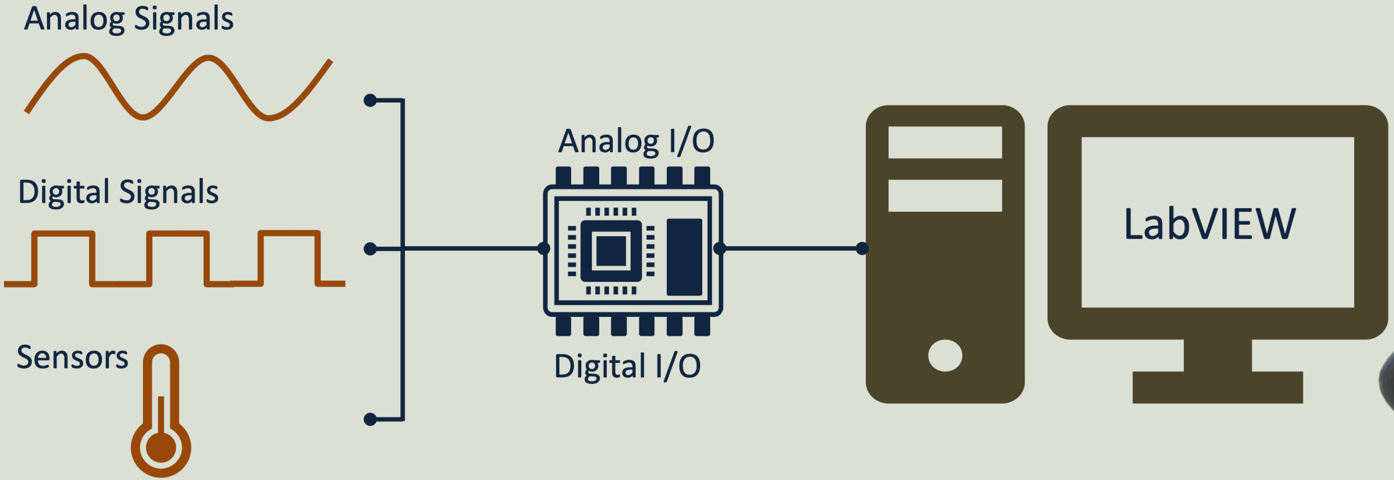
https://www.halvorsen.blog

DAQ and I/O Modules in LabVIEW



Hans-Petter Halvorsen

Contents

- Introduction to DAQ and I/O Modules
- Getting Started with USB-600x
- Practical LabVIEW Examples
  - Analog Out
  - Analog In
  - Digital I/O
    - Digital Out
    - Digital in

Introduction to DAQ and I/O Modules

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Hans-Petter Halvorsen

NI DAQ Hardware Examples

TC-01 Thermocouple

myDAQ

NI-DAQmx
Hardware Driver

USB-6001

USB-6008

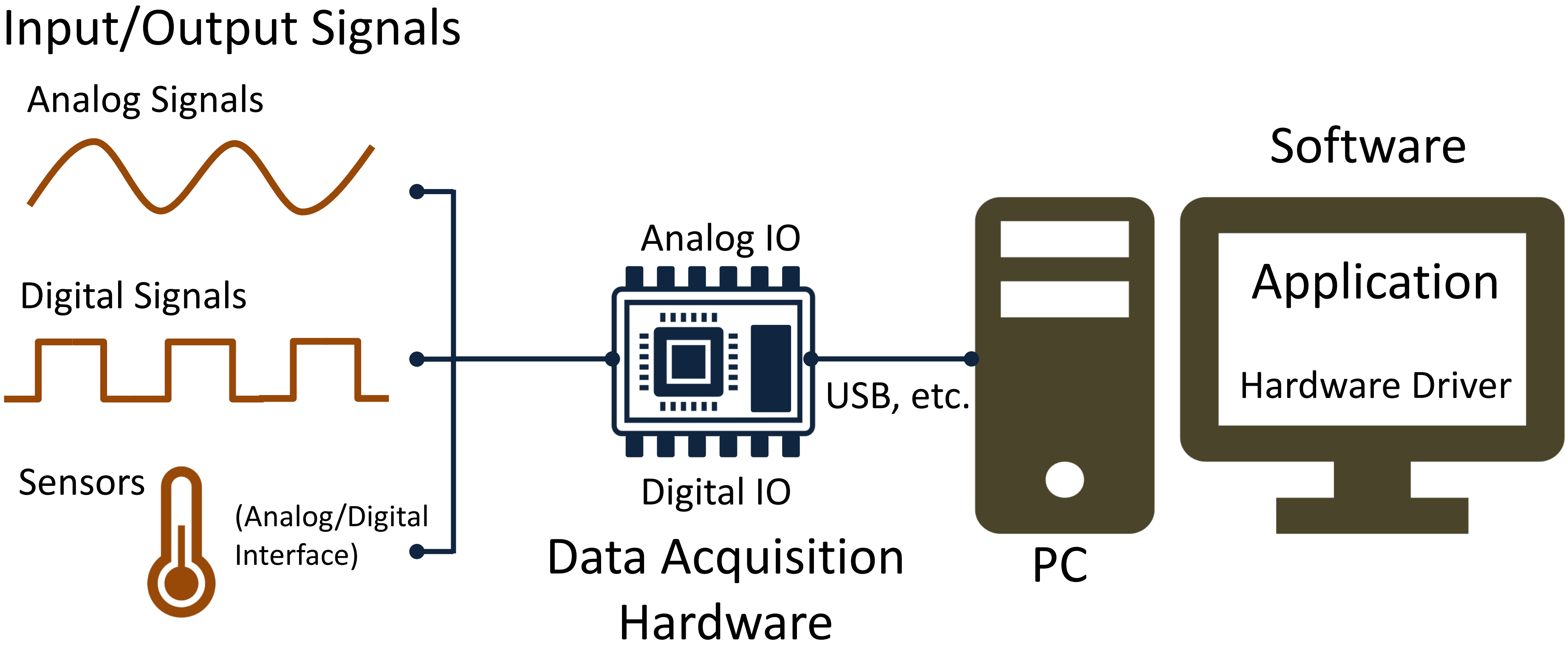
cDAQ

DAQ System

A DAQ System consists of 4 parts:

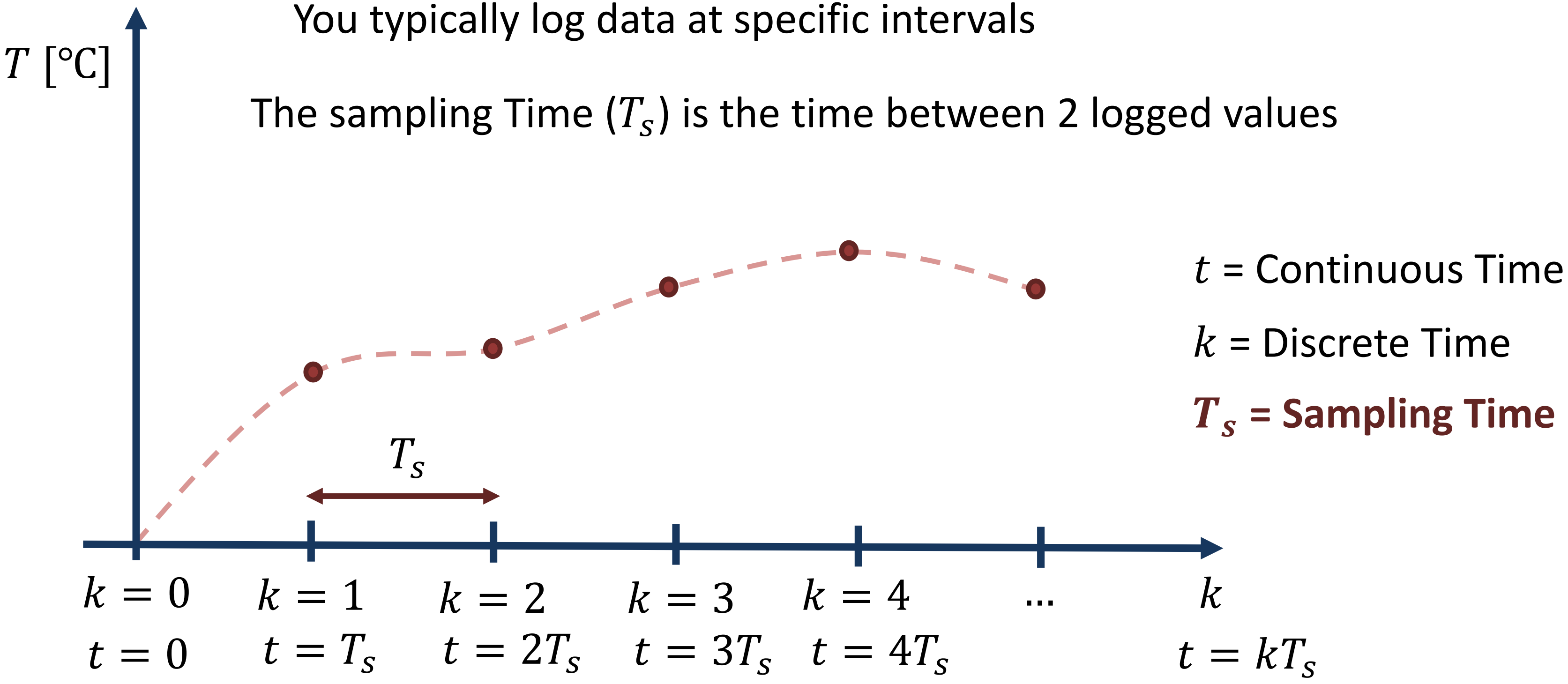
- Physical input/output signals, **sensors** – e.g., a Temperature Sensor or similar
- **DAQ device/hardware** – In this case the USB-600x device
- **Driver** software – In this case the DAQmx software
- Your software **Application** (Application Software) - in this case your LabVIEW application

DAQ System


Input/Output Signals
Analog Signals
Digital Signals
Sensors
(Analog/Digital
Interface)
Analog IO
Digital IO
Data Acquisition
Hardware
USB, etc.
PC
Software
Application
Hardware Driver

Digital Signals

A computer can only deal with discrete signals



You typically log data at specific intervals

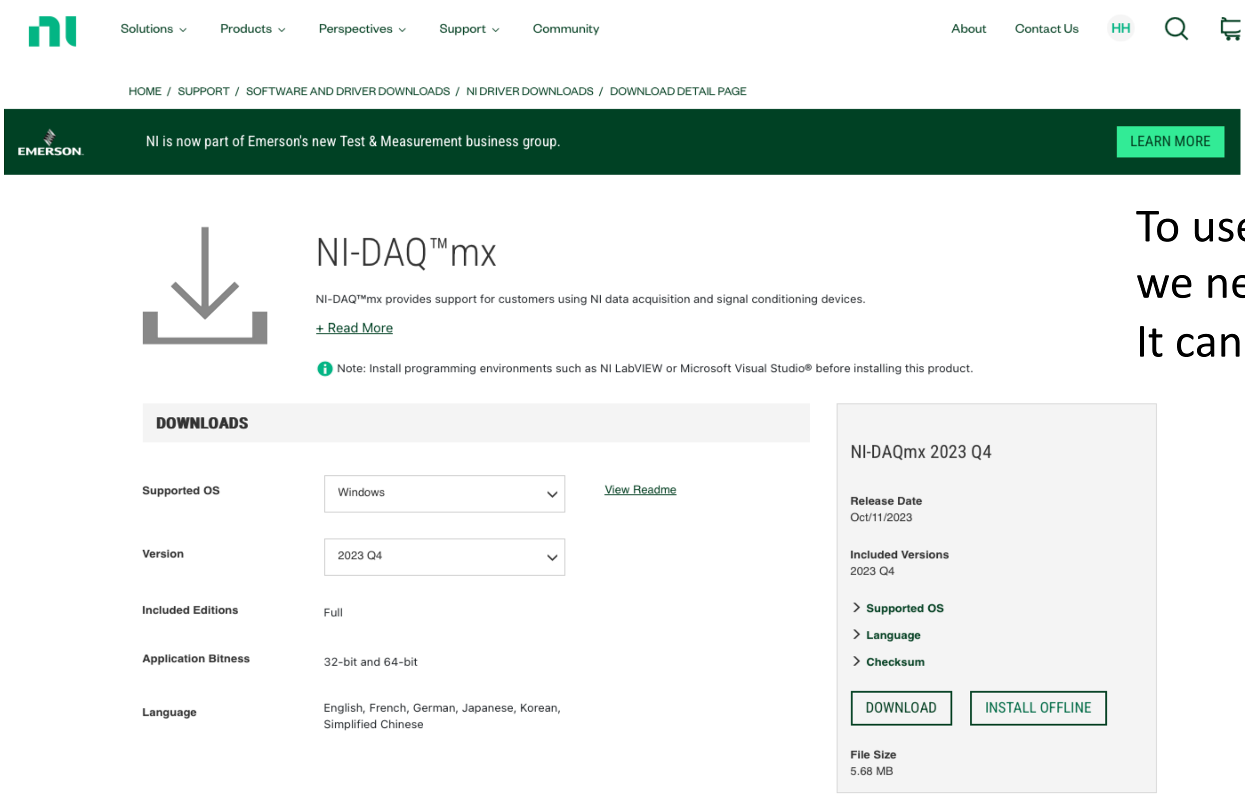
The sampling Time (T_s) is the time between 2 logged values

t = Continuous Time

k = Discrete Time

T_s = Sampling Time

DAQmx



NI is now part of Emerson's new Test & Measurement business group.

NI-DAQ™mx

NI-DAQ™mx provides support for customers using NI data acquisition and signal conditioning devices.

Note: Install programming environments such as NI LabVIEW or Microsoft Visual Studio® before installing this product.

DOWNLOADS

Supported OS	Windows
Version	2023 Q4
Included Editions	Full
Application Bitness	32-bit and 64-bit
Language	English, French, German, Japanese, Korean, Simplified Chinese

NI-DAQmx 2023 Q4

Release Date
Oct/11/2023

Included Versions
2023 Q4

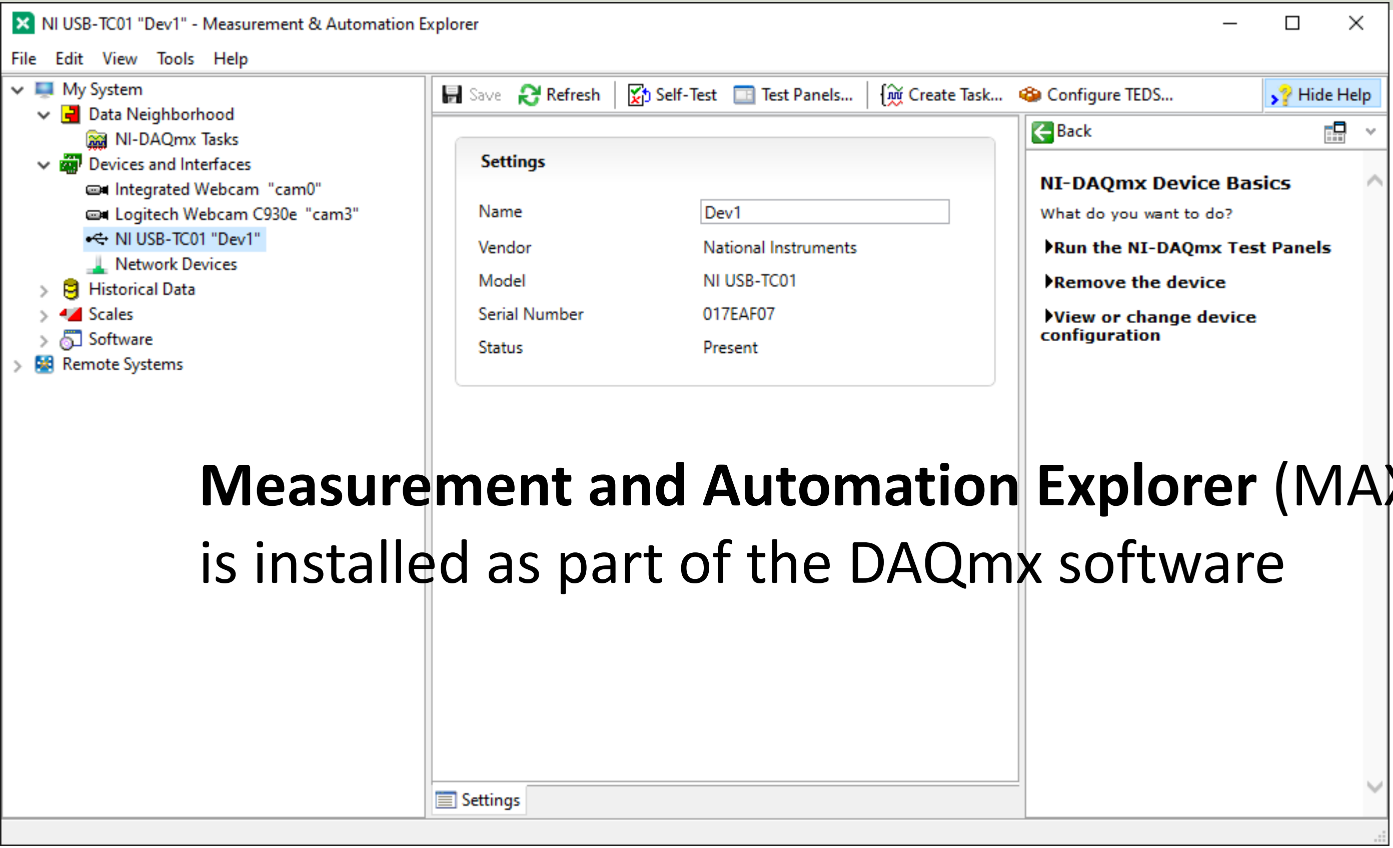
> Supported OS
> Language
> Checksum

File Size
5.68 MB

To use DAQ hardware in **LabVIEW** we need to use the **DAQmx** driver. It can be downloaded for free.

https://www.ni.com/en/support/downloads/drivers/download.ni-daq-mx.html

MAX



Settings

Name	Dev1
Vendor	National Instruments
Model	NI USB-TC01
Serial Number	017EAF07
Status	Present

NI-DAQmx Device Basics

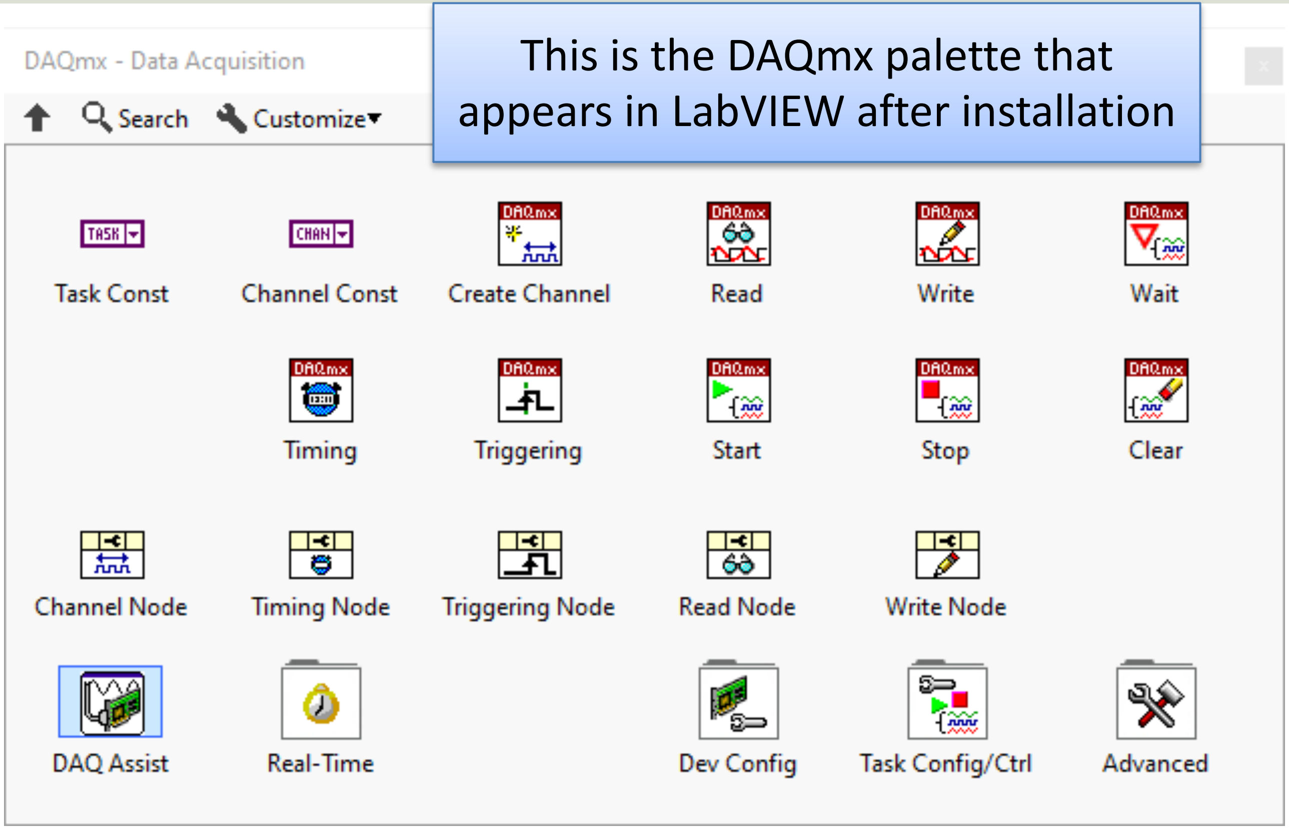
What do you want to do?

- **Run the NI-DAQmx Test Panels**
- **Remove the device**
- **View or change device configuration**

You can use MAX to test and configure your DAQ device

Measurement and Automation Explorer (MAX) is installed as part of the DAQmx software

DAQmx in LabVIEW



This is the DAQmx palette that appears in LabVIEW after installation

To use DAQ hardware in **LabVIEW** we need to use the **DAQmx** driver.

It can be downloaded for free.

https://www.ni.com/en-no/support/downloads/drivers/download.ni-daq-mx.html

Getting Started with USB-600x

Hans-Petter Halvorsen

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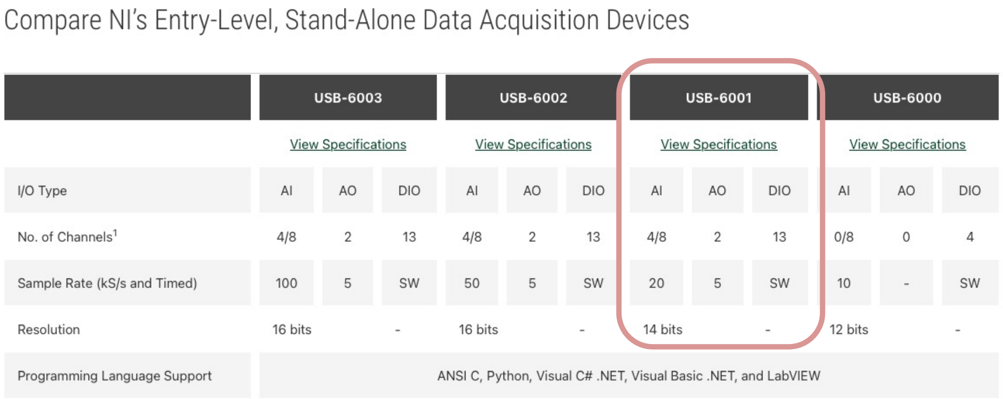
USB-600x DAQ series

Entry-Level, Plug-and-Play USB Data Acquisition

You depend on accurate measurements to make key decisions and discoveries, and NI's plug-and-play, USB multifunction I/O devices deliver quality measurements at an entry-level price.

