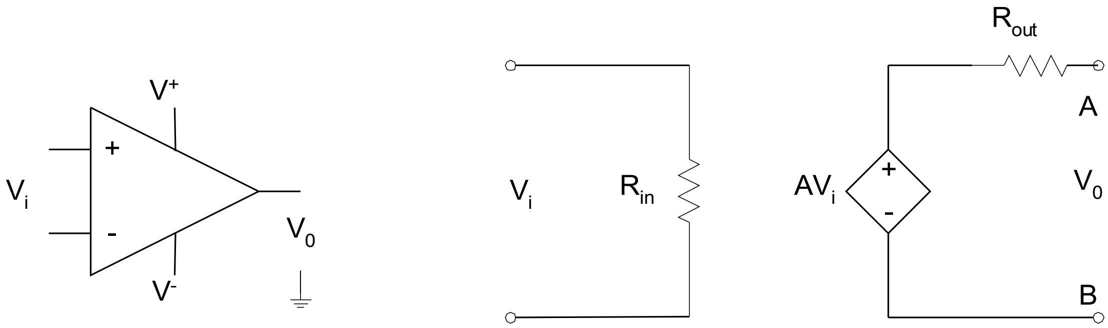
ECE 3254 PreLab 8 notes Op Amps

Edited 10-13-2009

FWIW: The 741 was the first internally compensated Op Amp. Before the 741, Op Amps were very tricky to use because they would oscillate if everything in the circuit design and layout was not perfect - bread boarding Op Amp circuits was very difficult. For more about Op Amp history, development, and use: just google lm741, and you will have more information that you can use.



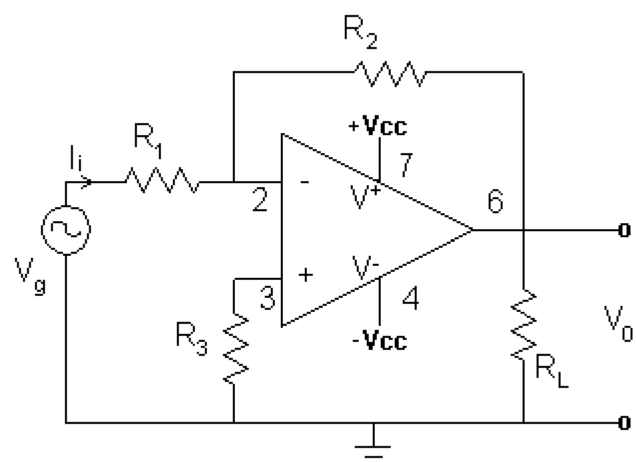
Op Amp Block Diagram and Equivalent Circuit

An ideal op amp has infinite gain ($A = \infty$), infinite input impedance ($R_{in} = \infty$), and zero Ω output impedance ($R_{out} = 0$).

- Infinite gain means that the two input pins must have the same voltage - if there was any voltage difference, infinite gain would peg the output against the power supply rail. A negative feedback amplifier configuration uses the feedback network to set the amplifier circuit gain.
- Infinite input impedance means that the input current to the signal pins is zero because if $R_{in} = \infty$, then $I_{in} = V_{in}/\infty = 0$.
- $R_{out} = 0$ means that the output stage has no internal voltage drop or current limit
- When the Op Amp is not ideal, the two input pins may not have exactly the same voltage, and there may be some current flowing into or out of the input pins. For most of our measurements, this will not be noticeable.
- Non-ideal characteristics may load the circuit, introduce noise, and reduce R_{in} and Gain.

Inverting Amplifier

The Op Amp ideal characteristics mean that $I_{R3} = 0$ and $V_{pin\ 2} = V_{pin\ 3}$.



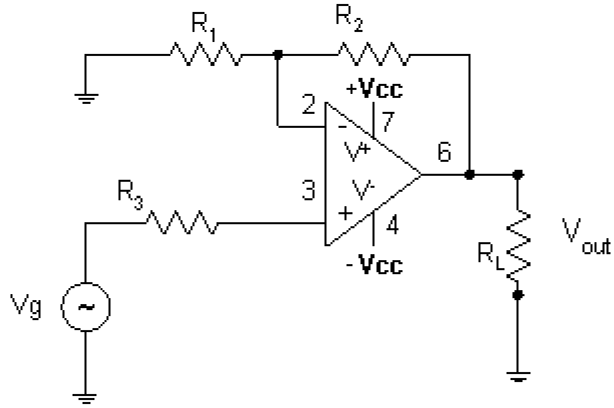
These conditions mean that $V_{pin\ 3} = V_{R2} = 0$, so $V_{pin\ 2} = 0$.

