Xi'an Jiaotong-Liverpool University

西交利物浦大学

MEC208 Instrumentation and Control System

2024-2025, semester 2

Lab 1: Sensors & Instrumentation

Name: ____________________

Student ID: _______________

Date: _____________________

Prepared by: Dr. Yuqing Chen

Schedule and Deliverable

Laboratory sessions: please refer to the email announcement and group list provided

Submissions: please submit **an individual PDF lab report** to LMO

Submission link: please refer to LMO

Deadline: End of Week 5, 11:59pm, 23 March 2024

Late Submission Policy: 5% of the total marks will be deducted for each working day after the submission date, up to a maximum of five working days. Submission after then will NOT be accepted.

~~~~~~

Instructions:

- Read this lab manual before coming to the laboratory.
- Some questions should be answered with numerical results or screenshots, and the questions should be answered while carrying out the experimental procedure. To obtain full marks of each questions, detailed derivations, explanations or discussions are required.
- The lab report should be your own work and individually completed. Plagiarism is strictly prohibited. Similarity check will apply on your submissions. University policies will apply once caught.
~~~~~~

Lab Manual:
Sensors and Instrumentation

Using the NI Automated Measurements Board for NI ELVIS III

Required Tools and Technology

Platform: NI ELVIS III • Digital Multimeter • Function Generator • Variable Power Supply • Oscilloscope	✓ View User Manual: http://www.ni.com/en-us/support/model.ni-elvis-iii.html ✓ View Tutorials: https://www.youtube.com/playlist?list=PLvcPIuVaUMIWm8ziaSxv0gwtshBA2dh_M
Hardware: NI Automated Measurements Board	✓ View Breadboard Tutorial: http://www.ni.com/tutorial/54749/en
Software: LabVIEW Version 19.0 or Later Toolkits and Modules: • LabVIEW Real-Time Module • NI ELVIS III Toolkit	✓ View Tutorials: http://www.ni.com/academic/students/learn-labview/

Sensors used in this lab:

Thermocouple	RTD	Thermistor	Strain Gauge
			

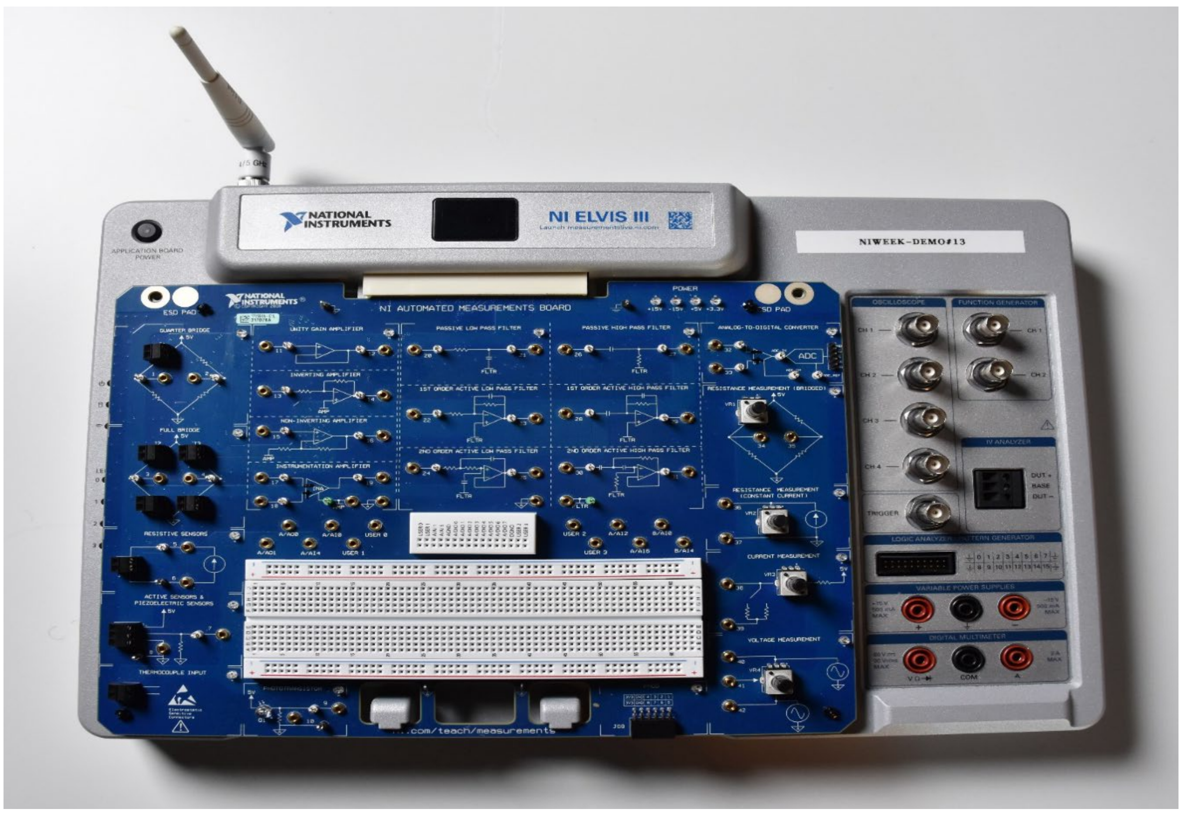
Introduction

This laboratory carries 15% of MEC208 total marks and will be conducted in IR112. The lab is equipped with sensors and instrumentation of National Instruments and with LabVIEW software installed. With different types of sensors available, this lab helps you to get hands on experience with various sensor measurement and instrumentation technologies using LabVIEW software.

To successfully complete the labs, you need access to a set of hardware and software packages.

NI ELVIS III

The NI Educational Laboratory Virtual Instrumentation Suite (NI ELVIS) is an engineering laboratory solution for project-based learning that combines instrumentation and embedded design with a web-driven experience to create an active learning environment in the lab and studio and flipped classrooms, delivering a greater understanding of engineering fundamentals and system design. NI ELVIS addresses engineering curriculum by integrating project-based learning, teamwork, and design with course-specific application boards and labs developed by experts from education and industry. NI ELVIS, as a programmable platform, gives educators the ability to scale to future multidisciplinary applications driving student employability.



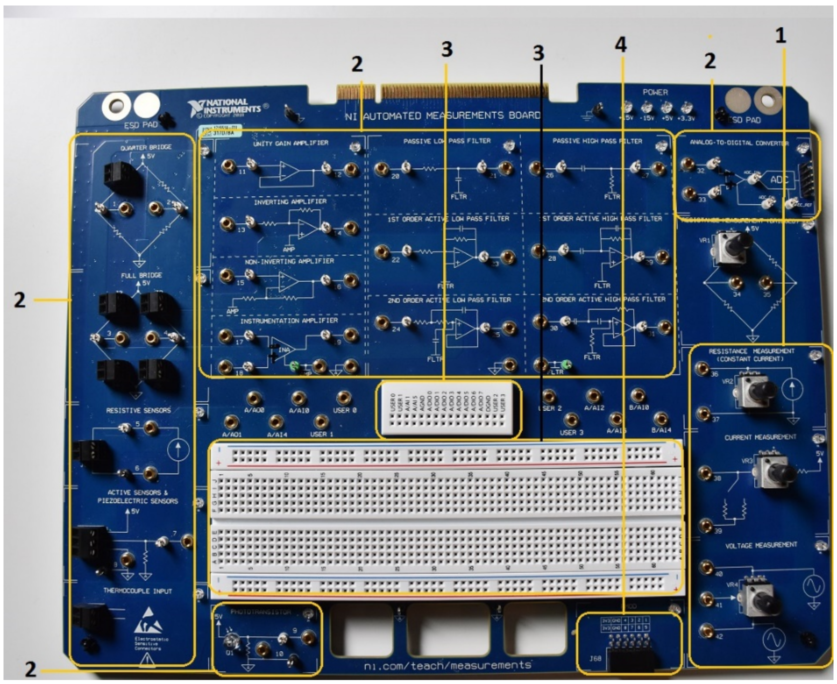
NI ELVIS III workstation fitted with an NI Automated Measurements Board.

