

# **NI Educational Laboratory Virtual Instrumentation Suite (NI ELVIS™)**

## **User Manual**

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### **National Instruments Corporate Headquarters**

11500 North Mopac Expressway Austin, Texas 78759-3504 USA Tel: 512 683 0100

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# Compliance

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## Compliance with FCC/Canada Radio Frequency Interference Regulations

### Determining FCC Class

The Federal Communications Commission (FCC) has rules to protect wireless communications from interference. The FCC places digital electronics into two classes. These classes are known as Class A (for use in industrial-commercial locations only) or Class B (for use in residential or commercial locations). All National Instruments (NI) products are FCC Class A products.

Depending on where it is operated, this Class A product could be subject to restrictions in the FCC rules. (In Canada, the Department of Communications (DOC), of Industry Canada, regulates wireless interference in much the same way.) Digital electronics emit weak signals during normal operation that can affect radio, television, or other wireless products.

All Class A products display a simple warning statement of one paragraph in length regarding interference and undesired operation. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

Consult the FCC Web site at [www.fcc.gov](http://www.fcc.gov) for more information.

### FCC/DOC Warnings

This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual and the CE marking Declaration of Conformity\*, may cause interference to radio and television reception. Classification requirements are the same for the Federal Communications Commission (FCC) and the Canadian Department of Communications (DOC).

Changes or modifications not expressly approved by NI could void the user's authority to operate the equipment under the FCC Rules.

### Class A

#### Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user is required to correct the interference at their own expense.

#### Canadian Department of Communications

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la classe A respecte toutes les exigences du Règlement sur le matériel brouilleur du Canada.

### Compliance with EU Directives

Users in the European Union (EU) should refer to the Declaration of Conformity (DoC) for information\* pertaining to the CE marking. Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit [ni.com/certification](http://ni.com/certification), search by model number or product line, and click the appropriate link in the Certification column.

\* The CE marking Declaration of Conformity contains important supplementary information and instructions for the user or installer.

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# About This Manual

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Thank you for purchasing the National Instruments Educational Laboratory Virtual Instrumentation Suite (NI ELVIS). The *NI ELVIS User Manual* contains information that you need to understand and program the NI ELVIS architecture and instruments. The *NI ELVIS User Manual* also discusses the components of an NI data acquisition (DAQ) system and the concept of virtual instrumentation.



**Note** Refer to the *Where to Start with NI ELVIS* document if you need information about how to set up the components of the NI ELVIS.

## Conventions

---

The following conventions appear in this manual:

<>

Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DIO<3..0>.

»

The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.



This icon denotes a note, which alerts you to important information.



This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash. When this symbol is marked on the product, refer to the [Safety Information](#) section of Chapter 1, [DAQ System Overview](#), for precautions to take.

**bold**

Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names and hardware labels.

DAQ device

DAQ device refers to any National Instrument DAQ device that meets the conditions listed in the [DAQ Hardware](#) section of Chapter 3, [Hardware Overview](#).

ELVIS

Educational Laboratory Virtual Instrumentation Suite.



<i>italic</i>	Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply.
monospace	Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.
PCI	Peripheral Component Interconnect—a high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA.

## Related Documentation

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The following documents contain information that you might find helpful as you read this manual:

- DAQ device documentation, available at [ni.com/manuals](http://ni.com/manuals)
- *Getting Started with LabVIEW*, available at [ni.com/manuals](http://ni.com/manuals)
- *LabVIEW Help*, available by selecting **Help»VI, Function, and How-To Help** from the LabVIEW block diagram or front panel
- *LabVIEW Measurements Manual*, available at [ni.com/manuals](http://ni.com/manuals)
- *Measurement & Automation Explorer Help for DAQmx*, available by selecting **Help»Help Topics»NI-DAQmx** from the Measurement & Automation Explorer (MAX) window
- *Where to Start with NI ELVIS*, available in PDF format on the NI ELVIS Software CD
- *NI ELVIS Help*, available on the NI ELVIS Software CD or from [ni.com/manuals](http://ni.com/manuals)

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# DAQ System Overview

This chapter briefly describes the concept of DAQ systems and introduces NI ELVIS, a DAQ system designed for educational laboratories.

## What is DAQ?

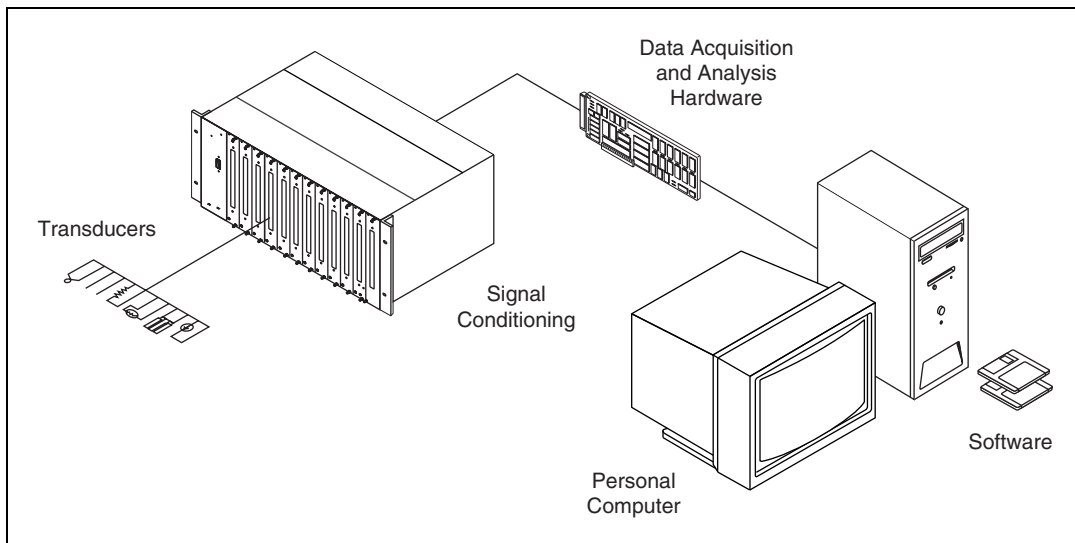
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DAQ systems capture, measure, and analyze physical phenomena from the real world. Light, temperature, pressure, and torque are examples of the different types of signals that a DAQ system can measure. Data acquisition is the process of collecting and measuring electrical signals from transducers and test probes or fixtures, and sending them to a computer for processing. Data acquisition may also include the output of analog or digital control signals.

The building blocks of a DAQ system include the following items:

- **Transducer**—A device that converts a physical phenomenon such as light, temperature, pressure, or sound into a measurable electrical signal such as voltage or current.
- **Signal**—The product of the DAQ system transducer.
- **Signal conditioning**—Hardware that you can connect to the DAQ device to make the signal suitable for measurement or to improve accuracy or reduce noise. The most common types of signal conditioning include amplification, excitation, linearization, isolation, and filtering.
- **DAQ hardware**—Hardware you use to acquire, measure, and analyze data.
- **Software**—NI application software is designed to help you easily design and program your measurement and control application.

Figure 1-1 shows the components of a typical DAQ system.



**Figure 1-1.** Typical DAQ System

NI ELVIS incorporates DAQ hardware and software, the last two of the DAQ system components, into one product. The following sections give more information about DAQ hardware and software, which is LabVIEW in the case of NI ELVIS.

## DAQ Hardware

Since DAQ devices acquire electrical signals, a transducer or a sensor must convert some physical phenomenon into an electrical signal. A DAQ system can also simultaneously produce electrical signals. These signals can either intelligently control mechanical systems or provide a stimulus so that the DAQ system can measure a response. Most DAQ devices have four standard elements: analog input (AI), analog output (AO), digital I/O (DIO), and counter/timers. The most common National Instruments DAQ devices are the E Series devices.

The *DAQ Hardware* section of Chapter 3, *Hardware Overview*, describes in greater detail the DAQ device used as part of the NI ELVIS. Refer to the DAQ device documentation, at [ni.com/manuals](http://ni.com/manuals) for specific information about the functionality and operation of the device.

# LabVIEW

LabVIEW is a graphical programming language frequently used for creating test, measurement, and automation applications. LabVIEW uses icons instead of lines of text to create applications. Unlike text-based programming languages, LabVIEW uses dataflow programming, where the flow of data determines execution. In LabVIEW, you build a user interface by using a set of tools and objects. The user interface is known as the *front panel*. You then add code using graphical representations of functions to control the front panel objects. The *block diagram* contains this code. In some ways, the block diagram resembles a flowchart. A *virtual instrument* (VI) is a LabVIEW program that models the appearance and function of a physical instrument.

The flexibility, modular nature, and ease-of-use programming possible with LabVIEW makes it popular in top university laboratories. With LabVIEW, you can rapidly create applications using intuitive graphical development and add user interfaces for interactive control. Scientists and engineers can use the straightforward I/O functionality of LabVIEW along with its analysis capabilities. LabVIEW can also be used in the classrooms to solve purely analytical or numerical problems.

For more information on programming with LabVIEW, refer to *Getting Started with LabVIEW* and the *LabVIEW Measurements Manual*, available at [ni.com/manuals](http://ni.com/manuals). The *LabVIEW Help* is available by selecting **Help»VI, Function, and How-To Help** from the LabVIEW block diagram or front panel, or you can select **Help»Search the LabVIEW Bookshelf** from the block diagram or front panel to display other relevant LabVIEW documentation.

## Virtual Instrumentation

*Virtual instrumentation* is defined as the combination of measurement and control hardware and application software with industry-standard computer technology to create user-defined instrumentation systems.

Virtual instrumentation provides an ideal platform for developing instructional curriculum and conducting scientific research. In an instructional laboratory course, students perform various experiments that combine measurements, automation, and control. Tools or systems used in these situations must be flexible and adaptable. In research environments, virtual instrumentation provides the flexibility that a researcher must have to modify the system to meet unpredictable needs. Research and instructional efforts also require that their systems be economical. Because you can reuse components in a virtual instrumentation system (without

purchasing additional hardware or software), virtual instrumentation is an economical choice. Finally, measurement systems must be scalable to meet future expansion needs. The modular nature of virtual instrumentation makes it easy for you to add new functionality.

## NI ELVIS Overview

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NI ELVIS uses LabVIEW-based software instruments, a multifunction DAQ device, and a custom-designed benchtop workstation and prototyping board to provide the functionality of a suite of common laboratory instruments.

The LabVIEW software that you use to interact with the NI ELVIS Benchtop Workstation and the DAQ device provides a high-level programming environment for easy implementation of the sophisticated display and analysis capabilities required for virtual instrumentation.

The NI ELVIS hardware provides a function generator and variable power supplies from the benchtop workstation. The NI ELVIS LabVIEW soft front panel instruments combined with the functionality of the DAQ device provide the functionality of the following SFP instruments:

- Arbitrary Waveform Generator (ARB)
- Bode Analyzer
- Digital Bus Reader
- Digital Bus Writer
- Digital Multimeter (DMM)
- Dynamic Signal Analyzer (DSA)
- Function Generator (FGEN)
- Impedance Analyzer
- Oscilloscope (Scope)
- Two-Wire Current Voltage Analyzer
- Three-Wire Current Voltage Analyzer
- Variable Power Supplies

Refer to Figure 2-1, [The NI ELVIS System](#), for an illustration of NI ELVIS.

# Safety Information

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The following section contains important safety information that you *must* follow when installing and using the product.

Do *not* operate the product in a manner not specified in this document. Misuse of the product can result in a hazard. You can compromise the safety protection built into the product if the product is damaged in any way. If the product is damaged, return it to National Instruments for repair.

Do *not* substitute parts or modify the product except as described in this document. Use the product only with the chassis, modules, accessories, and cables specified in the installation instructions. You *must* have all covers and filler panels installed during operation of the product.

Do *not* operate the product in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the product in such an environment, it must be in a suitably rated enclosure.

If you need to clean the product, use a soft, nonmetallic brush. Make sure that the product is completely dry and free from contaminants before returning it to service.

Operate the product only at or below Pollution Degree 1. Pollution is foreign matter in a solid, liquid, or gaseous state that can reduce dielectric strength or surface resistivity. The following is a description of pollution degrees:

- Pollution Degree 1 means no pollution or only dry, nonconductive pollution occurs. The pollution has no influence.
- Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3 means that conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation.

You *must* insulate signal connections for the maximum voltage for which the product is rated. Do *not* exceed the maximum ratings for the product. Do not install wiring while the product is live with electrical signals. Do not remove or add connector blocks when power is connected to the system. Avoid contact between your body and the connector block signal when hot swapping modules. Remove power from signal lines before connecting them to or disconnecting them from the product.

Operate the product at or below the *installation category*<sup>1</sup> marked on the hardware label. Measurement circuits are subjected to *working voltages*<sup>2</sup> and transient stresses (overvoltage) from the circuit to which they are connected during measurement or test. Installation categories establish standard impulse withstand voltage levels that commonly occur in electrical distribution systems. The following is a description of installation categories:

- Installation Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS<sup>3</sup> voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.
- Installation Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 V for U.S. or 230 V for Europe). Examples of Installation Category II are measurements performed on household appliances, portable tools, and similar products.
- Installation Category III is for measurements performed in the building installation at the distribution level. This category refers to measurements on hard-wired equipment such as equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.
- Installation Category IV is for measurements performed at the primary electrical supply installation (<1,000 V). Examples include electricity meters and measurements on primary overcurrent protection devices and on ripple control units.

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<sup>1</sup> Installation categories, also referred to as *measurement categories*, are defined in electrical safety standard IEC 61010-1.

<sup>2</sup> Working voltage is the highest rms value of an AC or DC voltage that can occur across any particular insulation.

<sup>3</sup> MAINS is defined as a hazardous live electrical supply system that powers equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

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# NI ELVIS Overview

NI ELVIS combines hardware and software into one complete laboratory suite. This chapter provides an overview of the hardware and software components of the NI ELVIS. Additionally, this chapter discusses how NI ELVIS can be used in various academic environments.

Chapter 3, *Hardware Overview*, provides more detailed information about NI ELVIS hardware components. Refer to the *NI ELVIS Help* for more information about the software components.

Refer to Figure 2-1 for a diagram of the NI ELVIS system.



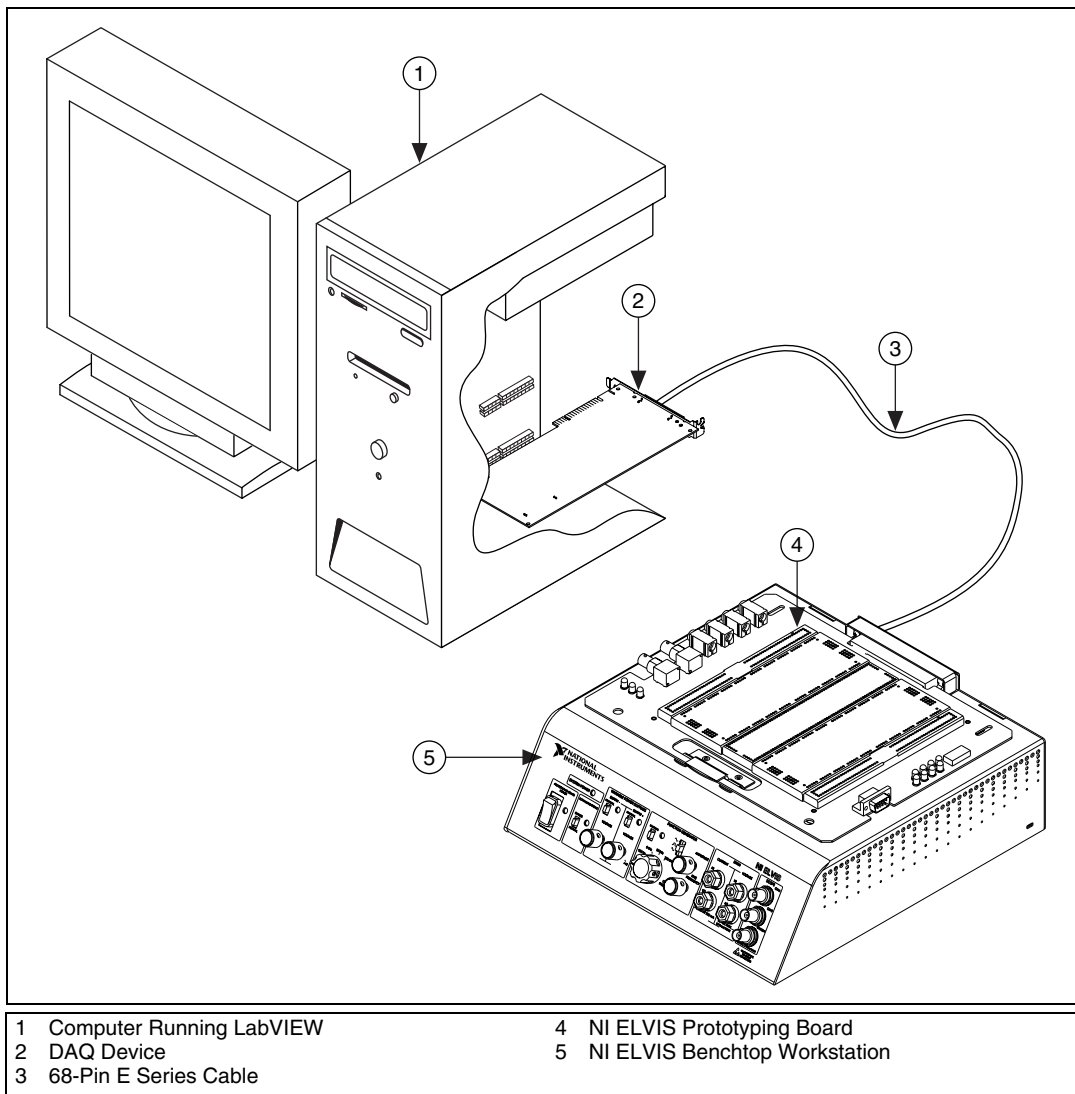


Figure 2-1. The NI ELVIS System

## NI ELVIS Hardware

The following sections briefly describe the hardware components of NI ELVIS. For more specific information about these components, refer to Chapter 3, [Hardware Overview](#).