If $V_{pin2} = 0$, $I_i = V_g / R_1$
Then $V_{R1} = V_g$ and
R_i (seen by the source) $= V_g / I_i = R_1$

With the input current into pin 2 = 0, $I_{R2} = I_i$ and $V_{R2} = I_i * R_2$.

Now what is the inverting amplifier output voltage and circuit gain?
Because the Op Amp is an active circuit with feedback, the output current at pin 6 will be whatever is necessary to produce the correct output voltage. Do not attempt to write a loop or node equation that includes pin 6 and R_L. If you look at the voltage across R_2, you see that $V_o = -V_{R2}$ because the pin 2 end of R_2 is at 0V. Inverting Gain = $V_o / V_i = -V_{R2} / V_{R1}$ and a little math will find the equation in terms of component values.

Non-Inverting Amplifier
The Op Amp ideal characteristics mean that $I_{pin\ 3} = 0$ and $V_{pin\ 2} = V_{pin\ 3}$.

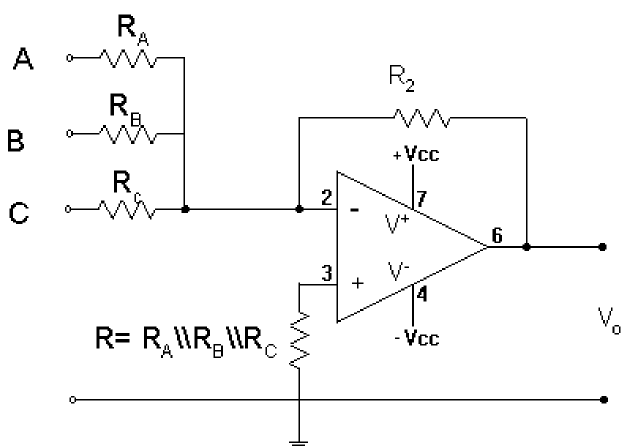


These conditions mean that $V_{pin\ 3} = V_g$ (there is no current through R3, so there is no voltage drop across R3), and $V_{pin\ 2} = V_g$.

If $V_{R1} = V_{pin2} = V_g$, $I_{R1} = V_g / R_1$, and $I_{R2} = I_{R1}$ because $I_{pin\ 2} = 0$.

Now what is that output voltage and circuit gain?
Again, the Op Amp is an active circuit and the output current at pin 6 will be whatever is necessary to produce the correct output voltage. Do not attempt to write a loop or node equation that includes pin 6 and R_L. If you look at the voltage across R_2, you see that $V_{out} = V_{R2} + V_{pin2}$ and the non-inverting gain = $V_{out}/V_g = (V_{R2} + V_{pin2}) / V_g$. From here, it is relatively easy to obtain the gain in terms of component values.

Inverting Summer Amplifier
Several input signals can be combined into an inverting amplifier by connecting each source through a separate resistor to the Op Amp input. The output will be the inverted sum of all inputs.



$V_{pin2} = V_{pin3} = 0$
$I_{Ai} = V_A / R_A$, $I_{Bi} = V_B / R_B$, and $I_{Ci} = V_C / R_C$

