Experiment-0

Laboratory Preliminaries and Data Acquisition Using LabVIEW

Introduction   The objectives of the first part of this experiment are to introduce the laboratory transformer and to show how to operate the oscilloscope as a curve tracer, displaying either a voltage transfer curve (VTC) or a current-voltage (I-V) characteristic. Other procedures are designed to better acquaint you with the test equipment in the laboratory.

The objectives of the second part of this experiment are to become acquainted with using computer-conrolled instrumentation for data acquisition. LabVIEW, a program developed by National Instruments, is the industry standard for programming computer-controlled instruments, and it will be used in this experiment as well as others to measure and record sensor readings and to characterize various electrical systems and devices.

LabVIEW is a graphical programming environment. Unlike C/C++ where programs are written in text, LabVIEW creates Virtual Instruments (VIs) by graphically composing them from different elements and structures that are placed like the blocks of a block diagram and interconnect with wires to indicate the intended signal flow paths. This is referred to as "G-code" for the graphical language that it uses. The most important aspect of understanding LabVIEW virtual instruments (VIs) is that they are data-driven, meaning that the execution of the block diagram procedes along the same path as which the data propagates through the block diagram. A new block is not executed until the new data arrives at its input. This is quite different from the event-driven programming of Windows, or the more familiar procedure-driven programming of FORTRAN, Pascal, or C/C++. A complete tutorial for programming in LabVIEW will not be presented in this laboratory handbook since other excellent references exist for this purpose.

This experiment will introduce opening and running virtual instruments in LabVIEW and using it to control a data acquisition (DAQ) hardware for making electrical measurements. In addition, some simple modifications to the virtual instruments will be performed to gain some experience with using the LabVIEW graphical interface and programming language. These basic operation skills will be useful starting points for developing more complex data acquisition instruments in later experiments, and will form the basis for automated measurement of semiconductor device characteristics. One of the important advantages of computer-based instruments is that recording measurement data becomes very easy, and some of this will be introduced in this experiment also.

Precautions   Procedure 2 in this experiment requires you to run a resistor far above its rated
                    power limit. This will cause the resistor to heat up excessively and the danger
                    to the operator is a thermal burn. Please handle the resistor in this section
                    with caution, allowing it to cool after use before it is handled.

Procedure 1   Transformer voltages

Comment   The two outputs of the lab transformer are nominally rated at ±6.3 VAC, rms with respect to the neutral terminal. This value of output voltage applies when the output current is at its full rated value of 2.0 Amps. In an unloaded condition the output voltage is closer to ±7.5 VAC, rms (a 10.6 V amplitude sinusoid) with respect to the neutral terminal. Because the two outputs are rated ±6.3 VAC, rms with respect to the common neutral terminal, they are also rated at 12.6 VAC, rms with respect to each other with a 2.0 Amp load current. They produce 15.0 VAC, rms (a 21.2 V amplitude sinusoid) in an unloaded condition. Your measured voltages may be a little different from these.

Set-Up   For this procedure you only need the laboratory transformer, the oscilloscope, a DC power supply, and some hook-up leads. When you perform this procedure, connect both the common terminal of the DC supply and the oscilloscope ground lead to the lab transformer ground terminal (green) and connect the power supply output to the appropriate lab transformer output. Be very careful to maintain only one ground point in your circuit! Vary the DC output voltage to get the desired offset voltages. If your sine wave does not have the specified amplitude, then adjust the offset voltages.
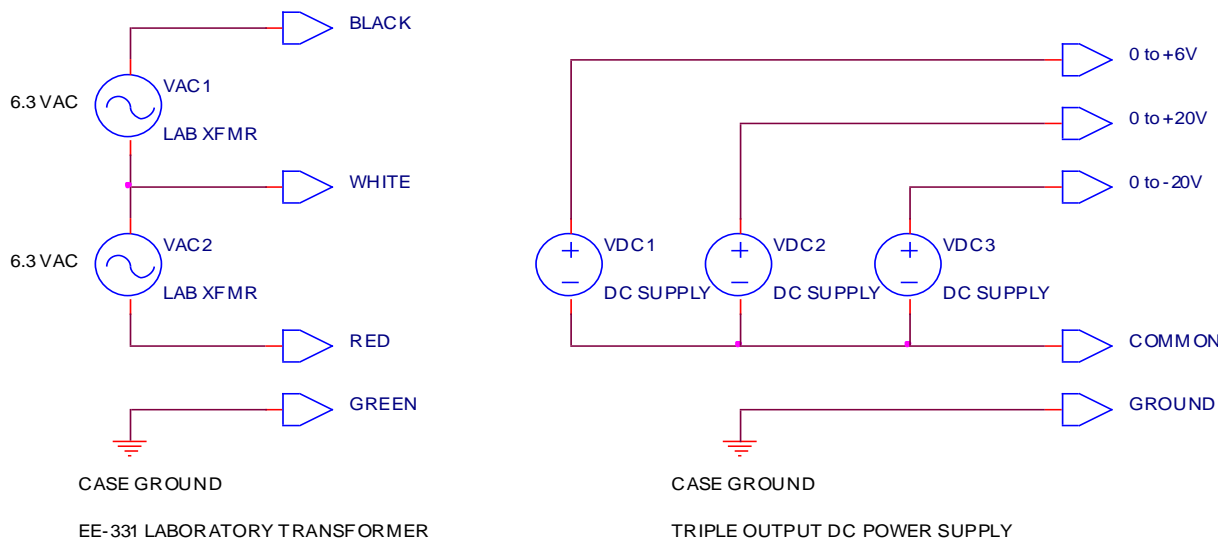

