
CERN

# LabVIEW FPGA @ CERN 2023


- Unofficial
- For fun
- Share knowledge

# About the workshop

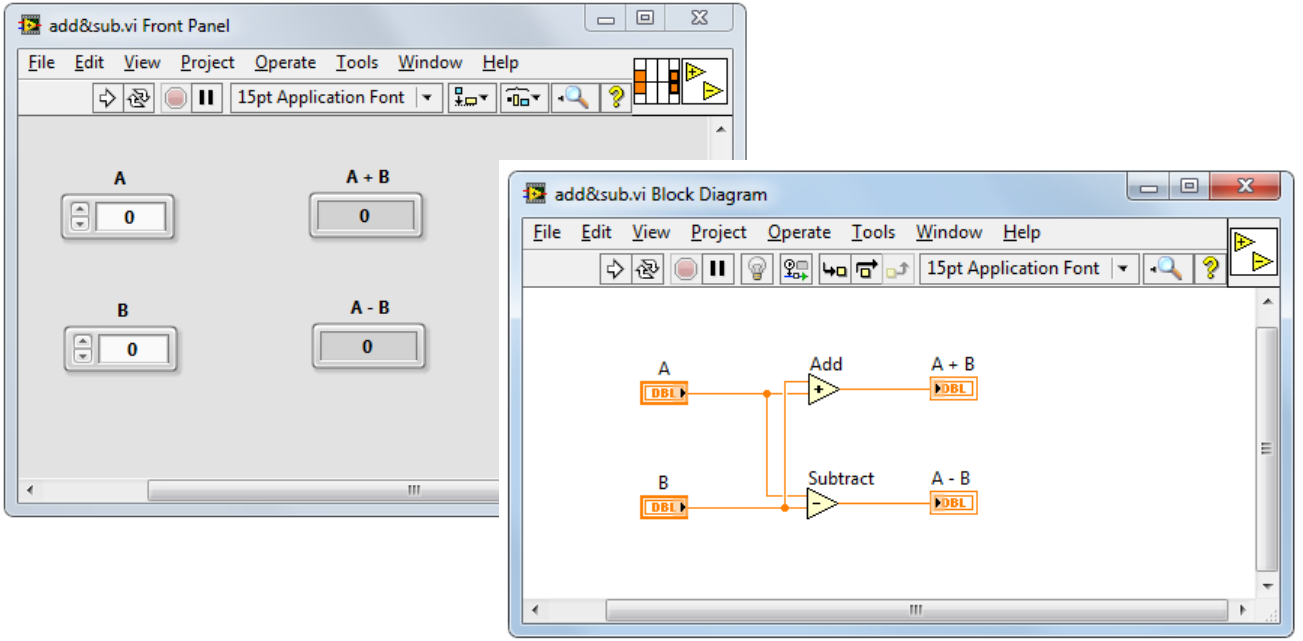
- 25.04 at 16:00  2 hours
- 26.04 at 16:00  2 hours

# About the workshops

- Minimize theory
- Maximize practice
- Some fun examples

# LabVIEW

- Intuitive
- Data driven
- Hardware integration



# National Instruments

Leader in data acquisition technology with innovative modular instruments and LabVIEW graphical programming software

Eric Starkloff CEO

- Corporate headquarters in Austin, TX
- Offices in nearly 50 countries
- 35,000+ companies served annually
- More than 1,000 products
- Approx. 7,100 employees
- 600 Alliance Partners

FORTUNE® 100 BEST COMPANIES TO WORK FOR

# Diversity of applications

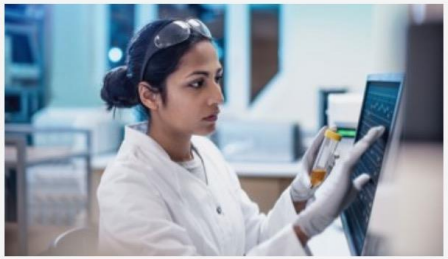
SEMICONDUCTOR

AUTOMOTIVE

AEROSPACE, DEFENSE, & GOVERNMENT

ELECTRONICS

ENERGY



ACADEMIC & RESEARCH

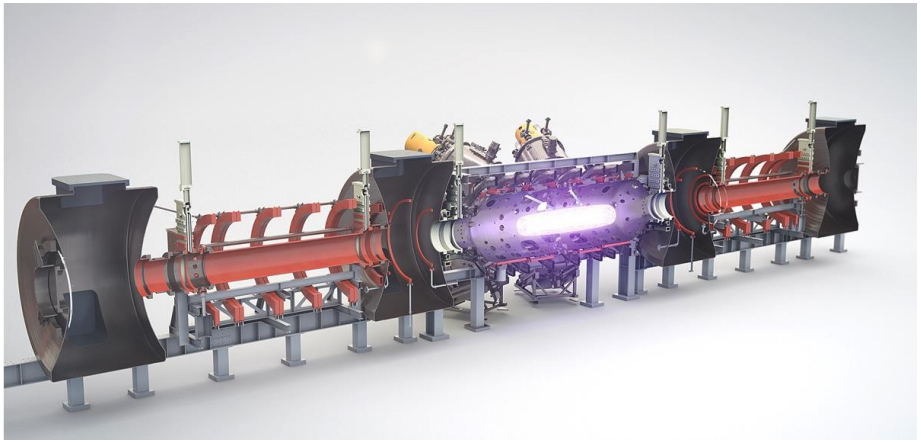
# Diversity of applications

SpaceX

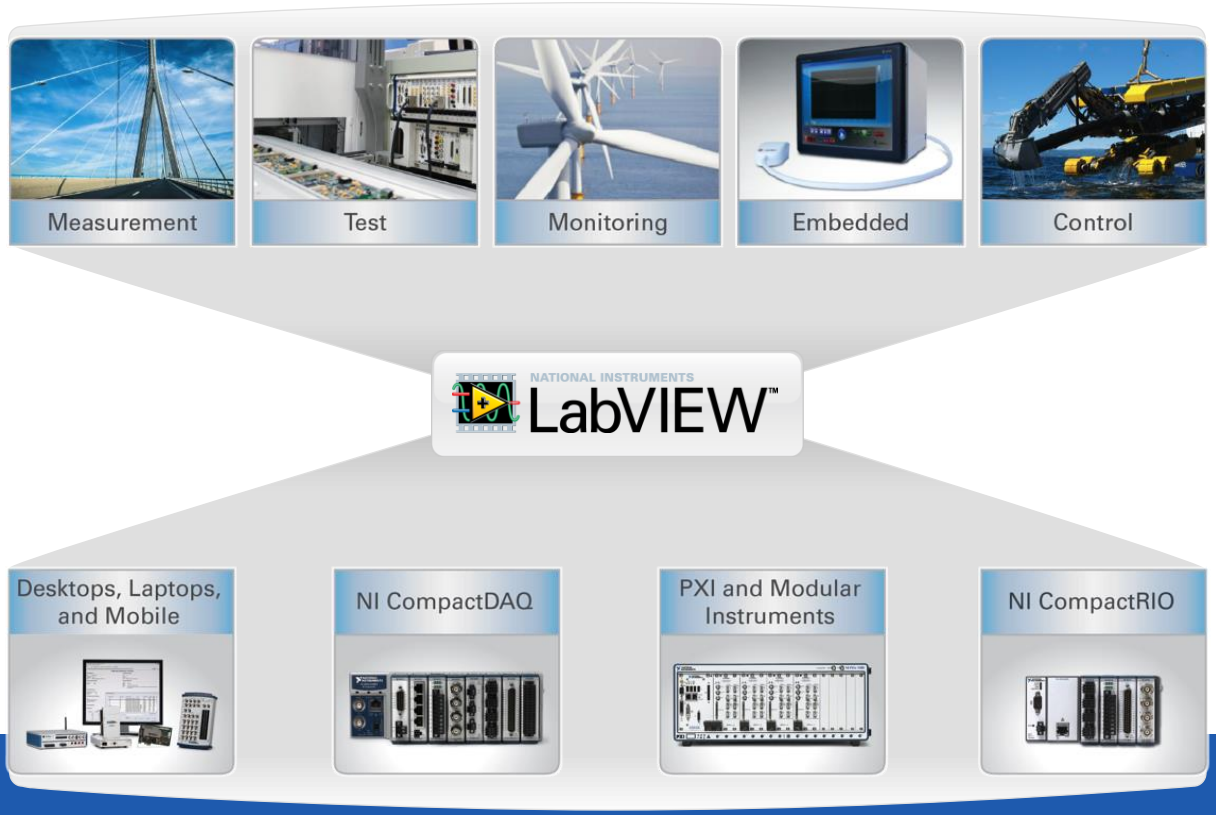
Falcon rocket launch pad software

# Diversity of applications


Commercial nuclear fusion power



# LabVIEW on different hardware

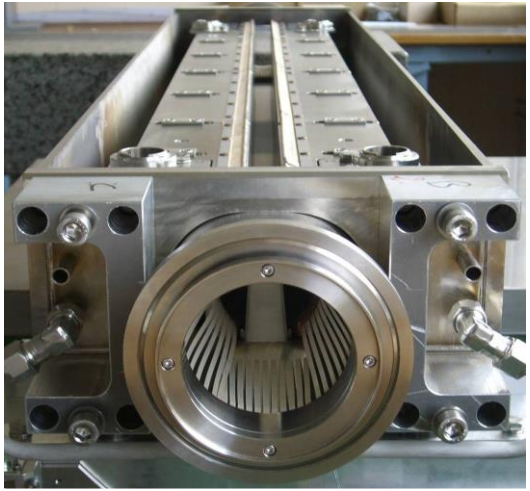



Applications

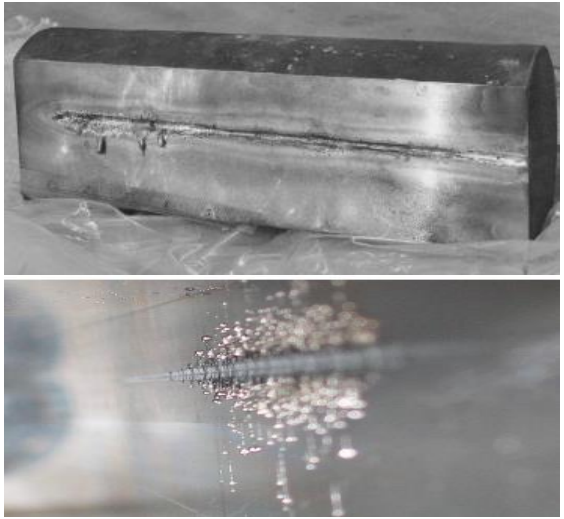
Hardware

# Projects based on NI @ CERN

- LHC collimators real-time control system

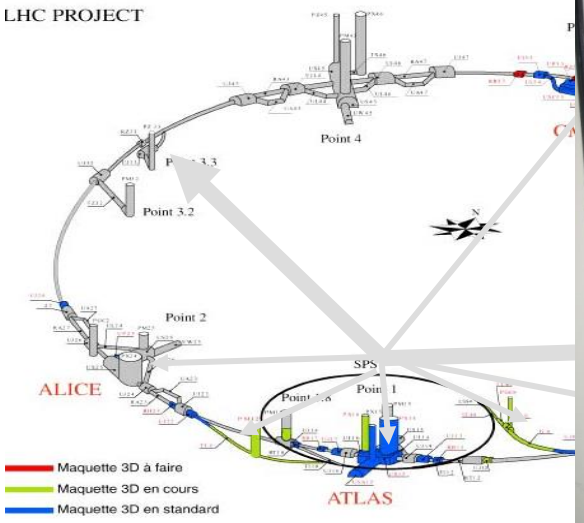


| Control system requirements | |
|---|---|
| Axes positioning accuracy | few µm |
| Axes motion synchronization | below 1 ms |
| Response delay to a digital start trigger | 100 µs |
| Position sensors RT survey frequency | 100 Hz |
| Reliability | Very high |