## NI ELVIS Benchtop Workstation

The benchtop workstation and the DAQ device together create a complete laboratory system. The workstation provides connectivity and functionality. The control panel on the workstation provides easy-to-operate knobs for the function generator and variable power supplies, and it offers convenient connectivity in the form of BNC and banana-style connectors to the NI ELVIS - Scope SFP and NI ELVIS - DMM SFP. The NI ELVIS software routes signals in the NI ELVIS Benchtop Workstation between the SFP instruments. For example, the output of the function generator may be routed to a specific channel of the DAQ device and ultimately acquired on a desired channel of the NI ELVIS - Scope SFP. The benchtop workstation also contains a protection board that protects the DAQ device from possible damage resulting from laboratory errors.

Refer to the [NI ELVIS Benchtop Workstation](#) section of Chapter 3, [Hardware Overview](#), for more detailed information about the benchtop workstation, including the parts locator diagram.

## NI ELVIS Prototyping Board

The NI ELVIS Prototyping Board connects to the benchtop workstation. The prototyping board provides an area for building electronic circuitry and allows the connections necessary to access signals for common applications. You can use multiple prototyping boards interchangeably with the NI ELVIS Benchtop Workstation.

Refer to the [NI ELVIS Prototyping Board](#) section of Chapter 3, [Hardware Overview](#), for more information about the prototyping board, including signal descriptions, connection instructions, and the parts locator diagram.

## NI ELVIS Software

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The NI ELVIS software, created in LabVIEW, takes advantage of the capabilities of virtual instrumentation. The software includes two main types: the soft front panel (SFP) instruments and the LabVIEW API for programming the NI ELVIS hardware.

### SFP Instruments

NI ELVIS ships with the SFP instruments, created in LabVIEW, and the source code for the instruments. You cannot directly modify the executable files, but you can modify or enhance the functionality of these instruments

by modifying the LabVIEW code. The instruments are virtual instruments (VIs) that are necessary in typical laboratory applications.

This section briefly describes each SFP instrument included with NI ELVIS. The instrument software is LabVIEW-based, so you can customize the instruments by modifying the LabVIEW code.

## Instrument Launcher

The NI ELVIS Instrument Launcher provides access to the NI ELVIS software instruments. To launch an instrument, click the button corresponding to the desired instrument. If the NI ELVIS software is properly configured and the benchtop workstation is cabled to the appropriate DAQ device, all buttons should be visible.

If there is a problem with your configuration, such as when the NI ELVIS Benchtop Workstation is powered off or disconnected from the configured DAQ device, all instrument buttons are dimmed, and the only available option is to click the **Configure** button. Refer to *Where to Start with NI ELVIS* for more information about configuring NI ELVIS.

Some instruments perform similar operations using the same resources of the NI ELVIS hardware and the DAQ device and cannot be run at the same time. If you launch two instruments with overlapping functionality that cannot run at the same time, the NI ELVIS software generates an error dialog describing the conflict. The instrument with the error is disabled and will not function until the conflict is resolved.

## Arbitrary Waveform Generator (ARB)

This advanced-level SFP instrument uses the AO capabilities of NI ELVIS (DAC0 and DAC1). You can create a variety of signal types using the Waveform Editor software, which is included with the NI ELVIS software. You can load waveforms created with the NI Waveform Editor into the ARB SFP to generate stored waveforms. Refer to the *NI ELVIS Help* for more information about the Waveform Editor.

Because a typical DAQ device has two AO channels, two waveforms may be simultaneously generated. You can choose continuous output or a one-shot output. The maximum output rate of the NI ELVIS - ARB SFP is determined by the maximum update rate of the DAQ device connected to the NI ELVIS hardware. Refer to the DAQ device documentation for these specifications.

## Bode Analyzer

By combining the frequency sweep feature of the function generator and the AI capability of the DAQ device, a full-function Bode Analyzer is available with NI ELVIS. You can set the frequency range of the instrument and choose between linear and dB display scales.

## Digital Bus Reader

This instrument reads digital data from the NI ELVIS digital input (DI) bus. You can either continuously read from the bus, or you can take a single reading.

## Digital Bus Writer

This instrument updates the NI ELVIS digital output (DO) bus with user-specified digital patterns. You can manually create a pattern or select predefined patterns, such as ramp, toggle, or walking ones. This instrument can either continually output a pattern or just perform a single write. The output of the NI ELVIS - Digital Bus Writer SFP stays latched until the instrument is stopped or another pattern is output. Output voltage levels of the SFP are TTL compatible.

## Digital Multimeter (DMM)

This commonly used instrument can perform the following types of measurements:

- DC voltage
- AC voltage
- Current (DC and AC)
- Resistance
- Capacitance
- Inductance
- Diode test
- Audible continuity

You can connect to the DMM from the NI ELVIS Prototyping Board or from the banana-style connectors on the front panel of the benchtop workstation.

## Dynamic Signal Analyzer (DSA)

This instrument is especially useful in advanced electrical engineering and physics classes. This instrument uses the analog input of the DAQ device to make measurements and can either continuously make measurements or make a single scan. You can also apply various window and filtering options to the signal.

## Function Generator (FGEN)

This instrument provides you with choices for the type of output waveform (sine, square, or triangle), amplitude selection, and frequency settings. In addition, the instrument offers DC offset setting, frequency sweep capabilities, and amplitude and frequency modulation.

## Impedance Analyzer

This instrument is a basic impedance analyzer that is capable of measuring the resistance and reactance for passive two-wire elements at a given frequency.

## Oscilloscope (Scope)

This instrument provides the functionality of the standard desktop oscilloscope found in typical undergraduate laboratories. The NI ELVIS - Scope SFP has two channels and provides scaling and position adjustment knobs along with a modifiable timebase. You also can choose trigger source and mode settings. The autoscale feature allows you to adjust the voltage display scale based on the peak-to-peak voltage of the AC signal for the best display of the signal. Depending on the DAQ device cabled to the NI ELVIS hardware, you can choose between digital or analog hardware triggering. You can connect to the NI ELVIS - Scope SFP from the NI ELVIS Prototyping Board or from the BNC connectors on the front panel of the benchtop workstation.

The FGEN or DMM signals can be internally routed to this instrument. In addition, this computer-based scope display has the ability to use cursors for accurate screen measurements. The sampling rate of the Oscilloscope is determined by the maximum sampling speed of the DAQ device installed in the computer attached to the NI ELVIS hardware.

Refer to the DAQ device documentation for information about the type of triggering supported on the device and for the specifications for the maximum sampling speed of the device.

## Two-Wire and Three-Wire Current-Voltage Analyzers

These instruments allow you to conduct diode and transistor parametric testing and view current-voltage curves. The two-wire instrument offers full flexibility in setting parameters such as voltage and current ranges and can save data to a file. In addition, the three-wire instrument offers base current settings for measurements of NPN transistors.



**Note** Other types of transistors can be measured, but these measurements are not currently supported by the SFPs.

Both instruments have cursors for more accurate onscreen measurements.

## Variable Power Supplies

You can control the output of the positive or negative variable power supply with these SFP instruments. The negative power supply can output between  $-12$  and  $0$  V, and the positive power supply can output between  $0$  and  $+12$  V.



**Note** For a detailed explanation of the soft front panel instruments and instructions for taking a measurement with each instrument, refer to the *NI ELVIS Help*. For more information about the operation of the NI ELVIS circuitry, refer to Appendix C, *Theory of Operation*.

## NI ELVIS LabVIEW API

The NI ELVIS software also includes APIs to program four features of the NI ELVIS hardware: the DIO, DMM, function generator, and variable power supplies. Refer to Chapter 4, *Programming NI ELVIS*, for more information about using the APIs to program NI ELVIS.



**Note** For the VI reference for each API, refer to the *NI ELVIS Help*.

## NI ELVIS Calibration Utility

The NI ELVIS 2.0 software also includes a calibration utility that you can use to recalibrate the NI ELVIS variable power supplies or function generator circuitry.

# NI ELVIS in Academic Disciplines

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You can use NI ELVIS in engineering, physical sciences, and biological sciences laboratories. NI ELVIS is suitable not only in terms of the included software, but also because of the custom signal conditioning hardware you can create with NI ELVIS. Instructors can implement the NI ELVIS curriculum with beginning to advanced classes to provide hands-on experience to students.

## NI ELVIS in Engineering

NI ELVIS is suited for teaching basic electronics and circuit design to students in electrical engineering, mechanical engineering, and biomedical engineering. The suite offers full testing, measurement, and data-saving capabilities needed for such training. Students can use the removable prototyping board at home to build circuits, thus using laboratory time more effectively.

NI ELVIS SFP instruments, such as the Bode Analyzer, offer instructors an opportunity to teach advanced courses in signal analysis and processing. Students may construct software filters in LabVIEW and hardware filters on the prototyping board and compare the performance of those two types of filters.

Mechanical engineering students can learn sensor and transducer measurements in addition to basic circuit design by building custom signal conditioning. Students can install custom sensor adapters on the prototyping board. For example, installing a thermocouple jack on the prototyping board allows robust thermocouple connections. The programmable power supply can provide excitation for strain gauges used in strain measurements.

## NI ELVIS in Biological Sciences



**Caution** The NI ELVIS hardware is *not* environmentally sealed; therefore, exercise extreme caution for use in chemical and biological sciences.

Biomedical engineering departments have challenges that are similar to those of mechanical departments. Students typically learn basic electronics and build instruments such as an electrocardiogram (ECG) monitor. The prototyping board offers signal conditioning capability for ECG sensors, and the NI ELVIS SFP instruments are ideal for testing the circuits as students build the signal conditioning circuits.

## NI ELVIS in Physical Sciences

Physics students typically learn electronics and circuit design theory. NI ELVIS provides these students with the opportunity to implement these concepts. Physics students sometimes need signal conditioning for common sensors such as photoelectric multiplier or light detector sensors. Students can build high-gain, low-noise circuits on a printed circuit board (PCB) and use them in modern physics labs.



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# Hardware Overview

This chapter describes the hardware components of NI ELVIS, including the DAQ device, the benchtop workstation, and the prototyping board. Appendix C, *Theory of Operation*, provides more information about the circuitry used for the different NI ELVIS measurements.

## DAQ Hardware

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NI ELVIS is designed to interact with National Instruments E Series DAQ devices, which are high-performance, multifunction analog, digital, and timing I/O devices for PCI bus computers. Supported functions on DAQ devices include AI, AO, DIO, and timing I/O (TIO).

To use NI ELVIS, the DAQ device installed in the computer connected to the NI ELVIS hardware must meet the following minimum requirements:

- 16 AI channels, minimum sample rate of 200 kS/s
- Two AO channels
- Eight DIO lines
- Two counter/timers



**Note** NI ELVIS also supports 64 AI channel DAQ devices when used with the appropriate cable. For cabling information, refer to the *E Series Help*. NI ELVIS does not support DIO-only devices or the NI DAQPad-6020E for USB.

## Using the DAQ Hardware in Bypass Mode

NI ELVIS communicates with the computer through the eight DIO lines of the DAQ device. The Communications switch controls the routing of the DIO to the NI ELVIS. In normal operation, the switch is in Normal mode, and the DIO lines are routed to the NI ELVIS hardware, allowing software control. When the Communications switch is set to Bypass mode, the LED next to the switch is lit. No communication changes occur unless you use the NI ELVIS - Enable Communications Bypass VI in conjunction with putting the switch in Bypass mode. After you move the switch and run the VI, the DIO lines are routed to the DI lines on the prototyping board. Figure 3-1 shows the location of the Communications switch.

When in Bypass mode, the hardware function generator and variable power supplies are still available through the manual controls. The counter/timers, AI, and AO on the DAQ device are also available. The NI ELVIS SFP instruments notify you when the Communications switch is in Bypass mode. Some SFP controls are dimmed when the Communications switch is moved to Bypass mode.

For detailed information about the DAQ device, refer to the DAQ device documentation, which you can download at [ni.com/manuals](http://ni.com/manuals).

## NI ELVIS Benchtop Workstation

This section describes the NI ELVIS Benchtop Workstation and the control panel on the front of the workstation.

Refer to Figure 3-1 for the parts locator diagram for the benchtop workstation.

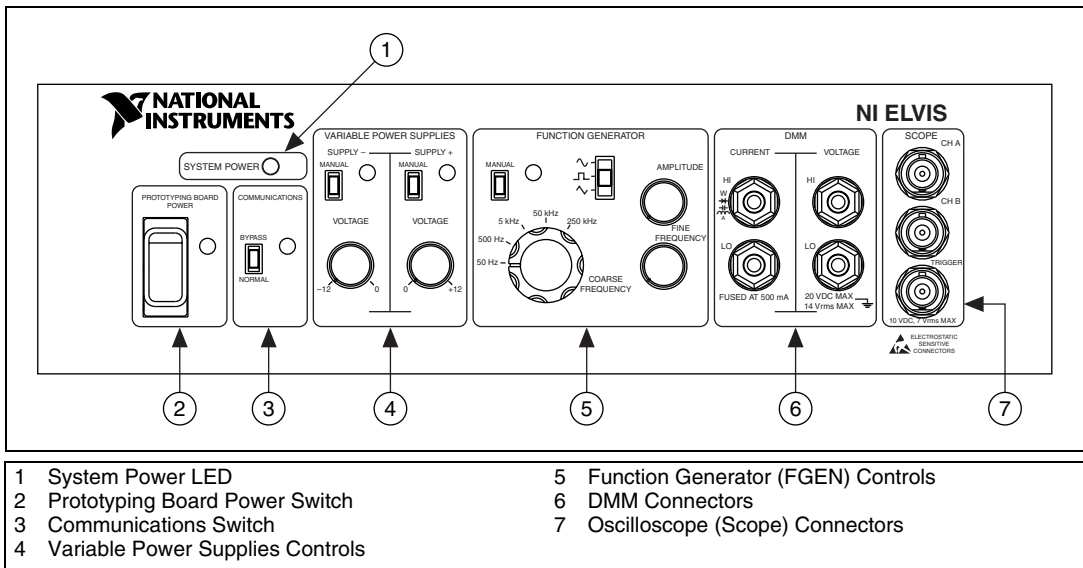


Figure 3-1. Control Panel Diagram of the Benchtop Workstation

The benchtop workstation has the following controls and indicators:

- **System Power LED**—Indicates whether the NI ELVIS is powered on.
- **Prototyping Board Power Switch**—Controls the power to the prototyping board.

- **Communications Switch**—Requests disabling software control of the NI ELVIS. This setting provides direct access to the DAQ device DIO lines. For more information about the Communications switch, refer to the [Using the DAQ Hardware in Bypass Mode](#) section.
- **Variable Power Supplies Controls**



**Note** You can control the variable power supplies through either the hardware controls on the benchtop workstation (Manual mode) or the controls on the NI ELVIS - Variable Power Supplies SFP (Software mode). You can only use the controls described in the following section when the variable power supplies are in Manual mode.

