EXCEL for Control and Automation of Laboratory Experiments

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EXCEL [1], a familiar software tool, is used by students and researchers for manipulation, display, and analysis of data. This note explains how one can also use EXCEL to acquire data from laboratory sensors and instruments, and to control devices for the automation of laboratory experiments. EXCEL's use for this purpose has been documented in the test and measurement literature [2], although it is largely unknown in the education and research field.

To illustrate the how EXCEL can be used to automate a laboratory experiment, consider a simple measurement to determine the current-voltage (I-V) characteristics of a 2-leaded component. A schematic diagram of the experiment is shown in Figure 1.
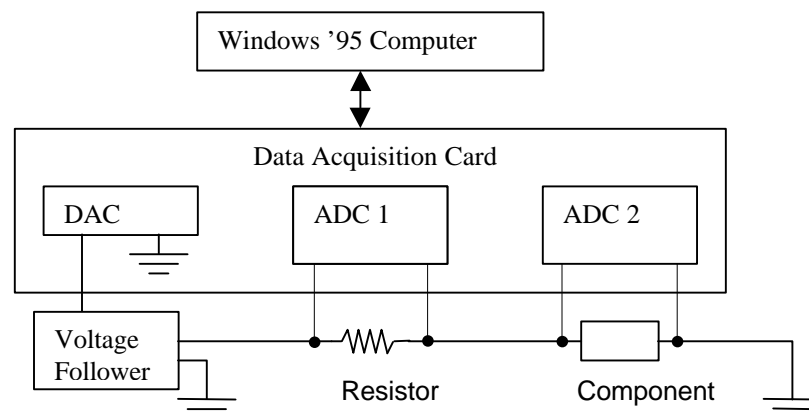

Figure 1. Schematic of Current-Voltage Curve Tracer

Here a buffered digital-to-analog converter (DAC) provides a voltage to drive current around a circuit. Two differential analog-to-digital converters (ADC) measure the voltage drops across a known resistor and the component under test. The voltage drop across the resistor is used to infer the current flowing in the circuit. The current in the circuit is given by Ohm's law,

$$I = \frac{V}{R},$$ (1)

where I is the current in amps, V is the voltage drop across the resistor in volts, and R is its resistance in ohms. By plotting the current derived from equation 1 versus the measured voltage across the component that is being tested for a series of excitation voltages from the voltage source, an experimental graph of the I-V characteristics of a component is obtained.

A National Instruments LAB-PC-1200 Data AcQuisition (DAQ) card [3] provides all of the necessary capability to carry out the automated measurement of the I-V characteristics of the component. The National Instruments card is programmed using Visual Basic. Since Excel (Office 97 version) allows for execution of macros written in Visual Basic, it quite easy to give Excel the ability to interact with the data acquisition card directly. To do this one need only to write a straightforward macro in Visual Basic. Given that Excel includes a Visual Basic editor as one of its basic tools, this task is possible without any additional software purchases, other than EXCEL '97 and the necessary device handlers (i.e., Dynamic Link Libraries (DLL)) which are included with the DAQ card.

For the I-V characteristics example, beginning in the first row an output voltage value, which is a cell in an EXCEL column vector, is sent to the DAC. Measurements are then made using two differential ADCs of the voltage drops across the resistor (which is proportional to the circulating current) and the component. The measured voltage drops are entered in cells of the same row of the two ADC column vectors, one vector for resistor voltage drop values and one vector for component voltage drop values. Table 1 lists all three vectors as they

appear in the EXCEL spreadsheet. After a delay time, which may be defined to be as short as 10 msec, the process is repeated for the next row (element) in the table of vectors, and so on. Once a sweep of all vector elements is completed, the measured data is plotted using the XY graph function in EXCEL.

