6. LabVIEW Data Acquisition and Analysis

Learning Objectives

Gain first-hand experience on computer automation using LabVIEW.

Measure current-voltage, i.e., I-V, characteristics of semiconductor devices.

Practice data analysis.

Assignments Before the Laboratory Session

Search the web for "Introduction LabVIEW." Read and learn what LabVIEW can do. We will use LabVIEW programs developed from codes posted by Prof. Robert Bruce Darling in University of Washington, Seattle to perform device characterizations. Refresh your knowledge or search the web for "A/D, D/A conversion," and "Nyquist rate." Search the web and learn "curve fitting," "Excel solver." Parts needed include one diode: 1N914 signal diode, 1N4001 rectifier diode, or 1N4733 Zener diode, one 2N3904 bipolar junction transistor (BJT), and one CD4007 CMOS chip. Read the data sheet of BJT and CMOS to identify pin layout.

Activities During the Laboratory Session

Data acquisition requires hardware and software. The data acquisition board, NI PCI 6221, in the computer is connected to a blue box, which facilitates connections to the prototype circuit board by using jumper wires. Alternatively, a National Instruments Elvis II is connected through USB port to the computer. To use NI Elvis II, you need to connect the power brick and turn on two switched, one in the back and the other in the front. You also need to connect a signal cable from NI Elvis II to a USB port on the computer. Click NI MAX icon on the computer screen. Double click "Devices and Interfaces." Make sure that the data acquisition hardware is recognized as device1. If not, you can right click and delete the hardware labeled as device1. Right click and rename PCI 6221 or NI Elvis II as device1. Save the setting. There are four A/D input channels, two D/A output channels, and ground. The A/D input channels can accept input voltages ranging from -10 to +10 V. The D/A output channels can put out voltages ranging from -10 to +10 V. For the blue box, connections are color coded. The wires used for making connections from the blue box to the prototype circuit board are shown in Table I.

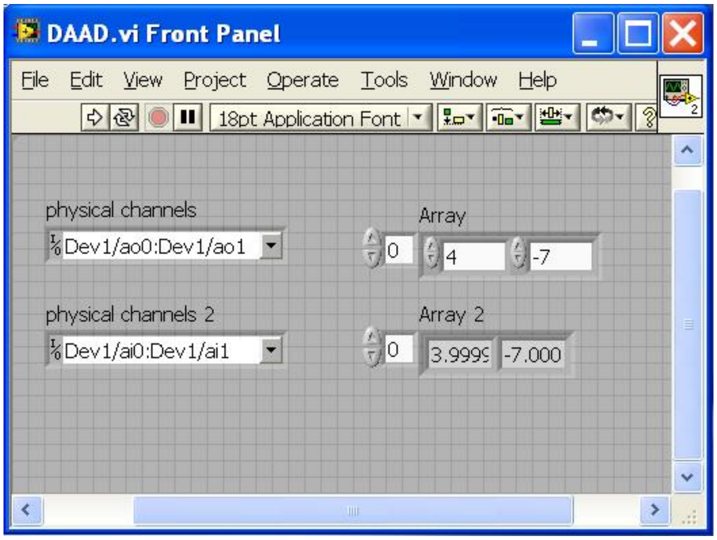
Table I. Colors of wires used for connecting the computer interface blue box to the circuit on the prototype board

Channel	Color	Ground
A/D0	Black	Black-White
A/D1	Brown	Brown-White
A/D2	Red	Red-White
A/D3	Orange	Orange-White
D/A0	Purple	Green-White
D/A1	Gray	Green-White

For NI Elvis II, connect rows 2, 4, 6 and the second to the last row to the blue ground bus line on the prototype circuit board. Analog input (AI) port 0 is located at row 1, AI1 at row 3, and AI2 at row 5. Analog output (AO) port 0 is located at row 31, AO1 at row 32.

