Fundamentals of Data Acquisition Using NI-DAQmx

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Topics

- Data Acquisition Systems
- Sampling and Timing
- The NI-DAQmx Driver
- The NI-DAQmx Application Programming Interface
- Reading or Writing a Finite Amount of Data
- Communicating Data Continuously

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Data Acquisition Systems

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What is Data Acquisition?

Data Acquisition (DAQ) is the process of sampling signals that represent real world phenomena and converting the samples into digital data that can be manipulated by a computer.

Real world signals

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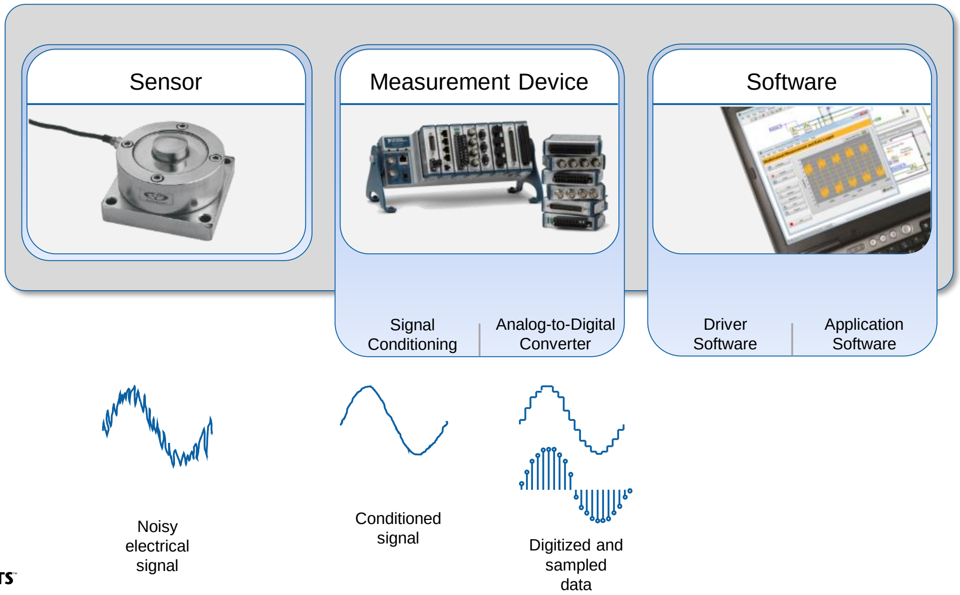
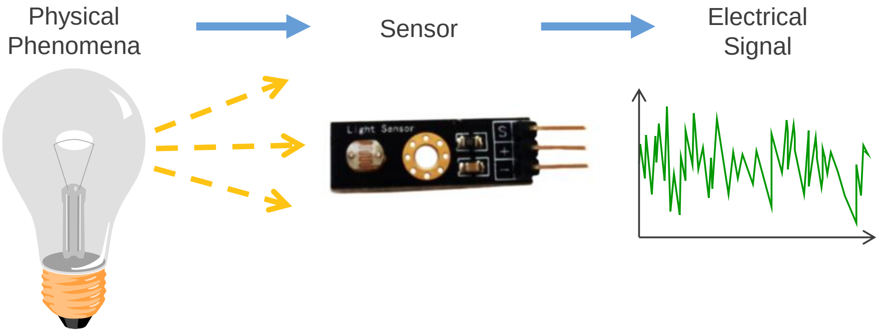
Architecture of an Integrated Measurement System



What is a Sensor?



Sensors are devices that convert physical phenomena into measurable electrical signals

Common Sensors and Transducers

Sensors and Transducers	Phenomenon
Thermocouple, RTD, thermistor	Temperature
Photo sensor	Light
Microphone	Sound
Strain gage, piezoelectric transducer	Force and Pressure
Potentiometer, LVDT, optical encoder	Position and Displacement
Accelerometer	Acceleration
pH probe	pH

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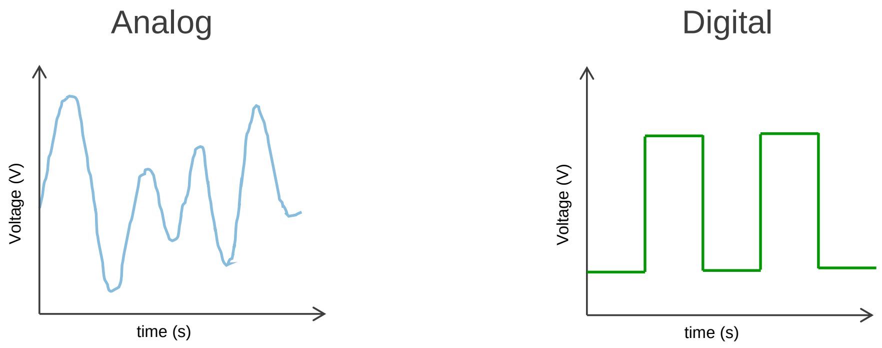
Types of Signals

Two Types of Electrical Signals



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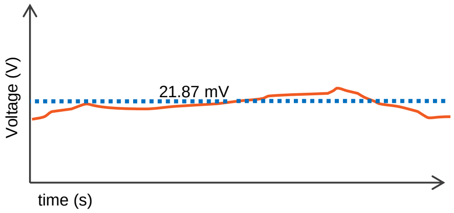
Signal Characteristics

What characteristics of a signal can we measure?

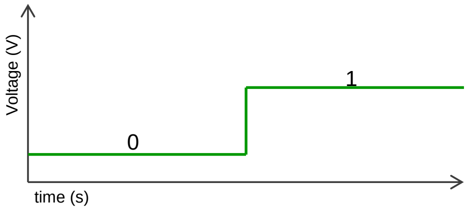
Analog

Level is the *steady-state* magnitude of a signal at a particular point in time



Digital

State is the level of a *static* digital signal at a particular point in time, usually shown as “0” or “1”



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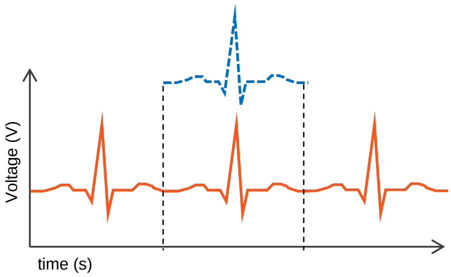
Signal Characteristics

What characteristics of a signal can we measure?

Analog

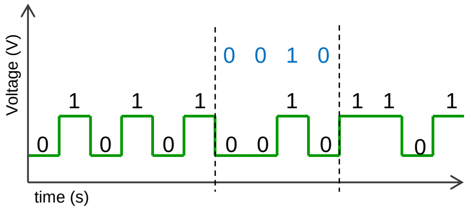
Shape is the *profile* of a waveform over a period of time



EKG signal

Digital

Pattern is a particular *sequence* of digital states over a period of time



4-bit pattern

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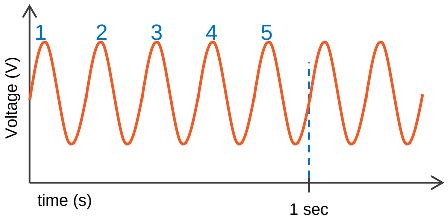
Signal Characteristics

What characteristics of a signal can we measure?

Analog

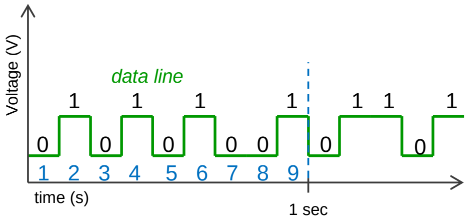
Frequency is the number of times a *recurring (periodic)* waveform occurs in a second



Frequency = 5 Hz

Digital

Rate can be either the number of *pulses* per second, or the number of *bits* conveyed each second



Rate = 9 bits/s

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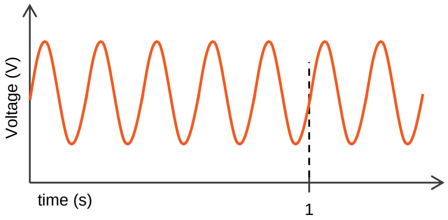
Signal Characteristics

What characteristics of a signal can we measure?

Analog

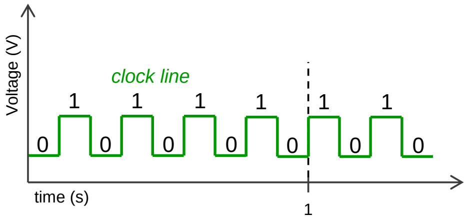
Frequency is the number of times a recurring (periodic) waveform occurs in a second



Frequency = 5 Hz

Digital

Rate can be either the number of pulses per second, or the number of bits conveyed each second



Rate = 4 pulses/s

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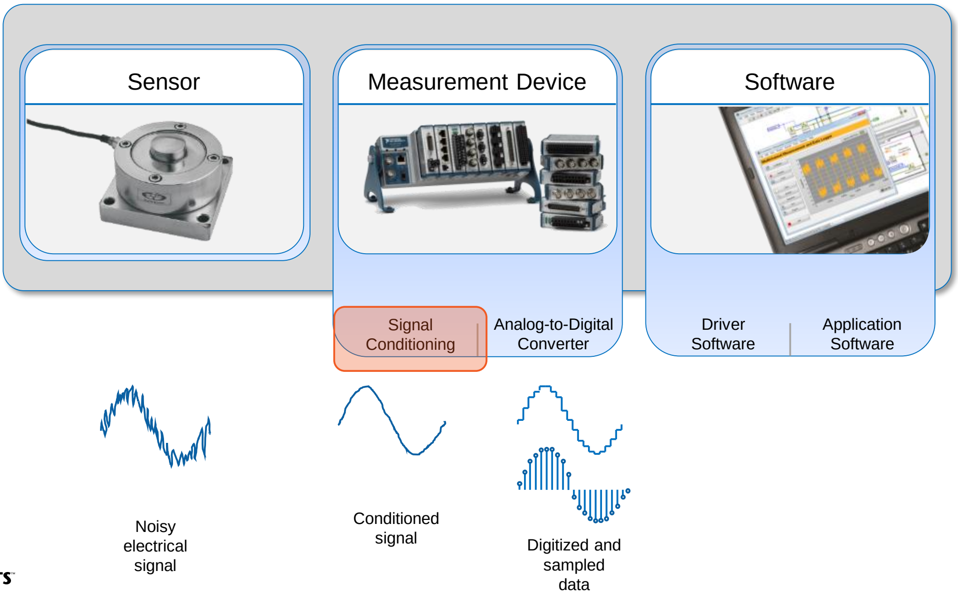
Signal Conditioning



Sensor

Measurement Device

Software

Signal Conditioning

Analog-to-Digital Converter

Driver Software

Application Software

Noisy electrical signal

Conditioned signal

Digitized and sampled data

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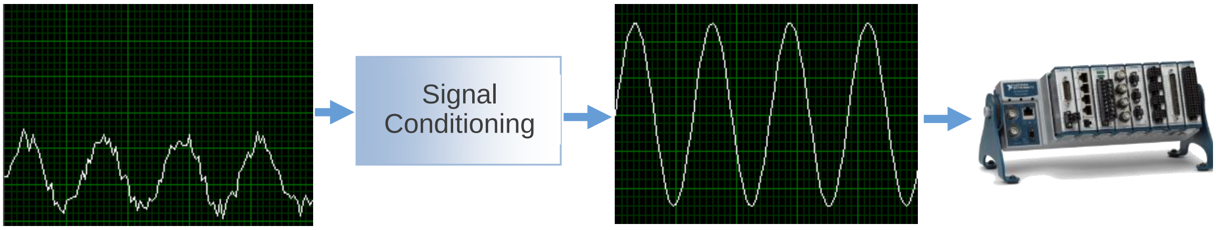
Signal Conditioning Makes Signals Easier to Measure



Signal Conditioning

Noisy, Low-Level Signal

Filtered, Amplified Signal

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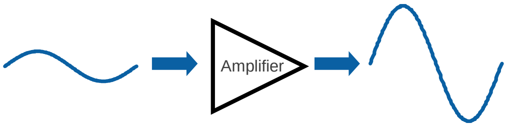
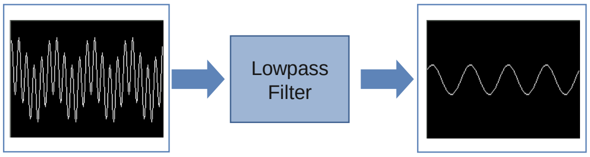
Signal Conditioning for Voltage Measurements