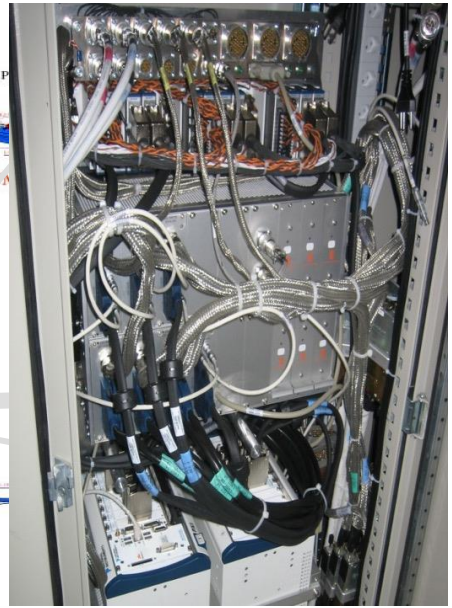


# • LHC collimators real-time control system

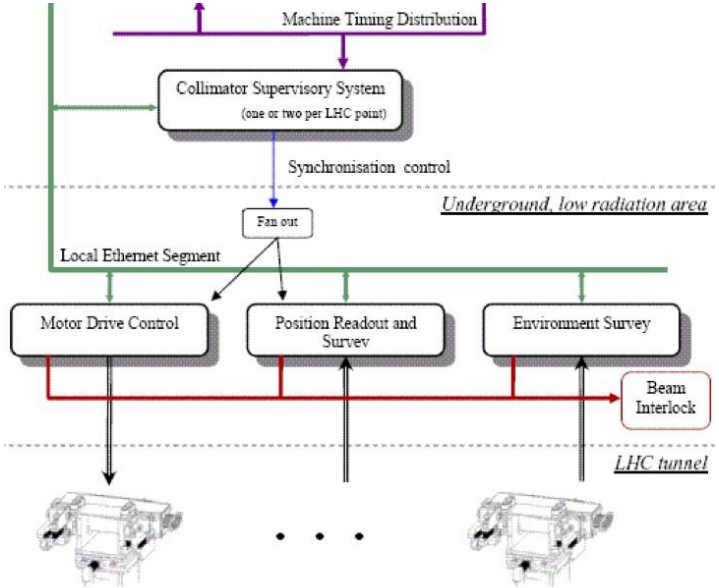
Layout




120 systems



Architecture



# Projects based on NI @ CERN

- Measurement setup for characterization of the radiation hardness of cryogenic bypass diodes for the LHC-HL

Power supplies for heaters

PXI system components:
- 7 x DMM 4081
- DAQ M-series 6251
- GPIB
- Ethernet

HV power supply – 3kV max

Discharge circuit

Capacitor bank 13,3 mF, 1500V

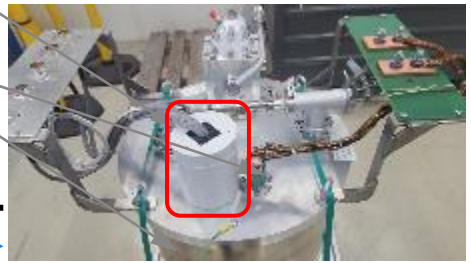
*Measurement rack*

LHC by-pass diodes

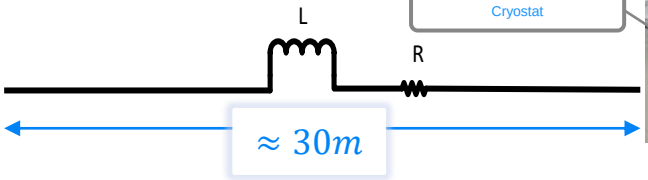
Mu-metal shield (against magnetic field)

Feedthrough 18kA

Cryostat



*Measurement setup assembly and closed cryostat*




$\approx 30m$

# CERN LabVIEW support

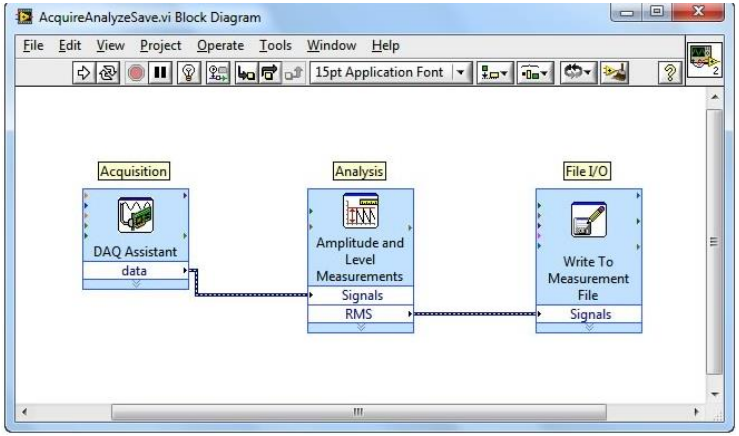
- Website: cern.ch/labview
- E-mail: labview.support@cern.ch

# Getting the Most out of This Course

- Ask questions!
- Experiment with hands-on exercises to understand the methods used
- Explore other solutions - you may find a better one

# Why LabVIEW?

- Same concepts as in most traditional languages (data types, loops, event handling, recursion and OOP)
- Data flow (execution is data-driven, not determined by sequential lines of text)
- Intuitive
- Easy to debug
- Automatic parallelism
- Hardware integration
- Combines with other languages



# B. Project Explorer

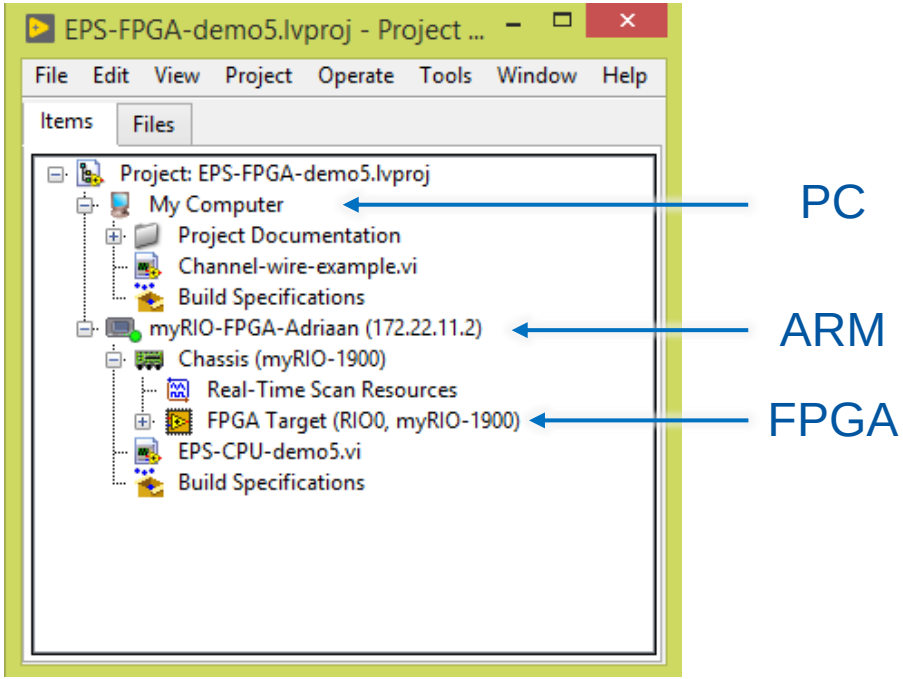
Project Explorer Window

Files Types

Project Folders

# Project Explorer

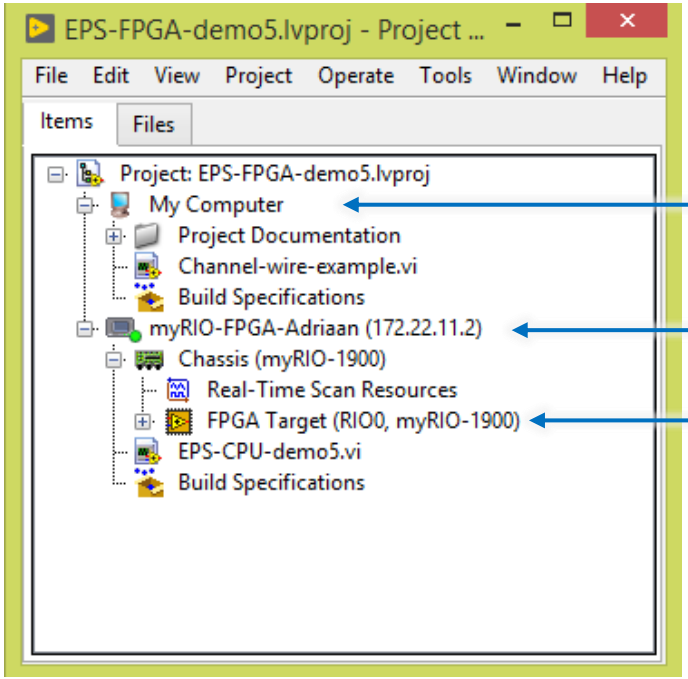
- See the hierarchy
- Organise project files
- Deploy files to targets
- Manage code for build options
  - Executables, installers, and zip files
- Integrate with source code control providers



# Project Explorer

PC

Xilinx Zynq 7010



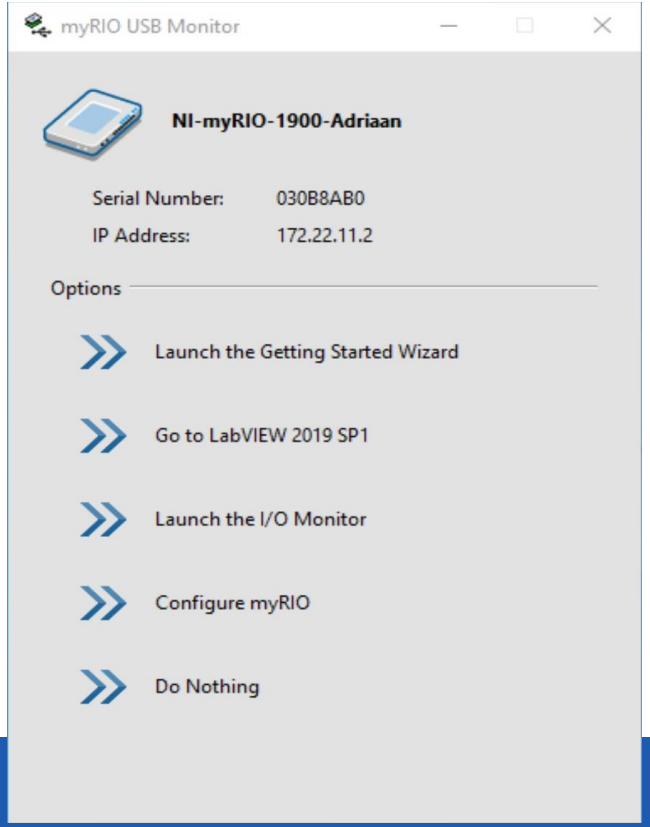
# Connect to myRIO


1. Don’t have the myRIO connected yet
2. Power up the myRIO
3. Wait until the Status LED is off
4. Connect the myRIO to your PC