– **Supply– Controls**

- **Manual Switch**—Controls whether the negative supply is in Manual mode or Software mode.
- **Voltage Adjust Knob**—Controls the output of the negative supply. The negative supply can output between  $-12$  and  $0$  V.

– **Supply+ Controls**

- **Manual Switch**—Controls whether the positive supply is in Manual mode or Software mode.
- **Voltage Adjust Knob**—Controls the output of the positive supply. The positive supply can output between  $0$  and  $+12$  V.

For more information about the software controls for the NI ELVIS - Variable Power Supplies SFP, refer to the *NI ELVIS Help*.

- **Function Generator Controls**



**Note** You can control the function generator through either the hardware controls on the benchtop workstation (Manual mode) or the controls on the NI ELVIS - FGEN SFP (Software mode). You can only use the controls described in the following section when the function generator is in Manual mode.

- **Manual Switch**—Controls whether the function generator is in Manual mode or Software mode.
- **Function Selector**—Selects what type of waveform is generated. NI ELVIS can generate sine, square, or triangle waves.
- **Amplitude Knob**—Adjusts the peak amplitude of the generated waveform.
- **Coarse Frequency Knob**—Sets the range of frequencies the function generator can generate.

- **Fine Frequency Knob**—Adjusts the output frequency of the function generator.

For more information about the software controls for the function generator, refer to the *NI ELVIS Help*.

- **DMM Connectors**



**Caution** By connecting different signals to both the DMM terminals on the prototyping board and the DMM connectors on the control panel, you are shorting them together, potentially damaging the circuit on the prototyping board.

- **CURRENT Banana Jacks**
  - **HI**—The positive input to all the DMM functionality, except measuring voltage.
  - **LO**—The negative input to all the DMM functionality, except measuring voltage.
- **VOLTAGE Banana Jacks**
  - **HI**—The positive input for voltage measurements.
  - **LO**—The negative input for voltage measurements.



**Note** The NI ELVIS DMM is ground referenced.

- **Oscilloscope (Scope) Connectors**



**Caution** By connecting different signals to the Scope terminals on the prototyping board and the Scope connectors on the control panel, you are shorting them together, potentially damaging the circuit on the prototyping board.

- **CH A BNC Connector**—The input for channel A of the Oscilloscope.
- **CH B BNC Connector**—The input for channel B of the Oscilloscope.
- **Trigger BNC Connector**—The input to the trigger of the Oscilloscope.

## NI ELVIS Protection Board

NI ELVIS protects the DAQ device installed in the desktop computer by means of a protection board located inside the NI ELVIS Benchtop Workstation. This removable protection board provides short-circuit protection from unsafe external signals. Removing the protection board enables you to quickly replace a nonfunctioning board with a replacement unit. The components on the protection board can be obtained from electronics vendors and thus can be serviced without sending the board to NI for repairs.

Refer to Appendix B, *Protection Board Fuses*, for more information about changing the fuses on the NI ELVIS Protection Board.

## NI ELVIS Prototyping Board

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This section describes the NI ELVIS Prototyping Board and how you can use it to connect circuits to NI ELVIS. This section also describes the signals that you can connect to NI ELVIS from the prototyping board and the connectors you can use to do so.



**Caution** Ensure the power to the prototyping board is off before inserting the prototyping board into the NI ELVIS benchtop workstation.

The prototyping board connects to the benchtop workstation with a standard PCI connector, so you can create custom PCBs to interact with NI ELVIS.

The prototyping board exposes all the signal terminals of the NI ELVIS to the user through the distribution strips on either side of the breadboard area. Each signal has a row, and the rows are grouped by function.

Refer to Figure 3-2 for the parts locator diagram for the prototyping board.

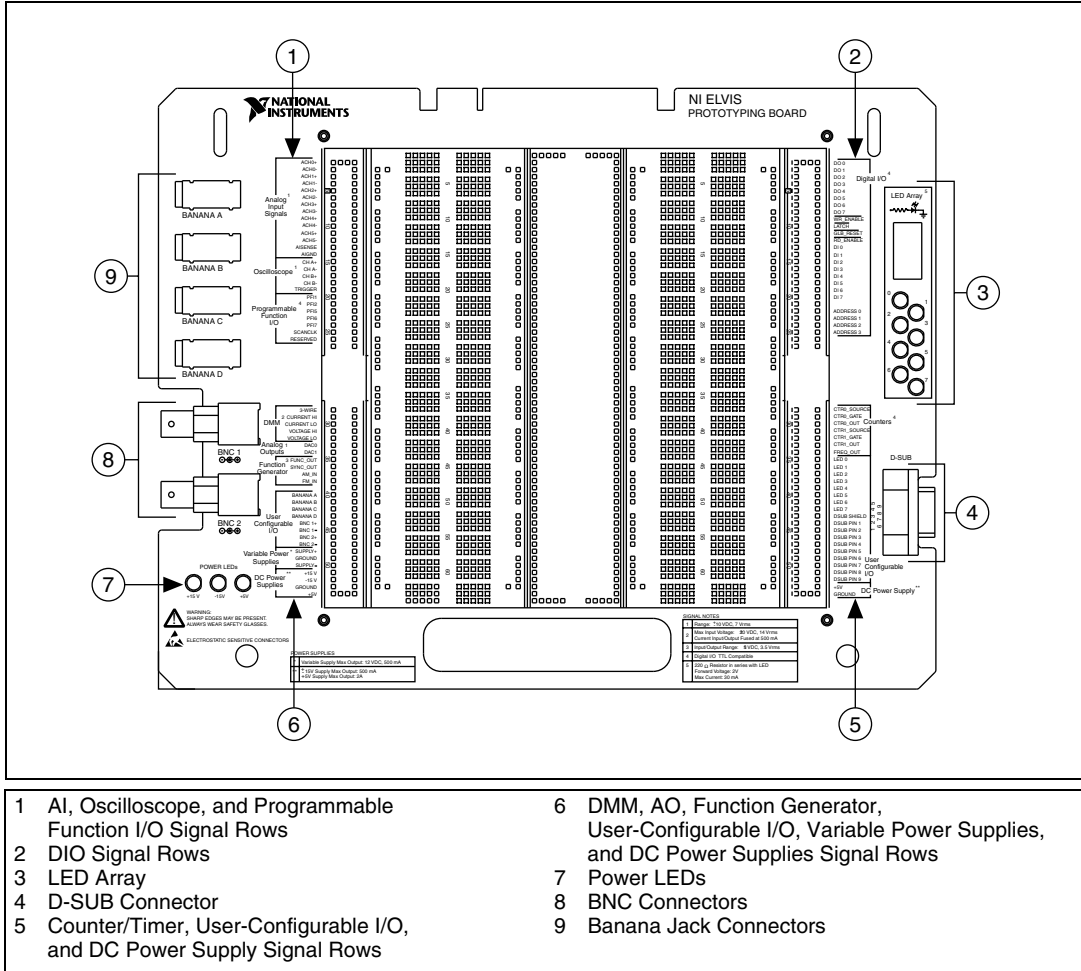


Figure 3-2. Prototyping Board Parts Locator Diagram

## Prototyping Board Power

The prototyping board provides access to a  $\pm 15$  V and a +5 V power supply. You can use these voltage rails to construct many common circuits. Refer to Appendix A, *Specifications*, for more information about these voltage rails.

## Prototyping Board Signal Descriptions

Table 3-1 describes the signals on the NI ELVIS prototyping board. The signals are grouped by the functionality section where they are located on the prototyping board.

**Table 3-1.** Signal Descriptions

Signal Name	Type	Description
ACH<0..5>+	General AI	Analog Input Channels 0 through 5 (+)—Positive differential input to the AI channels.
ACH<0..5>-	General AI	Analog Input Channels 0 through 5 (-)—Negative differential input to the AI channels.
AISENSE	General AI	Analog Input Sense—Reference for the analog channels in nonreferenced single-ended (NRSE) mode. For more information on AI modes, refer to the DAQ device documentation.
AIGND	General AI	Analog Input Ground—AI ground reference for the DAQ device. This ground signal is not tied to the NI ELVIS GROUND signals.
CH <A..B>+	Oscilloscope	Oscilloscope Channels A and B (+)—Positive input for the Oscilloscope channels.
CH <A..B>-	Oscilloscope	Oscilloscope Channels A and B (-)—Negative input for the Oscilloscope channels.
TRIGGER	Oscilloscope	Oscilloscope Trigger—Trigger input for the Oscilloscope, referenced to AIGND.
PFI <1..2>, PFI <5..7>	Programmable Function I/O	Programmable Function Input (PFI) 1 through 2 and 5 through 7—Programmable function I/O of the DAQ device. For more information about the PFI lines, refer to the DAQ device documentation.
SCANCLK	Programmable Function I/O	Scan Clock—Connected to the SCANCLK pin of the DAQ device. For more information about the SCANCLK signal, refer to the DAQ device documentation.
RESERVED	Programmable Function I/O	Connected to the EXTSTROBE* pin of the DAQ device. For more information about the EXTSTROBE* signal, refer to the DAQ device documentation.
3-WIRE	DMM	Three Wire—Voltage source for the DMM for three-wire transistor measurements.
CURRENT HI	DMM	Positive Current—Positive input for the DMM for all measurements besides voltage. The NI ELVIS is ground referenced.
CURRENT LO	DMM	Negative Current—Negative input for the DMM for all measurements besides voltage. The NI ELVIS is ground referenced.

**Table 3-1.** Signal Descriptions (Continued)

Signal Name	Type	Description
VOLTAGE HI	DMM	Positive Voltage—Positive input for the DMM voltmeter.
VOLTAGE LO	DMM	Negative Voltage—Negative input for the DMM voltmeter.
DAC<0..1>	NI ELVIS AO	Analog Output for Channels 0 and 1—Outputs of the DAQ device buffer. For more information about the DAQ device analog output signals, refer to the DAQ device documentation and Appendix C, <i>Theory of Operation</i> .
FUNC_OUT	Function Generator	Function Output—Output of the function generator.
SYNC_OUT	Function Generator	Synchronization Output—TTL signal of the same frequency as the output as the FUNC_OUT pin.
AM_IN	Function Generator	Amplitude Modulation Input—Input to the amplitude modulator for the function generator.
FM_IN	Function Generator	Frequency Modulation Input—Input to the frequency modulator for the function generator.
BANANA <A..D>	User Configurable I/O	Banana Jacks A through D—Connects to the banana jacks pins.
BNC <1..2>+	User Configurable I/O	BNC Connectors 1 and 2 (+)—Connects to the BNC pins.
BNC <1..2>-	User Configurable I/O	BNC Connectors 1 and 2 (-)—Connects to the BNC pins.
SUPPLY+	Variable Power Supplies	Positive—Output of 0 to 12 V variable power supply.
SUPPLY-	Variable Power Supplies	Negative—Output of -12 to 0 V variable power supply.
GROUND	Variable Power Supplies, DC Power Supplies	Ground—Prototyping board ground. These two ground signals are tied together.
+15 V	DC Power Supplies	+15 V Source—Output of fixed +15 V power supply, referenced to the NI ELVIS GROUND signal.
-15 V	DC Power Supplies	-15 V Source—Output of fixed -15 V power supply, referenced to the NI ELVIS GROUND signal.
+5V	DC Power Supplies	+5V Source—Output of fixed +5 V power supply, referenced to the NI ELVIS GROUND signal.
DO <0..7>	DIO	Digital Output Lines 0 through 7—Output of the write bus. These channels are used by the NI ELVIS Digital Bus Writer SFP to generate digital data.
WR ENABLE	DIO	Write Enable—Active low signal that updates when DO <0..7> are updated.
LATCH	DIO	Latch—Active low signal that pulses when data is ready on DO <0..7>.
GLB RESET	DIO	Global Reset—Active low signal that is used to reset all of the NI ELVIS hardware settings



**Table 3-1.** Signal Descriptions (Continued)

Signal Name	Type	Description
RD ENABLE	DIO	Read Enable—Active low signal that indicates data is being read from DI <0..7>.
DI <0..7>	DIO	Digital Input Lines 0 through 7—Input to read bus. These channels are used by the NI ELVIS Digital Bus Reader SFP to acquire digital data.
ADDRESS <0..3>	DIO	Address Lines 0 through 3—Output of address bus.
CTR0_SOURCE	Counters	Counter 0 Source—Connected to the GPCTR0_SOURCE pin on the DAQ device. For more information about the GPCTR0_SOURCE signal, refer to the DAQ device documentation.
CTR0_GATE	Counters	Counter 0 Gate—Connected to the GPCTR0_GATE pin on the DAQ device. For more information about the GPCTR0_GATE signal, refer to the DAQ device documentation.
CTR0_OUT	Counters	Counter 0 Output—Connected to the GPCTR0_OUT pin on the DAQ device. For more information about the GPCTR0_OUT signal, refer to the DAQ device documentation.
CTR1_GATE	Counters	Counter 1 Gate—Connected to the GPCTR1_GATE pin on the DAQ device. For more information about the GPCTR1_GATE signal, refer to the DAQ device documentation.
CTR1_OUT	Counters	Counter 1 Output—Connected to the GPCTR1_OUT pin on the DAQ device. For more information about the GPCTR1_OUT signal, refer to the DAQ device documentation.
FREQ_OUT	Counters	Frequency Output—Connected to the FREQ_OUT pin on the DAQ device. For more information about the FREQ_OUT signal, refer to the DAQ device documentation.
LED <0..7>	User Configurable I/O	LEDs 0 through 7—Input to the LEDs.
DSUB SHIELD	User Configurable I/O	D-SUB Shield—Connection to D-SUB shield.
DSUB PIN <1..9>	User Configurable I/O	D-SUB Pins 1 through 9—Connection to D-SUB pins.

## Connecting Signals

This section provides information about connecting signals between the NI ELVIS and the DAQ device. Refer to Appendix D, [Resource Conflicts](#), for a table showing possible resource conflicts when connecting NI ELVIS signals.

## Grounding Considerations

Because the analog channels are differential, you must establish a ground point somewhere in the signal path. As long as the signal you are measuring is referenced to one of the NI ELVIS GROUND pins, the measurement is correctly referenced. If a floating source, such as a battery, is being measured, be sure to connect one end of the signal to the NI ELVIS GROUND. Terminals for the NI ELVIS GROUND signal are located at several locations on the prototyping board. All these signals are tied together.



**Note** NI ELVIS does not support floating measurements.

## Connecting Analog Input Signals

This section describes how to connect AI signals on the NI ELVIS Prototyping Board. Refer to the DAQ device documentation for more information about types of signal sources, input modes, grounding configurations, and floating signal sources.

### Generic Analog Input

The NI ELVIS Prototyping Board has six differential AI channels available—ACH<0..5>. These inputs are directly connected to the DAQ device input channels. NI ELVIS also has two ground pins, AISENSE and AIGND, which are connected to the DAQ device. Table 3-2 shows how the NI ELVIS input channels map to the DAQ device input channels.

**Table 3-2.** Analog Input Signal Mapping

NI ELVIS Input Channel	DAQ Device Input Channel
ACH0+	AI 0
ACH0–	AI 8
ACH1+	AI 1
ACH1–	AI 9
ACH2+	AI 2
ACH2–	AI 10
ACH3+	AI 3
ACH3–	AI 11

**Table 3-2.** Analog Input Signal Mapping (Continued)

NI ELVIS Input Channel	DAQ Device Input Channel
ACH4+	AI 4
ACH4-	AI 12
ACH5+	AI 5
ACH5-	AI 13
AISENSE	AISENSE
AIGND	AIGND

The following sections describe some special considerations for connecting the AI signals on the prototyping board, including sections that specifically pertain to the Oscilloscope and DMM.

## Resource Conflicts

Some of the AI channels are used by the internal circuitry for other instruments, but the majority of the time the channel can still be used. ACH<0..2> can be used without interruption. ACH5 is interrupted if any of the impedance-analyzing capabilities of the DMM, such as the capacitance meter, diode tester, and so on, are used. If you are using the Oscilloscope, disconnect any signals from ACH3 and ACH4 to avoid double driving the channels. For more information about possible resource conflicts, refer to Appendix D, *Resource Conflicts*.



**Caution** By connecting different signals to both the DMM terminals on the prototyping board and the DMM connectors on the control panel, you are shorting them together, potentially damaging the circuit on the prototyping board.

## DMM

Both the CURRENT and VOLTAGE inputs are available on the prototyping board along with an additional terminal for three-wire transistor measurements. The differential voltmeter inputs are labeled VOLTAGE HI and VOLTAGE LO. The rest of the functionality of the DMM is available through the CURRENT HI and CURRENT LO pins.