Learn more at: http://ni.com/en-us/support/model.ni-elvis-iii.html

You can install various types of **application boards** on your NI ELVIS III. Each application board is designed to help you explore and innovate in a certain area of Engineering. This sequence of labs focuses on the NI Automated Measurements Board.

NI Automated Measurements Board

The NI Automated Measurements Board for NI ELVIS III supports fundamentals of measurements and instrumentation for common electrical and physical phenomenon. You can explore the full signal chain using real sensors and signal conditioning elements, with complete signal access at the inputs and outputs of each section.



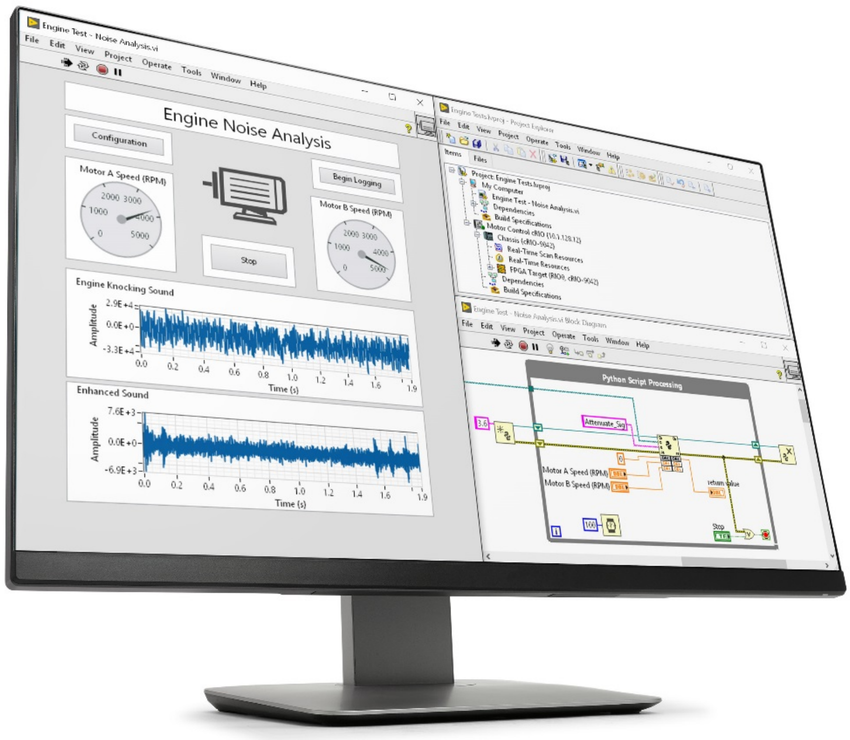
NI Automated Measurements Board.

The application board section covering:

1) Electrical Fundamentals provides you with hands-on experience of concepts related to voltage, current and resistance.
2) Signal Chain Elements give you a hands-on experience in the process starting in acquiring a signal and ending in analysing the signal on your computer.
3) Prototyping enables you to create custom circuits that you can integrate with the circuit that is built-in into the application board.

Software: LabVIEW

LabVIEW is systems engineering software for applications that require test, measurement, and control with rapid access to hardware and data insights. A widely-used, industry-standard tool for engineering system design, LabVIEW offers a graphical programming approach that helps visualize every aspect of an application. This visualization makes it easy to design engineering systems, convey concepts, and help you focus your time on the theory rather than get bogged down in the low-level implementation.



LabVEIW Interface.

Learn more at: https://www.ni.com/en-us/shop/labview/labview-details.html

Multisim Live

Multisim Live is a free, online circuit simulator that includes SPICE software, which lets you create, learn and share circuits and electronics online. You can access Multisim Live at https://www.multisim.com/

Safety Precautions

Take note of the following precautions to ensure safety while completing the activities in this lab manual:

- Always remember to turn off the application board power before wiring or making any wiring changes. Note that the application board power is found on the top left-corner of the NI ELVIS III next to the LED display. This button is different than the switch that controls the power to the NI ELVIS III workstation.
- Never touch exposed wires.
- Always use the supplied power cord. Turn off the platform while unplugging/plugging in the cable.
- When disassembling a circuit, turn off the power first.
- Follow the instructions in the experiments carefully to guard against short-circuiting and other hazards.

Before Experiments

You need to access LabVIEW to use application software for data acquisition and processing. The LabVIEW was pre-installed in virtual environment of lab computers. To access it:

- Click the “Software Center” on desktop
- Click “VMware Workstation 16 Player” in the prompt window
- Click “Open a Virtual Machine”, then choose C:\Program Files\NI and open it;
- Run the virtual machine by clicking “play” on the prompt window.

You also need to download the software package provided on LMO, unpack it, then drag the entire folder to the desktop of virtual machine.

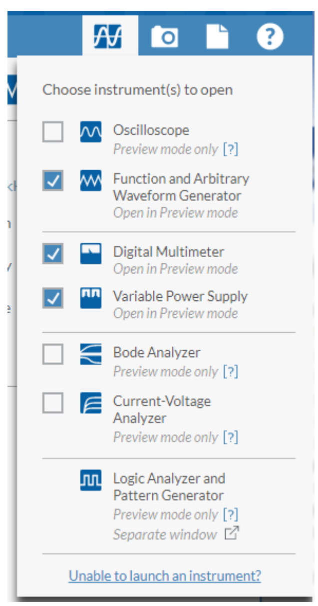
Experiment 1: Basics

E1.1 Use the Function Generator and Oscilloscope Soft Front Panels

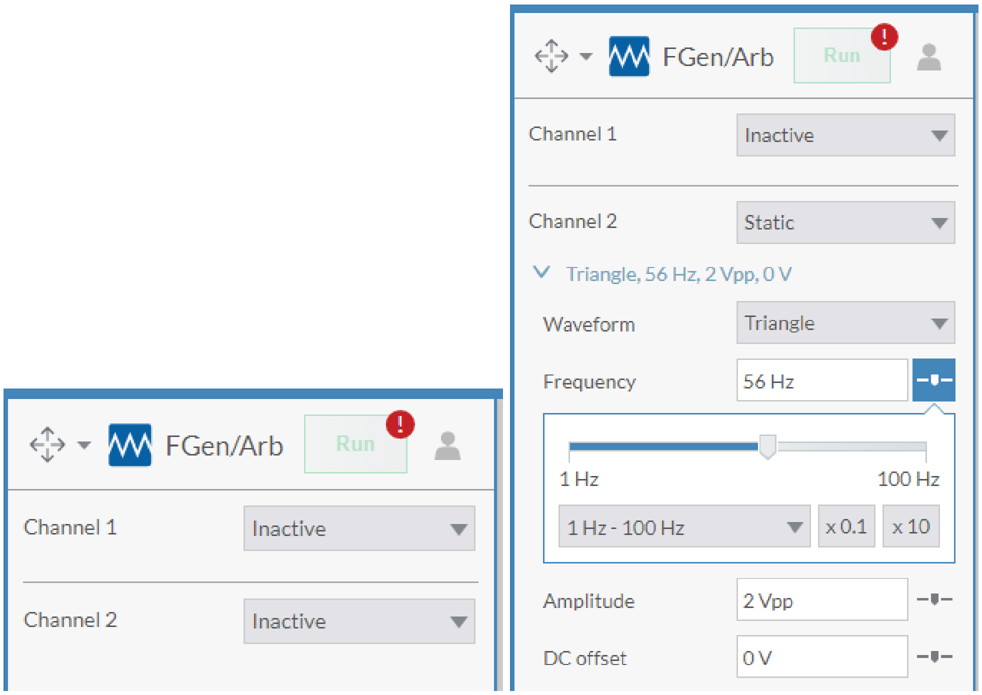
A **Function Generator** is an electronic device that generates specific forms of electric signals. An **Oscilloscope** is an electronic equipment that allows you to read an electronic signal and display its chart over time. Your NI ELVIS III is equipped with a Function Generator and an Oscilloscope that can be accessed from Measurement Live Soft Front Panels (SFPs).

