

USING ENGINEERING CONCEPTS TO ENHANCE THE STUDENTS' LEARNING IN A COMPUTER CLASS

Shen Liu

Division of Science and Mathematics
West Kentucky Community and Technical College
shen.liu@kctcs.edu

Abstract

At West Kentucky Community and Technical College, all pre-engineering majored students are required to take a computer class: Computational Techniques and Tools for Mechanical Engineers. The course introduces students with various modern computational tools, including LabVIEW, MATLAB and Excel. LabVIEW is a graphical programming language that has been extensively used in engineering and physics disciplines for data measurement and control. The class has traditionally focused on teaching computer codes and algorithms to run various programs, therefore the students do not see the connections between LabVIEW and engineering applications. We have recently incorporated teaching engineering concepts into the curriculum. Students would write LabVIEW programs not just for completing computer codes but rather for understanding some engineering principles. The effort has greatly enhanced the students' interests in the subject and better prepared them for future engineering classes.

Instruction

LabVIEW has become one of the most widely used software in engineering practices and has been incorporated in various engineering curriculums [1-6]. Known as the “G” or graphical language, LabVIEW allows users to build virtual instruments (VIs) on computers for data manipulations and signal analyses. At West Kentucky Community and Technical College, all pre-mechanical engineering students are required to take a computer class: Computational Techniques and Tools for Mechanical Engineers. The overall objective of the course is to introduce students with modern computational tools, including LabVIEW, MATLAB and Excel, to solve engineering problems. The LabVIEW-related topics covered in the course include:

- Basics of LabVIEW
- Virtual environment and data acquisition (DAQ)

*Proceedings of the 2014 ASEE Gulf-Southwest Conference
Organized by Tulane University, New Orleans, Louisiana
Copyright © 2014, American Society for Engineering Education*

- Functions, charts, graphs, indicators, controls, and analysis
- Programming applications
- Loops, Arrays, and structures
- Acquiring data
- Write data to text file

With the techniques learned from each topic, students would write programs to create various types of virtual instruments. The overall learning outcomes of the course are that the students should have abilities to

- Write and debug computer programs to solve engineering problems
- Use modern computational tools and software to analyze and graph data
- Develop proficiency in navigating and writing structured programs in LabVIEW

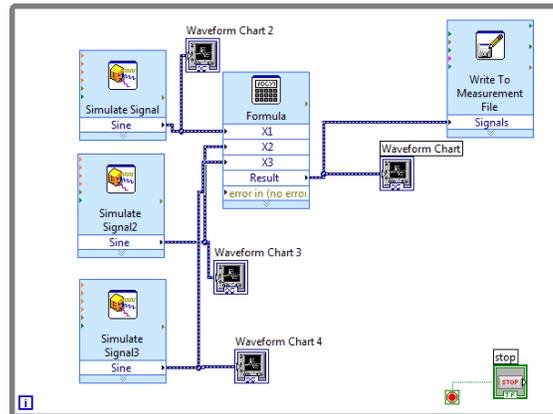
The course has been traditionally taught as in the lecture format that the LabVIEW programming codes and structures are lectured, following the textbook by Travis and Kring [7]. Students would be assigned exercises and homework on writing and executing various computer codes. Although the students have spent significant amount of time on exercise problems, they often do not see the connections between the software and engineering practices. Recently, we have started to incorporate various engineering concepts into the curriculum. Lecture samples and homework exercise are designed in such a way that LabVIEW would be used to demonstrate and solve common engineering problems rather than abstract computer science problems. Through those changes, the course has been shifted from a computer oriented discipline to a more engineering oriented discipline without compromising overall learning outcomes. The effort has greatly enhanced the students' interests in the subject and better prepared them for future engineering classes.

