PDAs and LabWorks—A New Way to Make Chemical Measurements

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Received March 4, 2002. Accepted April 5, 2002

Abstract: Computer-controlled data acquisition is rapidly becoming the rule rather than the exception in general chemistry laboratories. The LabWorks learning system is one of many computer-controlled data acquisition interfaces that allow students to quickly obtain and analyze chemistry data. This article explains how communication is established between a personal digital assistant (PDA) and the LabWorks interface. This project continues work previously accomplished using an HP 48 calculator to communicate with the LabWorks interface. The PDA has more computing power, more storage ability, and the Windows CE operating system provides a more user-friendly interface than the handheld graphing calculator. Sample experimental data is provided as an example of how this LabWorks/Palm PC combination can be applied to inexpensively enhance laboratory learning.

Introduction

The LabWorks learning system is an effective, inexpensive combination of hardware and software that enables students to obtain and analyze experimental data in general chemistry laboratories [1, 2], The LabWorks interface is controlled by a personal computer (PC), which tells the interface to obtain experimental data. PCs can be expensive, difficult to maintain, and they can take up valuable laboratory bench space.

It has been shown that other devices, such as a handheld graphing calculator, can control the LabWorks interface [3, 4]. This concept is taken a step further by using a handheld personal digital assistant (PDA) running the Windows CE operating system. In this project a program was created that enabled the PDA to communicate with the LabWorks interface, take a simple set of temperature-versus-time data, and manipulate that data using the PDA's built-in spread sheet.

Hardware and Software Used

There are many PDA models on the market, which use different processors, operating systems, and communication protocols. The HP 620LX was chosen for this project. It uses a Hitachi S70 RISC processor, the Windows CE 2.0 operating system, and has a touch screen and a small, built-in QWERTY keyboard. It weighs 586 grams with battery, and measures 19.8 × 10.4 x 3.6 cm [5].

There are also different versions of the LabWorks interface, and the model used in this project was the LabWorks II. The PDA and interface are shown in Figure 1. As the figure shows, this setup is much smaller than a computer connected to the LabWorks interface.

Microsoft Visual Basic 6.0 and Microsoft Windows CE Toolkit for Visual Basic were used to write the PDA program. Visual C++ and its associated Windows CE Toolkit were considered as development platforms, but the extra complexity and capabilities of C++ made Visual Basic the best development tool for this project.

Establishing Communications

The HP 620LX and LabWorks interface both communicate with a standard PC using a 9-pin RS-232 serial port. Because both devices communicate with a PC, a null- modem gender-changing adapter is necessary to allow the PDA and interface to communicate with each other. Figure 2 shows this connection at the back of the LabWorks interface.

After connecting the PDA and LabWorks interface, it is necessary to confirm that the calculator and interface can communicate. SCI Technologies, manufacturers of the LabWorks interface, assisted with this part of the project by supplying the machine-level command codes for the interface. Using this information, the PDA was programmed to send a series of commands to the interface and then receive incoming data. Communications protocol for the LabWorks II interface is 9600 baud, 0 parity bit, no stop bit. To have the option to connect to other models of the LabWorks interface, the PDA program gives users the option to change communication settings. See Figure 3.

All commands and numeric values that are communicated between the PDA and the interface are in the form of ASCII characters. ASCII stands for American Standard Code for Information Interchange, a binary number-to-letter conversion code. In this system, upper and lower case letters, numerals, and symbols all have assigned binary values. Both commands and data are exchanged between the interface and the PDA using this encoding scheme.

The simplest command sent to the interface confirms that communications exist between the PDA and the interface. The LabWorks interface receives an ASCII B character from the PDA, it returns an ASCII U. This character displays on the PDA, authenticating that the two devices have power, are connected, and are communicating.