In this lab you will use this Function Generator to generate an electric signal and read it using the Oscilloscope.

- Make sure your NI ELVIS III is powered on and launch the Measurements Live Website by clicking the icon on desktop.
- Click the Instruments icon and launch the Function Generator. This will launch the SFP of the Function Generator.



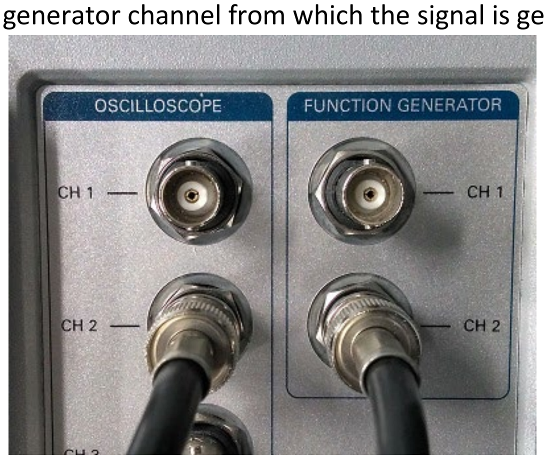
- The function generator SFP allows you to choose the NI ELVIS III Function Generator channel you want the electric signal to be generated through. It gives you the option to choose the type of signal you want to generate.



Left: The Function Generator Soft Front Panel. Right: a choice of a Triangle signal generated through channel 2 of the NI ELVIS III.

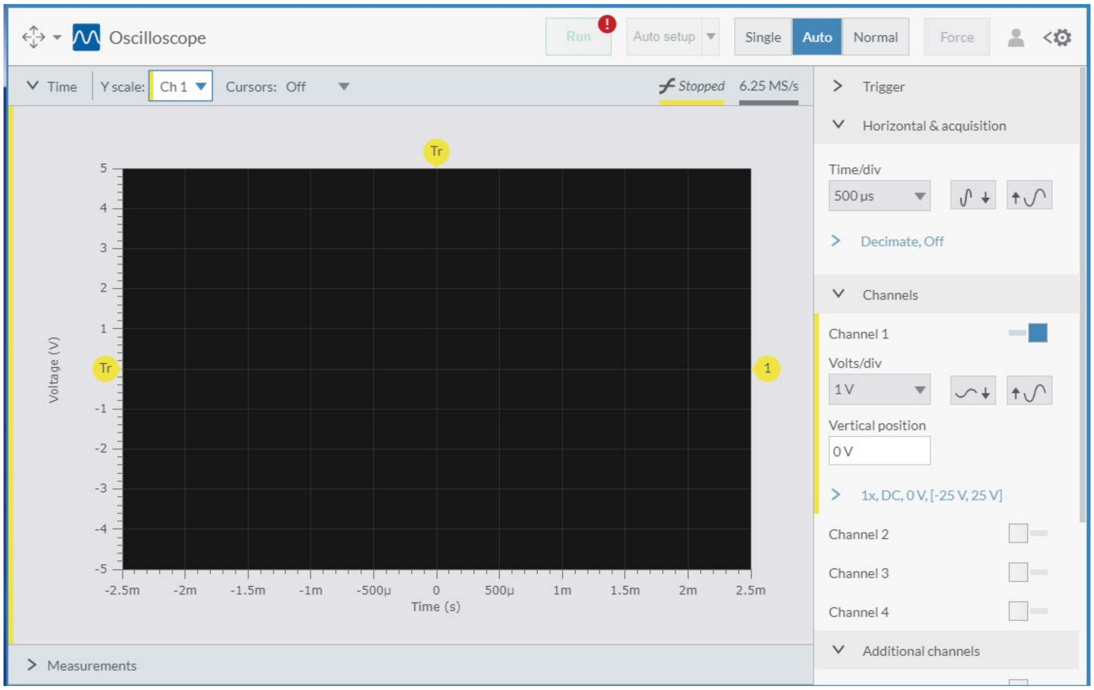
You can use the oscilloscope on your NI ELIS III to read an electric signal generated by the function generator. In order to do that:

- Using BNC connectors cable, connect the oscilloscope channel into which you are planning to read the signal to the function generator channel from which the signal is generated.



In the above figure, the signal is being generated from channel 2 of the function generator and read from channel 2 to of the oscilloscope.

- Launch the oscilloscope Soft Front Panel from Measurement Live. You will be prompted with the following



- Choose the channel you physically connected to the oscilloscope.
- Now that your function generator and oscilloscope are properly connected, click Run on the SFPs of both in order to see the electric signal produced.

Complete the following set of tasks and answer the corresponding questions.

1) Use you're the function generator on your NI ELVIS III to generate a sine wave with the following specifications:
   Frequency: 1kHz Amplitude: 2V DC Offset: 0V Output Channel: 1
   Read the function generator using channel 2 of the oscilloscope. Provide a screenshot of the SFP with generated function shown.
2) While both SFPs are running change the frequency of the signal generated to 500 Hz. Provide a screenshot. In your own words, describe the change that occurred to the read signal.
   ____
   ____
   ____
3) Return the frequency to its initial value of 1KHz. Change the amplitude to 4V. Provide a screenshot. In your own words, describe the change that occurred to the read signal.
   ____
   ____
   ____
4) Return the amplitude to its initial value. Change the DC Offset to 3. Provide a screenshot. In your own words, describe the change that occurred to the read signal.

____

____

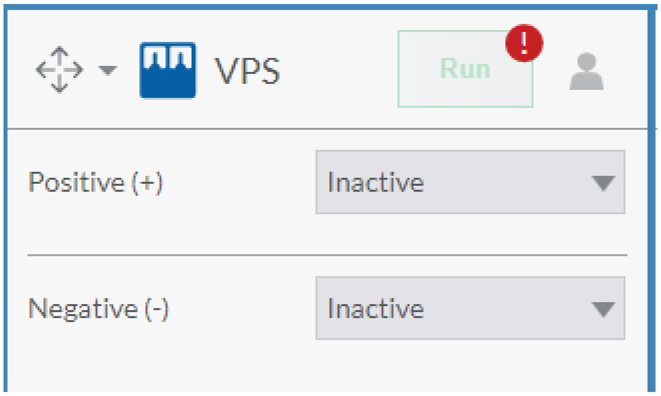
____

E1.2 Use the VPS and the DMM

The Variable Power Supply (VPS) can generate voltage power supply. This power supply can be a constant DC voltage such as the one produced by a battery or sweep. Your VPS voltage supply can be chosen from a range of -15V to +15V. A sweep power supply is a voltage supply that changes over time by spanning all the possible values from 0 to 15 V or -15V to 0V. The negative and positive voltage supplies can be combined to produce voltage ranging from -30V to 30V. See the figure below.

The positive voltage terminal outputs a positive voltage. The negative voltage terminal outputs negative voltage. Note that voltage is a relative concept that is measured with respect to a reference. Unless otherwise mentioned, the reference is considered to be the ground. The ground is considered to have a voltage 0V. The black terminal connects to the ground.

- To generate a power supply, launch the Variable Power Supply Instrument from Measurements Live. You will be prompted with its corresponding SFP.



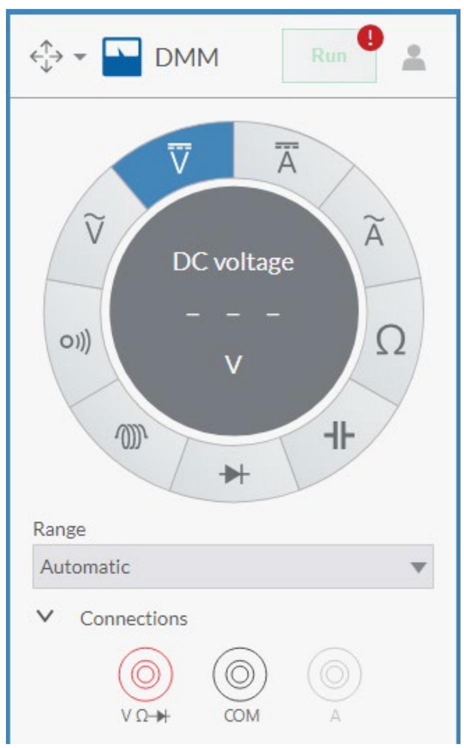
The positive power supply generates a positive voltage through the (+) channel output on your NI ELVIS III. The negative power supply generates a negative power supply through the (-) channel on your NI ELVIS III.