Waveform Analysis with LabVIEW

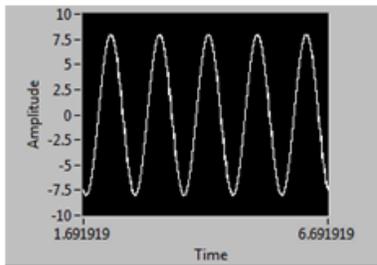
Waveform is a fundamental subject in virtually all engineering disciplines. It deals with the time-varying signals originated from various engineering systems. Example of time-varying signals include sound, pressure, acceleration, etc. The mathematical formula of a generic waveform is given in Equation 1 [8]. It shows that any waveform may be considered as a summation of numerous simple sine and cosine functions

$$y(t) = \frac{A_0}{2} + \sum_{n=1}^{\infty} (A_n \cos n\omega t \pm B_n \sin n\omega t) \quad [1]$$

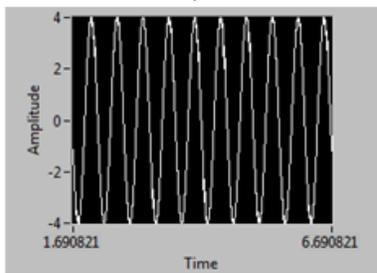
where A_0 , A_n , and B_n = amplitude-determining constants
 n = integers from 1 to ∞



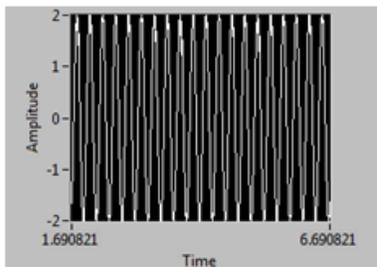
(a)



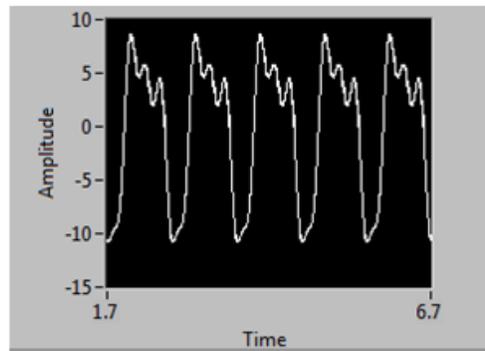
+



+



=



(b)

Fig. 1 – A LabVIEW VI used to analyze complex waveforms.
 (a) Block diagram and (b) Front panel.

For example, a complex signal, $y(t)=8\sin\omega t+4\sin 2\omega t+2\sin(4\omega t+\pi/6)$, is the combination of three simple sine functions: $y(t_1)=8\sin\omega t$, $y(t_2)=4\sin 2\omega t$ and $y(t_3)=2\sin(4\omega t+\pi/6)$. To observe this, students can quickly build a LabVIEW VI to simulate the three sinusoidal signals, as shown in the block diagram (Fig. 1a). Students then combine the three simple sinusoidal waveforms and observe the resultant complex waveform, as displayed on the front panel (Fig. 1b). By clicking the Simulate Signal icons, the Configuration Windows would open, which allows students to adjust the signal characteristics (frequency, amplitude, phase and offset). By changing the characteristics of the three sine functions, students can observe how the resultant complex function evolves.

Another example used to demonstrate waveform analysis is the square wave signal (Fig.2). The mathematical representation of the square wave is given in Equation 2 [8].

$$y(t) = \frac{4A}{\pi} \left(\sin\omega t + \frac{1}{3}\sin 3\omega t + \frac{1}{5}\sin 5\omega t + \dots \right) \quad [2]$$