USB-6008 has been replaced with newer versions like USB-6000, **USB-6001**, USB-6002 and USB-6003 which have similar functionality as USB-6008 and they all work in the same manner, and they all use the NI-DAQmx driver

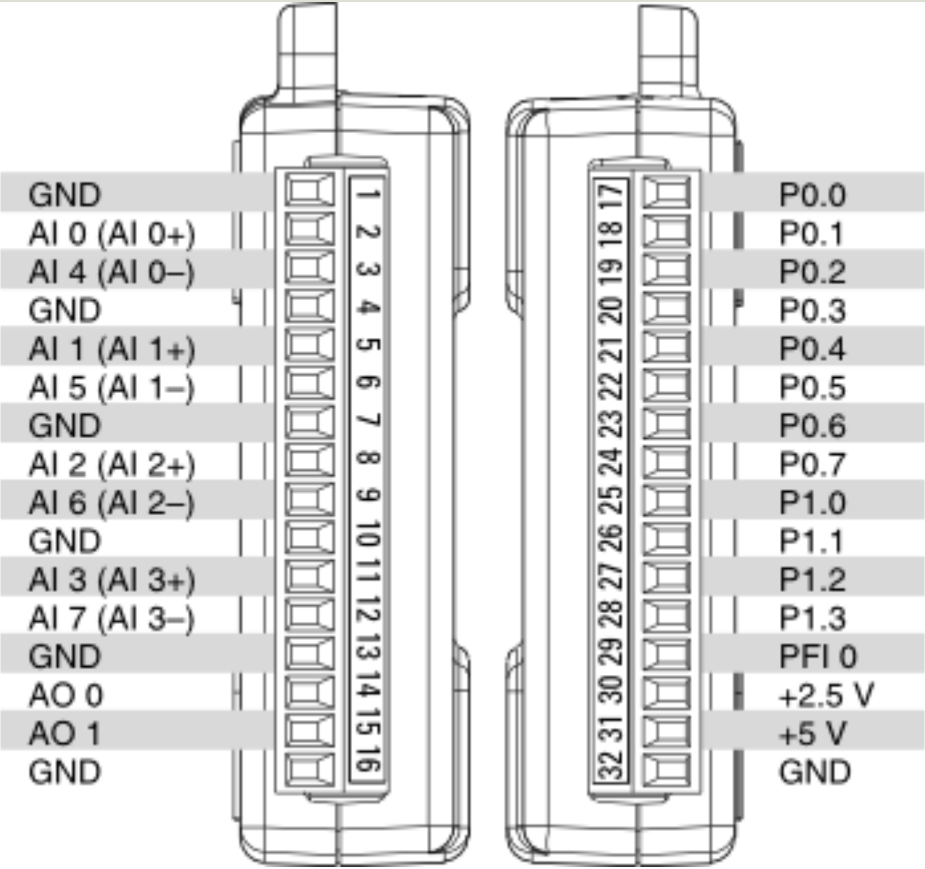


Compare NI's Entry-Level, Stand-Alone Data Acquisition Devices

	USB-6003			USB-6002			USB-6001			USB-6000		
	View Specifications			View Specifications			View Specifications			View Specifications		
I/O Type	AI	AO	DIO	AI	AO	DIO	AI	AO	DIO	AI	AO	DIO
No. of Channels[1]	4/8	2	13	4/8	2	13	4/8	2	13	0/8	0	4
Sample Rate (kS/s and Timed)	100	5	SW	50	5	SW	20	5	SW	10	-	SW
Resolution	16 bits		-	16 bits		-	14 bits		-	12 bits		-
Programming Language Support	ANSI C, Python, Visual C# .NET, Visual Basic .NET, and LabVIEW											

https://www.ni.com/en-no/shop/data-acquisition/entry-level-usb-daq.html

USB-600x Pinout



GND	1	17	P0.0
AI 0 (AI 0+)	2	18	P0.1
AI 4 (AI 0–)	3	19	P0.2
GND	4	20	P0.3
AI 1 (AI 1+)	5	21	P0.4
AI 5 (AI 1–)	6	22	P0.5
GND	7	23	P0.6
AI 2 (AI 2+)	8	24	P0.7
AI 6 (AI 2–)	9	25	P1.0
GND	10	26	P1.1
AI 3 (AI 3+)	11	27	P1.2
AI 7 (AI 3–)	12	28	P1.3
GND	13	29	PFI 0
AO 0	14	30	+2.5 V
AO 1	15	31	+5 V
GND	16	32	GND

DAQ and I/O Modules in LabVIEW

Practical LabVIEW Examples

Hans-Petter Halvorsen

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I/O Channels

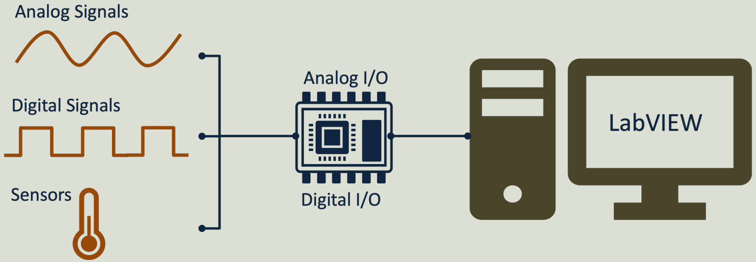
When using a DAQ or I/O Module device we have 4 options:

- **Analog Out** (Write) - AO
- **Analog In** (Read) - AI
- **Digital Out** (Write) - DO
- **Digital In** (Read) - DI

We will show some basic examples in each of these categories

DAQ and I/O Modules in LabVIEW

Analog Out



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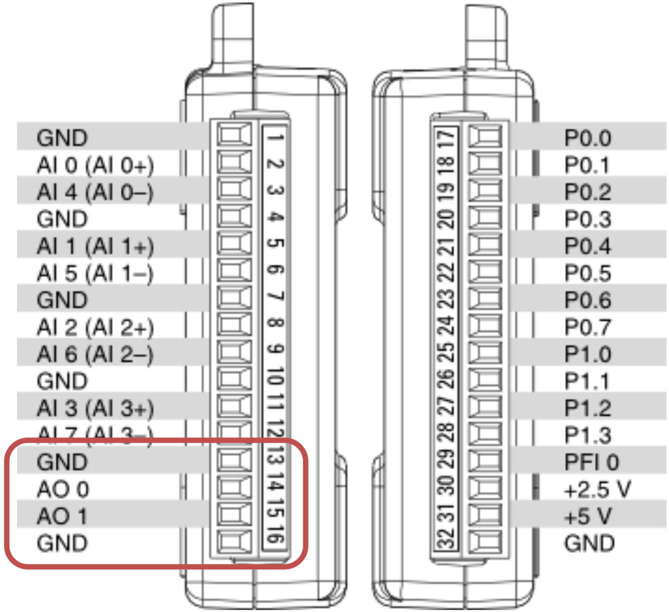
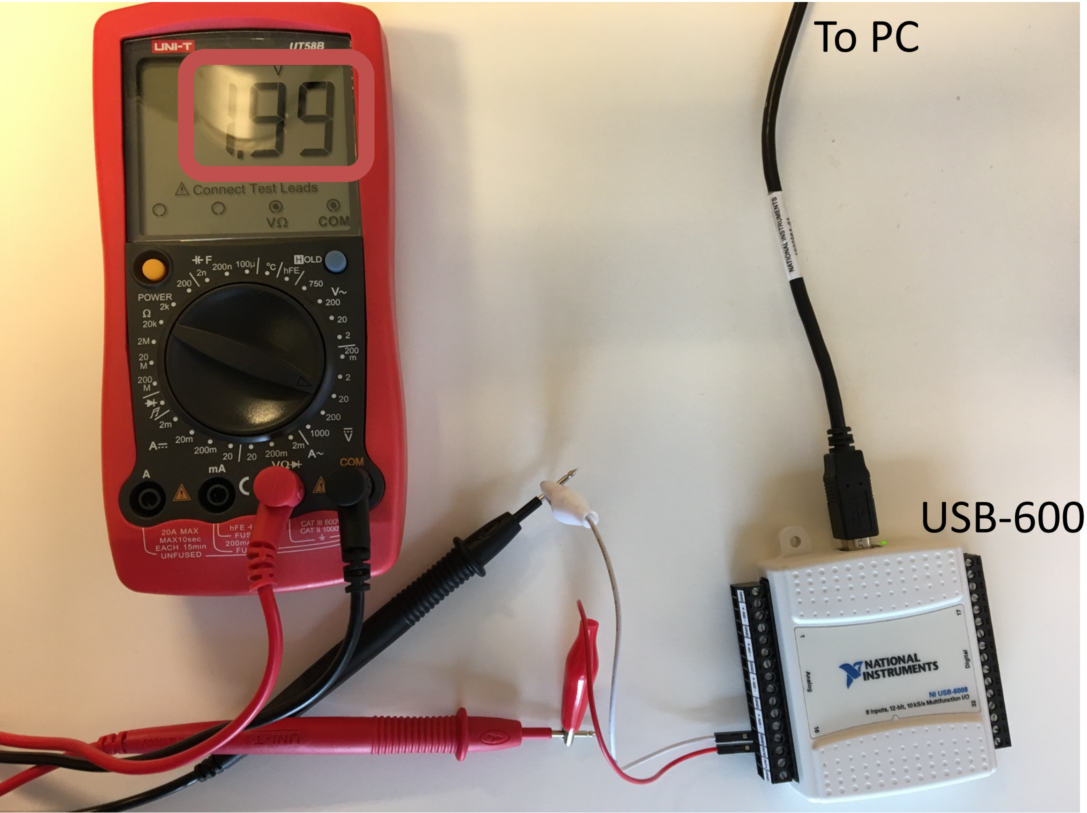
Analog Out (Write)

- Note! The USB-600x can only output a voltage signal between 0 and 5V
- The USB-600x has 2 Analog Out Channels:
  - **AO0**
  - **AO1**



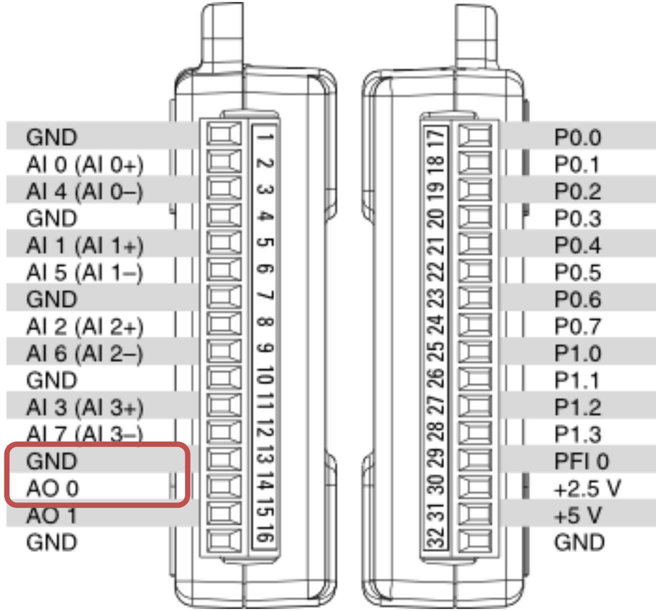
Hardware Setup and Testing

Multimeter



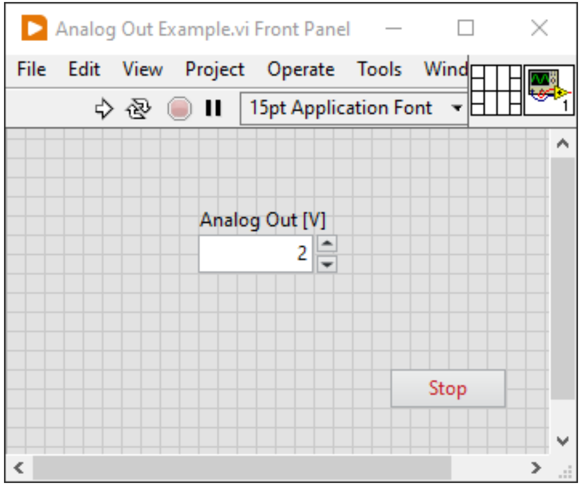
To PC

USB-6008

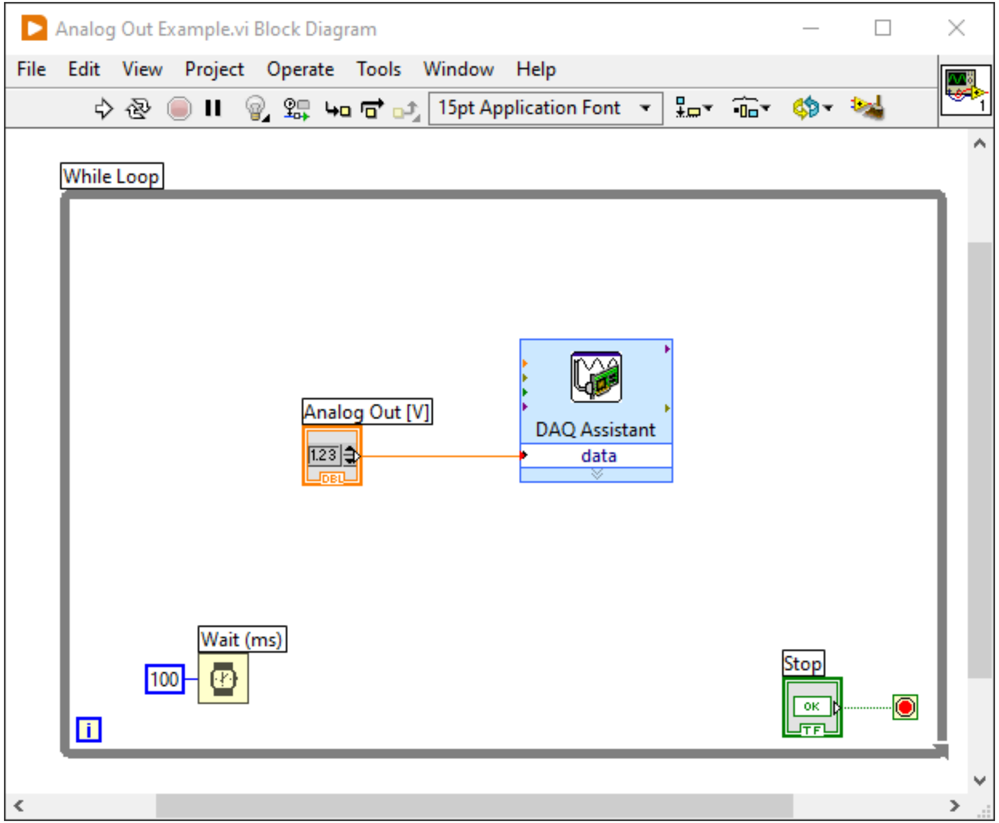


AO0

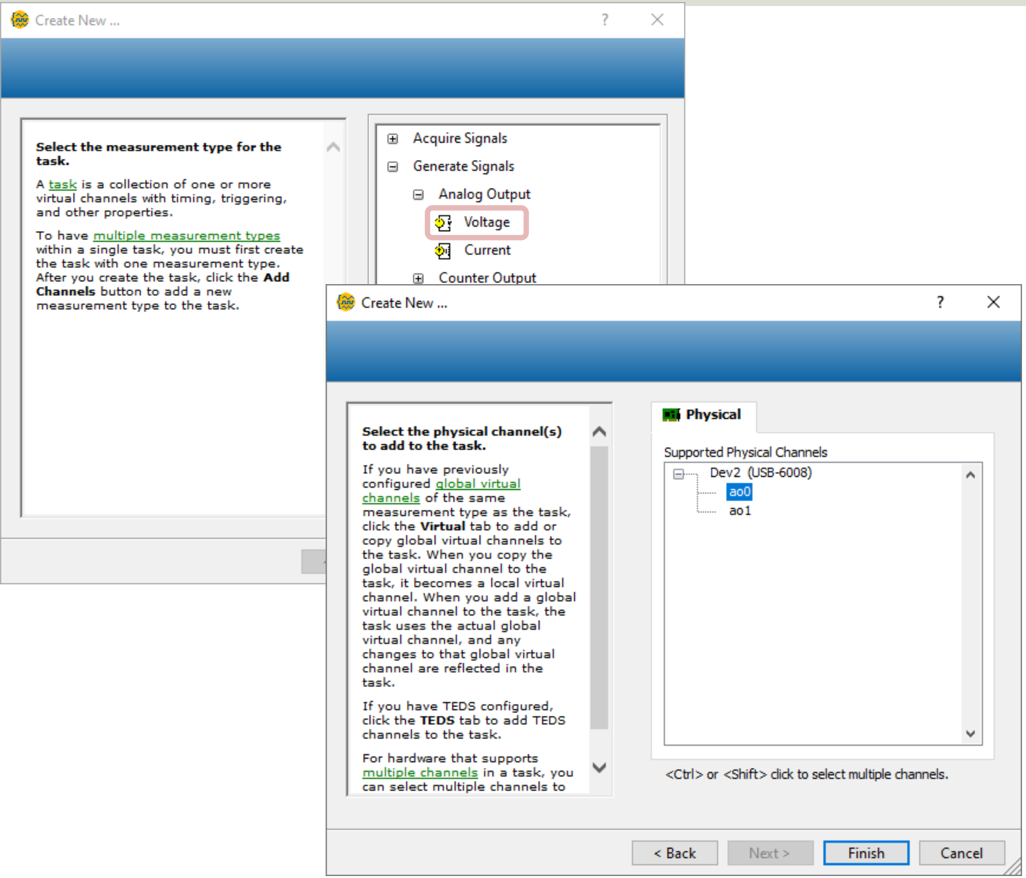
Analog Out Example



Analog Out Example.vi Front Panel
File Edit View Project Operate Tools Wind
15pt Application Font
Analog Out [V]
2
Stop



Analog Out Example



Create New ...

Select the measurement type for the task.

A task is a collection of one or more virtual channels with timing, triggering, and other properties.

To have multiple measurement types within a single task, you must first create the task with one measurement type. After you create the task, click the **Add Channels** button to add a new measurement type to the task.

Create New ...

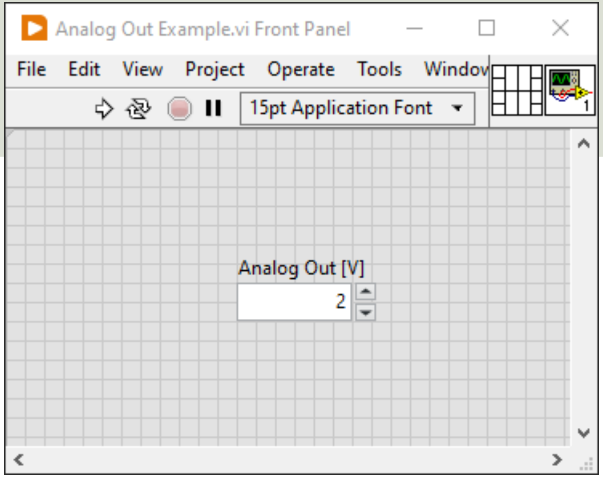
Select the physical channel(s) to add to the task.

If you have previously configured global virtual channels of the same measurement type as the task, click the **Virtual** tab to add or copy global virtual channels to the task. When you copy the global virtual channel to the task, it becomes a local virtual channel. When you add a global virtual channel to the task, the task uses the actual global virtual channel, and any changes to that global virtual channel are reflected in the task.

If you have TEDS configured, click the **TEDS** tab to add TEDS channels to the task.

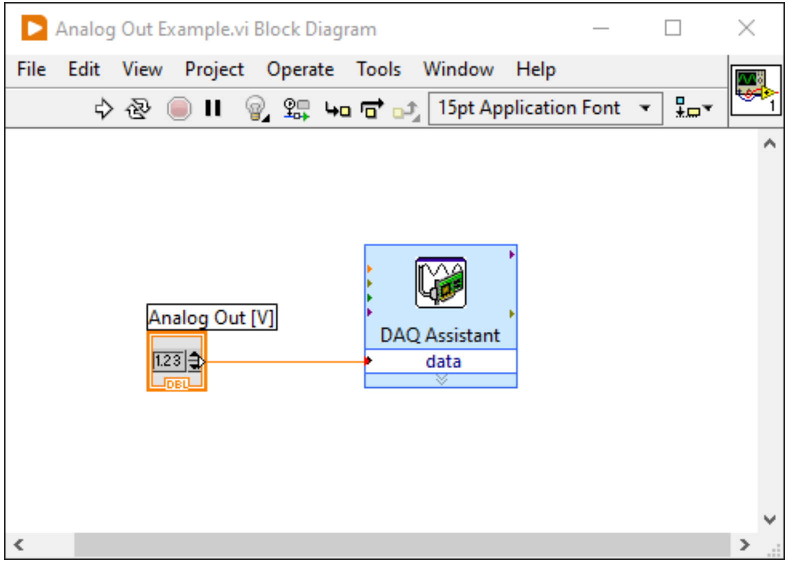
For hardware that supports multiple channels in a task, you can select multiple channels to

<Ctrl> or <Shift> click to select multiple channels.