- By clicking the appropriate Power Supply dropdown list, you can choose the type of power supply you want. Once, you click Run, the power will be supplied through the VPS outlet that you chose.

You can use the Oscilloscope to read the voltage signal generated by the VPS. However, in this experiment, we will use a DMM (Digital Multimeter) instead.

The COM terminal is the common ground with respect to which the voltage is measured. The common ground is assumed to have voltage 0. The V terminal is where you plug in the voltage that you want to measure. The A terminal is where you plug in the current you want to measure.

- To measure a voltage power supply through the DMM, launch its SFP from Measurements Live Instruments.



In the following set of steps you will generate various types of voltage from the VPS and read them using the DMM.

1) Make sure your NI ELVIS III is powered on and connected to your computer.
2) From Measurements Live website launch the SFPs of both the DMM and VPS.
3) Connect the (+) channel of the VPS to the (V) channel of the DMM using the cable and the ground of the VPS to the common ground of the DMM.

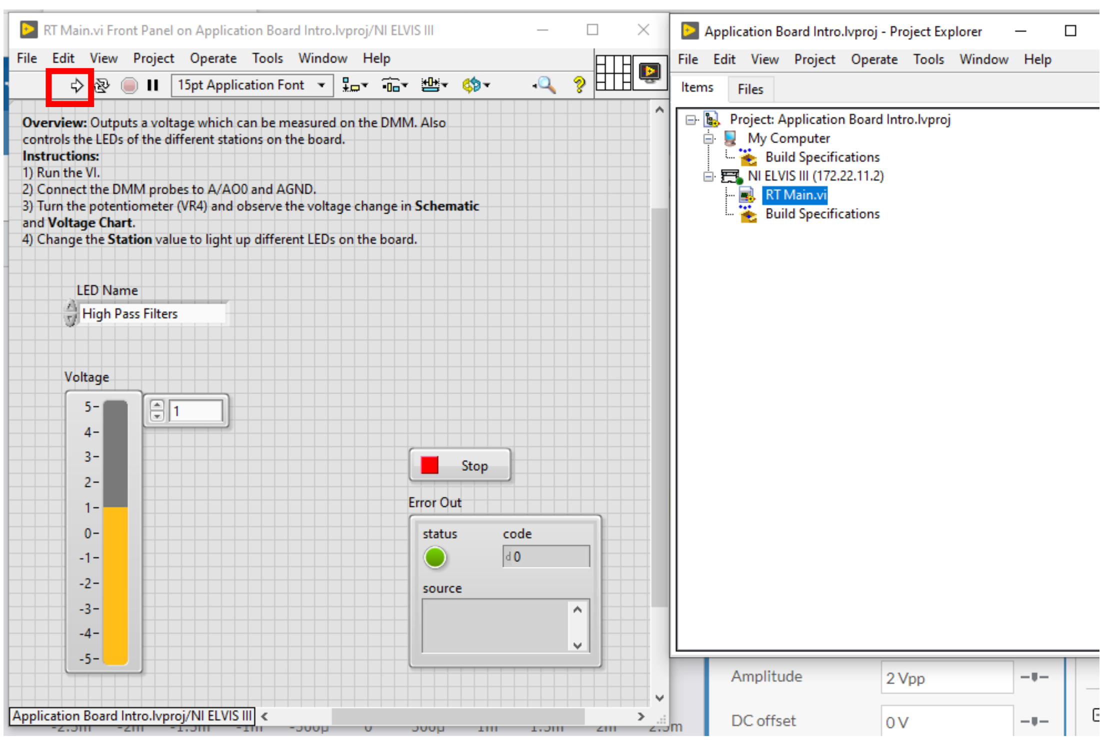
4) From the VPS SFP choose the positive power supply of +1V and a negative power supply of -1V. Click Run on both SFPs. What is the voltage read by the DMM? _______________
5) While both SFPs are running, unplug the Banana plug from the ground of the VPS and plug it in the (-) power supply of the VPS. What is the voltage reading on the DMM? __________.
6) Keep the cables connected the way they are. Change the negative voltage supply of the VPS successively to -2V, -3V and -4V. What are the voltage readings on the DMM? __________________________________

E1.3 Use NI Automated Measurements Board

Next you will experiment with the various electronic devices available through your application board. Each electronic device is equipped with an LED that you can control to indicate whether the device is in use. In this experiment you will run a LabVIEW VI that allows you to choose and activate which LED you want lit.

Furthermore, you will programmatically generate an electric voltage signal, output it though one of the application board output channels and read it using the DMM on your NI ELVIS III.

- Open the /Application Board/Intro folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Application Board Intro.lvproj.
- From the project window, configure the NI ELVIS III IP address to reflect the IP address of the actual NI ELVIS III your computer is connected to (skip this step if IP address has been configured)
  - To configure the NI ELVIS III from your project window,
    - right-click NI ELVIS III (0.0.0.0)[Unconfigured IP Address]
    - click General in the window prompt you get.
    - In the IP address section enter 172.22.11.2
- Open RT_Main.vi, click Run on the interface.



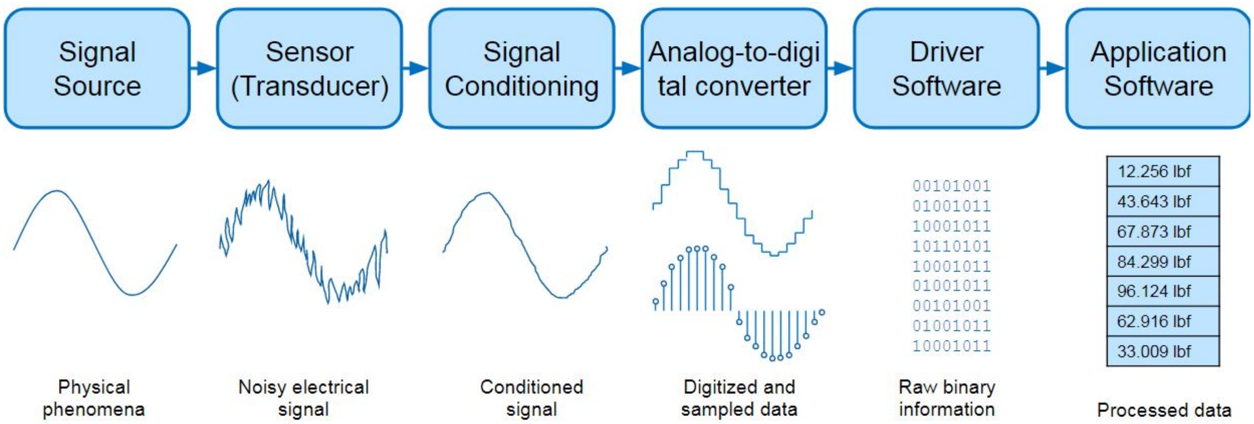
- Launch the DMM SFP from Measurement Live. Use the probes in your kit to measure the voltage signal.
    - Connect the probes respectively to the DMM terminals.
    - Use ground probe to touch the ground terminal on application board (see the figure below).

    - Connect the voltage probe to Output channel AO0 (See the figure below).

    - What is the voltage level you read on the DMM? ___________
- From the LED Name control, switch the selection to various values. The corresponding LED of your choice should light up. Provide a picture of lighting the "Amplifier".

Experiment 2: Signal Chain

Essentially the signal chain describes a series of electronic components and software that convert a real phenomenon to usable digital information. In the signal chain, the signal is a function (usually of voltage over time) that transfers information reflecting the event or phenomenon being measured. The chain is the series of components, including circuitry, devices, and software, through which the signal is passed. Each step in the chain uses the output from the previous component as its input.