The 3-WIRE pin is used for three-terminal device measurements in conjunction with the CURRENT HI and CURRENT LO pins.



**Caution** By connecting different signals to the Scope terminals on the prototyping board and the Scope connectors on the control panel, you are shorting them together, potentially damaging the circuit on the prototyping board.

## Oscilloscope

The inputs of the Oscilloscope are available on the prototyping board as CH <A..B>+, CH <A..B>-, and TRIGGER. CH <A..B> are directly connected to ACH3 and ACH4, respectively, on the DAQ device. Refer to the [Generic Analog Input](#) section for more information about resource conflicts and grounding.

## Connecting Analog Output Signals

This section describes how to connect the AO signals on the prototyping board.

## Generic Analog Output

NI ELVIS provides access to the two DAQ device DACs at the DAC0 and DAC1 terminals. These channels are used by the NI ELVIS hardware for arbitrary waveform generation. The output of the DAQ device is buffered and protected by the NI ELVIS hardware.



**Caution** Other functions of NI ELVIS, such as the DMM and FGGEN, internally use DAC0 and DAC1, and these functions can potentially interfere with the measurements. The driver software generates an error message when there is a potential resource conflict.

## DC Power Supplies

The DC power supplies output a static  $\pm 15$  V and +5 V. For more information on the DC power supplies output, refer to Appendix A, [Specifications](#).

## Function Generator (FGEN)

Access to the function generator on the prototyping board includes several additional terminals besides the function generator output signal, FUNC\_OUT. The SYNC\_OUT signal outputs a TTL-compatible clock signal of the same frequency as the output waveform. The AM\_IN and FM\_IN signals control the amplitude modulation (AM) and the frequency modulation (FM), respectively. These signals are in addition to the fine

frequency and amplitude controls on the benchtop workstation. Software AM is controlled by DAC0 and software FM is controlled by DAC1.

## Variable Power Supplies

The variable power supplies provide adjustable output voltages from 0 to +12 V on the SUPPLY+ terminal and -12 to 0 V on the SUPPLY- terminal. The GROUND pin provides a connection to the same ground of the DC power supplies.

## Connecting Digital I/O Signals

This section describes how to connect the DIO signals on the prototyping board.

NI ELVIS provides a digital input (DI) and digital output (DO) bus. The input and output bus are 8-bit buses that are controlled by NI ELVIS while in software mode. When the Communications switch is set to Bypass mode, DI <0..7> become directly connected to the DAQ device digital lines.

DO <0..7> are the digital output signals of NI ELVIS to the prototyping board. The output bus logic is +5 V TTL for high level and 0 V TTL for low level. DI <0..7> are the digital input signals to NI ELVIS from the prototyping board. The minimum voltage for logic high level is 2.0 V. The maximum voltage for a low level is 0.8 V. When in manual mode, logic levels high and low are dependent on the DAQ device.

The address bus is an 8-bit bus used for communication on the prototyping board. The lower four bits of the address bus, WR ENABLE, LATCH, GLB RESET, and RD ENABLE, are reserved for NI ELVIS communication. Refer to the [Prototyping Board Signal Descriptions](#) section in this chapter for more information about these signals.

The upper four bits of the address bus, ADDRESS<0..3>, are open. Some common uses for the address lines are digital controls lines for relays, multiplexers, or simple, low-current control lines.

## Connecting Counter/Timer Signals

The prototyping board provides access to the DAQ device counter/timer inputs, which are also accessible from software. These inputs are used for counting TTL signals and for edge detection. The CTR0\_SOURCE, CTR0\_GATE, CTR0\_OUT, CTR1\_GATE, and CTR1\_OUT signals are

equivalent to the DAQ device GPCTR0\_SOURCE, GPCTR0\_GATE, GPCTR0\_OUT, GPCTR1\_GATE, and GPCTR1\_OUT pins, respectively. Refer to the DAQ device documentation for details on using and configuring counter/timers.

The FREQ\_OUT signal is equivalent to the DAQ device FREQ\_OUT signal. Refer to the DAQ device documentation for more information about this signal.

## Connecting User-Configurable Signals

The prototyping board provides several different user-configurable connectors: four banana jacks, two BNC connectors, and a D-SUB connector. Each pin of the connector has a connection to the distribution strips of the prototyping board.

Eight LEDs are provided for general digital output. The anode of each LED is connected to the distribution strip through a 220  $\Omega$  resistor, and each cathode is connected to ground.

Refer to Table 3-1 for more information about the signal names for the user-configurable I/O connectors.

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# Programming NI ELVIS

An NI ELVIS measurement system is composed of the NI ELVIS hardware, the DAQ device, and the LabVIEW software that controls the hardware. Various measurements can be performed by NI ELVIS using either the NI-DAQmx driver or the NI ELVIS instrument driver. Three standard measurement functions of DAQ devices—AI, AO, and TIO—can be utilized when connected to the NI ELVIS Benchtop Workstation. The fourth DAQ device function, DIO, is unavailable with an NI ELVIS measurement system since the DAQ device DIO communicates with the control circuitry of the benchtop workstation. Additionally, the NI ELVIS Benchtop Workstation has variable power supplies, a function generator, a DMM, and DIO circuitry that you can control using the NI ELVIS instrument driver, which is located in the functions palette under **Instrument I/O»Instrument Drivers»NI ELVIS**.

This chapter explains how to program the NI ELVIS hardware using NI-DAQmx and the NI ELVIS Instrument Driver. This chapter is not intended to be an exhaustive guide to programming with LabVIEW or NI-DAQmx; its purpose is instead to familiarize you with concepts you should know about when programming NI ELVIS.

For more information on programming with NI-DAQmx or LabVIEW, refer to the NI-DAQmx documentation that shipped with the device or to the *LabVIEW Measurements Manual*.

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## Programming NI ELVIS Using NI-DAQmx

This section explains how to program NI ELVIS for AI, AO, and timing and control I/O applications. You can find other examples for using NI ELVIS for AI, AO, and counter/timer applications by launching LabVIEW and selecting **Find Examples»Hardware Input and Output»DAQ** and then the type of example, or you can find examples by selecting **Find Examples** and then searching for NI-ELVIS.



**Note** The DIO examples within LabVIEW do not work with the DIO lines of the NI ELVIS hardware. Refer to the [Using the DAQ Hardware in Bypass Mode](#) section of Chapter 3, [Hardware Overview](#), for more information about using the communications bypass.

## Analog Input



**Caution** ACH3 and ACH4 are used for Oscilloscope measurements on CH A and CH B, respectively. Do not connect signals to these channels on the prototyping board and the front panel BNC **Scope** connectors at the same time.

You can use NI ELVIS to measure up to six differential AI channels: ACH<0..5>.



**Note** The DAQ device must be configured for differential AI mode before making connections to the NI ELVIS Benchtop Workstation. For information on configuring the DAQ device, refer to the [Measurement & Automation Explorer Help for NI-DAQmx](#), which you can access by launching MAX, then selecting **Help»Help Topics»NI-DAQmx»MAX Help for NI-DAQmx**.

ACH<0..5> on the NI ELVIS Prototyping Board directly connect to corresponding AI channels on the DAQ device. ACH<0..5> can be used as normal input channels for any existing DAQ examples or for when you program with the LabVIEW Data Acquisition VIs. ACH5 is also used for measurements by the following NI ELVIS software instruments: Oscilloscope, DMM, DSA, Impedance Analyzer, Two-Wire Current-Voltage Analyzer, and Three-Wire Current-Voltage Analyzer. ACH5 might be unavailable if these software instruments are running.

Refer to the [NI ELVIS Prototyping Board](#) section of Chapter 3, [Hardware Overview](#), for an illustration of signal connections on the prototyping board.

Typical AI measurements include buffered continuous acquisitions and finite acquisitions with a start trigger. For more information on how to perform an AI acquisition using NI-DAQmx, refer to the NI-DAQmx documentation that shipped with the DAQ device.

## Analog Output

NI ELVIS allows access to the two analog outputs of a DAQ device through connectors on the prototyping board. The AO signals labeled DAC0 and DAC1 connect to the signals of the same name on the



DAQ device. These signals can be used as normal output channels for any existing DAQ examples and for when you program with DAQ VIs.

Refer to the *NI ELVIS Prototyping Board* section of Chapter 3, *Hardware Overview*, for an illustration of signal locations on the prototyping board.

The output channels are also used by the following NI ELVIS SFP instruments: FGGEN, DMM, Impedance Analyzer, Two-Wire Current-Voltage Analyzer, and Three-Wire Current-Voltage Analyzer. The output channels may not be available if these SFP instruments are running.

Typical AO applications include continuous waveform generation and single-point output updates. For more information on how to perform AO generation using NI-DAQmx, refer to the NI-DAQmx documentation that shipped with the DAQ device.

## Timing and Control I/O

NI ELVIS provides access to the two counter/timers of the DAQ device. Table 4-1 shows how NI ELVIS counter signals correlate with DAQ device timing signals.

**Table 4-1.** Counter Signal Correlations

NI ELVIS	DAQ Device
CTR<0..1>_SOURCE	GPCTR<0..1>_SOURCE
CTR<0..1>_GATE	GPCTR<0..1>_GATE
CTR<0..1>_OUT	GPCTR<0..1>_OUT

CTR0 and CTR1 can be used as normal counter/timers for any existing DAQ examples and for when you program with DAQ VIs. The counter/timers are also used by the NI ELVIS - FGGEN SFP. The counter/timers might be unavailable if the NI ELVIS - FGGEN SFP is running.

Refer to the *NI ELVIS Prototyping Board* section of Chapter 3, *Hardware Overview*, for an illustration of signal connections on the prototyping board.

Typical counter/timer applications include pulse train generation, event counting, and frequency measurement. For more information on how to

perform counter/timer measurements using NI-DAQmx, refer to the NI-DAQmx documentation that shipped with the DAQ device.

NI ELVIS also provides access to the programmable function input (PFI) pins on the DAQ device. These pins are typically used in advanced applications that require external control of a measurement. Examples of these advanced applications include triggering and scan clock control.

For more information on the PFI pins, refer to the DAQ device documentation. For more information on how to use the PFI pins using NI-DAQmx, refer to the NI-DAQmx documentation that shipped with the DAQ device.

## Programming NI ELVIS Using the NI ELVIS LabVIEW API

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An instrument driver is a set of software routines that control a programmable instrument. Each routine corresponds to a programmatic operation such as configuring, reading from, writing to, and triggering the instrument. Instrument drivers simplify instrument control by eliminating the need to learn the programming protocol for the instrument.

The NI ELVIS instrument driver is a collection of LabVIEW VIs that provides an API for controlling the NI ELVIS hardware. The API allows the user to connect VIs in a logical manner to control the hardware functionality of the NI ELVIS Benchtop Workstation—the variable power supplies, function generator, DMM, and DIO circuitry.

The general programming flow when using the NI ELVIS instrument driver is Initialization - Action - Close. The initialization VIs establish communication with the NI ELVIS Benchtop Workstation and configure the selected components to a defined state. A reference (refnum) to the specific component is generated and then used by subsequent VIs to perform the desired actions.

The instrument driver handles the resource sharing that occurs between the components of the NI ELVIS. For example, the DMM uses the function generator for its measurements. Without resource management, if an application using the function generator is running, when a DMM application runs, one or both applications might return incorrect results. To prevent this problem, if the driver detects that a resource is in use, an error is returned. Resource management is valid within one LabVIEW process only. Therefore, if an application (executable) built using the NI ELVIS instrument driver is running at the same time as another application using

the driver (LabVIEW development environment), resource management is not in effect across the processes, and incorrect behavior can occur.

The *NI ELVIS Help* includes function reference topics for each instrument API that lists and describes parameters for each instrument VI.

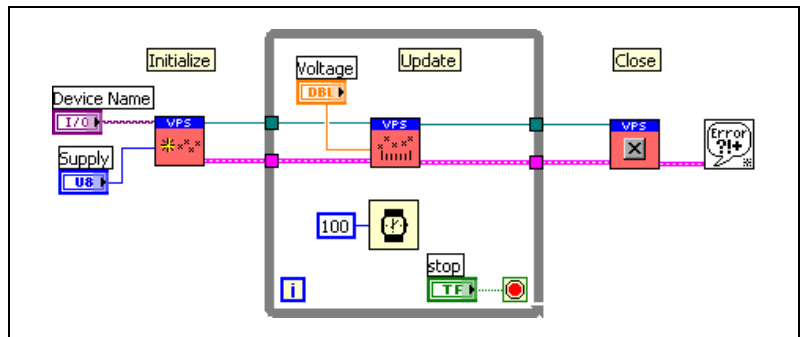


**Note** To ensure correct behavior with programs that use NI ELVIS with the instrument driver, first you must close the SFP instruments.

You can find other examples for using NI ELVIS for AI, AO, and counter/timer applications by launching LabVIEW and selecting **Find Examples»Hardware Input and Output»DAQ** and then the type of example, or you can find examples by selecting **Find Examples** and then searching for NI-ELVIS.

## Variable Power Supplies

The NI ELVIS Benchtop Workstation has two variable power supplies that can be controlled using the NI ELVIS instrument driver. The driver allows the user to select which supply to control and to set its output voltage. A simple variable power supply application is shown in Figure 4-1.



**Figure 4-1.** Simple Variable Power Supply Application

The supply to control is selected during initialization and then updated continuously in the loop. When the loop ends, the supply reference is closed and the output is set to zero. The DAQ device number is provided to identify the DAQ device that is cabled to the NI ELVIS Benchtop Workstation.

Refer to the *NI ELVIS Help* for more information about the specific VIs in the variable power supply API.

## Function Generator

The NI ELVIS Benchtop Workstation has a function generator that can be controlled using the NI ELVIS instrument driver. The driver allows the user to update the frequency, peak amplitude, DC offset, and type of the waveform that the function generator outputs. A simple application is shown in Figure 4-2.

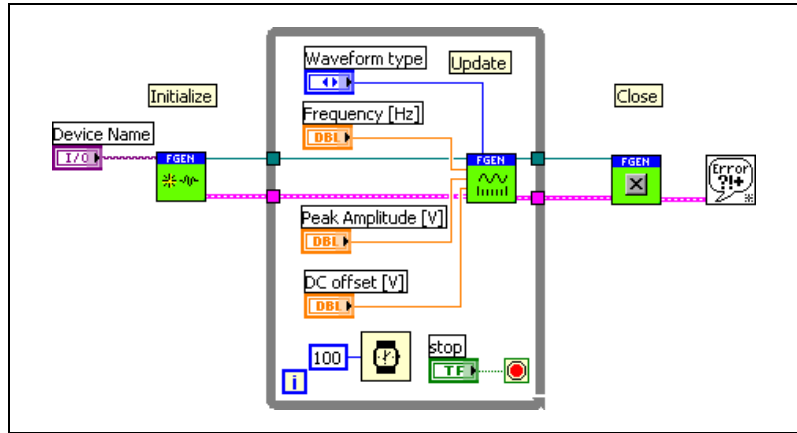


Figure 4-2. Simple Function Generator Application

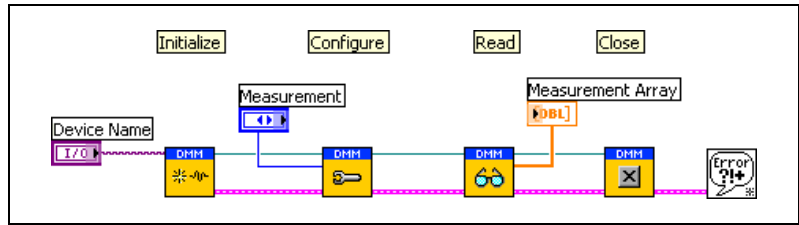
The output of the function generator is set to zero during initialization and then the waveform parameters are continuously updated in the loop. When the loop ends, the function generator reference is closed and the output is set to zero. The DAQ device number is provided to identify the DAQ device that is cabled to the NI ELVIS Benchtop Workstation.

The advanced features of the function generator—the Tuning and AO Modulation controls—can be configured using the NI ELVIS FGEN-Configure VI. By default, both these features are disabled. The refnum that is passed between the API VIs contains information about the current configuration state. If the configuration VI is used in a loop, you should wire the refnum to shift registers so that the refnum information persists between loops.

Refer to the *NI ELVIS Help* for more information about the specific VIs in the function generator API.