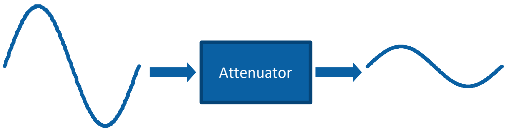
- Amplification



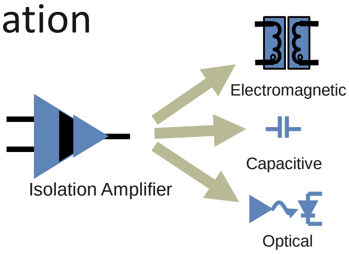
- Filtering



- Attenuation



- Isolation



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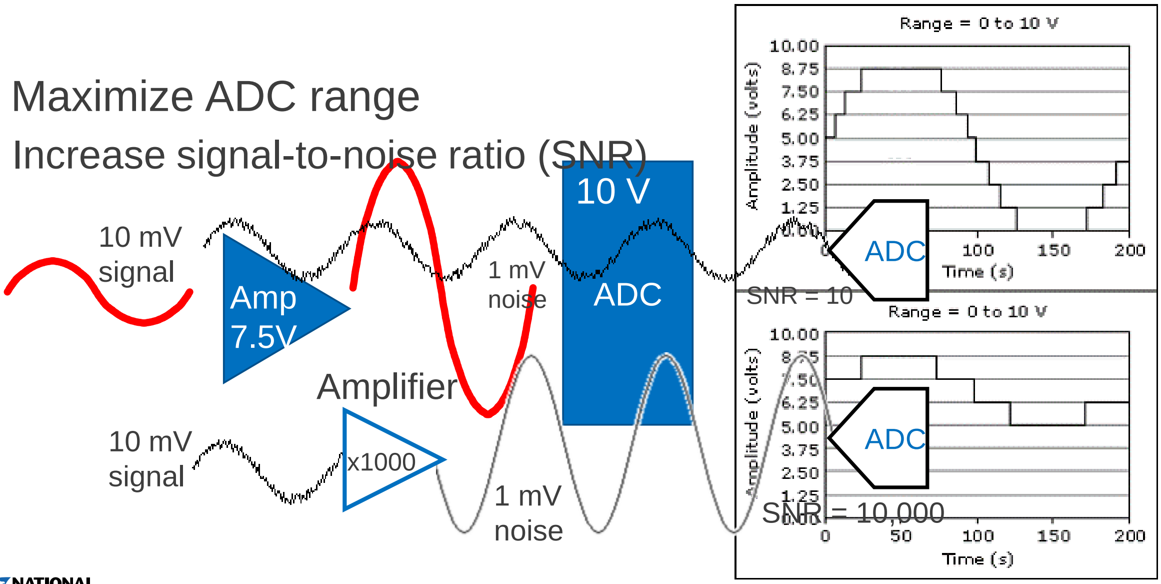
Amplification

- Maximize ADC range
- Increase signal-to-noise ratio (SNR)



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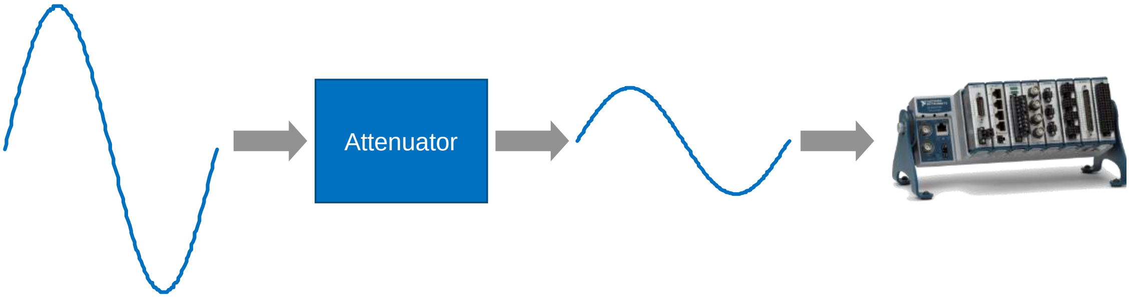
Attenuation

Brings signal into DAQ device range.



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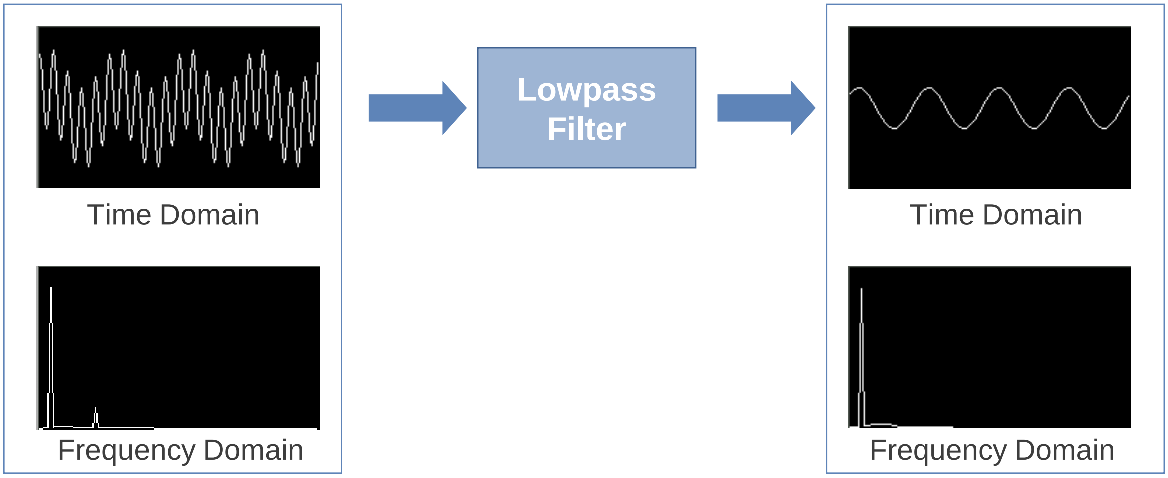
Filtering

Removes noise and unwanted frequencies



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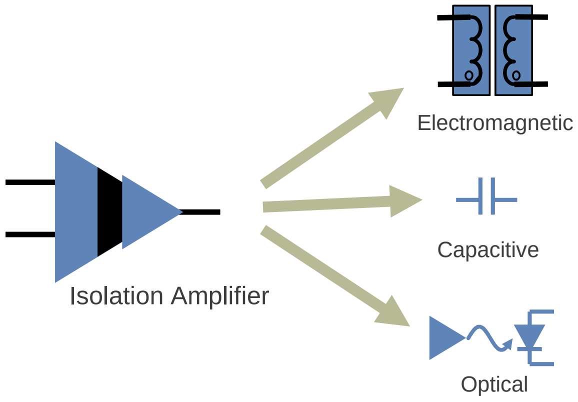
Isolation

Disconnects the signal from the internal DAQ circuitry.



Electromagnetic

Capacitive

Isolation Amplifier

Optical

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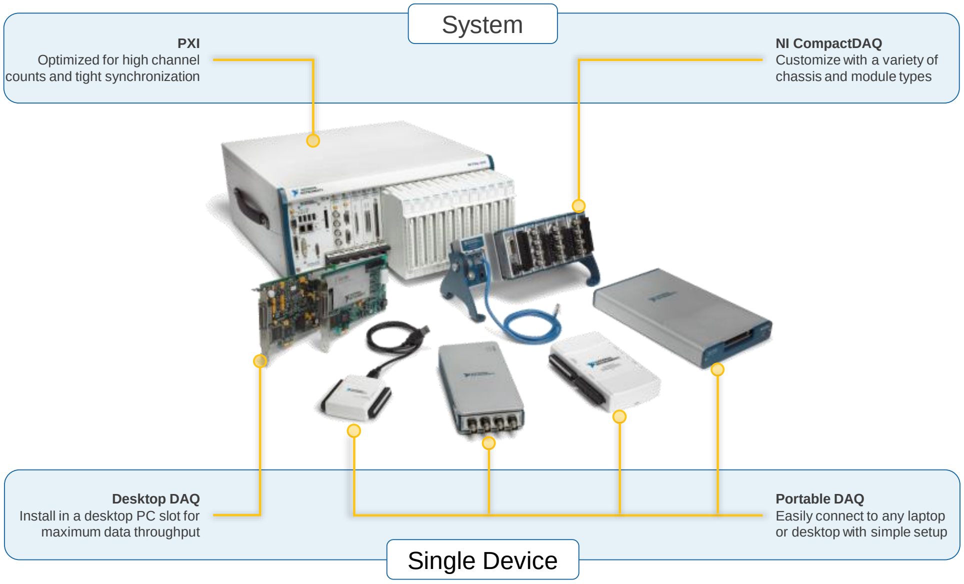
Measurement Device

NI Data Acquisition Hardware Families



System

PXI
Optimized for high channel counts and tight synchronization

NI CompactDAQ
Customize with a variety of chassis and module types

Desktop DAQ
Install in a desktop PC slot for maximum data throughput

Portable DAQ
Easily connect to any laptop or desktop with simple setup

Single Device

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Sampling and Timing

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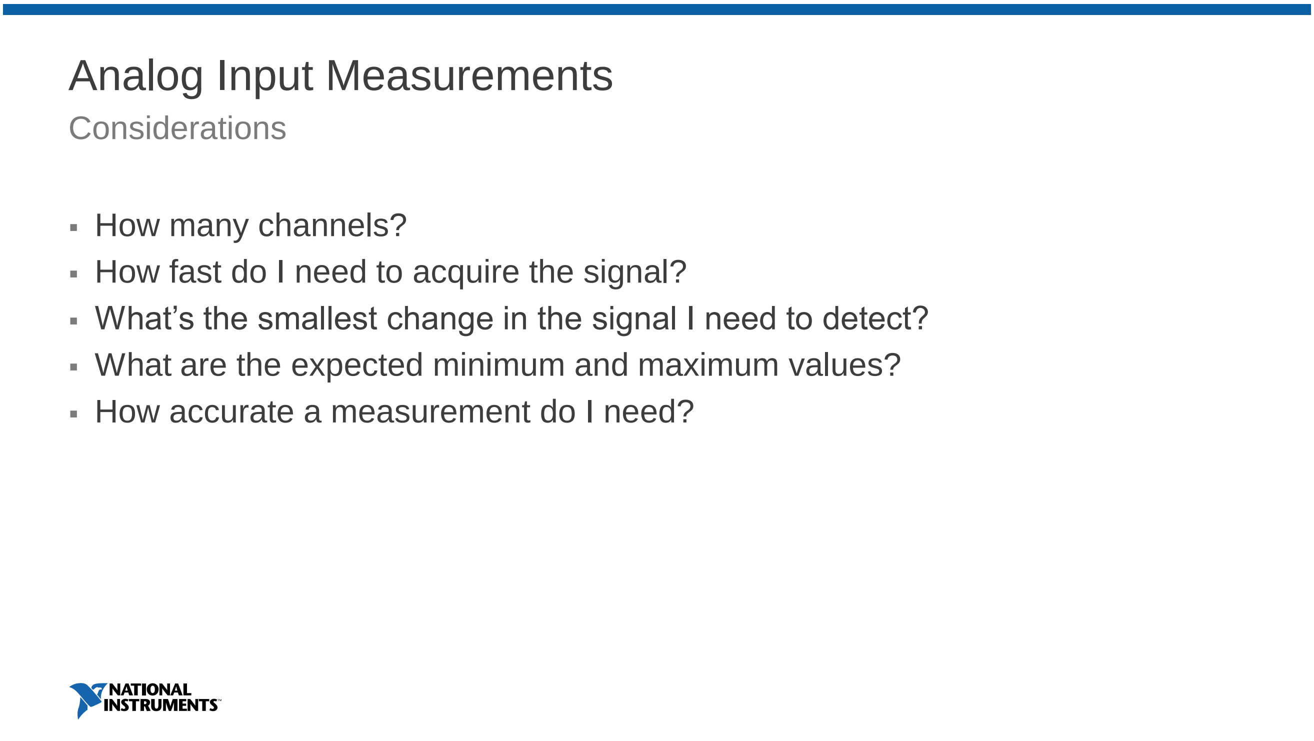

Analog Input Measurements

Considerations

- How many channels?
- How fast do I need to acquire the signal?
- What’s the smallest change in the signal I need to detect?
- What are the expected minimum and maximum values?
- How accurate a measurement do I need?

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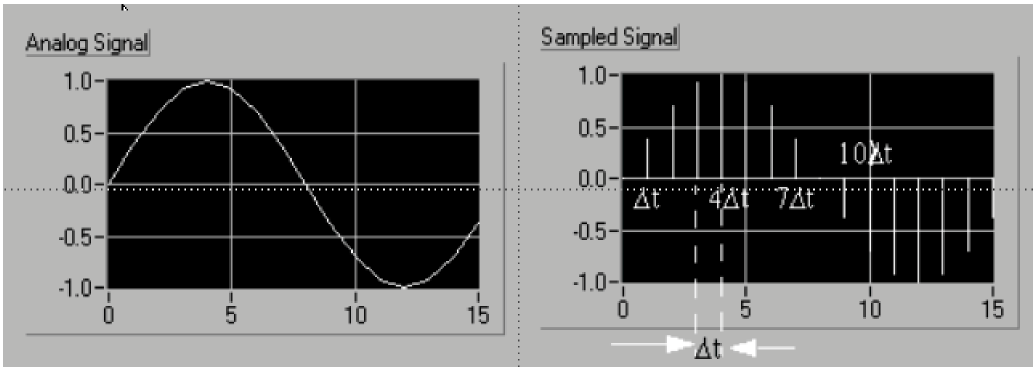
How Fast do I Need to Acquire the Signal?

