User Manual for Portable National Instruments Board, Bridge Amplifiers, and VI Logger Software

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National Instruments NI-DAQmx devices utilize supporting software VI Logger (NI 2004). Montpetit labs currently run VI Logger Lite. This version provides the user with all relevant functions of VI Logger including real time data monitoring and acquisition. This manual is intended for Biomechanics students and will focus on analog to digital input, device management, and data exportation to other vehicles such as Excel and BioProc2/3.

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System Requirements

As listed on National Instruments webpage and supplied support manual for NI-DAQmx hardware (NI, 2004), VI Logger (NI, 2006-2007) has the following system requirements:

• Windows 2000/XP.

• A minimum of a Pentium III or later or Celeron 600 MHz or equivalent processor, but National Instruments recommends a Pentium 4 or equivalent processor.

• A minimum of 256 MB of RAM and a screen resolution of 800 × 600 pixels. National Instruments recommends 512 MB of RAM and a screen resolution of 1,024 × 768 pixels.

• At least 200 MB of disk space for the VI Logger installation.
Additional disk space for data logging and storage depends on the speed and quantity of data logging.

• To use *VI Logger Help*, the MAX interactive help system, and the
NI Example Finder, you must have Microsoft Internet Explorer 5.0 or later.

• To use the Lite package, an NI-DAQmx device and NI-DAQmx software.

• To use the Full package, an NI-DAQmx device and NI-DAQmx software, or a Traditional NI-DAQ device and DAQ 7.0 or later, or a FieldPoint I/O module and FieldPoint 4.0 or later.

• To use the full package, you must purchase VI Logger 2.0, obtain a serial number, and activate the software.

Basic Hardware Setup

Ensure all required components are present prior to scheduling data collection and/or laboratory time.

- AC/DC 12 V power supply with pin-positive arrangement
- USB cable
- 8-module chassis with or without desktop mount (NI cDAQ-9172)
- Required data collection modules, model NI series I/O (e.g., NI 9237)