The signal chain is comprised of four main steps:

1. **The sensor:** Sensors are the first component of the signal chain. The role of the sensor is to convert the physical phenomenon into an electric phenomenon such as a voltage signal.
2. **The signal conditioning circuit(s):** A signal conditioning circuit modifies the sensor output if/as needed, such as by amplification, noise reduction, or attenuation.
3. **The analog-to-digital converter (ADC):** The ADC translates the analog signal into a digital binary stream of data so that it can be processed by a device such as a computer. It interfaces with the computer using a computer bus such as a USB and the appropriate driver software.
4. **The application software:** The final step in the signal chain is processing and analyzing the data. Software analysis can include producing graphic representations of the information, controlling a system based on the measurements taken, and more.

In data acquisition, the signal source is the physical phenomenon being measured. A sensor is used to generate an electrical signal from the physical phenomenon. Then, depending on the nature of the sensor and the signal being measured, the signal can undergo signal conditioning in preparation for the next step in the chain. A conditioned signal can then be digitized and sampled resulting in the generation of raw binary data. The signal chain ends with application software reading the processed data.

E2.1 Signal Chain using the NI Automated Measurements Board

Your application board is equipped with a sensor called a phototransistor. A phototransistor senses changes in the intensity of light it is subjected to. The sensor is embedded in your application board in such a way where a programmatically controlled electric current flows through it. Different levels of light intensity shining on the sensor causes the sensor to resist the current flow to different levels. This gives us a way of measuring light intensity.

The phototransistor section on the NI Automated Measurements Board.

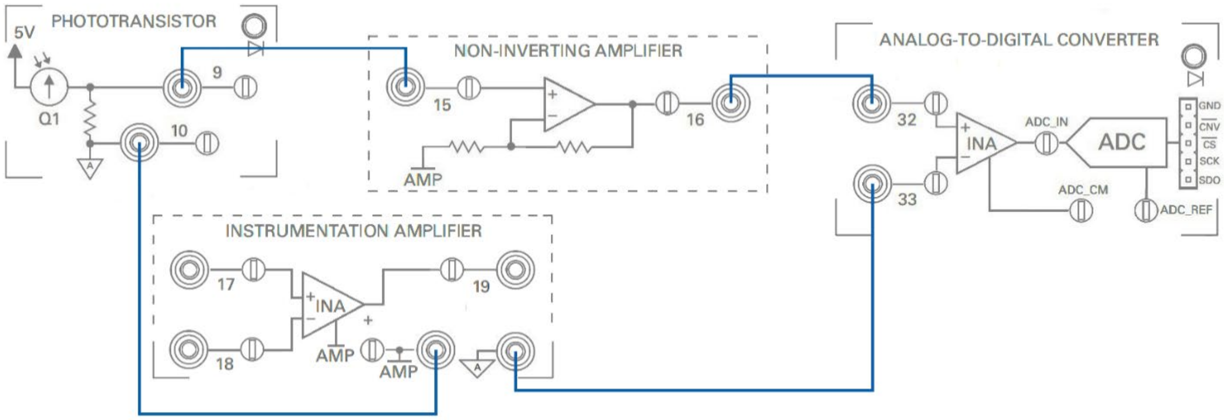
In this experiment, you will be provided with a step-by-step guide to making the necessary application board wiring and running a LabVIEW project that will help you test the Phototransistor by acquiring the signal from it, running it through the signal chain and displaying it on your screen.

<u>Load the LabVIEW Project</u>

- Open the /Signal Chain folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Signal Chain.lvproj.
- Open the VI named “Full Signal Chain.VI”.
- Perform the wiring on the NI automated Measurement Board following the below figure to acquire the voltage signal from the phototransistor into the non-inverting amplifier, the ADC, and then into your LabVIEW VI for software analysis.

- Run the VI named Full Chain.vi

Perform the proper wiring on the NI Automated Measurements Board



Open the Front Panel of your LabVIEW VI and run it.

Note: for the following labs, you can zoom in the figure shown on VI interface as needed by right clicking the mouse and select **"AutoScaleY"** to adjust scales of Y axis and obtain more precise reading of signals.

1. The Light Intensity chart on your Front Panel displays the intensity of light as it changes over time.
   a. What is the light intensity in your lab, measured in Volts? *(Make sure the sensor is not covered or overshadowed but rather is fully exposed to the light in the room)*

      ____

   b. Using a light source, such as your smart phone's camera flash light, subject the sensor to light from different angles and from various distances. Provide screenshots or photos for each of the following questions.
      i. What is the minimum intensity you were able to measure?

         ____

      ii. What is the maximum intensity you were able to attain?

         ____

      iii. In your own words describe the best angle and the distance from which your light source is best detected.

         ____
         ____
         ____

   c. From your Front Panel, set the sampling rate of your ADC successively to 0, 20, 100, 500 and 1000. With each sampling rate picked, repeat the earlier experiment. What do you notice about the chart displaying the changes in voltage?

      ____

____
____

2. The ADC LED display provides a view of the raw digital data that is provided by the ADC to the LabVIEW VI. Each row of LEDs represents one digital voltage value composed of 12 bits of 1's or 0's. An On-LED represents the digit 1 and an Off LED represents the digit 0. The most significant bit is the sign bit indicating the sign (+/-) of measured values, the absolute decimal numbers are represented by the rest 11 bits.
    a. What is the string of 12 bits corresponding to the lowest possible voltage reading? Shield your sensor from light to attain that value. Provide a screenshot. _____________________________________
    b. What is the string of 12 bits corresponding to the highest possible voltage reading? Subject your sensor to the brightest light source to attain that value. Provide a screenshot. _____________________________________
    c. What are the corresponding voltage readings to these 12-digit numbers? ____

E2.2 Measuring the Signal Directly from the Sensor

In the previous section you experimented with a complete signal chain. In this section you will skip most of the signal chain parts and simply observe the output of the sensor. You will do this by measuring the signal from the sensor directly using a digital multimeter (DMM).

First, we will switch the Phototransistor section ON programmatically using the following VI. Then we will use the DMM to measure the emitted signal.

Load the LabVIEW Project

- Open the /Signal Chain folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Signal Chain.lvproj.
- Open the VI named "Direct DMM.vi" from the same project and run it. The sensor is activated and emitting a signal however, the signal is not being read. The lit LED on the Phototransistor section indicates that the Phototransistor is operational.
- Launch the DMM SFP to measure the signal from the sensor.
- Place the probe connected to the Common Ground (COM) of the DMM in socket 10 and the probe connected to the voltage socket of your DMM to socket 9 of the application board.

Run the DMM. Provide screenshots for below questions.

1. What is the voltage reading corresponding to the light intensity in your room? ____
2. Using your phone's flashlight, shed light directly on the sensor. What is the corresponding DMM measurement? ____
3. What is the DMM measurement reading if the sensor is fully shaded? ________________________
4. Compare this measurement experiment with the preceding experiment you conducted. In your own words, list and justify two disadvantages that measuring the signal directly through the DMM has.
    a. ____
    b. ____

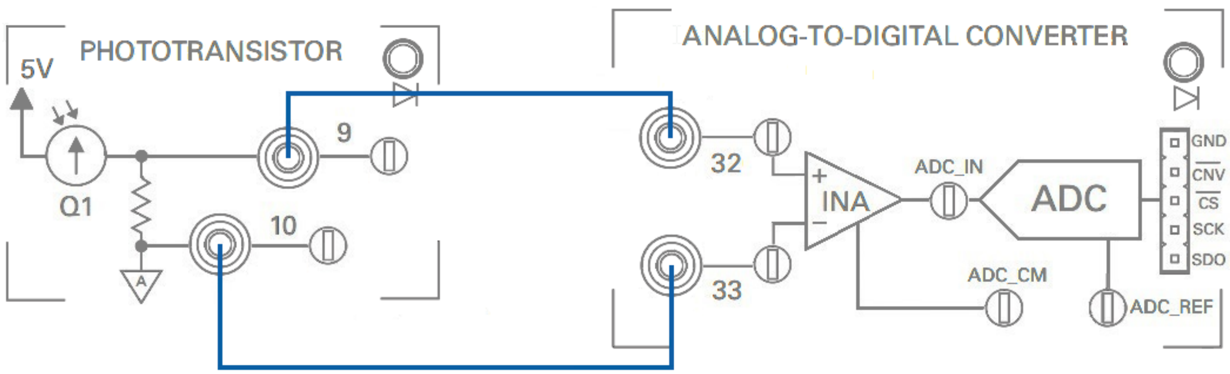
E2.3 Using the Analog to Digital Converter in the Signal Chain

In this section, your will use the ADC in your application board to convert the signal from the sensor into a digital signal.