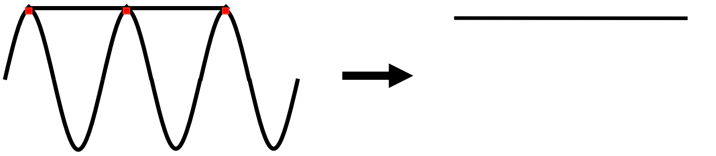
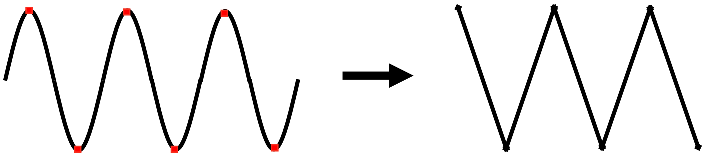
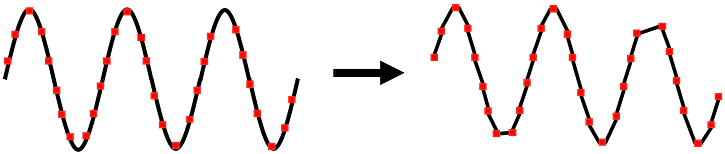


Sample rate is the frequency at which the ADC converts the signal to samples.

The Nyquist Theorem

- You must sample at greater than 2 times the maximum frequency component of your signal to accurately represent the **frequency** of your signal.
- You must sample between 5–10 times greater than the maximum frequency component of your signal to accurately represent the **shape** of your signal.

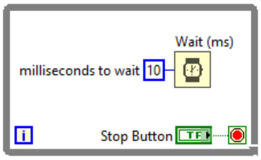
The Nyquist Theorem and Sample Rate

 100Hz Sine Wave → Sampled at 100Hz	Aliased Signal
 100Hz Sine Wave → Sampled at 200Hz	Adequately Sampled for **Frequency Only** (Same # of cycles)
 100Hz Sine Wave → Sampled at 1kHz	Adequately Sampled for **Frequency and Shape**

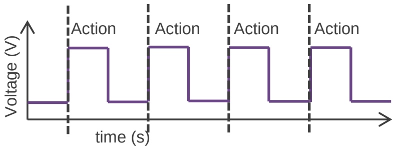
Timing

Two types of timing can be used to control when data samples are acquired (or generated):

Software timing: the application software controls when data is acquired or generated



Hardware timing: a digital signal controls when data is acquired or generated



Acquisition Modes

On Demand: The device produces a requested sample when prompted by a software acquisition request.

Finite Samples: The DAQ device acquires samples at a specified rate until it reaches the number of total requested samples, and then stops acquiring and sends the data to the computer.

Continuous Samples: The DAQ device acquires samples at a specified rate and sends blocks of samples to the computer when requested, until it receives a command to stop acquiring or encounters an error condition.

Hardware-Timed Single Point (HWTSP): The computer acquires data points one at a time from the DAQ device while the device runs off of a sample clock.

Hardware-Timed

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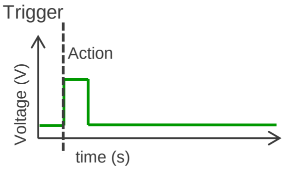
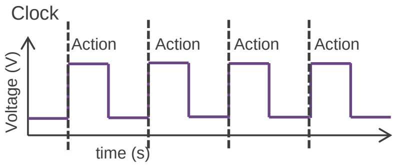
Clocks & Triggers

Triggers are digital signals that can be used to cause NI-DAQmx to perform an action



Clocks are a specific type of periodic digital signal that is used to trigger a DAQ device to perform actions at evenly distributed points in time



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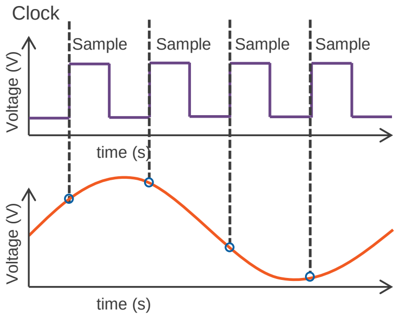
Clocks & Triggers

Sample Clock

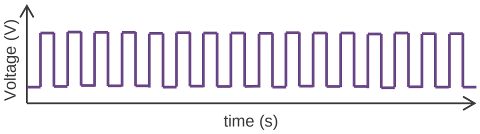
Sample Clocks are clocks that are used to determine when a signal is sampled (or generated)



Clocks & Triggers

Clocks are generated by dividing down from an onboard timebase, usually an electronic oscillator.

An electronic oscillator is a circuit that produces a periodic, oscillating electronic signal



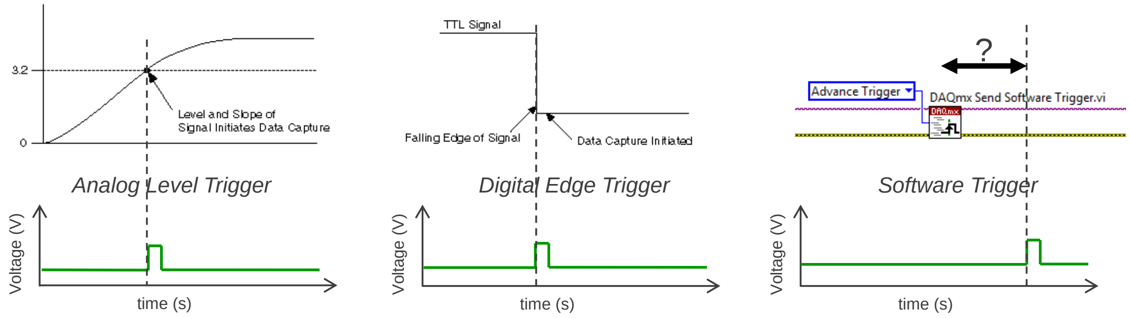
1 MHz quartz crystal electronic oscillator

NI DAQ devices usually have either a 20 MHz, 80 MHz, or 100 MHz oscillator onboard as the master timebase

Clocks & Triggers

Triggers

- can be used to cause other actions, such as starting, stopping, or pausing acquisition
- can be generated by analog, digital, or software events



Analog Level Trigger

Digital Edge Trigger

Software Trigger

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NI-DAQmx

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What is NI-DAQmx?

- NI-DAQmx is free driver software.
- It can be used in conjunction with several different programming languages to control thousands of different NI data acquisition devices with a consistent API (Application Programming Interface).

Download the Latest Version of NI-DAQmx

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Devices Supported by NI-DAQmx

- Academic devices:
  - NI myDAQ
  - NI ELVIS II
  - NI ELVIS II+
- CompactDAQ
- CompactRIO 904x, 905x
- X Series DAQ
- Digital I/O
- C Series, Network DAQ, and USB DAQ

. . .

and many more (complete list can be found in the NI-DAQmx Readme)

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What if I’m Using NI myRIO or NI ELVIS III?

- NI myRIO and NI ELVIS III are not supported by NI-DAQmx.
- Students can create NI-DAQmx simulated devices that behave similarly to real devices.
- Simulated devices can be used to develop and run an application without the data acquisition hardware present in the machine.

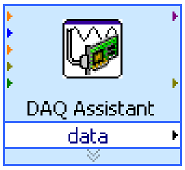
Tutorial: How to create an NI-DAQmx simulated device?

Three Ways to Connect with a DAQ Device

NI MAX

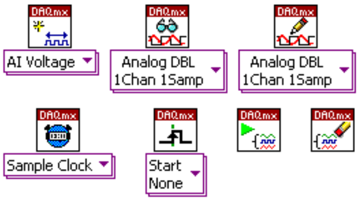
NI MAX lets you quickly test the connection to your DAQ device and configure the hardware.

DAQ Assistant Express VI



DAQ Assistant Express VI is a graphical interface for interactively creating, editing, and running NI-DAQmx virtual channels and tasks.

DAQmx API



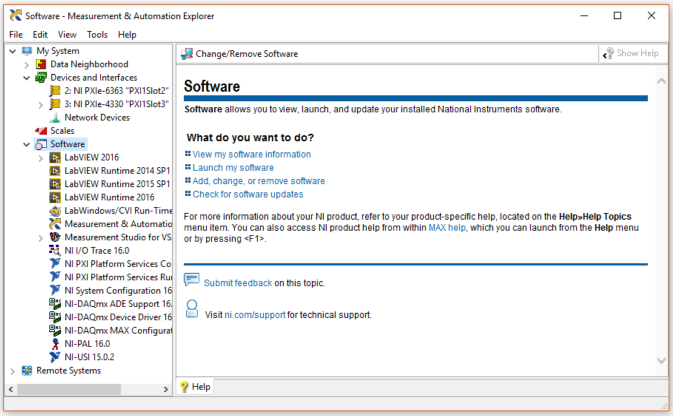
The LabVIEW DAQmx VIs let you control your hardware with finer options than the DAQ Assistant Express VI.

NI Measurement and Automation Explorer (MAX)

Measurement and Automation Explorer (MAX) is an application that installs automatically with the NI-DAQmx driver (and other NI software). MAX informs other programs which devices you have in your system and how they are configured.

You can use MAX to create NI-DAQmx Simulated Devices and build applications without hardware installed.

Learn More



Software

Software allows you to view, launch, and update your installed National Instruments software.

What do you want to do?

- View my software information
- Launch my software
- Add, change, or remove software
- Check for software updates

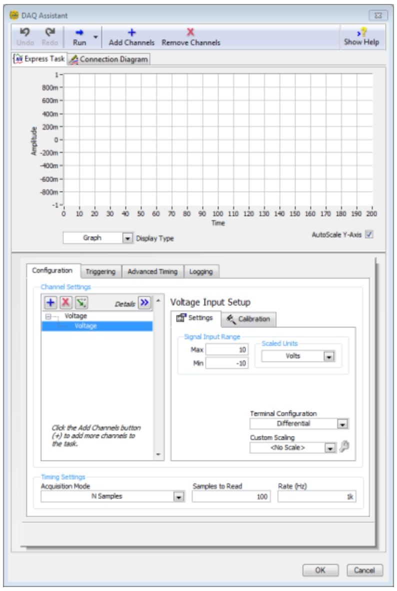
For more information about your NI product, refer to your product-specific help, located on the **Help»Help Topics** menu item. You can also access NI product help from within MAX help, which you can launch from the **Help** menu or by pressing <F1>.

Submit feedback on this topic.

Visit ni.com/support for technical support.

DAQ Assistant Express VI

- The DAQ Assistant is a configuration-based interface for controlling your DAQ instruments
- You can configure things like:
  - Channels
  - Voltage ranges
  - Sampling rate
  - …and many other aspects of your measurement



Display Type: Graph

AutoScale Y-Axis ☑

Signal Input Range: Max 10, Min -10

Scaled Units: Volts

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

Terminal Configuration: Differential

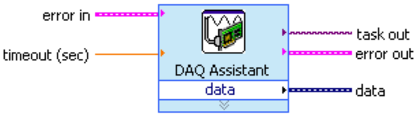
Custom Scaling: <No Scale>

Timing Settings

Acquisition Mode: N Samples

Samples to Read: 100

Rate (Hz): 1k



NI-DAQmx API

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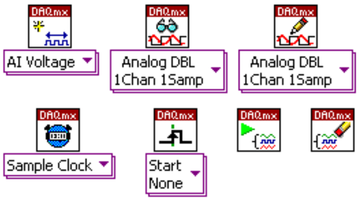
DAQmx API

DAQmx includes an Application Programming Interface (API), which is a library of VIs, functions, classes, attributes, and properties for creating applications for your DAQ device.

DAQmx LabVIEW API



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DAQmx Core Concepts

Physical Channel

Terminal or pin at which you can measure or generate an analog or digital signal.

Virtual Channel

Contains the physical channel and other channel-specific information.