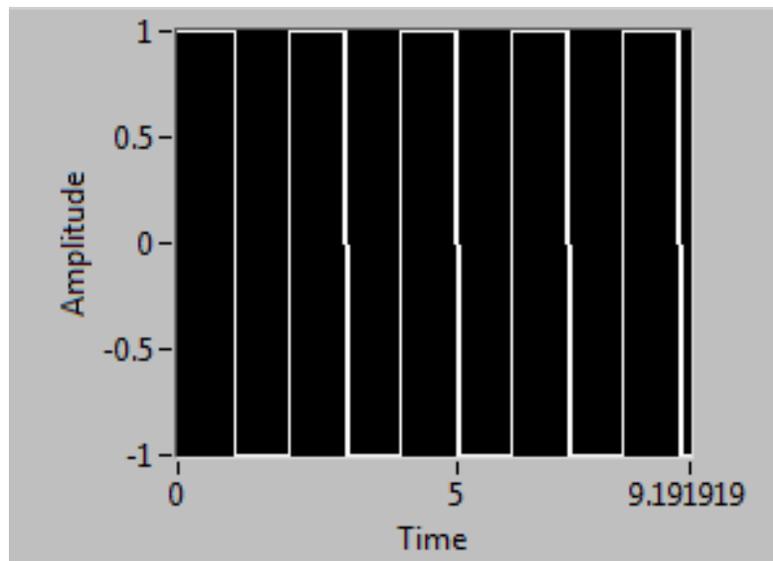
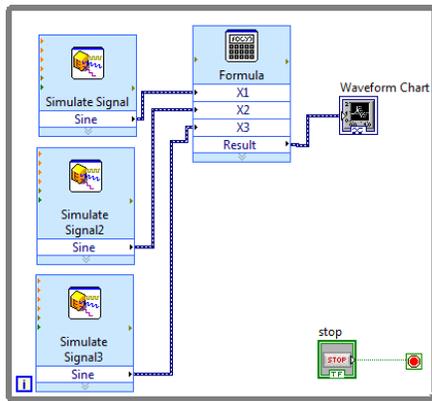
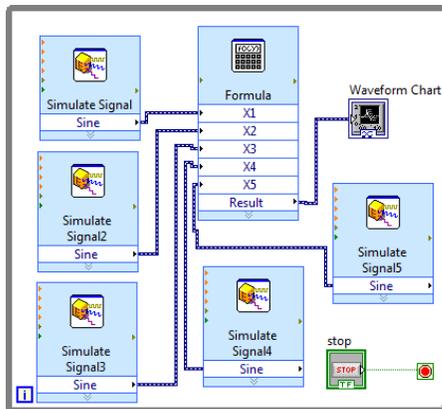
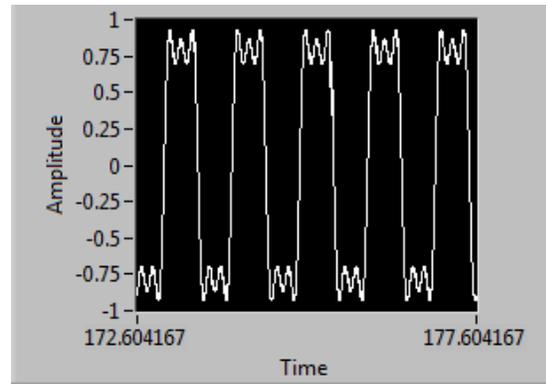


Fig. 2 – A square wave signal.

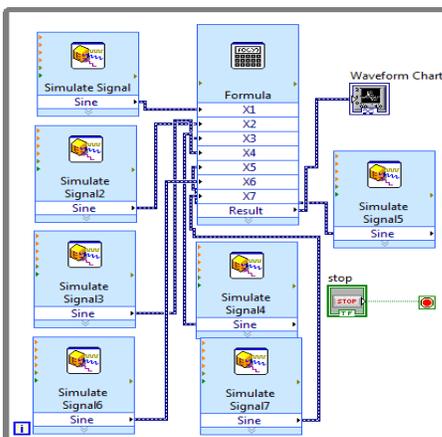
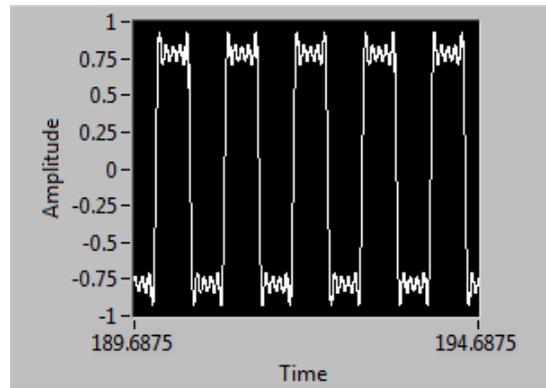
It is seen that the square wave is the summation of an infinite number of sinusoidal waveforms. To verify this, students would create a number of sinusoidal waveforms by using Simulate Signals and then add them together to produce the square wave. (Figs.3a-c). The waveform gradually approaches the square wave when more terms are added.