Do not turn on the power supply. Do not connect any wire to the power supply. You don't need the power supply in this experiment. LabVIEW programs can be found by clicking the folder icon on the computer screen. It points to a sub-directory. Programs are written using the DAQmx interface. If program error appears, click and run National Instruments, Measurement & Automation, Devices and Interfaces to ensure that the hardware is recognized as Dev1.

1. Perform simple D/A and A/D and determine the accuracy of computer assisted data acquisition. Connect D/A channel 0 and A/D channel 0. Do the same for D/A channel 1 and A/D channel 1. Connect ground leads of used D/A and A/D channels together. Do not connect unused A/D channels and their ground connections. Open the daad.vi program using the following steps.
   a. Start LabVIEW.
   b. Open daad.vi. A screen similar to the following one comes up. Your hardware should be identified as Dev1.



c. There are several input parameters: two physical channels for analog output (D/A), Array for two voltage values that you enter and will be produced at the output of D/A channel 0 and 1, two physical channels for analog input (A/D). Array 2 displays two voltages read by A/D channel 0 and 1. By clicking the black, filled, inverted triangle, you will find the physic devices and channels available. To activate more than one channel, type : and append the additional channel. For example, the front panel shown above indicates that two channels are used, ao0 through ao1. Both channels are on device 1. Likewise, both ai0 and ai1 channels are used. Both D/A and A/D share the same board, namely, device 1.

d. Enter two arbitrary voltage values, between -9.95 and 9.95, into Array. There are only two numbers. Both are displayed. There is no need to click the unfilled triangle to scroll down.

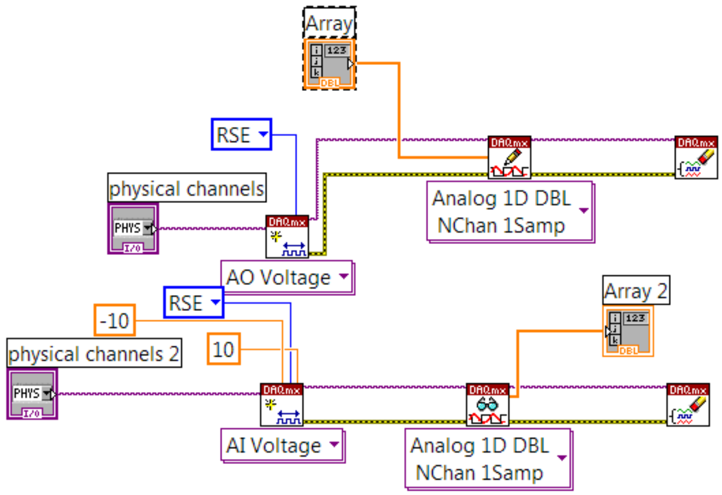
e. Click the right arrow to run the program. A small discrepancy may exist between the D/A voltage and the measured A/D voltage. The difference is a result of limited digitization accuracy, offset, or noise. You can also measure the voltage with a multimeter. Which one is the most accurate? Why?

f. Key in ten sets of voltages spreading evenly between -9.95 and 9.95 V for both D/A channels. Run the program for each set. Record data in an Excel file consisting of two columns: D/A output, A/D input. One block of data for channel 0 and another block of data for channel 1. Identify the maximum discrepancy.

g. D/A can only provide limited amount of current. Set D/A0 to 8 V. Without any load resistor, the output voltage is very close to 8 V. Attach a 4.7 kΩ load resistor between D/A0 and ground. Measure the output voltage. Reduce the load resistance to 1 kΩ. Measure the output voltage. Reduce the load resistance further down to 470 Ω. Measure the output voltage. You may reduce the load resistor further down to 220 Ω. You will observe that the output voltage deviates from its set value of 8 V substantially as current increases.

After measurements, disconnect D/A channels. Always place D/A output plugs back to the color coded receptacles on the blue box to prevent short circuit.

For those who would like to learn the LabVIEW code, click Windows and Show Block Diagram. This is what you see.



