EE 2274
RC and Op Amp Circuit
Completed Prior to Coming to Lab

Prelab Part I: RC Circuit

1. Design a high pass filter (Fig. 1) which has a break point f_b = 1 kHz at 3dB below the midband level (the -3dB point). Uses a C= 0.1uF capacitor, and calculate the value for R.
$f_b = 1 / (2\pi RC)$

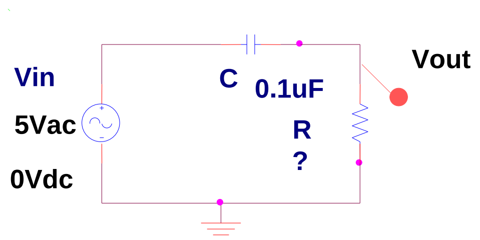


Fig. 1

2. Use LTspice to perform an AC sweep of your designed circuit from 10Hz to 10kHz with 10 points per decade. Place a Voltage source on the schematic from the edit tab - component tab - right click on voltage source - select – advanced – sine. You will need to use 5 Vpeak , 0 DC as your voltage source. Print out the AC sweep and label the frequency of the point on the plot that is 3dB below the midband level (the -3dB point). Run the AC sweep simulation. The graph the gain with a scale is **in dB with the decade selection** command, which is a **20*log** scale, then add the gain trace $\mathbf{V_{OUT}/V_{IN}}$ versus frequency. You do not need to add the scale factor of **20*log(Vout/Vin)**.
What type of filter? ans: _________________

3. Exchange C with R (Fig. 2) and measure the voltage across C and Vin as you did above. Do the LTspice sweep and change the graph to dB as in 2.
What type of filter? ans: _________________
Label and turn in both graphs.,

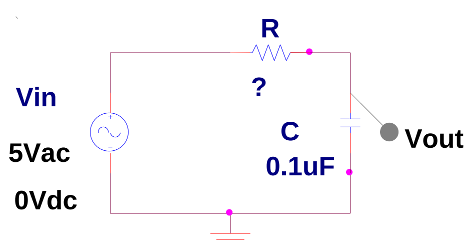


Fig. 2

Prelab Part II: Op-Amp Circuit

Adding a model to LTspice.
Copy the **LM741.sub** model file to the subcircuit directory for LTspice.
Your folder Documents\LTspiceXVII\lib\sub
In the drawing select **Edit** – **spice directive** – enter in text box **.LIB LM741.sub -** place on drawing – OK
Place an OPamp on the drawing select **Edit** – **Component** – [**Opamps**] – **OK** - **opamp2** – **OK** – place on drawing.
Change name **opamp2** to **LM741** on drawing

1. Simulate an inverting amplifier circuit using a LM741 Op amp.
    a. The closed loop voltage gain (Av = Vout/Vin) should be designed to be -7 with error less than 10%.
    Av = R2/R1, Vout is on pin 6 of the OP amp.
    b. Choose resistor values for R1 and R2 between 500Ω-20kΩ from the list of 10% nominal resistor values.
    c. The positive and negative voltage supplies, V+ and V-, should be set to 5Vdc (pin 7) and -5Vdc (Pin 4), for the LM741.
    d. The input voltage source should be a part called Vs. Set the DC offset voltage, VOFF, to 0V; the amplitude of the sinusoidal voltage source, VAPML, to 100mVp, and the frequency of the voltage source, FREQ, to 1k (which is equal to 1000 Hz).
    e. Put two voltage markers into the circuit. One should be Vin and the other Vout should be at the output of the LM741 Op Amp. Graphing both the input signal and the output signal allows comparison of what the circuit did to the input signal.
    f. Run a Transient analysis to confirm the gain of -7. Print out this transient to be turned in.
    g. Place the probe on node voltage to be displayed in the plot window (Vin Vout).
    h. Using the cursors, Right click on waveform label at top of plot window select **Attached Cursor** find the exact AC gain Vout/Vin of the op amp.

