Experiment 12

Non-Inverting Amplifier
Experimental Procedure

• Clarification in Step 3 (Modeling)
  – To perform the DC Sweep in the sinusoidal voltage source in the circuit must be replaced with a dc voltage source, $V_{dc}$.

• Typo in Step 4 (Modeling)
  – Gain of the VCVS should be set to 100,000.
  – The gain of the amplifier circuit should be 4, set by the values for $R_1$ and $R_f$. 
Op Amp Equivalent Circuit

\[ v_d = v_2 - v_1 \]

A is the open-loop voltage gain
## Typical Op Amp Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable</th>
<th>Typical Ranges</th>
<th>Ideal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-Loop Voltage Gain</td>
<td>A</td>
<td>$10^5$ to $10^8$</td>
<td>$\infty$</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>Ri</td>
<td>$10^5$ to $10^{13}$ Ω</td>
<td>$\infty$ Ω</td>
</tr>
<tr>
<td>Output Resistance</td>
<td>Ro</td>
<td>10 to 100 Ω</td>
<td>0 Ω</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>Vcc/V⁺</td>
<td>5 to 30 V</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>-Vcc/V⁻</td>
<td>-30V to 0V</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Voltage Transfer Characteristic

\[ \text{slope} = Av_d \]

Positive Saturation Voltage

Negative Saturation Voltage
PSpice Circuit for Non-Inverting Amplifier
Voltage Controlled Voltage Source

• An ideal op amp can be modeled as a voltage controlled voltage source.
  – The difference in voltage between the positive and negative inputs of the op amp \( (v_d = v_2 - v_1) \) is the reference voltage for the VCVS.
  – The output voltage of the VCVS should be the open-loop gain times \( v_d \).
    • Ideally, \( A \) is infinite.
Circuit with Voltage Controlled Voltage Source (Part E): Schematics

Note: Resistor values shown do not produce a gain of 4.
Set Open Loop Gain

• Double click on symbol and set GAIN to at least 100,000
  – Typical open loop gain of an op amp is $10^5$-$10^8$ V/V
Circuit with Voltage Controlled Voltage Source (Part E): Capture

Note: Resistor values shown do not produce a gain of 4.
Open Loop Gain

- Double click on symbol for Part E.
- Set GAIN in Property Editor pop-up window to at least 100,000.
Circuit to be constructed
Cables

• The connections to the Velleman scope are *BNC* (Bayonet Neill-Concelman) connectors.
  – You will need to use 3 BNC cables with either the alligator clips or the IC clips to make your connections between the scope and your circuit.
Input Voltage Source

• Use the sine wave generator on the Velleman scope.
  – Set the amplitude of the sine wave to 5V
    • Note that the amplitude on the Velleman scope is actually peak-to-peak so you should actually make this 3V.
  – Set the frequency of the sine wave to 1000Hz.

  – Connect BNC cable to function generator (bottom BNC connection).
    • Clip red probe to end of R2.
    • Clip black probe (ground) to end of R1 or R3.
Voltage Measurements using Oscilloscope

• Channel 1:
  – Red probe placed between function generator and R2.
  – Black probe connected to same point as the black wire from the function generator.

• Channel 2:
  – Red probe placed between output of the LM 324 and the feedback resistor, Rf, or between output of the LM 324 and R3.
  – Black probe connected to same point as the black wire from the function generator.
Measurements

1. Set trim pot value such that the output voltage of the op amp is equal to 2.0V when the input voltage is +1.0V.
   – Take a screen shot of the input and output voltage as a function of time, displaying at least 3 cycles.
   – Remove Rf from the circuit. Measure and record the resistance between pins 1 and 2.
   – Measure the output voltage at the following input voltages:
     • 0V, +/-1V, +/-2V, +/-3V, +/-4V, and +/-5V.
       – use cursors in scope program
   – Plot the output voltage vs. the input voltage using the X-Y plot function on the oscilloscope.
   – Export the data from the oscilloscope. You may use Excel to plot the DC voltage transfer characteristic.
     • Determine
       – the gain of the inverting amplifier in the linear region of the voltage transfer characteristic using a least squares determination of the slope in the linear region
       – the output voltage at the positive and negative saturation regions.

2. Repeat set of measurements where gain is set to +3 and +4 when the input voltage is +1.0V.
Exporting Data From Oscilloscope
Scaling Required: Time

To determine the time to print on the x-axis:

Look at TIME STEP: for the number of points (125) that are equal to a time increment (1ms).

This means that the time for each point in the column under N should be divided by 125 and then multiplied by 1ms to determine the time at which each voltage data point was taken.
### Scaling Required: Absolute Voltage

To determine the voltage associated with each data point for Channel 1 and Channel 2:

Look at the numbers next to CH1: and CH2: above the GND row. In this case, 1V is equivalent to 32.

This means that the value of the points in the columns CH1 and CH2 should be divided by 32 and then multiplied by 1V to finally obtain the voltage measured by the oscilloscope on Channels 1 and 2 as a function of time.

<table>
<thead>
<tr>
<th></th>
<th>CH1</th>
<th>CH2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-0.09375</td>
<td>-1.0625</td>
</tr>
<tr>
<td>0.000008</td>
<td>-0.125</td>
<td>-1.0625</td>
</tr>
<tr>
<td>0.000016</td>
<td>-0.125</td>
<td>-1.0625</td>
</tr>
<tr>
<td>0.000024</td>
<td>-0.125</td>
<td>-1.0625</td>
</tr>
<tr>
<td>0.000032</td>
<td>-0.15625</td>
<td>-1.09375</td>
</tr>
<tr>
<td>0.00004</td>
<td>-0.15625</td>
<td>-1.125</td>
</tr>
<tr>
<td>0.000048</td>
<td>-0.15625</td>
<td>-1.125</td>
</tr>
<tr>
<td>0.000056</td>
<td>-0.1875</td>
<td>-1.15625</td>
</tr>
<tr>
<td>0.000064</td>
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<td>-1.1875</td>
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<tr>
<td>0.000072</td>
<td>-0.1875</td>
<td>-1.21875</td>
</tr>
<tr>
<td>0.00008</td>
<td>-0.1875</td>
<td>-1.21875</td>
</tr>
<tr>
<td>0.000088</td>
<td>-0.21875</td>
<td>-1.25</td>
</tr>
<tr>
<td>0.000096</td>
<td>-0.21875</td>
<td>-1.25</td>
</tr>
<tr>
<td>0.000104</td>
<td>-0.21875</td>
<td>-1.28125</td>
</tr>
<tr>
<td>0.000112</td>
<td>-0.21875</td>
<td>-1.28125</td>
</tr>
</tbody>
</table>
Measurements

• Measure exact values of V+ and V- powering the LM 324 op amp.
  – Note that there is a statement about maximum and minimum output voltages that can be obtained from the LM 324 in the datasheet.
  • Datasheet can easily be found by entering LM324 and datasheet into Google or other internet search engine.
    – Find it and read the first page.
National Semiconductor

LM124/LM224/LM324/LM2902
Low Power Quad Operational Amplifiers

General Description
The LM124 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM124 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

Unique Characteristics
- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to within 50 mV of the supplies.

Advantages
- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows direct sensing near GND and VOUT also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

Features
- Internally frequency compensated for unity gain
- Large DC voltage gain 100 dB
- Wide bandwidth (unity gain) 1 MHz (temperature compensated)
- Wide power supply range:
  - Single supply 3V to 32V
  - or dual supplies ±1.5V to ±16V
- Very low supply current drain (700 µA)—essentially independent of supply voltage
- Low input biasing current 45 pA

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