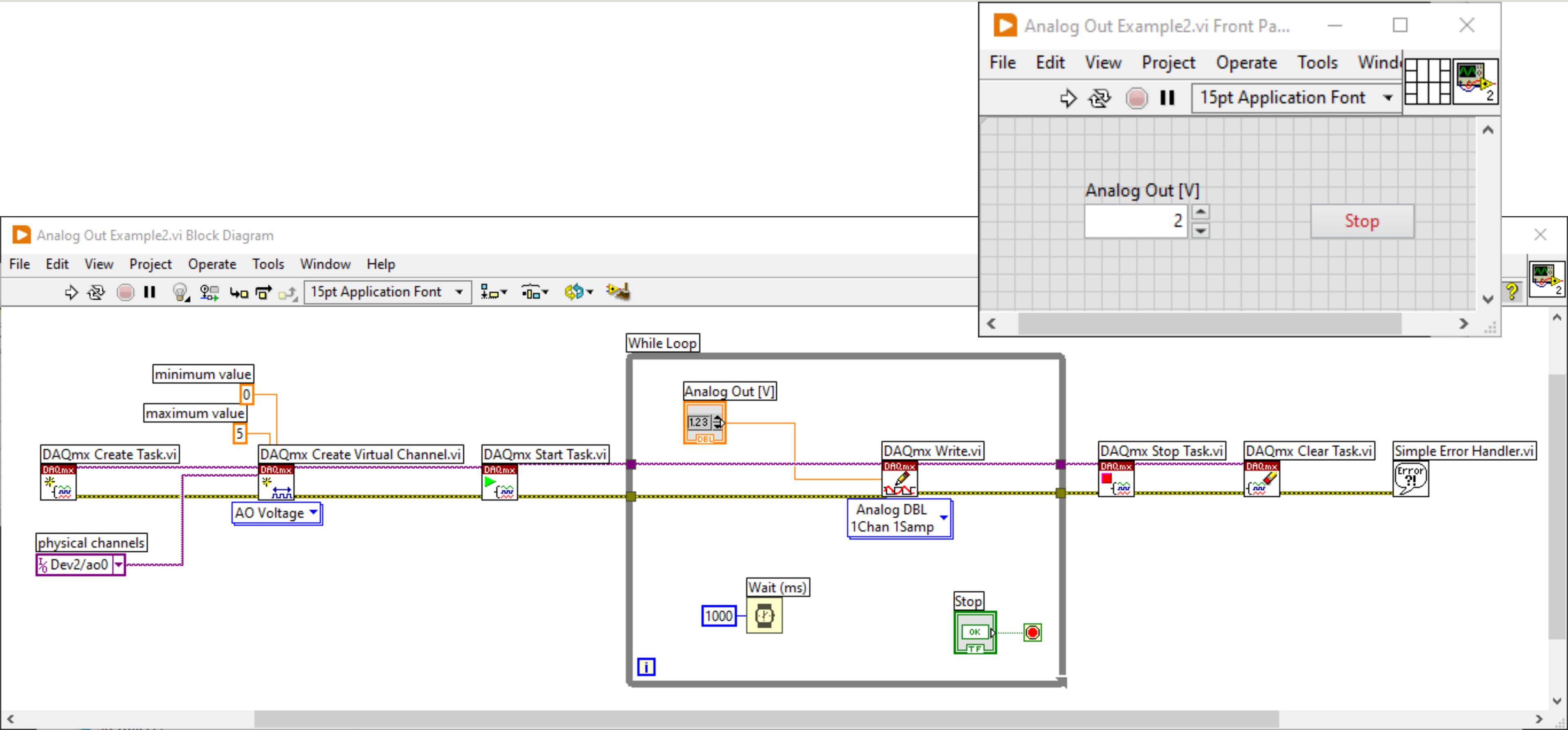
Analog Out Example.vi Front Panel

Analog Out [V]: 2



Analog Out Example.vi Block Diagram

Using “Low-level” DAQmx VIs



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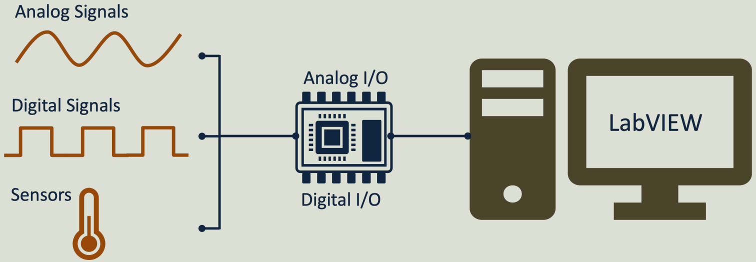
DAQ and I/O Modules in LabVIEW

Analog In



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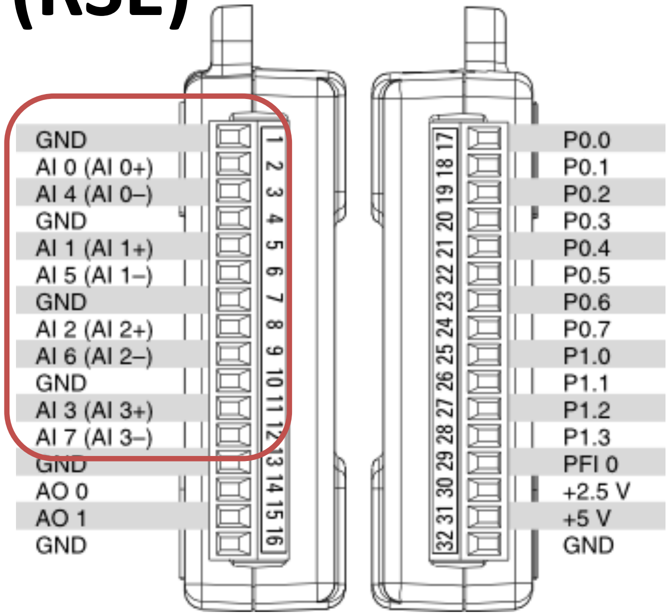
Analog In (Read)

USB-600x has

- 8 AI **Referenced Single Ended (RSE)** Analog Inputs Channels
- or 4 AI **Differential** Analog Inputs Channels

Default

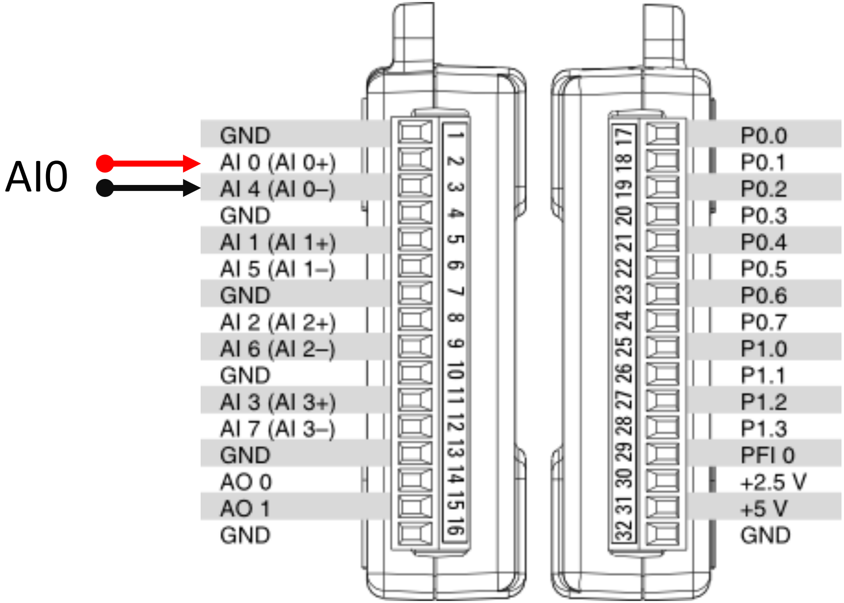


The Voltage Range is $-10V - 20V$

$0V - 5V$ is default

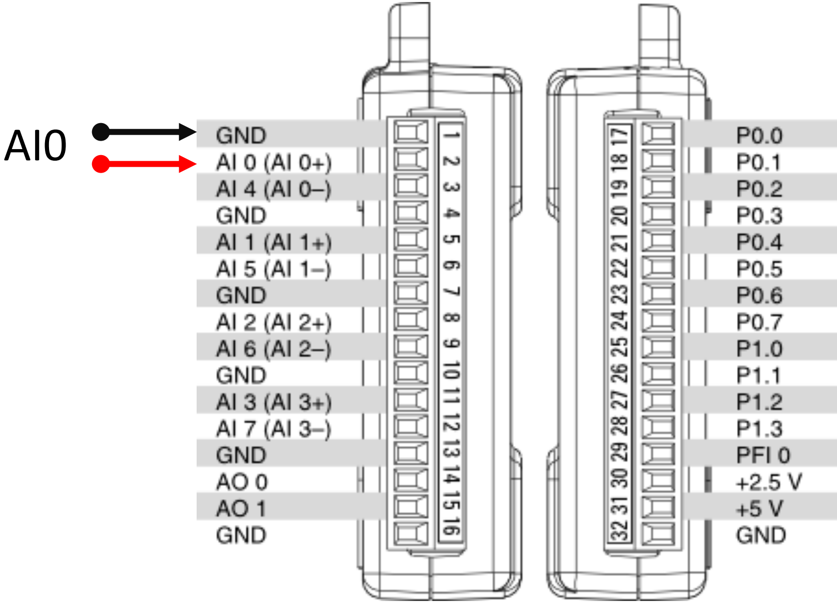
Differential vs RSE

AI Differential Analog - 4 channels

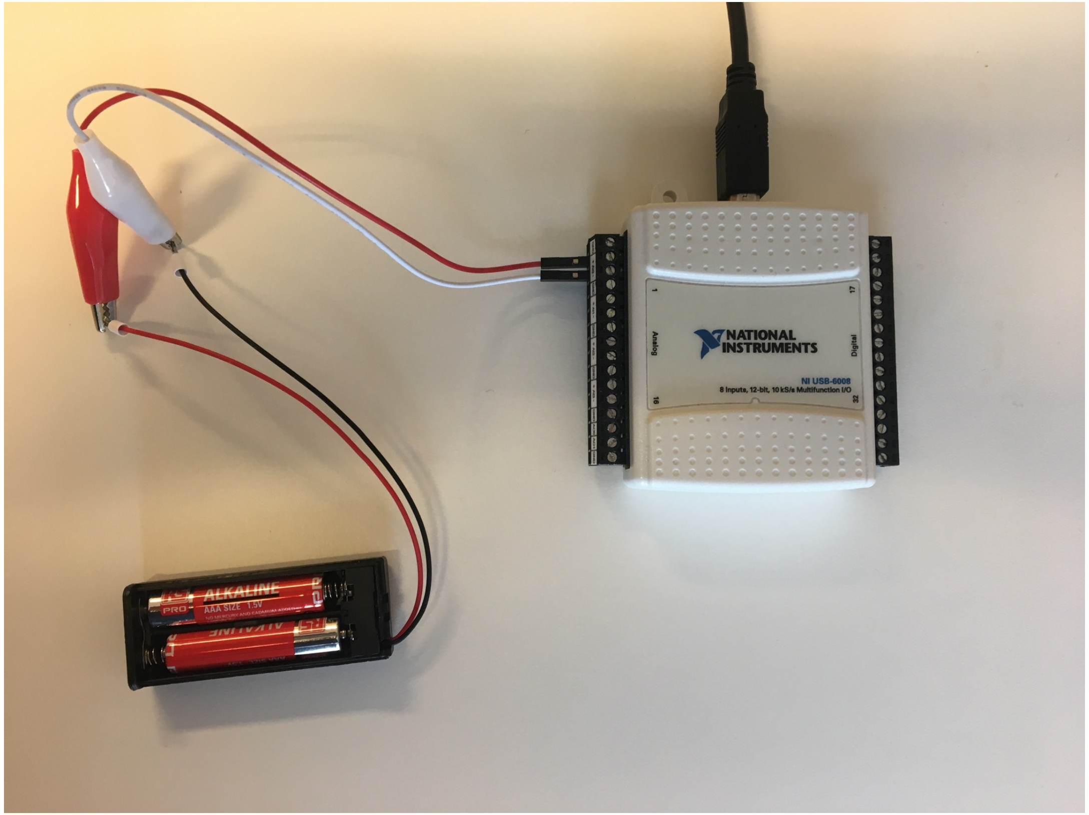


AI Referenced Single Ended (RSE) - 8 channels

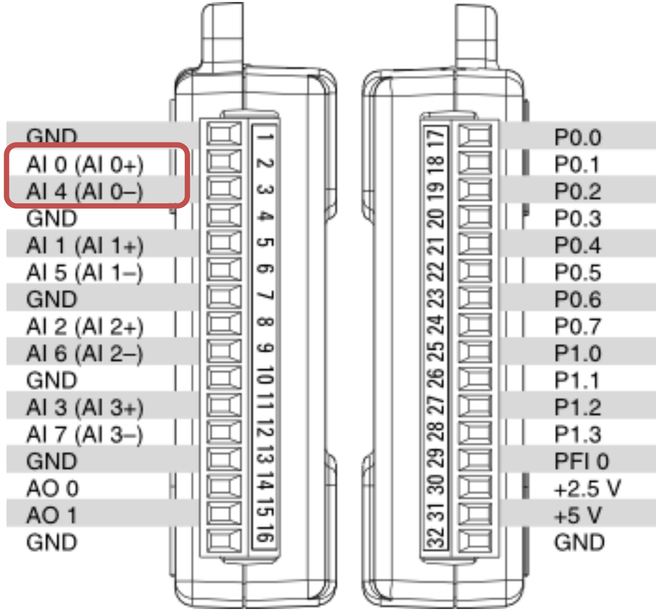
The Analog Channels have common ground



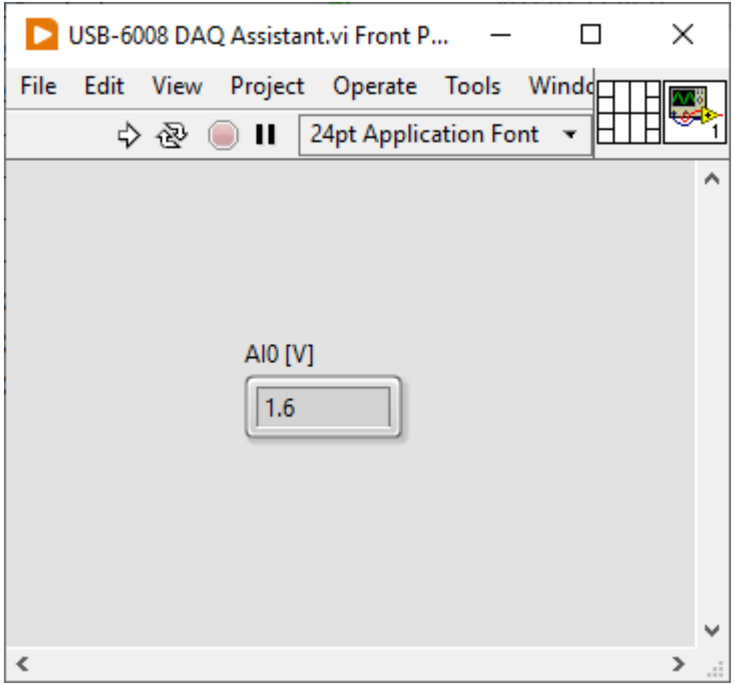
Hardware Setup and Testing



AI0

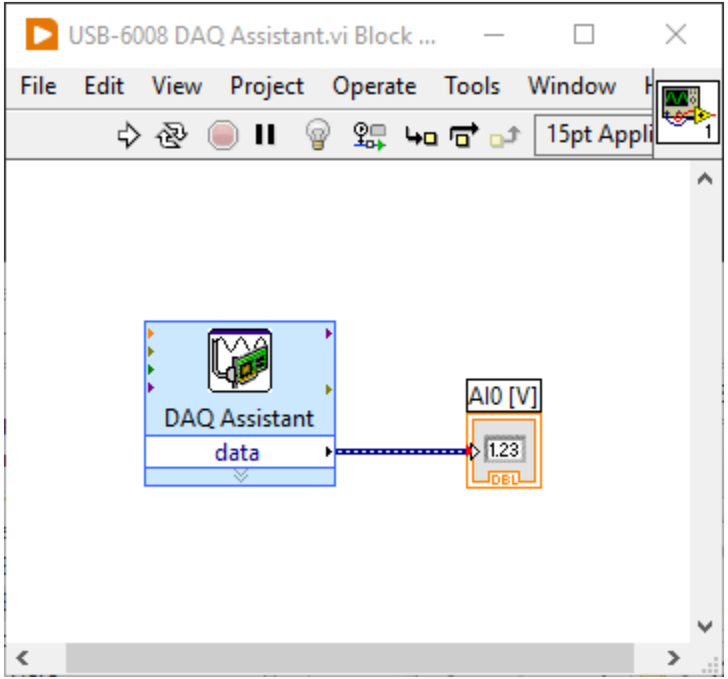


Analog In - DAQ Assistant



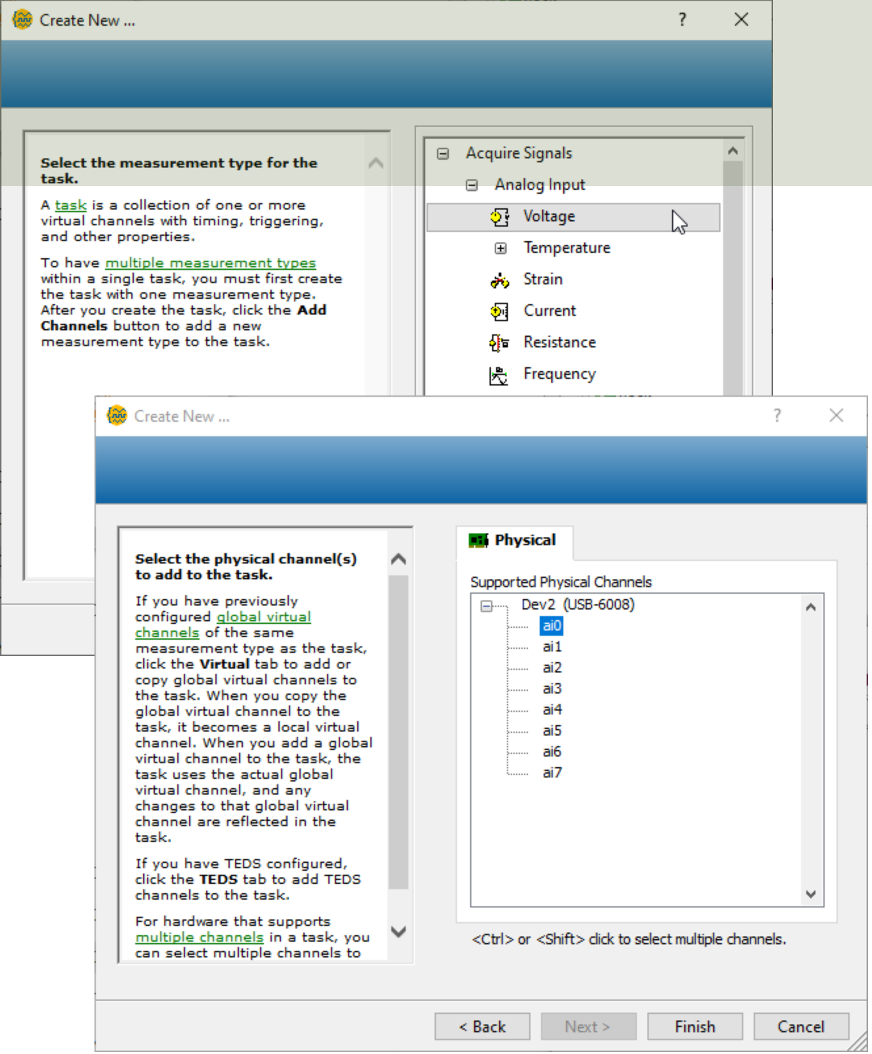
AI0 [V]

1.6



Here, a 1.5V Battery is connected to Analog Input Channel 0 (AI0)

DAQ Assistant



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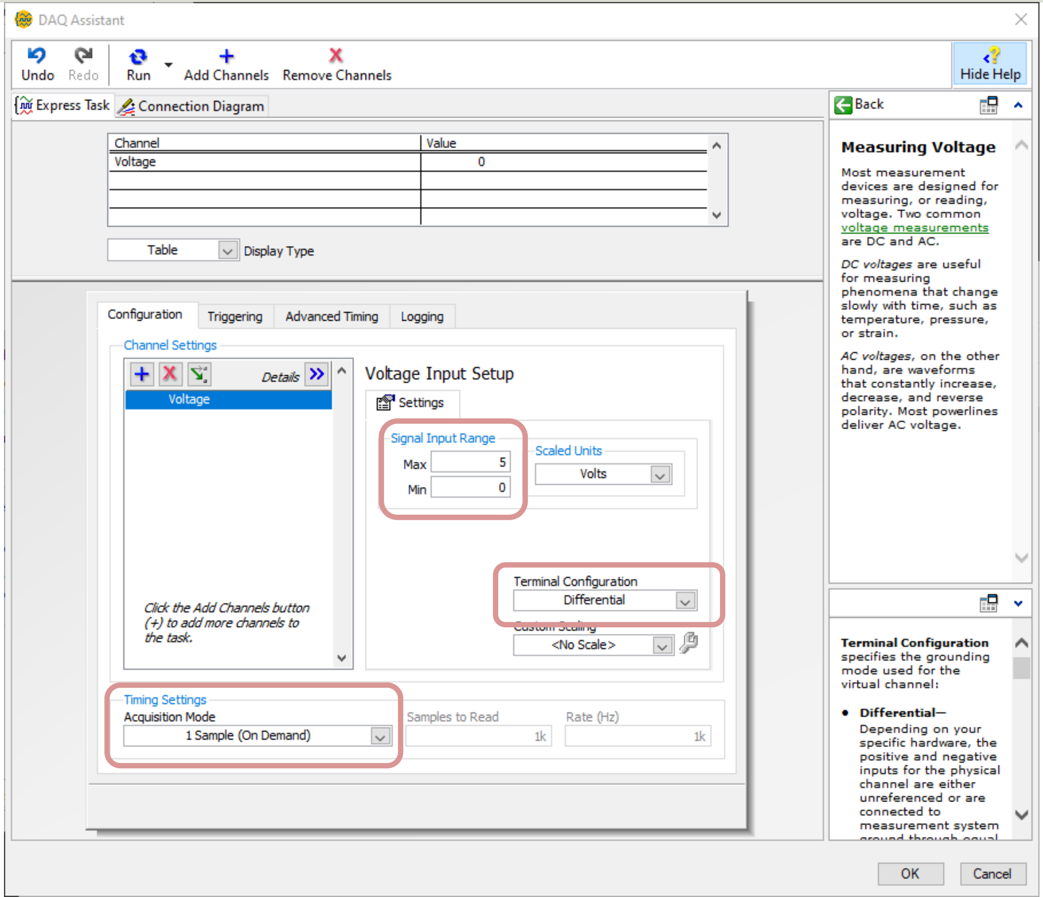
If you have TEDS configured, click the **TEDS** tab to add TEDS channels to the task.

For hardware that supports multiple channels in a task, you can select multiple channels to

Supported Physical Channels

- Dev2 (USB-6008)
  - ai0
  - ai1
  - ai2
  - ai3
  - ai4
  - ai5
  - ai6
  - ai7

<Ctrl> or <Shift> click to select multiple channels.



Channel	Value
Voltage	0

Display Type: Table

Voltage

Click the Add Channels button (+) to add more channels to the task.

Voltage Input Setup

Signal Input Range
Max 5
Min 0

Scaled Units: Volts

Terminal Configuration: Differential

Custom Scaling: <No Scale>

Timing Settings
Acquisition Mode: 1 Sample (On Demand)
Samples to Read: 1k
Rate (Hz): 1k

Measuring Voltage

Most measurement devices are designed for measuring, or reading, voltage. Two common voltage measurements are DC and AC.