V_{out} [volts]	$V_{resistor}$ [volts]	$V_{component}$ [volts]
-5	-1.79199219	-2.8808594
-4.9	-1.77978516	-2.8295898
-4.8	-1.72363281	-2.7905273
-4.7	-1.66748047	-2.7490234
-4.6	-1.61621094	-2.7075195
-4.5	-1.56494141	-2.6660156
-4.4	-1.51123047	-2.6220703
-4.3	-1.45996094	-2.5805664
-4.2	-1.40625	-2.5366211
-4.1	-1.35498047	-2.4926758
-4	-1.30371094	-2.4487305
-3.9	-1.25244141	-2.4047852
-3.8	-1.20117188	-2.3608398
-3.7	-1.15234375	-2.3168945
-3.6	-1.10351563	-2.2729492
-3.5	-1.05224609	-2.2290039
.	.	.
.	.	.
.	.	.

Table 1. DAC output values, and measurements from both ADCs

In this example, EXCEL has been set such that the "automatic calculations" feature is off. This means that acquired data is plotted only when a "calculate" command is given. This method is used to prevent the continual replotting of the data as it is being accumulated. Continual replotting slows the data accumulation process to a level that is undesirable with measurements that need to occur for times of less than 1 second per point. If desired, the plot may be automatically updated (by turning the "automatic calculations" feature on) while the data is accumulating.

Appendix A is a listing of a program that carries out the experiment discussed in this article. Appendix B is the sample output from the program for two common electrical components (Zener diode and incandescent light bulb). In all cases a voltage follower is used after the DAC to increase the system's ability to source current. The voltage follower circuit is shown in Figure 2.
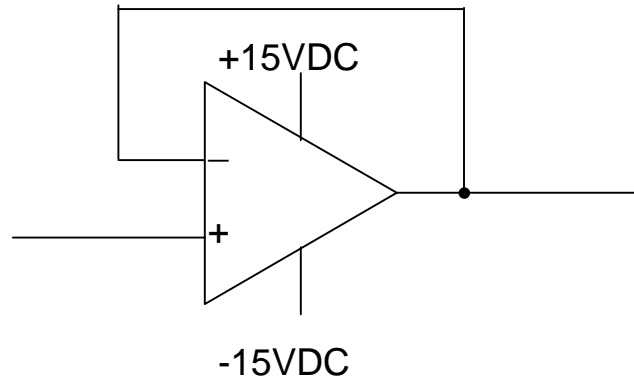

Figure 2. Voltage Follower Circuit

The example I-V curve tracer discussed in this article illustrates how easily EXCEL may be used to automate laboratory experiments. In the teaching laboratory EXCEL is especially useful because students new to experimentation are often intimidated by unfamiliar equipment and programs. Computers and programs like EXCEL are familiar to most college students.

EXCEL's use for data acquisition and control offers several distinct benefits. By extending EXCEL functioning to be able to acquire data and run experiments, it is possible to give student's powerful laboratory tools with the introduction of a minimum of new hardware and software. Since most students already know how to use EXCEL, valuable class time is not needed to explain basic operations. Lastly, since EXCEL provides the ability to acquire data and control experiments directly within one environment, a step in the experimentation process is saved relative to other methods such as LABVIEW in which one program is used to take the data, and another program is used to display and analyze it. With that last caveat being mentioned one should be aware that one drawback of EXCEL's use

for data acquisition and control is its slow speed. Indeed EXCEL may not meet the needs of many users. If speed is not an issue, however, EXCEL for direct acquisition and control is worth considering.