# Start LabVIEW

PC

myRIO

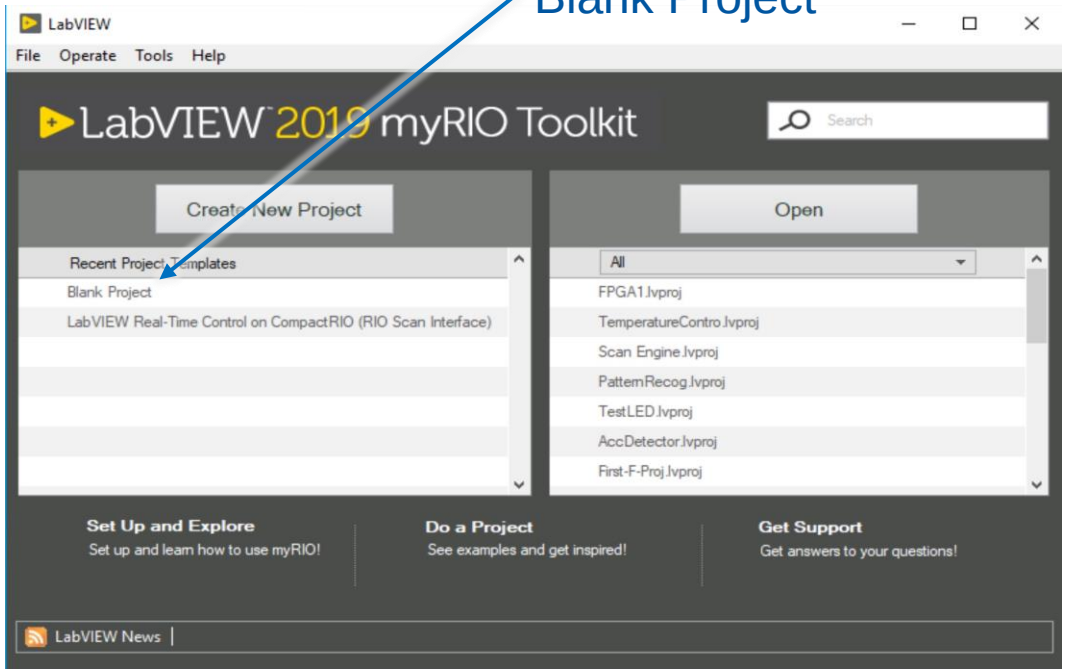



Go to LabVIEW

# Project

PC

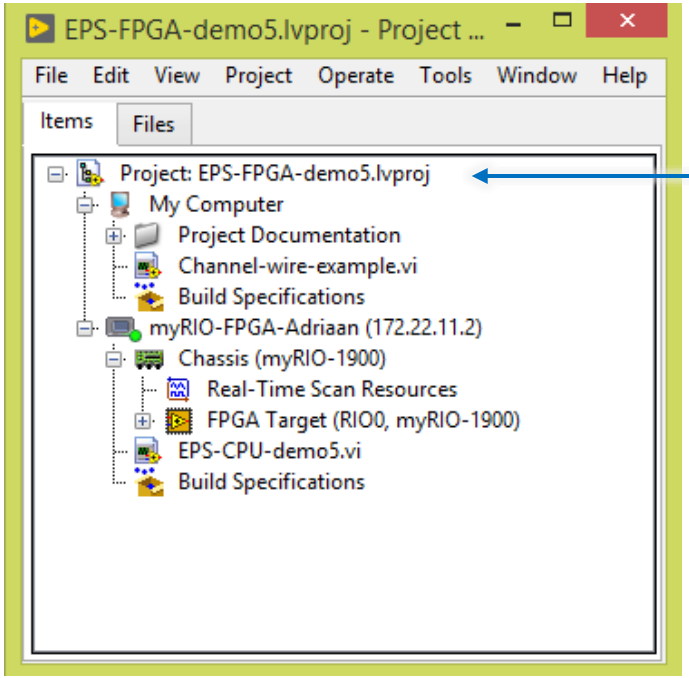
myRIO



# New target

PC

myRIO

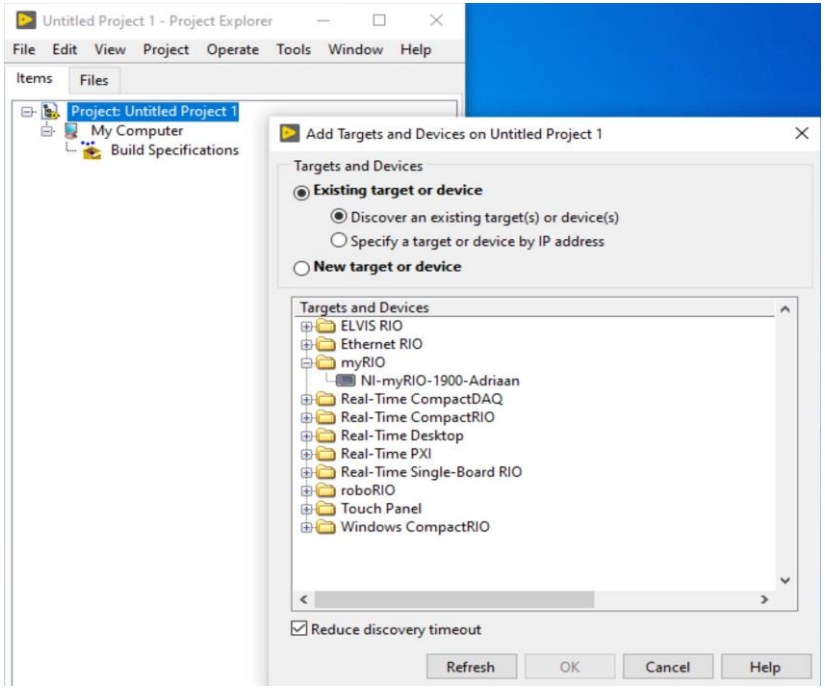



Right click Project
Choose: New ->
targets and devices

# Select myRIO

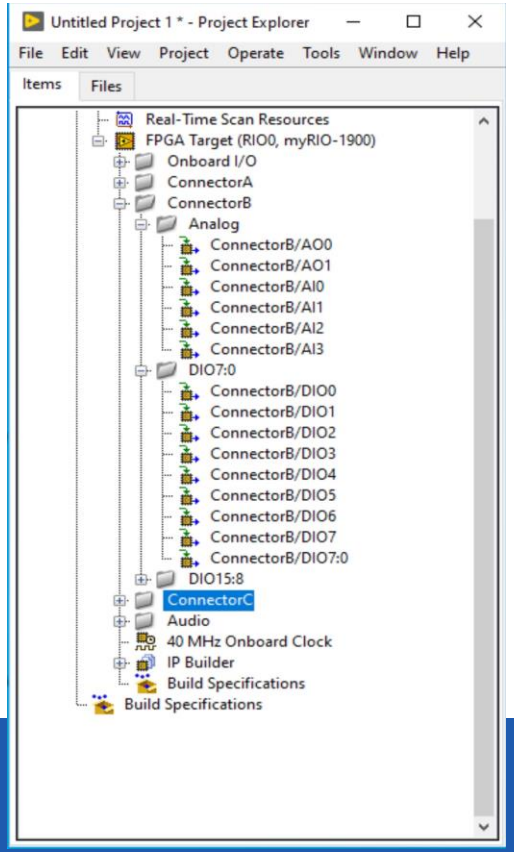
PC

myRIO




Open myRIO with +
Select NI myRIO
OK

# Prepare myRIO


Close tabs:

- Onboard I/O
- Connector A
- Connector B DIO15:8
- Connector C
- Audio

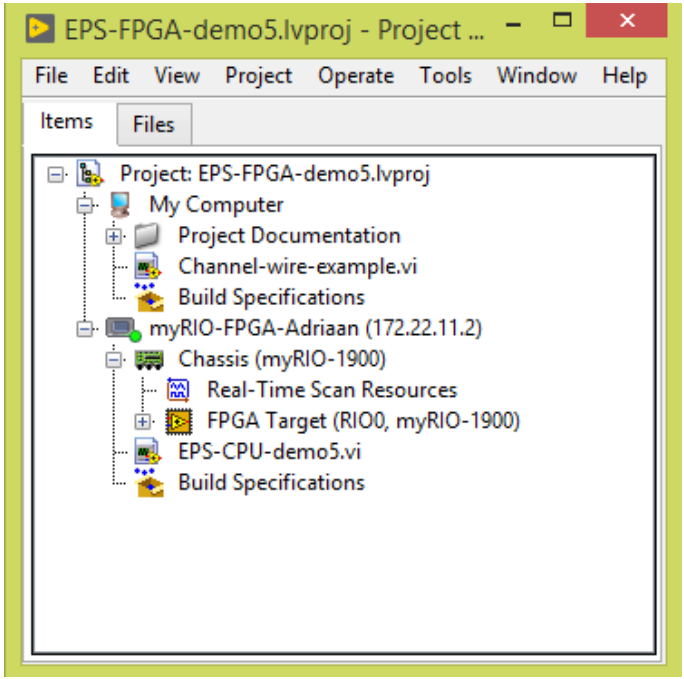
# LabVIEW Files

- Common LabVIEW file extensions:

LabVIEW project —.lvproj

Virtual instrument (VI) — .vi

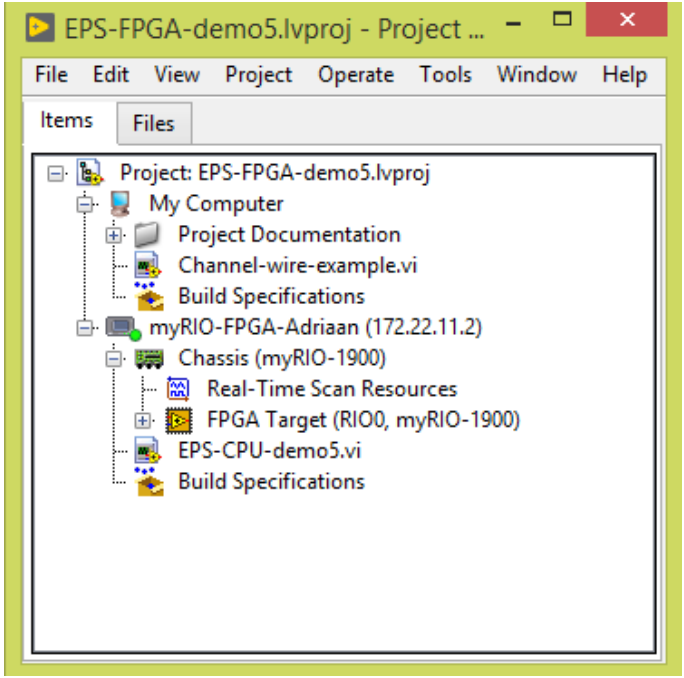
Custom control — .ctl



# Adding Folders to a Project

- Virtual folder
  - Organizes project items and does not represent files on disk

- Auto-populating folder
  - Adds a directory on disk to the project
  - LabVIEW continuously updates the folder according to changes made in the project and on disk