For this experiment, we need to programmatically activate both the Phototransistor and the ADC sections of the application board. We need to display the output of the ADC on the screen. i.e. The stream of bits corresponding to each voltage value output from the ADC.

<u>Load the LabVIEW Project</u>

- Open the /Signal Chain folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Signal Chain.lvproj.
- Open the VI named “ADC.vi” from the same project. The sensor is activated and emitting a signal however, the signal is not being read.
- Connect sockets 9 and 10 of the phototransistor respectively to sockets 32 and 33 of the ADC.



Follow the instructions on the Front Panel and Run the VI.

The Front Panel shows the output of the ADC. Your ADC is a 12-bit ADC. Thus, each voltage measurement reading from the sensor is represented using 12 digits of 1’s or 0’s. In order to obtain a measurement value similar to the one read on the DMM, this stream of digits has to be converted into a decimal format. Your ADC is designed with a specific protocol that determines which stream of bits corresponds to each voltage reading. Specifically, the most significant bit is the sign bit indicating the sign (+/-) of measured values, the absolute decimal numbers are represented by the rest 11 bits.

To convert the 11-bit binary-base numbers to absolute voltage measurements,

1. Convert the numbers from the binary base to the decimal base. To do this, multiply each digit by 2 raised to a power equal to the position of the digit in the number subtracted by 1. Then, add up all the answers. For example, $00000001011 = 1 \times 2^3 + 1 \times 2^1 + 1 \times 2^0 = 11$
2. Scale the decimal value obtained to the range of the ADC. In our specific case, Number 0 corresponds to 0V
   Number 2047 (Decimal number composed of 11 bits of 1’s) corresponds to 5V
   Thus, the scaling formula is

$$Decimal\ number = \frac{x \times (5)}{2047}$$

Where x represents the 11-bit number converted to the decimal system.

Please note the “ADC Raw Data” shown on your VI is decimal number directly converted from the 12-bit code, without considering the most significant bit as sign bit. Therefore its values cannot be simply converted to voltage reading by the above equation.

Run the VI and follow the instructions on the Front Panel.

1. Record the ADC output corresponding to the light intensity in the current room, and provide a screenshot: ___________________________________
2. Convert that value to voltage value (please show detailed derivations).
   ____
   ____
   ____

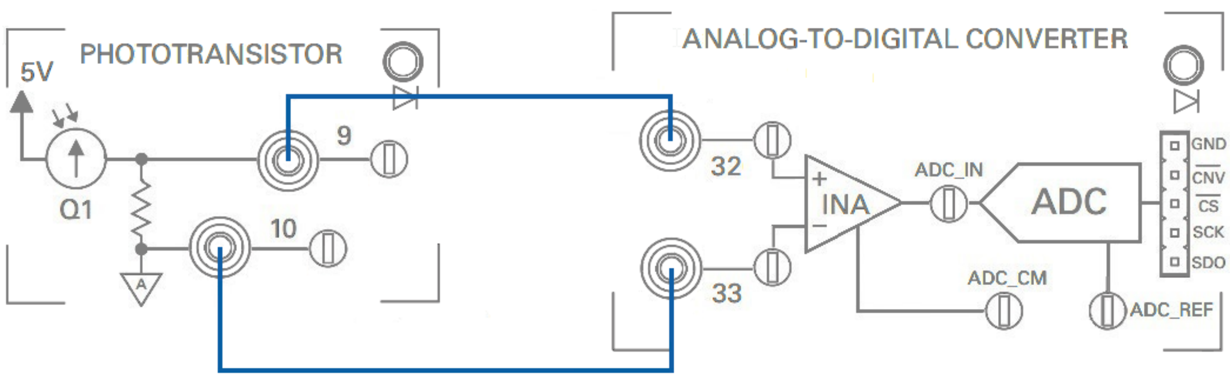
E2.4 Advantage of Amplifying a Signal

The amplifier essentially magnifies the strength of a signal. This allows small variations in a signal to be detected by the ADC and thus captured by your software.

In the following, you will experiment with a signal chain that skips the amplification step. Then, you will run the complete signal chain again and compare the performance of both.

Load the LabVIEW Project

- Open the /Signal Chain folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Signal Chain.lvproj.
- Open the VI named “No Amp Signal Chain.VI”.
- Connect sockets 9 and 10 respectively to sockets 32 and 33.



Shed a light source on the Phototransistor such as the camera flash light in your smartphone. Your task is to try to find the minimum change in intensity that can be recorded on your Front Panel. You might try achieving that by experimenting with placing your light source at various distances and angles from the Phototransistor.

1. Describe how well you are able to see small changes in light intensity? For example, what is the difference in the measurement between ambient light and the measurement with the phototransistor covered? Provide screenshots.

   ____
   ____
   ____

2. Repeat the above experiment but this time include the Non-Inverting Amplifier in the signal chain using the same wiring you did earlier, in the first experiment. Provide screenshots. Now how well are you able to see small changes in light intensity? What is the difference in the measurement between ambient light and the sensor being covered?

   ____
   ____
   ____

3. In your own words describe the impact the amplifier had on the signal acquisition.

   ____

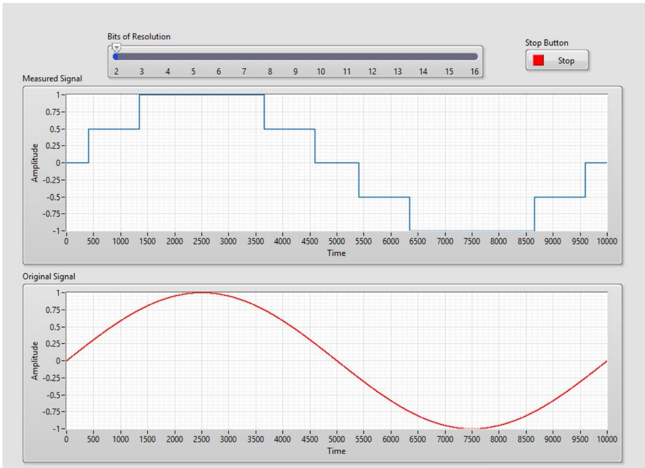
E2.5 The Impact of Resolution on Reading a Signal

The resolution of a measurement device is determined by the number of bits it uses to represent measurement numbers. Range and resolution of a measurement device work together to determine the way a signal is measured.

For example, a 4-bit measurement device with a range of 0V~ +10V has the capacity to:

- Capture signals with amplitude falling within the range of 0V and +10V
- Capture changes in a voltage signal as low as $\frac{(10-0)}{2^4} = \frac{10}{16} = 0.625V$

Attempting to read a voltage signal of 0.4V using this measurement device will yield a zero. Similarly, a change in the signal of less than 0.625V will not be captured by the ADC.