(a)



(b)



(c)

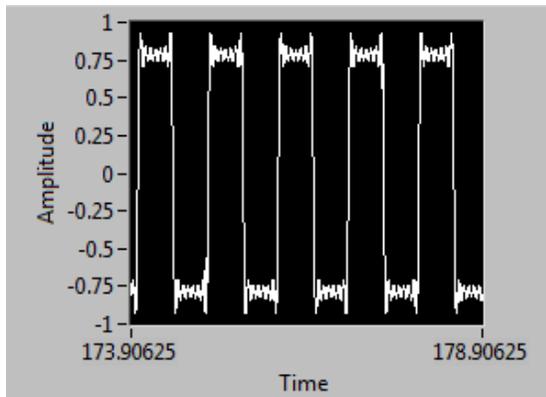


Fig. 3 – LabVIEW Block Diagrams and Front Panels showing that a square wave is produced by: (a) three sine terms, (b) five sine terms, and (c) seven sine terms.

Fourier Analysis with LabVIEW

While the physical signals are typically visualized in the time domain, engineering applications often require the signals be presented in the frequency domain. For example, the frequency response of a vibration signal from a structure would allow engineers to identify the modal frequencies, which help design a safer product. The process of transferring a signal from time domain to frequency domain is known as the Fourier transform. The discrete Fourier transform function is given in Equation 3 [8]:

$$y(t) = \frac{A_0}{2} + \sum_{n=1}^{\frac{N}{2}-1} [A_n \cos(2\pi n \Delta f t) + B_n \sin(2\pi n \Delta f t)] + \frac{A_{N/2}}{2} \cos(2\pi \frac{N}{2} \Delta f t) \quad [3]$$

where

$$A_n = \frac{2}{N} \sum_{r=1}^{\frac{N}{2}-1} y(r\Delta t) \cos\left(\frac{2\pi r n}{N}\right), n=, 0, 1, \dots, N/2,$$

$$B_n = \frac{2}{N} \sum_{r=1}^{\frac{N}{2}-1} y(r\Delta t) \sin\left(\frac{2\pi r n}{N}\right), n=, 0, 1, \dots, N/2$$

A Waveform Frequency Analysis VI has been built to demonstrate the concepts of Fourier analysis. For example, a time-varying square wave as shown earlier can have a frequency spectrum as shown in Fig.4.

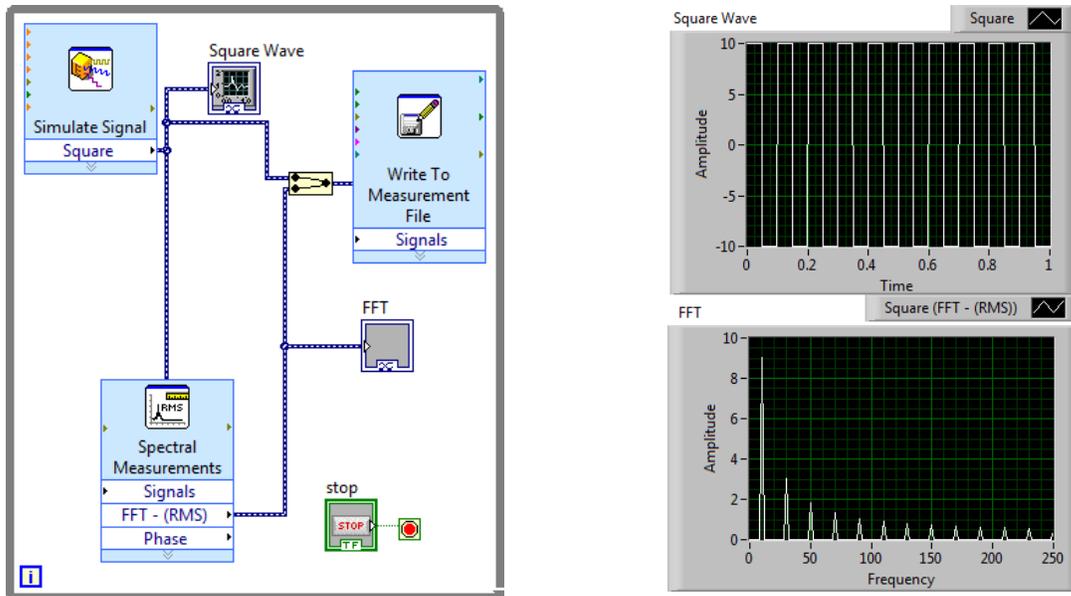


Fig. 4 – LabVIEW Block Diagram and Front Panel showing the Fourier analysis of a square wave.

