

LabVIEW 4: Analysis: Curve Fitting and Fourier Transformation

Reading :

	Reading	pages
Hands-On Introduction to LabVIEW by J. Essick	Chapter 9	All
	Chapter 10	All

Main focus :

- Learn how to fit data, how to determine the Power spectral density.
- Implement a temperature measurement circuit - this will be part of the final PID project.

Most relevant VI's :

- R-T Fit and Plot.vi
- Digital Thermometer.vi

Due Date: Friday, 11AM, Dec. 5

Assignments: Hand in a printout of the *Block Diagram* and *Front Panel*, where the *Front Panel* graphs should display relevant data. Make sure to include your name and date and most importantly sufficiently detailed comments. The comments on the *Block Diagram* should concern the details of how the program works, and why you chose to use certain LabVIEW language programming structures. The comments on the *Front Panel* can be used to talk about the meaning of the results.

Problem 3: Attach the analytic solution to Problem 3 as a separate sheet. Do calculations yourself. Only neatly written up solutions will be accepted. Solutions typeset with \LaTeX are preferred.

1. [Chapter 9, page 31, Do it yourself project] Construct the circuit as shown in the book on the NI-Elvis board. Make sure you use a **PNP transistor**, it should say “PN2907” on it. Write the **Digital Thermometer** VI and measure the temperature. In addition to the Digital Thermometer VI's *Block Diagram* and *Front Panel*, print out the front panel of **R-T Fit and Plot**, with a display of your values for A , B and C . Include in your comments the value of the current through your thermistor, which you need to measure and use as input to the **DAQ Assistant**

We will be using a thermistor that is different from the one mentioned in the book, so use the data shown on the next page.

Table 1: In the table, the $R - T$ data for the thermistor Epcos Model #B57863S0103F040 is given.

Temperature ($^{\circ}\text{C}$)	Resistance ($\text{k}\Omega$)
-50	670.1
-45	471.7
-40	336.5
-35	242.6
-30	177
-25	130.4
-20	97.07
-15	72.93
-10	55.33
-5	42.32
0	32.65
5	25.39
10	19.9
15	15.71
20	12.49
25	10
30	8.057
35	6.531
40	5.327
45	4.369
50	3.603
55	2.986
60	2.488
65	2.083
70	1.752
75	1.481
80	1.258
85	1.072
90	0.9177
95	0.7885
100.00	0.6800
105.00	0.5886
110.00	0.5112

2. Lorentzian Absorption Line: Taking the infrared frequency of $3.84566030 \times 10^{14}$ Hz as the zero of a frequency scale, the absorption line for an atom yields the following data [Data with header in "LV3_Lorentzian.txt"]:

Frequency (MHz)	Absorption (arbitrary units)
-50	2.33
-45	1.09
-40	2.38
-35	5.42
-30	5.35
-25	2.99
-20	6.81
-15	8.46
-10	11.29
-5	18.37
0	22.34
5	22.61
10	16.11
15	11.66
20	8.51
25	6.80
30	5.73
35	4.93
40	3.05
45	3.96

Theoretically, the absorption data $A(f)$ is described by a Lorentzian lineshape given by

$$A(f) = \frac{A_0}{2\pi} \frac{\Gamma}{(f - f_0)^2 + (\Gamma/2)^2} \quad (1)$$

where the constants A_0 , f_0 and Γ are the amplitude, resonant frequency and full-width at half maximum, respectively. Write a program that fits the above data to a Lorentzian lineshape and determines the best-fit values for A_0 , f_0 and Γ . To visualize the fit it is useful to (a) generate a array containing about 100 equally spaced frequency values that slightly extend beyond the range of the data both on the low frequency and high frequency side, (b) generate the corresponding 100 absorption amplitudes by using the best fit values and Eq. (1). This will allow for a much smoother curve on the graph showing the best fit and the data.

At what absolute frequency does the center of the absorption line occur?

The width of the absorption line is due to the energy width ΔE of the excited quantum state involved in this optical absorption process. Taking $\Delta E = h\Gamma$, use the Heisenberg uncertainty principle to find the lifetime of this excited state (in nsec).

3. The Hann-window is given by

$$w(t) = \begin{cases} \cos^2\left(\frac{\pi t}{T}\right) = \frac{1}{2} [1 + \cos\left(\frac{2\pi t}{T}\right)], & t \in \left(-\frac{T}{2}, \frac{T}{2}\right) \\ 0, & \text{otherwise.} \end{cases} \quad (2)$$

- (a) Determine the Fourier transform of the Hann window.
- (b) What is the ratio of Fourier-trafo-magnitudes for the rectangular and Hann window? Can you see why the Hann window results in less leakage than the rectangular window (box-function)?

4. Frequency Doubling: [Chapter 10, pg. 40, Problem 1] Use the VI called *FFT-Magnitude Only* to perform the following investigation: In many areas of experimental physics, a pure sine wave signal is input to a nonlinear detector/amplifier (e.g., radio wave on diode detector, monochromatic light on nonlinear crystal). To explore what happens in this case, modify the subVI *Sine Wave* so that it simulates the following process: a pure sinusoid Y is passed through a slightly nonlinear amplifier producing an output signal $A(Y)$ given by

$$A(Y) = \alpha Y + \beta Y^2,$$

where α and β are constants with α significantly larger than β . You can accomplish this simulation easily by adding one extra calculation within the Formula Node of Sine Wave.

Run *FFT-Magnitude Only* with some choice of α and β ($\alpha = 10$ and $\beta = 1$ might be a good place to start) to find the spectrum of $A(Y)$. From what you observe, can you think of how this process might be useful? The trick behind how it works can be seen by noting that the Y^2 term in $A(Y)$ produces a product of sine waves. From trigonometry,

$$\sin(\vartheta) \sin(\varphi) = \frac{1}{2} [\cos(\vartheta - \varphi) - \cos(\vartheta + \varphi)].$$

What happens if the amplifier is even more nonlinear so that $A(Y) = \alpha Y + \beta Y^2 + \gamma Y^3$?

Test both Rectangular and Hann(ing) windows. Comment on the difference.