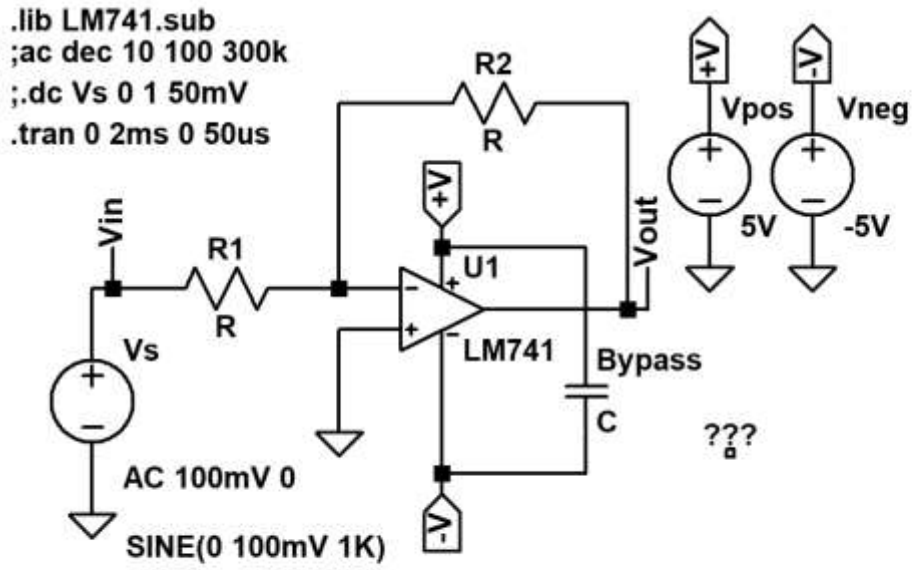
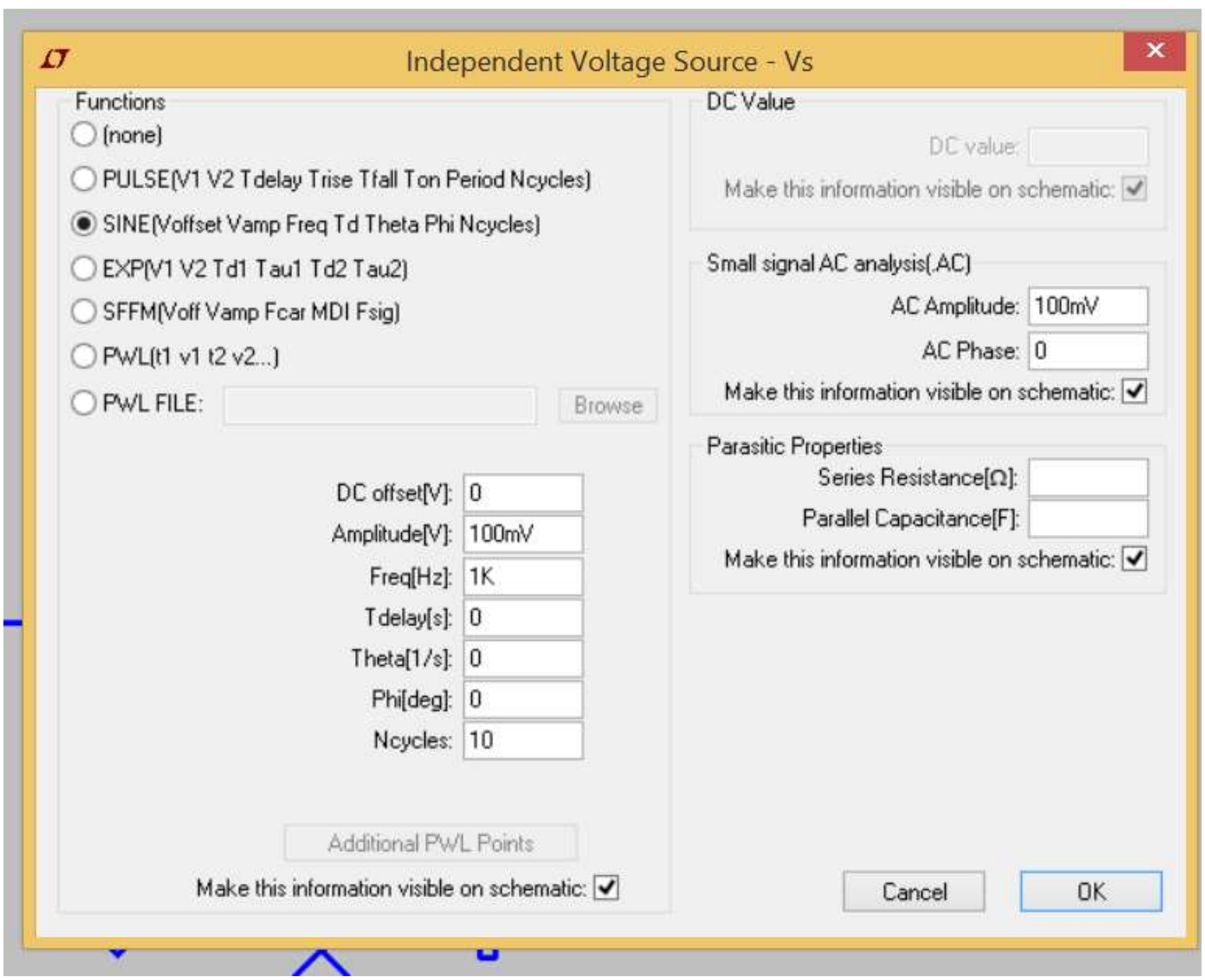