Task

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

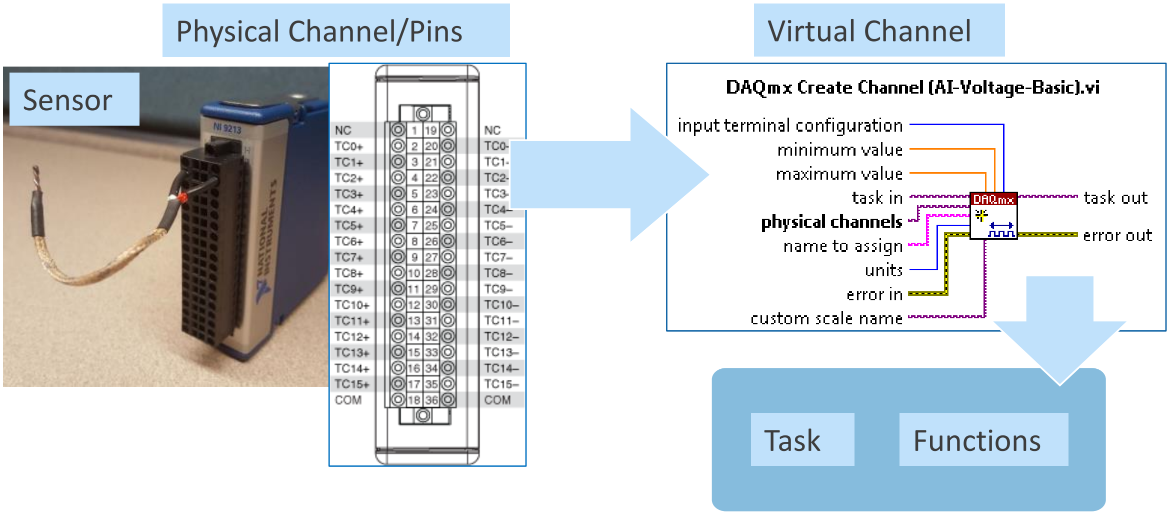
Functions

Performs a specific function in DAQmx.

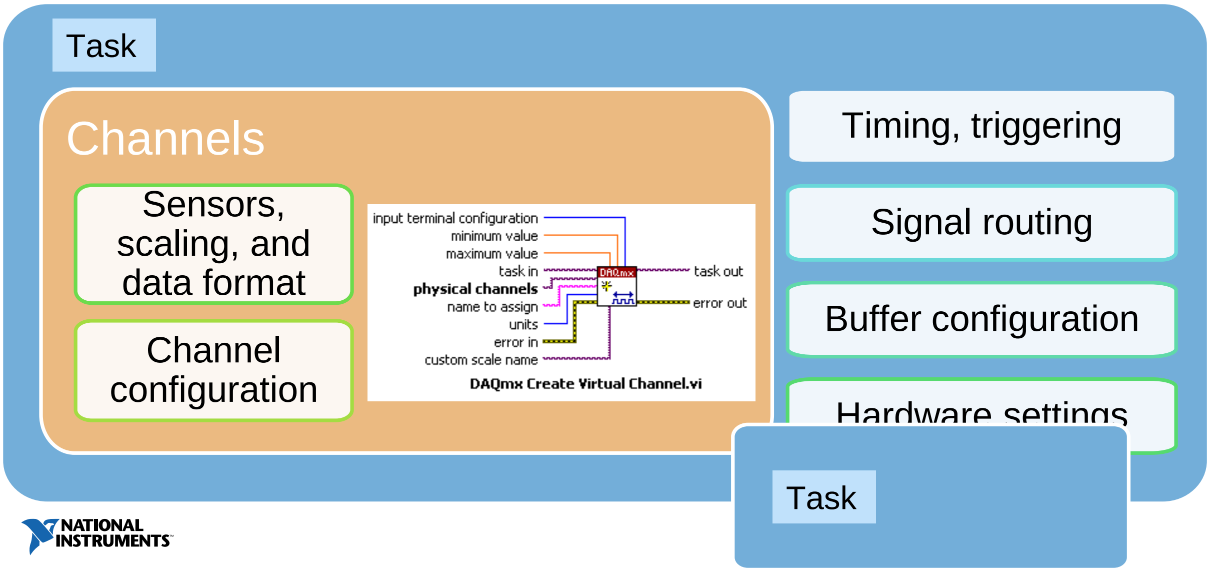
Properties

Control or set specific properties of your DAQmx session.

Physical Channel vs Virtual Channel



DAQmx Task



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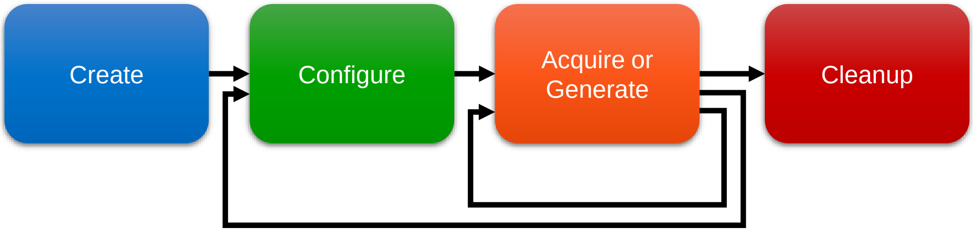
DAQmx Programming Model



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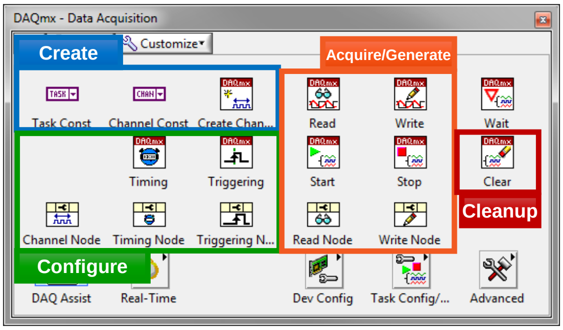
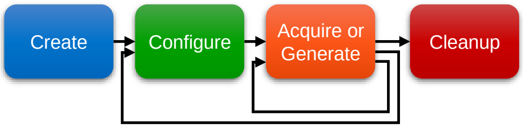
Primary DAQmx VI Palette





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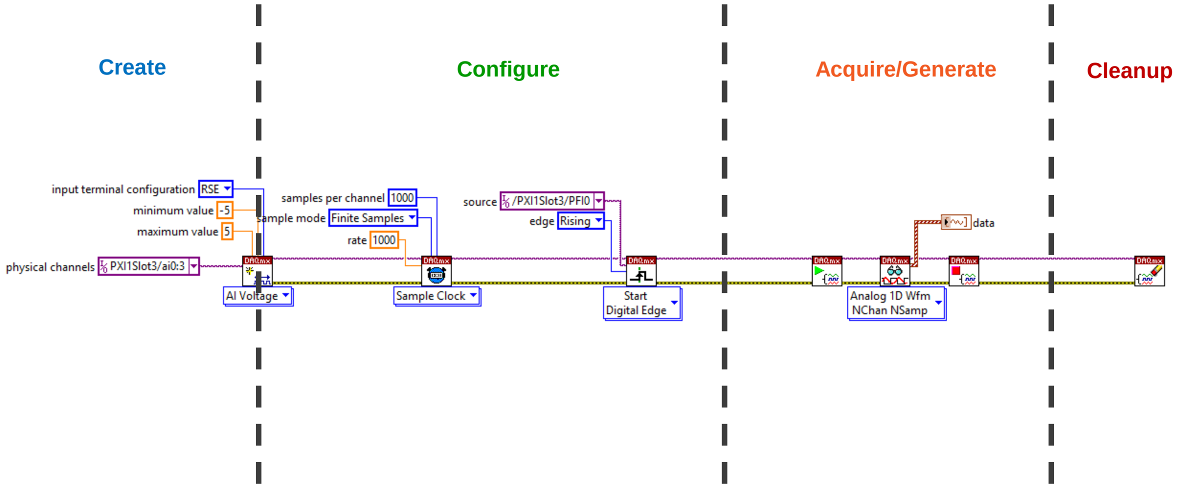
DAQmx Application



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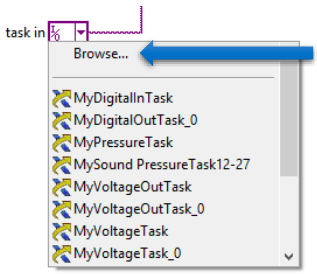
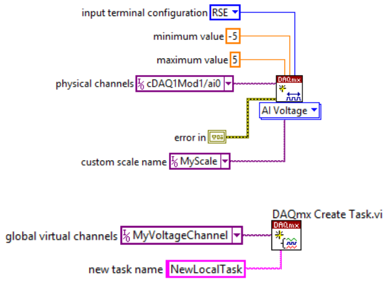
Essential DAQmx Functions

Task and Channel Creation using the API occurs in one of two ways:



Browse will allow you to create a new one using DAQ Assistant, select multiple channels, or to navigate more easily



Select a global task or channel from a task or channel control dropdown

Create a local task or channel with a DAQmx VI

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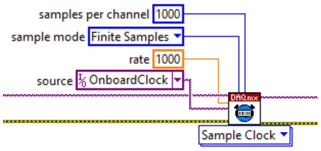
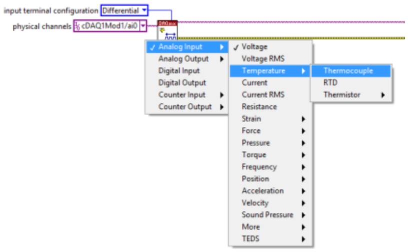
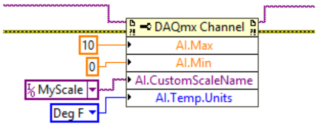
Essential DAQmx Functions

Configuration using the API occurs in one of three ways:







Input terminals on DAQmx VIs

Polymorphic VI Selectors

DAQmx Property Nodes

NATIONAL INSTRUMENTS

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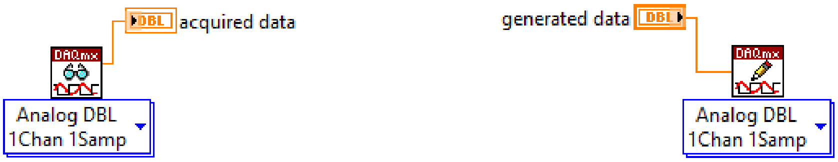
Essential DAQmx Functions

Acquisition and Generation using the API occurs in one way:



DAQmx Read and Write VIs

NATIONAL INSTRUMENTS

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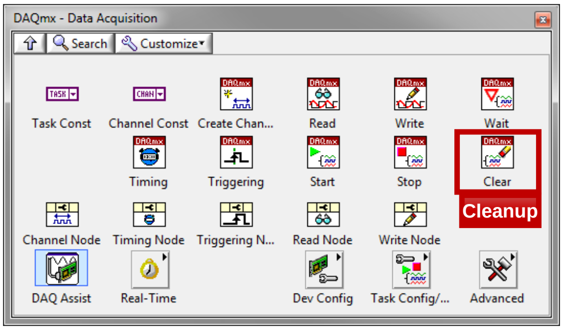
Essential DAQmx Functions

Cleanup using the API occurs by using the Clear Task VI:



NATIONAL INSTRUMENTS

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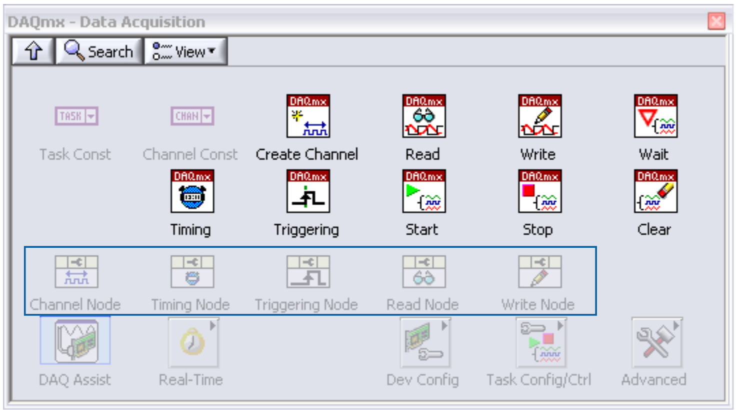
10 Functions to Handle 80% of your Data Acquisition Applications

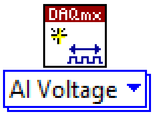


NATIONAL INSTRUMENTS

Create Virtual Channel

NI-DAQmx Create Virtual Channel

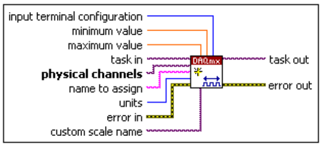
Create



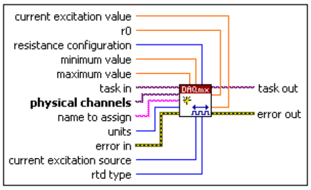
DAQmx Create Virtual Channel

- Creates a local virtual channel and places it into a task
- I/O Type and Measurement Type selected Polymorphically
- Channel Properties selected with input terminals to the VI (or property nodes) DAQmx Channel AI.Max
- A task can be wired from Create Virtual Channel to Create Virtual Channel to add multiple channels to a single task

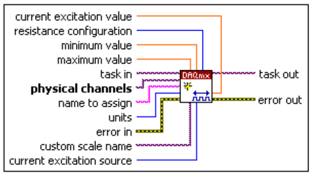
Voltage



Temperature



Resistance



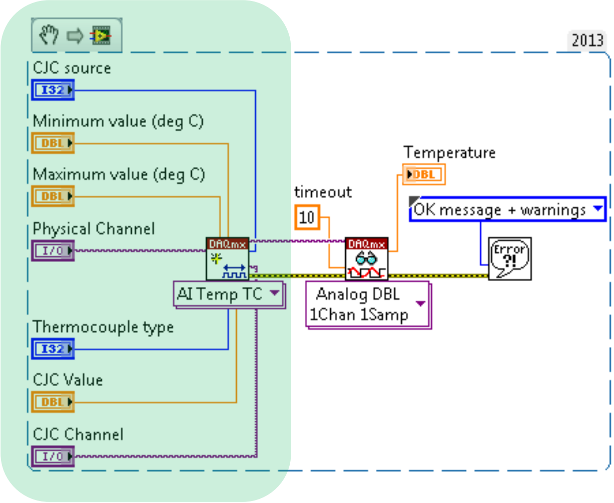
NATIONAL INSTRUMENTS

Create Virtual Channel

NI-DAQmx Create Virtual Channel

Create

NI-DAQmx Create Virtual Channel VI is used to create a thermocouple virtual channel.