# Show-off(1)
# Project Explorer

# C. Parts of a VI

Front Panel

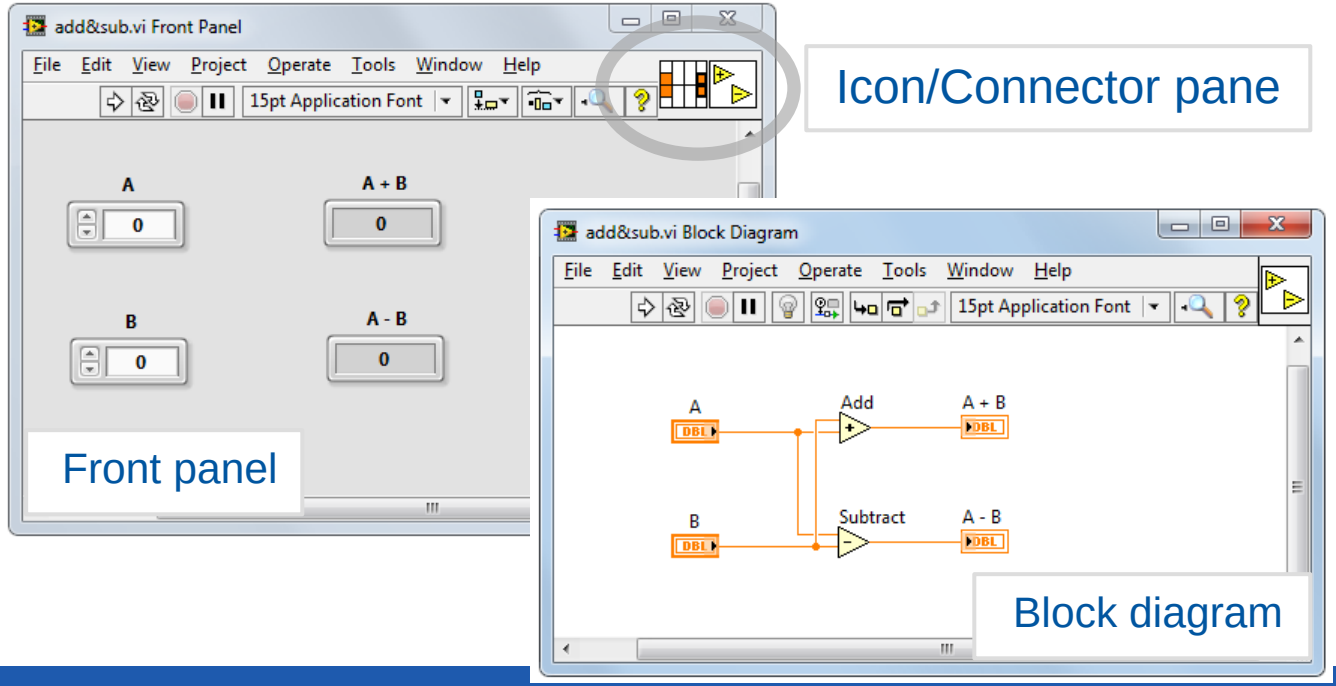
Block Diagram

Icon

Connector Pane

# Parts of a VI

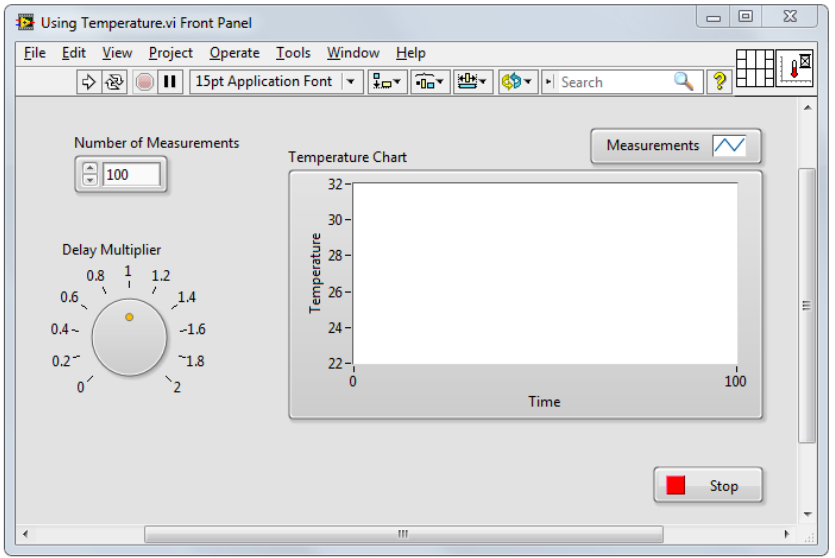
## VIs have 3 main components:



# Parts of a VI – Front Panel

**Front Panel** – User interface for the VI

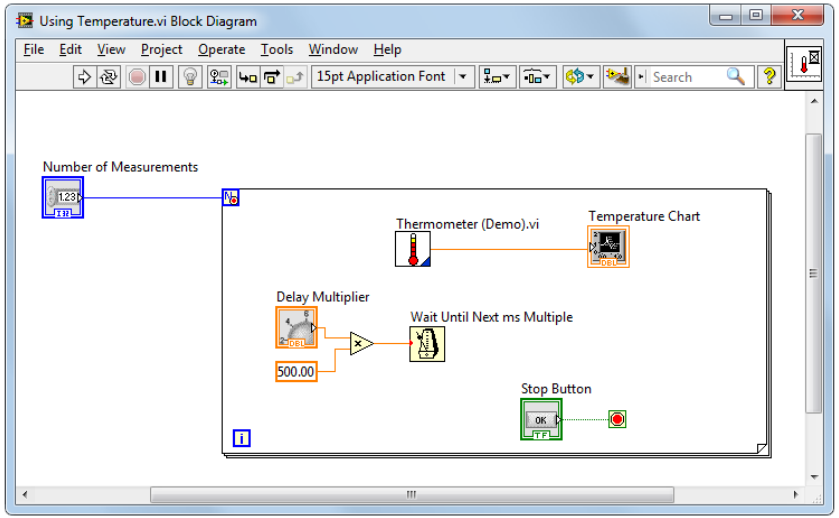
You build the front panel with controls (inputs) and indicators (outputs).



# Parts of a VI – Block Diagram

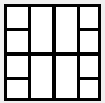
**Block Diagram** – Contains the graphical source code

Front panel objects appear as terminals on the block diagram.



# Parts of a VI – Icon/Connector Pane

**Icon** – Graphical representation of a VI



**Connector Pane** – Map of the inputs and outputs of a VI

Icons and connector panes are necessary to use a VI as a subVI.

- A subVI is a VI that appears on the block diagram of another VI.
- A subVI is similar to a subroutine or function in a text-based programming language.

# Show – off (2)

# Figures

# D. Front Panel

Controls and Indicators

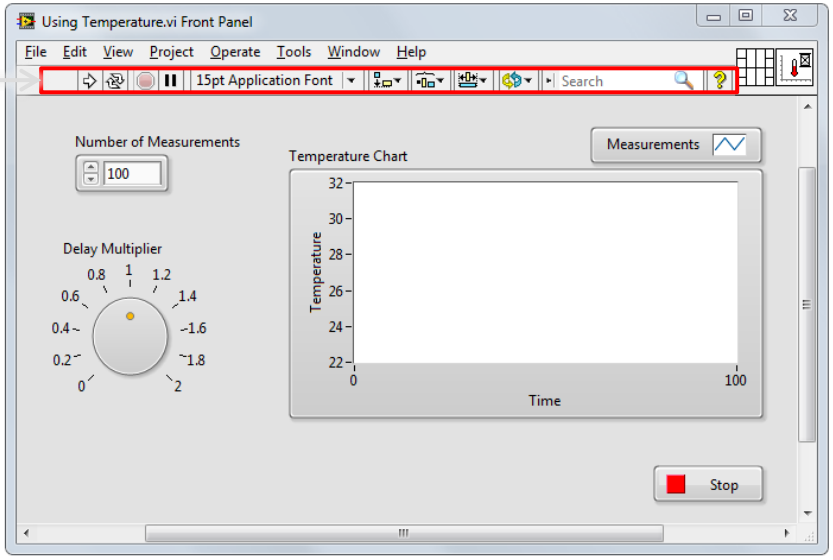
Object Styles

Object Types

- Boolean
- Numeric
- String

# Front Panel


15pt Application Font
Search


Using Temperature.vi Front Panel
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Number of Measurements
100
Delay Multiplier
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
Temperature Chart
Measurements
Temperature
32 30 28 26 24 22
0 100
Time
Stop

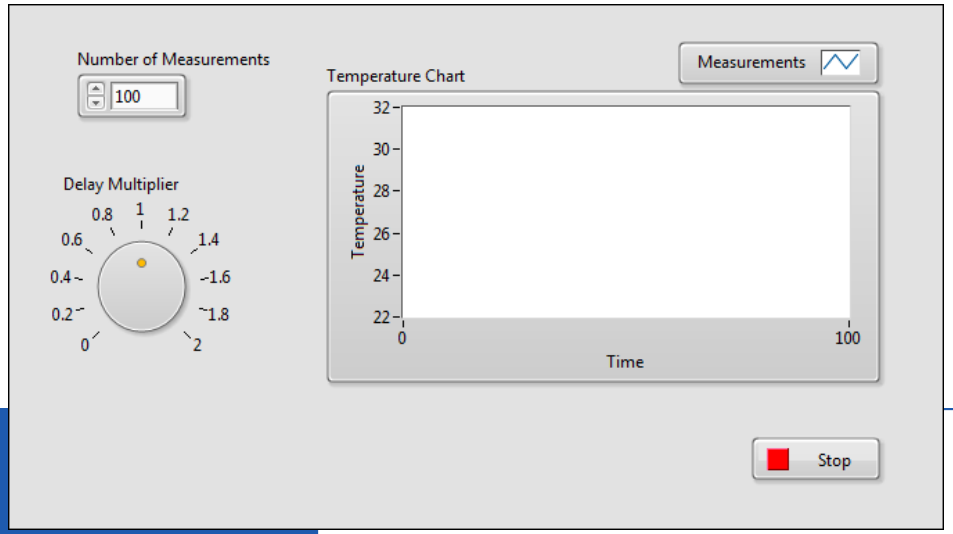
# Controls and Indicators

## Controls

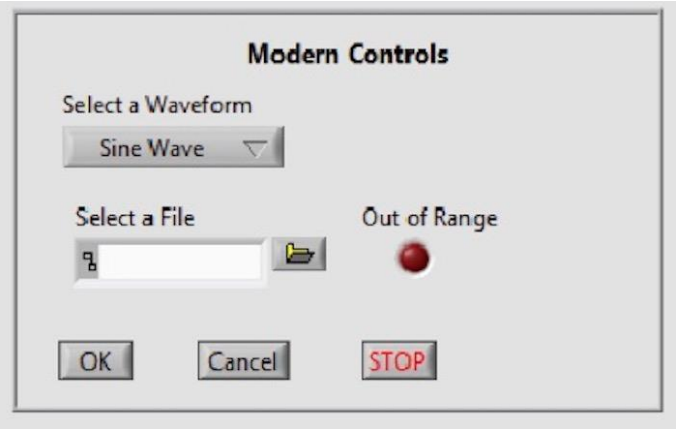
- Input devices
- Knobs, buttons, slides
- Supply data to the block diagram

## Indicators

- Output devices
- Graphs, LEDs
- Display data the block diagram acquires or generates

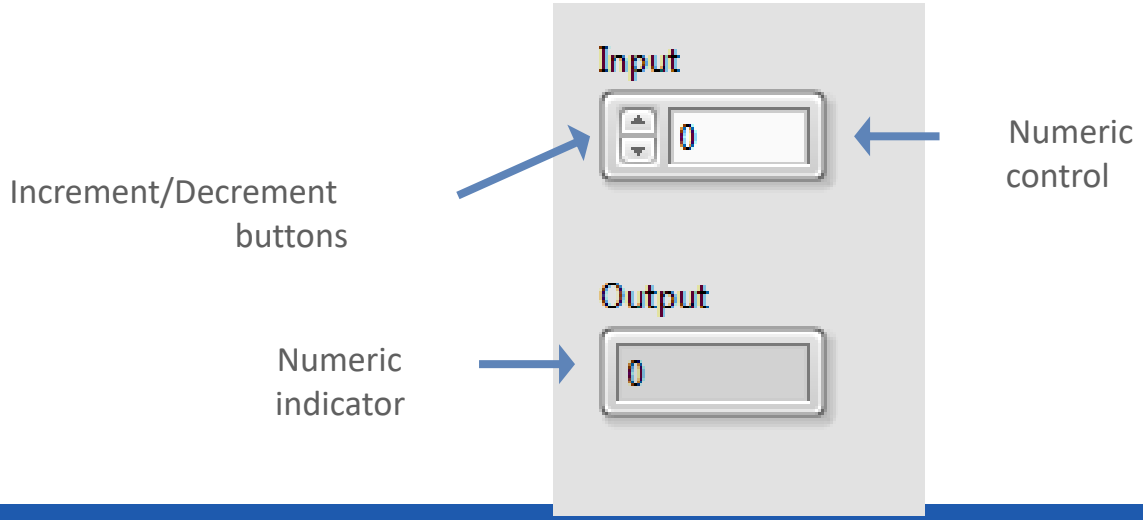


# Front Panel Object Styles



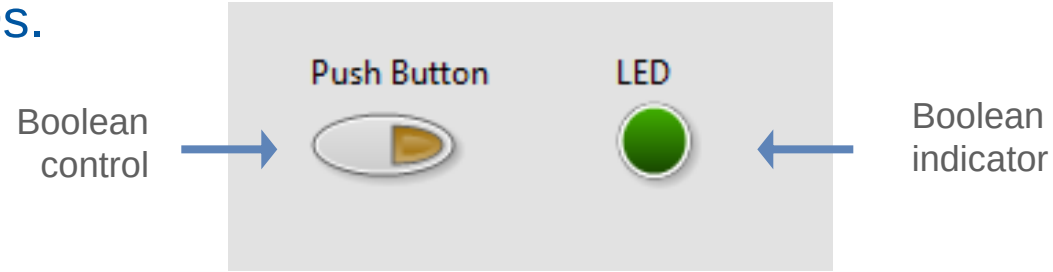

# Numeric Controls and Indicators

The numeric data in a control or indicator can represent numbers of various types, such as integer or floating-point.



