# Using Signal Express to Automate Analog Electronics Experiments

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## Introduction

It is well known that many undergraduate students, especially in engineering technology programs, learn best through hands-on experience. Thus, when teaching analog electronics, it is critical to provide the students with a meaningful laboratory experience. While this sounds straightforward, it is often difficult to do in practice. Many analog electronics experiments can be very time consuming. For example, plotting the frequency response of an active filter or transistor amplifier requires that the students make multiple amplitude and phase measurements of the input and output signals. This process can be tedious and the result is that the students often only have time to characterize a device once. This means they do not have time to perform "what-if" scenarios where they change out a component and see the effect. Thus, they are losing a valuable education experience. In addition, if their data is wrong then they have no opportunity to repeat the experiment, and as such have learned very little.

To address the problem, we have previously presented automated digital and analog measurement systems as a solution.[1,2] For example, using a LabVIEW program and GPIB (General Purpose Instrumentation Bus) instruments, one can build an automated frequency response analyzer that will rapidly characterize the frequency response of a circuit. Unfortunately, because the coding of this type of measurement requires a substantial amount of time, the program and the measurement process is typically provided for the student. So, while this method allows the students to characterize systems over and over, it removes them from the design of the test and measurement process, again costing the student a valuable learning opportunity.

Recently, National Instruments released a new software product called Signal Express. The package is a dedicated test and measurement environment where the individual can use high-level signal sourcing and measurement blocks to build an automated measurement system that will collect and present data in a graphical form. Like LabVIEW, the environment is graphical, allowing users to place individual measurement blocks in a particular sequence. Unlike LabVIEW, the environment has a very short learning curve so that students can rapidly


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program their own tests. Thus, it is easy to use while still leaving the need to design the required test in the hands of the student.

In the Summer of 2004, the EET Program at Texas A&M evaluated Signal Express and wrote two electronics labs based on it. It is currently being deployed in an electronics lab and will be used to see how students respond to this new measurement tool. In this paper, we will discuss the use of Signal Express and present an example for use in an analog electronics laboratory.

## ENTC 350 Electronics Laboratory

ENTC 350 is a typical first semester electronics course for engineering technology majors. The purpose of the course is to introduce students to basic active components such as diodes, operational amplifiers, transistors, and their applications. Thus, the associated laboratory is an integral part of the student's learning process. With this said, the ENTC 350 lab consists of ten two-hour experiments and two four-hour (two weeks) experiments. Unfortunately, two hours is a relatively short amount of time for students to perform complex lab experiments.

For example, in one of the lab experiments the students investigate active filters. The students have two two-hour lab sessions to complete this experiment. This includes designing several filter variations, simulating them in PSpice, implementing them on a breadboard, debugging them, and finally testing them and playing "what-if" scenarios by changing component values, etc. Using traditional laboratory techniques, the most tedious part of this process is obtaining the frequency response of the circuit. This typically involves sweeping the frequency of the input signal over many different values (20-30) and measuring both amplitude and phase of the input and output signals. The data then has to be graphed to make sure that it makes sense. Obviously, it is practically impossible for students to make this measurement repeatedly on multiple filters in the time allotted. For this reason, many students often have to return the lab during open lab hours to finish their work. The tedium of these measurements is not only inefficient, but it also affects the student's motivation to experiment and try different things.

To help alleviate this problem, virtual instruments (VIs) were written using National Instruments' LabVIEW™ to allow students to rapidly collect frequency response data[1]. These VIs were canned programs that used LabVIEW, data acquistion cards, and GPIB (General Purpose Instrumentation Bus) controlled instruments to automatically sweep the function generator and collect samples of the input and output waveforms. LabVIEW then processed the data and automatically plotted the amplitude and phase responses versus frequency. While this method saved a substantial amount of time during the testing process, it was not perfect either. Because students were given these automated VIs and not required to write them, they lost hands-on experience in the design and debugging of the testing process. They also gained no direct insight into performing frequency response measurements.