Figure 3: Inverting op-amp.



LTspice Setting For Vs

2. Run the following simulations:
   a. DC Sweep
      i. Create a new simulation profile from **simulate** tab select **edit simulation cmd**
      ii. Select **DC Sweep** tab the select **1st Source**.
      iii. Type the input voltage source label in the box next to the field **Name of 1st Source to Sweep.** Note that this would be Vs in the drawing above, but this will not be the default name of the input voltage source in your LTspice drawing. The start value should be 0V and the end value should be 2V increment of 0.1V Ensure that a **linear sweep** will be performed. Click OK in the Simulation Setup window.
      iv. Run the simulation. Another window should open and a plot of the output voltage versus the input voltage should appear. This graph is commonly known as the voltage transfer function. Use this plot to answer the questions located on the Pre-Lab Answer sheet
      v. Print a copy of the graph open Tools tab – Control Panel - Waveforms – check box **Plot data with thick lines** or for **newer LTspice** change **Data Trace Width to 4.**

   b. AC Sweep
      .
      i. Go to the **edit simulation cmd** window.
      ii. Select 'AC Sweep' from the "Analysis type" pull-down box.
      iii. Ensure that the type of sweep is decade. The graph scale is in dB
      iv. The start frequency should be 1k and the end frequency should be 1000k Vin = 0.2Vpp (amplitude 100mV) Select a reasonable number of points per decade to obtain a smooth curve. (10 points per decade).
      v. Click OK Simulation Setup window.
      vi. Run the AC sweep simulation. The graph scale is **in dB with the decade selection** command which is a **20*log** scale, then add the gain trace **V_{OUT}/V_{IN}** versus frequency. You do not need to add the scale factor of **20*log(Vout/Vin)**. In the plot window right click on equation at the top of the window. Select attach curser 1. Drag the cursor to the pass band on the plot select Plot Settings – Notes & Annotations – Label Curs. Pos. Now to determine the -3dB frequency point drag the curer to the breakpoint which is the point 3dB below the pass band value.
      Print a copy of the graph.

   c. Transient simulation of op-amp

      i. Run a Transient simulation of op-amp Vin = 0.2Vpp (amplitude 100mV) Frequency = 1KHz
      Plot Vin and, Vout on the same plot, between 2 and 5 complete waveforms.
      Print a copy of the graph.
      ii. Adjust the amplitude of the function generator **Vs** until you observe clipping of the waveform.
      Print a copy of the graph.