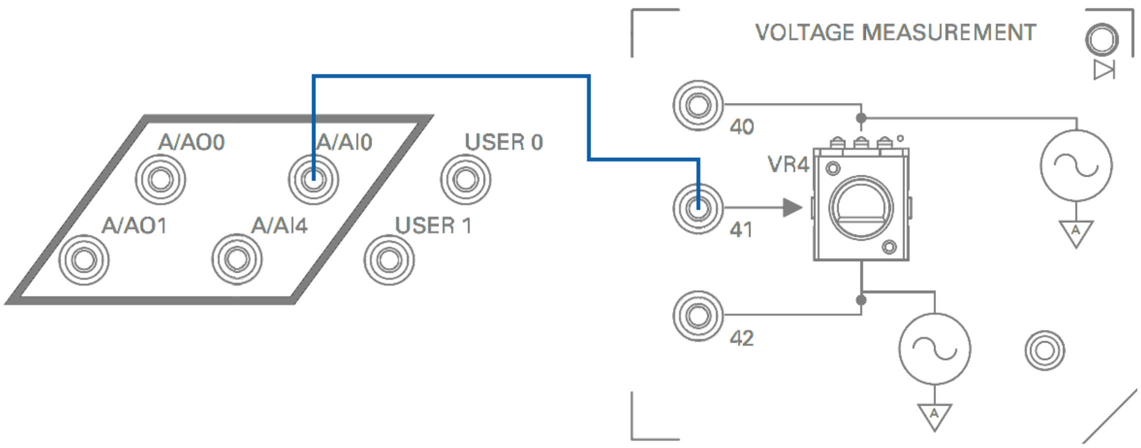


Bottom: A simulated sinewave analog signal that ranges from -1V to 1V. Top: a digitized version of the same signal using a 2-bit resolution ADC. Note that changes in the sinewave signal that are less than 0.5V are not detected.

In this experiment you will use your NI Automated Measurements Board and LabVIEW to experiment the impact of measurement resolution on signal acquisition.

To run the experiment,

- Open the /Voltage/Resolution folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Voltage Resolution.lvproj.
- Open the RT Main.vi.
- Run the VI.
- Connect A/AI0 to socket 41.



1. Set the resolution to 2 bits. Turn the potentiometer wiper up and down slowly. What is the minimum change in voltage captured by the chart or Voltage Box in the schematic? Provide a screenshot. ________________________
2. List all the possible voltage readings that can be done at 2-bit resolution:
   ____
   ____
3. Change the resolution to 4 bits. What is the minimum amount of voltage change that can be captured by the chart or the Voltage Box in the Diagram? Provide a screenshot.
   ____
4. What is the total number of voltage readings that can be done at 4-bit resolution?
   ____
5. In your own words, describe how a change in resolution under a fixed range impacts the analog to digital conversion.
   ____
   ____
   ____

Conclusion

1. Indicate whether each of the following is true or false. [T/F]
   a. The higher the resolution in bits the larger the resolution in volt. [T/F]

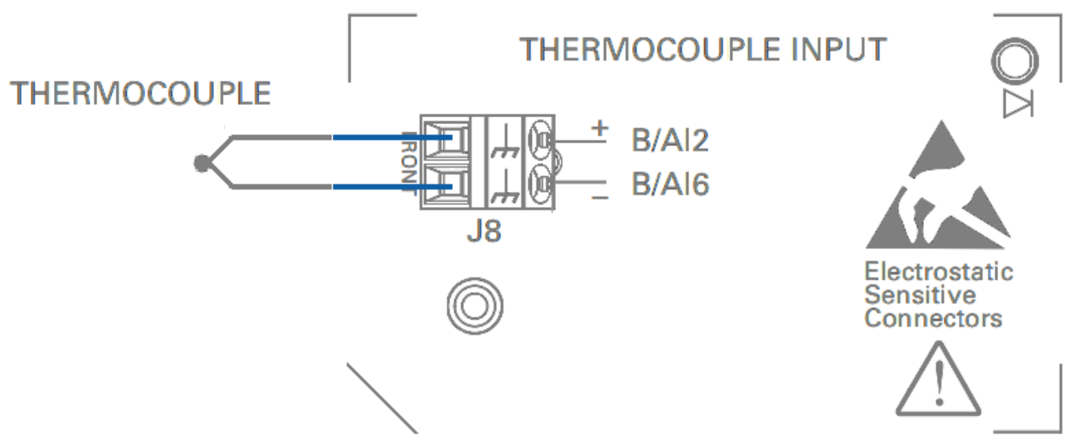
   b. The higher the sampling rate the more accurate your digital representation of an analog signal. [T/F]
2. In your own words, describe resolution and sampling rate of an ADC.
   a. ____
      ____
      ____
      ____
   b. ____
      ____
      ____
      ____

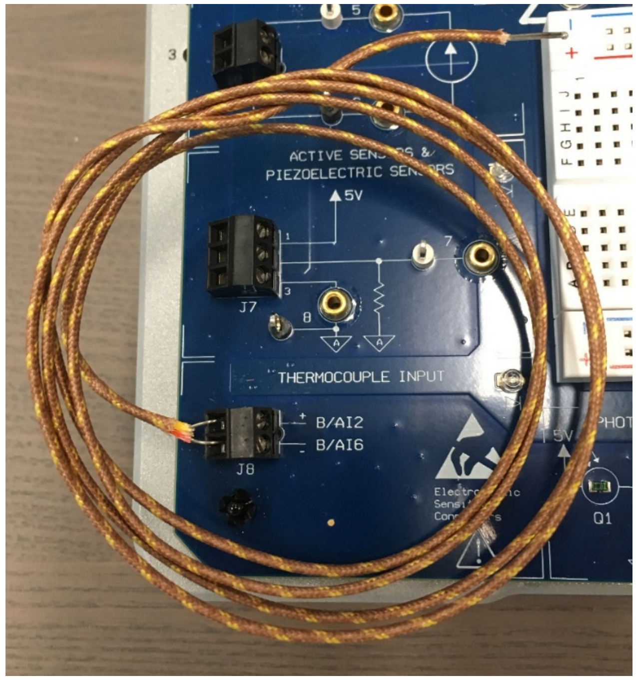
Experiment 3: Temperature and Strain Measurement

E3.1 Temperature Measurement with a Thermocouple

Your NI Automated Measurements Board is equipped with Thermocouple Input. In the following lab you will learn how to connect a thermocouple to the Thermocouple Input on your Automated Measurements Board and measure the voltages.

- Open the \Temperature\Thermocouple\ folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Thermocouple.lvproj.
- Make sure all other projects are closed.
- Connect the thermocouple to the thermocouple input of the Automated Measurements Board.
  - Connect + yellow wire of thermocouple to B/AI2
  - Connect – Red wire of thermocouple to B/AI6





Open the Thermocouple VI and run it.

1. Observe the change in the sensor reading when touching the glass bead at the end of the wire.
2. Write down the sensor reading before and while touching the thermocouple with your hand. Provide screenshots.

   ____
   ____
   ____

3. How long does it take for the sensor reading to stabilize after touching it?

   ____

4. Write down the sensor noise level at room temperature. Provide a screenshot. How much change in temperature does the noise cause?

   ____

5. What filter would you use to reduce the noise but not affect the signal due to real temperature changes? Explain why.

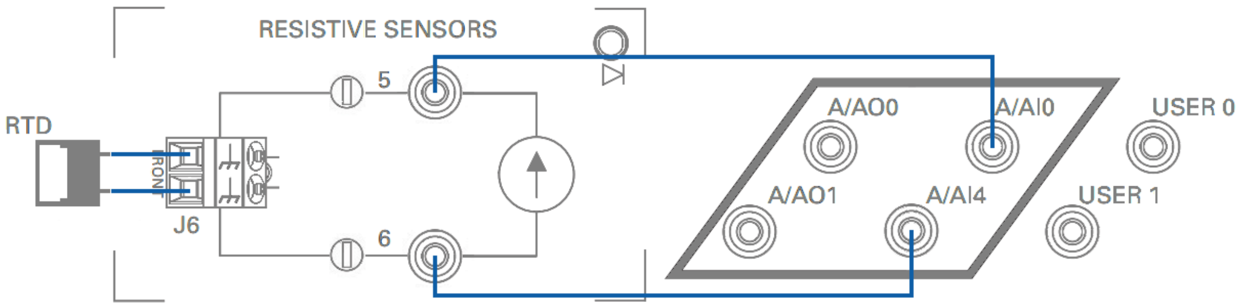
   ____
   ____
   ____

E3.2 Temperature Measurement with an RTD

The following experiment explains how to connect a resistive temperature detector (RTD) to the resistive sensing Input in your NI Automated Measurements Board.