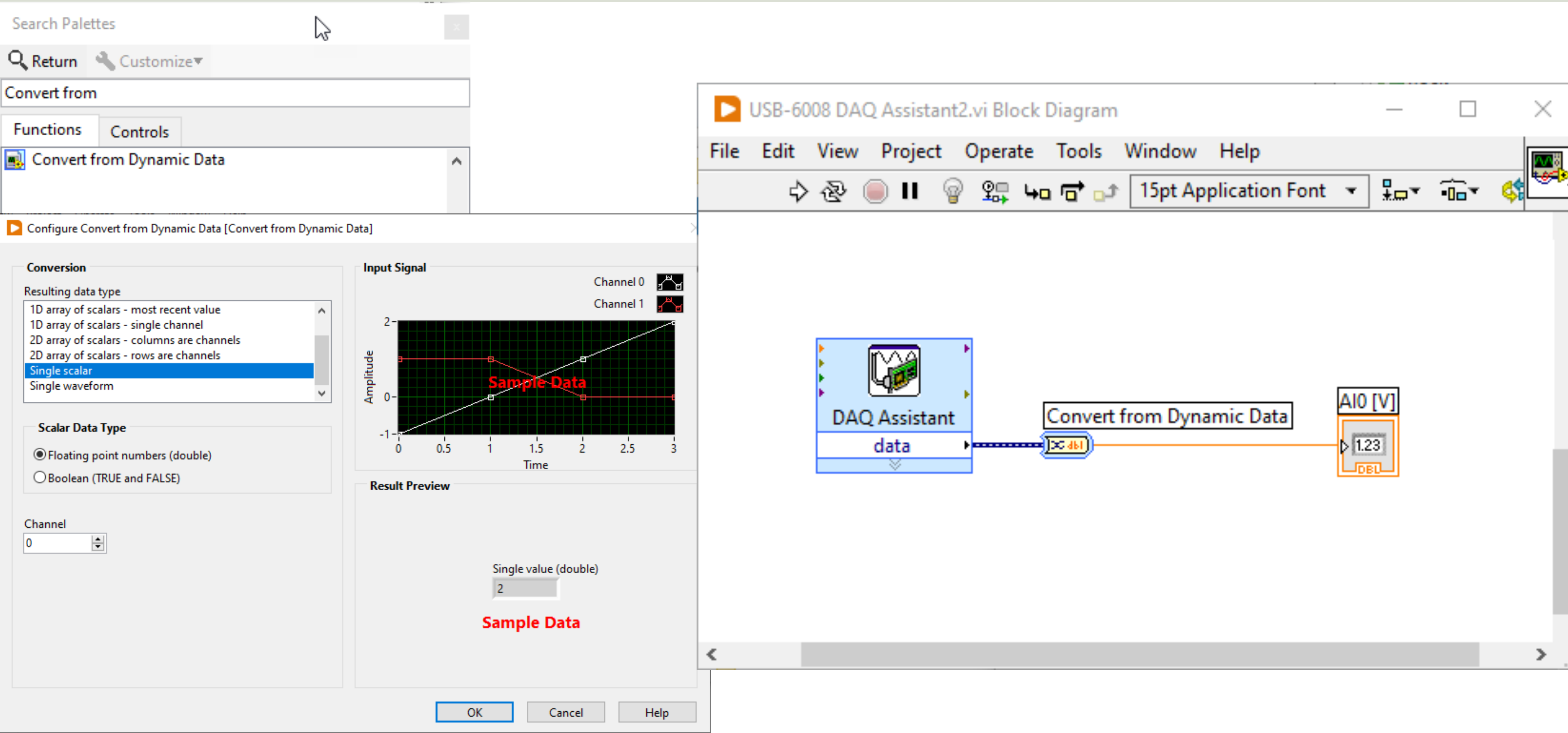
DC voltages are useful for measuring phenomena that change slowly with time, such as temperature, pressure, or strain.

AC voltages, on the other hand, are waveforms that constantly increase, decrease, and reverse polarity. Most powerlines deliver AC voltage.

Terminal Configuration specifies the grounding mode used for the virtual channel:

- **Differential**—Depending on your specific hardware, the positive and negative inputs for the physical channel are either unreferenced or are connected to measurement system ground through equal

Convert from Dynamic Data



Search Palettes

Convert from

Functions | Controls

Convert from Dynamic Data

Configure Convert from Dynamic Data [Convert from Dynamic Data]

Conversion

Resulting data type

- 1D array of scalars - most recent value
- 1D array of scalars - single channel
- 2D array of scalars - columns are channels
- 2D array of scalars - rows are channels
- Single scalar
- Single waveform

Scalar Data Type

● Floating point numbers (double)

○ Boolean (TRUE and FALSE)

Channel: 0

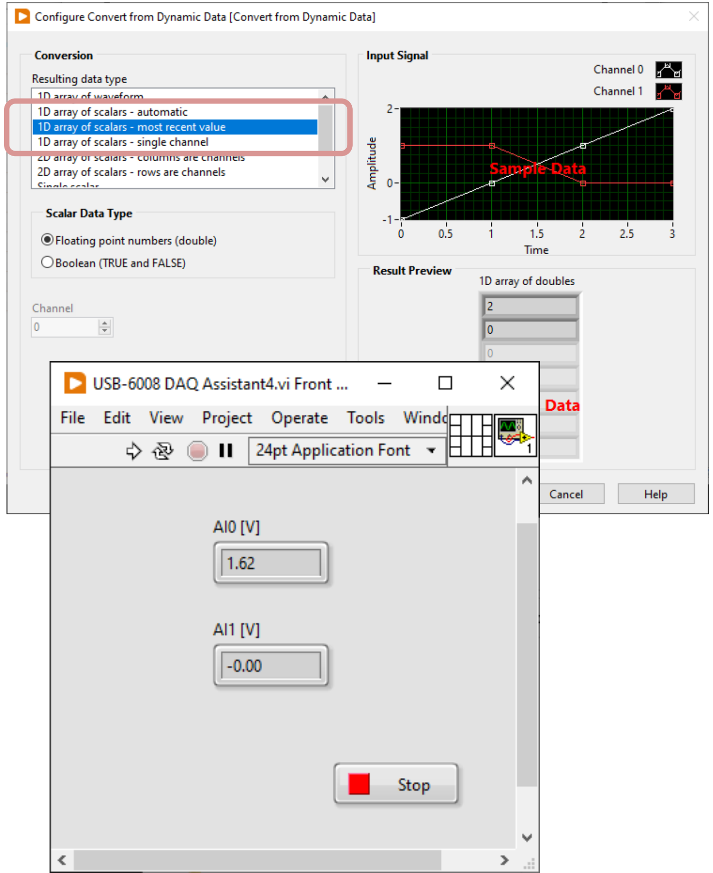
Result Preview

Single value (double): 2

Sample Data

USB-6008 DAQ Assistant2.vi Block Diagram

Reading Multiple Channels



Configure Convert from Dynamic Data [Convert from Dynamic Data]

Conversion

Resulting data type

- 1D array of waveform
- 1D array of scalars - automatic
- 1D array of scalars - most recent value
- 1D array of scalars - single channel
- 2D array of scalars - columns are channels
- 2D array of scalars - rows are channels
- Single scalar

Scalar Data Type

● Floating point numbers (double)

○ Boolean (TRUE and FALSE)

Channel: 0

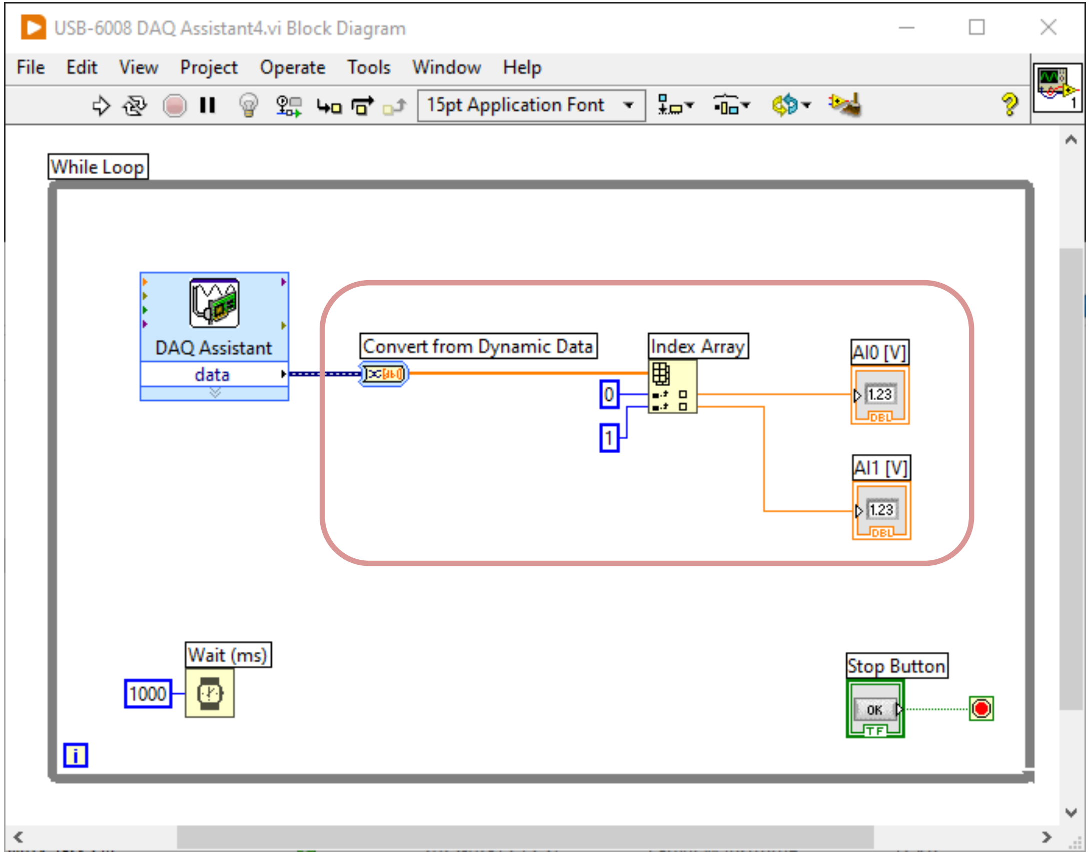
Result Preview

1D array of doubles: 2, 0, 0

USB-6008 DAQ Assistant4.vi Front ...

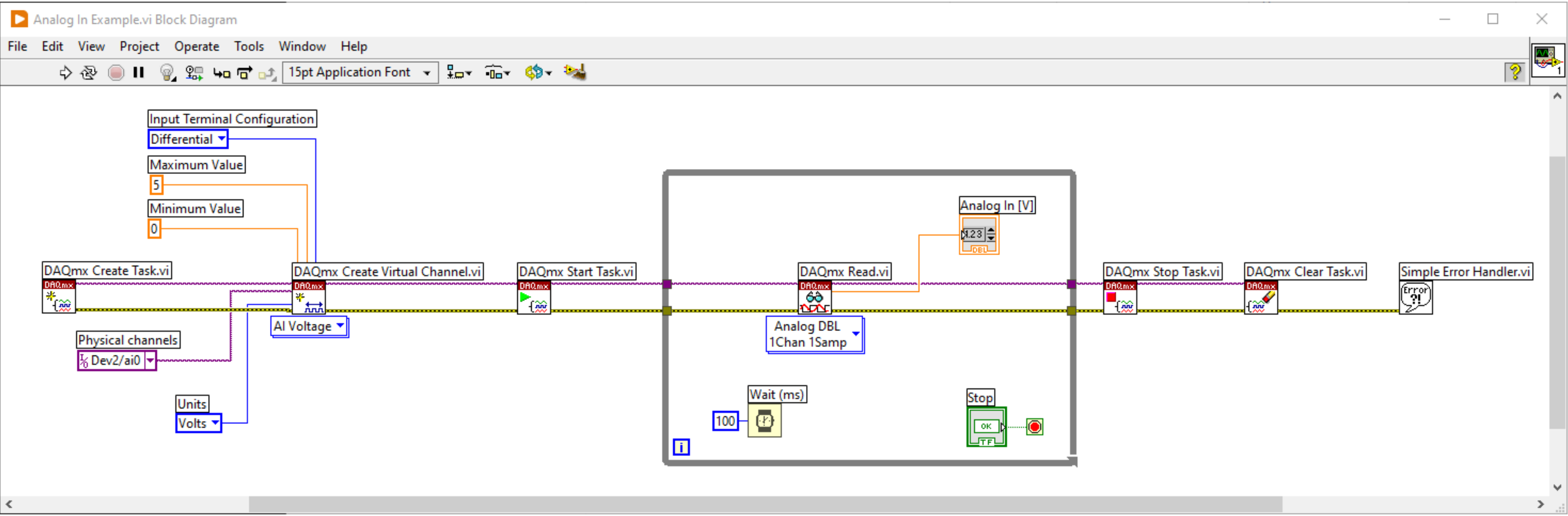
AI0 [V]: 1.62

AI1 [V]: -0.00



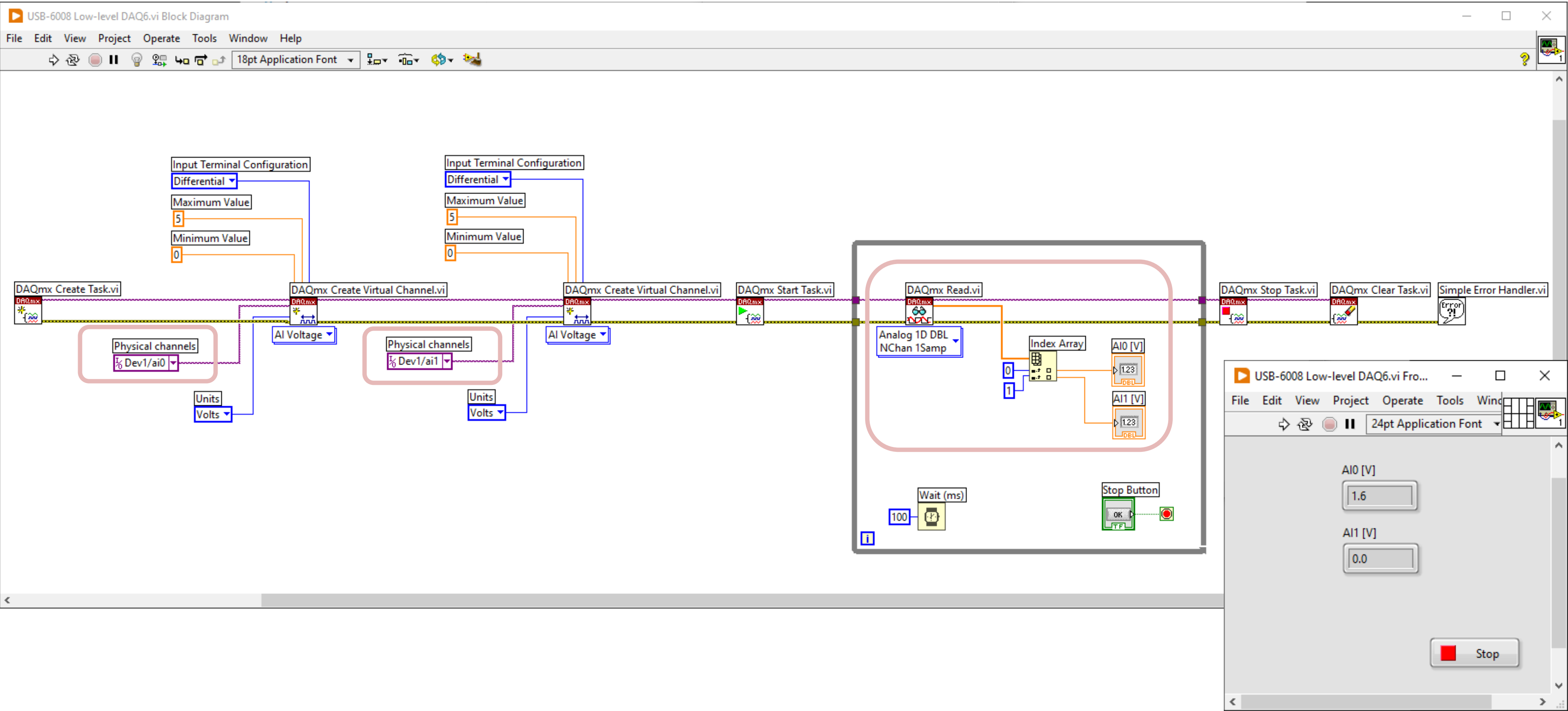
USB-6008 DAQ Assistant4.vi Block Diagram

Using "Low-level" DAQmx VIs

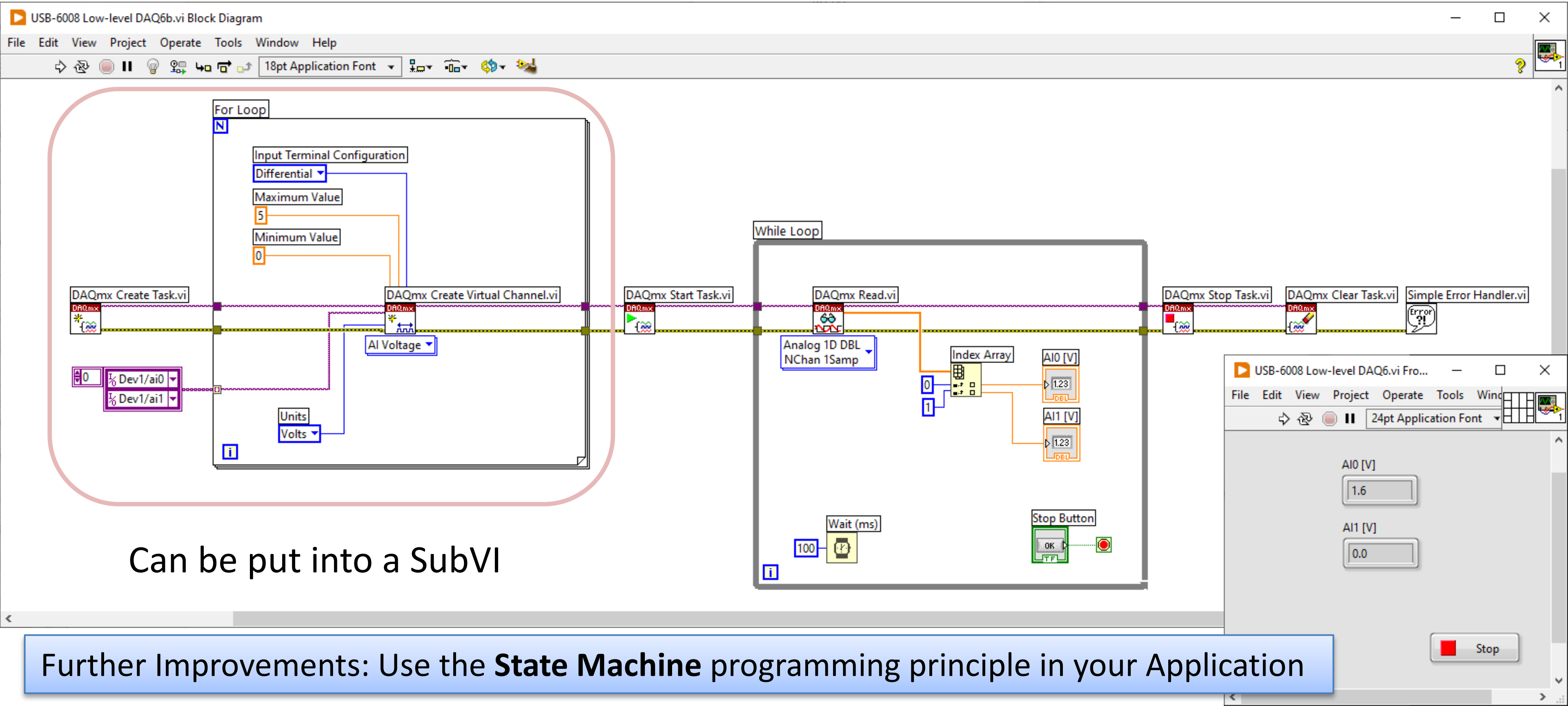


All Applications should have proper Error Handling

Reading Multiple Channels



Reading Multiple Channels – Alt B



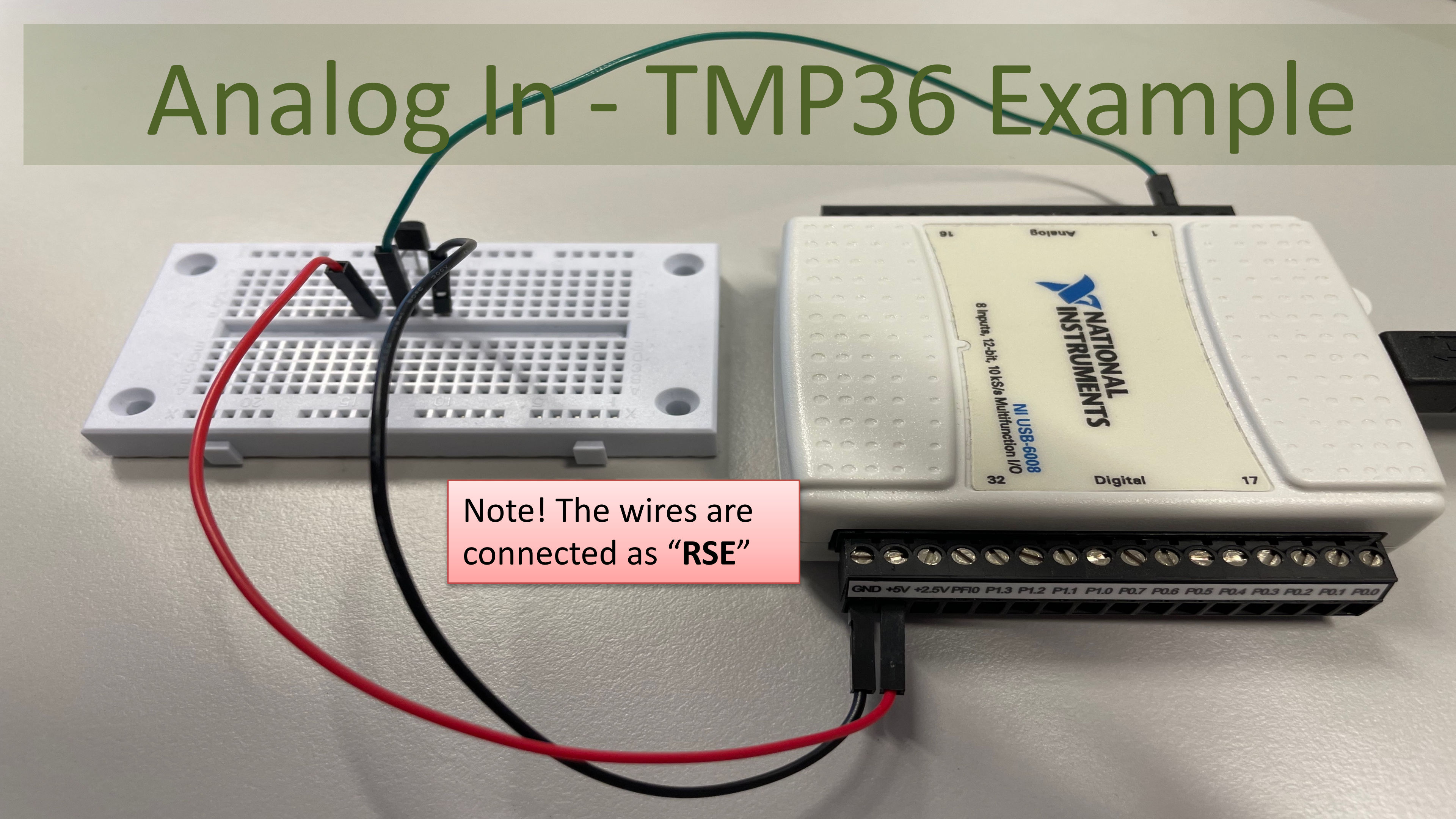
AI0 [V]: 1.6

AI1 [V]: 0.0

Can be put into a SubVI

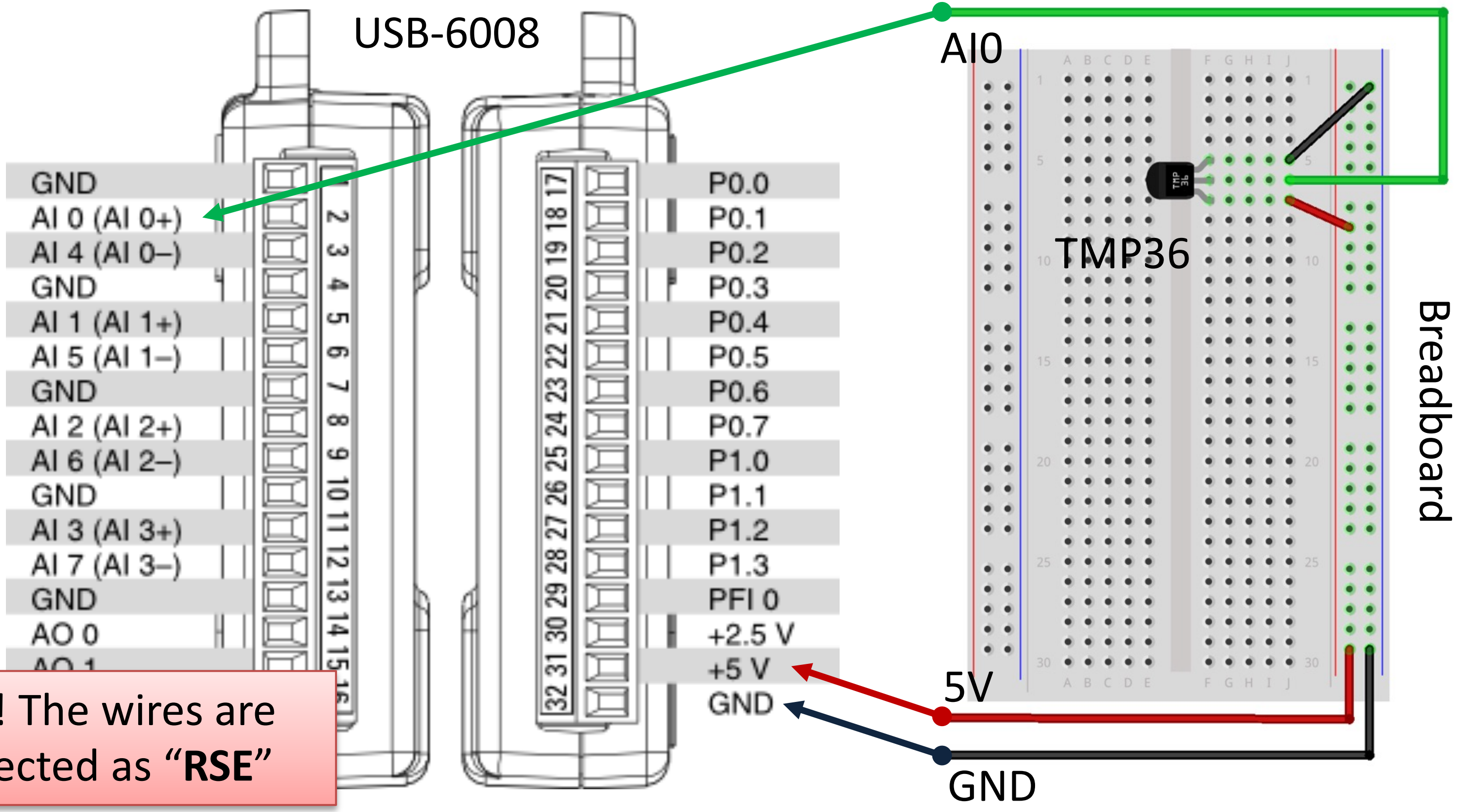
Further Improvements: Use the **State Machine** programming principle in your Application

