

Hands-On

Introduction

to

SECOND EDITION

# LabVIEW™

for Scientists

and

Engineers

JOHN ESSICK

OXFORD  
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*Hands-On Introduction to LabVIEW™ for Scientists and Engineers*, Second Edition, provides a “learn-by-doing” approach to acquiring the computer-based skills used in daily experimental work in engineering and the sciences. Ideal as an instructional lab textbook or for self-study by individual researchers, this book is not a manual-like presentation of LabVIEW™, but rather leads its readers to mastery of this powerful laboratory tool through the process of carrying out interesting and relevant projects. Readers—who are assumed to have no prior computer programming or LabVIEW™ background—will begin writing meaningful programs within the first few pages. *Hands-On Introduction to LabVIEW™* is designed for flexible use so that readers can easily choose the desired depth of coverage.

## New to the Second Edition

- All chapters fully updated to the latest version of LabVIEW™ and commonly used low-cost data acquisition devices
- Full-color reference card of LabVIEW™ programming icons
- “Quick Example” sections at the chapter beginnings give concise introductions to the MathScript Node, Shift Register, and Case Structure
- Coverage of USB control of stand-alone instrumentation
- Solutions to even-numbered back-of-the-chapter problems available on the companion website

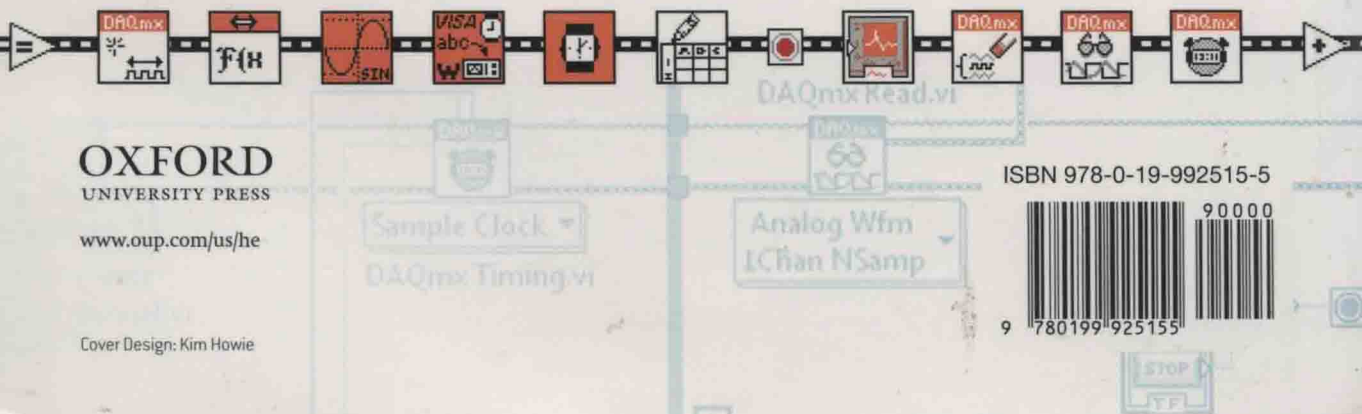
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**JOHN ESSICK** is the David W. Brauer Professor of Physics at Reed College. Since 1993, he has taught computer-based experimentation using LabVIEW™ as part of Reed’s Advanced Laboratory course.

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# ESSICK

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for Scientists and Engineers**

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Hands-On Introduction to  
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for Scientists and Engineers

Second Edition

**John Essick**

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Hands-On Introduction to  
**LabVIEW™**  
for Scientists and Engineers



*To my wife, Katie*





# Preface

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*Hands-On Introduction to LabVIEW for Scientists and Engineers* provides a learn-by-doing approach to acquiring the computer-based skills used daily in experimental work. This book is not a manual-like presentation of LabVIEW. Rather, *Hands-On Introduction to LabVIEW* leads its readers to mastery of LabVIEW through the process of using this powerful laboratory tool to carry out interesting and relevant projects. Readers, who are assumed to have no prior computer programming or LabVIEW background, begin writing meaningful programs in the first few pages.