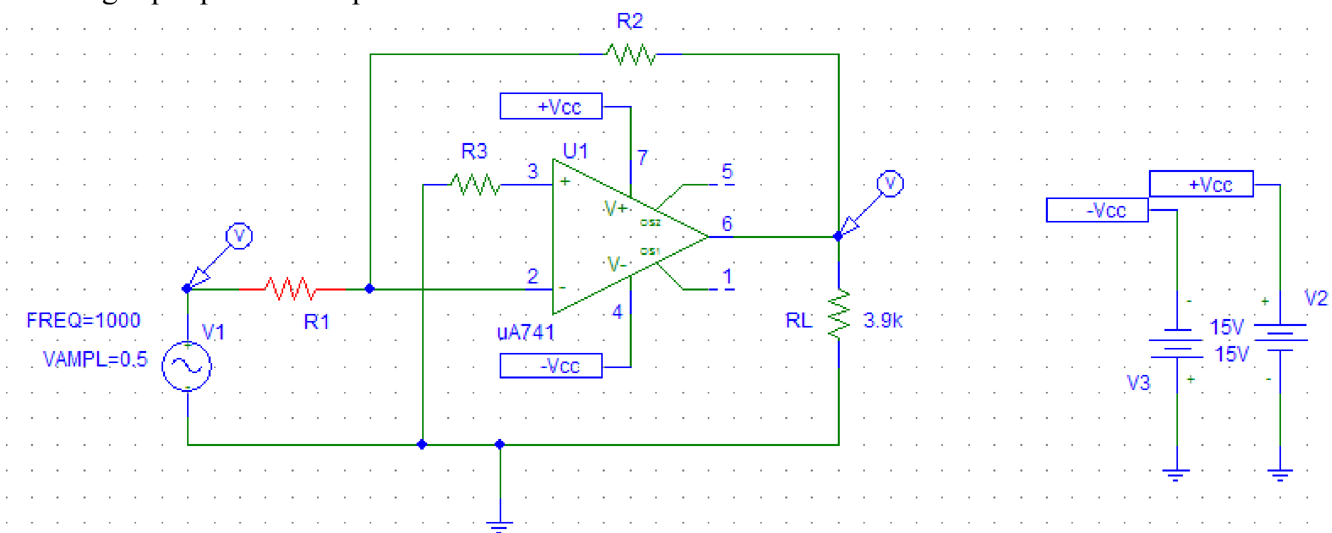
$I_{R2} = I_{Ai} + I_{Bi} + I_{Ci}$
$V_{R2} = (I_{Ai} + I_{Bi} + I_{Ci}) * R_2$.
$= (V_A R_2 / R_A) + (V_B R_2 / R_B) + (V_C R_2 / R_C)$

Note how the gain for each input can be different by using different values for R_A, R_B, and R_C. While the input voltages to a summer may add to a large value, the output of the amplifier circuit can never be greater than the power supply (rail) voltage, and the 741 Op Amp does not have the ability to push the output voltage all of the way to the supply rails. So, while you might expect to see voltages sum to more than 12V, in reality the output will not be able to reach ±12V.

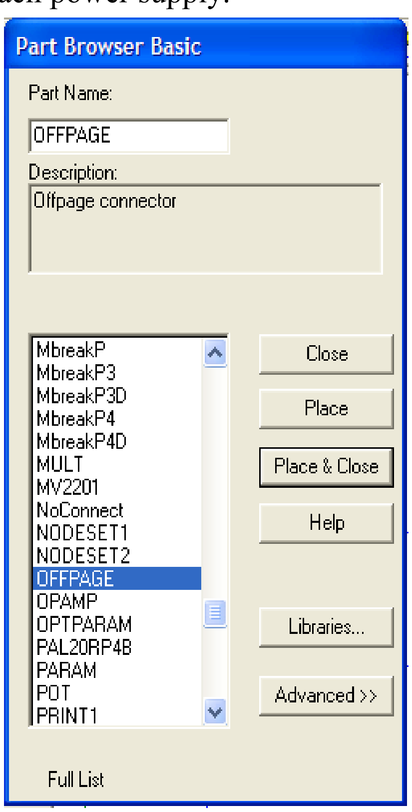
Note: by using different weighting for each input voltage, you can build a D→A converter. The first bit would have a gain of 1, the next bit would have a gain of 2, the next bit would have a gain of 4, etc.

Pspice Simulations for the Inverting Amplifier

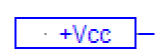
Build the **Inverting amplifier** of Figure 8-5 in the Lab as shown in the schematic capture below.
The 741 OpAmp is part uA741.
Note that the OpAmp input pin locations are reversed in Pspice. Many schematics will place the inverting pin (pin 2) at the top; here Pspice places the inverting input pin at the bottom and the non-inverting input pin at the top.



For the +Vcc (+15V) and Vcc (-15V) supplies, you may wire the supplies (V2 and V3) directly to the OpAmp pins, or place the supplies elsewhere on the schematic and use "offpage" labels to tie the supplies to the OpAmp pins. The offpage label [Draw > Get New Part > Offpage] is very useful when you have more than one device in the circuit that needs power connections. Double click the label to set the name. If you use offpage labels, you will need one on pin 7 (for +15V), on pin 4 (for -15V), and on each power supply.

