Elvis Has Entered Digital Circuits!

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Abstract
NI Elvis II is an educational design and prototyping platform for measurement and instrumentation, circuits, controls, telecommunications, and embedded/MCU experiments with an integrated suite of commonly used instruments including an oscilloscope, a function generator, a digital multimeter (DMM) and a variable power supply. It is based on NI LabVIEW graphical system design software with data acquisition and USB plug-and-play capabilities.

We have undertaken to replace our conventional CMOS/TTL Designer used in the hands-on portion of our introductory Digital Systems course, CPE 220, with the NI Elvis II platform. This paper will provide a survey of the use of this platform at other institutions, describe the software interface generated to utilize this platform in our freshman level CPE 220 course as well as highlight the modifications to our existing experiments to take advantage of new capabilities this platform offers.

Introduction
Engineering Department at Geneva College currently owns four unutilized National Instruments (NI) ELVIS units. These units were purchased to upgrade introductory circuit labs. With the untimely passing of a faculty member, the third author started teaching CPE 220, Digital Systems, which is the first digital course electrical and computer engineering students take at our institution. We have decided to utilize the NI ELVIS units to replace CMOS/TTL Designers that have served CPE 220 for decades. Whereas current digital design practice favors the utilization of hardware description languages and automatic logic synthesis, the employment of TTL chips forces students to learn breadboarding skills. Since CPE 220 is the introductory course in electrical and computer engineering, the advantage of instilling good breadboarding techniques still warrants the use of these chips. We also resolved to explore possible uses for NI ELVIS outside of the CPE 220 class.

Figure 1 shows one of the NI ELVIS-II platforms. National Instruments literature describes the ELVIS-II platform as a “design/prototyping platform for measurement and instrumentation, circuits, controls, telecommunications, and embedded experiments that has complete Multisim integration, fully customizable with LabVIEW, and has Express VIs for point-and-click configuration in LabVIEW”\(^1\). Hardware and software identified as necessary to perform most tasks with the ELVIS II are listed in Table 1. Not included but implied in that table is a computer to run the software. We should note that while LabVIEW development software is not essential to utilize the platform, it provides more versatility than the stand-alone programs included in the NI ELVISmx Software package.
Figure 1: NI ELVIS II platform.

Table 1: Components of a functional NI ELVIS station.

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
<th>Included with ELVIS II?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required for Minimal Operation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power supply</td>
<td>Supplies power to ELVIS</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Required for Operation with Computer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NI ELVISmx Software</td>
<td>Driver for connecting ELVIS to a computer, includes software to control ELVIS from computer; different computers require different software versions, available from NI.com</td>
<td>YES</td>
</tr>
<tr>
<td>NI LabVIEW Software</td>
<td>Optional; software package for creating programs that can be used with ELVIS; ELVISmx driver software must be installed to use LabVIEW with the ELVIS</td>
<td>NO</td>
</tr>
<tr>
<td>USB Cable</td>
<td>Connects ELVIS to computer</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Required for most Operation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prototyping Board</td>
<td>Contains breadboard or physical components such as microprocessors; multiple circuit board types are available</td>
<td>YES</td>
</tr>
<tr>
<td>Oscilloscope BNC Leads</td>
<td>Provides connection to oscilloscope and function generator on ELVIS platform</td>
<td>NO</td>
</tr>
<tr>
<td>Multimeter Leads</td>
<td>Provides connection to DMM on ELVIS platform</td>
<td>NO</td>
</tr>
<tr>
<td>Standard Wires</td>
<td>Provides connection to components on breadboard</td>
<td>NO</td>
</tr>
<tr>
<td>Banana Plugs</td>
<td>Provides connection to user configurable I/O pins on some prototyping boards</td>
<td>NO</td>
</tr>
</tbody>
</table>

The Express VIs which are part of the built-in software suite “NI ELVISmx” are shown in Fig. 2. The instruments (from left to right in Fig. 2) are: Digital Multimeter (DMM), Oscilloscope.
(Scope), Function Generator (FGEN), Variable Power Supply (VPS), Bode Analyzer (Bode), Dynamic Signal Analyzer (DSA), Arbitrary Waveform Generator (ARB), Digital Reader (DigIn), Digital Writer (DigOut), Impedance analyzer (Imped), 2-wire Current Voltage Analyzer (2-Wire), & 3-wire Current Voltage Analyzer (3-Wire).

Figure 2: The instruments provided in the software suite for NI ELVIS II.