What is needed is a happy medium between the traditional methods of performing complex repetitive measurements manually and a completely automated system that saves time but removes crucial learning aspects from the experimental process. Ideally, this new testing


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environment would allow students to easily design their own automated experiments, remotely control multiple instruments through software, and create dynamic processing routines for presenting data. While an environment such a LabVIEW could be used, the learning curve and overhead would mean that the majority of the student's time would be spent programming. This is typically not a primary objective for an electronics course. While searching for a solution, the authors recently came across an new environment called Signal Express which allows engineers to rapidly produce their own software-controlled test setups.

**What is Signal Express™?**

Signal Express™ is a new test and measurement environment released by National Instruments in the Fall of 2004.[3] Like LabVIEW, it is an instrumentation environment that allows an engineer to design software-controlled tests. It supports the use of data acquisition cards as well as GPIB instruments such as the HP 33120A Arbitrary Waveform Generator and allows the user to create looping structures to automate repetitive measurements. Unlike LabVIEW, the Signal Express environment is fairly high-level, intuitive and has a very short learning curve. Thus, instead of performing low-level programming to setup the data acquisition, data processing, and data presentation, the user can focus on creating a measurement using high-level application specific blocks. In the event that Signal Express does not support a needed function, the user does have the option of creating user-defined LabVIEW blocks that can be imported into their test routine.

From a hardware perspective, test setups using Signal Express are similar to those using LabVIEW (see Figure 1). A PC running Signal Express is used to control either internal data acquisition cards or standalone instruments on a bus. These instruments are then connected to the device under test (DUT).

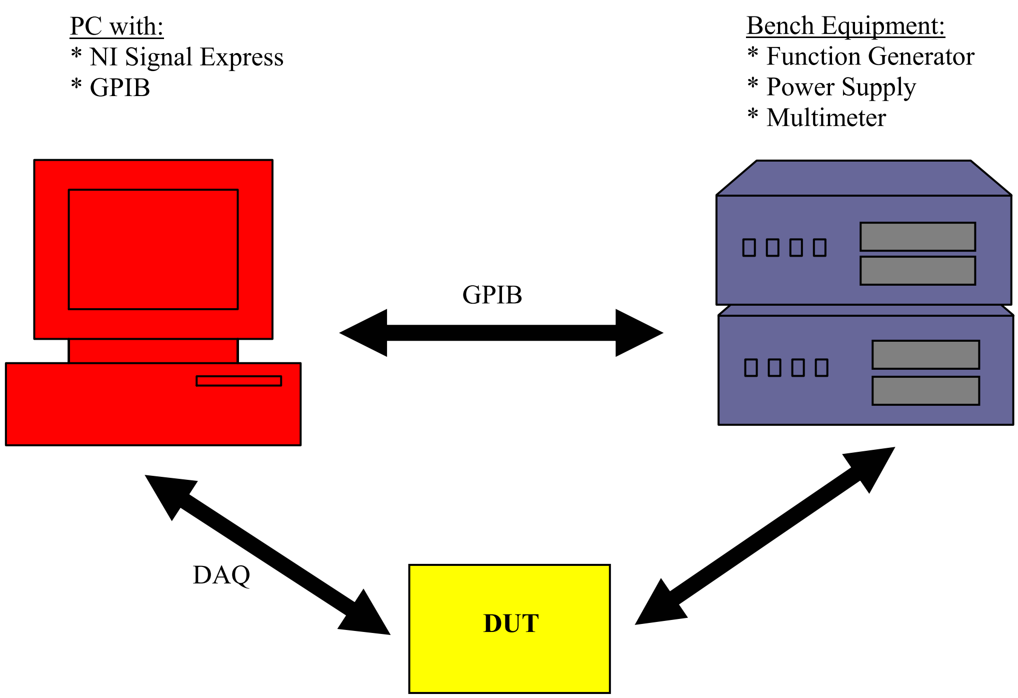


Figure 1 – Block diagram of the Signal Express test environment.


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To implement a test, the user creates a graphical flow diagram with the necessary steps to perform the measurement. This leaves the design of the test and the setup of the instruments in the hands of the student. Therefore, they still have the responsibility of testing the circuit correctly while being able to efficiently collect large amounts of data. The following section demonstrates the use of Signal Express with an example.