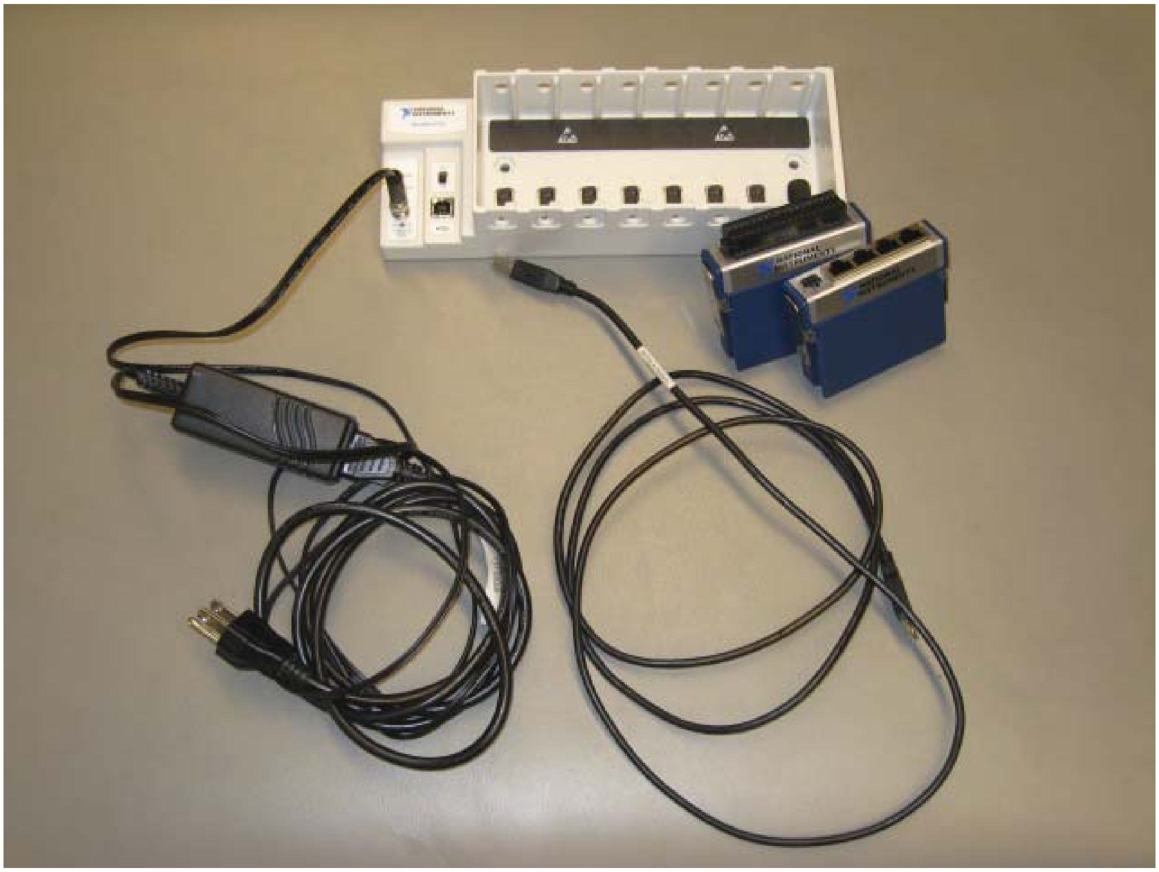

Figure 1. Required equipment for data capture

Bridge Amplifiers

Strain is the measure of physical deformation of a material caused by an applied force (Serway & Vuille, 2006). In the natural world an object is often subject to a combination of compression, tension, torsion and shear forces. If a force is, however, applied uniaxially the ratio of stress to deformation is known as the Young's modulus (Serway & Vuille, 2006). Young's modulus is defined as the fractional stress (applied force divided by orthogonal cross-sectional area) divided by fractional strain (change in uniaxial length divided by original length). Under constant uniaxial applied force (within the elastic limit of a material), a material deforms in a linear fashion. Various elastic moduli exist for the various force application vectors (shear, torsion, and compression) (Serway & Vuille, 2006).

Strain gauges

Strain gauges exploit the physical deformation caused by applied force. A strain gauge contains various electrical resistors wired into a specific circuit design. The resistors consist of a series of winding or tightly woven wires bound to a carrier (inert mounting material) on the measurement device. Ideally, any strain on the test device (ring, bar, cable, etc.) is completely transferred to the gauge. Consequently, the resistor's resistance to electrical current varies in linear proportion to the strain experienced by the device. Most commercial gauges are outfitted with precise bridge-arm loads of 120, 350 and/or 500 ohms (Robertson, 2008).

Poisson strain is an unavoidable result of force application. For example, in compression of a beam along its longitudinal axis, the beam's width will also increase due to transverse (i.e., perpendicular to applied force) expansion. Hence, strain occurs in three dimensions: two planes orthogonal to the applied force and one parallel. Poisson's Ratio is the ratio of strain in the transverse direction divided by strain parallel to applied force. Typically, a strain gauge will consist of a series of active/live resistors and Poisson gauges to mediate transverse strain. Additionally, resistors are physically engineered such the majority of their material is parallel to applied force thus minimizing Poisson Strain (NI, 2008).

To measure strain in the test device, strain gauges are wired using a variety of possible combinations. In biomechanics, the Wheatstone full-bridge configuration is often used. This bridge consists of four resistive arms wired in series with an external excitation voltage (V_{EX}, e.g., 12-VDC power supply).