## Digital Multimeter

The NI ELVIS Benchtop Workstation contains circuitry that combines with the DAQ hardware to allow DMM-type measurements such as voltage, current, and resistance. The DMM hardware can be controlled using the NI ELVIS instrument driver. The driver allows the user to configure the measurement type and read the measurement results. A simple application is shown in Figure 4-3.



**Figure 4-3.** Simple DMM Application

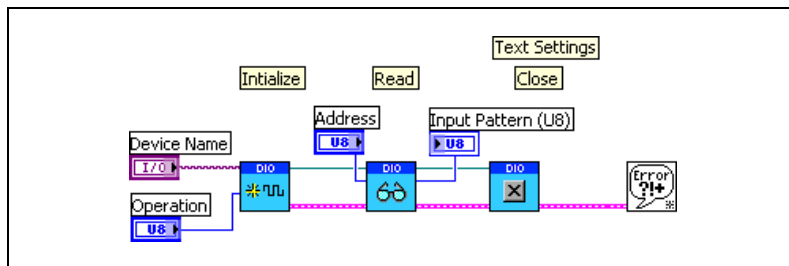
The type of measurement is configured, the measurement value is returned, and then the DMM reference is closed. The DAQ device number is provided to identify the DAQ device that is cabled to the NI ELVIS Benchtop Workstation. Refer to the DAQ documentation that shipped with the DAQ device for more information about device numbers.

The refnum that is passed between the API VIs contains information about the current configuration state. If the configuration VI is used in a loop, you should wire the refnum to shift registers so that the refnum information persists between loops.

Refer to the *NI ELVIS Help* for more information about the specific VIs in the DMM API.

## Digital I/O

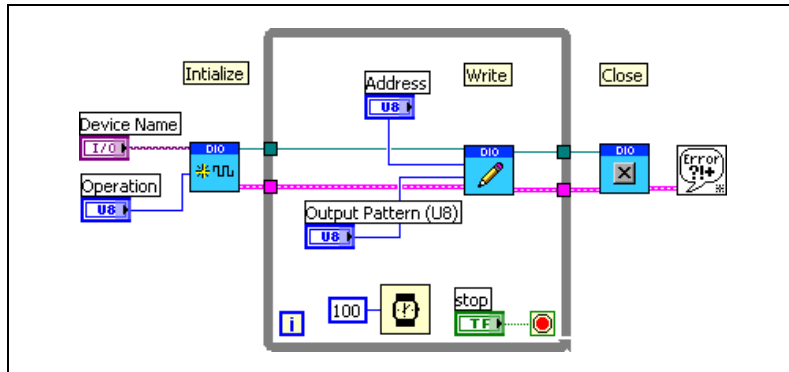
The DAQ device digital lines are used to control the NI ELVIS Benchtop Workstation. Therefore, those lines are not directly accessible on the prototyping board. However, the benchtop workstation contains circuitry that multiplexes the DAQ DIO lines to provide digital input and output signals. The DIO hardware can be controlled using the NI ELVIS instrument driver. The driver allows the user to configure the digital operation and read or write 8-bit digital data. A simple application to perform digital input is shown in Figure 4-4.



**Figure 4-4.** Simple Digital I/O Input Application

The digital operation is configured, the digital data is returned, and then the DIO reference is closed.

A simple application to perform digital output is shown in Figure 4-5.



**Figure 4-5.** Simple Digital I/O Output Application

The digital operation is configured, the digital data is output, and then the DIO reference is closed. The DAQ device number is provided to identify the DAQ device that is cabled to the NI ELVIS Benchtop Workstation.

Refer to the *NI ELVIS Help* for more information about the specific VIs in the DIO API.

## Scope

The Oscilloscope component of NI ELVIS is not addressed in the instrument driver since you can use NI-DAQmx to directly access its functionality.

# Specifications

This appendix lists the specifications of the NI ELVIS. These specifications are typical after a 30 minute warm-up time, at 25 °C, unless otherwise noted.



**Note** NI ELVIS includes a calibration utility so that you can recalibrate the circuitry for the variable power supplies and function generator.

## Analog Input

Refer to the *Analog Input* section of the DAQ device specifications documentation.

## Arbitrary Waveform Generator<sup>1</sup>/Analog Output

Number of output channels .....	2
Maximum frequency .....	DC to DAQ device AO update rate/10
Full-power bandwidth.....	27 kHz
Output amplitude.....	±10 V
Resolution .....	12 bits or 16 bits, DAQ device dependent
Output drive current .....	25 mA
Output impedance .....	1 Ω
Slew rate.....	1.5 V/μs

<sup>1</sup> The Arbitrary Waveform Generator does not work with the NI 6014 or NI 6024.

## Bode Analyzer

Amplitude accuracy .....	12 or 16 bits, DAQ device dependent
Phase accuracy .....	1 degree
Frequency range .....	5 Hz–35 kHz

## DC Power Supplies

### +15 V Supply

Output current .....	Fused at 500 mA
Output voltage .....	15 V at $\pm 5\%$ max
Line regulation .....	0.5% max
Ripple and noise .....	1%

### –15 V Supply

Output current .....	Fused at 500 mA <sup>1</sup>
Output voltage .....	–15 V at $\pm 5\%$ max
Line regulation .....	0.5% max
Ripple and noise .....	1%

### +5 V Supply

Output current .....	Fused at 2 A
Output voltage .....	+5 V at $\pm 5\%$ max
Line regulation .....	0.50% max
Ripple and noise .....	1%

---

<sup>1</sup> Total current drawn from –15 V supply and variable power supplies cannot exceed 500 mA.



## Digital I/O

Digital input resolution .....	8 bits
Digital output resolution .....	8 bits
Digital addressing .....	4 bits

## DMM

### Capacitance Measurement

Accuracy .....	1%
Range .....	50 pF–500 $\mu$ F in three ranges
Test frequency .....	120 or 950 Hz, software-selectable
Max test frequency voltage .....	1 $V_{p-p}$ sine wave, software-selectable

### Continuity Measurement

Resistance threshold.....	15 $\Omega$ max, software-selectable
Test voltage .....	3.89 V, software-selectable

### Current Measurement

Accuracy	
AC .....	0.25% $\pm$ 3 mA <sup>1, 2</sup>
DC .....	0.25% $\pm$ 3 mA <sup>2</sup>
Common-mode voltage.....	$\pm$ 20 V max
Common-mode rejection.....	70 dB min
Range .....	$\pm$ 250 mA in two ranges, max
Resolution .....	12 bits or 16 bits, DAQ device dependent

---

<sup>1</sup> 25 Hz to 10 kHz

<sup>2</sup> Proper null correction at the common-mode voltage can reduce the  $\pm$ 3 mA offset error to 200  $\mu$ A of noise.

Shunt resistance .....0.5  $\Omega$   
 Voltage burden .....2 mV/mA

## Diode Measurement<sup>1</sup>

Voltage threshold.....1.1 V max

## Inductance Measurement

Accuracy .....1%  
 Range .....100  $\mu$ H–100 mH  
 Test frequency .....950 Hz, software-selectable  
 Test frequency voltage.....1 V<sub>p-p</sub> sine wave,  
 software-selectable

## Resistance Measurement

Accuracy .....1%  
 Range .....5  $\Omega$ –3 M $\Omega$ , in four ranges  
 Test frequency .....120 Hz, software-selectable  
 Test frequency voltage.....1 V<sub>p-p</sub> sine wave,  
 software-selectable

## Voltage Measurement

### AC

Accuracy .....0.3%  $\pm$  .001% full-scale<sup>2</sup>  
 Range ..... $\pm$ 14 V<sub>rms</sub> in four ranges, max

### DC

Accuracy .....0.3%  $\pm$  .001% full-scale, max  
 Range ..... $\pm$ 20 V in four ranges, max

Input impedance .....1 M $\Omega$

---

<sup>1</sup> The Two-Wire Current Voltage Analyzer SFP is the recommended instrument for diode measurement.

<sup>2</sup> 100 Hz to 10 kHz

## Dynamic Signal Analyzer

Input range .....	$\pm 10$ V in four ranges
Input resolution .....	12 bits or 16 bits, DAQ device dependant

## Function Generator

Frequency range .....	5 Hz–250 kHz in five ranges
Software-controlled frequency resolution.....	0.8%
Frequency set point accuracy .....	3% of range, max
Frequency read back accuracy .....	$\pm 0.01\%$
Output amplitude.....	$\pm 2.5$ V
Software amplitude resolution .....	8 bits
Offset range.....	$\pm 5$ V
AM voltage .....	10 V, max
Amplitude modulation .....	Up to 100%
FM voltage .....	10 V, max
Amplitude flatness	
To 50 kHz .....	0.5 dB
To 250 kHz .....	3 dB
Frequency modulation.....	$\pm 5\%$ of full-scale, max
Output impedance .....	50 $\Omega$ guaranteed. Refer to Appendix C, <i>Theory of Operation</i> , for more information on the output impedance configuration options.

## Impedance Analyzer

Measurement frequency range .....	5 Hz–35 kHz
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## Oscilloscope

Refer to the *Analog Input* section of the DAQ device specifications documentation.

Accuracy .....	12 bits or 16 bits, DAQ device dependent
Input impedance .....	DAQ device dependent
Maximum horizontal resolution .....	DAQ device dependent
Range .....	$\pm 10$ V
Sampling rate per channel .....	100 kHz–500 kHz, DAQ device dependent
Maximum input bandwidth .....	10 kHz–50 kHz, DAQ device dependent
Vertical resolution .....	12 bits or 16 bits, DAQ device dependent

## Two-Wire Current-Voltage Analyzer

Current range .....	$\pm 10$ mA
Voltage sweep range.....	$\pm 10$ V

## Three-Wire Current-Voltage Analyzer<sup>1</sup>

Minimum base current increment .....	15 $\mu$ A
Maximum collector current .....	10 mA
Maximum collector voltage.....	10 V

## Variable Power Supplies

### Positive Supply

Output voltage .....	12 V
Ripple and noise .....	0.25%

---

<sup>1</sup> This SFP instrument is intended for use only with NPN BJT transistors.

Software-controlled resolution.....	7 bits
Current limiting.....	0.5 V at 160 mA, 5 V at 275 mA, 12 V at 450 mA

## Negative Supply

Output voltage.....	-12 V
Ripple and noise.....	0.25%
Software-controlled resolution.....	7 bits
Current limiting.....	0.5 V at 130 mA, 5 V at 290mA, 12 V at 450mA <sup>1</sup>

## Maximum Working Voltage

Maximum working voltage refers to the signal voltage plus the common-mode voltage.

Channel-to-earth.....  $\pm 20$  V, Installation Category I

Channel-to-channel .....  $\pm 20$  V, Installation Category I

## Environmental

Operating temperature..... 0 to 40 °C

Storage temperature ..... -20 to 70 °C

Humidity ..... 10 to 90% relative humidity,  
noncondensing

Pollution Degree (indoor use only) ..... 1

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<sup>1</sup> Total current drawn from -15 V and the negative variable power supply cannot exceed 500 mA.

## Safety

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1
- CAN/CSA C22.2 No. 61010-1



**Note** For UL and other safety certifications, refer to the product label or to [ni.com](http://ni.com).

## Electromagnetic Compatibility

Emissions .....EN 55011 Class A at 10 m  
FCC Part 15A above 1 GHz

Immunity .....EN 61326:1997 + A2:2001,  
Table 1

CE, C-Tick, and FCC Part 15 (Class A) Compliant



**Note** For EMC compliance, operate this device with shielded cabling. In addition, all covers and filler panels must be installed.

## CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

Low-Voltage Directive (safety).....73/23/EEC

Electromagnetic Compatibility  
Directive (EMC) .....89/336/EEC



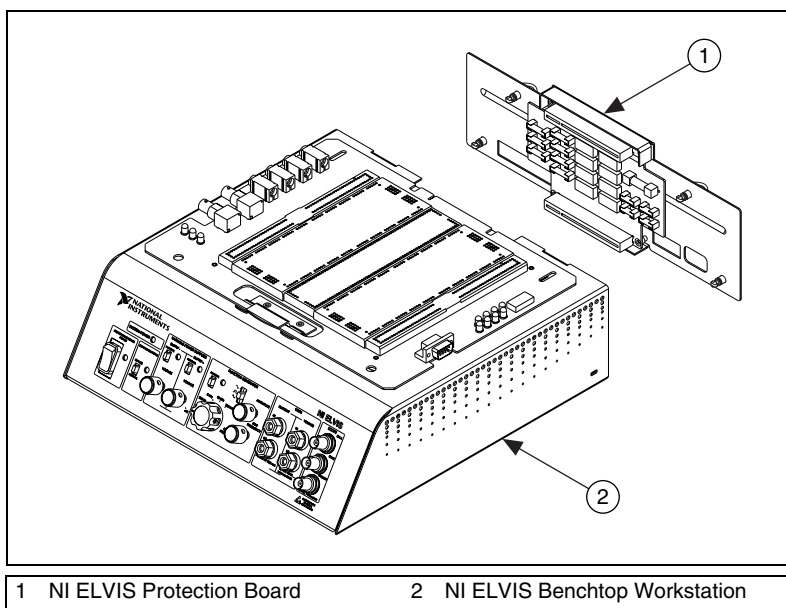
**Note** Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit [ni.com/certification](http://ni.com/certification), search by model number or product line, and click the appropriate link in the Certification column.

# Protection Board Fuses

This appendix describes the fuses on the NI ELVIS Protection Board and gives instructions on how to remove the protection board from the NI ELVIS Benchtop Workstation, debug the protection board, and change fuses.

## Removing the Protection Board

The protection board detaches from the NI ELVIS Benchtop Workstation as shown in Figure B-1. Refer to *Where to Start with NI ELVIS* for more parts locator diagrams of the NI ELVIS Benchtop Workstation.



**Figure B-1.** NI ELVIS Benchtop Workstation with Protection Board Removed

Complete the following steps to remove the protection board from the benchtop workstation. Refer to Figure B-1 as needed.

1. Move the NI ELVIS Power Switch to **Standby**. The **Standby** switch is located on the back side of the benchtop workstation. Refer to *Where to Start with the NI ELVIS* for an illustration of the switch location.
2. Unplug the 68-pin cable and the power supply cable from the benchtop workstation
3. Disconnect the prototyping board from the benchtop workstation.
4. Unscrew the captive screws located on the back of the NI ELVIS Protection Board.
5. Gently pull on the captive screws to remove the protection board.

## Debugging the Protection Board

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The protection board provides a level of electrical protection between the prototyping board and the motherboard of the NI ELVIS. This protection consists of fuses for the high-current signals—such as the power supplies, AO channels, and DMM—and 100  $\Omega$  current-limited resistors for the low-current signals, such as the AI channels, and digital signals. If too much current begins to flow to or from a particular signal on the prototyping board, the fuse or resistor breaks down, opening the connection electrically.

To debug the protection board, you need a DMM with an ohmmeter. Complete the following steps:

1. Verify that the NI ELVIS is in Standby mode. The **Standby** switch is located on the back of the NI ELVIS Benchtop Workstation.
2. Remove the protection board assembly from the rest of the NI ELVIS workstation. For instructions on removing the protection board, refer to the [Removing the Protection Board](#) section.
3. Check the fuses, since these signals are much more likely to have been overloaded. To check the fuse, verify that the resistance across the fuse is less than 50  $\Omega$ . If all the fuses are operational, proceed to the resistor packs.
4. Verify that the resistance across each resistor is 100  $\Omega$ ,  $\pm 5\%$ .  
One resistor is located between each of the following pairs of pins: 1 and 16, 2 and 15, 3 and 14, 4 and 13, 5 and 12, 6 and 11, 7 and 10, and 8 and 9. The resistor packs are socketed so that you can easily replace resistors.





**Caution** Before restoring power to the circuit, be sure the problem that caused the protection board component to fail has been resolved to keep the same fuse or resistor from failing again.

If you need to replace a fuse, use the fuse types listed in Table B-1.



**Caution** For continued protection against fire, replace only with fuses of the same type and rating. Refer to the Table B-1 for fuse types.

**Table B-1.** NI ELVIS Fuse Information

Fuse Rating	Fuse Type	Manufacturer
0.5 A/250 V	5 × 20 mm, Slow acting	LittelFuse
0.5 A/250 V	2AG, Fast acting	LittelFuse
2 A/250 V	3AG, Fast acting	LittelFuse



**Caution** The fuses on NI ELVIS are glass. Use care when removing the fuses to prevent injury from broken glass.

Figure B-2 shows the location of the different fuses for the NI ELVIS hardware and the location of the resistor packs.