Appendix A – Visual Basic Module

```
Sub main()

Declare Function AO_Configure% Lib "nidaq32.dll" (ByVal a%, ByVal b%, ByVal c%, ByVal d%, ByVal e#, ByVal f%)

Declare Function AI_Configure% Lib "nidaq32.dll" (ByVal a%, ByVal b%, ByVal c%, ByVal d%, ByVal e%, ByVal f%)

Declare Function AO_VWrite% Lib "nidaq32.dll" (ByVal a%, ByVal b%, ByVal c#)

Declare Function AI_VRead% Lib "nidaq32.dll" (ByVal a%, ByVal b%, ByVal c%, d#)

    Dim iStatus As Integer
    Dim iDevice As Integer
    Dim iChan As Integer
    Dim iInChan As Integer
    Dim iInChan2 As Integer
    Dim dVoltage1 As Double
    Dim dVoltage2 As Double
    Dim oValue As Double

    iDevice% = 1
    iInChan% = 0
    iInChan2% = 2
    iChan% = 1

    iStatus% = AO_Configure(iDevice%, iChan%, 0, 0, 0, 0)
    iStatus% = AI_Configure(iDevice%, -1, 0, 5, 0, 0)
```

```vba
    Dim Start As Double
    Dim Pause As Integer
    Dim LoopVar As Integer

    MsgBox "Press to Start"

    LoopVar = 0
    Do Until LoopVar = 1
       Range("A4").Select
       Start = Timer
       Pause = 0
       Do Until Pause = 100
          Do Until Timer > Start + Pause
          Loop
          iStatus% = AO_VWrite(iDevice%, iChan%, ActiveCell.Value)
          iStatus% = AI_VRead(iDevice%, iInChan%, 1, oValue#)
          ActiveCell.Offset(0, 2).Activate
          ActiveCell.Value = oValue#
          iStatus% = AI_VRead(iDevice%, iInChan2%, 1, oValue#)
          ActiveCell.Offset(0, 1).Activate
          ActiveCell.Value = oValue#
          ActiveCell.Offset(0, -3).Activate
          Pause = Pause + 1
          ActiveCell.Offset(1, 0).Activate
       Loop
       LoopVar = LoopVar + 1
    Loop
    Range("A4").Select

    MsgBox "DONE"

End Sub
```
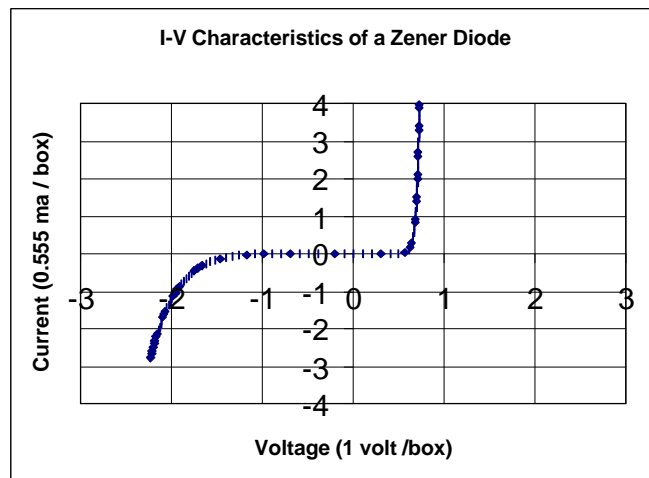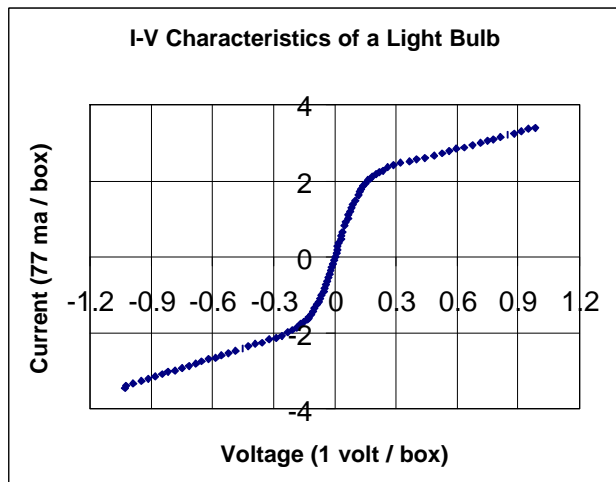
Appendix B

I-V Characteristics of a Light Bulb

Current (77 ma / box)

4

2

0

-1.2 -0.9 -0.6 -0.3   0   0.3   0.6   0.9   1.2

-2

-4

Voltage (1 volt / box)

I-V Characteristics of a Zener Diode

Current (0.555 ma / box)

4
3
2
1
0

-3   -2   -1   -1   0   1   2   3

-2
-3
-4

Voltage (1 volt /box)

References

1. Microsoft Corportation, Office '97.
2. W. Haussmann,"Custom Control Runs Instruments from Excel", Test and Measurement World, January 1998; C. B. Grantham, "Office 97 Controls Analog and Digital I/O Ports", Test and Measurement World, September 1997.
3. National Instruments Corporation, Austin, Texas.