Virtual Instrumentation—Lab 10

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See https://mviordache.name/EEGR2051 for more information.

Name________________________ Date___________ Section_____

EEGR 2051 – Frequency Domain Measurements. Virtual Instrumentation.

Materials

- One NI Elvis or one NI SC2075.
- One 100 Ω resistor (or closest available value), one 27 mH inductor, and one 1 µF capacitor.

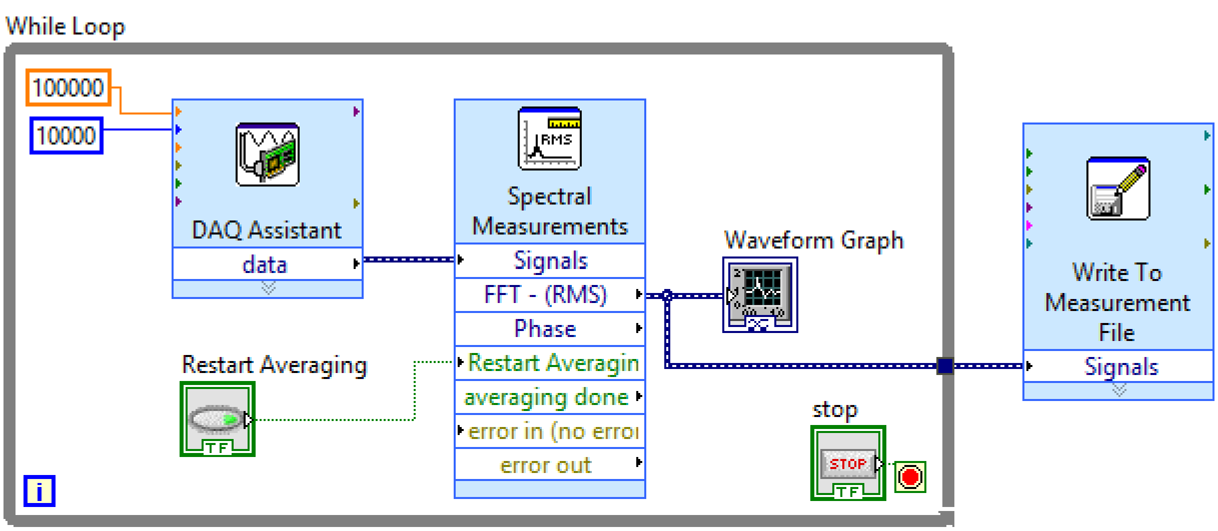
Procedure

1. Measure the resistor and use the measured value in all calculations. R = ___________
2. Verify with an ohmmeter the inductor; when connected correctly, its resistance should be less than 50 Ω.
3. Recall that any periodic signal $y(t)$ of frequency f can be decomposed into a weighted sum of sine waves of frequency $n \cdot f$, where $n = 1, 2, 3, ...$

$$y(t) = c_0 + c_1 \sin(\omega t + \phi_1) + c_2 \sin(2\omega t + \phi_2) + c_3 \sin(3\omega t + \phi_3) + \cdots$$

   Note that $\omega = 2\pi f$.

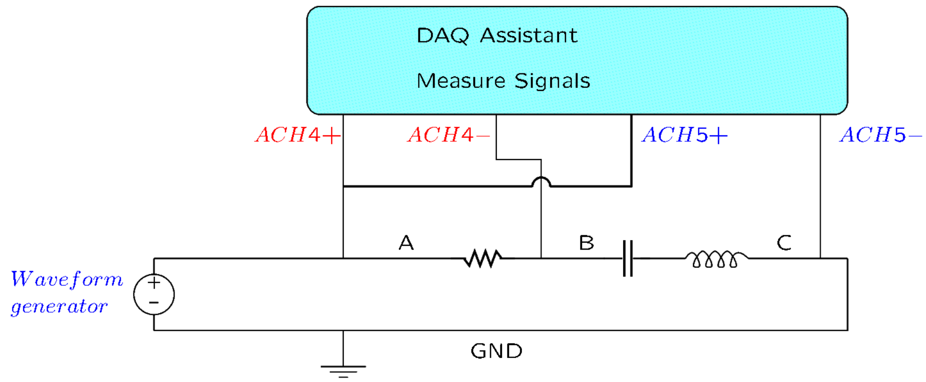
4. A spectrum analyzer is an instrument that can measure the coefficients c_0, c_1, c_2, ... A spectrum analyzer VI could be created as shown in the following block diagram.