Figure E0.1

Measurement-1   Display (and printout) on the screen of your oscilloscope the following output sinusoids from the lab transformer:
- A 10.6 V amplitude sinusoid with a −10.6 V offset voltage
- A 10.6 V amplitude sinusoid with a 0.0 V offset voltage
- A 21.2 V amplitude sinusoid with a 0.0 V offset voltage
- A 21.2 V amplitude sinusoid with a +21.2 V offset voltage

To do this, set the center line of the oscilloscope display so that it corresponds to zero volts and set the oscilloscope coupling to DC. As with all required oscilloscope printouts in this course, paste, tape, or staple the printout into your lab notebook and include any important information about the situation (instrument settings, etc.) under which the data was taken.

Comment   Because the input is DC coupled to the oscilloscope, the only way to produce these waveforms is by connecting the power supply to the appropriate output terminal. This sets the terminal to the DC voltage output by the supply. You can do this because the three lab transformer output terminals have a fixed voltage relative to each other, but no fixed voltage relative to ground; there is no connection between any of the secondary windings and anything else except via the flux linkages to the primary of the transformer. When one of the secondary outputs is set to a DC value, the other voltages remain at their relative potentials, shifting up or down to accommodate the one fixed potential.

Question-1   (a) In producing the above waveforms, how much DC current flows through the ground connection (the green binding post) when it is connected to the DC power supply? You should be able to deduce what this current is; however, you can also measure it with an ammeter. Explain why the current is what it is.

(b) How pure is the power line sinusoid? Describe any deviations that you see.

Procedure 2   Internal resistance of the lab transformer

Comment   This procedure will dissipate more power in the 100 Ω load resistor than its rated value of 1/4 W, resulting in a very hot resistor. It is possible that the resistor may get hot enough to burn your fingers should you try to handle it while it is connected to the power supply (or immediately after the current through the resistor has been turned off). When performing this procedure, use the solderless breadboard to hold the resistor and control the current through the resistor via the lab transformer power switch. Try to minimize the time that the current flows through the resistor in order to minimize its heating.

Set-Up   For this procedure you will use the lab transformer and a 100 Ω, 1/4 W resistor from your lab kit. Disconnect all wires from the outputs of the lab transformer, turn it off and plug it into a 120 VAC receptacle.
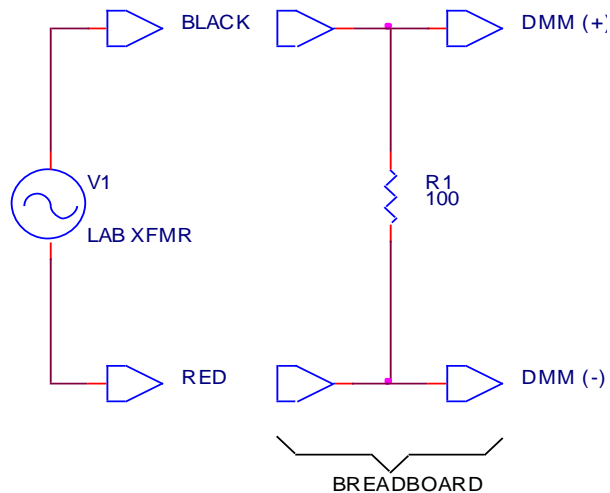

Figure E0.2

Measurement-2   Use the red and black output terminals of the lab transformer to produce the largest possible sinusoid. With no load present, turn on the transformer and measure precisely the rms output voltage of the lab transformer with a DMM (set to AC volts) and record this value in your notebook.

Turn off the transformer and connect the selected outputs to a 100 Ω resistor mounted on the breadboard (see Fig. E0.2). Connect the DMM across the resistor and configure the DMM to read AC volts, turn on the power and read the voltage across the resistor. Turn off the power immediately after the measurement in concluded and record the value of the voltage across the resistor in your lab notebook.

Question-2   (a) Assuming that the load resistor does not change its resistance when it heats up (it does somewhat), how much power is dissipated in the resistor?

(b) Using the data that you have taken, what is the effective source resistance of the lab transformer when it is configured to output its largest voltage?