Another example used to demonstrate the importance of Fourier analysis is the acoustic analysis of a sound signal. A Sound Frequency Analysis VI is created to acquire sound signals by using the microphone of the laptop computer. The frequency spectrum of a female's voice is shown in Fig.5.

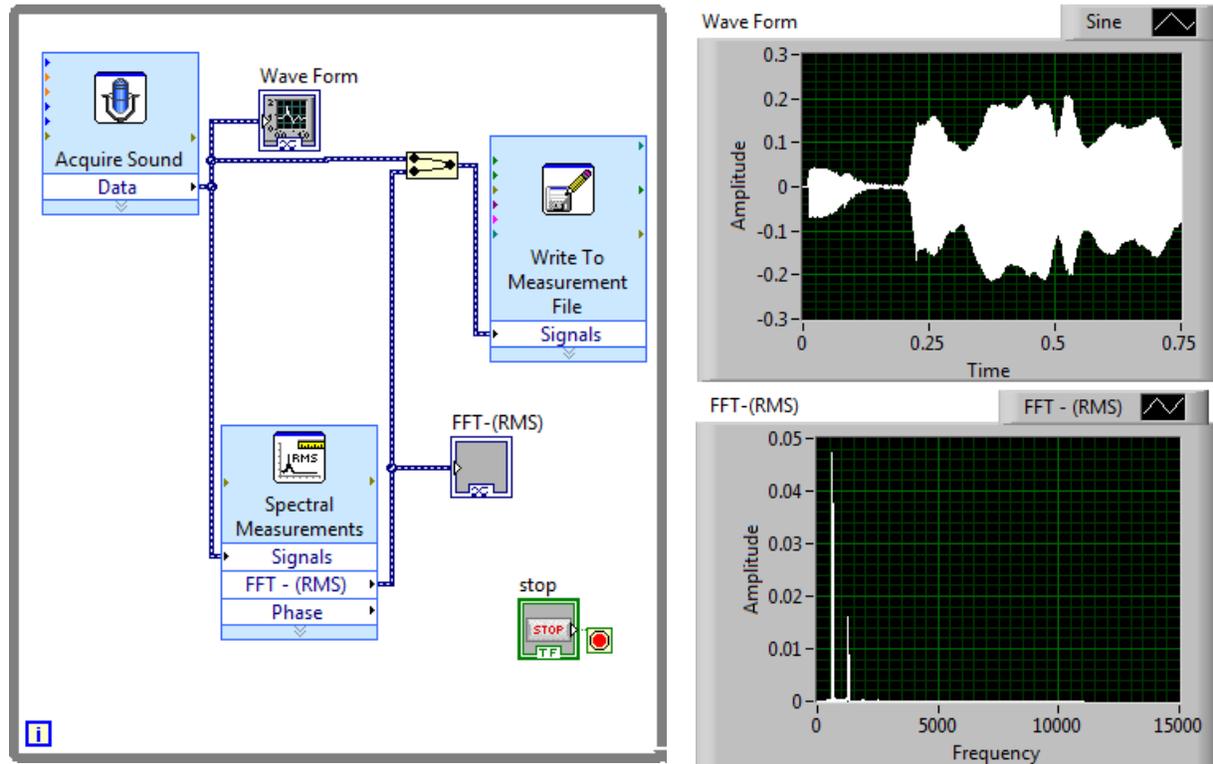


Fig. 5 – LabVIEW Block Diagram and Front Panel showing the Fourier Analysis of a sound signal.