Analog In - TMP36 Example


16
Analog
1
NATIONAL INSTRUMENTS
8 Inputs, 12-bit, 10 kS/s Multifunction I/O
NI USB-6008
32
Digital
17
GND +5V +2.5V PFI0 P1.3 P1.2 P1.1 P1.0 P0.7 P0.6 P0.5 P0.4 P0.3 P0.2 P0.1 P0.0

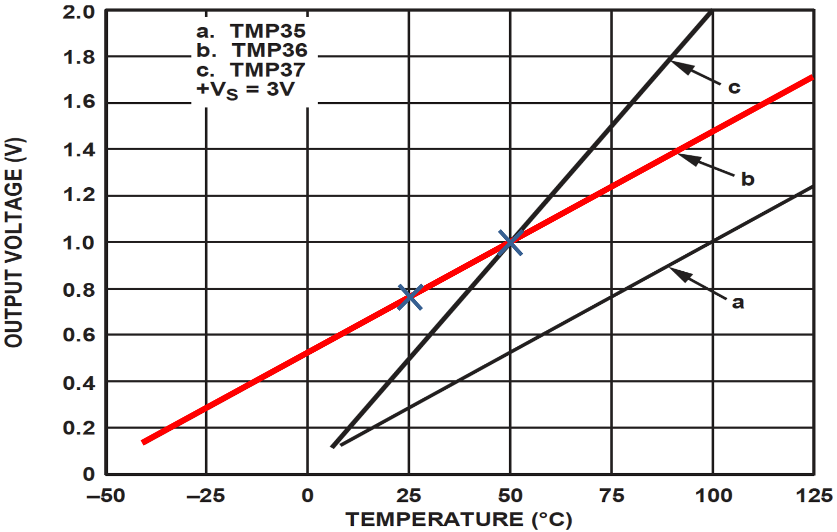
Note! The wires are connected as “**RSE**”

TMP36 Wiring Example



Note! The wires are connected as "**RSE**"

TMP36 - Linear Scaling



Convert form Voltage (V) to degrees Celsius

From the Datasheet we have:

$$(x_1, y_1) = (0.75V, 25°C)$$
$$(x_2, y_2) = (1V, 50°C)$$

There is a linear relationship between Voltage and degrees Celsius:

$$y = ax + b$$

We can find a and b using the following known formula:

$$y - y_1 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

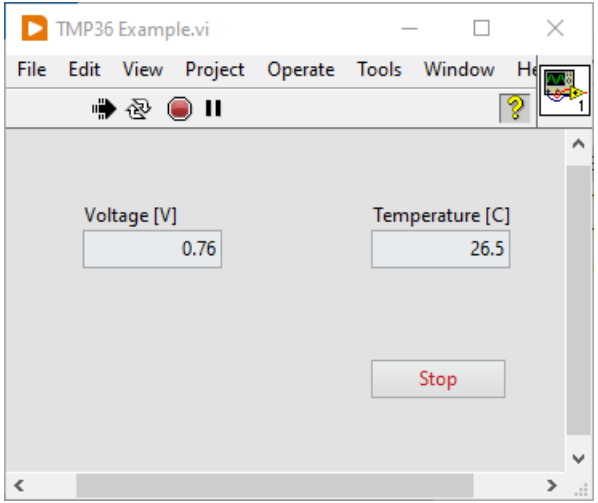
This gives:

$$y - 25 = \frac{50 - 25}{1 - 0.75}(x - 0.75)$$

Then we get the following formula:

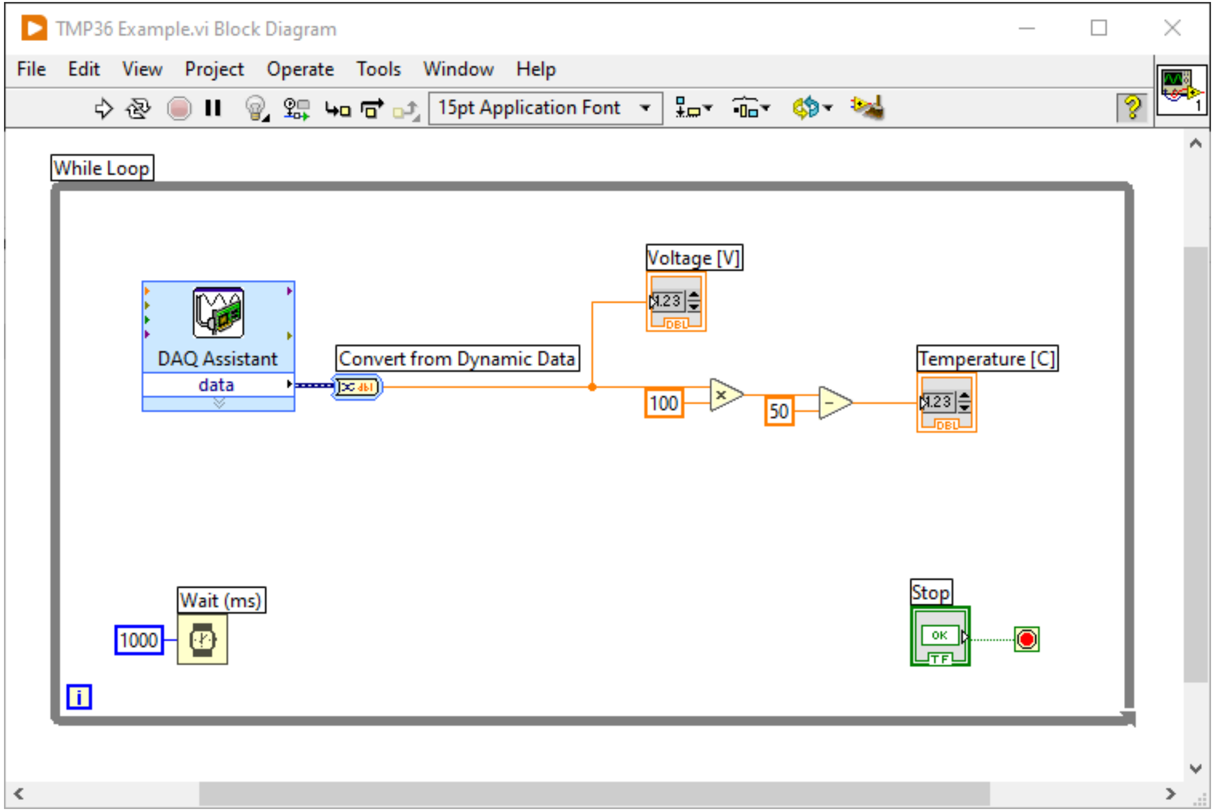
$$y = 100x - 50$$

TMP36 LabVIEW Example

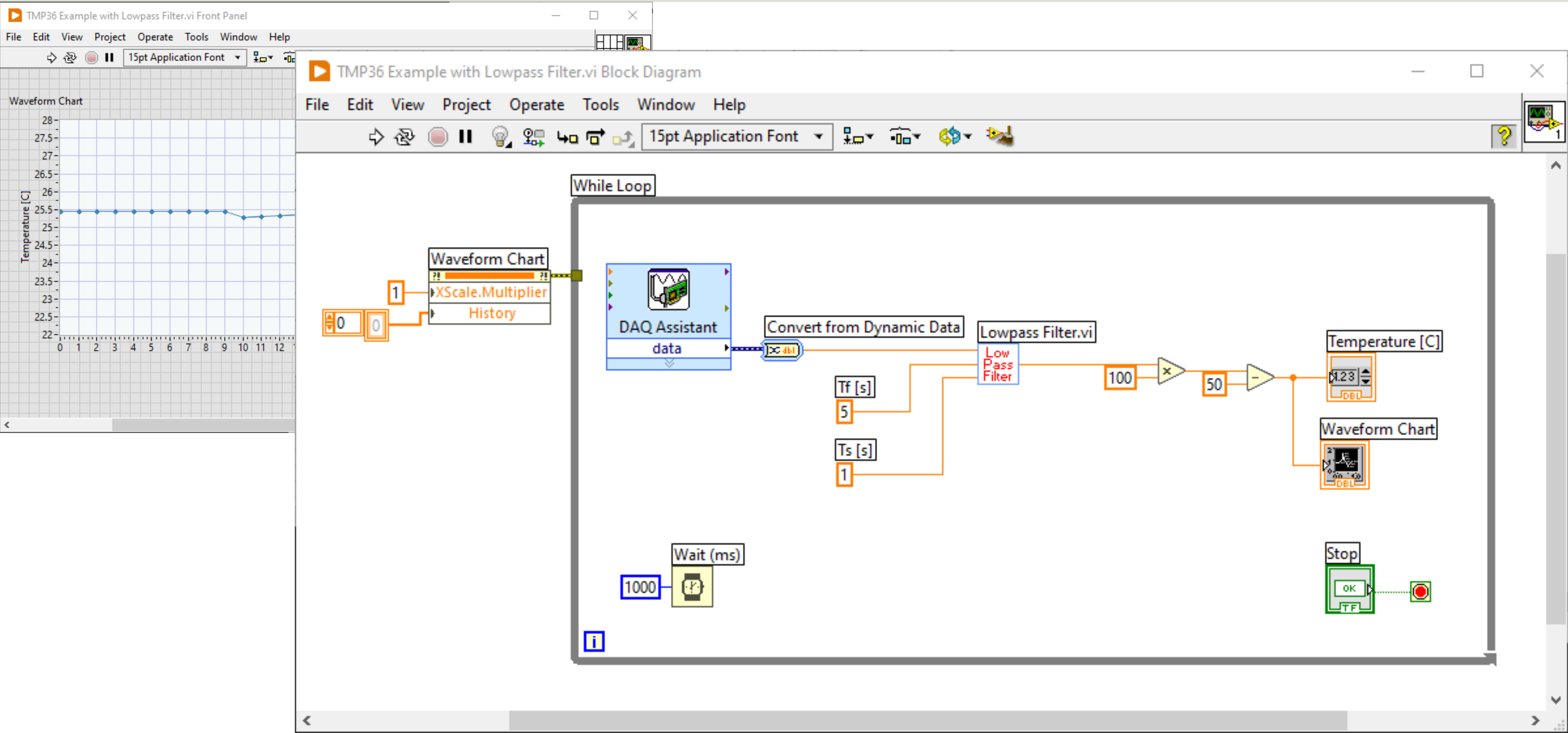


Voltage [V] 0.76

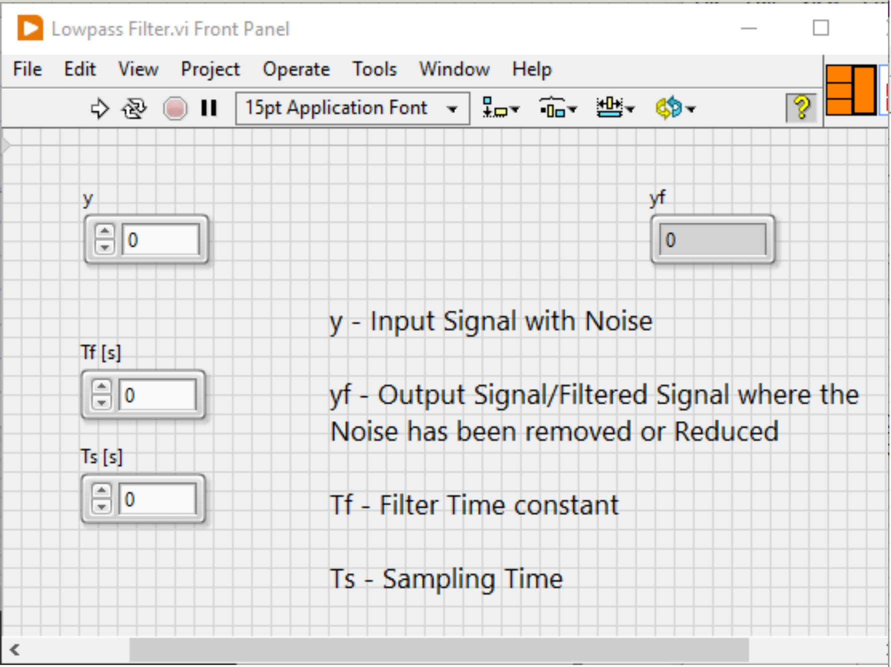
Temperature [C] 26.5



TMP36 with Lowpass Filter



Lowpass Filter

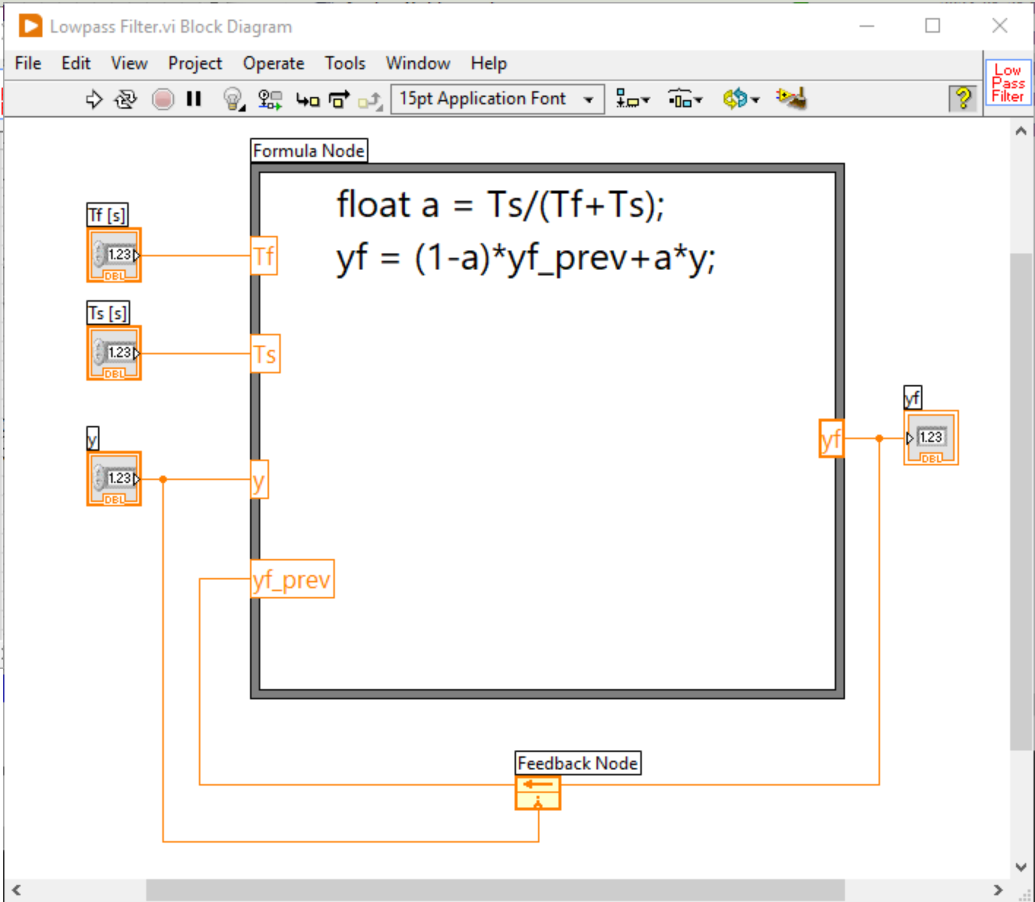

Lowpass Filter.vi Front Panel
File Edit View Project Operate Tools Window Help
15pt Application Font
y
0
yf
0
Tf [s]
0
Ts [s]
0

y - Input Signal with Noise

yf - Output Signal/Filtered Signal where the Noise has been removed or Reduced

Tf - Filter Time constant

Ts - Sampling Time



```
float a = Ts/(Tf+Ts);
yf = (1-a)*yf_prev+a*y;
```

Lowpass Filter

A Low-pass Filter has the following Transfer Function:

$$H(s) = \frac{y_f(s)}{y(s)} = \frac{1}{T_f s + 1}$$

We can find the Differential Equation for this filter using Inverse Laplace

We get:

$$y_f(s)\left[T_f s + 1\right] = y(s)$$

$$T_f y_f(s) s + y_f = y(s)$$

Finally, we get the following Differential Equation:

$$T_f \dot{y}_f + y_f = y$$

We apply Euler on the Differential Equation to find the Discrete Differential equation.

Discrete Lowpass Filter

Discrete Lowpass Filter:

$$y_f(k) = (1 - a)y_f(k - 1) + ay(k)$$

Where:

$$\frac{T_s}{T_f + T_s} \equiv a$$

$y(k)$ is the current Signal from the DAQ device (that contains noise)

$y_f(k)$ is the Filtered Signal

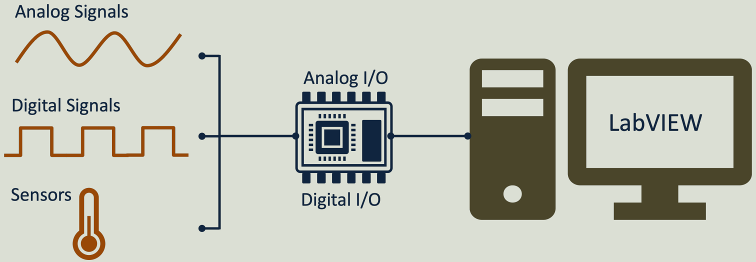
$y_f(k-1)$ is previous filtered signal

T_f is the Filter Time Constant

T_s is the Sampling Time

DAQ and I/O Modules in LabVIEW

Digital I/O

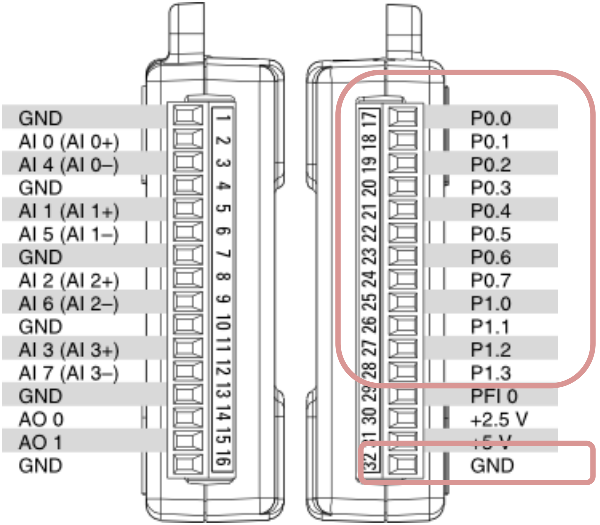


Hans-Petter Halvorsen

Table of Contents

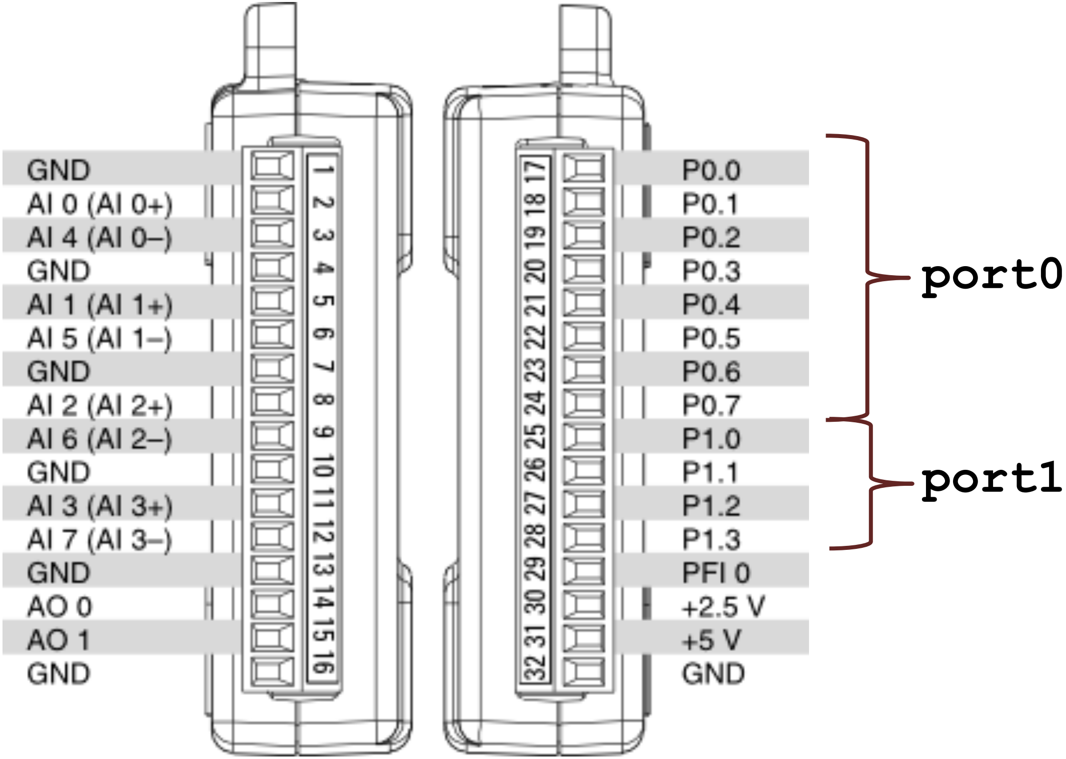
Digital I/O

- 12 Digital Channels
  - Port 0 Digital I/O Channels 0 to 7
  - Port 1 Digital I/O Channels 0 to 3



- You can individually configure each signal as an input or output.