A literature search on the use of the ELVIS-II platform has revealed that several schools such as Georgia Tech, Texas-San Antonio, Virginia Tech, and Clemson utilize this Platform in their undergraduate programs:

- Georgia Tech University employ LabVIEW, Multisim, & ELVIS to implement a hands-on approach to teach theoretical electrical engineering concepts with real-world signals. The platform serves their Instrumentation and Circuits as well as Microelectronics Circuits Lab classes, which cover: voltmeters, multimeters, diodes, op-amps (operational amplifiers), transistors, switching logic, and MOSFETs (metal-oxide-semiconductor field-effect transistor).
- The University of Texas at San Antonio utilize ELVIS for the field of biomedical engineering to help teach basic concepts of lab practices and instrumentation.
- Virginia Technical University use the platform primarily in their Physics department to teach Electronics and Modern Physics laboratory. The board is helpful in teaching students about computers, thermometry, nuclear spectra, and experimentation in the field of modern physics.
- Clemson University have recently redesigned their undergraduate Electrical Engineering labs and have specifically renovated them for the ELVIS-IIs. They use these laboratories for classes that would parallel our institution’s Linear Circuit Analysis, Linear Systems, Electronic Devices & Circuits I & II (covering BJT’s MOSFET’s, FET’s, Op-Amps) courses.

In addition to these applications, we have observed some novel combinations of the NI ELVIS platform with other tools:

Moslehpour, et al have employed NI ELVIS with the FreeScale board to offer distance laboratory activities in computer engineering technology, similar to the units we own. They observe that while the FreeScale MCU Project board does provide microprocessor functionality to NI ELVIS, it is best suited for third and fourth year students.

Zhang & Chen have implemented a digital / analog telecommunication laboratory with the Digital Analog Telecommunication EXPERImenter unit (DATex) (add-on board for the NI ELVIS) for engineering technology students. They conclude that this combination for
digital/analog telecommunication laboratory has proven effective for reinforcing telecommunication principal and concept, as evidenced by students’ favorable survey responses.

Wright, et al have used a combination of ELVIS, LabVIEW and BIOPAC for introductory bioinstrumentation laboratories. This unique combination provided the authors the ability to offer a highly integrated, easy-to-use learning laboratory environment at an affordable price compared to using stand-alone test equipment as well as the capability to render certain BIOPAC products more accessible for hands-on experiences. In the end, the authors recommend investigating the use of ELVIS for other courses.

Problem Statement
Our primary goal is to update the experiments in the CPE 220 Digital Systems class to incorporate the ELVIS platforms. Updating the experiments consists of two main parts: developing a working system with the ELVIS platforms such that they could replace the analog/digital trainer pads currently used with the CPE 220 experiments, and rewriting the existing experiments instructions to reflect this shift.

Two of the units are equipped with the standard NI ELVIS Prototyping Board and the other two have the additional FreeScale Semiconductor’s design board, the PBMCUSLK (Project Board Microcontroller Unit Student Learning Kit) for digital circuit design. The FreeScale board contains a number of additional components special to digital system development, such as a microprocessor, an LCD display, and push buttons for digital IO. While the FreeScale board offers more features than the NI board, we have found it more confusing to operate. Some of the settings useful for introductory experiments involve more jumper cables than the standard NI board and would be more difficult to troubleshoot. In light of these issues, Moslehpour et al’s observation, and the fact that the standard NI prototyping boards appear to be sufficient for the purposes of the Digital Systems course, we decided that the experiments would be performed using the NI boards and that the FreeScale board is more appropriate for upper level computer engineering.

Development of an ELVIS Controller for Digital Systems Experiments
In order to provide a standard, simple interface for the introductory Digital Systems experiments, a program was written in LabVIEW to control the various instruments supplied in the ELVIS platform. Figure 3 shows the front panel of this program. This program enables the student to turn digital lines on and off, read digital signals, as well as to control two DC voltage supplies, a function generator, and a low frequency TTL clock signal. These represent all of the instruments found on the original trainer pad, which the ELVIS platform replaces. All of these are controlled from the computer and are linked directly to the ELVIS II platform. In addition, the student has the option of controlling the DC voltage supplies and the waveform generator manually, via control knobs on the ELVIS II platform.

A couple of issues should be mentioned with regards to developing this program. We decided that a logic probe be implemented in the software, a feature that was not included in the old trainer pad but that could be useful for students for checking their hardware. The original design for the probe was to use the multimeter (DMM) on the ELVIS to read the voltage of a signal,
compare it to standard TTL logic levels, and then indicate if the signal is a logic low, logic high, or floating between these values. This scheme worked well and gave consistent and reliable results.