- Open the \Temperature\RTD\ folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named RTD.lvproj.
- Make sure all other projects are closed.
- Acquire the signal of the RTD from the analog input A/AI0 and A/AI4

- Connect the two lines of the RTD to connector J6.
- Connect A/AI0 to socket 5 and connect A/AI4 to socket 6. Note that B/AI3 and B/AI7 are preconnected to the two terminals of the resistor.



Open the RTD VI and run it.

1. Observe the change in the sensor reading when touching the glass bead at the end of the wire.

2. Write down the sensor reading before and while touching the RTD with you hand. Provide a screenshot.
   ____
   ____
   ____

3. How long does it take for the sensor reading to stabilize after touching it? Is this sensor slower or faster in its reaction to a temperature change compared to the thermocouple in the previous experiment?
   ____

4. Write down the sensor noise level at room temperature. Provide a screenshot. How much change in temperature does the noise cause?
   ____

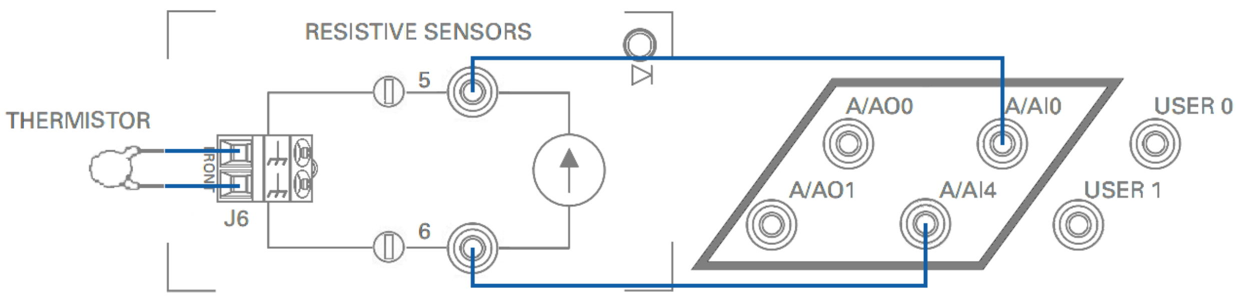
5. How does this noise level compare to the thermocouple?
   ____

E3.3 Temperature Measurement with a Thermistor

The following experiment explains how to connect a Thermistor to the Resistive Sensing Input in your NI Automated Measurements Board.

- Open the \Temperature\Thermistor\ folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Thermistor.lvproj.

- Make sure all other projects are closed.
- Connect the Thermistor to the Resistive Sensors input of the ELVIS NI Automated Measurement Board.
    - Connect the two lines of the Thermistor to connector J6.
    - Connect A/AI0 to socket 5 and connect A/AI4 to socket 6. Note that B/AI3 and B/AI7 are preconnected to the two terminals of the resistor.



    - Set values for parameters R and B. R is the nominal resistance of the thermistor at 25 degrees Celsius and B is coefficient parameter. Set R, B to 10Kohm and 4300K respectively.

Open the RTmain VI and run it.

Observe the change in the sensor reading when touching the sensor.

1. Write down the sensor reading before and while touching the thermistor with your hand. Provide screenshots.

   ____

2. How long does it take for the sensor reading to stabilize when touching it?

   ____

3. Write down the sensor noise level at room temperature. Provide screenshots. How much change in temperature does the noise cause?

   ____

4. How does this noise level compare to the thermocouple and RTD?

   ____

Conclusion

1. Which of the three temperature sensors was most affected by noise? How much of a swing in temperature did this cause? How could you overcome this noise?

   ____

   ____

   ____

2. Which of the sensors reached the peak temperature fastest, when touching it? What would this mean for a real-world measurement system?

____
____
____

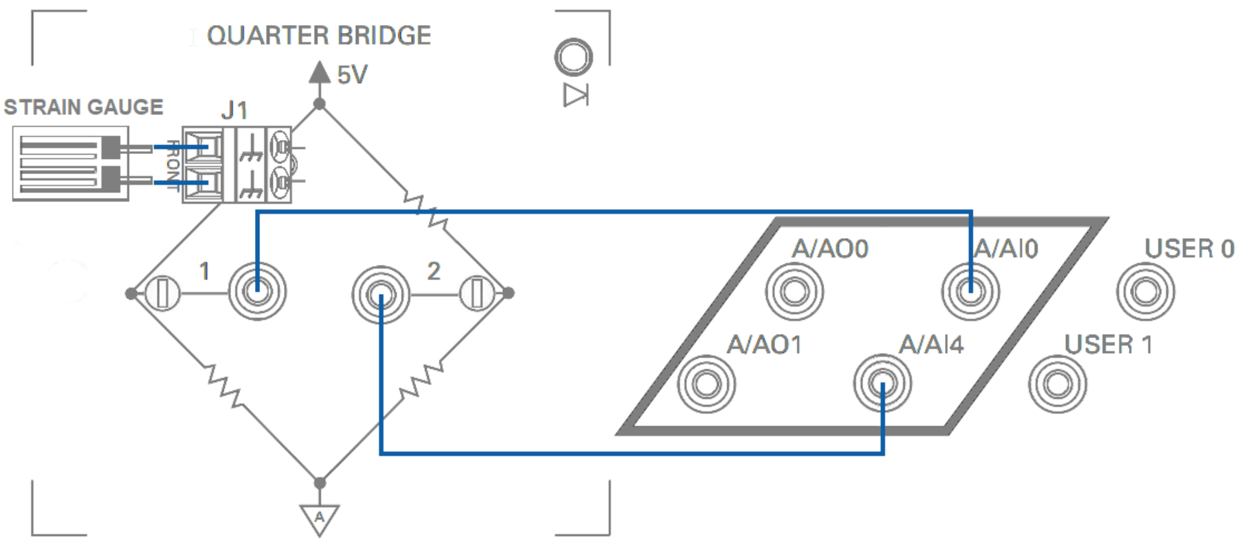
3. In your own words, describe the difference in construction, connection, and behavior between the three sensors.

____
____
____

E3.4 Strain Measurement with Quarter Bridge

- Open the \Strain\Quarter Bridge\ folder in the zip file provided in your lab kit.
- Launch the LabVIEW Project named Strain Quarter Bridge.lvproj.
- Make sure all other projects are closed.
- Connect the strain gauge to the quarter bridge input of ELVIS NI Automated Measurement Board.
  - Connect two lines of the strain gauge to connector J1.
  - Connect A/AI0 to socket 1 and connect A/AI4 to socket 2. Note that B/AI1 and B/AI5 are preconnected to the excitation of the quarter bridge.
  - Configure Gauge Factor to 2 and Strain Gauge Resistance to 350.

Open the RT Main VI and run it.



1. Observe the change in the sensor reading when carefully flexing the sensor by flexing the protection bag. **Note: please don't take the sensor out of the plastic protection bag. The senor is fragile and easily broken.**

2. Write down the sensor reading before and while flexing the metal foil gauge with your hand. Provide screenshots.

   ____

____

3. How long does it take for the sensor reading to take affect? Compare this to the RTD temperature sensor in the previous lab.

   ____

4. Write down the sensor noise level? What filter would you use to reduce the noise?

   ____

5. Use the breadboard of the Automated Measurements Board and add some extra wires in between the strain gauge and the J1 connector (i.e. make the connection path between the strain gauge and the J1 connector go through at least 1 extra wire per lead). How does the additional lead wire affect the sensor reading when no strain is applied? How does it affect the measurement when applying strain?

   ____
   ____
   ____

Conclusion

1. In your own words, describe the impact of using a bridge to perform a resistance measurement. What are the differences between bridge types and their uses?

   ____
   ____
   ____

2. In general, how did the strain gauge compare in performance to the temperature sensors in the previous lab? (consider signal-to-noise ratio and response time of the sensors). How would this affect how the sensors are implemented in real-world systems?

   ____
   ____
   ____

3. Discuss factors that would influence your strain measurement, and how to overcome them.

   ____
   ____
   ____

Discussions and Conclusions of the whole experiment

(Discuss your observations/findings, different sensor characteristics, influencing factors, possible solutions etc.; conclude the measurement system; summarize what you have learned from this lab)

____
____