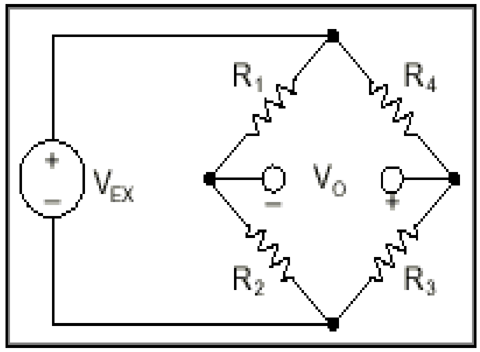

Figure 2. Typical Wheatstone bridge

A voltmeter is wired between the bridge arms. When the ratios of the series resistors (R_1/R_2 and R_3/R_4) are equivalent, no current will flow across the voltmeter (V_o); hence the voltmeter needle will remain unperturbed at 0 V. With these ratios equivalent the bridge is now balanced. This can be verified quickly by placing multimeter leads across specific input pins on a port of the NI-DAQmx full-bridge module. These bridge amplifiers contain a circuit diagram on their casing. Placing a multimeter monitoring resistance across pin channels 4 and 5 will read the lowest load across the bridge. If we assume the bridge to be balanced, then each arm is loaded equally at this measured resistance. To verify bridge balance, set the multimeter to read voltage and place pointers of multimeter across pin channels 2 and 3 while an external voltage is applied across the bridge. If balanced, the multimeter should read a voltage close to zero. One must be sure to contact only the specified pins on the circuit diagram. To verify specific loads across portions of the bridge, simply isolate pin channels on either side of the resistor of interest using the circuit diagram on the back of the module case.

The Wheatstone bridge amplifier aligns one or more of its resistors with the principle strain axis (It is possible to have multiple active resistors in a gauge. The ring strain gauge in Montpetit labs uses 4 active resistors. Thus small strain perturbations are effectively multiplied by a factor of 4). Therefore, strain on the test device will impart strain on the active resistor(s). The change in resistor length results in increased resistance in one arm of the bridge and hence the bridge is no longer balanced. This is observed by current flow across the voltmeter (Robertson, 2008).

A key descriptive trait of a strain gauge is it sensitivity to strain. This quality is known as Gauge Factor and is the ratio of fractional change in electrical resistance to fractional change in length of material (strain). It is worth noting resistors in the bridge will be affected by temperature fluctuation. Most manufacturers will treat their materials to minimize this effect, but if the portable device is used in extreme weather conditions this may affect validity collected data. As well, if extensive leads are used to connect between data acquisition hardware and computer terminals, this will add load to the circuit and affect results. It is best to use leads of minimal length when possible.

Montpetit Lab Configuration

University of Ottawa, Montpetit Lab NI-DAQmx Bridge Amplifier Configuration: Analog strain data is collected through NI 4-Channel 24-bit full bridge analog input with 60 V_{DC} isolated bridge amplifier module using a 2 metre lead.

Figure 3. Strain ring

Task Function and Data Collection

Creating Tasks

To open National Instruments software, double click “Measurement and Automation” shortcut icon on desktop. The opening interface contains a directory of functions on the right, and a configuration tree on the left. In the configuration tree, open “Devices and Interfaces”. Select the device model for use in data collection – Montpetit Labs utilize NI-DAQmx devices. Select NI-DAQmx devices and all connected NI-DAQmx devices will appear. If desired device is not listed refresh the configuration tree by ensuring connection between device and computer, then repeat above steps.

Select the device of interest. On the right of the screen a summary of the modules present in your device will exist. Numbering begins with modules closest to the power switch on the chassis or frame. Select the module for use, and either right click to activate drop-down menu, or select “Create Task” from above the right of the screen. Select the category of task. Biomechanics labs will use analog input. Select the task function. MAX identifies modules capable of capturing this data type. An example configuration finds modules 2, 6, and 7 appropriate for strain gauge data collection. Select specific module and port for use. Mont Petit Labs bridge amplifiers contain four ports, number 0 to 3. Select port for use and click “Next”. Apply a name to the task and click “Finish”.