Figure 3: Front panel of the ELVIS controller.

Later, this design was changed so the voltage would be read by the analog input (AI) channels provided on the ELVIS II prototyping board. This decision was made to free up the DMM in the case that DMM was needed during the lab for any unforeseen reason. The AI channels worked well when connected to a test signal, but the open circuit the value it read would approach ±rail voltage. This was undesirable as it should have read a fairly steady value of about 0V. To eliminate this problem the program was changed back to read from the DMM for the logic probe tool.

The other issue is with the TTL clock generator. To implement the clock, an alternating +5 V and 0 V signal is generated through the analog output (AO) channels. This provides a pulse train of +5 V. The lowest time resolution available in LabVIEW is 1 millisecond, which means that the smallest amount of time that the signal can be at +5V is 1 ms. Since the program will then set the voltage to 0 V and wait another 1 ms, the shortest period for the pulse train will be 2 ms resulting in a maximum frequency of 500 Hz. The next highest frequency occurs when the pulse width is 2 ms, for a frequency of 250 Hz. the next few frequencies available are 166.67, 125, and 100 Hz.

Thus the frequency resolution is rather crude, due to the crude time resolution available in LabVIEW. When using this clock at low frequencies, however, the steps between available
frequencies are closer to 1 Hz. Considering that the Digital Systems experiments do not require high speeds, we decided that having allowable frequencies of 1-10 Hz in 1 Hz increments would be sufficient. Thus it was determined that this program did not need to match the +10 kHz frequency range of the clock on the original trainer pad.

It became evident that, until the students become very familiar with the ELVIS platform and prototyping board, they may have trouble finding the connections for all of the components controlled by the program. Therefore a pop-up help program was written so that the student can see a picture of the component being used, as well as a description and any information needed to use it properly. The program is shown in Figure 4 below. In this figure, the program is showing a picture of the connections for the waveform generator, and is detailing what the waveform generator is used for and how to use it.

Figure 4: Help window for the ELVIS controller.

**Updating Old Experiment Instructions**
Our other challenge is updating the old experiment instruction set to reflect the shift to the ELVIS systems. The first task involved in this was creating an experiment to introduce the students to the ELVIS. This experiment teaches students the operations commonly performed on
the ELVIS platform through a set of simple exercises with chips. These exercises were designed to give students familiarity with wiring 7400 series chips (such as OR and NAND chips) on a breadboard while using enough of the ELVIS board to become familiar with its most basic parts.

Students from non-technical fields tested this introductory experiment for style, clarity, and content. These students attempted to complete the experiment with minimal outside help, and afterwards gave written and verbal feedback on the instructions. The feedback provided useful help in refining the instructions, particularly with regards to the explanation of how the terminals in a breadboard are connected together\textsuperscript{ii,vi}.

After the instructions for the introductory experiment were written, instructions for the experiments used in previous Digital Systems classes were updated for use with the ELVIS. These instructions were written to describe the same basic experiments, but in a way that these experiments could be performed on the ELVIS.

**Conclusions and Recommendations for Future Work**

We have also explored other uses for the ELVIS. One discovery was that the ELVIS prototyping board can readily be used with E-Blocks. E-Blocks are small electronic modules that connect through a DB-9, 9-pin connector\textsuperscript{vii}. An LED, a push button, and a keypad E-block were all successfully used when connected to the ELVIS II. Some E-blocks, such as the keyboard E-block, require some programming in LabVIEW to work properly. The flexibility and ease of use of the E-blocks in conjunction with the ELVIS makes the combination an excellent tool for making quick prototypes for projects, as well as allowing quick experimentation with electronic systems that would otherwise take much longer to develop.

Because of the features it provides in a single, compact platform, the ELVIS promises to be very convenient for use with student projects and labs, such as the Digital Systems lab, and for initial electronic design or presentations. Also, the large variety of third party prototyping boards that are available for different fields adds versatility to the ELVIS such that it could be used for a variety of courses and projects. Its uses are essentially limited to educational and exploratory tasks as well as presentation.

The initial offerings of the experiments were conducted with minimal difficulties by the students. At the first iteration, we are able to duplicate our existing lab experiments. We are currently looking into taking advantage of the automation and report generation capabilities that LabVIEW provides for our next iteration.

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**Bibliography**

\textsuperscript{i} NI ELVIS: Educational Design and Prototyping Platform, National Instruments, \textless http://www.ni.com/nielvis/\textgreater , accessed 01/31/12.