**An Example: Transistor Curve Tracing**

An important step in characterizing Bipolar Junction Transistors (BJT) is to obtain the characteristic curves. These curves indicate the active, saturation, and cutoff regions of the BJT; which can be useful in determining how to bias the transistor to remain in a particular state or to switch from one state to another. Figure 2 shows an example of typical BJT characteristic curves.

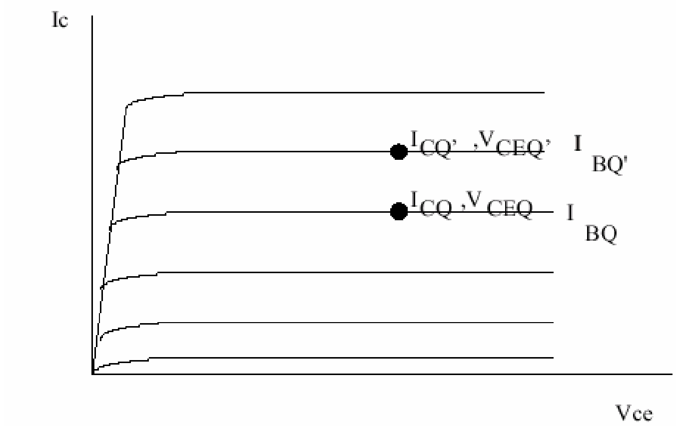


Figure 2 - BJT Characteristic curves

There are two traditional methods used to obtain the BJT curves: manually and by using a curve tracer. To manually obtain the curves the students must implement a circuit, setup the voltage sources, setup the measurement devices, manually sweep the voltages, and take measurements by hand. This process is very tedious, prone to mistakes, and takes a long time to perform. To reduce the time required to characterize a BJT, the students can use a curve tracing instrument. The curve tracer requires that the students insert the transistor and record the output. The downside to this method is the students do not learn the process of making characteristic curve measurements. While this in itself may not be considered important, there are many issues involved in measuring the characteristic curves of a transistor that are also lost. For example, the fact that each individual characteristic curve is produced by holding the base current constant is often lost on students. Also, methods for building constant current sources is also lost. Signal Express provides a compromise between the manual method and the curve tracer method by reducing the test time while still allowing the students to design the measurement process.

For this example, the students must first implement a constant-current transistor biasing circuit as shown in Figure 3. This particular current source is a current mirror setup that creates a voltage controlled current source and gives Signal Express the ability to sweep a current by


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sweeping a voltage. By using a data acquisition card analog output to sweep $V_{CC}$, a single characteristic $I_C$-$V_{CE}$ curve of the bipolar junction transistor is measured. By sweeping $V_{BB}$, the base current of Q3 is swept and a whole family of curves can be obtained.

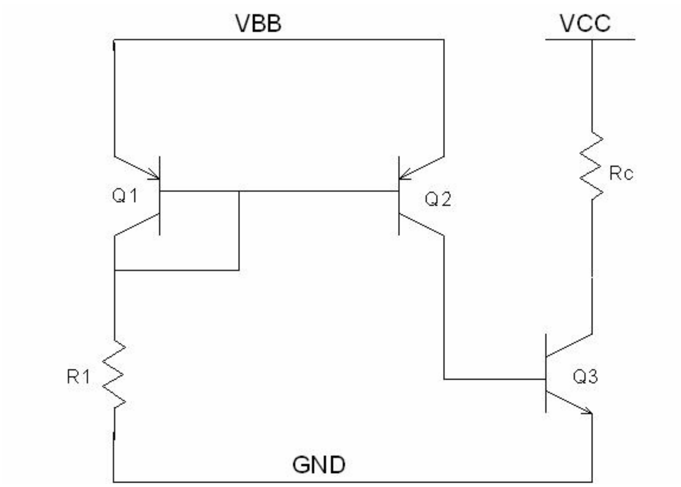


Figure 3 - Characterization setup

Next, the measurement is "programmed" in Signal Express to sweep source voltages and measure the circuit outputs. Figure 4 shows a blank Signal Express front panel. The blank space on the left is where the steps will appear as they are added. In the middle is a graph where many user selectable items can be displayed. The graph can display inputs, outputs, and results of calculations.