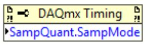


Timing

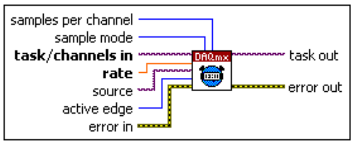
NI-DAQmx Timing

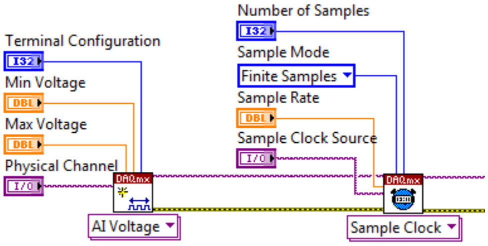
Configure

DAQmx Timing

- Configures the sample clock timing settings for a task
- "Acquisition Mode" from DAQ Assistant is a compilation of Sample Mode and Sample Timing Type properties that must be individually adjusted in the API
- Timing Settings selected with input terminals to the VI (or property nodes)
- Timing Type selected Polymorphically (no Timing VI = On Demand) 

Sample Clock



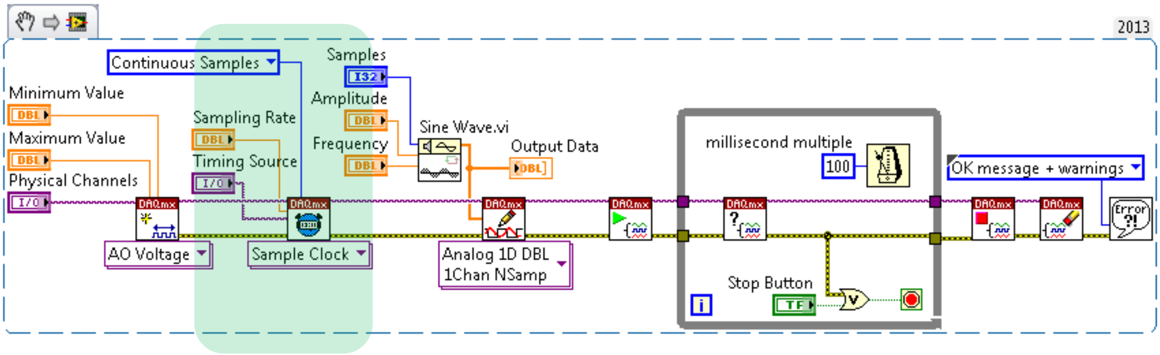


Timing

Configure

NI-DAQmx Timing

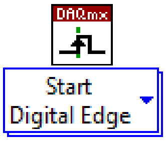
The following LabVIEW block diagram demonstrates the use of the Sample Clock instance of the NI-DAQmx Timing VI to configure a continuous analog output generation with an external sample clock.



Trigger

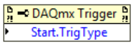
Configure

NI-DAQmx Trigger

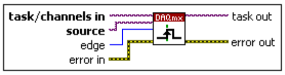


DAQmx Triggering

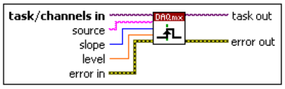
- Configures the triggering settings for a task
- Trigger Type selected Polymorphically (tasks default to implicit trigger at Start)
- Trigger settings selected with input terminals to the VI (or property nodes)



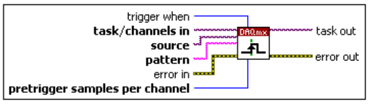
Start Digital Edge



Start Analog Edge



Reference Digital Pattern

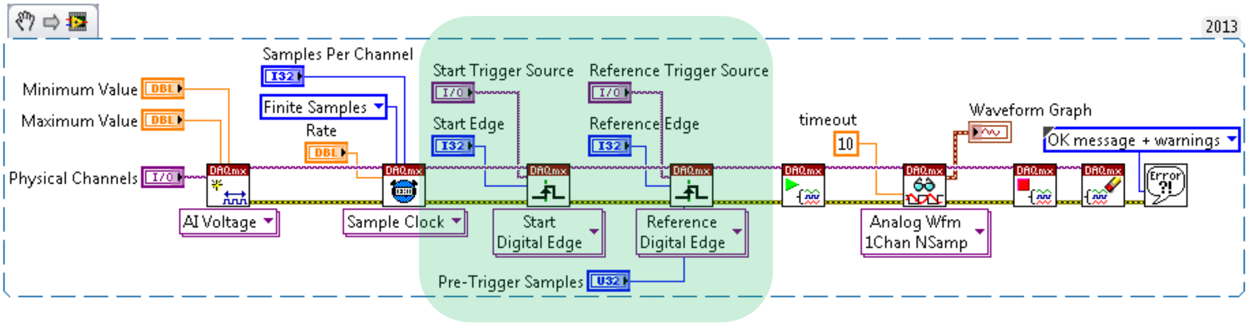


Trigger

Configure

NI-DAQmx Trigger

In the following LabVIEW block diagram, both a start trigger and a reference trigger are configured, using the NI-DAQmx Trigger VI, to occur on digital edges for an analog input operation.

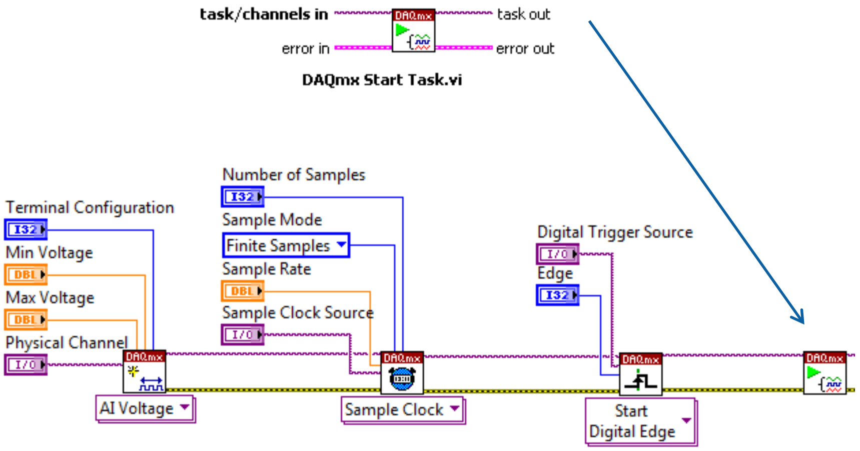


Start Task

Acquire or Generate

NI-DAQmx Start Task

Starts your task. The task is now in the running state.

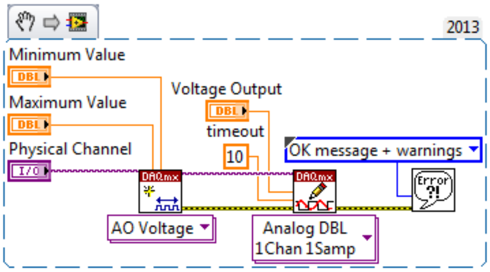


Start Task

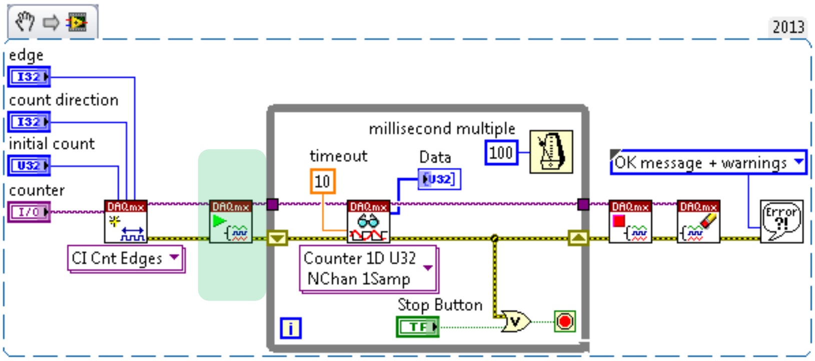
NI-DAQmx Start Task

Acquire or Generate

The following LabVIEW block diagram demonstrates a situation where the NI-DAQmx Start function does not need to be used because the analog output generation only consists of a single, software-timed sample.



Conversely, the following LabVIEW block diagram demonstrates a situation where the NI-DAQmx Start function should be used because the NI-DAQmx Read function is executed multiple times to read from the counter.



NATIONAL INSTRUMENTS

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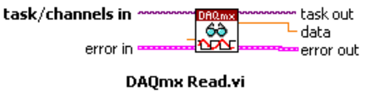
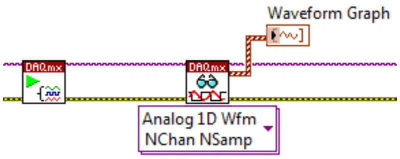
Read

NI-DAQmx Read

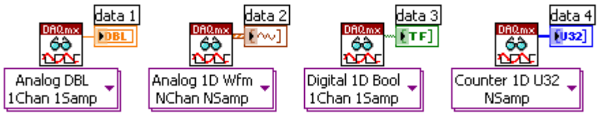
Acquire or Generate

Reads samples from the acquisition task.





Start your task and read data



The Read function adapts to different data types and channel counts

NATIONAL INSTRUMENTS

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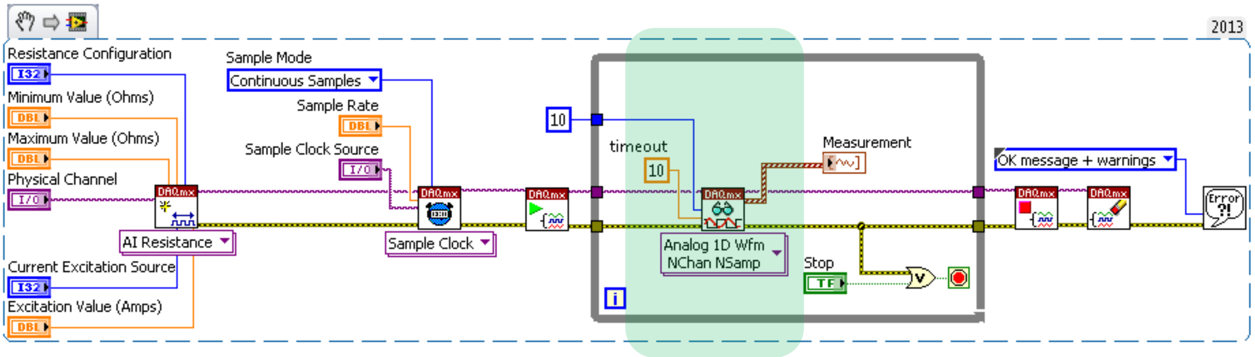
Read

Acquire or Generate

NI-DAQmx Read

In the following LabVIEW block diagram, the NI-DAQmx Read VI has been configured to read multiple samples from multiple analog input virtual channels and return the data as waveforms. Furthermore, since the number of samples per channel input has been wired to a constant value of 10, each time the VI executes it will read 10 samples from each virtual channel.



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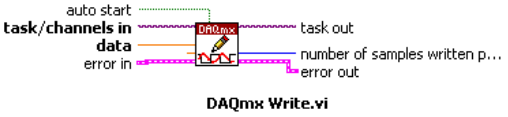
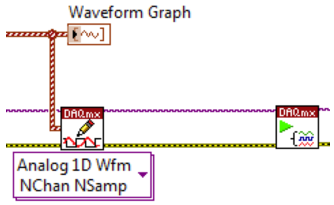
Write

Acquire or Generate

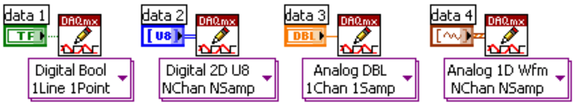
NI-DAQmx Write

Writes samples to the generation task.