First-Order System Response with LabVIEW

Although the real engineering systems are complicated, they can be described with three basic mechanical elements: spring (k), mass (M), and damper (ζ). The combinations of these three elements result in various differential equations, the so-called system equations. First-order systems are governed by differential equations that contain the zero and first derivatives. The general equation for first-order thermal systems is shown in Equation 4 [8]:

*Proceedings of the 2014 ASEE Gulf-Southwest Conference
Organized by Tulane University, New Orleans, Louisiana
Copyright © 2014, American Society for Engineering Education*

$$T = T_{\infty} + (T_A - T_{\infty})e^{-\frac{t}{\tau}} \quad [4]$$

where

T = magnitude of any first-order process at time t ,

T_{∞} = limiting magnitude of the process as $t \rightarrow \infty$,

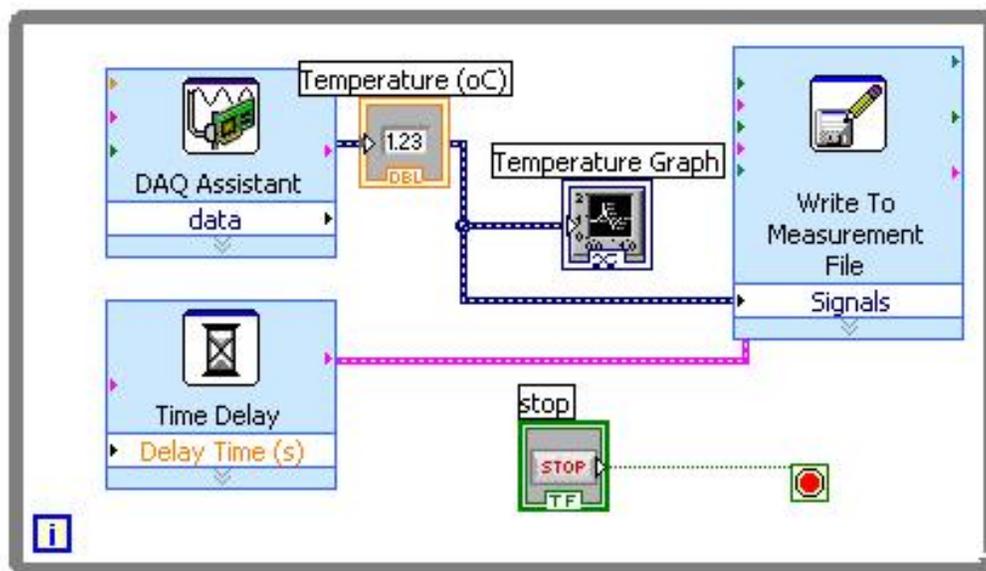
T_A = initial magnitude of the process at $t = 0$,

t = time in seconds,

τ = time constant

To help students understand the first-order systems, a LabVIEW homework is assigned to measure and analyze the temperature response of the water in a beaker. In this exercise, a beaker of water is placed on a hotplate and the temperature is recorded as a function of time (Fig.6). By plotting the temperature versus time, the time constant (τ) of this simple thermal system can be calculated:

$$\tau = -\frac{t}{\ln\left[\frac{T-T_{\infty}}{T_A-T_{\infty}}\right]} = 2040 \text{ sec} \quad [5]$$