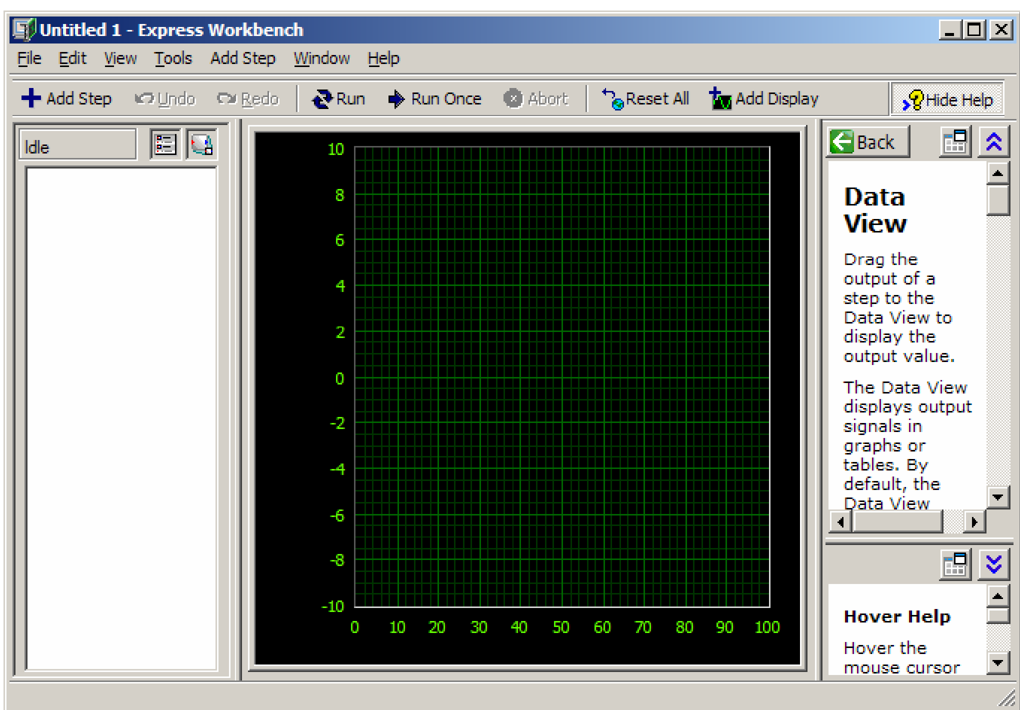


Figure 4 - Initial Signal Express View

To "program" the measurment, steps are added to the configuration, typically in the order that they will be performed. Figure 5 displays the Add Step window, the key tool for developing measurements with Signal Express. The Add Step button contains all the functions that Signal Express can perform such as creating, acquiring, and processing signals.

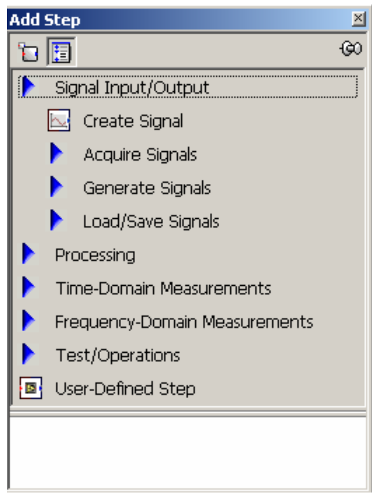


Figure 5 - Signal Express, Add Step

When a step is added, a window will pop up that allows you to set the parameters of the step. This window can contain information such as the frequency and amplitude of an output sine wave or the sampling rate of an input signal coming into Signal Express. Figure 6 demonstrates the configuration of a basic 5V signal output.