Write data, then start your task


data 1
TF
DAQmx
Digital Bool 1Line 1Point
data 2
U8
Digital 2D U8 NChan NSamp
data 3
DBL
Analog DBL 1Chan 1Samp
data 4
Analog 1D Wfm NChan NSamp

The Read function adapts to different data types and channel counts

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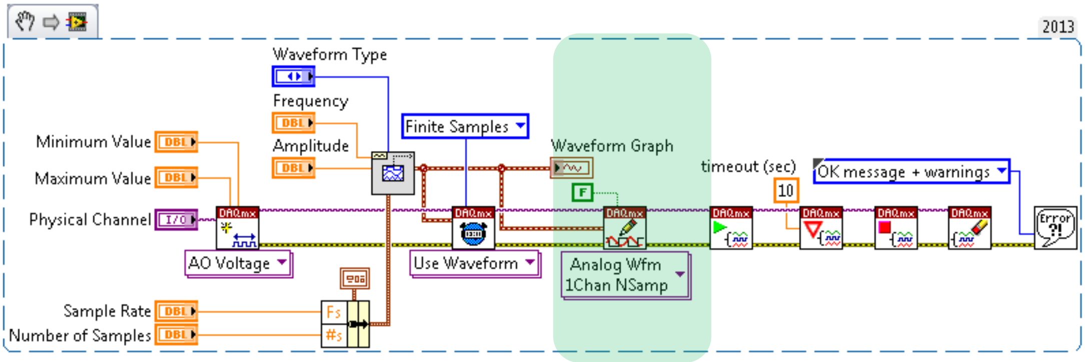
Write

Acquire or Generate

NI-DAQmx Write

The following LabVIEW block diagram, for a finite analog output generation, includes a "False" Boolean constant wired to the auto start input of the NI-DAQmx Write VI because the generation is hardware-timed. The NI-DAQmx Write VI has been configured to write multiple samples of analog output data for one channel to the task as an analog waveform.

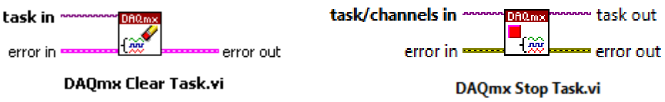


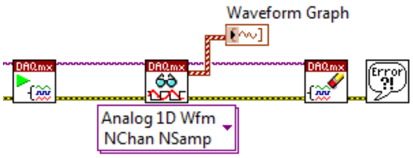
Clear Task

Cleanup

NI-DAQmx Clear Task

Clears the task, and releases all of the resources. If the task needs to be reused, use **Stop Task** instead.





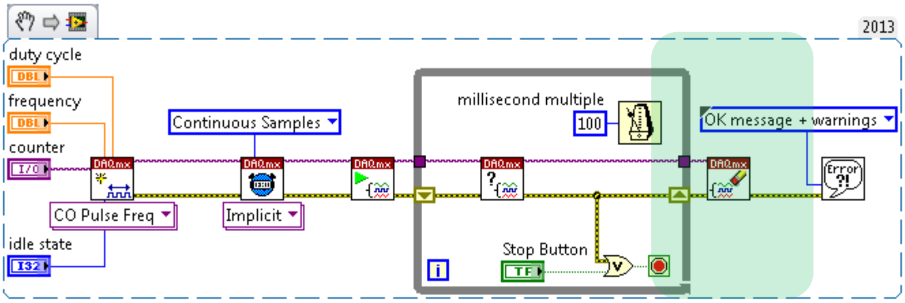
After the DAQmx read, clear the task.

Clear Task

Cleanup

NI-DAQmx Clear Task

In the following LabVIEW block diagram, a continuous pulse train is being generated with a counter. The pulse train continues to be output until the While Loop is exited and the NI-DAQmx Clear Task VI executes.



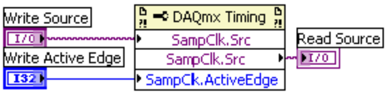
Properties

NI-DAQmx Properties

Access all of the properties associated with DAQmx. Properties can by written to or read.

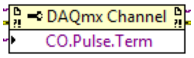
DAQmx Timing

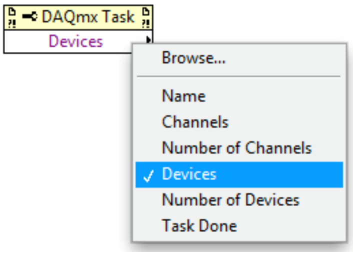
Query the actual sample rate



DAQmx Channel

Specify which terminal pules

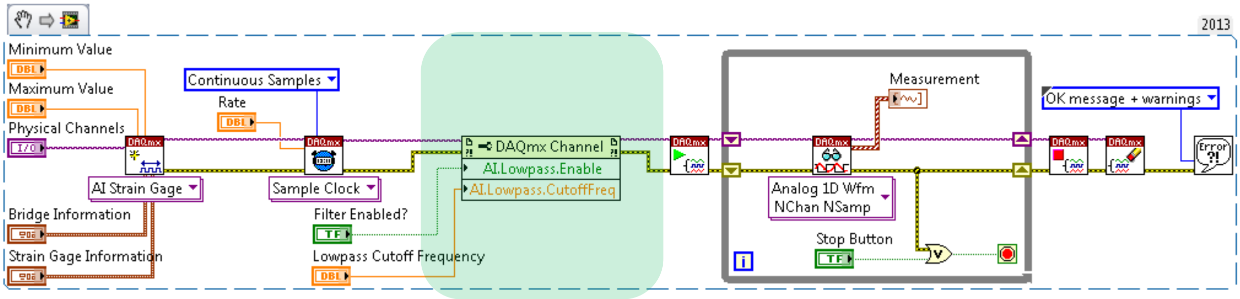




Properties

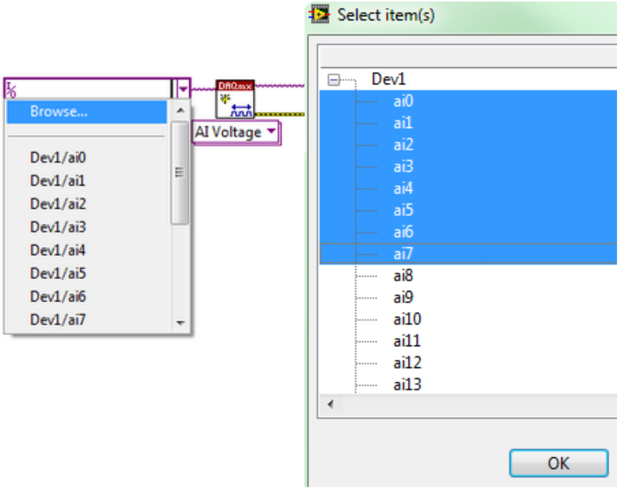
NI-DAQmx Properties

In the following LabVIEW block diagram, an NI-DAQmx Channel Property Node is used to enable the hardware lowpass filter and then set the filter cutoff frequency for use with a strain gage measurement.

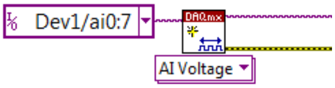


Other DAQmx Considerations

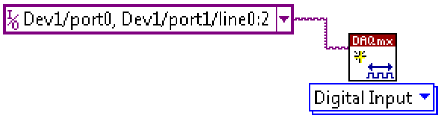
Selecting More than One Channel on a Device



Use colon between channel numbers



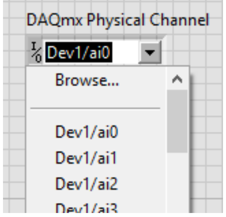
Use comma between channel numbers



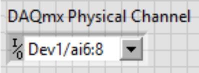
Other DAQmx Considerations

Selecting More than One Channel on a Device

- Channels are zero-indexed
  - Example: This is:
    - 1st Channel
    - of Analog Input
    - on Device 1

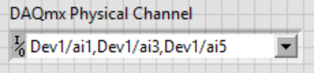


- Range (continuous) indicated by ":"



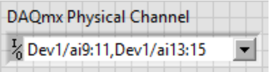
7th, 8th, 9th

- List (discontinuous) indicated by ","



2nd, 4th, 6th

- Mix Range & Lists is allowed



10th, 11th, 12th, 14th, 15th, 16th

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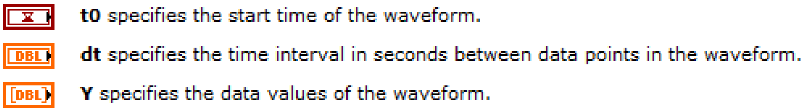
Other DAQmx Considerations

Waveforms

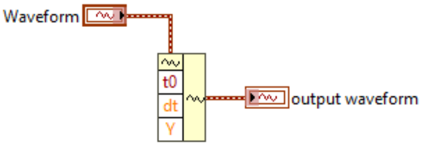
Waveforms are a data type consisting of cluster of three values used to represent evenly-distributed samples



t0 specifies the start time of the waveform.

dt specifies the time interval in seconds between data points in the waveform.

Y specifies the data values of the waveform.



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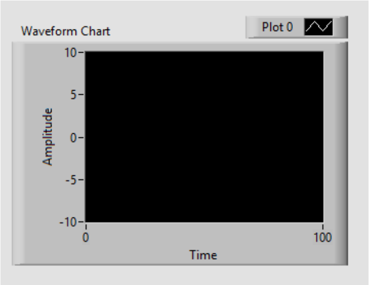
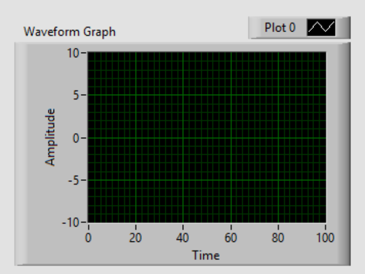
Other DAQmx Considerations

Charts vs Graphs





Charts have an array in the background that is used to save the last X values that were sent into it.

Graphs display only whatever data was written most recently.

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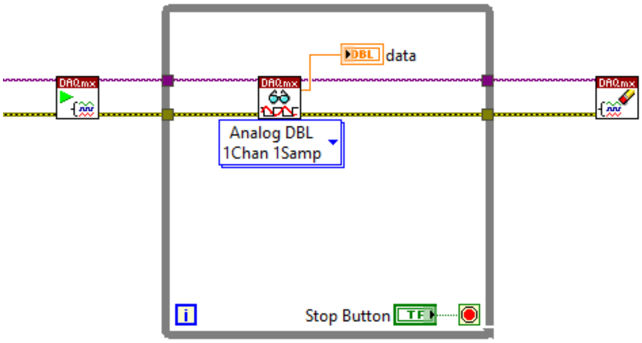
Other DAQmx Considerations

Error Handling

Error handling: What would happen if we got a DAQmx Read error here?



NATIONAL INSTRUMENTS

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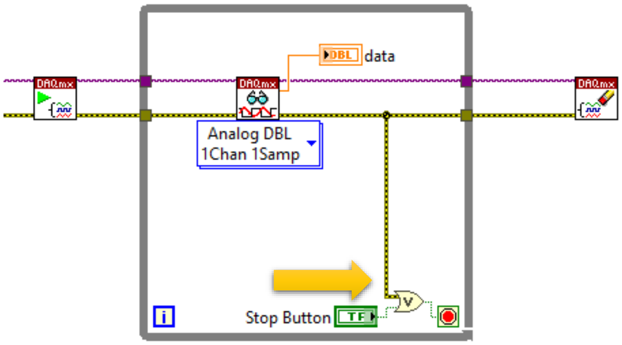
Other DAQmx Considerations

Error Handling

Error handling: Including error handling will help with troubleshooting

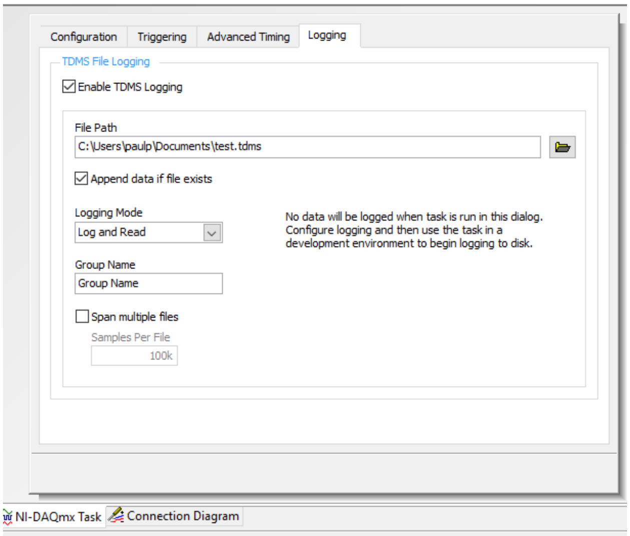


Other DAQmx Considerations

Logging and Writing Data

DAQmx includes functionality for logging data directly to a TDMS file.

This functionality can be implemented in both DAQ Assistant and in LabVIEW using the DAQmx Configure Logging VI.