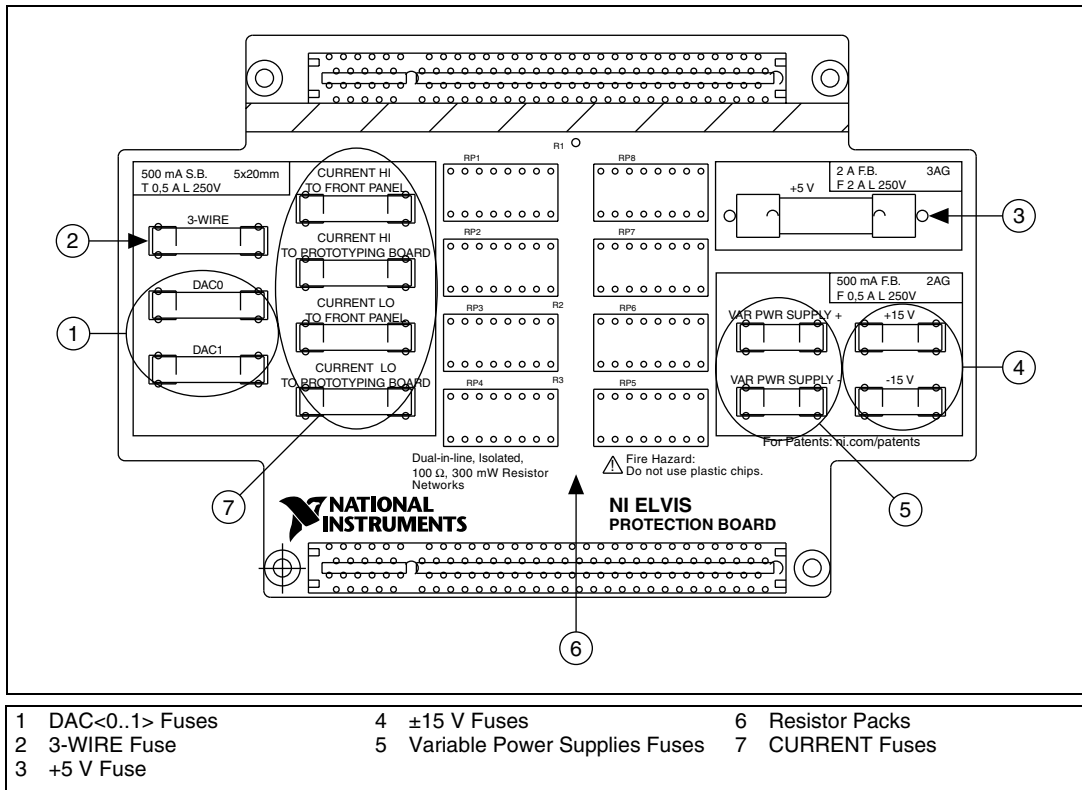


Figure B-2. Parts Locator Diagram for NI ELVIS Protection Board

Table B-2 shows the relationship between the resistor packs and the NI ELVIS components.

Table B-2. Resistor Packs and NI ELVIS Components

Resistor Pack	NI ELVIS Component
RP1	analog input
RP2	analog input
RP3	AM_IN, FUNC_OUT, SYNC_OUT, AISENSE
RP4	counter/timer I/O
RP5	digital output

**Table B-2.** Resistor Packs and NI ELVIS Components (Continued)

<b>Resistor Pack</b>	<b>NI ELVIS Component</b>
RP6	digital input
RP7	SCANCLK, programmable function I/O
RP8	ADDRESS <0..3>

## Reinstalling the Protection Board

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Reinstall the NI ELVIS Protection Board before resuming use of NI ELVIS. To replace the protection board, complete the following steps:

1. Reinsert the PCI connector of the protection board into the benchtop workstation rear connector.
2. Tighten the four captive screws located on the back of the protection board.
3. Plug in the 68-pin cable and the power supply.
4. Power on NI ELVIS.



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# Theory of Operation

This appendix provides additional information about the basic operation of the NI ELVIS circuitry for the DMM, function generator, impedance analyzer, two- and three-wire current-voltage analyzers, and analog output.



**Note** To reduce measurement error, calibrate the DAQ device before each session.

## DMM Measurements

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The DAQ device is configured for differential measurement mode for all DMM measurements. Each DMM reading is referenced to the NI ELVIS GROUND signal. The NI ELVIS software typically sets the input signal limitations, but some NI ELVIS SFP instruments allow you to manually change the limits.



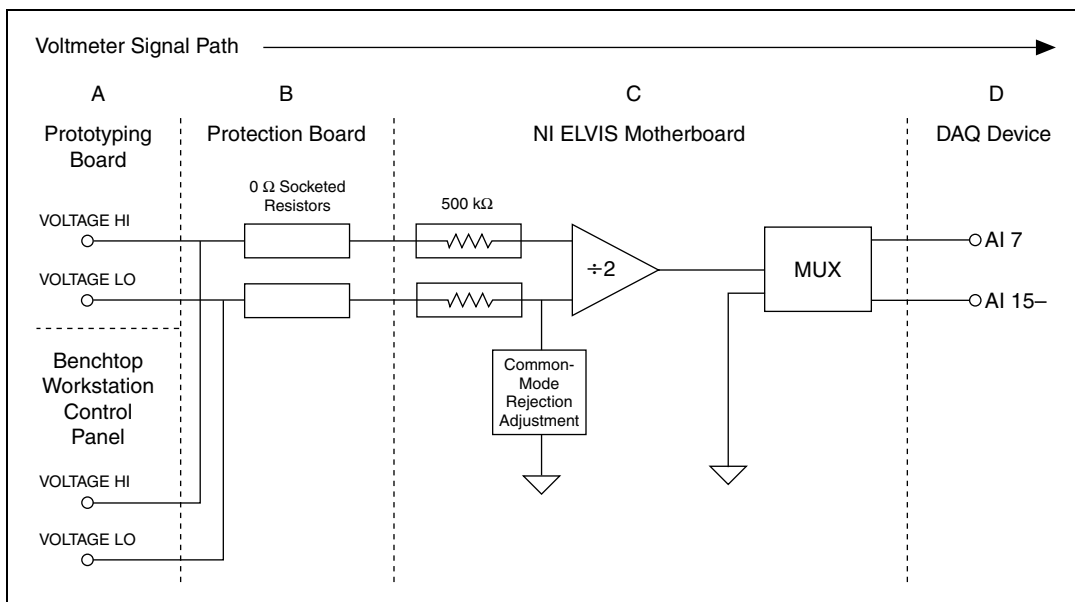
**Note** NI ELVIS does not support floating measurements.

## Voltmeter

When you use the voltmeter, differential channel seven of the DAQ device (AI 7 and AI 15) is used to read the voltage signal from NI ELVIS. NI ELVIS applies a gain of 0.5 to the voltages that are applied to VOLTAGE HI and VOLTAGE LO.

## Block Diagram

Figure C-1 shows a basic block diagram of the NI ELVIS voltmeter. The paragraphs that follow the figure describe each section of the figure in more detail.



**Figure C-1.** NI ELVIS Voltmeter Block Diagram

**Prototyping Board and Benchtop Workstation Connectors**—The input to the NI ELVIS voltmeter circuit can come from the NI ELVIS Prototyping Board or from the connectors on the NI ELVIS Benchtop Workstation control panel. When the prototyping board is powered off, both connections remain active.

**Protection Board**—The inputs to the voltmeter are not externally protected on the NI ELVIS Protection Board. The two inputs are combined on the protection board and passed to the NI ELVIS motherboard.

**NI ELVIS Motherboard**—The VOLTAGE HI and VOLTAGE LO input terminals are divided with 500 k $\Omega$  input resistors. A manual adjustment is made at the factory for common-mode rejection. The adjusted common-mode rejection is typically above 80 dB.

The operational amplifier used by NI ELVIS is a fully differential JFET input with a gain of 0.5. The input slew rate is typically 11 V/ $\mu$ s. This high slew rate helps minimize AC signal distortion.

The internal NI ELVIS bus sets the differential channel seven multiplexer to read the voltmeter voltage. You cannot run the voltmeter with any other DMM functions.

**DAQ Device**—The DAQ device takes the voltage reading on differential channel seven and converts the raw voltage into the voltage reading that is displayed in the NI ELVIS software.

## Internal Calculations

The following values are stored in the NI ELVIS EEPROM:

- *Gain*—gain error correction for NI ELVIS and the DAQ device
- *Offset*—offset error correction for NI ELVIS and the DAQ device

These values are used when calculating voltage readings from the NI ELVIS. To calculate the voltage read on differential channel seven, use the following formula:

$$\text{Voltage read} = (\text{VOLTAGE HI} - \text{VOLTAGE LO})/2$$

The NI ELVIS software then performs the following calculations:

$$\text{Voltage Returned DC} = (\text{Voltage Read} - \text{Offset}) \times \text{Gain}$$

$$\text{Voltage Returned AC} = \text{Gain} \times \sqrt{(\text{VAC}^2 - \text{VDC}^2)}$$

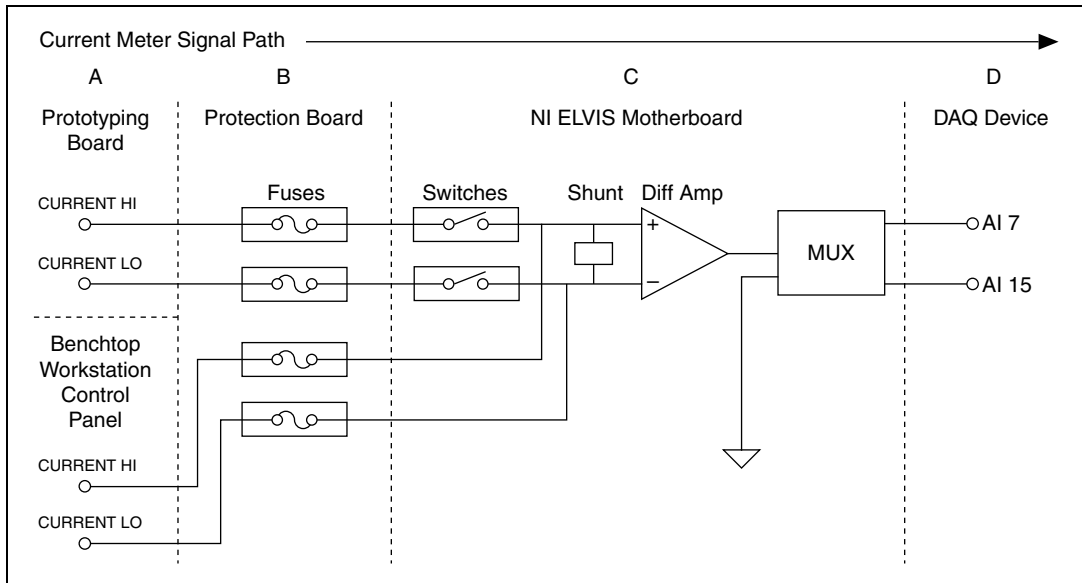
*Voltage Returned* is displayed in the NI ELVIS software.

## Current Meter

When you use the current meter, differential channel seven of the DAQ device (AI 7 and AI 15) is used to read the current from NI ELVIS. The current read from NI ELVIS is referenced to the NI ELVIS GROUND signal. The current is measured across the CURRENT HI and CURRENT LO terminals. The current flowing across the shunt is converted to voltage by a difference amplifier.

## Block Diagram

Figure C-2 shows a basic block diagram of the NI ELVIS current meter. The paragraphs that follow the figure describe each section of the figure in more detail.



**Figure C-2.** NI ELVIS Current Meter Block Diagram

**Prototyping Board and Benchtop Workstation Connectors**—The input to the NI ELVIS current meter circuit can come from the NI ELVIS Prototyping Board or from the connectors on the NI ELVIS Benchtop Workstation control panel. When the prototyping board is powered off, the CURRENT HI and CURRENT LO terminals from the prototyping board are disconnected, and any current from the prototyping board stops flowing.

**Protection Board**—The protection board has fuses for each channel. These fuses handle overcurrent conditions.

**NI ELVIS Motherboard**—A 0.5  $\Omega$  current shunt resistor is used at the input of a difference amplifier to convert the current to a voltage.

The current meter is not adjusted for common-mode rejection. The common-mode rejection of the current meter is determined by the difference amplifier.

The output voltage is multiplexed to differential channel seven.

**DAQ Device**—The DAQ device takes the reading on differential channel seven and converts the voltage reading into the current that is displayed in the NI ELVIS software.

## Internal Calculations

The following values are stored in the NI ELVIS EEPROM:

- *Gain*—shunt resistor value, gain error correction for NI ELVIS and the DAQ device are included
- *Offset*—system offset error correction, includes NI ELVIS and DAQ device offset

The voltage returned can represent AC or DC current. The offset variable should remove most offset caused by NI ELVIS and/or the DAQ device.

*VDC*—DC measurement of the voltage on differential channel seven

*VAC*—AC measurement of the voltage on differential channel seven

$$\text{Current AC} = \text{Gain} \times \sqrt{(VAC^2 - VDC^2)}$$

$$\text{Current DC} = (VDC - \text{Offset}) \times \text{Gain}$$

*Current AC* or *Current DC* is displayed in the NI ELVIS Software.

## Function Generator

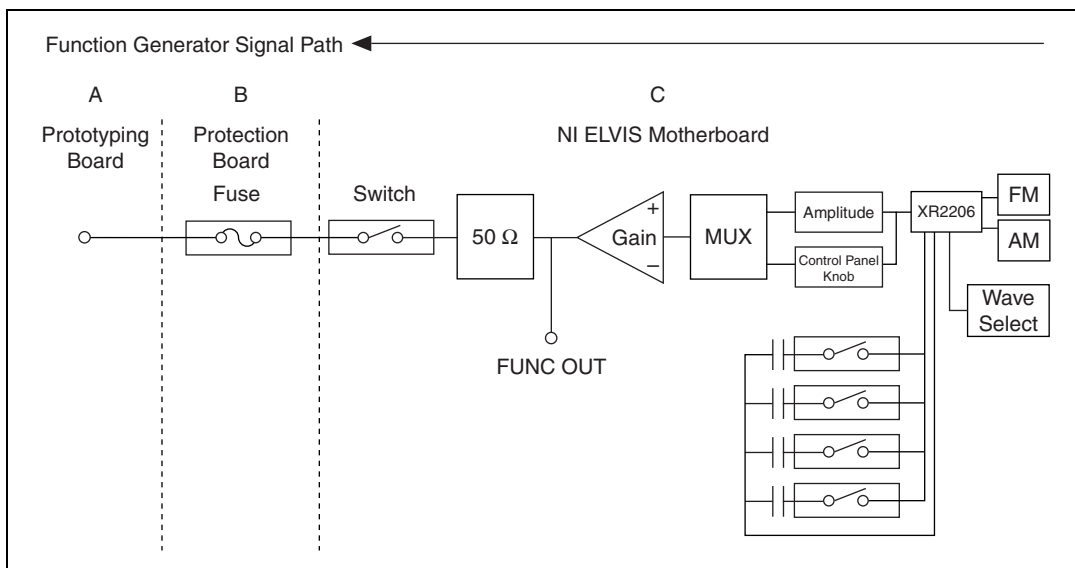
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NI ELVIS includes a hardware function generator. The function generator can generate sine, triangle, and square waves. You can modulate the output amplitude and frequency manually, with software, or using a combination of both.



## Block Diagram

Figure C-3 shows a basic block diagram of the NI ELVIS function generator. The paragraphs that follow the figure describe each section of the figure in more detail.



**Figure C-3.** Function Generator Block Diagram

**Prototyping Board and Benchtop Workstation Connectors**—The function generator output signal, FUNC\_OUT, is only on the prototyping board.

**Protection Board**—On the protection board, the function generator passes through a 100 Ω current-fused resistor.

**NI ELVIS Motherboard**—NI ELVIS uses a monolithic function generator integrated circuit (IC) to generate waveforms. This IC accepts frequency and amplitude modulation. You can adjust the output amplitude of the XR 2206 with an internal 8-bit MDAC or manually with a knob on the NI ELVIS Benchtop Workstation control panel.

The coarse frequency is set by using one of four frequency selection capacitors. The fine frequency is adjusted by the adjusting the onboard 8-bit DAC.

The adjusted output signal is multiplexed into a unity gain circuit. The output of the gain circuit runs through a 50  $\Omega$  resistor. NI ELVIS uses the function generator output signal, FUNC\_OUT, after the 50  $\Omega$  resistor for other internal instruments.