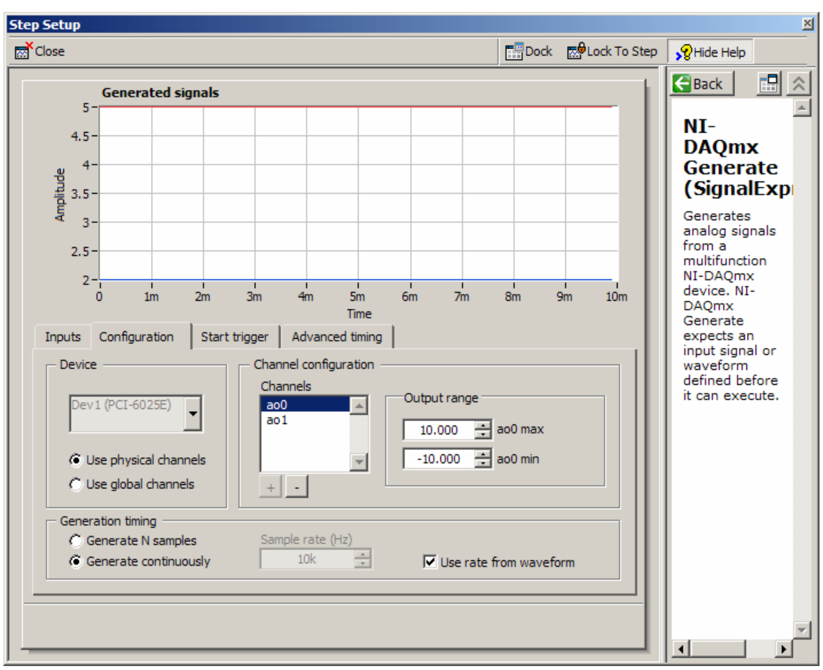


Figure 6 - Signal Express, Step Configuration

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There are a variety of different steps that can be added to Signal Express to create a measurement. As an example, an output signal is created by first using the Create Signal step to calculate the data that describes the output waveform. Then, the Generate Signal step is used to output the signal using the selected National Instruments (NI) DAQ board. To acquire a signal, one would use the Acquire Signal step and configure it to read the inputs on the selected NI DAQ board. Acquired signals can be named as needed and this name will act as a reference to the signal in order to perform any calculations or filtering.

When an operation is performed on a signal, the output of the operation will be assigned a different name automatically or can be manually changed as needed. Once all the required steps are added to create a measurement, a Sweep step can be used to repeat the measurement as many times as necessary. Finally, data displays can be configured and graphs can be set to autoscale or they can be manually scaled as in LabVIEW.

The final curve tracer can be seen in Figure 7. The left column has the steps that will occur when the program is executed. In this example, voltage signals are created and applied to the circuits on the base and collector of the transistor. Two nested Sweep steps allow both the collector-emitter voltage and the base current to be swept.