*Hands-On Introduction to LabVIEW* can be used as a text in an instructional lab course or for self-study by individual researchers. The book is designed for flexible use so that readers can easily choose the desired depth of coverage. The first four chapters, which form the foundation appropriate for all readers, focus on the fundamentals of LabVIEW programming as well as the basics of computer-based experimentation using a National Instruments data acquisition (DAQ) device. These opening chapters can be used as the basis of a three-week introduction to LabVIEW-based data acquisition. Subsequent chapters have been written as independently as possible so that an instructor or self-learner can fill out his or her course of study as desired. Those who work through most of the text's chapters will attain an intermediate skill level in computer-based data acquisition and analysis.

The progression of topics in *Hands-On Introduction to LabVIEW* is as follows:

*Chapters 1–3:* Fundamentals of the LabVIEW Graphical Programming Language. Central features of LabVIEW including its control loop structures, graphing modes, mathematical functions, and text-based MathScript commands are learned in the course of writing digitized waveform simulation programs.

*Chapter 4:* Basic Data Acquisition: Concepts of digitized data such as resolution, sampling frequency, and aliasing are covered. Then, using LabVIEW's high-level Express VIs, programs are written that execute analog-to-digital, digital-to-analog, and digital input/output tasks on a National Instruments DAQ device. Computer-based instruments constructed include a DC voltmeter, digital oscilloscope, DC voltage source, waveform generator, and blinking LED array.

*Chapters 5–8:* More LabVIEW Programming Fundamentals. Implementation of data file input/output, local memory, and conditional branching in LabVIEW is investigated while writing several useful programs (e.g., spreadsheet data storage, numerical

integration, and differentiation). Additionally, LabVIEW's control flow approach to computer programming is studied.

*Chapters 9 and 10: Data Analysis.* Proper use of LabVIEW's curve fitting and fast Fourier transform functions is investigated. Using Express VIs to control a DAQ device, two computer-based instruments—a digital thermometer and a spectrum analyzer—are constructed.

*Chapter 11: Intermediate-Level Data Acquisition.* Programs are written to carry out analog-to-digital, digital-to-analog, and digital counter tasks on a DAQ device using the conventions of DAQmx. This lower-level approach (in comparison to the high-level Express VIs) allows utilization of the full available range of DAQ device features. A DC voltmeter, DC voltage source, waveform generator, and frequency meter are constructed, as well as a sophisticated digital oscilloscope based on the state machine architecture.

*Chapter 12: Temperature Control Project.* A wide range of the LabVIEW skills acquired throughout the book are used to construct a Proportional-Integral-Derivative (PID) temperature control system. Appendix I gives a design for the hardware required for this project.

*Chapter 13: Control of Stand-Alone Instruments.* Using LabVIEW's VISA communication driver, control of a stand-alone instrument over the General Purpose Interface Bus (GPIB) as well as the Universal Serial Bus (USB) is studied. An Agilent 34410A Multimeter is used to demonstrate the central concepts of interface bus communication between a PC and stand-alone instrument.

Key features of *Hands-On Introduction to LabVIEW* include its emphasis on real-world problem solving, its early introduction and routine use of data acquisition hardware, its “Do It Yourself” projects at the end of each chapter, and its healthy offering of back-of-the-chapter homework problems.

**Real-World Problem Solving:** Chapter topics and exercises provide examples of how commonly encountered problems are solved by scientists and engineers in the lab. LabVIEW features, along with relevant mathematical background, are introduced in the course of solving these problems. The “best practice” strategies presented (such as modularity and data dependency) equip readers to optimize their use of LabVIEW.