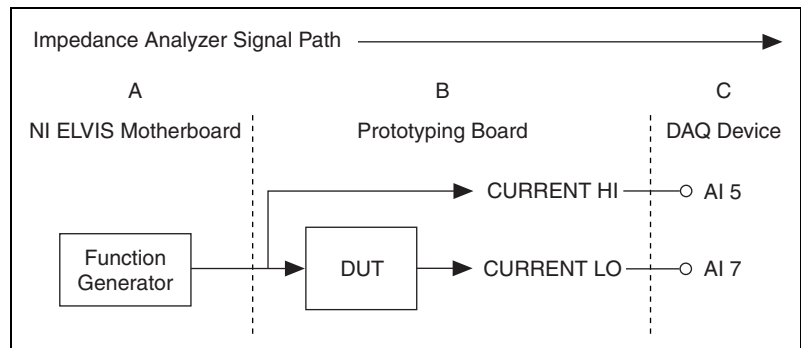
You can disconnect the function generator from the NI ELVIS Prototyping Board with the prototyping board power switch.

## Impedance Analyzer

The NI ELVIS - Impedance Analyzer is an SFP instrument that can measure specific device under test (DUT) impedance characteristics. NI ELVIS determines impedance using an AC sine wave source that is produced by the NI ELVIS function generator on the CURRENT HI pin to excite the DUT. The resulting sine waves are measured on CURRENT HI and CURRENT LO. The NI ELVIS Impedance Analyzer breaks out the phase, magnitude, resistance, and reactance of the DUT.

### Block Diagram

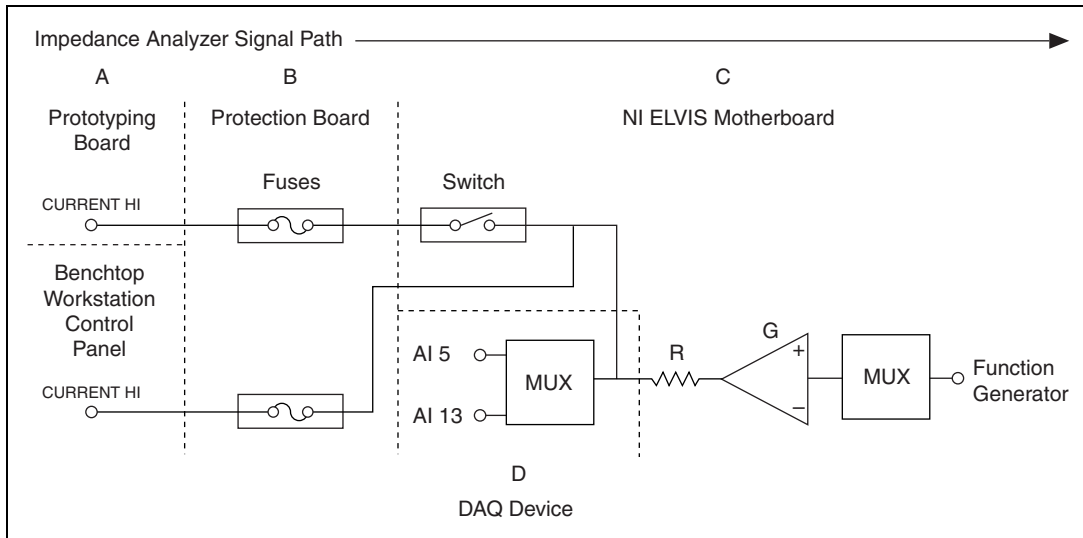
Figure C-4 shows a basic block diagram of the NI ELVIS impedance analyzer. The diagrams and paragraphs that follow Figure C-4 describe the circuitry for the CURRENT HI and CURRENT LO signals.



**Figure C-4.** Impedance Analyzer Block Diagram

## CURRENT HI

The hardware connection to the CURRENT HI pin is shown in Figure C-5. The paragraphs that follow the figure describe each section of the figure in more detail.



**Figure C-5.** CURRENT HI Block Diagram

**NI ELVIS Motherboard**—The output of the NI ELVIS hardware function generator is routed internally to the gain of the CURRENT HI pin.

The gain circuit (labeled  $G$  in the preceding figure) provides a resistive element (labeled  $R$  in the preceding figure) to always insure a minimum resistance.

CURRENT HI is routed to AI 5 for measurements. Because the AI 5 voltage is measured after the onboard resistor, the onboard resistor is not included in the calculations.

The output to the NI ELVIS Prototyping Board is controlled by the prototyping board power switch.

**Protection Board**—The output of the CURRENT HI is fused for overcurrent protection. Simple shorts should not blow the fuse.

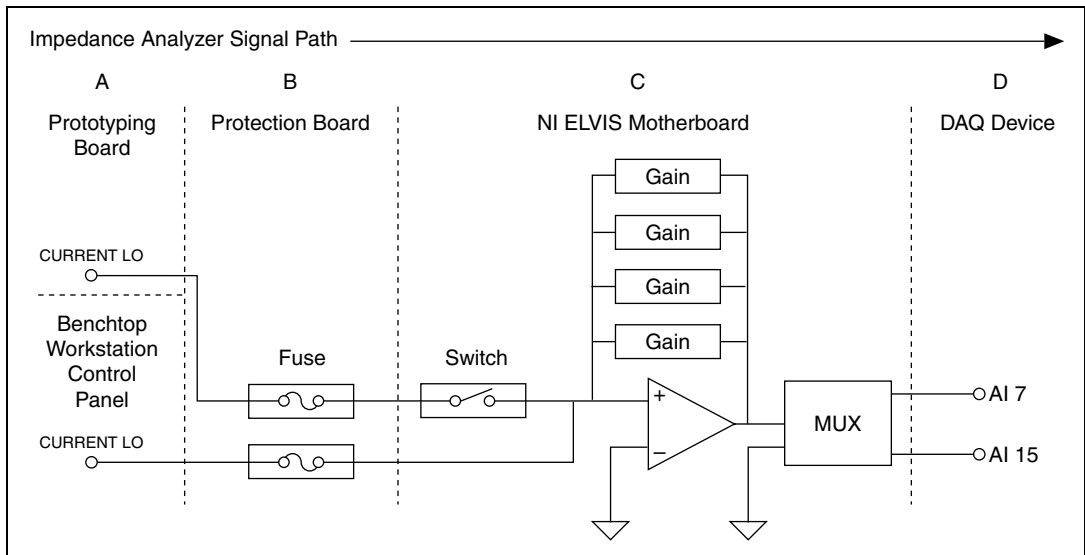
**Prototyping Board and Benchtop Workstation Connectors**—When the NI ELVIS Prototyping Board is powered off, the CURRENT HI pin from

the prototyping board is disconnected; however, the NI ELVIS Benchtop Workstation control panel connection is always connected.

**DAQ Device**—The DAQ device reads the reference sine wave on AI 5. The AI 5 voltage reading is the input from the NI ELVIS to the DUT.

## CURRENT LO

The hardware connection to the CURRENT LO pin is shown in Figure C-6. The paragraphs that follow the figure describe each section of the figure in more detail.



**Figure C-6.** CURRENT LO Block Diagram

**Prototyping Board and Benchtop Workstation Connectors**—When the NI ELVIS Prototyping Board is powered off, the CURRENT LO pin from the prototyping board is disconnected. The NI ELVIS Benchtop Workstation control panel connection is always connected.

**Protection Board**—The signal from the DUT passes through a fuse on the protection board. This fuse adds resistance to the measurement.

**NI ELVIS Motherboard**—When the prototyping board is powered off, the CURRENT LO pin from the prototyping board is disconnected.

You can switch the input path between impedance and current measurements by modifying the LabVIEW VIs that are included in the

NI ELVIS source code. You cannot measure impedance and current at the same time.

The input voltage across the DUT has a programmable gain applied. NI ELVIS has four programmable gain ranges that you can select with the NI ELVIS - Impedance Analyzer SFP.

The input to the op-amp is protected from overvoltage and overcurrent conditions. This protection should prevent damage to the op-amp or the gain stage. The output of the op-amp is multiplexed to differential channel seven.

**DAQ Device**—The DAQ device reads the output sine wave on differential channel seven. The AI 7 reading is used as the signal (reference B) for the impedance measurements.

## Internal Calculations

The following values are stored in the NI ELVIS EEPROM:

- *Gain*—system gain error correction, gain error correction for NI ELVIS and the DAQ device
- *Inductance Offset*—system inductance offset error correction, NI ELVIS and the DAQ device
- *Capacitance Offset*—system capacitance offset error correction, NI ELVIS and the DAQ device
- *CA SLOPE*—actual calibrated value of each feedback resistor (four values)

The software acquires two waveforms from differential channel seven (the signal) and AI 5 (the reference channel) and applies the following formula:

$$\text{Gain Amplitude} = \text{Reference Amplitude} / \text{Signal Amplitude}$$

*Gain Amplitude* is combined with the feedback resistor used on the NI ELVIS to determine the impedance. *CA Slope* is calibrated at the factory to determine the actual impedance for the feedback resistor.

$$\text{Impedance (Z)} = \text{CA Slope} / \text{Gain Amplitude}$$

Z is combined with the phase to determine the resistive and reactive components of the DUT. The phase difference of the acquired sine waves is measured in reference to AI 5.

$$\text{Resistance} = Z \times \cos(\text{Phase} \times \pi / 180)$$

$$\text{Reactance} = Z \times \text{sine}(\text{Phase} \times \pi/180)$$

$$\text{Susceptance} = -1/\text{Reactance}$$

To determine the inductive or capacitive elements of the DUT, *Reactance* and *Susceptance*. The magnitude of the phase determines which element is present. The frequency is the frequency you set.

$$\text{Inductance} = (\text{Reactance}/2 \times \pi \times \text{Frequency}) + \text{Inductance Offset}$$

$$\text{Capacitance} = \{ \text{Susceptance}/(2 \times \pi \times \text{Frequency}) \} + \text{Capacitance Offset}$$

Each inductance and capacitance reading includes the offset variable stored in the EEPROM to help eliminate offset errors.

## Resistance Meter

The resistance meter is a subset of the NI ELVIS - Impedance Analyzer, and it uses the same circuitry. To get more accurate readings, the function generator output frequency is set to 120 Hz, and the amplitude is locked at 1 V<sub>p-p</sub>. These settings allow a focused calibration that reduces resistive and capacitive offset. The resistance meter uses four ranges to measure from 5 Ω to 3 MΩ.

## Inductance Meter

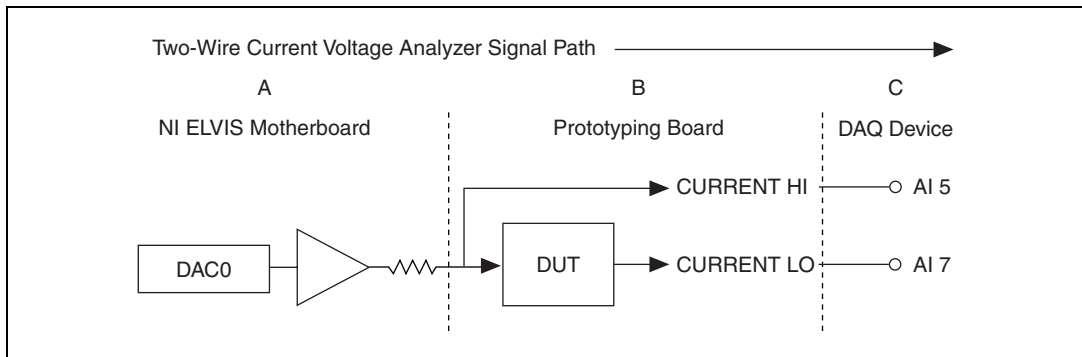
The inductance meter is a subset of the NI ELVIS - Impedance Analyzer, and it uses the same circuitry. To get more accurate readings, the function generator output frequency is set to 950 Hz, and the amplitude is locked at 1 V<sub>p-p</sub>. These settings allow a focused calibration that reduces resistive and capacitive offset.

## Capacitance Meter

The capacitance meter is a subset of the NI ELVIS - Impedance Analyzer, and it uses the same circuitry. You can select electrolytic and normal capacitors. To get more accurate readings on electrolytic capacitors, the function generator output frequency is set to 120 Hz, and the amplitude is locked 2 V<sub>p-p</sub> with a DC offset of 2.5 V. For normal capacitors, the function generator output frequency is set to 950 Hz, and the amplitude is locked at 1 V<sub>p-p</sub>. These settings allow a focused calibration that reduces resistive and capacitive offset.

## Two-Wire Current-Voltage Analyzer

The two-wire measurement is made by using the DAQ device AO 0 signal to generate a user-controlled voltage sweep. The voltage is read before the DUT on AI 5 and then across the DUT on AI 7. The NI ELVIS Impedance - Analyzer circuitry provides the feedback resistor that transforms the current flowing into the CURRENT LO pin into a voltage. The CURRENT HI pin is the output voltage source on the prototyping board and benchtop workstation control panel.



**Figure C-7.** Two-Wire Measurement Block Diagram

### Internal Calculations

The following values are stored in the NI ELVIS EEPROM:

*CA SLOPE*—actual value of each feedback resistor (four values)

The voltage output on CURRENT HI pin is from the DAQ device DAC0. The CURRENT HI pin is read on AI 5 and stored as the *VOLTAGE* (V) that is displayed.

The input current is measured on the CURRENT LO pin of the prototyping board. The CURRENT LO pin is read on AI 7. The DAQ device can only read voltage, so the current is converted to voltage. The NI ELVIS - Impedance Analyzer circuitry converts the current to voltage.

The voltage read is then converted back to current using Ohm's Law:

$$V = I \times R$$

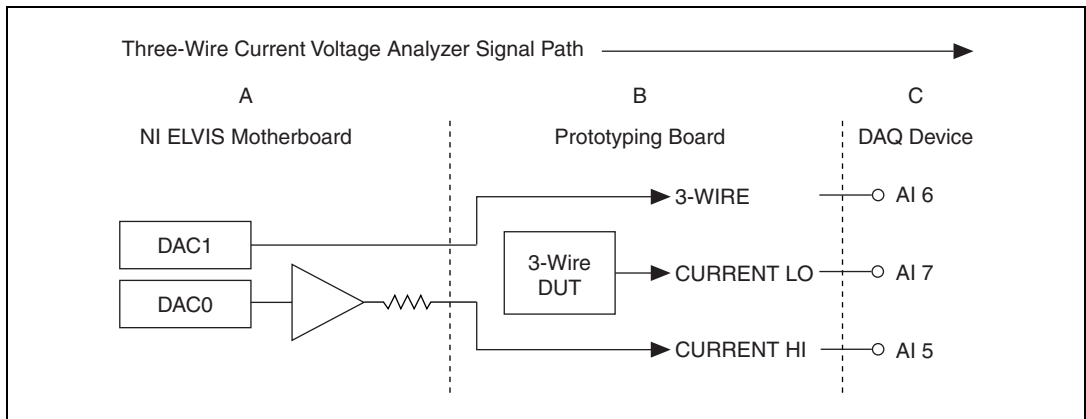
For  $R$ , use the NI ELVIS feedback resistor,  $CA$  Slope, and for  $V$  use the AI 7 voltage.

$$\text{Measured Current (in Amps)} = \text{CH7 voltage} / \text{CA Slope}$$

*Measured Current* is converted to milliamps and displayed.

## Three-Wire Current-Voltage Analyzer

The three-wire measurement is made by using the DAQ device AO 0 and AO 1 to generate output voltages that you control. The voltage is read before going into the DUT on AI 5 and AI 6 and then across the DUT on AI 7. The NI ELVIS - Impedance Analyzer circuitry provides the feedback resistor that transforms the current flowing into the CURRENT LO pin into a voltage. The CURRENT HI pin is the output current source for the DUT on the prototyping board. This current is measured and converted to voltage by a  $332 \Omega$  resistor on NI ELVIS. The 3-WIRE pin is measured on AI 6 and is the source voltage that is swept.



**Figure C-8.** Three-Wire Measurement Block Diagram

## Internal Calculations

The following values are stored in the NI ELVIS EEPROM:

*CA SLOPE*—Actual value of each feedback resistor (four values)

The voltage generated on the 3-WIRE pin is from the DAQ device AO 1. This voltage is read on AI 6 internal to NI ELVIS. This voltage is displayed as the Voltage ( $V_c$ ) in the Three-Wire Current-Voltage Analyzer SFP.



The base current output on the CURRENT HI pin is from the DAQ device AO 0. The CURRENT HI pin is read on AI 5 as a voltage. The DAQ device can only read voltage, so the current is converted to voltage.

The voltage read is then converted back to current by using Ohm's Law.

