ELC 3414: Electronic Design

Lab 1: Introduction to Operational Amplifiers

Objective

In this laboratory exercise, you will investigate an operational amplifier (or "op-amp"). You will become familiar with common op-amp circuits and see the response of an op-amp to certain inputs.

Procedure

Note: Use separate components (e.g. 2 op-amps) for circuits #1 and 2 because they will be combined to get circuit #3.

1. Using a LM741 integrated circuit op-amp and discrete resistors, design a non-inverting voltage amplifier having a nominal voltage gain A_v = 10. Use power supply voltages of +/- 15 V. (You should be able to find a data sheet for the 741 on the web.)

    a. Provide a **complete schematic diagram** for your circuit. Show all signal and power connections and identify IC pin numbers on your schematic. Identify unused pins and show if they are to be left open (floating) or connected to a reference point (i.e. ground).

    b. Measure the **actual resistor values** used in the implementation of your design to determine if they are within specification (+/- 10%).

    c. Calculate the true **expected gain** for your amplifier based upon actual verses standard resistance values.

    d. Breadboard your design. Apply a 1.0 V_{pp} sine wave @ 1.0 kHz to the input of the amplifier and measure the **gain as implemented**. Discuss possible reasons for **any differences** in expected and measured gain that exceed measurement error.

    e. Capture an **oscilloscope display** of the input and output signals to verify the amplitude and phase response of your amplifier. See 2.

2. To capture an oscilloscope display, do the following:
    a. Click the Windows button →All Programs →Agilent →Agilent_Scope_MSOffice.
    b. This will open a Word document with a lot of text that you do not need. To clean up the document, select all of the text (using CTRL+A) and delete it.

Note: Do <u>NOT</u> use this (Agilent scope) document for your report, as it is formatted very differently.

   c. If there is a Security Warning bar at the top, click Options…, select Enable Content, and click Ok.
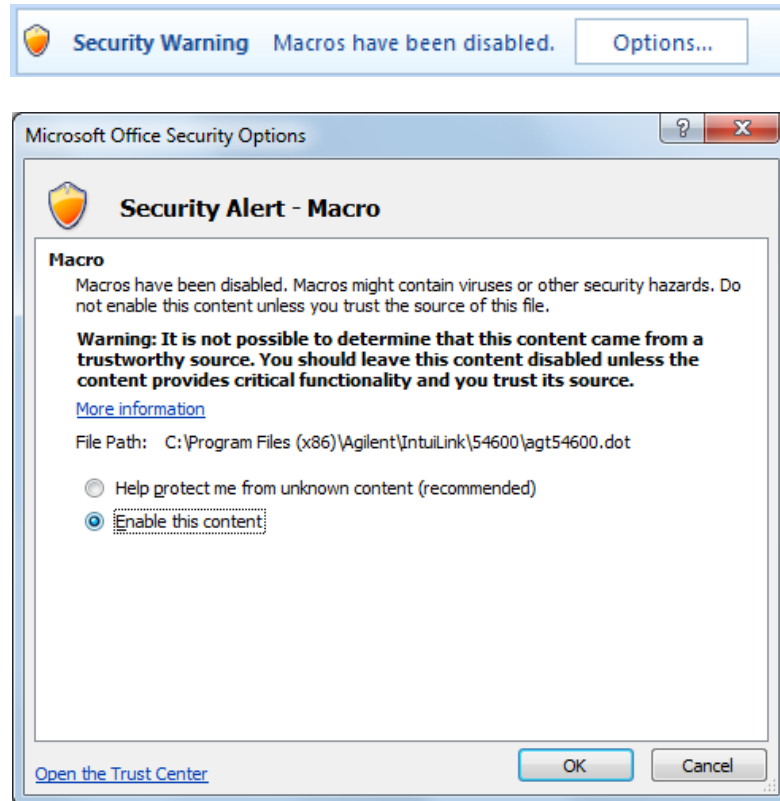
   d. Click on the Add-Ins tab in the Word menu bar to find the Agilent Custom Toolbar:
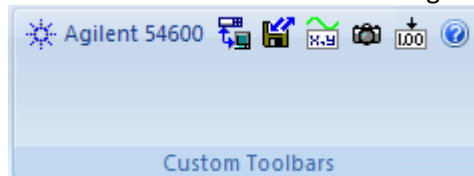
   e. Connect to the oscilloscope by pressing the Connect to Scope button ( ) on the toolbar. Then click Search on the popup window. When the search is completed the Model Number of your scope should appear in the search box. Click OK.