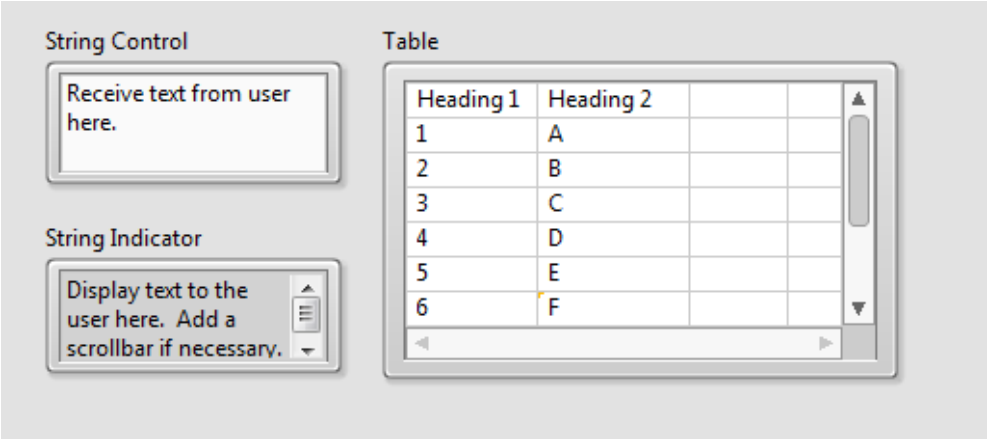
# Boolean Controls and Indicators

- The Boolean data type represents data that has only two options, such as True/False or On/Off.
- Use Boolean controls and indicators to enter and display Boolean (TRUE/FALSE) values.
- Boolean objects simulate switches, push buttons and LEDs.



# Strings

- The string data type is a sequence of ASCII characters.
- Use string controls to receive text from the user.
- Use string indicators to display text to the user.



# E. Block Diagram

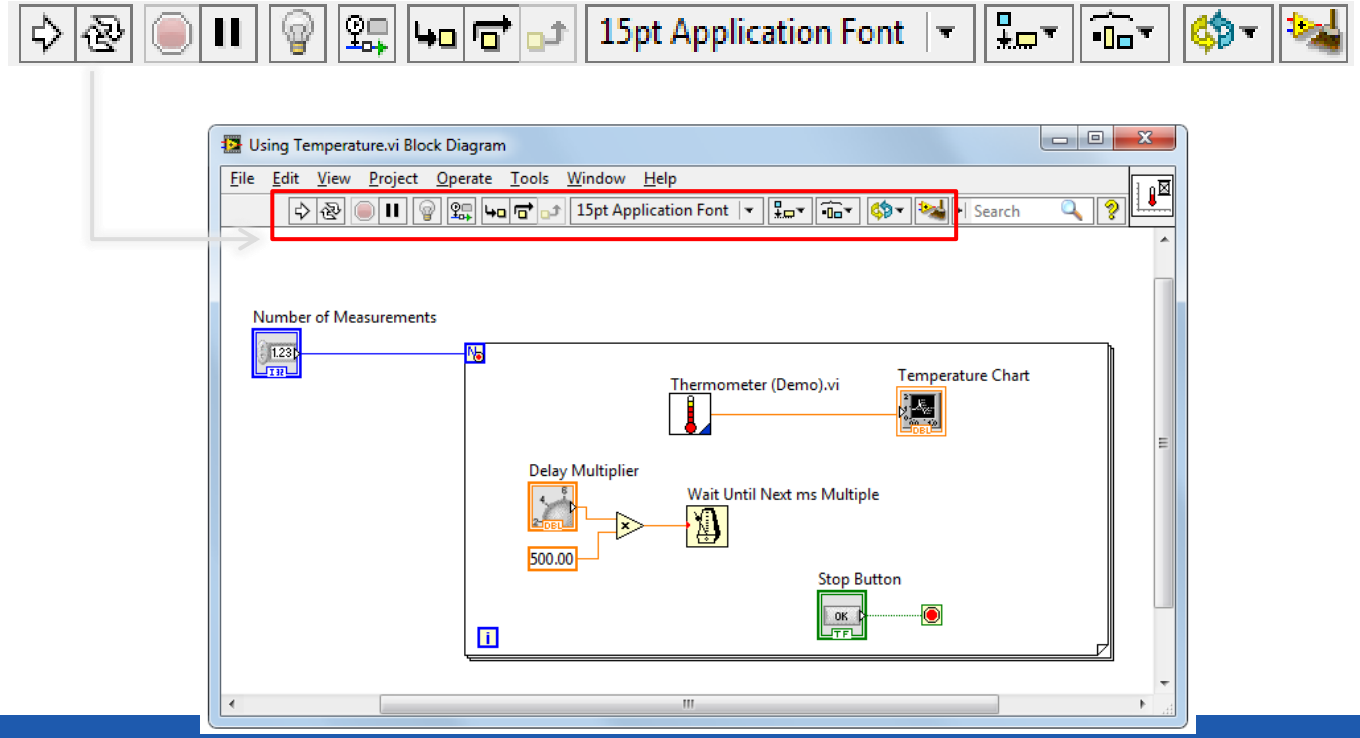
Terminals

Nodes

Wires

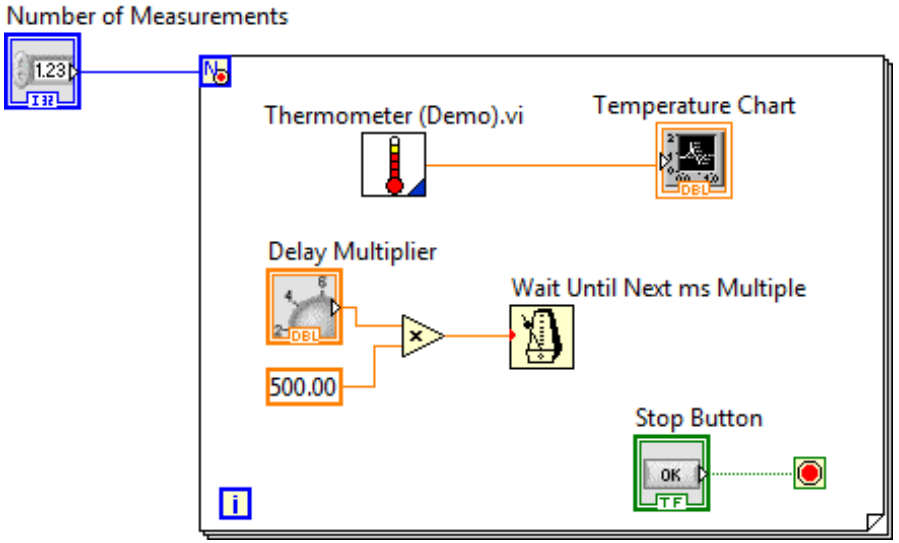
Help

# Block Diagram

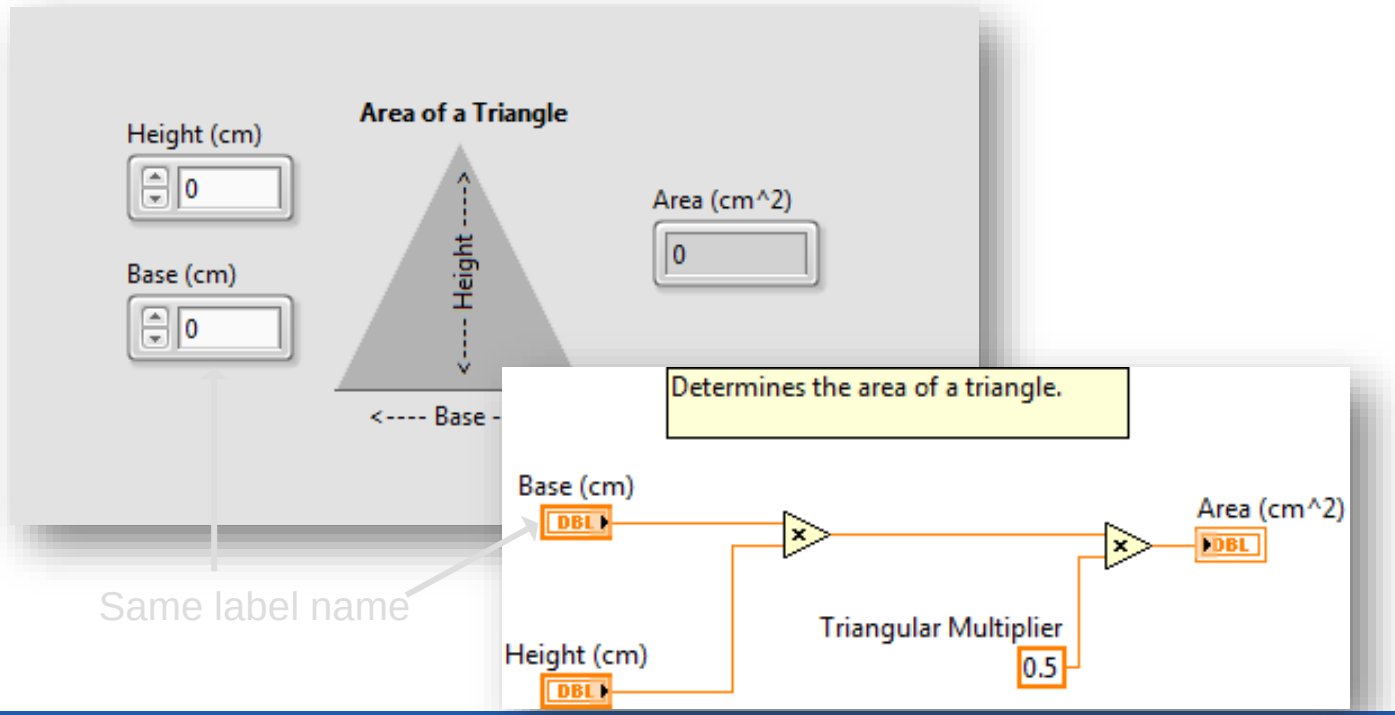


# Block Diagram

- Block diagram items:
  - Terminals
  - Constants
  - Nodes
    - Functions
    - SubVIs
    - Structures
  - Wires
  - Free labels