For  $R$  use the NI ELVIS onboard  $332\ \Omega$  resistor, and for  $V$  use the CH5 voltage.

$$I_b \text{ (Amps)} = \text{CH5 voltage} / 332\ \Omega$$

The Base current,  $I_b$ , is not displayed on the soft front panel.

The input collector current is measured on the CURRENT LO pin of the prototyping board. The CURRENT LO pin is read on AI 7. The DAQ device can only read voltage, so the current is converted to voltage. The NI ELVIS Impedance - Analyzer circuitry is used to convert the current to voltage.

The voltage read is then converted back to current by using Ohm's Law.

For  $R$  use the NI ELVIS feedback resistor,  $CA\ Slope$ , and for  $V$  use the CH7 voltage.

$$I_c \text{ (in Amps)} = \text{CH7 voltage} / CA\ Slope$$

The collector current is displayed as Current  $I_c$  (A).

To determine the Beta,  $\beta$ , of the DUT use the following equation:

$$\beta = I_c / I_b$$

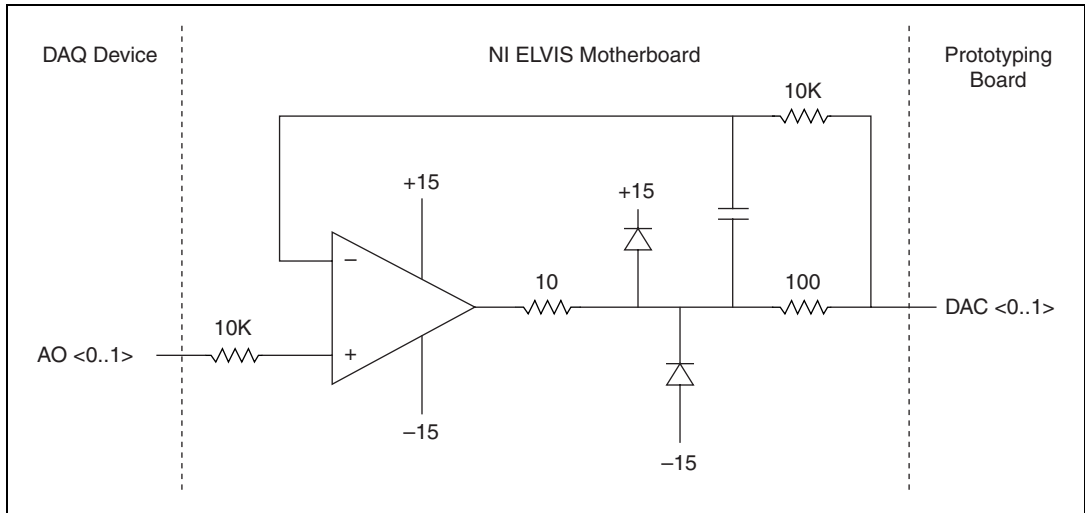
$\beta$  is not displayed on the soft front panel.

## Arbitrary Waveform Generator/Analog Output

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The NI ELVIS buffers the output from the DAQ device. This buffer prevents damage to the DAQ device. The NI ELVIS is protected against overvoltage and overcurrent conditions.

Figure C-3 shows a basic block diagram of the NI ELVIS AO circuitry. The paragraphs that follow the figure describe each section of the figure in more detail.



**Figure C-9.** Analog Output Block Diagram

**Prototyping Board and Benchtop Workstation Connectors**—The output channels of the NI EVLVIS DAC<0..1> can only be accessed on the prototyping board. When the prototyping board is powered off, the output is disconnected.

**Protection Board**—The protection board has fuses for each output channel. These fuses handle overcurrent conditions.

**NI ELVIS Motherboard**—The DAQ device AO 0 and AO 1 are buffered on the NI ELVIS. This buffer allows the NI ELVIS power supply to drive DAC0 and DAC1. The DAQ device provides the voltage but not the current. The output signal is not adjusted for offset caused by NI ELVIS

Refer to the [Arbitrary Waveform Generator/Analog Output](#) section of Appendix A, [Specifications](#), for further details.

**DAQ Device**—The DAQ device must have analog output capability to use the NI ELVIS analog output. In order to generate waveforms or patterns the DAQ device must have buffered output.

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## Resource Conflicts

The following table summarizes the resource conflicts you might encounter if you run certain NI ELVIS circuitry simultaneously. The variable power supplies and digital circuitry are not included in this table because they do not create any resource conflicts.

	Function Generator – Base	Function Generator – Ultrafine	Function Generator – Modulated	ARB DAC<0..1>	Oscilloscope	Dynamic Signal Analyzer	DMM – Continuity Tester	DMM – Resistance Meter	DMM – Capacitance Meter	DMM – Inductance Meter	DMM – Voltmeter	DMM – Ammeter	DMM – Diode Tester	Impedance Analyzer	Bode Analyzer	Two-Wire Current-Voltage Analyzer	Three-Wire Current-Voltage Analyzer
Function Generator – Base	-	fg	fg	-	-	-	-	fg	fg	fg	-	-	-	fg	fg	-	-
Function Generator – Ultrafine	fg	-	fg	ao	-	-	-	fg	fg	fg	-	-	-	fg	fg	-	-
Function Generator – Modulated	fg	fg	-	ao	-	-	-	fg	fg	fg	-	-	-	fg	fg	-	-
ARB DAC<0..1>	-	ao	ao	-	-	-	ao	-	-	-	-	-	ao	-	-	ao	ao
Oscilloscope	-	-	-	-	-	ais	aid	aid	aid	aid	aid	aid	aid	aid	aid	aid	aid
Dynamic Signal Analyzer	-	-	-	-	ais	-	aid	aid	aid	aid	aid	aid	aid	aid	aid	aid	aid
DMM – Continuity Tester	-	-	-	ao	aid	aid	-	ca	ca	ca	ais	ca	ca	ca	aid	ca	ca
DMM – Resistance Meter	fg	fg	fg	-	aid	aid	ca	-	ca	ca	ais	ca	ca	ca	aid	ca	ca
DMM – Capacitance Meter	fg	fg	fg	-	aid	aid	ca	ca	-	ca	ais	ca	ca	ca	aid	ca	ca
DMM – Inductance Meter	fg	fg	fg	-	aid	aid	ca	ca	ca	-	ais	ca	ca	ca	aid	ca	ca
DMM – Voltmeter	-	-	-	-	aid	aid	ais	ais	ais	ais	-	ca	ca	ca	aid	ca	ca
DMM – Ammeter	-	-	-	-	aid	aid	ca	ca	ca	ca	ca	-	ca	ca	aid	ca	ca
DMM – Diode Tester	-	-	-	ao	aid	aid	ca	ca	ca	ca	ca	ca	-	ca	aid	ca	ca
Impedance Analyzer	fg	fg	fg	-	aid	aid	ca	ca	ca	ca	ca	ca	ca	-	aid	ca	ca
Bode Analyzer	fg	fg	fg	-	aid	aid	aid	aid	aid	aid	aid	aid	aid	aid	-	aid	aid
Two-Wire Current-Voltage Analyzer	-	-	-	ao	aid	aid	ca	ca	ca	ca	ca	ca	ca	ca	aid	-	ca
Three-Wire Current-Voltage Analyzer	-	-	-	ao	aid	aid	ca	ca	ca	ca	ca	ca	ca	ca	aid	ca	-

**Conflict Codes:**  
aid = DAQ AI, different channels  
ais = DAQ AI, same channels  
ao = DAQ AO  
ctr = DAQ counter/timers  
fg = NI ELVIS function generator  
ca = NI ELVIS current amplifier  
vdc = NI ELVIS variable power supplies  
do = NI ELVIS digital output

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- **Calibration Certificate**—If your product supports calibration, you can obtain the calibration certificate for your product at [ni.com/calibration](http://ni.com/calibration).

If you searched [ni.com](http://ni.com) and could not find the answers you need, contact your local office or NI corporate headquarters. Phone numbers for our worldwide offices are listed at the front of this manual. You also can visit the Worldwide Offices section of [ni.com/niglobal](http://ni.com/niglobal) to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

# Glossary

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Symbol	Prefix	Value
p	pico	$10^{-12}$
n	nano	$10^{-9}$
$\mu$	micro	$10^{-6}$
m	milli	$10^{-3}$
k	kilo	$10^3$
M	mega	$10^6$

## Symbols

%	Percent.
-	Negative of, or minus.
+	Positive of, or plus.
/	Per.
°	Degree.
$\Omega$	Ohm.
$\pm$	Plus or minus.
$\sqrt{\quad}$	Square root.

## A

A	Amperes.
AC	Alternating current.
ACH	Analog input channel signal.
ADDRESS	The DIO output signals of the address bus.

AI	Analog input.
AIGND	Analog input ground signal.
AISENSE	Analog input sense signal.
AM	Amplitude modulation—the process in which the amplitude of a carrier wave is varied to be directly proportional to the amplitude of the modulating signal.
AM IN	Amplification modulation input signal.
amplification	A type of signal conditioning that improves accuracy in the resulting digitized signal and reduces noise.
amplitude	The voltage amplitude of a signal. When speaking of the amplitude of a signal, it is usually assumed to be the RMS value for an AC signal. However, amplitude can also refer to the instantaneous amplitude, or the peak, peak-to-peak, or average amplitude, if so specified.
AO	Analog output.
ARB	Arbitrary waveform generator.

## **B**

block diagram	Pictorial description or representation of a program or algorithm. The block diagram, consists of executable icons called nodes and wires that carry data between the nodes. The block diagram is the source code for the VI. The block diagram resides in the block diagram window of the VI.
BNC	A type of coaxial signal connector.
board	Refers to the DAQ device.
bode plot	The plot of the gain and phase of a system as a function of frequency.
bus	The group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other devices are connected. An example of a PC bus is the PCI bus.



**C**

C	Celsius.
capacitance	The ability to hold an electrical charge.
CH	Channel.
channel	Pin or wire lead to which you apply or from which you read the analog or digital signal. Analog signals can be single-ended or differential. For digital signals, you group channels to form ports. Ports usually consist of either four or eight digital channels.
counter/timer	A circuit that counts external pulses or clock pulses (timing).
CTR0_GATE	Counter 0 gate signal.
CTR0_OUT	Counter 0 output signal.
CTR0_SOURCE	Counter 0 source signal.
CTR1_GATE	Counter 1 gate signal.
CTR1_OUT	Counter 1 output signal.
CURRENT	Input signals for current-related measurements for the DMM.

**D**

D/A	Digital-to-analog.
DAC	D/A converter.
DAQ	Data acquisition.
dB	Decibel—the unit for expressing a logarithmic measure of the ratio of two signal levels: $dB = 20 \log_{10} V_1/V_2$ , for signals in volts.
DC	Direct current.
default setting	A default parameter value recorded in the driver. In many cases, the default input of a control is a certain value (often 0) that means <i>use the current default setting</i> .

DI	Digital I/O input signals sent to the DI bus.
differential input	An analog input consisting of two terminals, both of which are isolated from computer ground, whose difference is measured.
digital trigger	A TTL level signal having two discrete levels—a high level and a low level.
DIO	Digital I/O.
diode	A specialized electronic component with two electrodes called the <i>anode</i> and the <i>cathode</i> .
DMM	Digital multimeter.
DO	Digital I/O output signals from the DO bus.
DOC	Canadian Department of Communications.
DSA	Dynamic signal analyzer.
DUT	Device under test.

## E

ECG	Electrocardiogram.
EEPROM	Electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed.
ELVIS	Educational Laboratory Virtual Instrumentation Suite.
EMC	Electromechanical compliance.
EMI	Electromagnetic interference.
EXTSTROBE	External strobe signal.

## F

FCC	Federal Communications Commission.
FGEN	Function generator.

floating signal sources	Signal sources with voltage signals that are not connected to an absolute reference or system ground. Also called nonreferenced signal sources. Some common example of floating signal sources are batteries, transformers, or thermocouples.
FM_IN	Frequency modulation input signal.
FREQ_OUT	Frequency output signal.
frequency	The basic unit of rate, measured in events or oscillations per second using a frequency counter or spectrum analyzer. Frequency is the reciprocal of the period of a signal.
front panel	The user interface of a LabVIEW virtual instrument.
FUNC_OUT	Output signal for the function generator.

## G

gain	The factor by which a signal is amplified, sometimes expressed in decibels.
GPCTR0_GATE	General purpose counter timer 0 gate signal, available from a DAQ device.
GPCTR0_OUT	General purpose counter timer 0 output signal, available from a DAQ device.
GPCTR0_SOURCE	General purpose counter timer 0 clock source signal, available from a DAQ device.
GPCTR1_GATE	General purpose counter timer 1 gate signal, available from a DAQ device.
GPCTR1_OUT	General purpose counter timer 1 output signal, available from a DAQ device.
GPCTR1_SOURCE	General purpose counter timer 1 clock source signal, available from a DAQ device.
GROUND	Prototyping board ground signal.

## H

hardware triggering      A form of triggering where you set the start time of an acquisition and gather data at a known position in time relative to a trigger signal.

Hz      Hertz—the number of scans read or updates written per second.

## I

I/O      Input/output—the transfer of data to/from a computer system involving communications channels, operator interface devices, and/or data acquisition and control interfaces.

in.      Inch or inches.

impedance      The electrical characteristic of a circuit expressed in ohms and/or capacitance/inductance.

inductance      The characteristic of a coil that generates a voltage due to changes in the current. An inductor creates a voltage that is the derivative of the current, while a capacitor creates a voltage that is the integral of the current.

## J

JFET      Junction Field Effect Transistor. A three-terminal semiconductor device constructed with a PN junction at its input and a conducting channel as the output section. The PN junction of the input section is reverse biased to provide an extremely high input resistance.

## L

LabVIEW      A graphical programming language.

LATCH      DIO output signal that pulses when data is ready on the write bus.

LED      Light-emitting diode.

**N**

NI-DAQ	National Instruments driver software for DAQ hardware.
NI-DAQmx	The latest NI-DAQ driver with new VIs, functions, and development tools for controlling measurement devices.
NPN transistor	A two-junction (bipolar) semiconductor transistor with an N-type (negative ion) collector and emitter and a P-type (positive ion) base. An NPN transistor is created by adding a thin layer of P-type semiconductor material between two regions of N-type material.
NRSE	Nonreferenced single ended mode—all measurements are made with respect to a common (NRSE) measurement system reference, but the voltage at this reference can vary with respect to the measurement system ground.

**O**

op-amp	Operational amplifier—pre-built amplifier modules that are general enough to be used almost anywhere an amplifier is needed.
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**P**

PCB	Printed circuit board.
PCI	Peripheral Component Interconnect—a high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. It is achieving widespread acceptance as a standard for PCs and workstations; it offers a theoretical maximum transfer rate of 132 Mbytes/s.
peak to peak	A measure of signal amplitude; the difference between the highest and lowest excursions of the signal.
PFI	Programmable function input.

**PN** The simplest semiconductor structure. It consists of a positive or P-region (containing positive ions) in junction with a negative or N-region (containing negative electrons).

**potentiometer** An electrical device the resistance of which can be manually adjusted; used for manual adjustment of electrical circuits and as a transducer for linear or rotary position.

## R

**RD\_ENABLE** Read enable signal—DIO output signal that indicates when data is being read from the read bus.

**referenced signal sources** Signal sources with voltage signals that are referenced to a system ground, such as the earth or a building ground. Also called grounded signal sources.

**resistance** The resistance to the flow of electric current. One ohm ( $\Omega$ ) is the resistance through which one volt of electric force causes one ampere to flow.

**rms** Root mean square.

## S

**s** Seconds.

**S** Samples.

**S/s** Samples per second—used to express the rate at which a DAQ device samples an analog signal.

**SCANCLK** Scan clock signal.

**Scope** Abbreviation for oscilloscope.

**SYNC\_OUT** TTL signal of the same frequency of the function generator.

## T

**TIO** Timing I/O.

**TRIG** Trigger signal.

trigger	Any event that causes or starts some form of data capture.
TRIGGER	Trigger input signal for the oscilloscope.
TTL	Transistor-to-transistor logic.
<b>V</b>	
V	Volts.
VI	Virtual instrument—a combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic stand-alone instrument.
VOLTAGE	Input signals for the DMM voltmeter.
$V_{p-p}$	Peak-to-peak voltage.
<b>W</b>	
waveform	Multiple voltage readings taken at a specific sampling rate.
WR_ENABLE	DIO output signal that indicates data is being written to the write bus.

# Index

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## Symbols

+5 V

- +5 V power supply
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