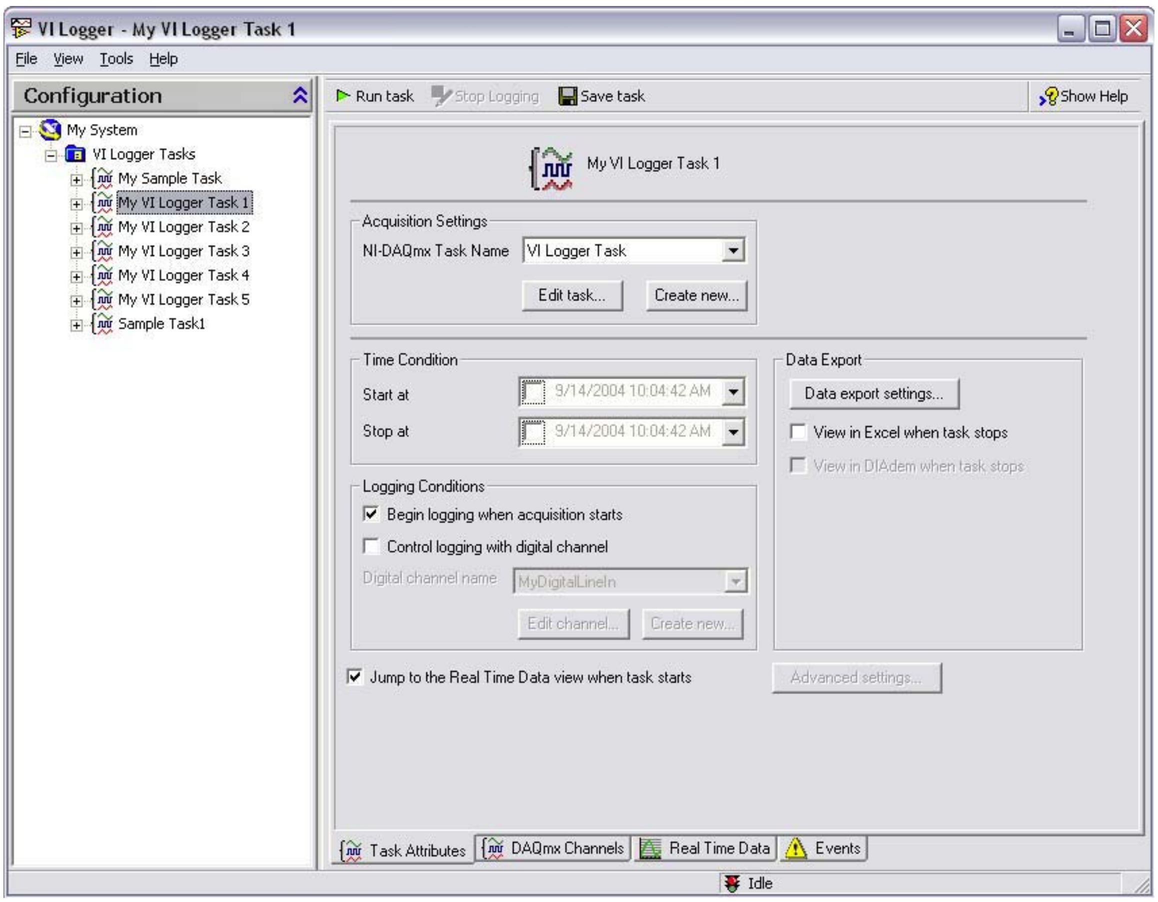

Figure 4. VI Logger configuration menu

Task Function

The configuration tree is modified and the new task is added to the sub-branch “NI-DAQmx Tasks” of “Data Neighbourhood” directory. The right side of the screen is now split into two sections. The first contains modifiers for the new task and the second contains real-time information display. This display provides description of the functionality or meaning of various tabs and is updated as the mouse cursor passes over them.

Scaling Analog Inputs

Select "Strain Setup" tab on the right side of the screen. Verify the gauge sensitivity on the particular strain gauge in use. Most strain gauges in Montpetit Labs use a gauge factor of 2, but this should be verified prior to use. |Gauge resistance is not 350 ohms for the strain gauges in Montpetit Labs, rather, 150 ohms. This value **must** be changed for valid results. Our strain gauges use Full Bridge 1.

The next step in collecting strain gauge data is scaling the voltage data into force values. Scaling factors must be known for each strain gauge device. Click "Custom Scaling" and select "Force". An animated wrench will appear beside the tab. Click the wrench to view a brief instruction about how to determine a custom scaling factor using the equation for a line, y = mx + b. Provided your relationship is linear (strain values in a strain gauge are well within the elastic region of the material), the scaling factor is simply the slope "m" of the line. This can be experimentally determined by adding increments of known mass to the strain gauge and plotting the force of gravity on these masses against the increasing voltage values. The mass should be suspended from the strain gauge and oriented such the full force of gravity is transmitted to the gauge (aligned parallel to the applied force). Thus, a known force will produce a know voltage by some constant "m"– the scaling factor.

