WORKREADY ELECTRONICS
lab activity

Data Acquisition Lab
USB-Based Temperature Sensor

Acknowledgements: Developed by Jesus Casas, Faculty of Austin Community College, Austin, Texas

Lab Summary

PC-based data acquisition has been around for many years. Up until recently, data acquisition was done primarily through proprietary interface cards, the serial port, or the parallel port. Then, a few years ago, the USB (Universal Serial Bus) was introduced. As time progressed, more and more peripherals implemented this new bus type, making the parallel and serial ports obsolete. This lab utilizes the USB port to acquire data from a temperature measuring circuit. The circuit introduces the fundamental building blocks of a data acquisition system and the PN junction as a viable temperature sensor.

Lab Goal

The goal of this lab is to build a functional and calibrated USB-based temperature measuring system.

Learning Objectives

1. Construct and calibrate a USB-based temperature measuring system.
2. Measure different temperatures of water and compare the readings of the Temp-USB program against that of a thermometer.

Time Required

Approximately 3 hours

Equipment and Supplies

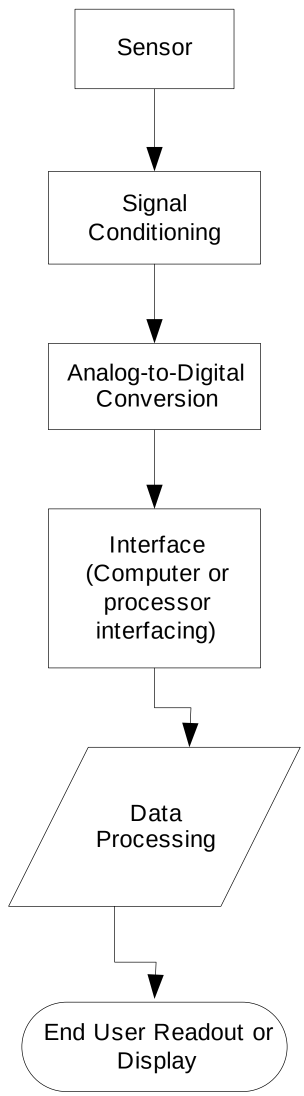
Part	Quantity
DLP-USB245M Module (http://www.dlpdesign.com/usb/)	1
DLL Drivers (http://www.dlpdesign.com/usb/usb245.shtml)	1
ADC0831 Analog-to-Digital Converter	1
INA122 Instrumentation Amplifier	1
2N2222 Transistor	1
10 kOhm Resistor	1
10 kOhm Potentiometer	1
100 kOhm Potentiometer	1
Lab Software (Visual Basic programs)	1
Styrofoam Cups	2
Assorted Sizes Heat Shrink Tubing	As needed
Thermometer: Glass-type; range of 32 thru 212 degrees Fahrenheit)	1
PC with Visual Basic 6.0 installed	1
Protoboard	1
Wire	As needed

Lab Preparation

1. Assemble all equipment and components.
2. Read Introduction (below)
3. Review Lab Procedures (below)
4. Read the User Manual for the DLP-USB245M module.
5. Read the specification sheets for the ADC0831 analog-to-digital converter and the INA122 instrumentation amplifier.

Lab Introduction

A typical electronic measuring system can be represented by the following flow chart:



A ***sensor*** is a device that performs the initial measurement and energy conversion of a variable into analogous information (usually electrical). A sensor is also called a "transducer" because "transducer" represents a device that converts any signal from one form to another. For example, a device that converts a voltage into a proportional current would be a transducer. In other words, all sensors are transducers, but not all transducers are sensors.

Often, the desired signal from the sensor may not always be in the form that is needed, therefore the signal must be altered (conditioned) to meet the requirements of the analog-to-digital (ADC) converter. This ***signal conditioning*** can include amplification, buffering, filtering, linearization, decoding, or detecting the signal.

The analog output signal of the signal conditioning circuit is then converted into a digital signal (***data***) which can be interfaced to a computer or microprocessor.