Answer Sheet: Prelab RC and Op Amp CRN# ________________
Student Name: _________________________________ Date: _________________

Part I: RC Circuit

%error = (Measured-Expected)/Expected

1. What value of R gave a cutoff point 3dB below the midband gain (-3dB point) at 1 kHz?
   R = _______

2. Cutoff point Fig 1

Breakpoint Gain (dB) _________   Frequency _________ Filter Type _____

3. Cutoff point Fig 2

Breakpoint Gain (dB) _________ Frequency _________ Filter Type _____

4. Explain why in Fig. 1 we measured across R, then in Fig. 2 across C, and is a different type of filter?

   (hint: $X_c = -1/2\pi fC$)

Part II: Op-Amp Circuit

1. What is the DC gain of the op amp from LTspice? __________
   At what input voltage V_{IN} does the output voltage V_{OUT} reach an absolute maximum?

   V_{IN} = __________ V_{OUT} = __________

   Why does the output voltage hit an absolute maximum at this value?

2. What is the AC gain of the op amp from LTspice? __________
   Vin = 0.2Vpp Frequency = 1KHz
3. At what frequency does the output voltage V_{OUT} reach high frequency cutoff the 3dB below the midband level?   Frequency =________________ save plot.
4. At what high frequency does V_{OUT} equal the input voltage V_{IN}?
   Frequency = __________
4. Run a Transient simulation of op-amp Vin = 0.2Vpp Frequency = 1KHz save plot Vin, and Vout
5. Adjust the amplitude of the function generator **Vs** until you observe clipping of the wave form. Save plot Vin, and Vout.

Required Attachments:

1. AC Sweep of first circuit
2. AC Sweep of second circuit
3. DC Sweep of op-amp circuit
4. AC Sweep of op-amp circuit frequency response.
5. Transient simulation of op-amp
6. Transient simulation of op-amp clipping

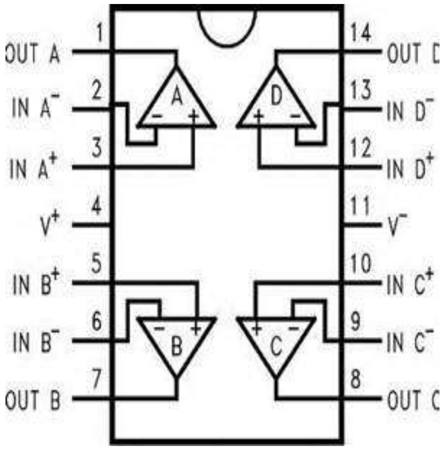
Experiment Lab procedure:
RC and Op Amp Circuit
Power off the PC (shutdown) and cycle the power switch on the back (by the power cord) of the 3 multimeters before you start the lab. Use a 0.1uF, 0.047uF, 0.001uf or 0.0047uF for the bypass capacitor on the OpAmp.