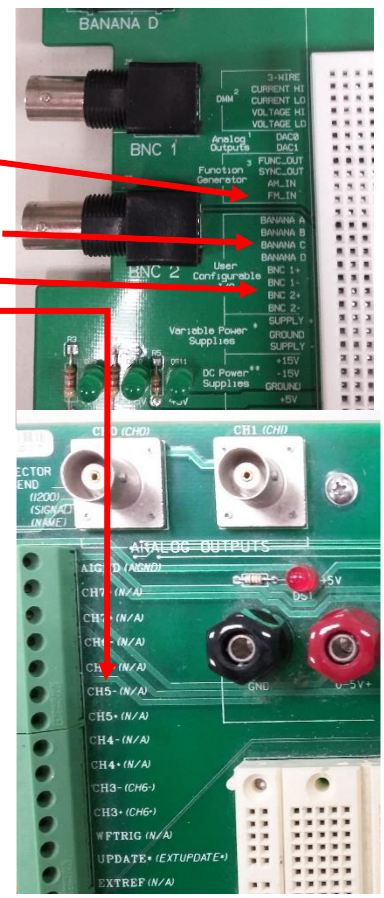
   a. For the *DAQ assistant* select **analog input, voltage, Dev1, ai5**.
      i. Note that the analog input 5 (ai5) selects the differential channel 5, which is connected at the terminals ACH5+ and ACH5-.
   b. In the *spectral measurements* block select *averaging* and 20 averages.
   c. In the *write to measurement file* block select *one column per channel* and *no headers*. The data should be written to a *text file*.
   d. In the Waveform Graph, replace the "Time" label of the horizontal axis with "Frequency".
   e. The 100,000 constant at the input of the DAQ sets the sampling rate to $f_s = 100\ kHz$, overriding any rate setting that may have been entered when creating the DAQ block.
   f. The 10,000 constant at the input of the DAQ specifies the number of samples N. Note that the resolution of the FFT plot will be $\frac{f_s}{N} = 10\ Hz$.

5. Ensure that the NI Elvis or NI SC2075 is turned off.

6. Connect the circuit shown in the figure.
    a. **Connect the GND of the waveform** generator to the GND of NI Elvis or NI 2075.
    b. Make sure that point C is also connected to GND.
    c. In this exercise, the DAQ Assistant will be used first with channel 5, and then with both channels 4 and 5.



    d. The components can be connected to the breadboard with alligator clips. Alternatively, if using the NI Elvis, the components could be connected to the banana A, B, and C jacks and the waveform generator to the BNC1 terminal.
        i. The banana A, B, C jacks are connected to the BANANA A, B, C pins of the prototyping board.
        ii. BNC1+ and BNC1- are also connected to the prototyping board.
        iii. BNC1- is floating; connect it to GROUND.
    e. Note the position of ACH5+ and ACH5- on NI 2075.
        i. To attach wires to the ACH5 pins, insert the wire into the terminal hole while pressing gently the corresponding yellow lever.



7. Use the following settings for the waveform generator:
    a. 100 Hz **square** wave.
    b. An output load equal to the DC resistance of the series RLC network (the sum of the DC resistances of the resistor, inductor and capacitor).
    c. The waveform should have 5V peak-to-peak.
8. Verify with the oscilloscope that the waveform has 5V peak-to-peak.