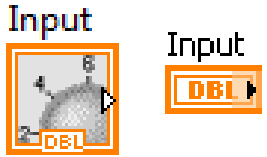


# Terminals


Area of a Triangle
Height (cm)
0
Base (cm)
0
Height ---->
<---- Base ----
Area (cm^2)
0
Same label name
Determines the area of a triangle.
Base (cm)
DBL
Height (cm)
DBL
Triangular Multiplier
0.5
Area (cm^2)
DBL

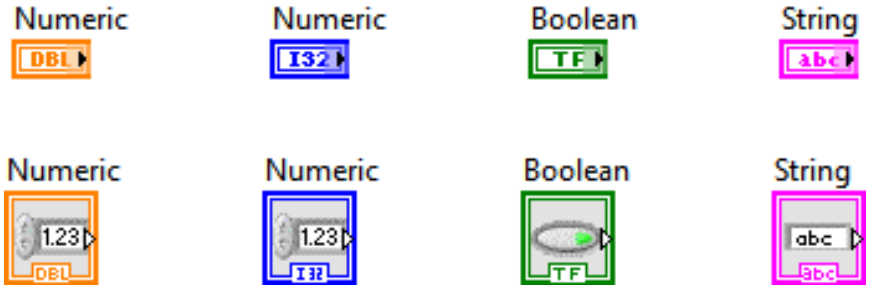
# Terminals for Front Panel Objects

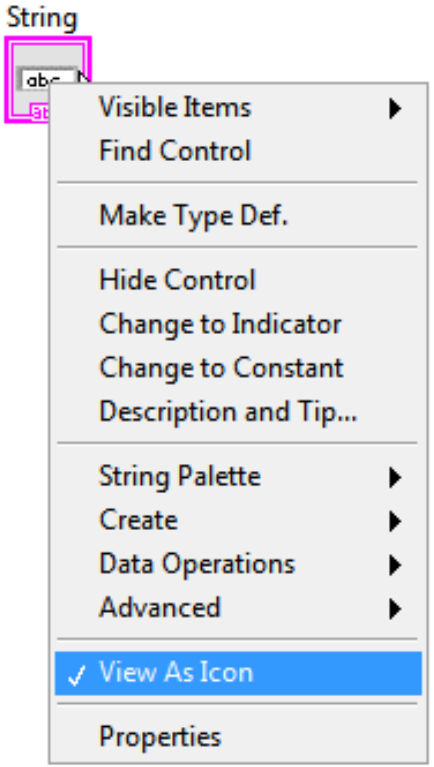
- Terminals are:
  - Entry and exit ports that exchange information between the front panel and block diagram.
  - Analogous to parameters in text-based programming languages.
- Double-click a terminal to locate the corresponding front panel object.



# View Terminals as Icons

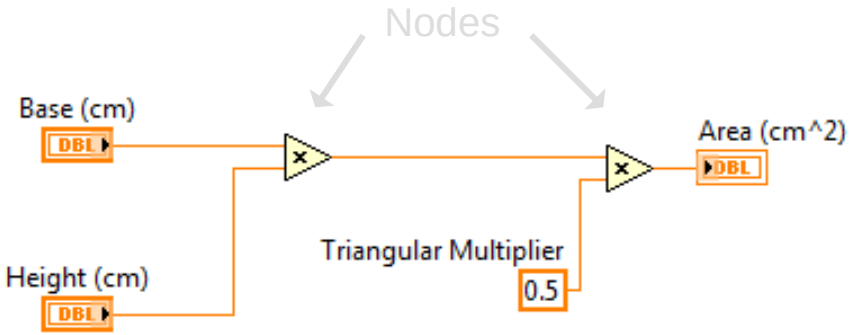
- By default, View as Icon option enabled.
- Deselect View as Icon for a more compact view.



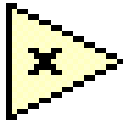



# Nodes

Nodes are objects on the block diagram that have inputs and/or outputs and perform operations when a VI runs.

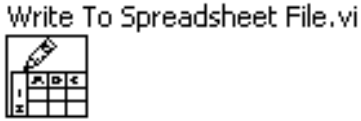


# Function Nodes



- Functions are:
  - Fundamental operating elements of LabVIEW.
  - Do not have front panels or block diagrams, but do have connector panes.
  - Has a pale yellow background on its icon.
- Double-clicking a function only selects the function.
- Functions do not open like VIs and subVIs.

# SubVI Nodes



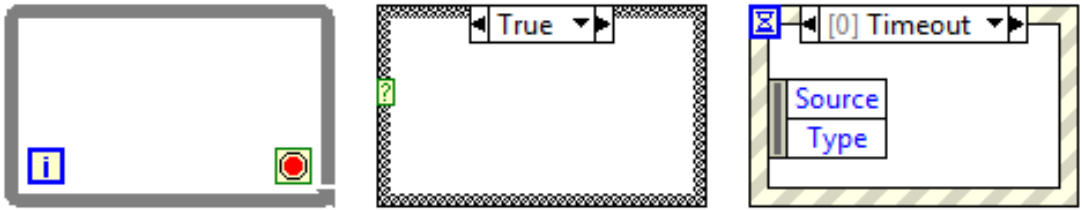

- SubVIs :
  - Are VIs that you use on the block diagram of another VI.
  - Have front panels and block diagrams.
  - Use the icon from the upper-right corner of the front panel as the icon that appears when you place the subVI on a block diagram.
- When you double-click a subVI, the front panel and block diagram open.
- Any VI has the potential to be used as a subVI.

# Express VIs


- Express VIs:
  - Are a special type of subVI.
  - Require minimal wiring because you configure them with GUI dialog boxes.
  - Save each configuration as a subVI.
- Icons for Express VIs appear on the block diagram as icons surrounded by a blue field.

# Structures

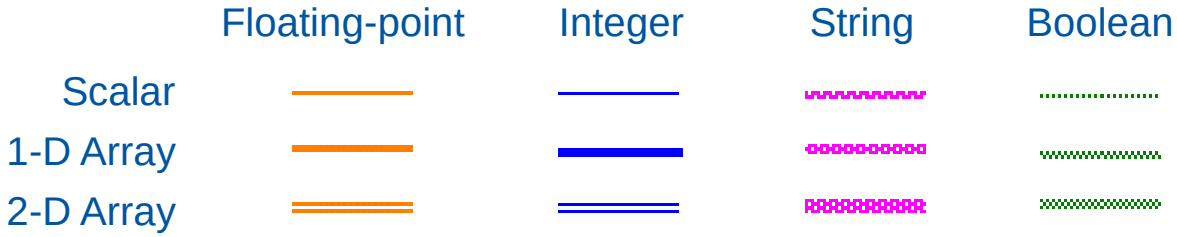
- Structures in LabVIEW have the form of frames.




- Other nodes (functions, subVIs, more structures) can be inserted into the frames.

# Wires

- Wires transfer data between block diagram objects.
- Wires are different colors, styles, and thicknesses, depending on their data types.




- A broken wire appears as a dashed black line with a red X in the middle.

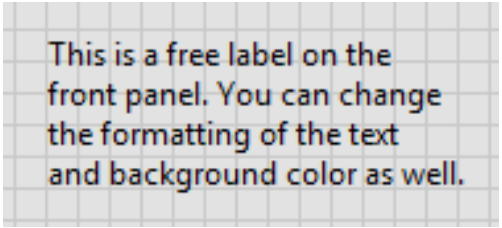
# Constants

- Constants are the source of values just as control terminals, but their value is fixed in the code.

- You can create a constant of each data type.

# Free labels

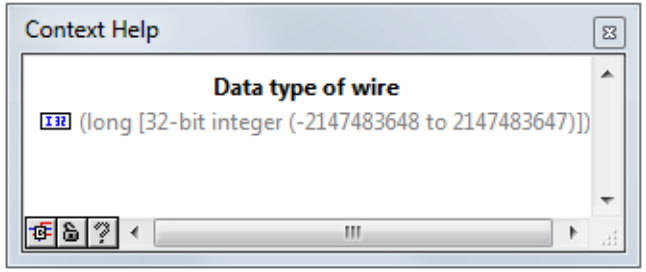
- A free label is a label (a text box) not attached to any object.
- Free labels can be put on the front panel or block diagram. They are created by double-clicking on empty space in the window.
- They can serve as comments or instructions to the user of the application.

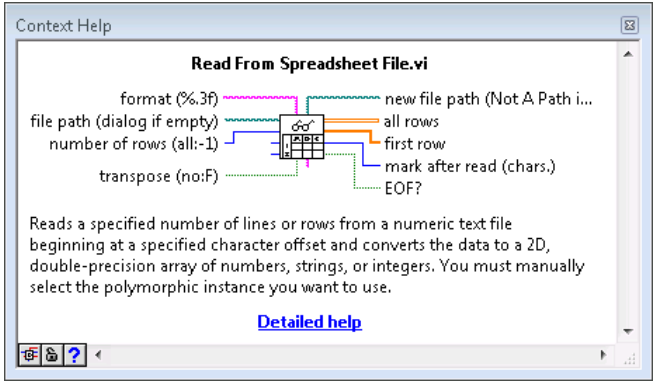



This is the default formatting
of a block diagram free label.

# Context Help

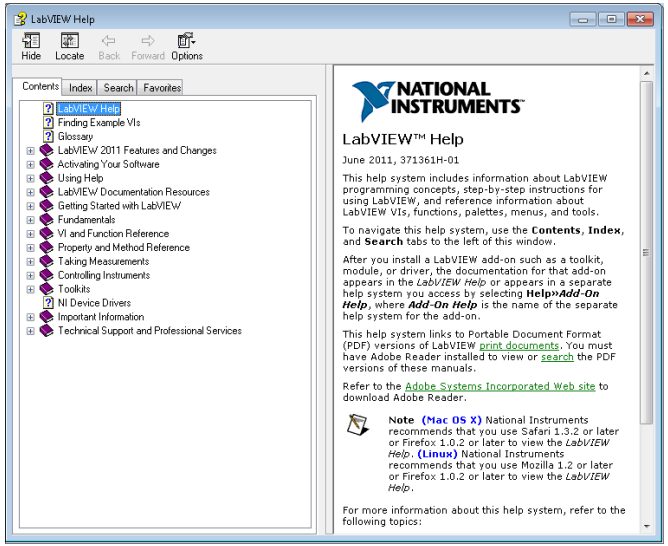
- Displays basic information about wires and nodes when you move the cursor over an object.
- Can be shown or hidden in the following ways:
  - Select **Help»Show Context Help** from the LabVIEW menu.
  - Press <Ctrl-H>.
  - Click the following button on the toolbar:



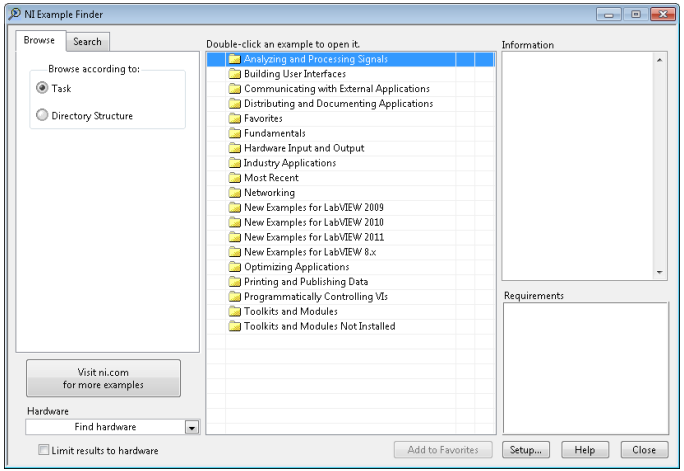

# LabVIEW Help

- Contains detailed descriptions and instructions for most palettes, menus, tools, VIs, and functions.
- Can be accessed by:
  - Selecting Help» LabVIEW Help from the menu.
  - Clicking the Detailed help link in the Context Help window.
  - Right-clicking an object and selecting Help from the shortcut menu.