(c) What is the smallest 1/4 W resistor in your lab kit that can be hooked up to the lab transformer between the red and black terminals without exceeding the resistor's power rating?

Procedure 3   *Create a curve tracer with your oscilloscope!*

Comment   In this procedure you will use a standard oscilloscope and the laboratory
                 transformer to display the current-voltage (I-V) characteristics of two
                 components: a diode and a resistor. This procedure relies upon the ability to
                 float the transformer output at a potential which is different from the ground
                 of the oscilloscope.

Set-Up   Connect the circuit as shown in Fig. E0.3 using the following components
                     R1 = 1 kΩ 1% 1/4 W resistor
                     DUT (Device Under Test) = 1 kΩ 1% 1/4W resistor or a 1N4007 diode

                 Connect up only one component as the DUT at any time. For the diode, note
                 that the banded end is the cathode which corresponds to the bar end on the
                 circuit symbol. When a diode is used as the DUT, connect its cathode end to
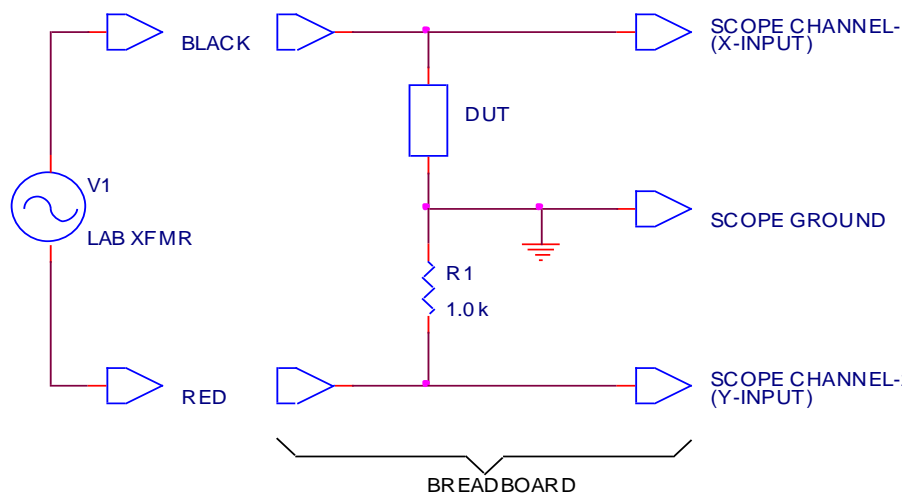   R1.

Figure E0.3

Measurement-3   Turn the lab transformer power switch off and plug it into a 120 VAC
                 receptacle. Connect one lead from the black terminal (+6.3 VAC) of the lab
                 transformer to the DUT (select the 1N4007 diode first) and then connect
                 another lead from the red terminal (−6.3 VAC) of the lab transformer to the
                 resistor R1 on the breadboard as indicated in Fig. E0.3. This will establish a
                 21.2 V amplitude, 60 Hz sinusoidal input to the circuit.

                 Next, configure the oscilloscope to display the I-V curve as follows. Attach
                 the channel-1 oscilloscope probe to the DUT (at the same end as the power
                 connection) and connect its ground lead to the point between the DUT and the
                 resistor. Attach the channel-2 oscilloscope probe to the resistor R1 (at the
                 same end as the power connection) and also connect its ground lead to the
                 point between the DUT and the resistor. Configure the oscilloscope for an X-

Y display and invert the signal on channel-2. Make sure that the DUT voltage appears as the X-axis and the resistor R1 voltage as the Y-axis. Since the voltage across the resistor is linearly proportional to the current through it and the DUT, the vertical (Y) axis also represents the diode current with a scaling factor of 1 Volt per milliamp.

Turn on the transformer and display the DUT I-V characteristic on the oscilloscope. Make sure that the oscilloscope coupling to each channel is set to DC. Calibrate the curve by aligning the displayed I-V characteristic to the origin of the screen display. Sketch a copy of the I-V characteristic in your notebook using 1 V/div for the X-axis and 1 mA/div for the Y-axis. Record any extra information that you think may be important.

Repeat this procedure for the resistor.

Question-3   Which of the above DUTs is a linear circuit element?

Procedure 4   *Oscilloscope input resistance*

Comment   All voltage measurement devices, such as the DMM and oscilloscope, draw some current from the circuit to which they are connected. For a high quality instrument, the key is to minimize this current so that the voltmeter affects the circuit as little as possible. In this procedure the input resistance of the oscilloscope and its probes will be measured.