Digital Input

The LabWorks interface receives data from two general types of sensors, digital and analog. Digital measurements include time, drop counts, and photogate events. Timer readings come

 S1430-4171(02)03556-6, Published on Web 05/03/2002, 10.1007/s00897020556a, 730173mm.pdf

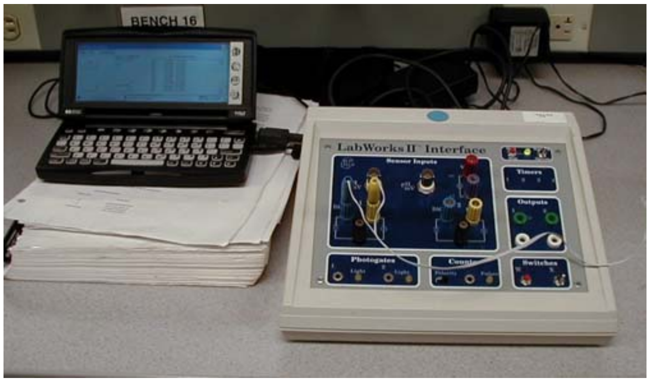

Figure 1. HP 620LX and LabWorks II Interface.

Figure 2. PDA serial cable attached to the LabWorks interface using a null modem gender changer.

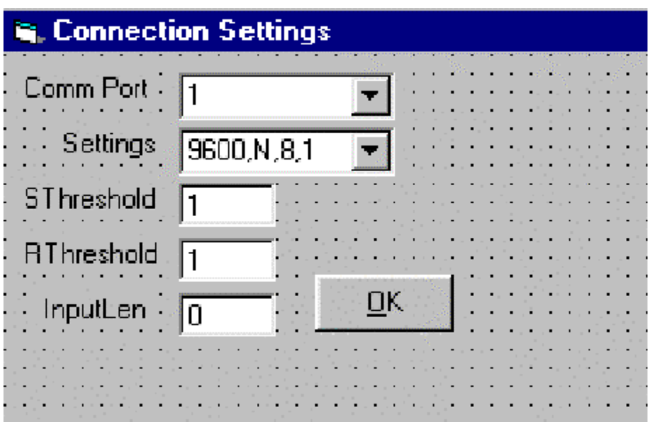

Figure 3. PDA/LabWorks interface communication settings.

directly from hardware or software and require no additional processing, while drop counts and photo events are integer values.

To collect data from a digital sensor, the PDA sends a specific byte to the interface, and the interface returns an appropriate number of data bytes. For example, the counter goes up to 65536 (2^{16}) and the interface sends this value to the PDA via two 8-bit ASCII characters. The PDA combines these ASCII characters into a single binary number and converts this number to an integer. The number is then displayed and stored. This process is identical to that used to send and receive data using an HP 48 calculator [3].

One improvement has been made in the digital measurements. Rather than use the hardware timer built-in to the LabWorks interface, this project employed a software timer that was part of Visual Basic. It is much quicker and easier to use a timer inherent in the PDA than it is to send timing commands and receive and process the incoming data bytes.

Analog Input

Analog measurements are more complicated and require more processing than readings from digital sensors. Typical analog input is electrical current or voltage, which comes from sensors such as a thermistor or pH probe. Data from these sensors are processed by the LabWorks interface's analog-to-digital converter (ADC) and require further manipulation in the form of calibration.

The LabWorks II interface uses a 12-bit ADC, which takes a theoretically infinite range of readings from a current or voltage source and changes this range to 4096 (2^{12}) discrete steps. For example, the LabWorks II's millivolt sensor reads a range of ±2048 millivolts in single millivolt increments. The interface reads the analog signal and converts it to a 12-bit binary number. The PDA receives this number in two bytes, like the counter, but only 12 bits of the incoming data are significant. The software then combines two data bytes received from the interface, drops the four irrelevant bits, converts the binary number to a decimal, and then sends this value to an appropriate calibration routine.

Interface Calibration Constants

Data received from the ADC is digitized, but is still not in a recognizable or useful form. Calibration constants for the various types of analog inputs are hard-coded in the LabWorks interface's erasable, programmable, read-only memory (EPROM) chip. In the LabWorks II PC software, these constants are copied from the interface into computer memory when the program starts. This process was difficult to duplicate with the PDA, and calibration constants were empirically derived and stored as variables in PDA software.

