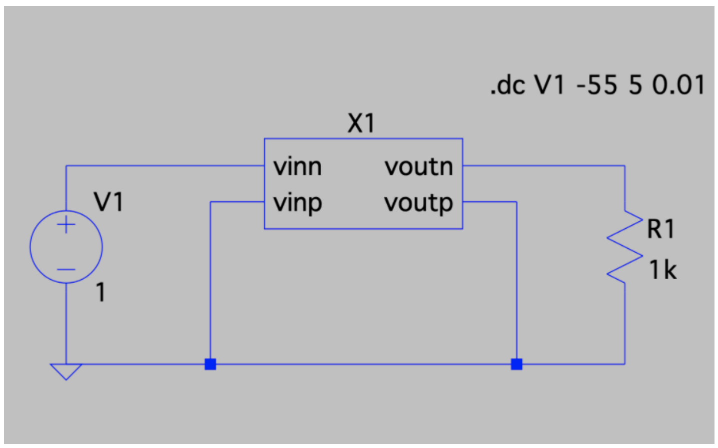

Figure 14: Simplified Schematic Created with the Constructed Opamp Component