Set-Up   For this procedure you will need the following component
R1 = 10 MΩ 5% 1/4W resistor
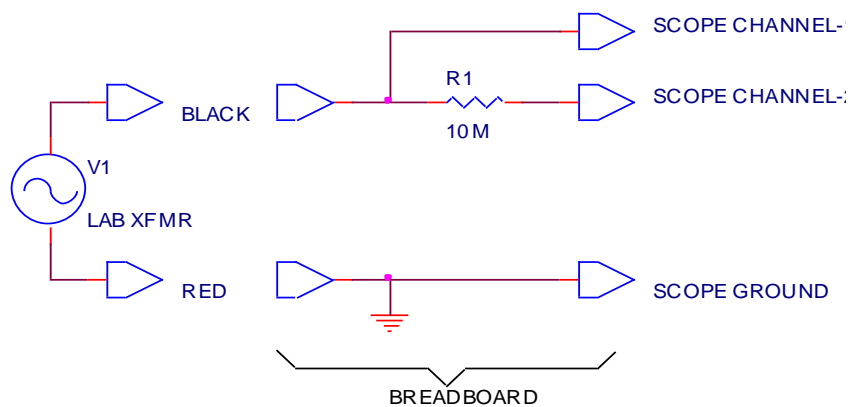which is connected as shown in Fig. E0.4.

Figure E0.4

Measurement-4   Set both channels on the oscilloscope to DC coupling and to either 5 or 2 V per division. Using simple 1X probes, record the voltages as measured by each channel. You can read the voltage off the display or use one of the options from the measurement menu of the oscilloscope. Repeat the measurements using 10X probes for the oscilloscope.

Question-4   Using the data you recorded and the fact that the internal resistance of the laboratory transformer is quite small compared to the 10 MΩ resistor, calculate the input resistance of the oscilloscope with a 1X and with a 10X probe, assuming that both channels have the same input resistance.

Procedure 5   When is a wire not a wire?

Comment   A common frustration is that the components indicated in text books and in schematics represent ideal elements, and yet there are no such things as ideal resistors, inductors, or capacitors. Every real component has at least a little of each! The purpose of this procedure is to illustrate a situation where two common components behave quite differently from their ideal forms.

Set-Up   For this procedure you will need the following components:
                R1 = 100 Ω 5% 1/4 W resistor
                R2 = an 8 inch length of hook-up wire
                C1 = 10 µF electrolytic capacitor.
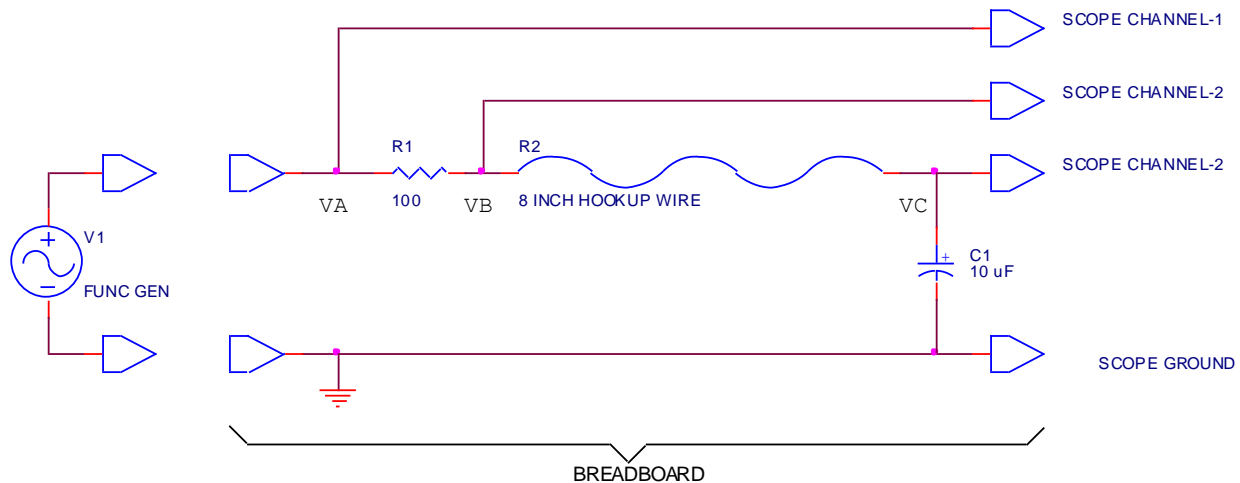   These components are to be connected as shown in Fig. E0.5.

Figure E0.5

Measurement-5   Configure the function generator to output a 5.0 V amplitude, 10 MHz sinewave. Construct the circuit on your breadboard as shown above, connecting both channel-1 (V_A) and channel-2 (V_B) to the leads of resistor R1. Be sure to use only one piece of hook-up wire and to connect the ground of the function generator and oscilloscope probes directly to the capacitor lead. If the capacitor lead is too short to allow all of these connections to it, then use a short piece of hook-up wire (less than an inch long) plugged into the breadboard next to the capacitor and connect your grounds to that.