A more accurate and valid approach for developing the scaling factor involves a dynamic compression of the strain gauge against a force platform. Montpetit 319 has a Kistler force platform with an isolated lead for the vertical (F_z) force component.

Figure 5. Kistler force platform with F_z output channel

This lead uses a BNC connection and must be fed into a specific box (attached to the NI-DAQmx chassis) with BNC input and NI-DAQmx compatible analog output. This analog output is wired into the one of the analog input modules. Similarly, the strain gauge is connected to a port of one module (as shown above).

Figure 6. BNC connector

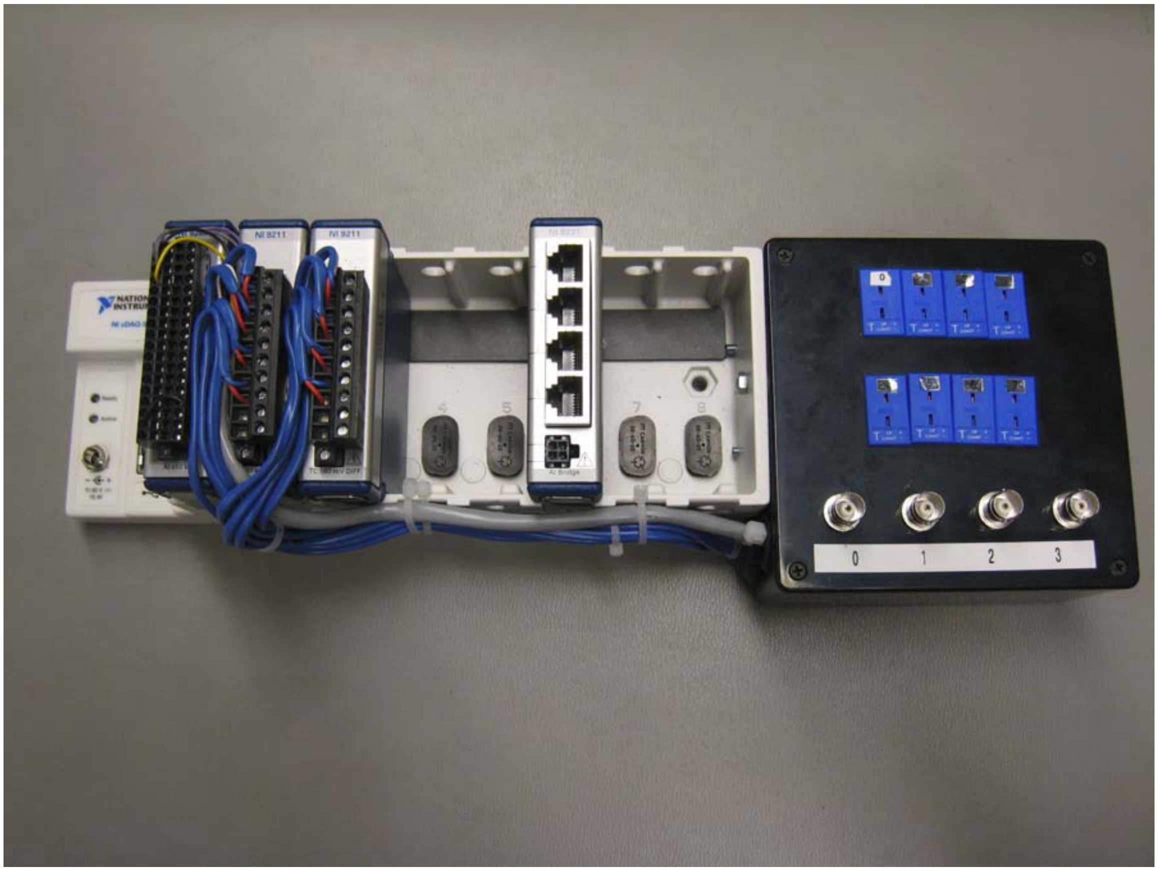

Figure 7. NI-DAQmx chassis with several modules. Only channel 6 (middle) is needed.