In some cases with the LabWorks PC software, analog readings go through multiple calibration routines before they are finally displayed on the computer. A thermistor reading is such a case. An electric current reading from the thermistor is sent to the interface and converted to a digital value by the ADC. An initial calibration routine changes this digital signal to microamps, then a second calibration converts the current reading to temperature. The PDA software does a single calibration, translating the raw ADC output directly to temperature. These new calibration values have been found empirically.

PDA User Interface

One of the major weaknesses of the previous HP-48 LabWorks project was the small display size and the lack of a user-friendly interface. Because most students are computer-literate and familiar with the Windows operating system, using a PDA and Windows CE gives users a head start on program operation. Most students should already know how to use software controls such as action buttons and drop down menus.

The first screen the user sees when starting the program is shown in Figure 4.

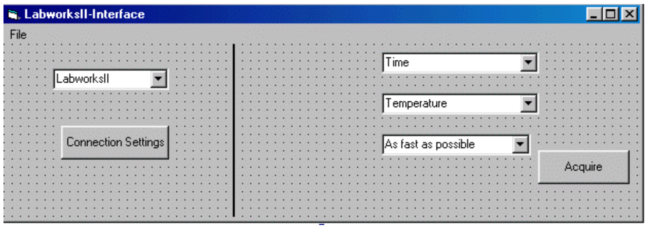

Figure 4. Opening Screen of LabWorks PDA Software.

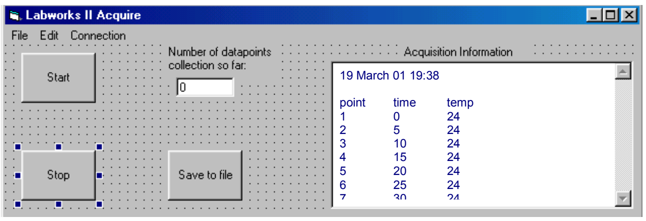

Figure 5. LabWorks-PDA data acquisition screen.

Users can select which interface, LabWorks II or II-100, which sensors to read, and how much delay between readings. The right side of the screen allows users to select which sensors they will use to take their experimental data. Time and temperature are the default measurements, but other sensors can be chosen from a drop down menu. A delay interval in the data acquisition process can also be set using a drop down menu. The acquisition speed is limited by the communication rate between the PDA and the LabWorks interface. The maximum rate of data acquisition is 3 to 4 data points per second. After sensors and delay interval have been chosen, users click on the Acquire button to begin taking data.

Taking Data

The data acquisition screen is shown in Figure 5. To begin taking data, users click on the Start button. As the data acquisition proceeds, the data is displayed in the Acquisition Information window.

To stop the experiment, the user clicks on the Stop button. If the experimental data is good, clicking on the Save to File button stores the acquired data in a text file.

Data Analysis

At this time, the best way to analyze data acquired by the PDA is to transfer the data to a personal computer and load the data into a spreadsheet program such as Microsoft Excel. A scaled-down version of Excel is loaded on the PDA, but this version does not support graphical analysis. The PDA saves the data file in a space-delimited text format, and Excel will automatically import the file and place the data in appropriate columns.

Conclusions and Future Work

The scope of this project was limited to a single model of PDA communicating with the LabWorks II interface. Future work will include the smaller, faster LabWorks II-100 interface communicating with different types of PDAs. Graphical analysis of data on the PDA should also be a goal to make this system more self-contained. A more capable and user-friendly interface to include student calibration and in-program data analysis will also be developed.

Acknowledgments. This project could not have been accomplished without the help of many individuals and organizations. Thanks go to the Department of Defense, the Air Force, and the Dean of Faculty at the United States Air Force Academy for providing the funding, workspace, and time to accomplish this work. Dennis Doney and Marie Dorsey from SCI Technologies provided invaluable information and assistance with the LabWorks interface. Finally, special thanks go to Cadet First Class Erich Kring for his initial work with PDAs and LabWorks.

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