Channel-1 gives the total voltage applied to the circuit. Measure the magnitude of each sinusoid and the phase of V_B relative to V_A. Switch the channel-2 probe to the capacitor lead as shown above and measure the magnitude and phase of V_C (relative to V_A).

Comment   Phasor analysis can be used to treat linear circuits with sinusoidal excitations under steady-state conditions. The phasor voltages V_A, V_B, and V_C all contain

both magnitude and phase information. The current through each element is the same, since they are in a series connection, and equal to I = (V$_A$ − V$_B$)/ R1. Knowing the current phasor, the impedance of the wire and capacitor can be calculated as Zwire = (V$_B$ − V$_C$)/ I and Zcap = V$_C$ / I.

Question-5   Using the data you recorded and the above equations, answer the following:
(a) What is the impedance of the wire? Is it predominantly inductive, resistive, or capacitive?
(b) What is the impedance of the capacitor? Is it predominantly inductive, resistive, or capacitive?
(c) Using a few well-chosen sentences, summarize what you have learned in the form of "advice" you would give a friend about how to make a circuit that operates at 10 MHz.

Procedure 6   Temperature measurement using LabVIEW and DAQ hardware

Comment   The goal of this procedure is to get LabVIEW up and running and open an existing VI which can be used to measure and log the ambient temperature using an LM35DZ integrated circuit temperature sensor.

Set-Up   The first step is to set up the data acquisition (DAQ) hardware. All of the these laboratories will utilize the National Instruments NI-USB-6009 DAQ which provides 8 single-ended or 4 differential analog inputs with 14-bit resolution and up to 48 kS/s sampling, 2 analog outputs with 12-bit resolution and up to 150 S/s data rate, a 12-bit multifunction digital I/O block, and a built-in 32-bit counter module. This DAQ is very versatile and completely powered through the USB connection. To connect the DAQ to the computer, simply use a standard USB cable to any USB 2.0 port on the computer. Once connected, the DAQ will be recognized by the computer, and if a driver has not already been installed, the Windows operating system will automatically install the driver for it. Connect the NI-USB-6009 DAQ to the computer using a standard USB cable if it is not already connected.

Inputs and outputs to the DAQ are from 16 screw terminals on each side of the DAQ. The most convenient method for using the NI-USB-6009 in these laboratories is to use a solderless breadboard, also known as "superstrip", and make connections to the DAQ using some solid wire jumpers, as shown below in Fig. E0.6a. The best wires to use are 8 inch long, solid, #22 gauge, with different insulation colors to distinguish the different pins, as also shown in the figure. This system then allows subcircuits to be easily constructed on the superstrip and allows the DAQ to easily connect to any tie points on the superstrip for signal acquisition or injection.
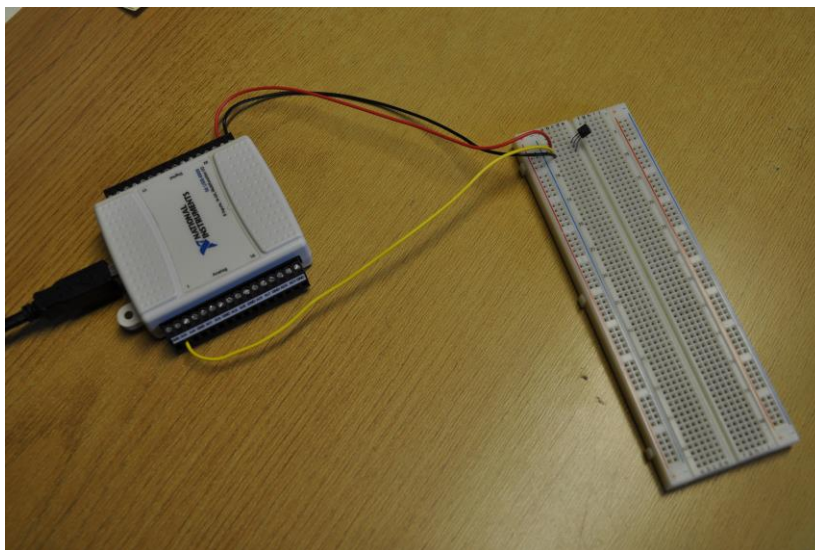