Once this hardware setup is completed create a VI Logger task as described above and select “Strain Ring” or any other strain setup which includes both strain and voltage channels. If none exist, simply create a strain or voltage task, add additional channels and save task. The strain gauge is placed vertically and the researcher will smoothly increase compression directly downwards through the gauge into the force plate, and then smoothly unload the gauge and force plate. VI Logger will capture both the analog force signal from the force platform, and voltage data from the strain gauge. Export these data to BioProc2/3 (see section Exportation of Data) and run Pearson correlation on both channels. This processing in BioProc2/3 will provide the user with the regression line or slope. This is the conversion factor between voltage and newtons. As well a hysteresis value is obtained.

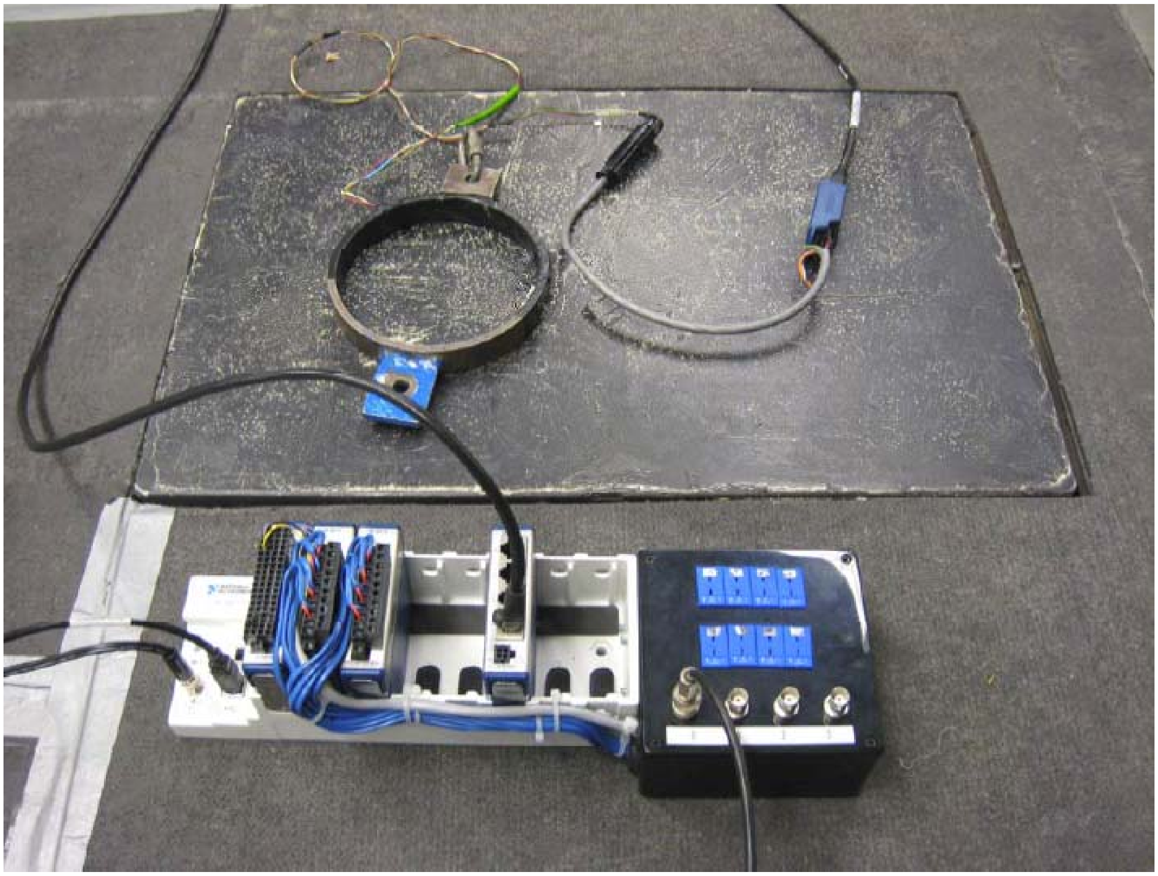

Figure 8. Complete setup for calibration

Task Timing and Triggering

Below "Strain Setup" is "Task Timing" tab. An error in this version of MAX software means only one sampling rate is possible, despite an input box allowing the user to select a sampling rate of their choice. The set sampling rate is 3846.1 samples per second (Hz). Therefore, if you wish to sample for a certain time period you must convert your time period to number of samples by multiplying the time period in seconds by the sampling rate (3.8461 kHz) and enter the sample number into the text box marked "Samples to Read". Other timing options such as "Continuous Acquisition" mode are possible. This mode will continuously collect data without a time frame or sample limit, but still uses the default 3.8461 kHz sampling rate.