The digital signal is then processed electronically (***data processing***). In this stage, the data is analyzed, examined, and some form of conclusion or output is derived.

Finally, it is converted to a form useful to the user. The user can be a human observer, a control mechanism, a computer, or a recording system. The user can also be part of an automatic control system, in which the data is acted on in some manner to control a process. For human observers, the output is normally made into some form of visual display but occasionally is made into an audible form.

P-N Junction Temperature Sensors

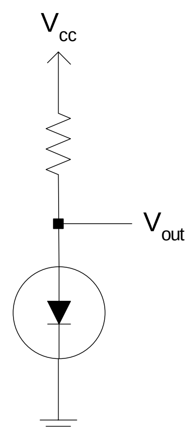
The sensor used in this lab is of the silicon kind, a P-N junction to be exact. This type of sensor has been used in applications from thermostats to cryo-pumps. Recently, silicon sensors, which employ several P-N junctions, have become increasingly important transducers in electronic systems. As systems become increasingly smaller and inherently hotter, it is increasingly vital to monitor critical temperatures. Silicon sensors have been incorporated into the die of microchips, a place where traditional sensors, such as thermocouples, thermistors, and resistance temperature devices (RTDs) are not easily integrated.

Each of the traditional temperature sensors has its advantages and disadvantages. Thermocouples are ideal for monitoring extreme temperatures, but are not very accurate or stable. Thermistors have small form factors, low cost, and high sensitivity, but they operated over a limited temperature range. They also require additional conditioning circuitry to overcome nonlinearities. RTDs are accurate and stable, but are expensive due to the platinum wire used as the sensing mechanism. Many traditional sensor types are non-linear and require extensive signal conditioning; however, P-N junction based sensors are linear, accurate, and low-cost.

A single P-N junction temperature sensor is sometimes referred to as a diode temperature sensor. Diodes are affected by temperature, just as all semiconductor devices are. An increased temperature means increased thermal activity and decreased diode resistance. This holds true for both forward and reverse diode operation.

As temperature increases, I_F will increase for a specified value of V_F. As temperature increases, V_F will decrease for a specified value of I_F. In practice, a rise in temperature will usually be followed by both a slight increase in I_F and a slight decrease in V_F.

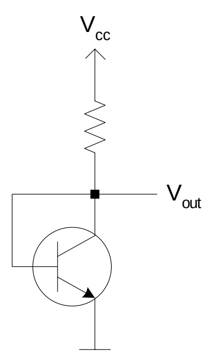
It is the V_F that is monitored in a diode temperature sensor. Since this is the case, the easiest way of developing a V_F across the diode is to place it in a voltage divider circuit such as the one shown here.



Though a diode can be used as a temperature sensor, other semiconductor devices having a P-N junction can be used as well.

A BJT transistor can readily serve as an inexpensive temperature sensor. Silicon transistors used in this way have a temperature coefficient of about -2mV/EC. That is, at 0 EC, the drop would be about .8 volts. As temperature increases, the forward voltage drop decreases. At 100 EC, the forward voltage drop will be about 0.6 volts. Although every transistor has a slightly different temperature coefficient, all transistors vary linearly with temperature.

In this lab, a standard 2N2222 transistor will be used to measure temperature. If the collector and base of the 2N2222 transistor are shorted together, a diode is provided by the base/emitter junction. When power is applied across this junction, a V_F is developed. The easiest way to develop a V_F across the diode junction is to place the transistor in a voltage divider circuit such as the following.



Signal Conditioning
In this lab, the signal conditioning will be handled by Burr-Brown's INA122 instrumentation amplifier. The INA122 provides low noise differential signal acquisition and is ideal since it can be operated with a single 5 volt power supply.

Since the V_F of the P-N junction will vary approximately between .560 and .660 volts, a voltage divider will provide a reference voltage at $V\text{-}_{IN}$ of about .560 volts and the gain will be adjusted so that the output of the INA122 is just below 5.0 volts when the V_F is about .660 volts.