Figure E0.6a

The ambient temperature is measured by an LM35DZ temperature sensor which is a small 3-lead part in a TO-92 case. A DC voltage of 4~20 Volts is supplied between the VS and GND pins, and the device will output a DC voltage between the VOUT and GND pins which is proportional to the ambient temperature in degrees Celsius. The conversion factor for the LM35DZ is 100 mV/°C, and it is calibrated so that 0°C will produce 0.0 Volts output. Looking at the LM35DZ with its labeled flat side facing you and its leads pointing downward, the pin on the left is VS, the pin in the middle is VOUT, and the pin on the right is GND. A +5 Volt DC power supply can be obtained from the NI-USB-6009 DAQ itself, using the +5V terminal, pin #31, and the digital ground terminal GND, pin #32. These two leads can be used to power up the LM35DZ temperature sensor. For a stable output, the LM35DZ should have a 200 Ω load resistor connected between the VOUT and GND pins. The output voltage is then taken across this 200 Ω load, as shown in Fig. E0.6b below.
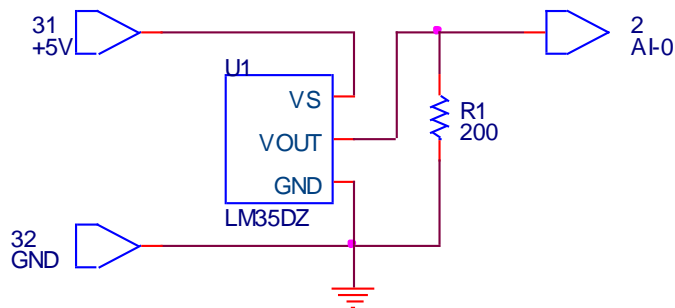

Figure E0.6b

As shown below in Figs. E0.6c and E0.6d, use a superstrip and some solid insulated wire jumpers to connect an LM35DZ temperature sensor to the NI-USB-6009 DAQ. Connect a wire from analog input 0 (ai0, pin 2) on the NI-USB-6009 DAQ to VOUT lead (center) of the LM35DZ, shown in yellow in the figures below. Connect a wire from ground (GND, pin 32) on the NI-USB-6009 DAQ to GND lead of the LM35DZ, shown in black in the figures. Connect a wire from the +5.0 Volt power supply (+5V, pin 31) on the NI-USB-6009 DAQ to VS lead of the LM35DZ, shown in red in the figures. Finally, connect a 200 Ω 1/4 Watt resistor between the VOUT and GND leads of the LM35DZ. The two black screw-terminal blocks on the DAQ should have some decals attached which identify the terminals. If not, see the TA or lab manager for some replacement decals. The terminal blocks can also be removed and changed from the DAQ, if needed as well.
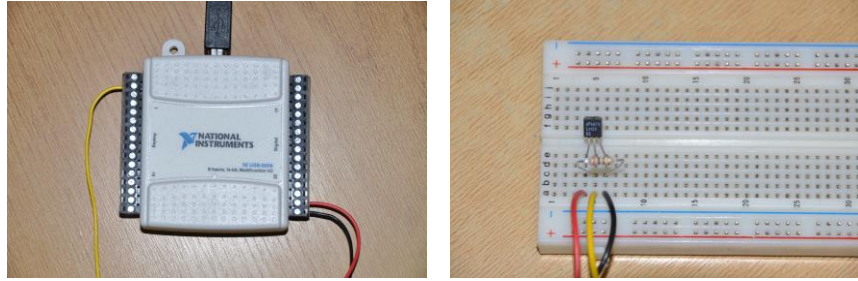
Figure E0.6c,d

A very simple and quick method to test that the DAQ card is connected and working properly is to use the National Instruments Measurement and Automation Explorer (NI-MAX). From Windows, launch the Measurement and Automation Explorer (NI-MAX) from the Start Menu by clicking on Start > All Programs > NI-MAX, or alternatively, there may already be a shortcut for NI-MAX on the desktop. After NI-MAX opens, on the left hand side of the window is a configuration panel. Click on the expand button [+] beside Devices and Interfaces. Select the NI USB-6009 DAQ, and the Settings and External Calibration should appear in the central panel. Above the central panel, click on a toolbar button called "Self-Test." This should return a small message window saying that the device has passed its self test. This indicates that the DAQ is properly connected to the computer, that Windows has properly recognized the device and has loaded its drivers, and that LabVIEW has properly registered the device so that it can be accessed by various VIs that call it. This self-test only tests the DAQ computer connection, not anything that may be connected to the DAQ I/O pins.

If you wish to test the system further, the toolbar button to the right of "Self-Test" is "Test Panels…" and this provides a more detailed set of commands which directly control the DAQ card and can be used to insure that the entire system is working properly. Click on "Test Panels…" and select the Analog Input tab. Make sure that the Channel Name is set to Dev1/ai0 and the Mode is set to On Demand. Change the Max Input Limit to 5 and Min Input Limit to 0, and change the Input Configuration to RSE (referenced, single-ended). Click on Start, and the chart should show a streaming set of analog measurements from the ai0 channel of the DAQ in the range of 0.25 to 0.35 (Volts). This validates that the LM35DZ is properly connected to the DAQ and that the DAQ is properly sampling the voltage on the center output lead of the device. Click Stop to halt the data streaming and close the Test Panels window.