9. Make sure that NI Elvis or NI 2075 is turned on.
10. Turn on the waveform generator.
11. Run the VI.
    a. The VI will display the frequency spectrum of the waveform generator.
    b. Do not stop the VI before the image stabilizes.
    c. If data is wrong, press the red button to terminate the VI without saving the data.
    d. If data is right, press the *stop* button to terminate the VI and save the data.
12. The VI displays a curve showing the value of $\frac{c_1}{\sqrt{2}}, \frac{c_2}{\sqrt{2}}, \frac{c_3}{\sqrt{2}}, \Lambda$ (the RMS values) in decibels at the frequencies 100 Hz, 200 Hz, 300 Hz, ….
13. With a logarithmic scale the first peaks of the spectrum are clearly seen.
    a. While the VI is not running, right click on the x axis of the waveform graph.
    b. Select Mapping/Logarithmic.
14. Verify your plot with the oscilloscope.
    a. Without disconnecting the waveform generator from the circuit, connect it also to the oscilloscope (you could use a T-adapter).
    b. Press the *Math* button of the oscilloscope and select FFT.
    c. Note that the oscilloscope has a linear (not logarithmic) horizontal scale.
    d. Adjust the *Center* frequency to 500 Hz and *Span* to 1 kHz.

e. Change time per division until the resolution of the plot is good enough. *When resolution is good, the peaks of the frequency spectrum are narrow.*

15. Open Excel.
16. From Excel, open the data file produced by the *write to measurement file* block.
    a. The first column of the file (though perhaps mislabeled “Time”) lists the frequencies for which the FFT was calculated. The unit is Hz.
    b. The second column lists the dB values for each frequency.
17. Using the second column of the data file, fill in the second column of the following table.

Frequency [Hz]	Value [dB]	Coefficient [V]	Ideal Coefficient [V]
100			
200			
300			
400			
500			

18. Let v denote the value in decibels on column 2. Calculate the coefficients of the third column according to the formula $c = \sqrt{2} \cdot 10^{\frac{v}{20}}$. Do all calculations in Excel.
19. Let V_{pp} denote the measured value of the peak-to-peak value of the square wave generated by the waveform generator. $V_{pp} =$ ___________.
20. Let n be the harmonic number (that is, the ratio of the harmonic frequency and the fundamental frequency).
21. For an ideal square wave, the coefficients of the Fourier series decomposition are
    a. $c_n = \frac{2V_{pp}}{n\pi}$ if n is odd
    b. $c_n = 0$ if n is even.
22. Use the formulas above to fill in the last column of the table.
23. If the measured coefficients do not match the calculated values, check your work.
24. Add channel 4 to the *DAQ assistant* without removing channel 5. In this way, the resistor voltage and the source voltage will be measured at the same time.
25. Run again the VI. Wait until the image stabilizes.
26. Make the *Waveform Graph* display the graph up to 1000 Hz.
27. You should see two curves: one in white (the source on channel 5), and one in red (the resistor voltage on channel 4).
28. Two voltages are proportional if their frequency spectra have exactly the same shape and differ only in their vertical position. If a circuit distorts its input voltage, the input and output frequency spectra will have different shapes.
29. Looking to the frequency spectra displayed by the VI, are the two voltages proportional or not? How can you tell it?