# Examples

- LabVIEW includes hundreds of example VIs.
- Use NI Example Finder to browse and search installed examples.
  - Select **Help»Find Examples** in the menu.




- Click the example buttons in *LabVIEW Help* topics.

# Group Exercise
# Concept: Exploring a VI

Identify the parts of an existing VI.

# F. Searching for Controls, VIs and Functions

Palettes

Quick Drop

NI Global Search

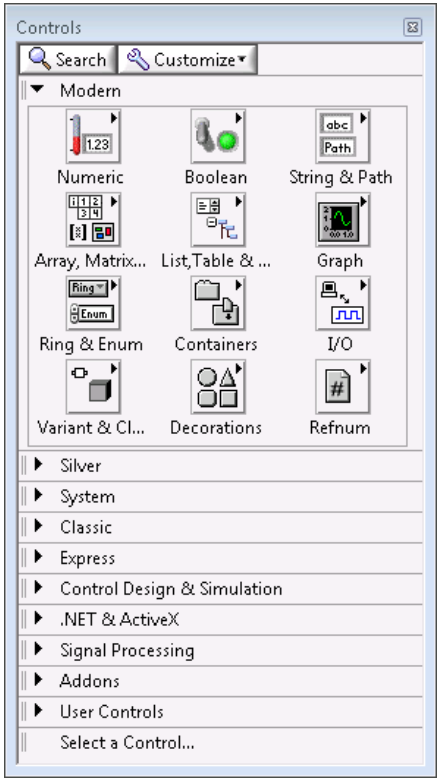
# Searching for Controls, VIs and Functions

Ways to find controls, VIs, and functions:

- Search or navigate the palettes.
  - Controls palette
  - Functions palette
- Search by name of object.
  - Quick Drop dialog box
- Search palettes, *LabVIEW Help*, and `ni.com`.
  - Search text box in toolbar

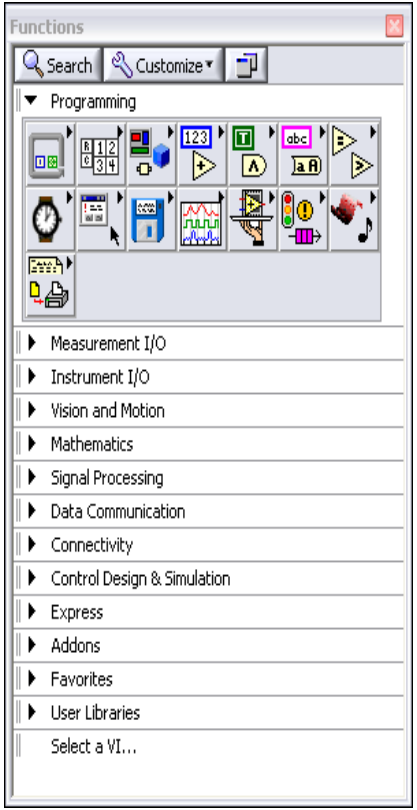
# Controls Palette

- Contains the controls and indicators you use to create the front panel.
- Navigate the subpalettes or use the **Search** button to search the Controls palette.



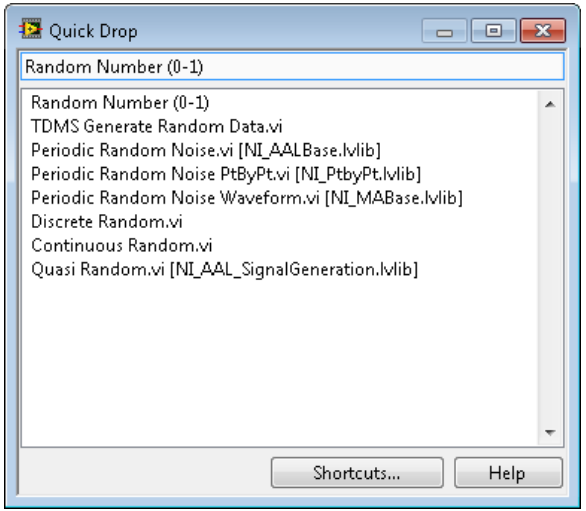
# Functions Palette

- Contains the VIs, functions, and constants you use to create the block diagram.
- Navigate the subpalettes or use the **Search** button to search the Functions palette.



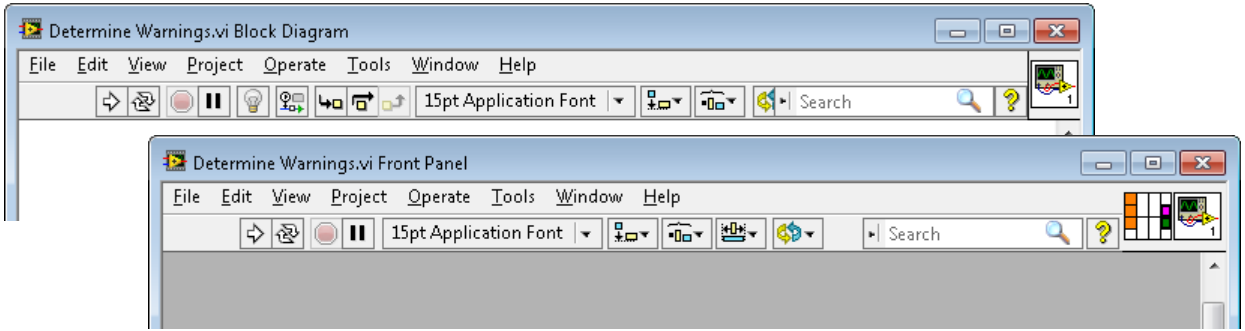
# Searching with Quick Drop

- Lets you quickly find controls, functions, VIs, and other items by name.
- Press the <Ctrl-Space> keys to display the Quick Drop dialog box.



# Global Search

Use the Search bar in the top right of the front panel and block diagram windows to search palettes, *LabVIEW Help*, and `ni.com`.



# Search for Controls, VIs and Functions

- Configure palettes to customize visible palettes.
- Search and navigate the palettes.
- Search for help using global search.
- Use Quick Drop to search by name.

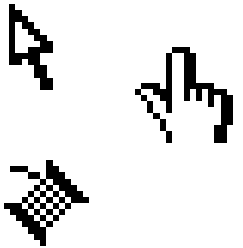
# G. Selecting a Tool

Selecting a Tool

Block Diagram Clean-Up

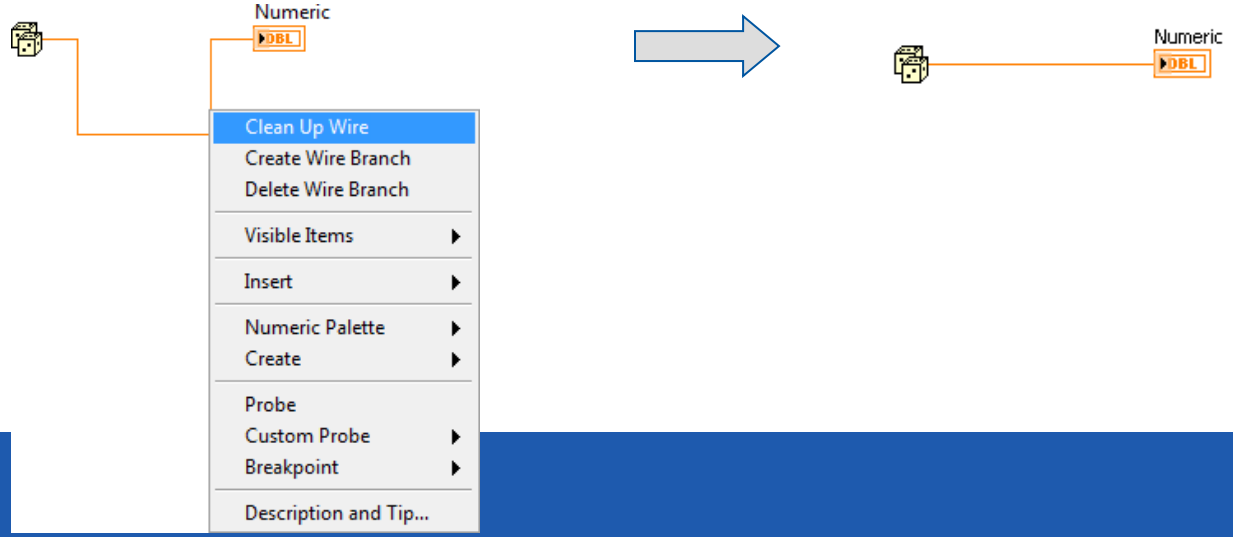
# Selecting a Tool

- A tool is a special operating mode of the mouse cursor.
- Create, modify, and debug VIs using the tools provided by LabVIEW.
- By default, LabVIEW automatically selects tools based on the context of the cursor.
- If you need more control, use the **Tools** palette to select a specific tool.
  - Select **View»Tools Palette** to open the **Tools** palette.



# Wiring Tips

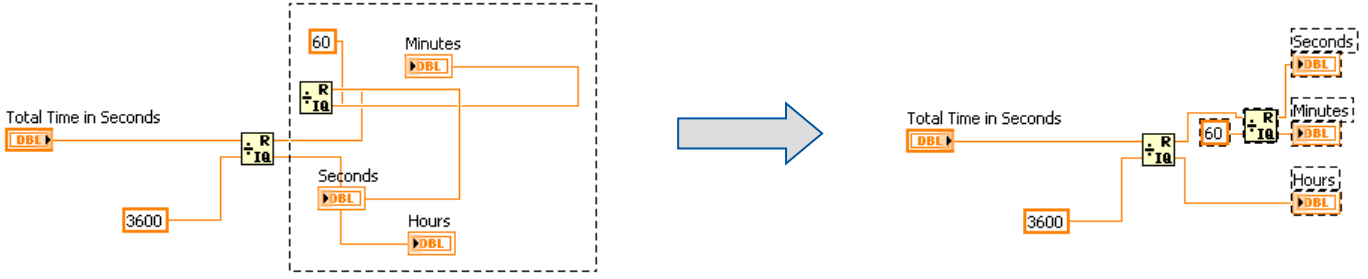
- Press <Ctrl-B> to delete broken wires.
- Right-click and select **Clean Up Wire** to reroute the wire.



# Wiring Tips – Clean Up Diagram

Use the Clean Up Diagram tool to reroute multiple wires and objects and to improve readability.

1. Select a section of your block diagram.
2. Click the Clean Up Diagram button on the block diagram toolbar (or press <Ctrl-U>).



# Cloning and Moving Items

- Clone an object in Windows using the following steps:

1. Select the Positioning tool.
2. Press the <Ctrl> key while clicking an object.
3. Drag the copy to new location.

- Move an object using the following steps:

1. Select the Positioning tool.
2. Click and drag the object to new location.

Note: Avoid cutting and pasting objects as this can impact related items. For example, cutting and pasting a block diagram terminal also moves the front panel object.