The National Instruments device driver system allows multiple USB hardware devices to be installed simultaneously. Each are uniquely identified by their hardware model number and serial number, and each are given a name which allows them to be more conveniently referred to in various VIs. The present name for the NI-USB-6009 appears in the box to the right of "Name" and it probably says something like Dev1 or Dev2. All of the laboratory VIs have

been written for the NI-USB-6009 DAQ as "Dev1." If the NI-USB-6009 is not listed as "Dev1" you can change this by typing in "Dev1" in the name box and clicking on the Save button at the left top of the central panel. If it responds saying that Dev1 is already in use, make the change anyway. Do this now if your DAQ is not already listed as "Dev1." If the DAQ has the wrong name assigned to it, none of the VIs will properly recognize it. Once you have verified that the DAQ is properly connected and named Dev1, you can EXIT MAX at this point.

The next step is to launch LabVIEW and start up a VI which has already been written for making a simple temperature measurement. From the Windows Start Menu, click on Start > All Programs > National Instruments LabVIEW, or use the desktop shortcut if it is present. All of the VIs are written in LabVIEW version 13.0, and will run on any version of LabVIEW that is 13.0 or more recent. The main LabVIEW window should appear. Use the Open Existing button to navigate to the EE-331 laboratory VIs and select the TempSensorReadout.vi. LabVIEW will first open the front panel window for this VI which is from where the virtual instrument is controlled. If you wish to view the internal G-code for this instrument, click on Window > Show Block Diagram (or type Ctrl+E). This is a relatively simple VI, and the block diagram shows how the voltage reading from the DAQ card is first multiplied by a factor of 100 and then sent to a waveform chart for display. The temperature readings are taken each 500 milliseconds, and a STOP button is set up to end the program. LabVIEW virtual instruments (VIs) always consist of two parts: a front panel and a block diagram. Ctrl+E switches between the two. Only the front panel needs to be open in order to run the VI.

Measurement-6   To start the temperature measurement VI, make the front panel window active by either clicking on it somewhere or select it from the Window menu. Click on the run button, which is shaped like a right-pointing arrow on the toolbar. The front panel appearance will change from the grid pattern to a solid pattern, and the stop sign will turn to brighter shade of red. The waveform chart will start scanning and you should soon see a signal waveform appear that represents the running output of the LM35DZ temperature sensor being sampled every 500 milliseconds.

After the measurement has been running for a few seconds, press your finger tip onto the top of the LM35DZ temperature sensor and you should see the measured temperature rise by a few degrees Celsius. After removing your finger tip, you should similarly see the measured temperature fall back to close to its original value. Once you have finished running the VI, you can stop it by simply clicking on the rectangular STOP button on the front panel. If for some reason this does not work, you can stop the VI by clicking on the red stop sign button in the toolbar. The results of a rising temperature are shown in the screen shot of Figure. E0.6e.
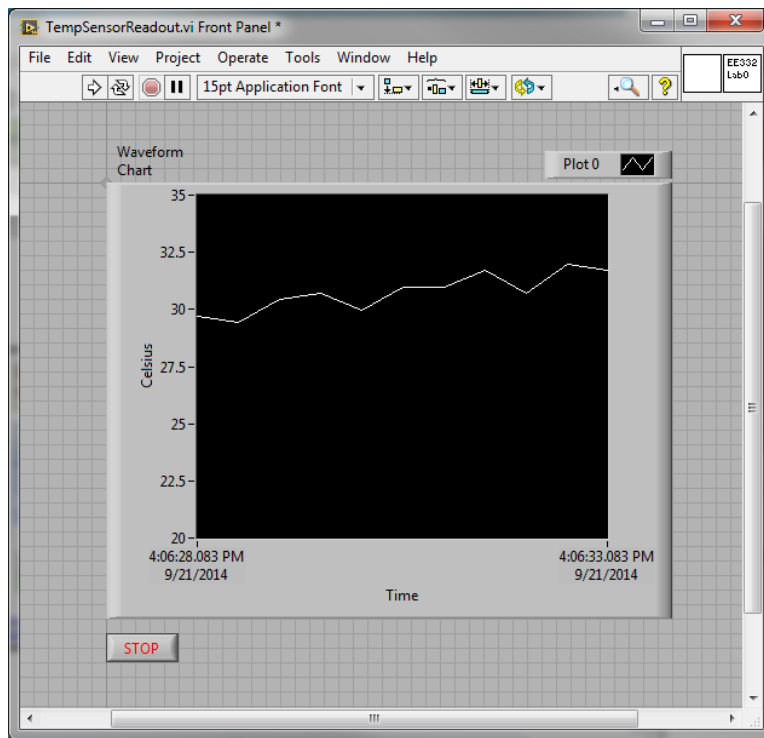
Figure E0.6e

Comment Generally, it is always best to stop a running VI by using the STOP button that is part of the VI front panel. Using the red stop sign button to stop the VI is a more drastic measure which sometimes leaves LabVIEW in a less predictable state. The red stop sign is really a program abort, which should be used as a last resort.