TDMS File Logging

☑ Enable TDMS Logging

File Path: C:\Users\paulp\Documents\test.tdms

☑ Append data if file exists

Logging Mode: Log and Read

Group Name: Group Name

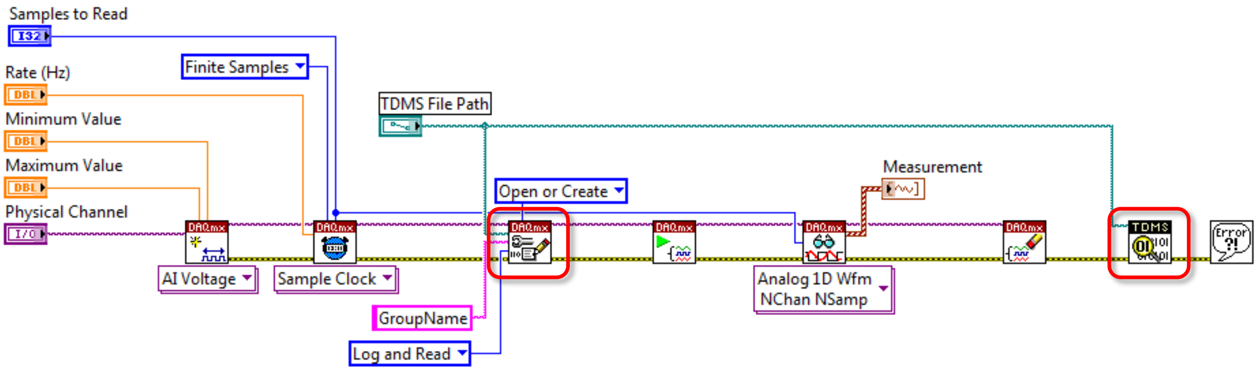
☐ Span multiple files

Samples Per File: 100k

No data will be logged when task is run in this dialog. Configure logging and then use the task in a development environment to begin logging to disk.

Other DAQmx Considerations

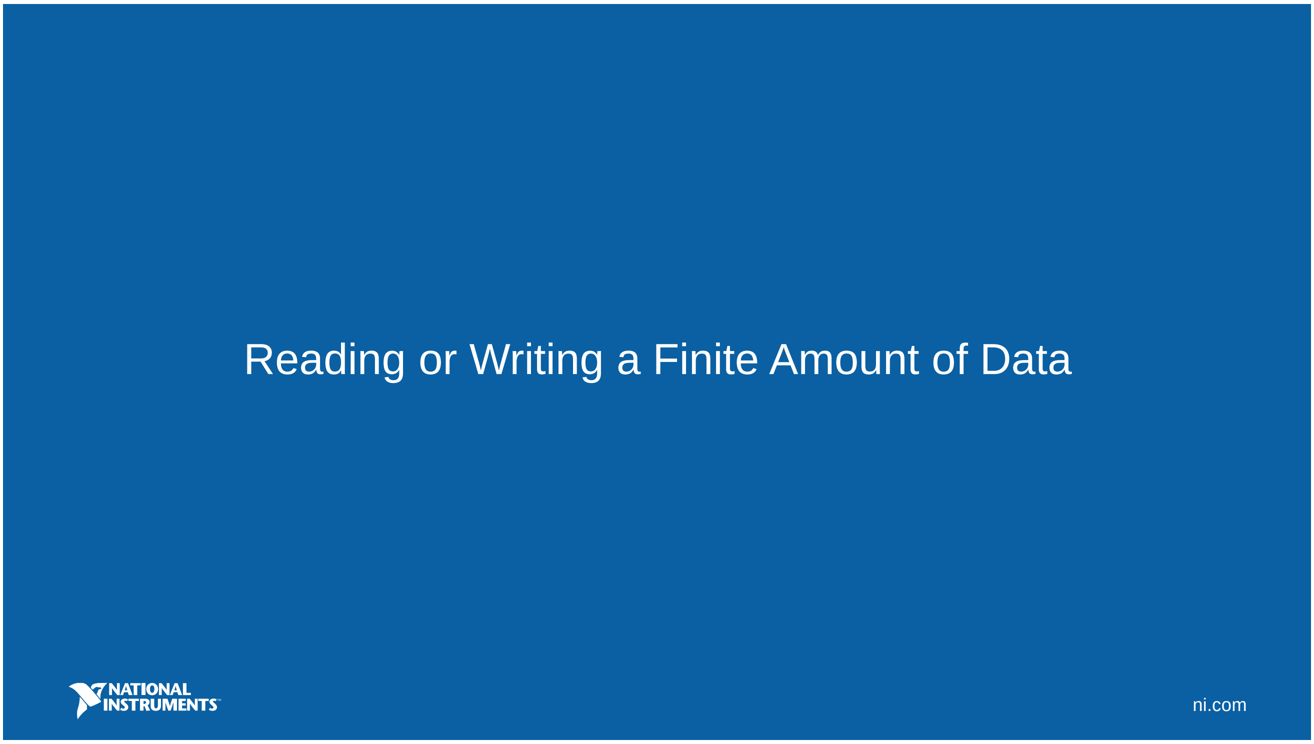
Set Up Data Logging in the DAQmx Task



DAQmx Reference Materials

There are extensive resources for quick research into DAQ issues that customers can access to learn and build DAQmx knowledge:

- NI Example Finder
- DAQmx API in LabVIEW Help
- DAQmx Help (in MAX)
- Specifications Sheets and User Guides



Reading or Writing a Finite Amount of Data

ni.com

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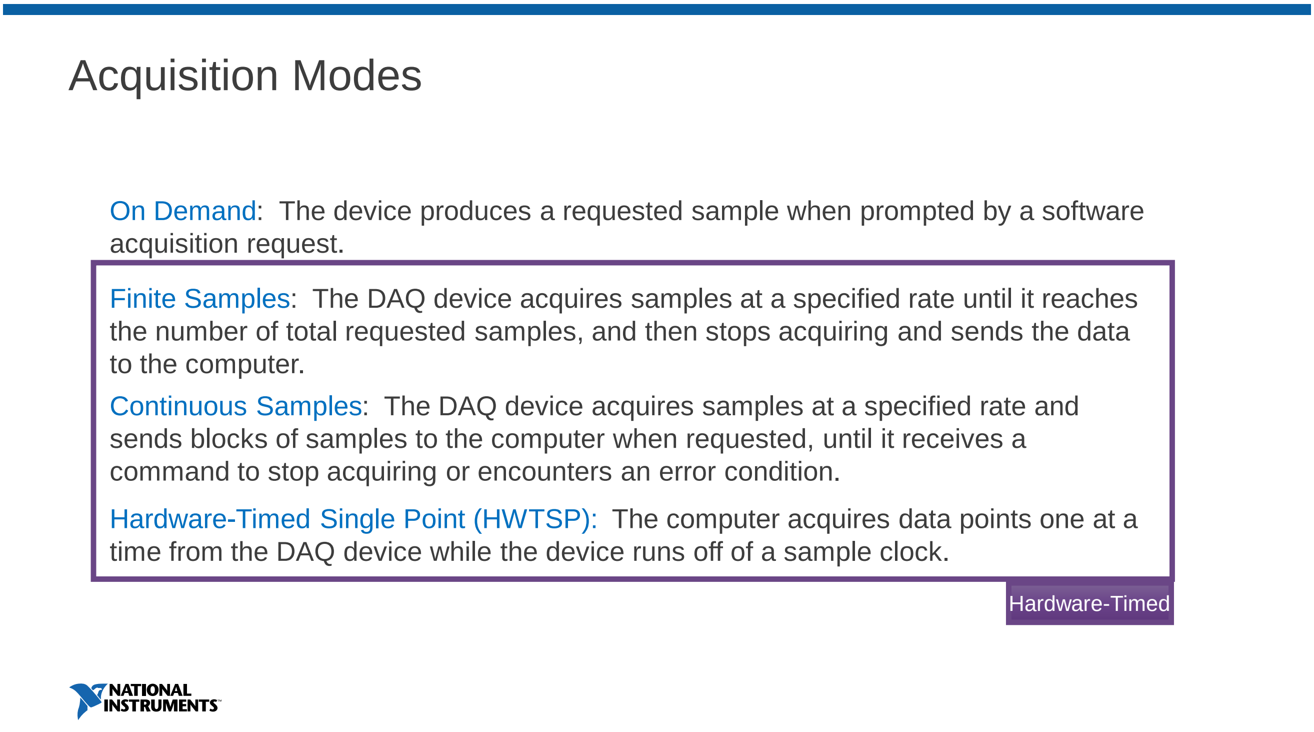

Acquisition Modes

On Demand: The device produces a requested sample when prompted by a software acquisition request.

Finite Samples: The DAQ device acquires samples at a specified rate until it reaches the number of total requested samples, and then stops acquiring and sends the data to the computer.

Continuous Samples: The DAQ device acquires samples at a specified rate and sends blocks of samples to the computer when requested, until it receives a command to stop acquiring or encounters an error condition.

Hardware-Timed Single Point (HWTSP): The computer acquires data points one at a time from the DAQ device while the device runs off of a sample clock.

Hardware-Timed

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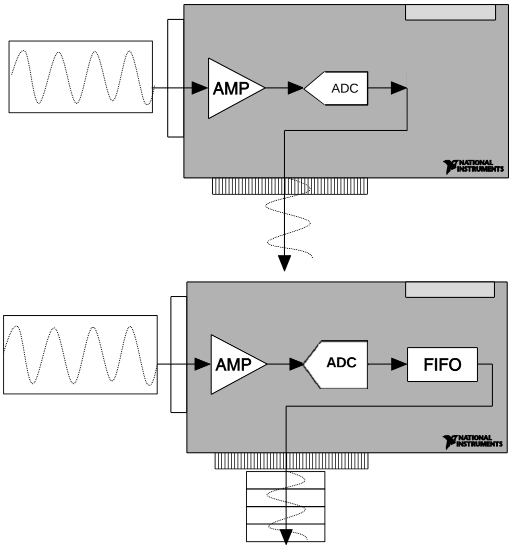
Reading or Writing a Finite Amount of Data

Two Approaches to Finite Data Transfer

Single-Point

Buffered



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Reading or Writing a Finite Amount of Data

Point-By-Point Transfer

Read/write one value at a time

- Measure the current temperature
- Set the target speed for a fan

Use a For Loop with a timing function to use point-by-point transfers for multiple samples

- Ramp the output from one value to another over a fixed period of time
- Acquire a fixed number of samples and perform a calculation

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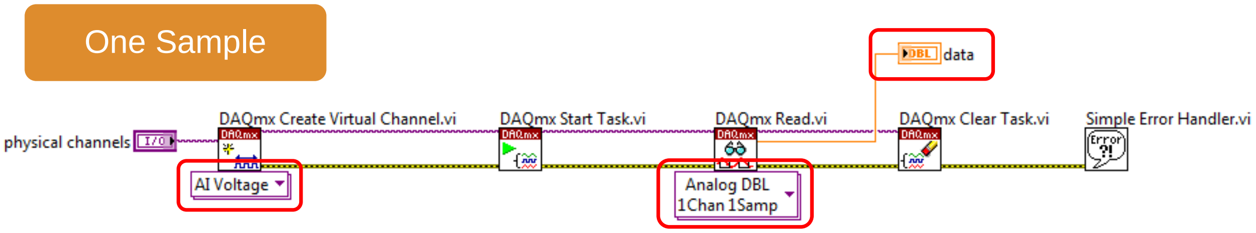
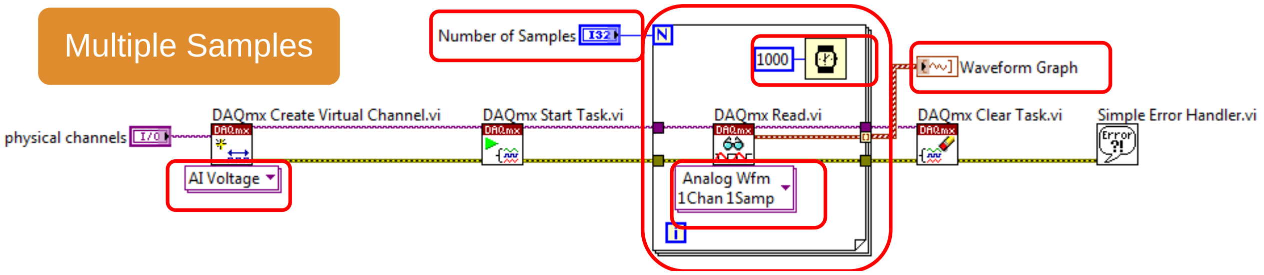
Reading or Writing a Finite Amount of Data