Part I: Passive RC filter

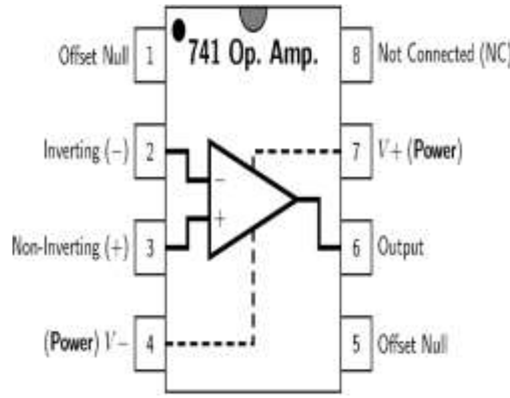
1. Build the high pass filter designed (Fig. 1) in the Pre-Lab
2. Open the **BasicACsweep** project, and modify the exponential sweep range to 10Hz to 10,000Hz. The output sine waveform amplitude is set to 5Vp. Use 10 frequency steps per decade, (3 decades) x (10 steps) + 1 = 31 frequency steps. Check that the function generator output impedance is set to High Z by setting the output impedance in the function generator is set to "0". **Note: the cursors will not work with the XY graph type**.
3. **Two multimeters** are used one connected to the **input voltage multimeter (DM3068LL**). The other connected to the **output multimeter (DM3068LR)** both set to AC volts.
    a. Save the plot snapshot (must use snapshot for multiple plots) of Gain dB verse frequency (plot with log-x and dB-y axis) and paste it to the project document. Select the plot in project document right click on the plot select visible items, select cursors. Use the scales (you may need to zoom in) to identify the two 3dB below the midband points. How close is the frequency from the design value? What could cause this error?
    b. Export the project document to your flash to be printed include both student's names. Mark on the printed graphs by hand the cutoff points.
    c. Measure the exact value of the capacitor using the capacitance meter and measure the exact value of your resistance.
    d. Recalculate the -3dB cutoff point (3dB below MidBand) using the measured capacitance and resistance value.
4. Build the low pass filter designed (Fig. 2) in the Pre-Lab.
    a. Run an **AC sweep** from 10Hz to 10,000Hz. The waveform amplitude is set to 5Vp. Set the total number of steps to 31 such that there are 10 steps per decade. **DM3063LL** in connected to **input signal**. The **DM3068LR** is connected to the **output signal**.
    b. Print out the plot with log-x and dB-y axis.
    c. Again, mark on the graphs the point 3dB below midband level (-3dB point).

Part II: OP amp

1. DC Sweep:
    a. Build the inverting amplifier that you designed in the pre-lab. Supply power (**DP831LR power supply** Channel 2, 3) to **LM741** -5Vdc **Pin 4** and +5Vdc **Pin 7** include a **bypass capacitor** on the two supplies**,** place it **between -V Pin 4** and **+V Pin 7.** Select the (**BasicDCsweep**) from the signal express software. **Use the other supply (DP831LL power supply _ channel 2) to supply the input signal to the OPamp. Rember the DP831LR Power supply will supply the power to the op amp**. Sweep parameters for the power supply **DP831LL Vin**: Initial 0V, end voltage 1V, set the total number of steps such that the per step voltage is 50mv. (Number of steps = V_per sweep / V_per step). Configure the multimeter **DM3068LL Vout** for DC volts. Save your waveform to the project document to be printed out and turn in with your lab data.
2. AC Sweep:
    a. Run an AC Sweep from 100Hz to 300,000Hz with the waveform amplitude of 200mVpp set the total number of steps such that there are 10 steps per decade. **DM3063LL** in connected to **input signal**. The **DM3068LR** is connected to the **output signal**.
    b. Print the plot with a log-x and dB-y axis.
    c. What frequency is the point 3dB below the midband level? How does this compare to LTspice?
3. Transient:
    a. Using the function generator **Vin**, select a sinusoid with an amplitude of 100mVp (200mV peak to peak) and a frequency of 1 kHz.
    b. Using the oscilloscope, measure the maximum output voltage in the positive and negative halves of is cycle. Use 10X probes.
    c. Adjust the amplitude of the function generator **Vin** until you observe clipping of the waveform.
    d. Capture this waveform on the scope (**BasicScopeCapture**), turn in with your lab to show clipping
    e. At what output voltage does this clipping occur? Why?
    f. How does this compare to LTspice?