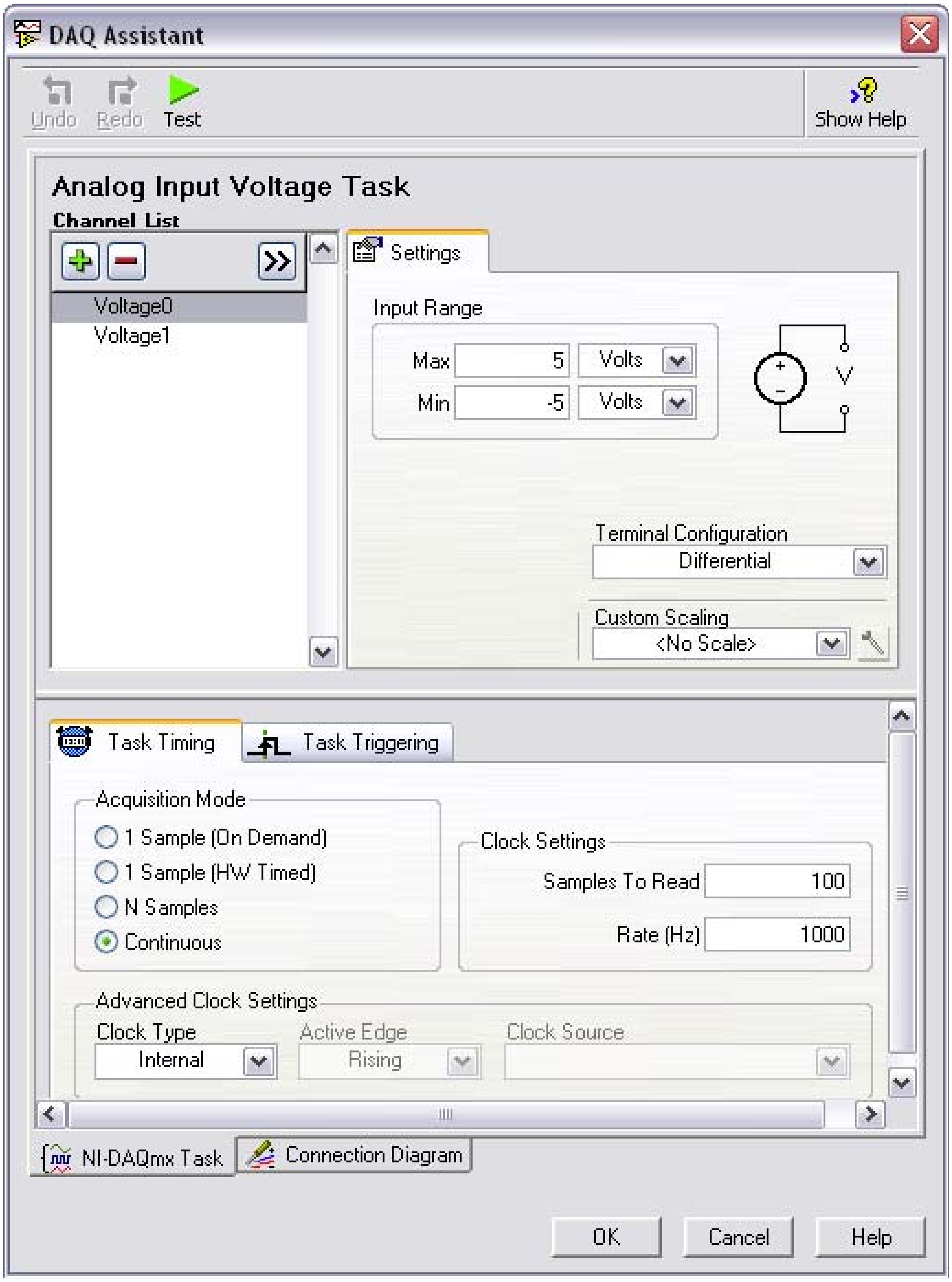

Figure 9. VI Logger analog input voltage task menu

Triggering allows data collection based on some voltage threshold or digit input value. "Trigger Type" determines the type of trigger to be used. Typically, "Analog Edge" is used and either starts or stops data collection or signal generation when the analog signal reaches specific threshold. "Trigger Source" is in Voltage. "Slope" modifies the trigger to start or stop collection or generation of the analog data only when threshold is crossed in either a rising or falling slope.

If “Analog Window” is selected as triggering type, then collection or generation stops when voltage leaves a specific range. “Top” and “Bottom” voltages of the window are input numerically and “Trigger Condition” determines if the trigger acts when voltage enters or exits the voltage window cut-off(s).

“Reference Trigger” sets a point such data may be collected prior to triggering (pre-trigger). “Pre-Trigger Samples” specify the minimum number of samples per channel to acquire prior to trigger reference. NI-DAQmx devices require a minimum of 2 pre-trigger samples.

Running a Task

Select “VI Logger Tasks” from the configuration tree. Select “Create New” at the top of the screen, or right click and select. From the connected hardware select “Using NI-DAQmx”. A new default task will appear labelled “My VI Logger Task”. From “Acquisition Settings” drop-down menu, select the NI-DAQmx task you desire. For experimental determination of the scaling factor for a strain gauge select a task with both analog “Strain” and “Voltage” channels selected. For standard strain gauge data collection select “Strain” task and appropriate channel. If triggering is set, data acquisition will occur when voltage threshold is disturbed. If no triggering is employed, click “Run task” to collect data. Click “End task” to manually end acquisition. Data collection will also be halted when the preset number of samples is collected as specified in “Task Timing”. Continuous data collection will run until user selects “End Task”.