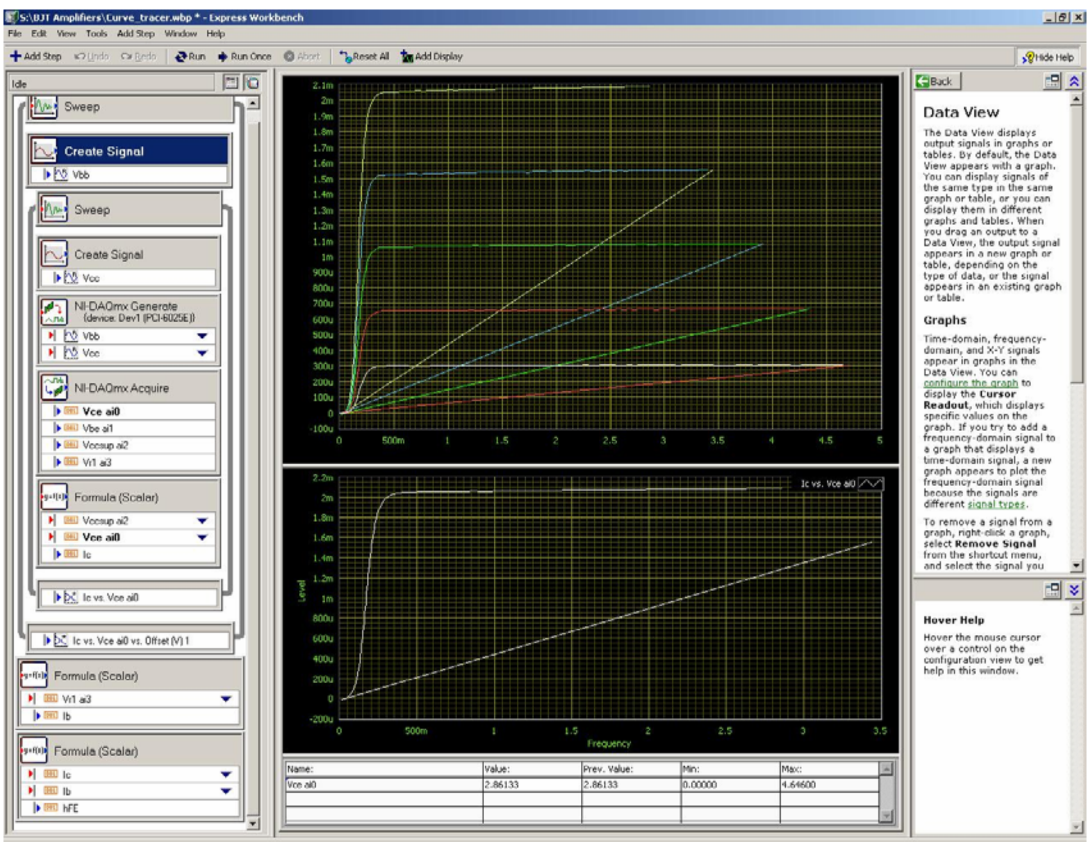


Figure 7 - Signal Express, Curve Tracer

In this example, Vcc is swept from 0V to 5V in one hundred increments and the result, indicated by the label "Ic vs. Vce ai0.", is a single Ic versus Vce curve. The outer sweep step increments Vbb from 1.1V to 3.1V in five steps that produces separate Ib curves. At each Ib, the Ic versus Vce curves are plotted on the graph based on the acquired Vce and calculations performed in the Formula (Scalar) step to obtain Ic. Outside of the sweep steps, $h_{FE}$ (Beta) is calculated and could also be displayed (not shown). Overall, a measurement of this complexity could be "programmed" in about ten minutes.

## Discussion and Conclusions

Over the course of the Summer of 2004, Signal Express was used to create two laboratory experiments. The first was a beta tester and curve tracer for BJTs, and the second was a frequency response tester for use with filters and amplifiers. Once the experiments were debugged, laboratory procedures were written for each of the two experiments. During the Fall 2004 semester, an undergraduate was hired to perform each of the experiments and to make any final edits to the laboratory procedures. These procedures are available upon request.

Even from the outset, the software was easy to use. Within an hour of installing it, the authors were able to source/capture signals and process the returned data. Unlike a programming environment such as LabVIEW, the Signal Express environment simplifies test creation by allowing the user to select test and measurement "blocks" and configure them through an intuitive front panel. The blocks are placed in a more or less chronological order based on the order of the steps a user would normally take when performing a test. Looping is accomplished by placing any repeated steps in a graphical loop and configuring the parameter(s) that should change between steps. To present data, the intuitive interface allows the user to select which variable(s) should be displayed or graphed. Most common time and frequency domain data processing routines are also supported. Finally, for added flexibility, the user can insert custom measurement blocks created in LabVIEW.

Feedback from the undergraduate student hired to test the labs indicated that the use of Signal Express could easily be learned through a single lab devoted to introducing the software. While the environment is not necessary for many of the measurements performed in an analog electronics lab (often a single DMM or oscilloscope measurement will suffice), it is flexible enough to be used for any of the more complex measurements a student will need to perform. During the Spring of 2004, Signal Express will be used in an actual student lab setting. Results from this will be reported at the conference.

### References


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**Biographies**

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Benjamin Brannaka is a senior undergraduate student at Texas A&M University scheduled to graduate in May 2005 with a BS degree in Electronics Engineering Technology. He currently works for Mobile Integrated Solutions Laboratory (MISL) as the Location Independent Video Education (LIVE) Administrator.

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