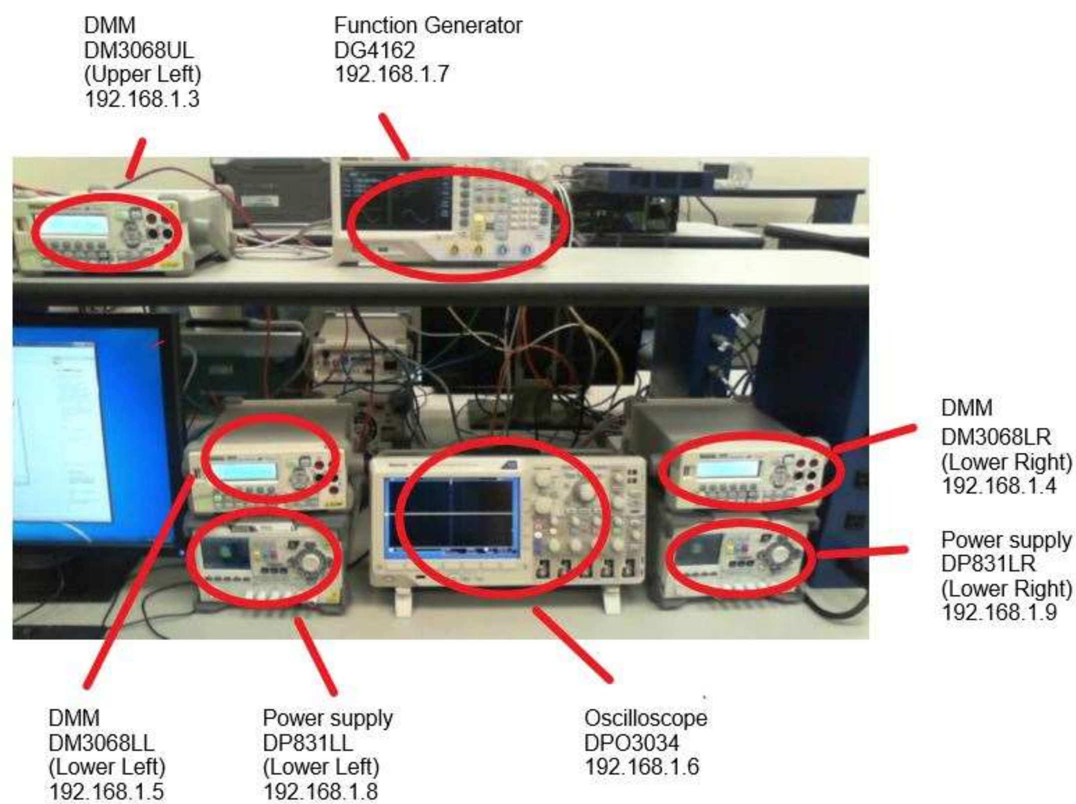
LM324 Top View



LM741 Top View

Equipment location

Friday, July 26, 2013 13:58



Bench layout and equipment names and IP address for National Instrument Signal Express

RC and Op Amp Circuit Experiment Data Sheet CRN# _______________
Students: #1_______________________ #2 ___________________________
Bench #__________ Date: _______________

Part I:

2. a. Frequency of the cutoff point 3dB below the midband level of high pass filter Fig1.
Frequency = ____________

b. % error from LTspice ____________ %error = (measured- LTspice)/LTspice

c. What could have caused the error?

d. Frequency of cutoff point calculated from measured values. __________

4. a. Frequency of the point 3dB below the midband level of low pass filter Fig2.
Frequency = ____________

b. % error from LTspice _____________

c. What could have caused error?

Part II: add Bypass capacitor.

2. c. 3dB cutoff point of op-amp Measured: ________ LTspice: ________

% error from LTspice ____________

3. b. Maximum output voltages Measured: _________ LTspice:____________

3. e. When does clipping occur? V_{in} = ____________ V_{out} = ____________

Why?

3. f. How does this compare with LTspice?

Required Attachments:

1. AC Sweep of low pass
2. AC Sweep of high pass
3. DC Sweep of op-amp
4. AC Sweep of op-amp
5. Scope capture of op-amp
6. Scope capture of op-amp clipping