Viewing Collected Data in MAX interface

As trials are captured, task labels in the configuration tree will branch to include captured trials. Select a trial to view collected data. Ensure tab at the bottom “Historical Data” is selected. “Summary” provides only brief overview of collection statistics, but does contain sample numbers and units of measure. At the top of the graph, function tabs exist. The blue arrows with solid bar scroll to the beginning or end of the data set. The blue arrows without bar allow for fine scrolling of data. Cursors may be introduced by selecting the crossed black arrows. One or two cursors may be selected. The cursors are moved with the mouse or by specifying a time difference.

Exportation of data

To view the data in Excel, click “View in Excel when task stops” and VI Logger will automatically open the data in Excel. Another option is to collect multiple trials and then view one by one in Excel. To do this collect data and then select the trial of interest and click “View in Excel” tab above graph.

Export to BioProc2/3

To view data file in BioProc2/3 a custom export format must be loaded. Within the configuration tree right click the data trial for export and select “Export Data”. The pop-up window displays the time frame to be exported. Default or no cursors used, VI Logger exports the entire trial. Ensure to apply an identifiable name to the output file and browse export location. Select “Tab” for delimiter method. Next select “Custom Template” for export style, and click “Customize Template” button. Click “Load” and from the available options select “BioProc2.vet”. This will produce a header and row format appropriate for BioProc2/3 graphing, processing and analysis.

To modify footer format a list of possible variables to be added to header, row or footer is displayed on the right. This function is not drag and drop. Therefore any new variables must be typed in manually.

References

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