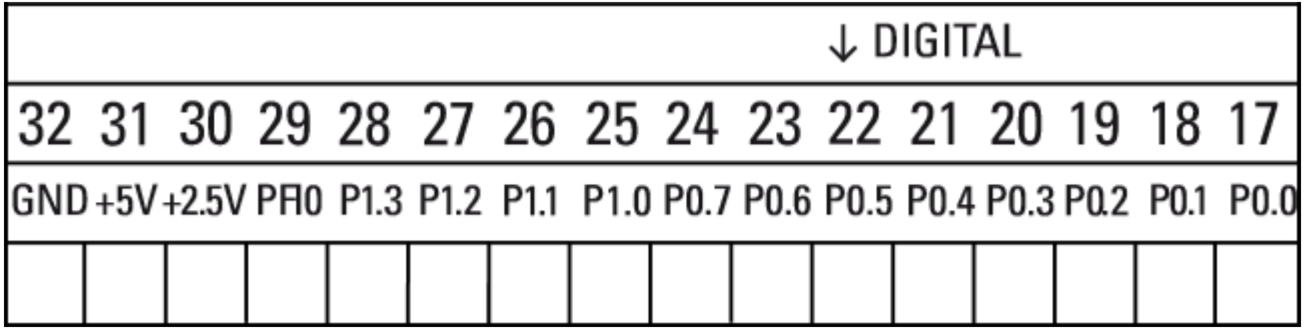
Digital I/O



Dev1/port0/line0
Dev1/port0/line1
Dev1/port0/line2
Dev1/port0/line3
Dev1/port0/line4
Dev1/port0/line5
Dev1/port0/line6
Dev1/port0/line7

Dev1/port1/line0
Dev1/port1/line1
Dev1/port1/line2
Dev1/port1/line3

Digital I/O



										↓ DIGITAL					
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
GND	+5V	+2.5V	PFI0	P1.3	P1.2	P1.1	P1.0	P0.7	P0.6	P0.5	P0.4	P0.3	P0.2	P0.1	P0.0

Dev1/Port0/line0:7

P0.<0..7> Port 0 Digital I/O Channels 0 to 7 — You can individually configure each signal as an input or output.

Dev1/Port1/line0:3

P1.<0..3> Port 1 Digital I/O Channels 0 to 3 — You can individually configure each signal as an input or output

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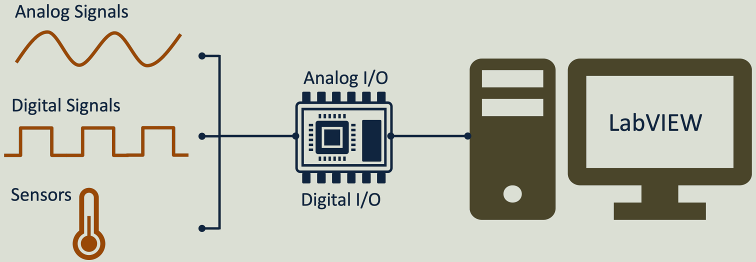
DAQ and I/O Modules in LabVIEW

Digital Out

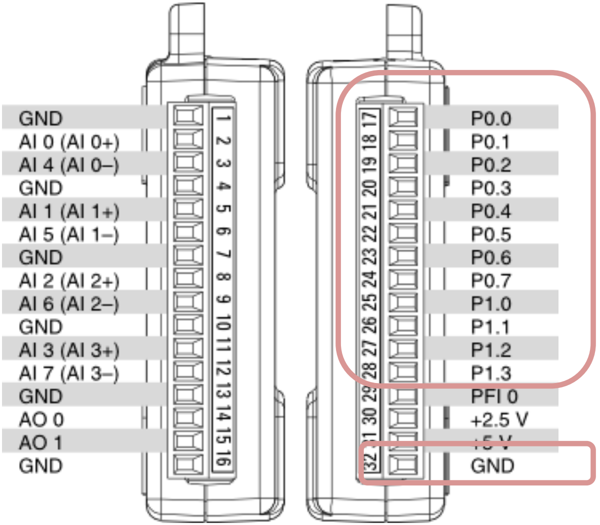


Hans-Petter Halvorsen

Table of Contents

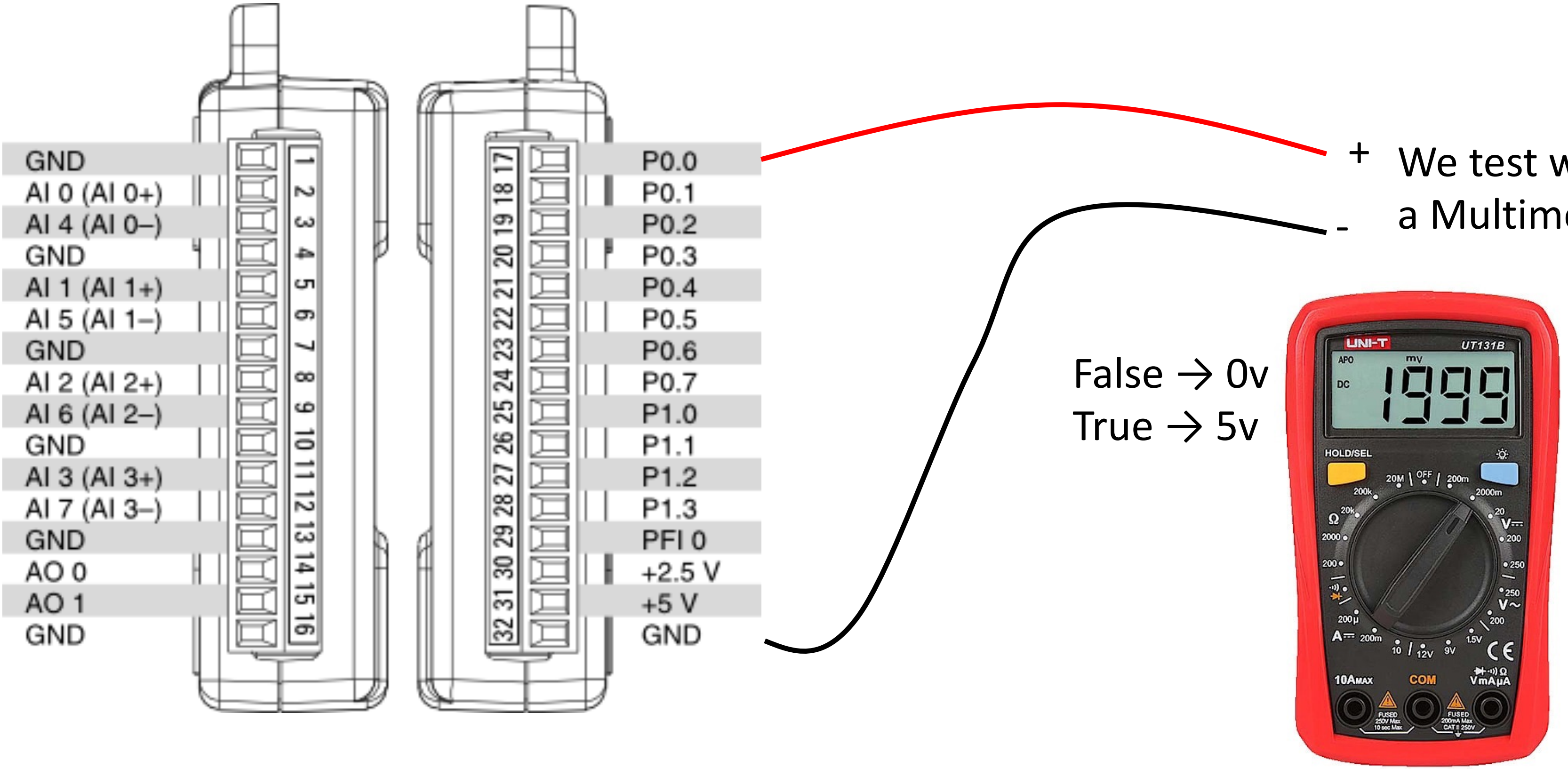
Digital Out

- 12 Digital Channels
  - Port 0 Digital I/O Channels 0 to 7
  - Port 1 Digital I/O Channels 0 to 3



- You can individually configure each signal as an input or output.

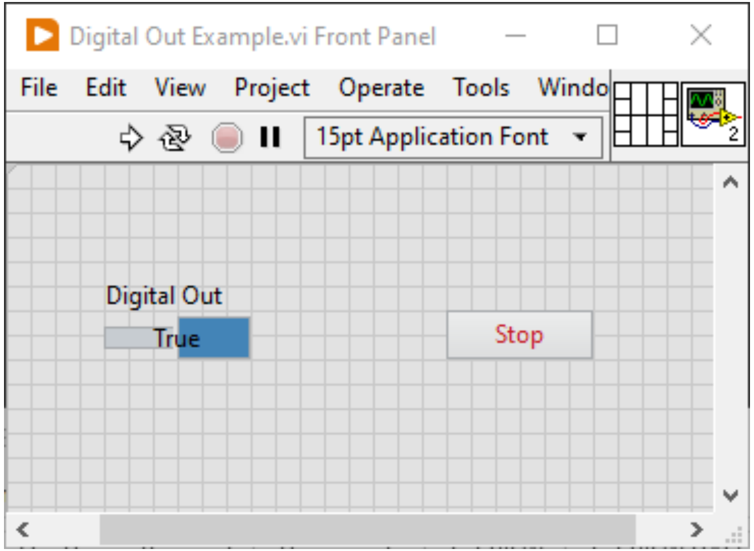
Hardware Setup and Testing

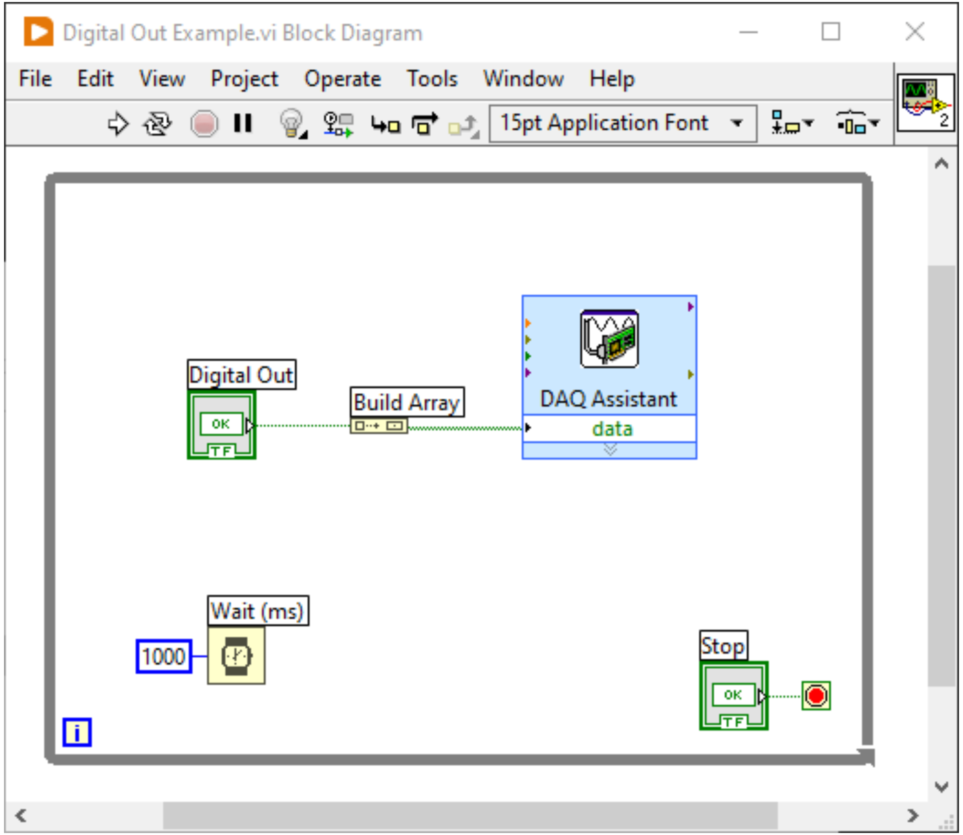


We test with a Multimeter

False → 0v
True → 5v

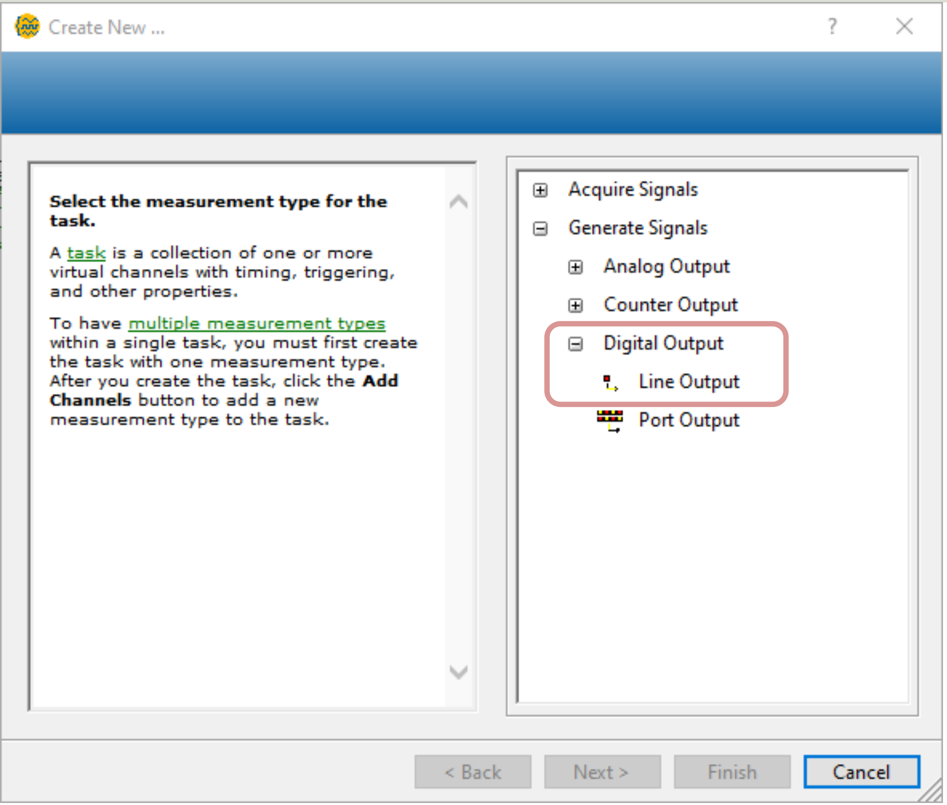
Digital Out LabVIEW Example





False → 0v
True → 5v

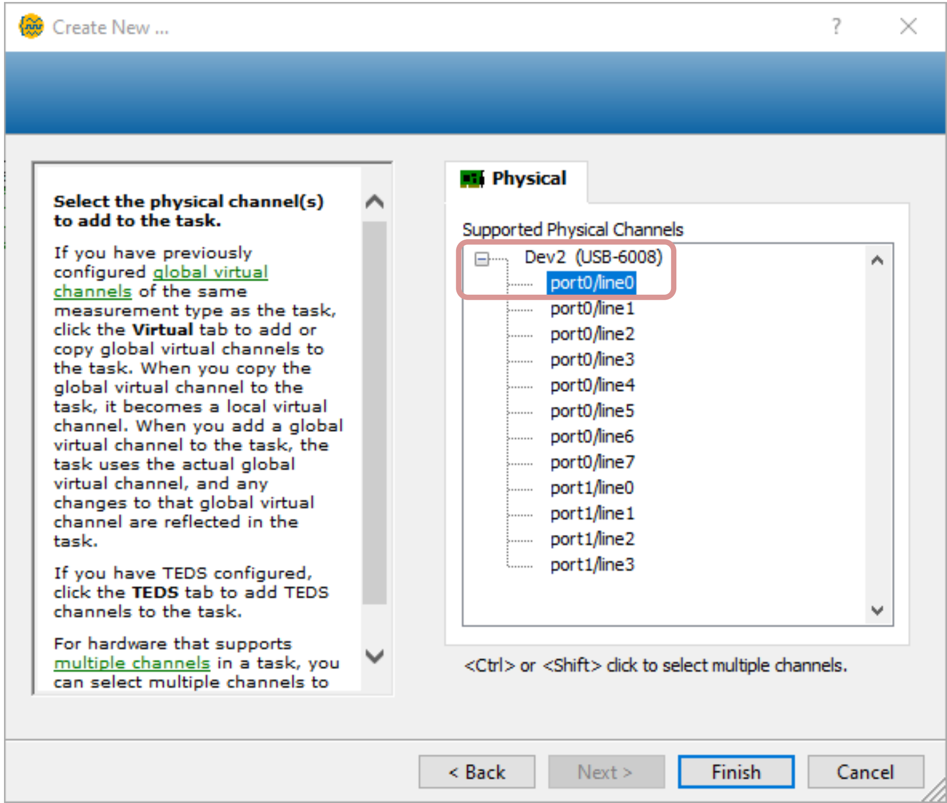
Configuration



Select the measurement type for the task.

A task is a collection of one or more virtual channels with timing, triggering, and other properties.

To have multiple measurement types within a single task, you must first create the task with one measurement type. After you create the task, click the **Add Channels** button to add a new measurement type to the task.



Select the physical channel(s) to add to the task.

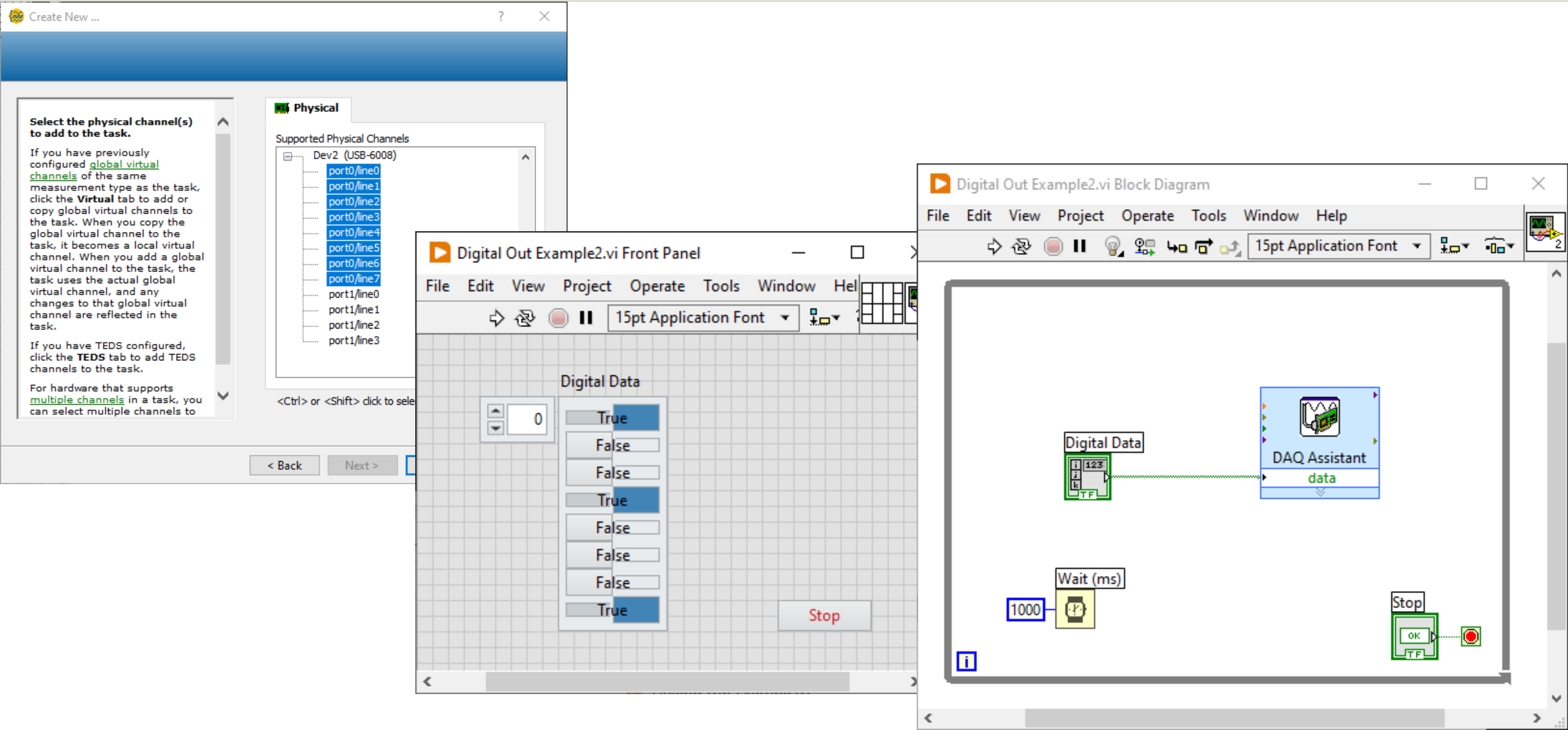
If you have previously configured global virtual channels of the same measurement type as the task, click the **Virtual** tab to add or copy global virtual channels to the task. When you copy the global virtual channel to the task, it becomes a local virtual channel. When you add a global virtual channel to the task, the task uses the actual global virtual channel, and any changes to that global virtual channel are reflected in the task.

If you have TEDS configured, click the **TEDS** tab to add TEDS channels to the task.

For hardware that supports multiple channels in a task, you can select multiple channels to

<Ctrl> or <Shift> click to select multiple channels.

Multiple Digital Out



Create New ...

Select the physical channel(s) to add to the task.

If you have previously configured global virtual channels of the same measurement type as the task, click the **Virtual** tab to add or copy global virtual channels to the task. When you copy the global virtual channel to the task, it becomes a local virtual channel. When you add a global virtual channel to the task, the task uses the actual global virtual channel, and any changes to that global virtual channel are reflected in the task.

If you have TEDS configured, click the **TEDS** tab to add TEDS channels to the task.