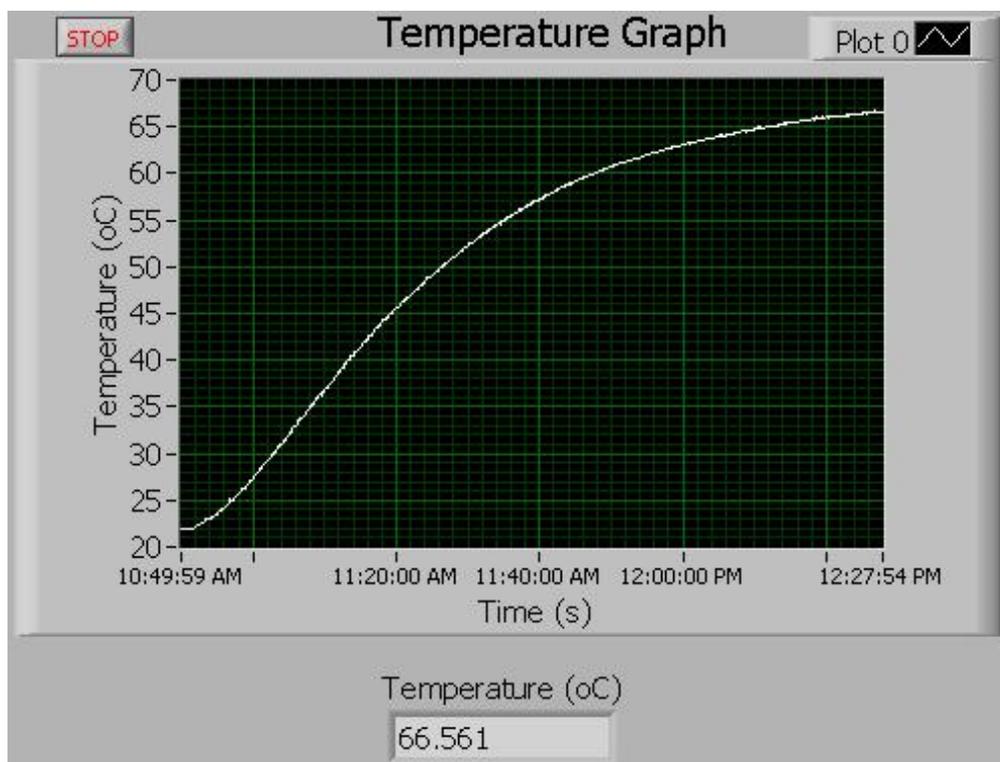


Fig. 6 – LabVIEW Block Diagram and Front Panel used to measure the temperature-time profile in a thermal system.

Conclusions

Traditional theory-oriented instructional method has not adequately provided students with necessary interests and skills in teaching computer based class, such as LabVIEW. We have incorporated various engineering concepts into the curriculum through lecture samples and homework exercises. These examples can be used effectively to teach both LabVIEW programming and engineering concepts. Through those changes, the course has been shifted from a computer oriented discipline to a more engineering oriented discipline. The effort has greatly enhanced the students' interests in the subject and improved the overall learning outcomes of the course. Most pre-engineering students have subsequently enrolled in engineering curriculums. It has been found that the proper exposure of engineering concepts in a computer class have better prepared them for future engineering classes.

References

- [1] Walters, D. L., “Integration of equation solving software with data acquisition equipment for a senior engineering measurements course”, *Proceedings of the 1999 American Society of Engineering Education Annual Conference & Exposition* (1999).
- [2] Young, R. A., LabVIEW: A Modern Data Acquisition System in an Introductory Mechanics Laboratory, *Proceedings of the 1999 American Society of Engineering Education Annual Conference & Exposition* (1999).
- [3] Schwartz, T.L. and B.M. Dunkin, "Facilitating Interdisciplinary Hands-on Learning using LabVIEW," *International Journal of Engineering Education*, **16**, 218-227 (2000).
- [4] Orab, I.I., “Application of LabVIEW for undergraduate lab experiments on materials testing”, *Proceedings of the 2002 American Society of Engineering Education Annual Conference & Exposition* (2002).
- [5] Ayrapetyan, D. and Y. Huang, N. Kiritsis, “A Multi-Purpose Vibration Experiment Using LabVIEW”, *Proceedings of the 2003 American Society of Engineering Education Annual Conference & Exposition* (2003).
- [6] Parten, M., “Using Virtual Instruments in A Measurements Laboratory”, *Proceedings of the 2003 American Society of Engineering Education Annual Conference & Exposition* (2003).
- [7] Travis J. and J. Kring, “*LabVIEW for Everyone: Graphical Programming Made Easy and Fun*”, Prentice Hall, Upper Saddle River, NJ (2006).
- [8] Beckwith, T.G. and R.D. Marangoni, J.H Lienhard V, *Mechanical Measurements*, 6th, Prentice Hall, Upper Saddle Rivers, NJ (2007).

Shen Liu

Dr. Shen Liu is an Associate Professor of Physics at West Kentucky Community and Technical College and an adjunct professor at University of Kentucky College of Engineering-Paducah campus. She got her BS and MS in Jet Propulsion from Beijing University of Aeronautics and Astronautics, China and PhD in Aerospace Engineering from Old Dominion University.