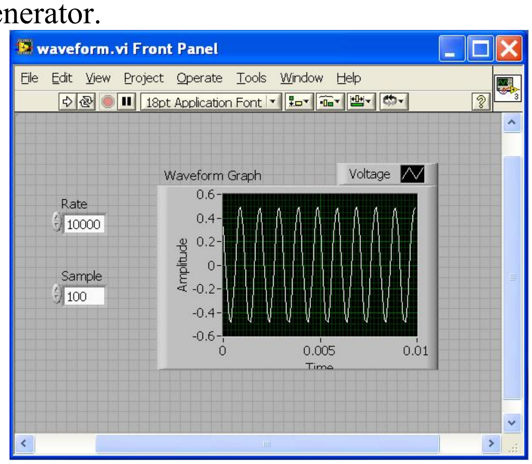
The code is composed not in text but as icons. Each icon performs a specific function. The flow of code and data is represented by lines interconnecting icons. The upper half of the code performs analog output while the low half of the code performs analog input. Beginning from the left side, conditions for input/output operations are set, e.g., physical channel, voltage range, and terminal configuration. Data entered are sent as voltage in D/A or read in A/D. Data read are displayed. The last icon is for error tracking and handling.

2. Digitize a sine wave and learn the importance of sampling rate in digitization. Operate the function generator to produce a sine wave, 1 kHz, 1-V peak-to-peak output. Connect the output of function generator to AD0. The ground wire of the function generator, the ground wire of AD0, and the ground wire of D/A channels should all be connected together to establish the common ground. Do not connect unused A/D channels and their ground connections. Keep the unused D/A plugs on the blue box.
    a. Open waveform.vi under LabVIEW. You will see the following panel. There are two input parameters. Start with a "Rate", i.e., sampling rate, of 10000 (10 kHz). Enter 100 in "Sample" indicating the number of points to digitize. What is the duration of the waveform being digitized? It is 100/10000 or 10 msec. A larger number of "Sample" captures a longer span of the waveform. A smaller number of "Sample" captures a shorter span of the waveform. Click the right arrow. If prompted, enter a

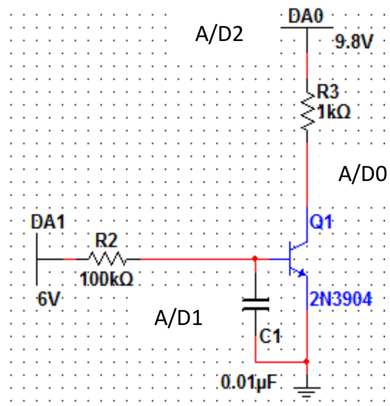
file name to save the data. You can open the data file with Word. The information in the data file includes the time increment, Δx, between adjacent samples and a series of voltage readings.

b. Explore and learn the effect of sampling rate by changing the “Rate” from 10k, 8k, 4k, to 2k and “Sample” from 100, 80, 40, to 20, in corresponding pairs. Save each set of data to a different file. Save the screen by going through the following procedures. Make sure that LabVIEW is the active window. Press <Alt>+<PrintScreen>. This will copy an image to the Windows clipboard. Open Word. Paste the image. Keep track of which file is for what sampling rate.