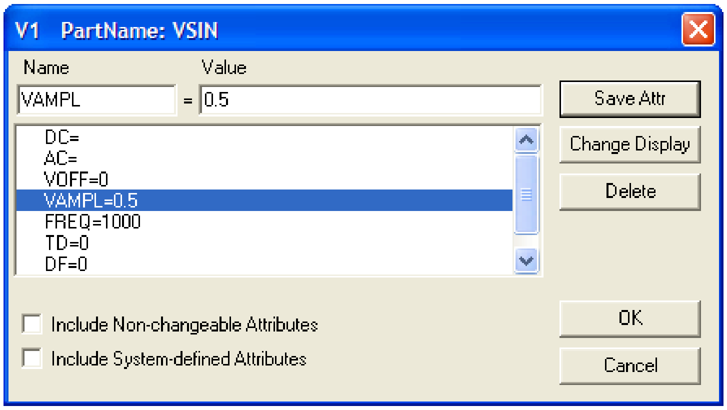


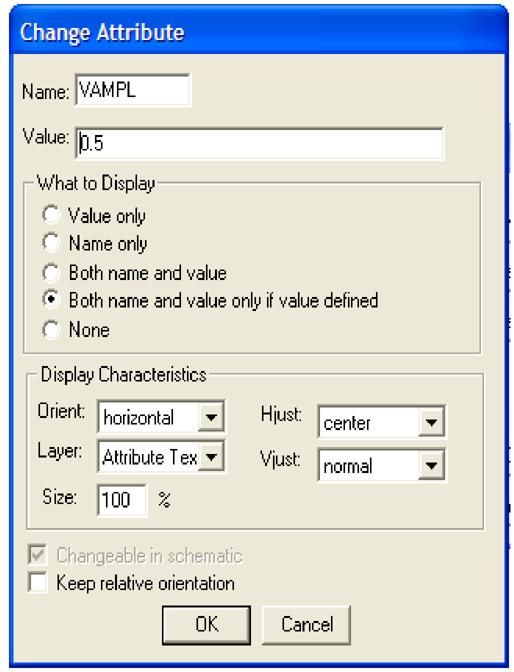
Blank Offpage label.



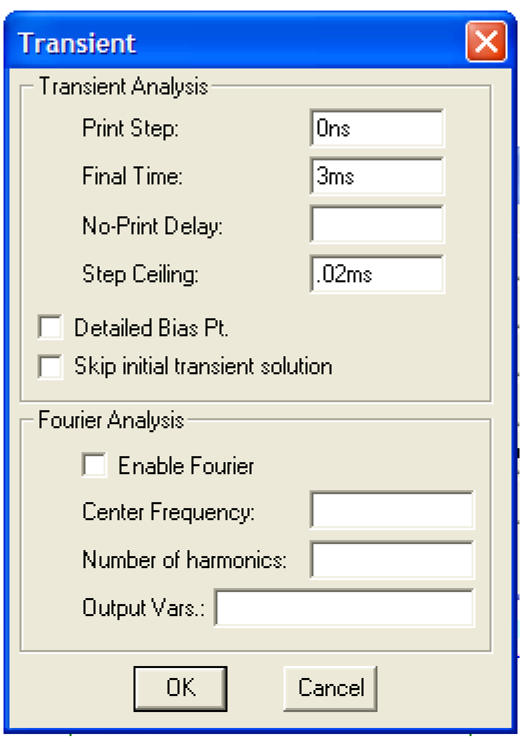
Double click each label
and enter the value

If your source (Vsin) does not show the settings on the schematic and you would like to see them, double click the source > click the parameter you wish to display > click Change Display > Click the box for "Both name and value if....". You should do this for each values you wish to display (e.g. Freq and Amplitude). The amplitude should be set to ½ of Vpp.





Place voltage probes to measure Vin (at source) and Vout (at RL).
Run the transient analysis from 0 to 3 ms, with 0.02ms steps.



Attach the Pspice schematic to your Prelab.
Save the simulation results for attachment to the Lab Data Sheet and comparison with measured results.