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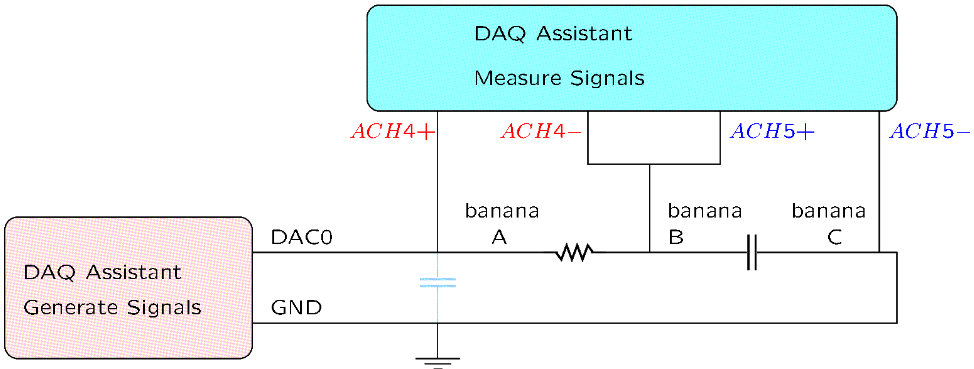
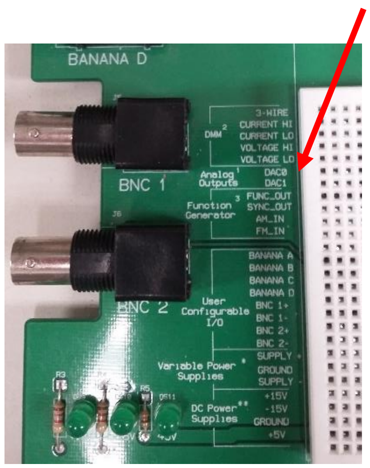
30. Turn off NI Elvis or NI SC2075.
31. Turn off the waveform generator.
32. Disconnect the waveform generator from the circuit.
33. Connect the series RC circuit shown in the figure.

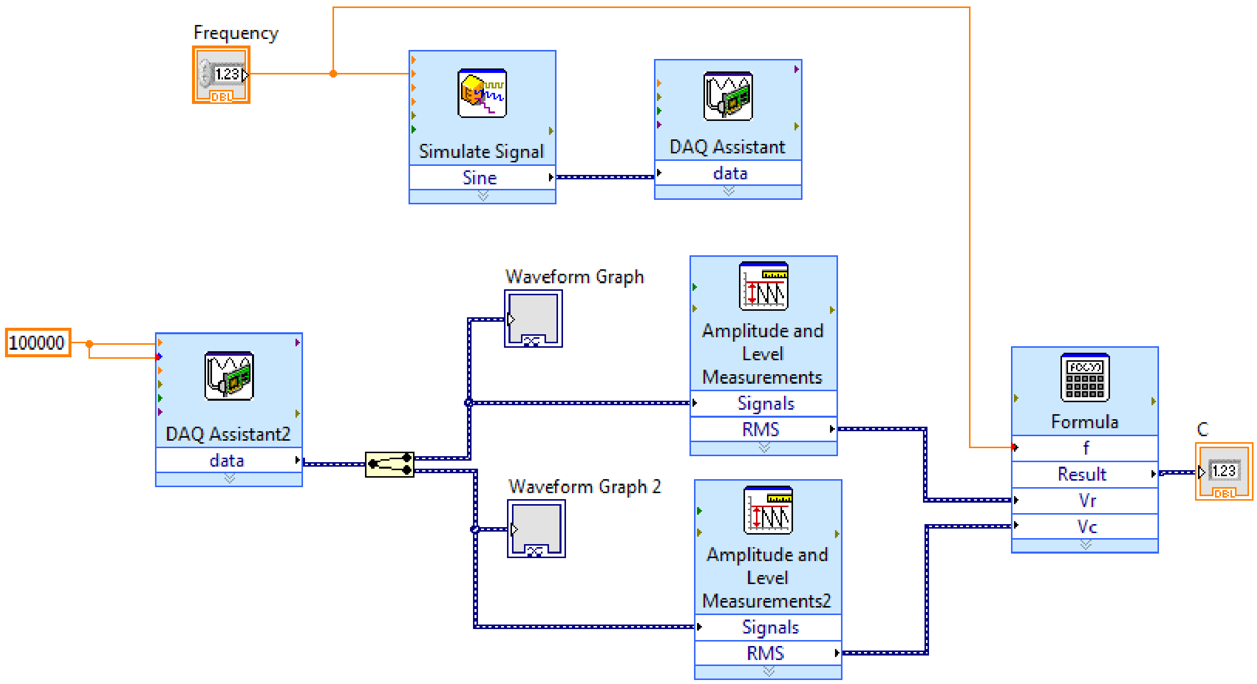
a. Instead of the waveform generator, the circuit uses the output channel 0 of the DAQ board to generate a signal.
b. Make sure you connect point C to GND.



c. Note the DAC0 position on NI Elvis. On NI SC 2075, DAC0 is called CH0.