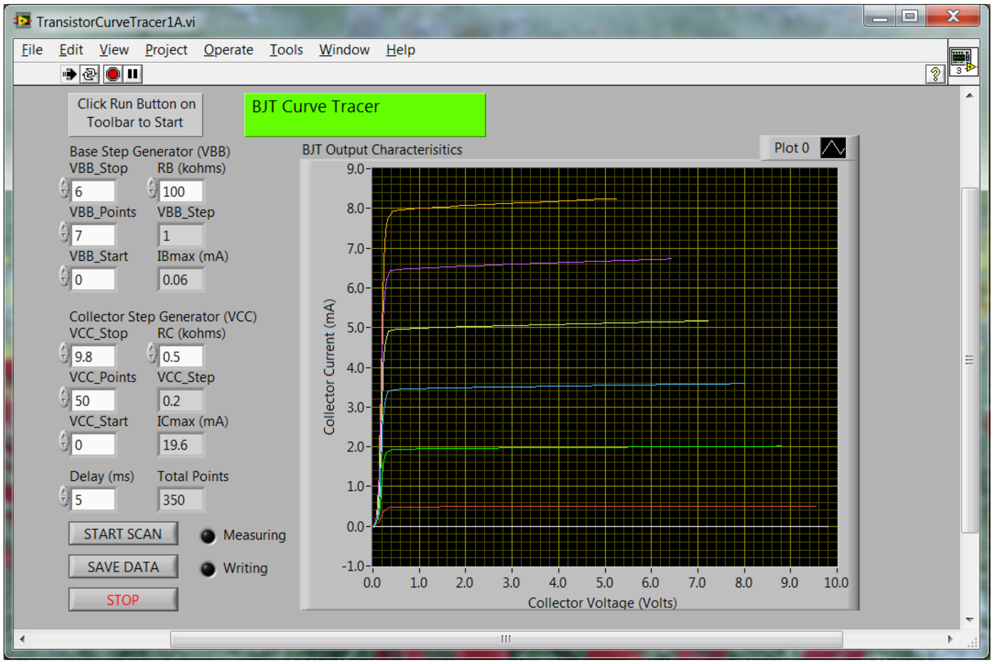
c. When the sampling rate falls below 2x the bandwidth of the signal, i.e., the Nyquist rate, one can’t rely on the digitized data to faithfully represent the signal. Try it with “Rate” of 1900 and “Sample” 40. What is the waveform observed? It is no longer a sine wave. Try with other “Rate.” After waveform digitization, disconnect and turn off the function generator.



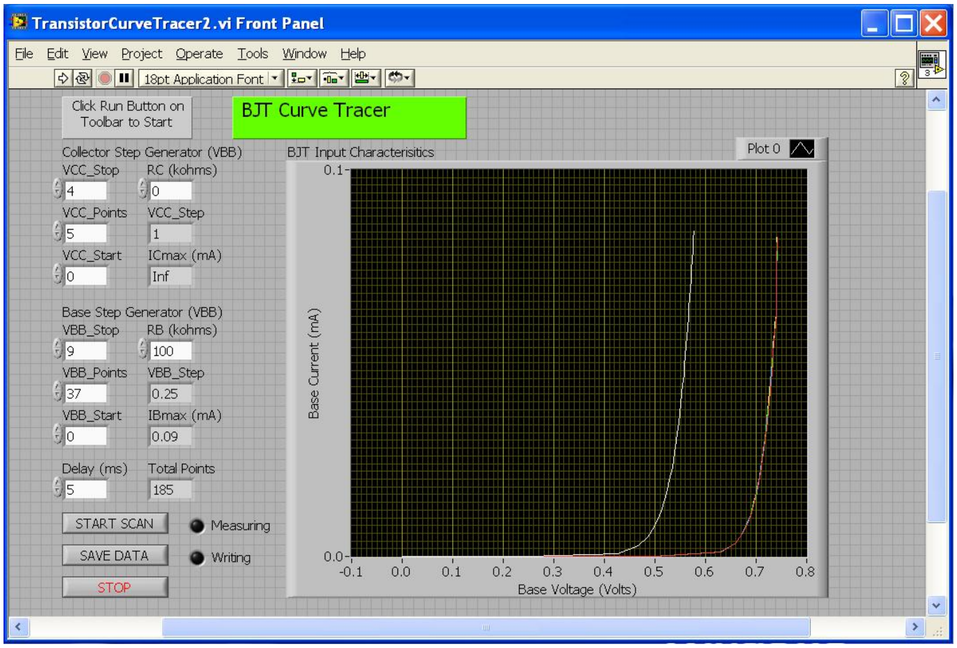
3. Construct a transistor characterization circuit as shown below. DA0 is used as the collector power supply. Connect it through a 1 kΩ or 500 Ω resistor to the collector. Because of output impedance, D/A voltage can be lower than the set value at high current. You need to connect AD2 to DA0 to measure the actual power supply voltage. DA1 serves as the base supply. Connect it through a 100-kΩ resistor directly to the base. Ground the emitter. Attach AD0 to collector and AD1 to the base. Connect ground leads of used D/A and A/D channels.