**Data Acquisition Usage Throughout:** LabVIEW's Express VIs allow exercises involving DAQ hardware to appear early and then routinely in *Hands-On Introduction to LabVIEW*. Express VIs package common measurement tasks into a single graphical icon and so allow the user to write a program with minimal effort. Of particular note, following the book's first three software-only chapters that teach the fundamentals of the LabVIEW programming language, data acquisition using a DAQ device is covered in Chapter 4. For a professor or self-learner who wishes to devote only three weeks (or so) to instruction in computer-based data acquisition, Chapters 1 through 4 will provide the needed instructional materials. For those planning a more comprehensive study of LabVIEW, the Express VIs allow construction of a computer-based digital thermometer and spectrum analyzer in Chapters 9 and 10, respectively. In Chapter 11, the control of a DAQ device via the more advanced programming DAQmx icons is covered. In contrast

to the Express VIs, the DAQmx icons enable a user to utilize the full available range of the DAQ-device features. In Chapter 12, readers use a DAQ device to precisely control the temperature of an aluminum block, and in Chapter 13, data are acquired remotely from a stand-alone instrument using the GPIB and/or USB interface bus.

**Do It Yourself Projects:** To allow a reader to gauge his or her understanding of the presented material, each chapter of *Hands-On Introduction to LabVIEW* concludes with a Do It Yourself project. Each of these projects poses an interesting problem and (loosely) directs the reader in applying the chapter's material to find a solution. In some chapters, this project involves writing a program that functions as a stopwatch (Chapter 1) or determines a person's reaction time (Chapter 8); in other chapters the reader constructs a computer-based instrument including a digital thermometer (Chapter 9), a spectrum analyzer (Chapter 10), and a frequency meter (Chapter 11).

**Back-of-the-Chapter Homework Problems:** A selection of homework-style problems is included at the end of each chapter so that interested readers can further develop their LabVIEW-based skills. In some of these problems, readers test their understanding by applying the chapter topics to new applications (e.g., Bode magnitude plot); in others, readers use programs written within the chapter to explore important experimental issues (e.g., frequency resolution of a fast Fourier transform). Finally, a number of problems introduce readers to features of LabVIEW relevant to, but not included in, the chapter's text (e.g., data storage in binary format).

## IMPROVEMENTS TO THE SECOND EDITION

This new edition includes the following improvements:

- All chapters are fully updated to the latest version of LabVIEW. Functionality of the new Probe Watch Window (Chapter 2) and Icon Editor (Chapter 3) is explained.
- MathScript Node's online help and automated data-type formatting features are covered (Chapter 3).
- Low-cost DAQ hardware commonly used in instructional laboratories and self-learning is highlighted, including the USB-6009, myDAQ, PCI-6251, and ELVIS II DAQ devices (Chapter 4).
- "Quick Example" sections at the chapter beginnings give concise introductions to the MathScript Node, Shift Register, and Case Structure (Chapters 3, 6, and 7).
- Property Node usage is included in earlier chapter text (Chapter 7).
- Both GPIB and USB control of stand-alone instrumentation is implemented using a late-model Agilent 34410A Digital Multimeter; presentation is compatible with the older Agilent 34401A multimeter (Chapter 13).
- As an aid to instructors designing their courses, a table is provided that cites sections where an earlier-written program is needed as a subroutine (Appendix II).
- Solutions to even-numbered back-of-the-chapter problems are available to all at [www.oup.com/us/essick](http://www.oup.com/us/essick); for instructors who adopt this book for a course, a password-protected link to the solution set for every problem is available from Oxford University Press.

*Hands-On Introduction to LabVIEW* is compatible with both the Full Development System and the Student Edition of LabVIEW. An instructor might consider having students purchase personal copies of the low-cost Student Edition software (the Student Edition can now be purchased by itself at a very affordable price; that is, it is no longer necessary to buy an expensive bundled book/software package). With their own LabVIEW software, students can perform non-hardware-related chapter sections and/or back-of-the-chapter problems as homework on their own computers.

To aid readers in creating their LabVIEW programs, the following conventions are used throughout the book: **Bold** text designates the features such as graphical icons, palettes, pull-down menus, and menu selections that are to be manipulated in the course of constructing a program. The descriptive names that label controls, indicators, custom-made icons, programs, disk files, and directories (or folders) are given the **straight** font. *Italic* text highlights character strings that the programmer must enter using the keyboard and also signals the first-time use of important terms and concepts.