34. Create a VI capable of measuring the capacitor as shown in the following figure.
35. The *split signals* function is found in *Express/Signal Manipulation*.
    a. Increase the vertical dimension of the *split signals* block to obtain two outputs.
36. In the *simulate signal* block:
    a. Select a rate of 100,000 samples per second and 100,000 samples.
    b. Right click on the frequency input to create a numerical control.
37. The first DAQ assistant should output the samples of the *simulate signal* block to the analog channel 0.
    a. Select ***generate signals***, ***analog output***, ***voltage***, ***Dev1, ao0,*** 100,000 samples and a rate of 100,000 samples per second.
38. The second DAQ assistant should read the input channels 4 and 5.
    a. Select ***analog input***, ***voltage***, ***Dev1, ai4,*** and then, in the next dialog window, press the *add channel* button to add the channel *ai5*.
39. Select RMS in the *amplitude and measurement* blocks.
40. Before connecting the *formula* block, the formula must be written.
    a. Note that the virtual instrument applies a sinusoidal voltage to the series RC circuit and then it measures the RMS voltage of the resistor (V_r) and the RMS voltage of the capacitor (V_c).
    b. Since the RMS current I satisfies both $I = V_r/R$ and $I = 2\pi f C V_c$, it is possible to calculate the capacitance C with the formula $C = V_r/(2\pi f R V_c)$.
    c. Enter the formula above in the formula block. Use the measured value of R and substitute X1 with f, X2 with V_r, and X3 with V_c.
    d. Right click on the *result* output to create a numerical indicator.
41. **Set the frequency numerical control to 200 Hz.**
42. Make sure the numerical indicator is wide enough to display the entire result.



43. Turn on NI Elvis and the prototyping board.
44. Run the VI. The waveform graphs should show voltages in the order of hundreds of millivolts or volts. If this is not the case, check your connections.
45. Run continuously the VI. It should show the capacitance in farads. The measured value of the capacitor is _____________.
46. Calculate the relative error of the measurement with respect to the nominal value of the capacitor. Error: ________.
47. If the error is unreasonable, check your work and go back to step 44.
48. Connect the inductor in the place of the capacitor.
49. Modify the VI to display also the inductance L.
    a. Add a new formula block that calculates L.
    b. Note that for an inductor $I = V_L/(2\pi f L)$. Solve for L by substituting $I = V_r/R$.
50. **Set the frequency to 1000 Hz** and measure the inductor with the VI. L = ______________.
51. Calculate the relative error of the measurement with respect to the nominal value of the inductor. Error: ________.
52. If the error is unreasonable, check the formula used in the formula block.
53. The formula $I = V_L/(2\pi f L)$ neglects the resistance of the inductor. Since this approximation is inappropriate at low frequencies, L was measured at 1000 Hz.
54. Modify the VI to display also the absolute value of the impedance between the banana jacks B and C.
    a. Let Z denote the absolute value of the impedance.
    b. Add a new formula block that calculates Z.
    c. Note that $I = V_Z/Z$. Solve for Z by substituting $I = V_r/R$.
55. Connect between the banana jacks B and C the inductor in series with the capacitor.
56. The resonance frequency of a series RLC circuit is $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$. Using the measured values of L and C, find the resonance frequency. f_0 = ________
57. For a series RLC circuit, impedance is minimum at resonance. Vary the frequency of your VI between 900 Hz and 1100 Hz and record the frequency for which the impedance is minimum. f_0 = _________. The impedance at resonance is Z = ________.
58. Disconnect the inductor and measure its resistance with a DMM. r = ________.
59. Compare r and Z measured above. Should they be equal? ____________________________________
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