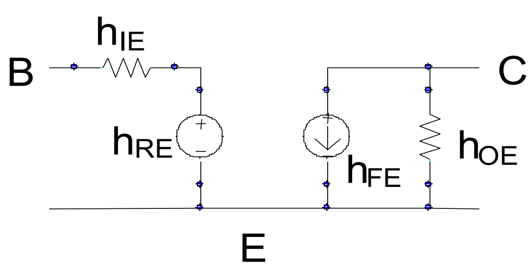
Run TransistorCurveTracer1.vi to obtain the collector current versus collector-to-emitter voltage plot as a function of base current. Fill in the stop voltage, number of curves, the start voltage, and the resistance used in the circuit. Fill in a 5-msec delay between measurements. For npn transistors, such as 2N3904, enter positive voltage values. For pnp transistors, enter negative voltage values. If curves appear zigzagged, noise at the base is an issue. You may connect a jumper wire between the ground node on the circuit board, i.e., emitter, and the metal case of the computer. You may also insert a 0.01-µF capacitor between base and emitter. When noise is extreme, you may simply remove AD1 from the base. Without AD1, you won't be able to measure the base voltage and current. Nevertheless, you will get a set of clean curves. Save the screen. Save data file for BJT output characteristics. Data in the file are recorded in six columns corresponding to power supply voltage for the base, power supply voltage for the collector, base voltage, collector voltage, base current, and collector current. Unit of current is mA.



To obtain the input characteristics, replace the collector resistor with a jumper wire, i.e., reduce the collector resistance to 0 Ω. Run TransistorCurveTracer2.vi to obtain base current versus base-to-emitter voltage plots as a function of collector-to-emitter voltage. For npn transistors, such as 2N3904, enter positive voltage values. For pnp transistors, enter negative voltage values. Save the screen. Save data file for BJT input characteristics. Data in the file are recorded in six columns corresponding to power supply voltage for the collector, power supply voltage for the base, collector voltage, base voltage, collector current, and base current. Unit of current is mA.



The model of BJT is shown below. The input impedance, h_{IE}, the current amplification factor, h_{FE}, and the output impedance, h_{OE}, can be determined from data by finding the slope or inverse slope.



$$h_{IE} = \frac{\Delta V_{BE}}{\Delta I_B} \qquad V_{CE}=\text{constant}$$

$$h_{FE} = \frac{\Delta I_C}{\Delta I_B} \qquad V_{CE}=\text{constant}$$

$$h_{OE} = \frac{\Delta I_C}{\Delta V_{CE}} \qquad I_B=\text{constant}$$

From the slope of the curve in input characteristics, determine h_{IE} at I_B=20 μA. From current change between adjacent curves in output characteristics, determine h_{FE} at V_{CE}=5 V. From the slope of the curve in output characteristics, determine h_{OE} at I_B near 20 μA.

Activities After the Laboratory Session

From data and curves obtained, determine h_{IE}, h_{FE}, and h_{OE} of your transistor. Prepare a summary with the following data and comment or explanation.

1. Voltages recorded and measured by A/D. Identify the maximum discrepancy in percent.
2. Present one digitized waveform at high sampling rate. Present one digitized waveform below the Nyquist rate. What will happen when the sampling rate is too low?
3. Present output and input I-V plots of a BJT. Present h_{IE}, h_{FE}, and h_{OE}.

Cover and Score Sheet

Experiment 6 - LabVIEW Data Acquisition and Analysis

Author:_______________________________ Partner:__________________________

Score

Item	Credit	Score
Data	4	
Basic A/D D/A Measurements		
Waveform Digitization at High Sampling Rate		
Waveform Digitization at Low Sampling		
Two I-V Plots of BJT		
h-Parameters		
Conclusion	1	
Total	**5**	

TA Signature:_________________________ Date:_______________________________