The goal is to have the output range of the INA122 be between 0 and 5 volts which will then be feed into the ADC.

The analog-to-digital conversion will be handled by National Semiconductor's ADC0831. It is a single input, 8-bit, serial output converter. The ADC0831 is TTL/MOS compatible and it operates from a single 5 volts power supply, consuming only 15 mW.

This lab will interface the digital output of the ADC0831 to the PC USB port via DLP Design's DLP-USB245M Module. This module provides an easy method of transferring data to / from a peripheral and a host at up to 8 million bits per second. The module can utilize both Virtual Com Port drivers as well as DLL drivers. This lab makes use of the DLL drivers.

In both sensor and signal conditioning, the output is represented in some functional relationship to the input. The only stipulation is that this relationship be unique: that is, for each value of the input variable there exists one unique value of the output variable.

Functional relationships (transfer functions) need to be represented mathematically due to the dominance of computers and microcontrollers in measurement applications. The output of the ADC0831 is the data, once this data is inputted into a computer or microcontroller, an equation is needed which will convert the data value into a desired form of output, such as temperature.

In this lab, the output of the temperature sensor is linear; therefore, both the output of the instrumentation amplifier and the output of the ADC are linear. A linear equation will be arrived at by use of two extreme data points and their known temperature.

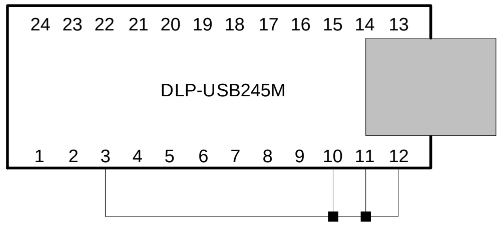
A linear relationship between input and output is highly desirable and the simplest method to use. When a linear relationship exits, a straight-line equation can be used to relate the measured variable and measurement output.

The equation for a straight-line is $y = mX + b$, where X is the input, m is the slope of the line, b is the y-intercept, and y is the output. In this lab, the data from the ADC0831 is X and temperature, in Fahrenheit, is y.

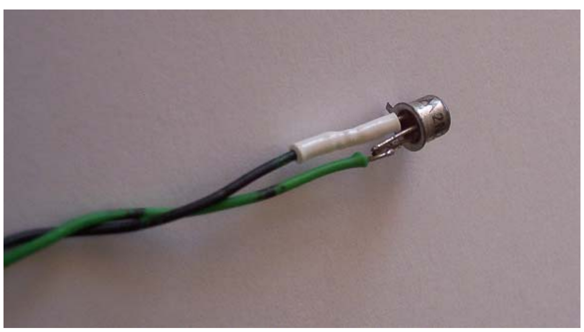
The end result of this lab will be displayed in a Graphical User Interface written in Visual Basic (Version 6.0).

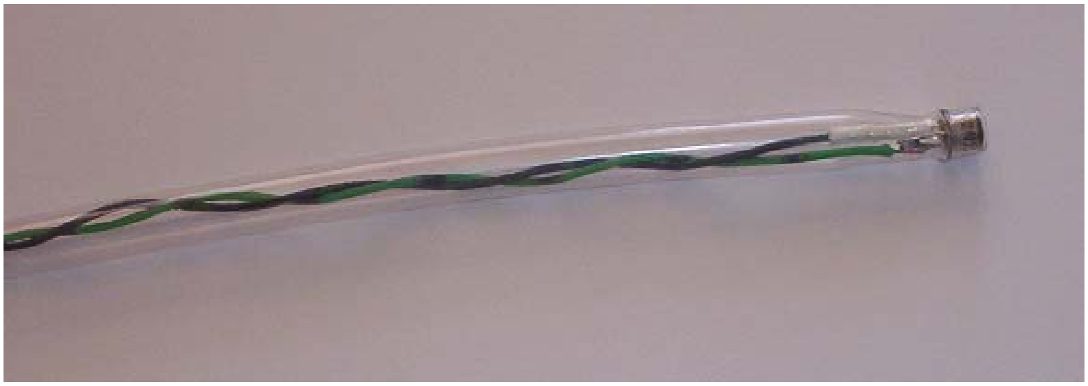
Lab Procedures

1. Configure the DLP-USB245M module to work off of bus-power. Wire the module according to the following diagram. Do **not** connect to the PC's USB port yet.