For hardware that supports multiple channels in a task, you can select multiple channels to

Physical

Supported Physical Channels

- Dev2 (USB-6008)
  - port0/line0
  - port0/line1
  - port0/line2
  - port0/line3
  - port0/line4
  - port0/line5
  - port0/line6
  - port0/line7
  - port1/line0
  - port1/line1
  - port1/line2
  - port1/line3

<Ctrl> or <Shift> click to sele

< Back   Next >

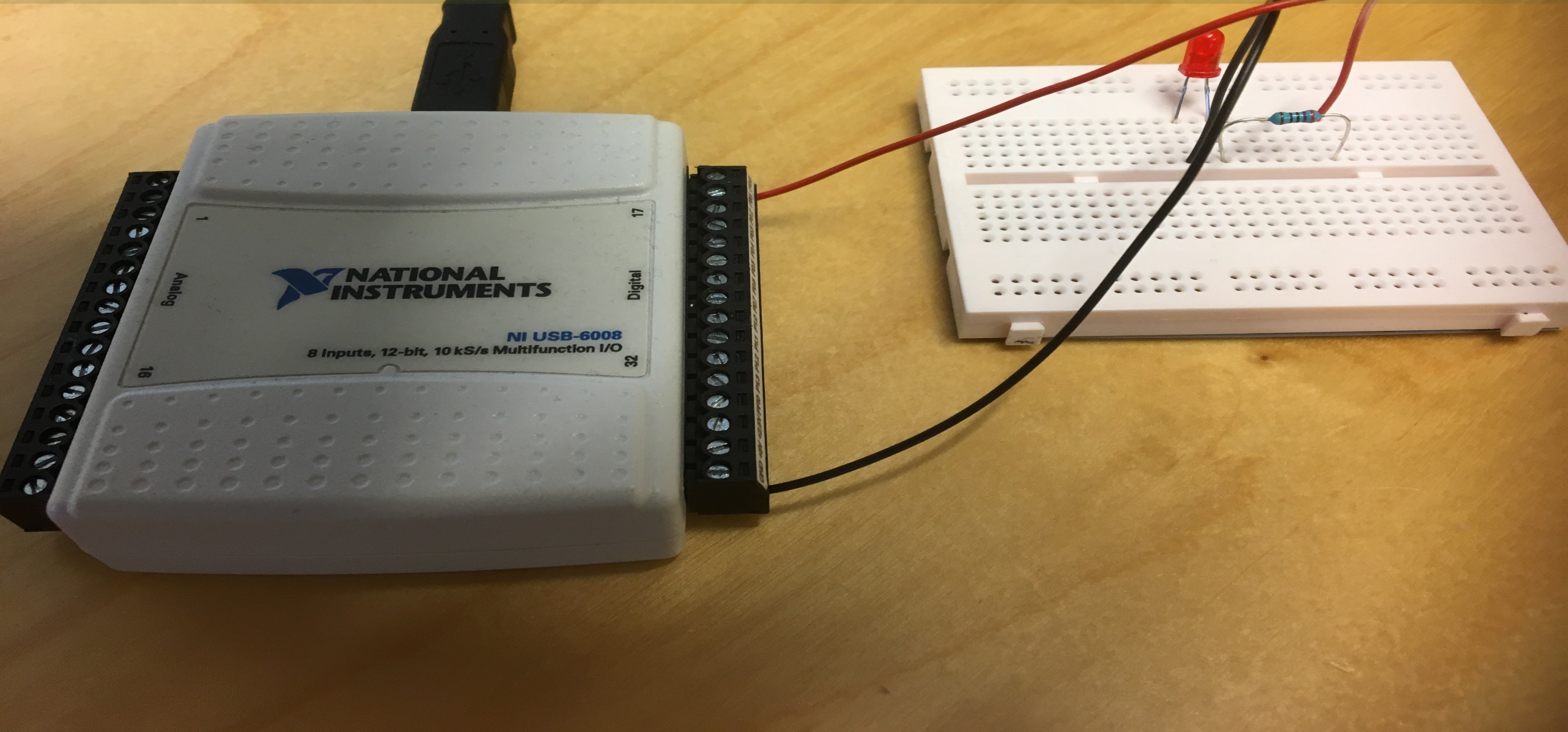
Digital Out Example2.vi Front Panel

Digital Data

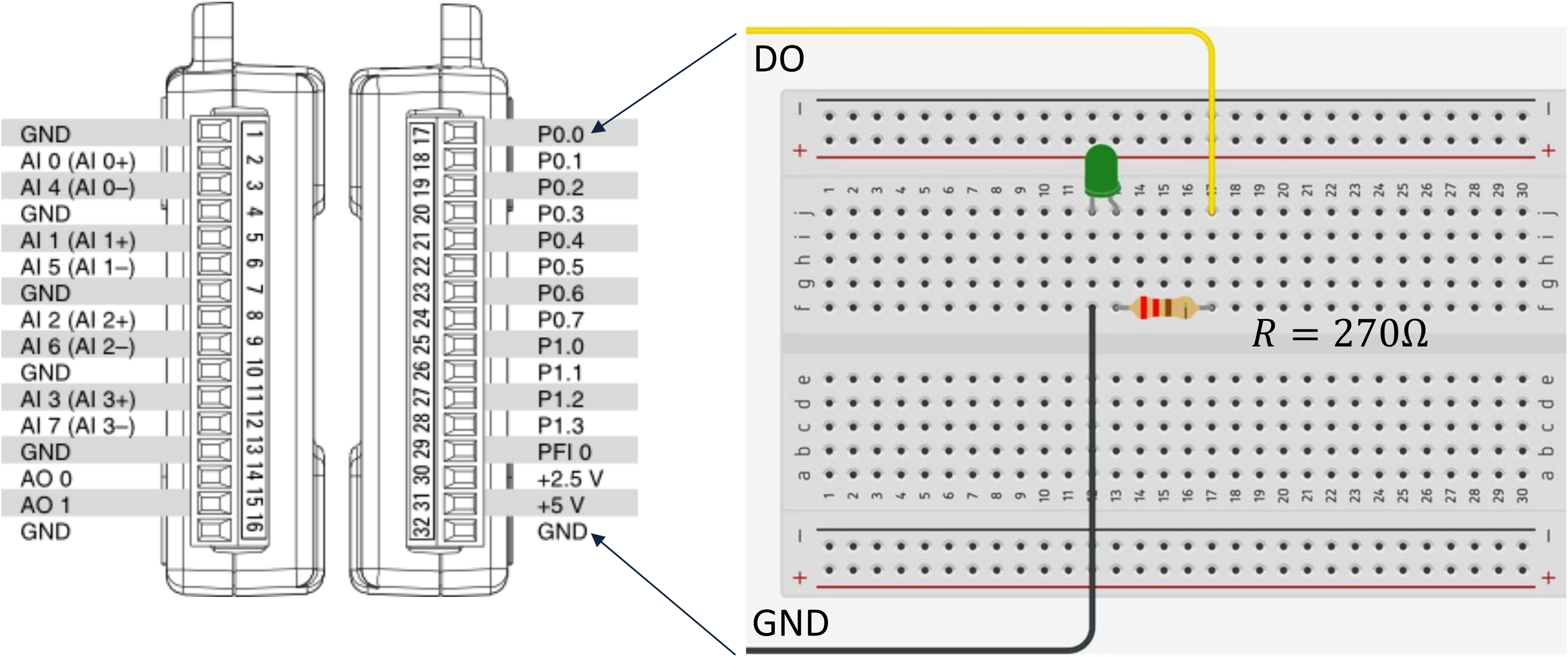
True
False
False
True
False
False
False
True

File Edit View Project Operate Tools Window Hel
15pt Application Font
0
Stop
Digital Out Example2.vi Block Diagram
File Edit View Project Operate Tools Window Help
15pt Application Font
Digital Data
DAQ Assistant
data
Wait (ms)
1000
Stop
OK
TF
i

LED Example


NATIONAL INSTRUMENTS
NI USB-6008
8 Inputs, 12-bit, 10 kS/s Multifunction I/O
1
16
17
32
Analog
Digital

LED Wiring Example

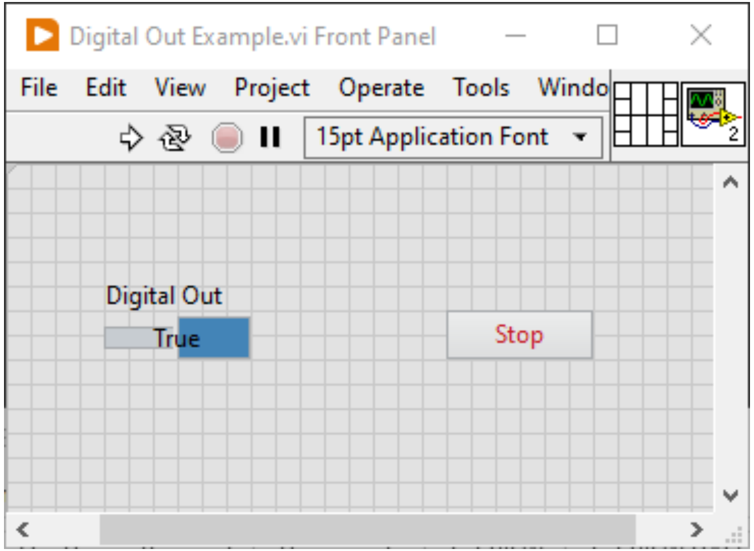


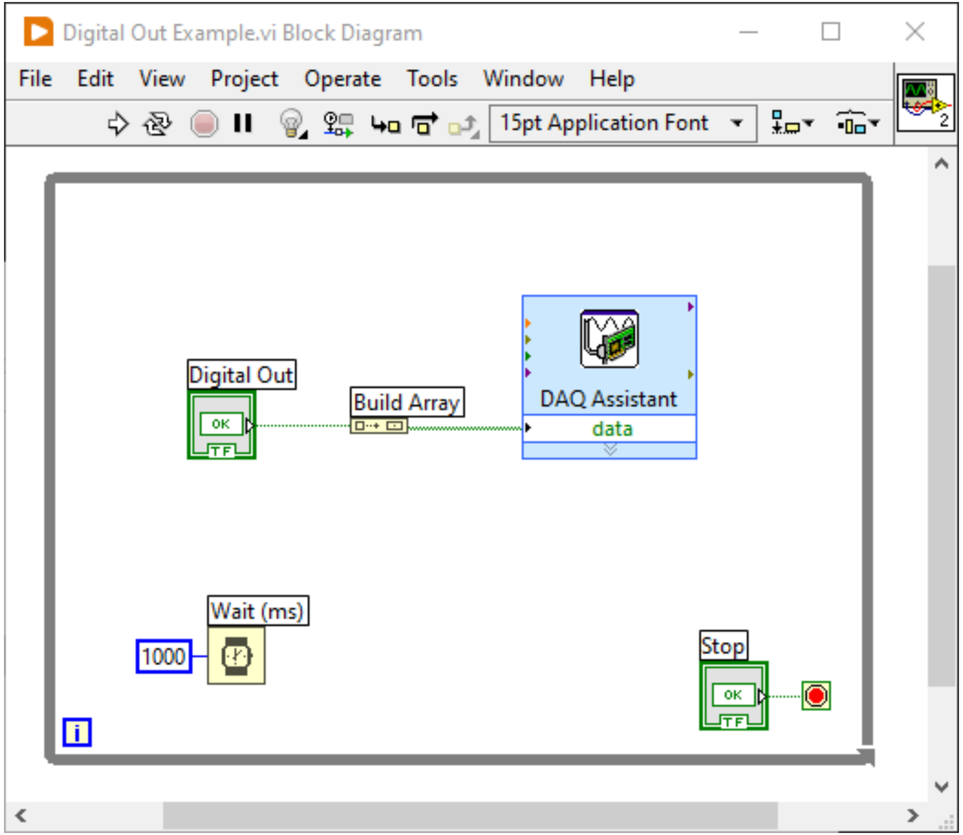
DO

$R = 270\Omega$

GND

LED Example





False → 0v → LED OFF
True → 5v → LED ON

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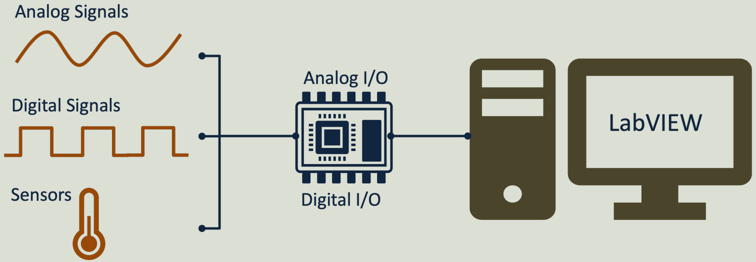
DAQ and I/O Modules in LabVIEW

Digital In

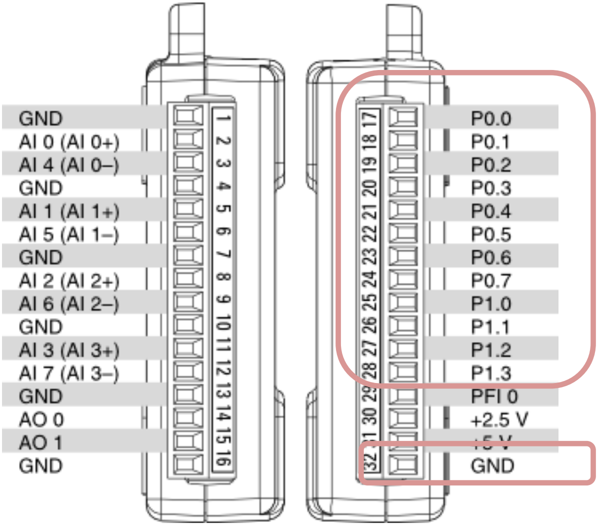


Hans-Petter Halvorsen

Table of Contents

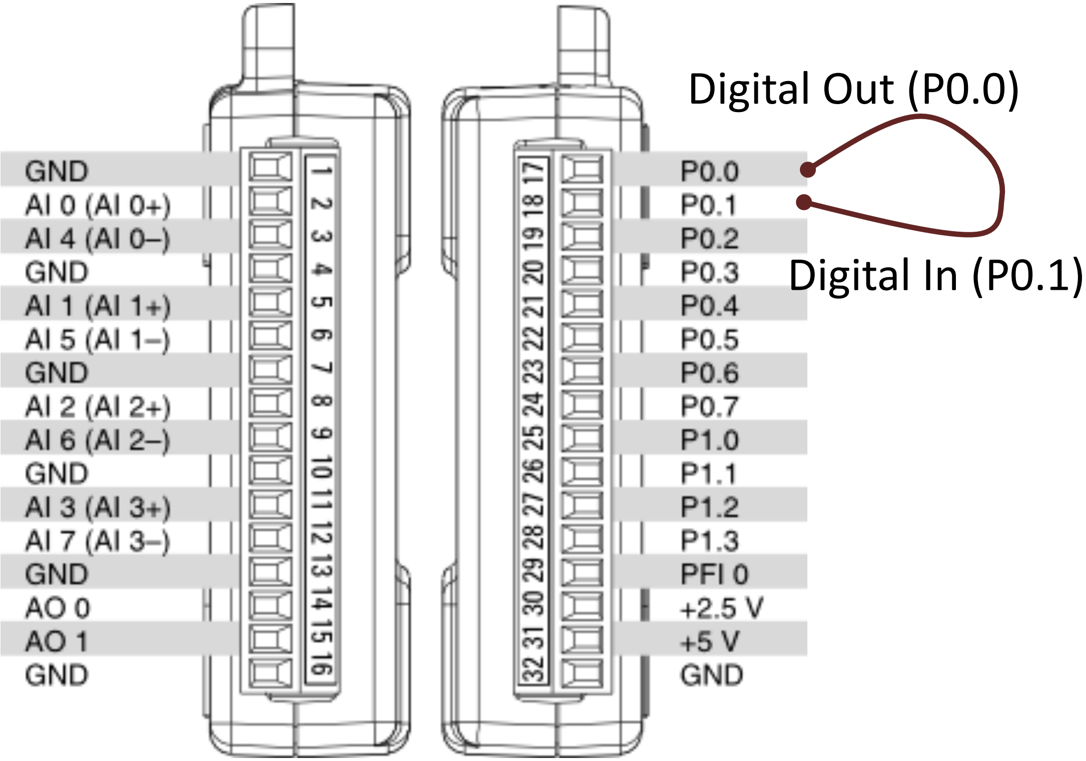
Digital In

- 12 Digital Channels
  - – Port 0 Digital I/O Channels 0 to 7
  - – Port 1 Digital I/O Channels 0 to 3



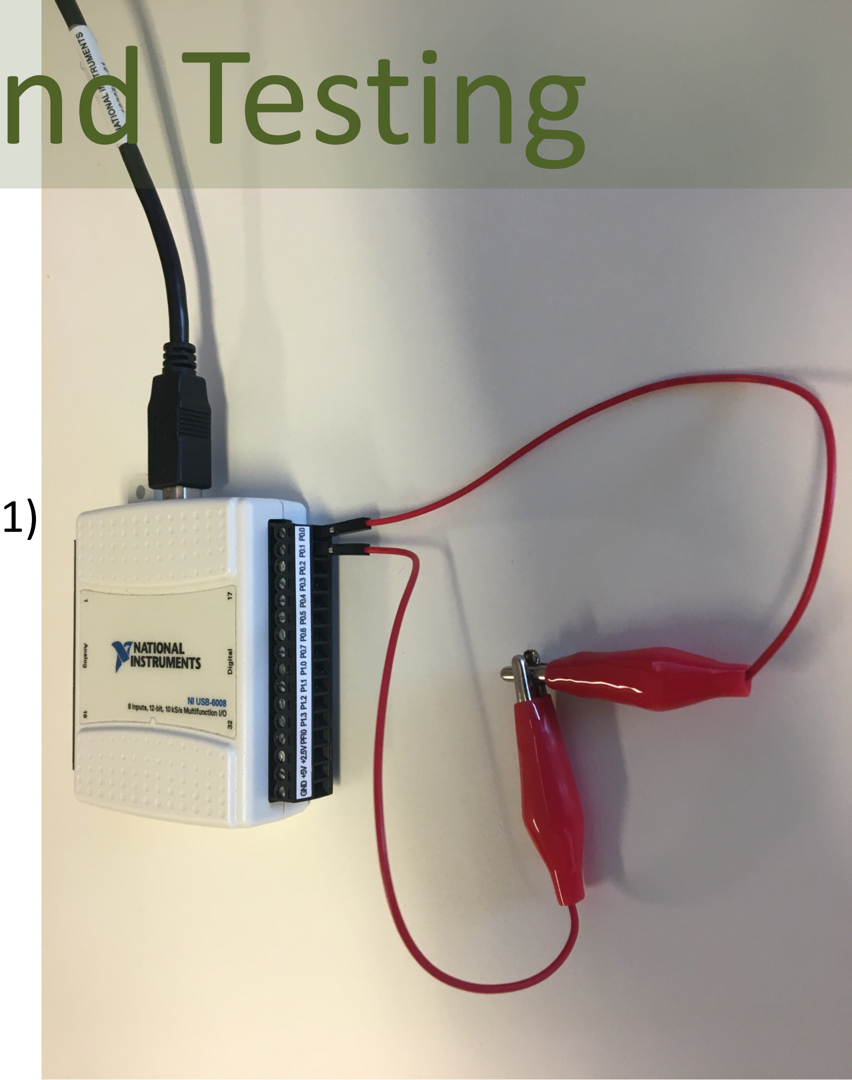
- You can individually configure each signal as an input or output.

Hardware Setup and Testing

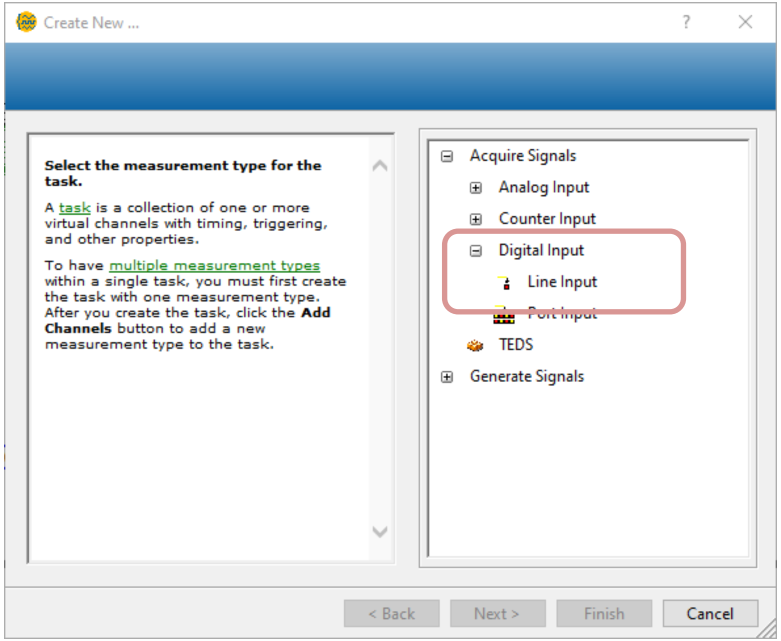


Digital Out (P0.0)

Digital In (P0.1)


NATIONAL INSTRUMENTS
NI USB-6008
8 Inputs, 12-bit, 10 kS/s Multifunction I/O
Analog
Digital
GND +5V +2.5V PFI0 P1.3 P1.2 P1.1 P1.0 P0.7 P0.6 P0.5 P0.4 P0.3 P0.2 P0.1 P0.0

Digital In



Create New ...

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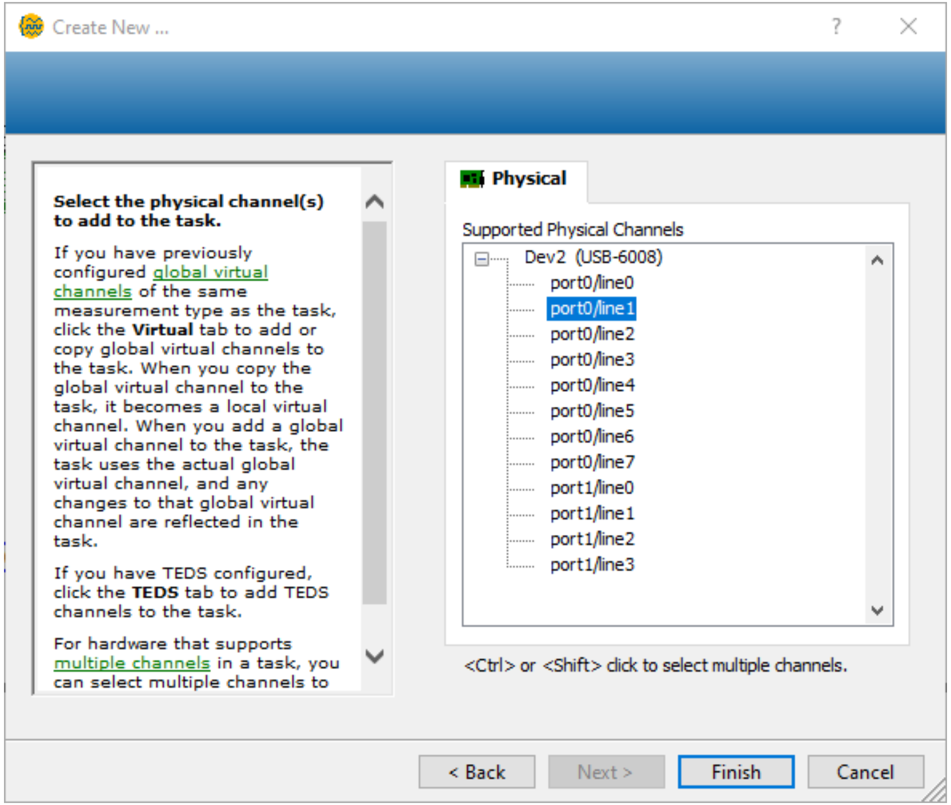

Create New ...