   f. To capture the scope screen, press the Get Screen Image button ( ) on the toolbar, select Place in document at cursor, and click OK.
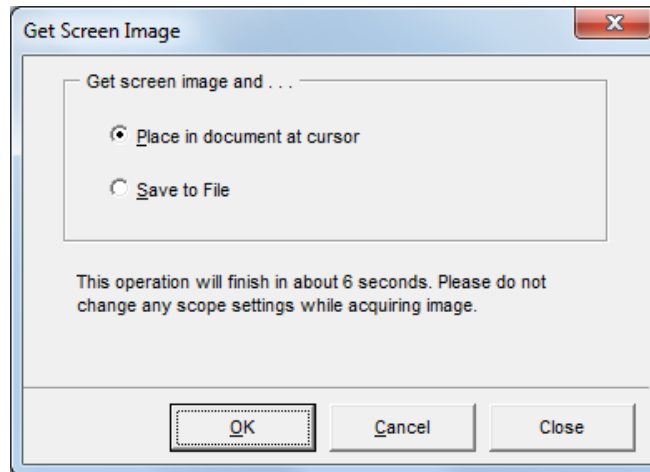
g. Select this image and copy/paste it into your report (a <u>separate</u> Word document).

3. Design an inverting amplifier with voltage gain $A_v = -2$. Use a 10 K-ohm linear potentiometer as the input resistor. Select the feedback resistor such that the pot setting will be near 90% of its full range value.

   a. Produce a **schematic diagram** for your circuit. Again, show all connections. (Leave the circuit of step 1 connected and use a second IC to breadboard your inverting amp.)

   b. Apply a 1.0 V_{pp} sine wave @ 1 KHz to the input of the amplifier. Adjust the gain of the amp to -2, within the tolerance available using the scope peak-voltage function. <u>Remove the potentiometer from the circuit</u>, and use the multimeter measure its **actual resistance** to confirm that it is around 9 K.

   c. Capture an **oscilloscope screen shot** for your report. Label input and output waveforms.

4. Cascade circuit #2 to follow circuit #1. Confirm that the overall voltage gain is the product of the measured gains of the independent amplifier circuits.

   a. By adjusting the potentiometer, you should be able to vary the gain from -20 to a very large value (for our purposes, $-\infty$). Of course, your amplifier will saturate (rail) near its power supply voltages to create an approximation of a square wave. Verify this performance for your amplifier and capture **screen shots** showing an undistorted sine wave and a fully "clipped" square wave (i.e. 2 different screen shots).

   b. Using the Fast Fourier Transform (FFT) feature of the scope, view the spectrum of the clipped signal.
      o Turn off channels 1 and 2 to minimize screen clutter
      o Turn on the "math" features (button between 1 and 2)
      o Select the FFT feature and adjust the sampling rate (with the horizontal axis control) so that the sampling rate is 20 kSa/s.
      o Press "settings" and verify the center frequency is 5 kHz and the span is 10 kHz. (At this point stop and make sure that you understand what you are seeing.)

- Press "more FFT" and adjust the vertical offset so that the relative amplitudes of the fundamental, 3rd, 5th, 7th, and 9th harmonics can be measured. The vertical axis is in dB. You can use the "Cursors" button to measure the relative amplitudes of the different frequencies.
- **Compare** the relative harmonic amplitudes to those expected for a pure square wave.

c.   Capture a **screen shot** of the FFT for your report.

Deliverables

- Submit an *informal report* containing all of the items described in the procedure (highlighted in **bold**), including measured and calculated values (actual resistor values, actual gain, etc).
- Upload your report to Blackboard by the <u>beginning</u> of the next lab session (i.e. you have 1 week).
- Name your report: "ELC3414_Lab_1"

Note: See the Lab Reports handout for correct format.