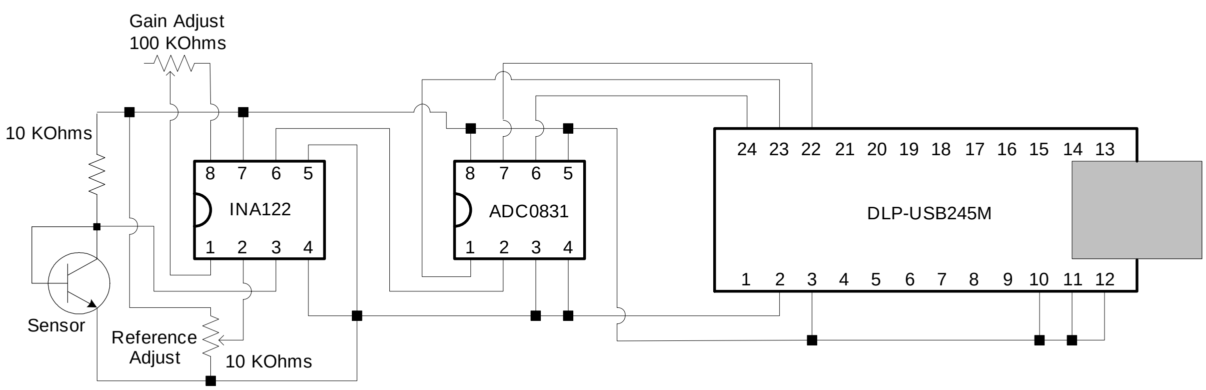


2. Download the appropriate DLL version of the device drivers from either www.dlpdesign.com or www.ftdichip.com . Unzip the drivers onto a folder on the hard-drive or onto a blank floppy disk.
3. Connect the DLP-USB245M module to one of the PC's USB ports.
   a. The operating system will recognize that a new USB device has been plugged in and will prompt you for the location of the drivers.
   b. Select the folder where the DLL device drivers were stored in Step 2.
   c. Windows will then complete the installation of the device drivers.
   d. Once installed, the drivers will be automatically loaded whenever the DLP-USB245M is connected.
4. To see the USB connection tree and the USB devices that are connected to it, along with their configuration data, use USBView, which can be downloaded from www.dlpdesign.com .
5. Make the sensor by using a 2N2222 transistor (see figures below).
   a. Join the base and collector leads, and solder a wire lead to them.
   b. Solder another wire lead to the emitter.
   c. Use heat-shrink tubing to form a watertight seal around the transistor.





6. Assemble the following circuit. (Note: A picture of the Protoboard layout is at the end of this procedure.)



7. Connect the above circuit to the PC's USB port.
8. Run the lab software program named "Temp-USB." The software is under the Learning Resources tab of this module titled "USB Temperature lab software."
9. Place the sensor and thermometer in a cup of very hot water.
10. While monitoring the decimal value readout on the software program, adjust the reference adjust potentiometer until the decimal value is about 20. Write down the decimal value shown and the temperature. These values are X_1 and Y_1 respectively.
11. Place the sensor and the thermometer in a cup of ice water.
12. While monitoring the decimal value readout, adjust the gain adjust potentiometer until the decimal value is about 235. Write down the decimal value shown and the temperature. These values are X_2 and Y_2 respectively.
13. Repeat Steps 9 thru 12 to ensure the circuit is calibrated.
14. Using the X,Y data points from Step 10 and 12, calculate the slope and the y-intercept for the straight line equation: $y = mX + b$.
15. Input the slope and y values into the Temp-USB program.
16. Measure different temperatures of water and compare the readings of the Temp-USB program against that of the thermometer. Compare the results.

Protoboard Layout