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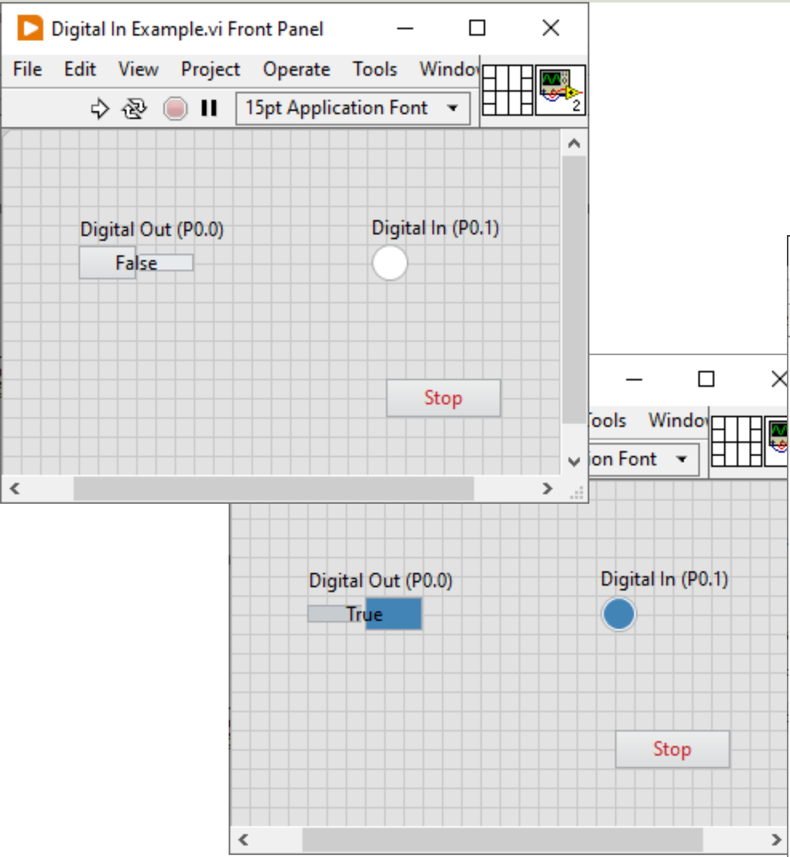
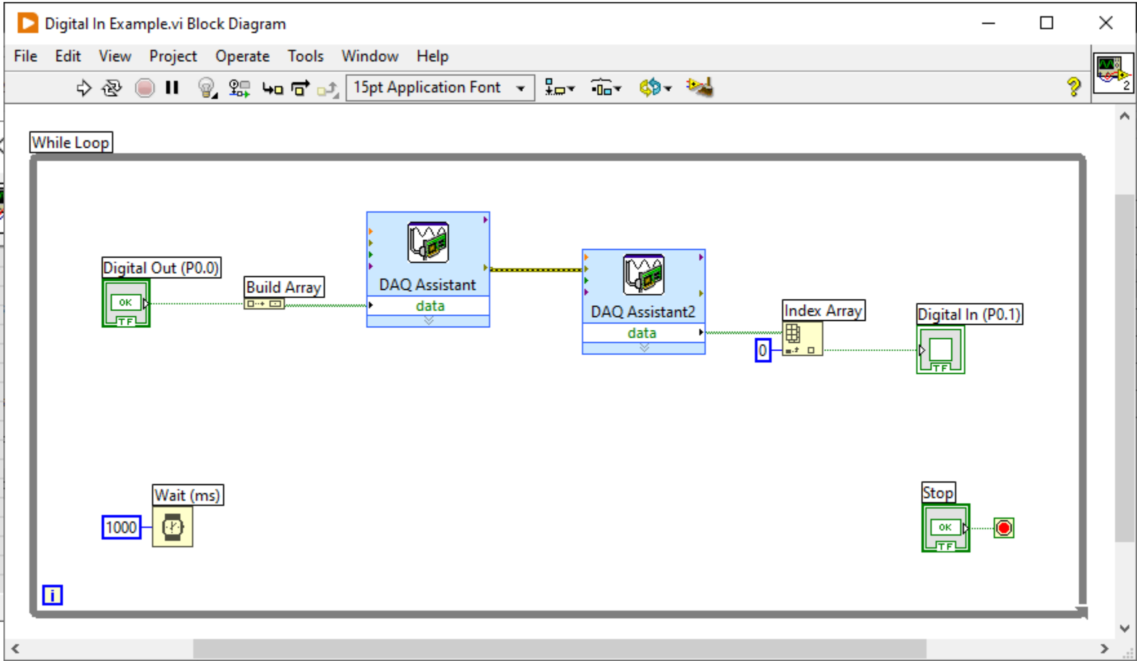
If you have TEDS configured, click the **TEDS** tab to add TEDS channels to the task.

For hardware that supports multiple channels in a task, you can select multiple channels to

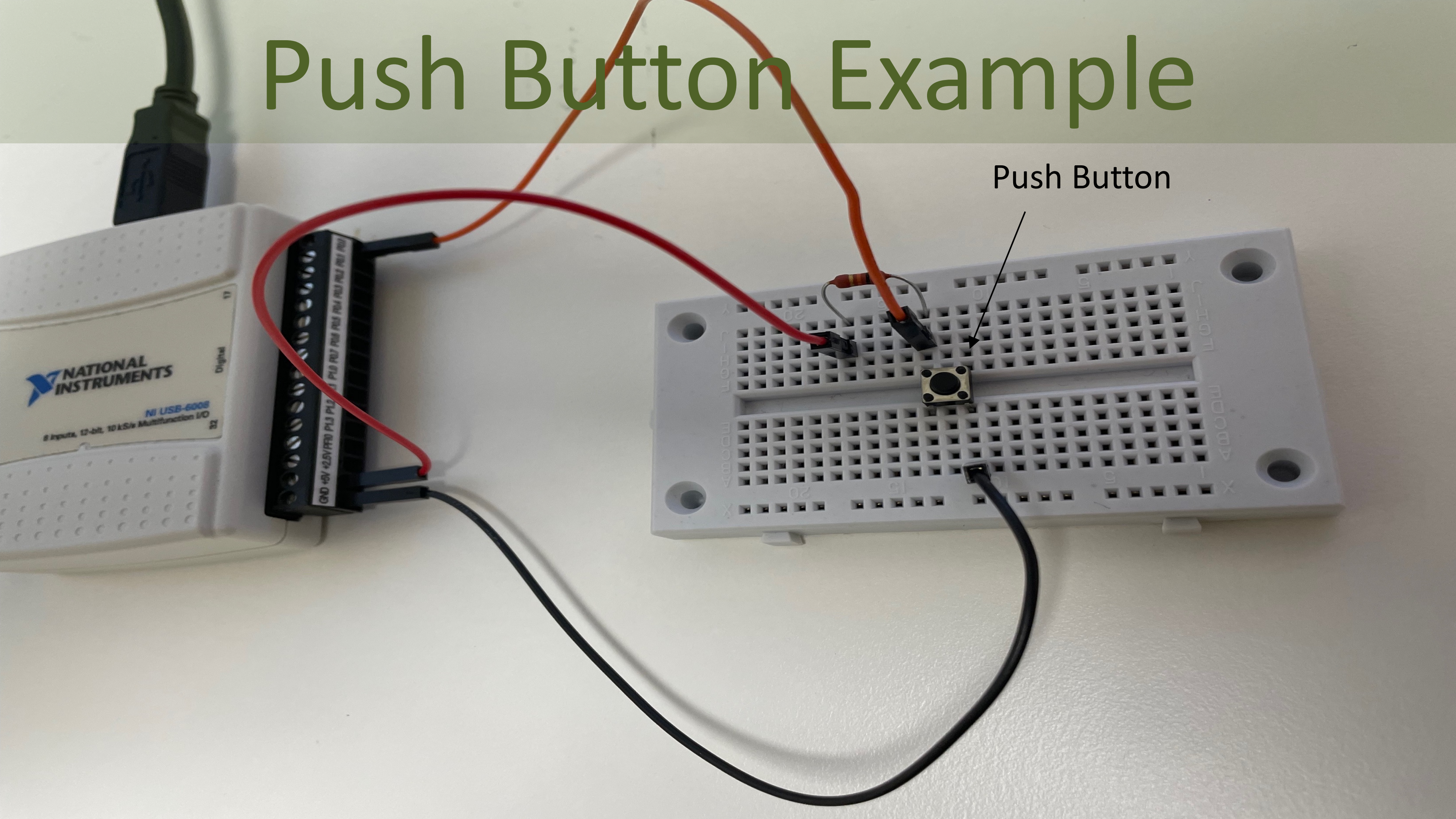
Digital Out and In Example

Digital P0.0 is wired directly to P0.1 in this example



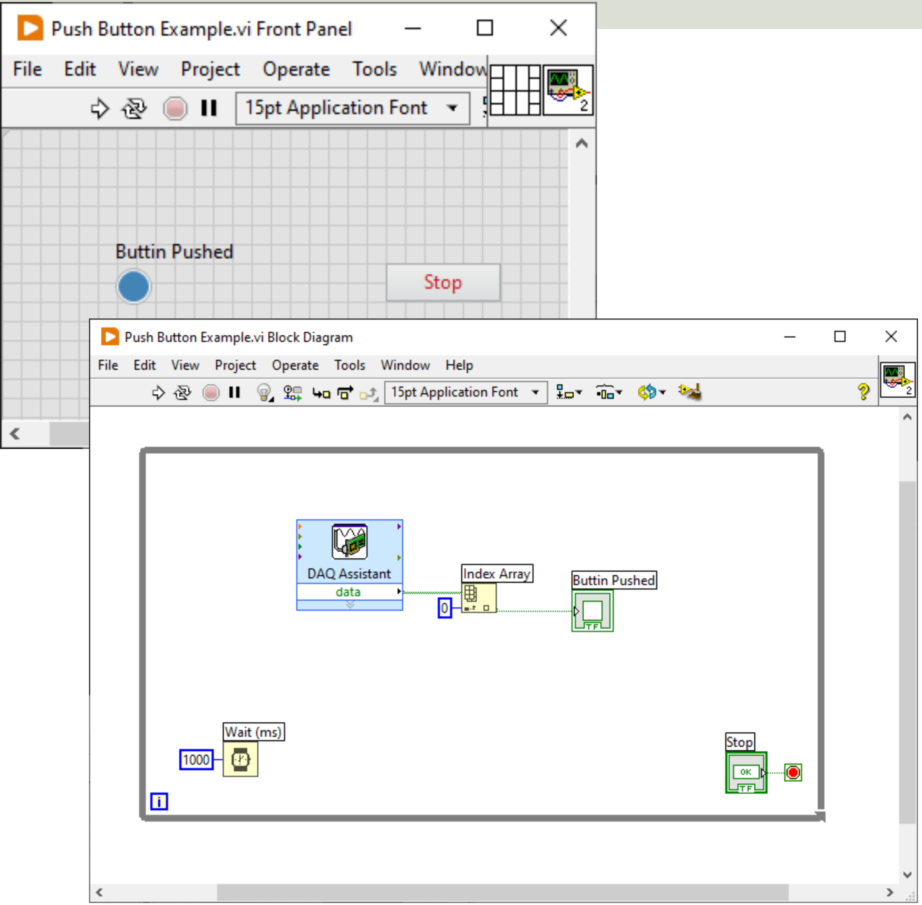


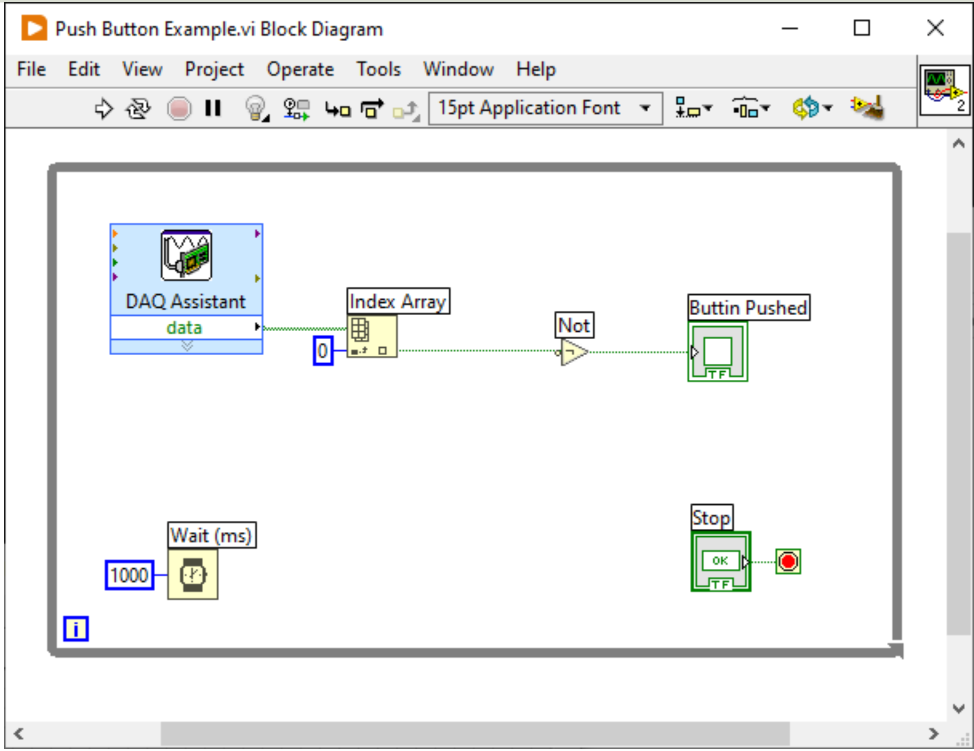
Push Button Example


NATIONAL INSTRUMENTS
NI USB-6008
8 inputs, 12-bit, 10 kS/s Multifunction I/O
Digital
GND +5V +2.5V PFI0 P1.3 P1.2

Push Button

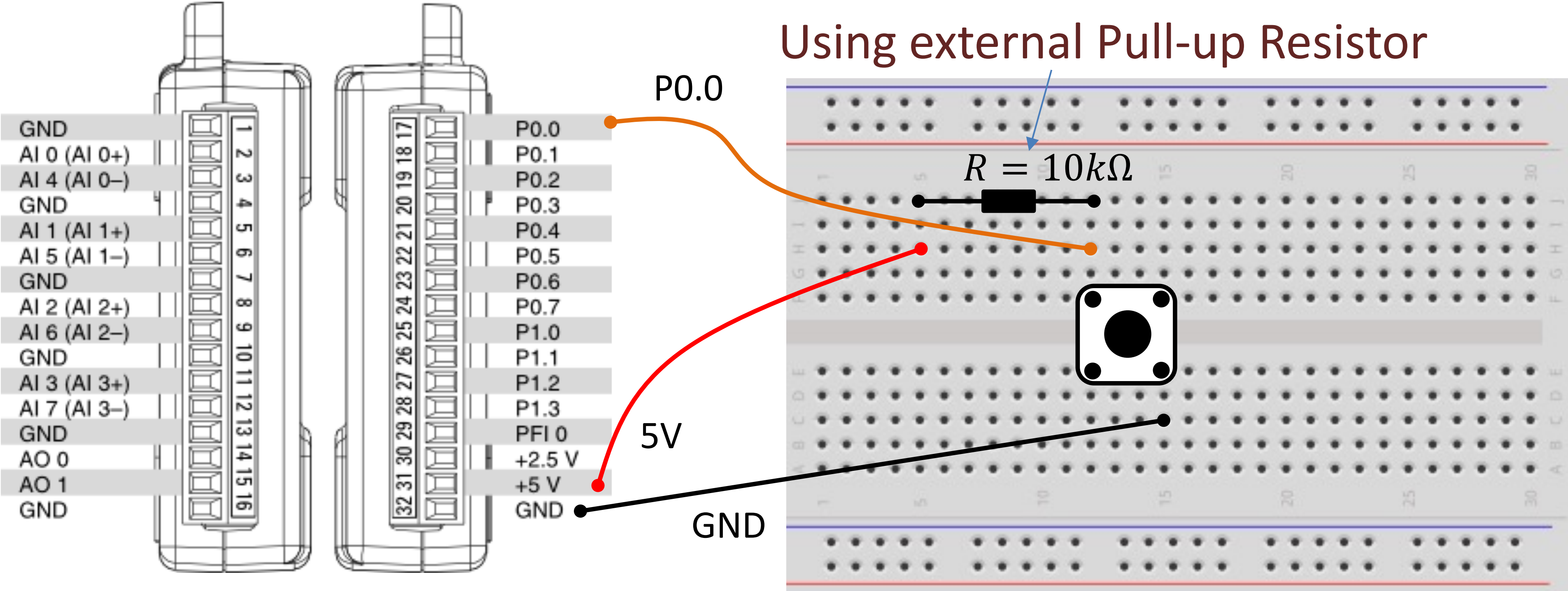
Push Button Example


Push Button Example.vi Front Panel
File Edit View Project Operate Tools Window
15pt Application Font
Buttin Pushed
Stop
Push Button Example.vi Block Diagram
File Edit View Project Operate Tools Window Help
15pt Application Font
DAQ Assistant
data
Index Array
0
Buttin Pushed
Wait (ms)
1000
Stop
OK
i



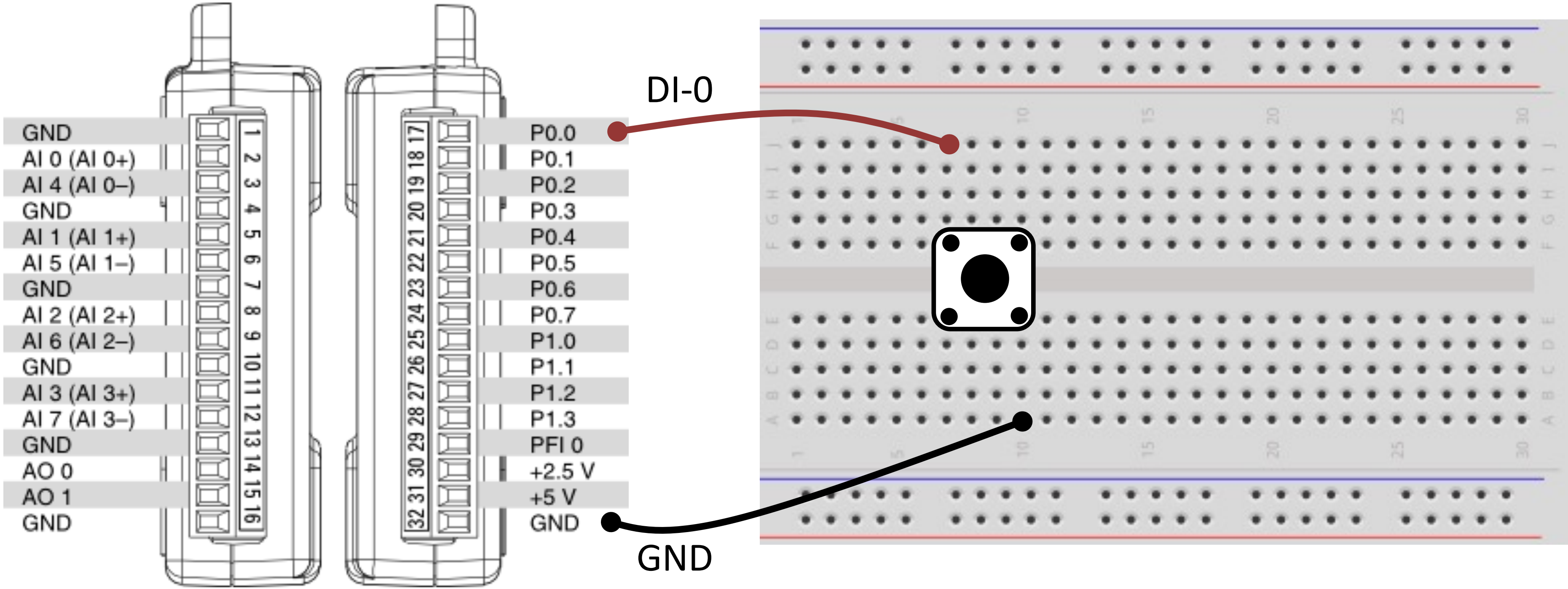
Push Button Wiring Example

Using external 10 kΩ Pull-up Resistor



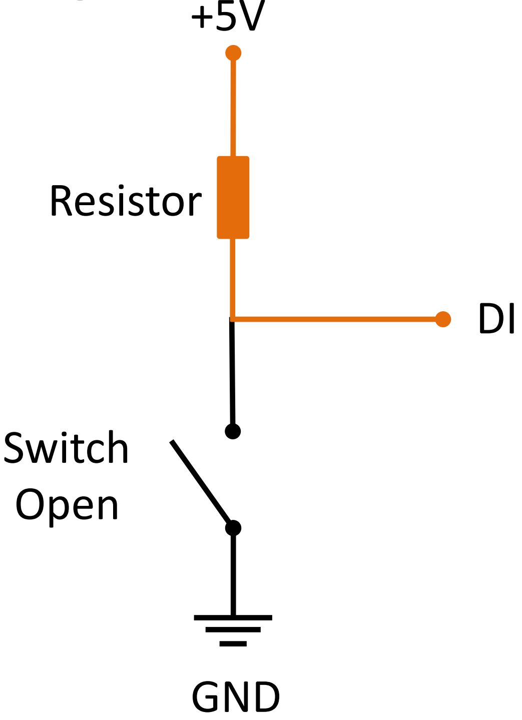
Push Button Wiring Example

Using built-in/internal 4.7 kΩ **Pull-up Resistor**



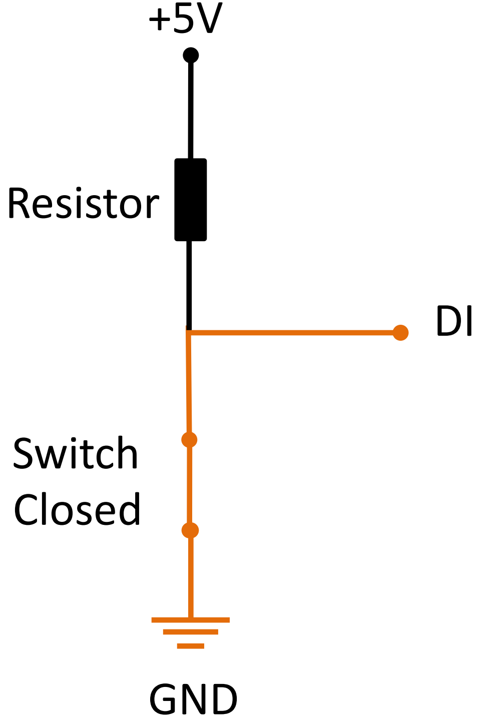
Pull-up Resistor

True/High



We Push the Button

False/Low



DAQ and I/O Modules in LabVIEW

When using a DAQ or I/O Module device we have 4 options:

- **Analog Out** (Write) - AO
- **Analog In** (Read) - AI
- **Digital Out** (Write) - DO
- **Digital In** (Read) - DI

We will show some basic Step by Step examples in each of these categories

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