Acquiring Data Point-by-Point

One Sample



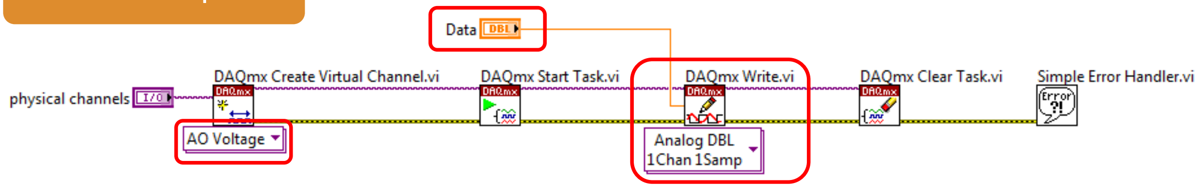
Multiple Samples



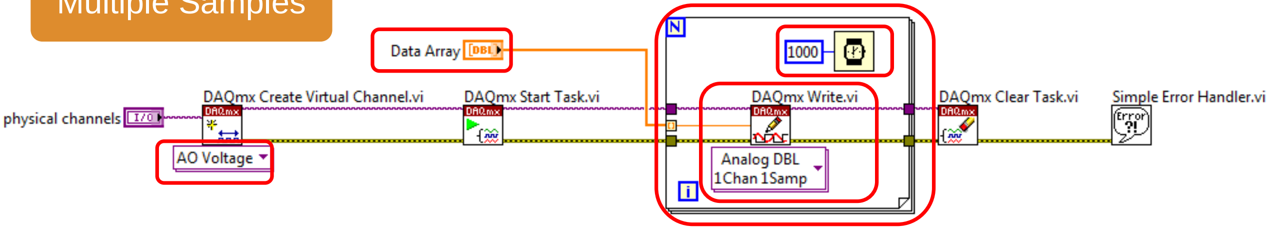
Reading or Writing a Finite Amount of Data

Generating Data Point-by-Point

One Sample



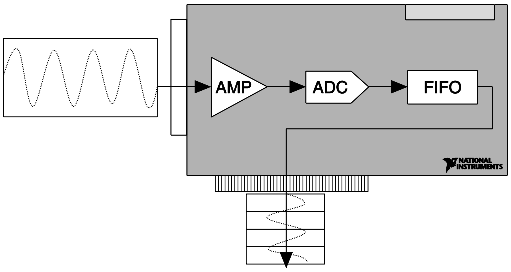
Multiple Samples



Reading or Writing a Finite Amount of Data

Buffered Transfer

- Uses a buffer to temporarily store the samples to read or write
- Transfers multiple data points to/from the DAQ device at a time
- Enables faster transfer than a loop with a timing function



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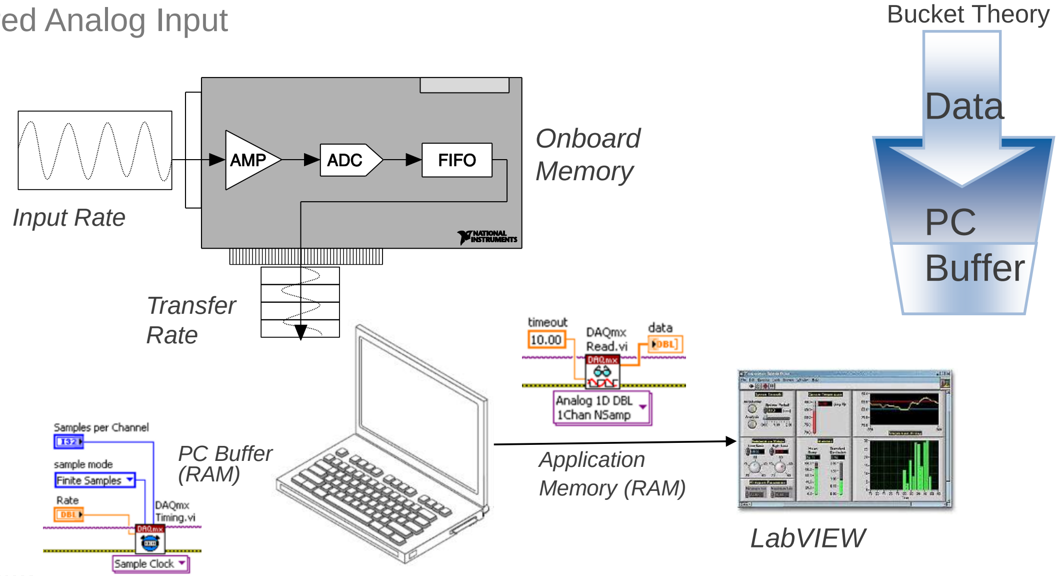
Reading or Writing a Finite Amount of Data

Buffered Analog Input


Bucket Theory

Data

PC Buffer

Onboard Memory

Input Rate

Transfer Rate

PC Buffer (RAM)

Application Memory (RAM)

LabVIEW

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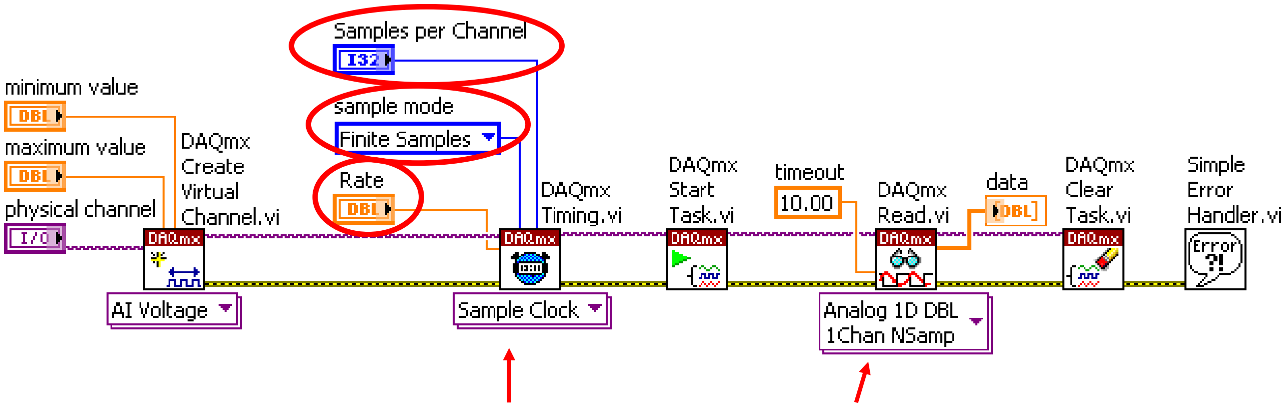
Reading or Writing a Finite Amount of Data

Finite Buffered Acquisition

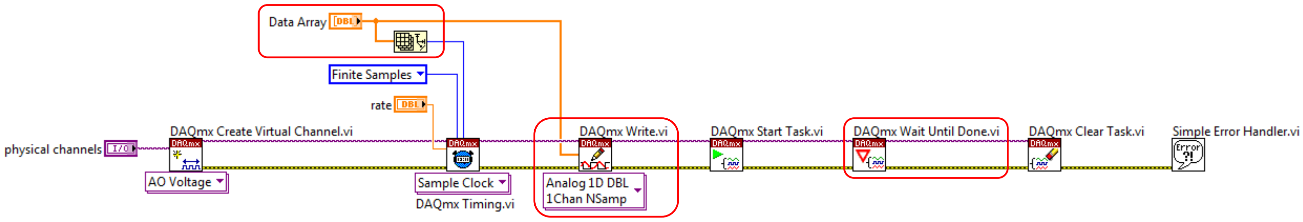


Uses sample clock to count samples

Read multiple samples

Reading or Writing a Finite Amount of Data

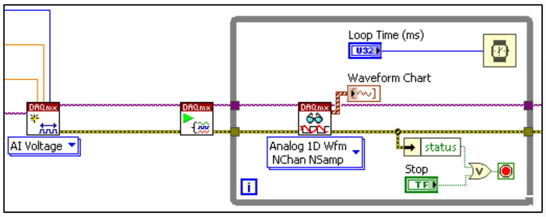
Finite Buffered Generation



Reading or Writing a Finite Amount of Data

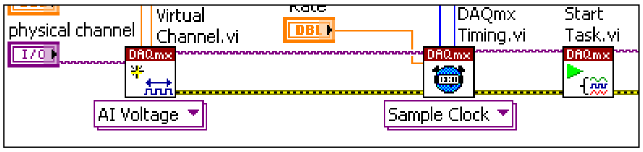
What is Hardware Timing?

Software-Timed



The software and operating system controls the communication rate.

Hardware-Timed



A digital signal, such as a clock on your device, controls the communication rate.

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Communicating Data Continuously

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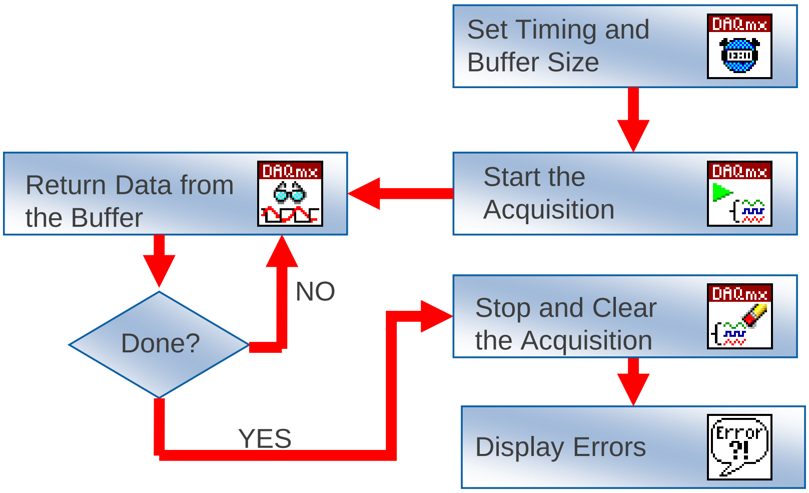
Communicating Data Continuously

Continuous Buffered Acquisition Flowchart



Set Timing and Buffer Size

Start the Acquisition

Return Data from the Buffer

Done?

NO

YES

Stop and Clear the Acquisition

Display Errors

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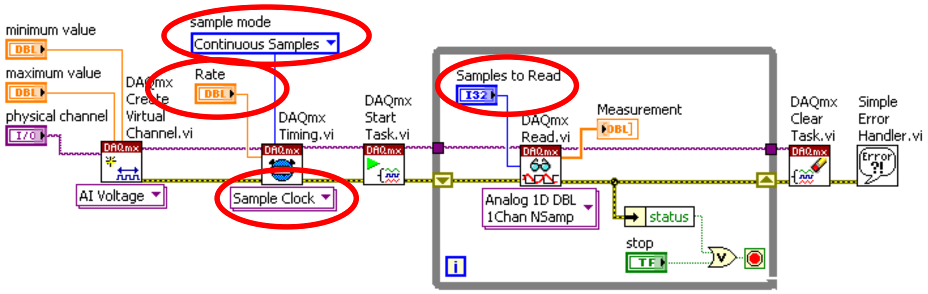
Communicating Data Continuously

Continuous Buffered Acquisition



- Perform a hardware-timed, continuous buffered acquisition
- Set the sample mode to **Continuous Samples**

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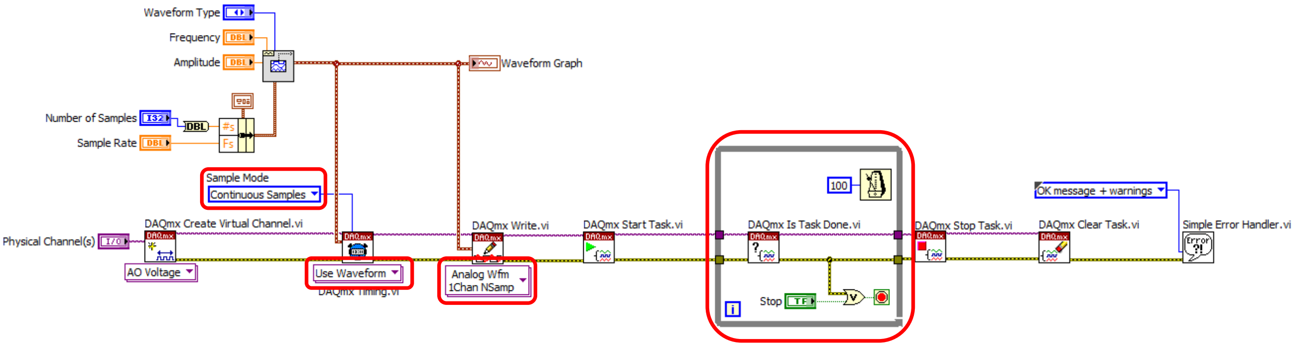
Communicating Data Continuously

Continuous Buffered Generation



Additional Resources

- Learning Badges
  - Measurement Fundamentals
  - NI-DAQmx Programming
  - Sensors and Signals
- Tutorials
  - Introduction to Data Acquisition
  - Getting Started with NI-DAQmx
  - NI-DAQmx Hardware Installation