Any suggestions or corrections are gladly welcomed and can be sent to John Essick, Reed College, 3203 SE Woodstock Boulevard, Portland, OR 97202, USA, or [jessick@reed.edu](mailto:jessick@reed.edu).

Updates, answers to frequently asked questions, and ancillary materials for *Hands-On Introduction to LabVIEW* are available at <http://academic.reed.edu/physics/faculty/essick>.

Additionally, solutions to the even-numbered back-of-the-chapter problems can be downloaded at [www.oup.com/us/essick](http://www.oup.com/us/essick). Instructors who adopt this book for a course can obtain a password-protected link to the solution set for every problem from Oxford University Press.

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Finally, to my family: Thank you for your love and support while I worked on this project.

John Essick  
Portland, Oregon



# Contents

Preface	xiii
<b>1. THE WHILE LOOP AND WAVEFORM CHART</b>	<b>1</b>
1.1 LabVIEW Programming Environment	1
1.2 Sine-Wave Plot using a While Loop and Waveform Chart	2
1.3 Block Diagram Editing	3
1.4 LabVIEW Help Window	20
1.5 Front Panel Editing	22
1.6 Pop-Up Menu	27
1.7 Finishing the Program	30
1.8 Program Execution	31
1.9 Program Improvements	33
1.10 Date-Type Representations	43
1.11 Automatic Creation Feature	46
1.12 Program Storage	48
Do It Yourself	50
Problems	51
<b>2. THE FOR LOOP AND WAVEFORM GRAPH</b>	<b>56</b>
2.1 For Loop Basics	56
2.2 Sine-Wave Plot using a For Loop and Waveform Graph	57
2.3 Waveform Graph	58
2.4 Owned and Free Labels	59
2.5 Creation of Sine Wave using a For Loop	60
2.6 Cloning Block-Diagram Icons	63
2.7 Auto-Indexing Feature	65
2.8 Running the VI	68
2.9 x-Axis Calibration of the Waveform Graph	69
2.10 Sine-Wave Plot using a While Loop and Waveform Graph	75
2.11 Array Indicators and the Probe Watch Window	79
Do It Yourself	90
Problems	92



<b>3.</b>	<b>THE MATHSCRIPT NODE AND XY GRAPH</b>	<b>99</b>
3.1	MathScript Node Basics	99
3.2	Quick MathScript Node Example: Sine-Wave Plot	102
3.3	Debugging with Error List	109
3.4	Waveform Simulator using a MathScript Node and XY Graph	111
3.5	Creating an <i>xy</i> Cluster	115
3.6	Running the VI	116
3.7	MathScript Interactive Window	117
3.8	Adding Shape Options to Waveform Simulator	121
3.9	The Enumerated Type Control	122
3.10	Finishing the Block Diagram	124
3.11	Running the VI	128
3.12	Control and Indicator Clusters	129
3.13	Creating an Icon using the Icon Editor	136
3.14	Icon Design	137
3.15	Connector Assignment	142
	Do It Yourself	146
	Problems	148
<b>4.</b>	<b>DATA ACQUISITION USING DAQ ASSISTANT</b>	<b>152</b>
4.1	Data Acquisition VIs	152
4.2	Data Acquisition Hardware	153
4.3	Analog Input Modes	155
4.4	Range and Resolution	157
4.5	Sampling Frequency and the Aliasing Effect	158
4.6	Measurement & Automation Explorer (MAX)	160
4.7	Simple Analog Input Operation on a DC Voltage	164
4.8	Digital Oscilloscope	175
4.9	Analog Output	184
4.10	DC Voltage Source	185
4.11	Software-Timed Sine-Wave Generator	192
4.12	Hardware-Timed Waveform Generator	194
4.13	Placing a Custom-Made VI on a Block Diagram	197
4.14	Completing and Executing Waveform Generator (Express)	199
4.15	Modified Waveform Generator	201
	Do It Yourself	203
	Problems	204