Question-6 Explain the time dependent behavior of the measured voltage that you observed in the above. Speculate on what factors determine how fast the temperature sensor will react to a change in its case temperature. Suggest some ways of speeding this up, or for slowing it down.

 The waveform chart attempts to display the data from the temperature sensor as a "real-time" signal that moves across the display. From the sampling at 500 ms intervals, you should notice some corners in the waveform as the chart connects the data points by straight lines. Describe how the sampling rate affects (or does not affect) the response time of the temperature measurement system.

Procedure 7   Adding a Celsius to Fahrenheit conversion

Comment   This next procedure will modify the previous VI to add a Celsius to Fahrenheit conversion, allowing the measured result to be displayed simultaneously on both temperature scales.

Set-up   If the previous TempSensorReadout.vi was closed, re-open it. Open the block diagram for this VI by clicking on Window > Show Block Diagram, or typing Ctrl+E.

A sub-VI has already been written which performs the C to F conversion. Place this sub-VI inside the while loop by selecting All Functions from the Functions pallet and then selecting Select a VI… Browse to where you find the Convert C to F.vi and open this. With the mouse, click on the block diagram to drop the sub-VI into place, somewhere inside the while loop. Click on the tools pallet to change the cursor to the wiring tool (this looks like a small bobbin) and click on the left side of the Convert C to F sub-VI to connect to its input and then drag the wire over to the output from the 100X multiplier and click there to make the connection.

Switch to the front panel window and make it active. From the Controls pallet, select the "Waveform Chart" and drop this into the front panel below the existing waveform chart for the Celsius measurement. You may need to resize the front panel window to create enough space to do this. Position and resize the waveform chart to your liking. You can also copy the first waveform chart and paste a copy below it. Right click on the new waveform chart and select Properties. From the properties window, the scales can be adjusted. Format the vertical scale to read "Fahrenheit" and give it a range of 50 to 100. Format the horizontal (time) scale to run from 0 to 10 samples, which is equivalent to 5 seconds on the original waveform chart. Switch back to the block diagram window and use the wiring tool to connect the output of the C to F sub-VI to the input of the new Waveform Chart.

Using File > Save As … , save the modified VI with a new name "Experiment 0 Procedure 7.vi" in your own directory.

Measurement-7   Switch back again to the front panel window. Click the run button on the front panel and observe that both waveform charts show the correct temperature behavior. Click on the STOP button to halt the program.

Question-7   Describe how you would create another VI that would display the temperature in degrees Kelvin. You do not need to write another VI for this unless you want to; just describe in general terms how you would go about doing so.

Procedure 8   Saving measurement results to spreadsheet files

Comment   This next procedure will modify the temperature measurement VI once more
                 to add the capability to store the measurement results in a spreadsheet file.

Set-Up   Open the VI that you modified and saved in Procedure 7, if it is not open
                 already, and open its block diagram window.

                 From the Functions pallet, select All Functions > Programming > File I/O >
                 Write To Spreadsheet File, and use the mouse to drop this function into the
                 block diagram to the right of, and outside of, the while loop. Change the
                 cursor to the wiring tool and click on the output of the Convert C to F sub-VI
                 and drag the wire to the right edge of the while loop. A small box will appear
                 at this termination. Use the wiring tool to click on this small box and extend
                 the wire to the 1D Data input of the Write To Spreadsheet File function.
                 Right click on the small box to pop up the options, and select "Enable
                 Indexing." This should make the small box appear with braces ([ ]) inside it.
                 The orange wire inside the while loop should be a thin one, indicating a
                 simple double precision value, and the orange wire outside the while loop
                 should be a thick one, indicating that the output from the while loop is now an
                 array of values. Once the STOP button is pressed, the while loop will end,
                 and all of the measurements that have been taken up to this point will then be
                 passed to the Write To Spreadsheet File function as one row array of values.
                 To put these instead into a single column, wire a True Boolean constant to the
                 Transpose terminal of the Write to Spreadsheet File function.

                 Using File > Save As … , save the modified VI with a new name "Experiment
                 0 Procedure 8.vi" in your own directory.

Measurement-8   Make the front panel window for the new modified VI active and click on the
                 run button to start its operation. The Celsius and Fahrenheit waveform charts
                 should both begin displaying the running temperature data. After a few
                 minutes, click on the STOP button. A Save As … dialog window will open in
                 which you can specify the location to where the new Excel (.xls) file will be
                 written. Enter a new file name, such as "Experiment0Procedure8.xls" and
                 click on "OK." After the file has been written, use Excel to open this file and
                 verify that the correct data values have been written there in the first column
                 of the worksheet. You might also create a plot within Excel and compare this
                 to what you saw displayed on the waveform chart for the Fahrenheit
                 temperatures.

Question-8   If the new VI is kept running for 5 minutes, how many Fahrenheit temperature
                 readings will be stored in the spreadsheet file?