# Selecting, Editing, Resizing and Wiring

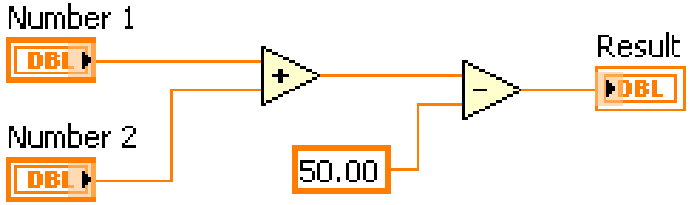
- Select item to move, copy, or delete
- Edit text
- Resize an object
- Wire terminals and nodes
- Automatic and manual tool selection

# Setting Options for the Environment

- In **Tools»Options…** dialog box you can customize settings for the LabVIEW environment.
- Suggested changes:
  - Front Panel page
    - Set Control Style for New VIs to **Silver style**
  - Block Diagram page
    - Uncheck **Place front panel terminals as icons**
    - Configure **Block Diagram Cleanup** to customize your block diagram

# H. Dataflow

# Dataflow



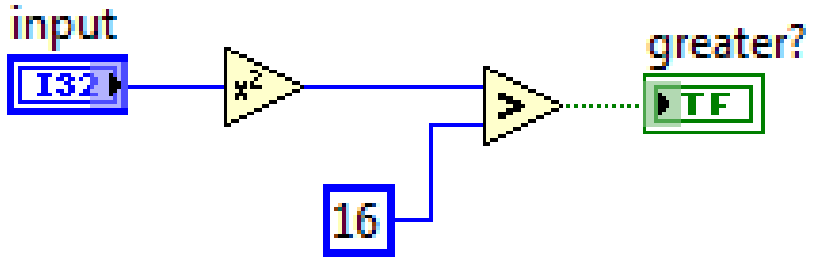

LabVIEW follows a dataflow model for running VIs.

- A node executes only when data are available at all of its required input terminals.
- A node supplies data to the output terminals only when the node finishes execution.

# Dataflow – Quiz

What are the nodes in this fragment of code?

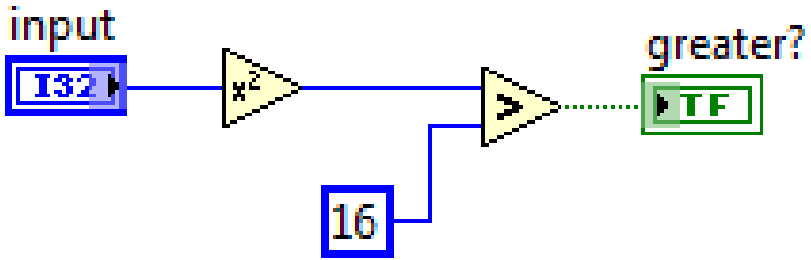
Which node executes first?



# Dataflow – Quiz Answer

There are two nodes: „square” and „greater than?” functions.

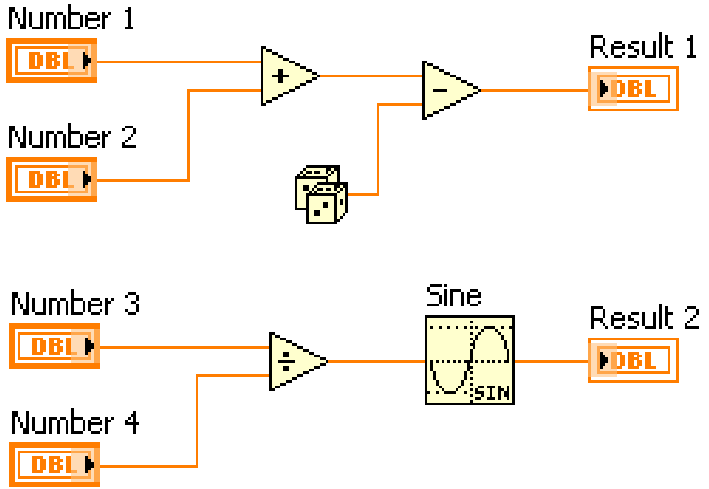
Square executes first.



# Dataflow – Quiz

Which node executes first?

a) Add
b) Subtract
c) Random Number
d) Divide
e) Sine



# Dataflow – Quiz Answer

**No single correct answer.**

Which node executes first?

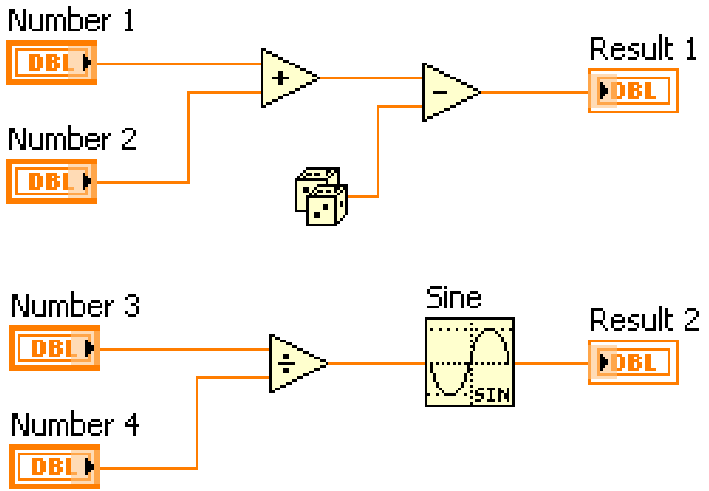
a) Add – **Possibly**

b) Subtract – **Definitely not**

c) Random Number – **Possibly**

d) Divide – **Possibly**

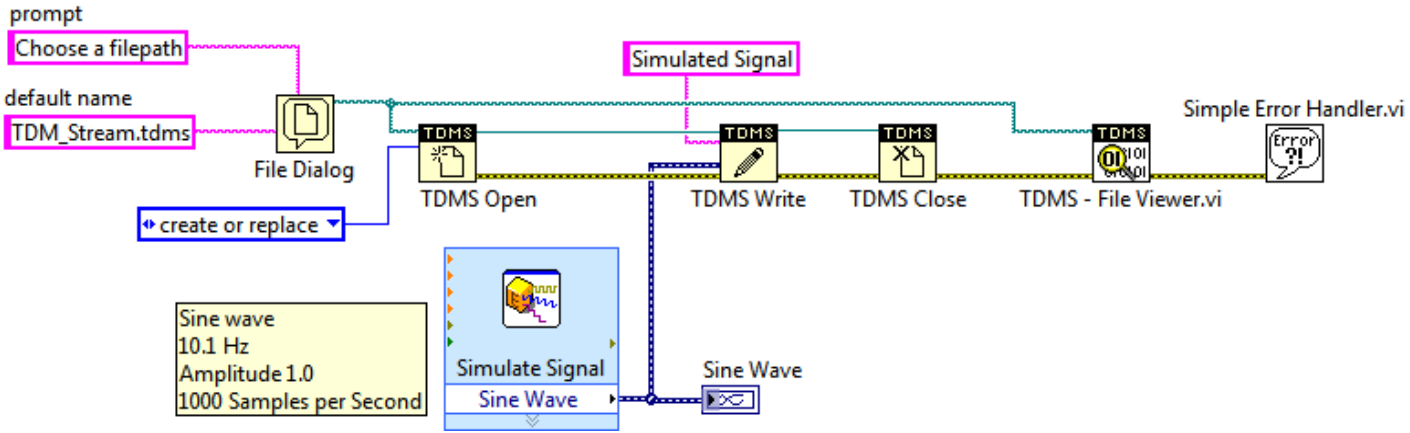
e) Sine – **Definitely not**



# Group Exercise
# Concept: Dataflow

Identify dataflow execution order in the following block diagrams.

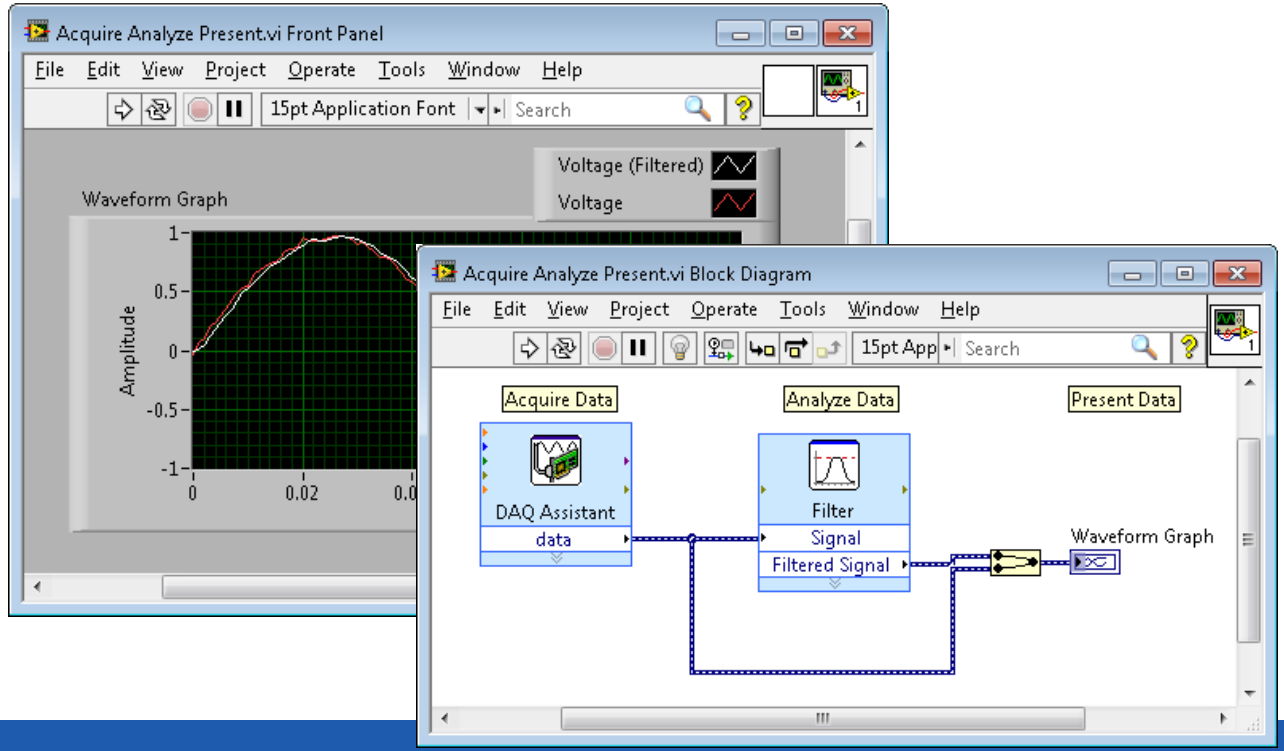
# Group Exercise
# Concept: Dataflow




Which node executes first? Last?
Where are the data dependencies?

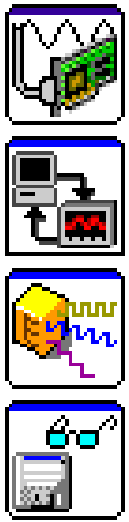
# I. Building a Simple VI

# Building a Simple VI



# Acquire Express VIs

- DAQ Assistant Express VI
- Instrument I/O Assistant Express VI
- Simulate Signal Express VI
- Read from Measurement File Express VI

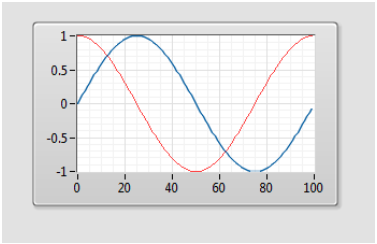


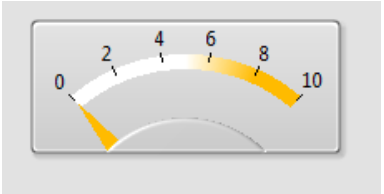
# Analyze Express VIs

- Amplitude and Level Measurements Express VI
- Statistics Express VI
- Spectral Measurements Express VI
- Tone Measurements Express VI
- Filter Express VI

# Present Express VIs and Indicators

- Display Message Express VI
- Play Waveform Express VI
- Report Express VI
- Write to Measurement File Express VI
- DIAdem Report Express VI



# Building and Running a VI

1. Place Express VI on the block diagram.
2. Configure the dialog box that opens.
3. Wire Express VIs together.
4. Save and run the VI.

The **Run** button appears broken when the VI you are creating or editing contains errors.

# Homework: Navigating LabVIEW

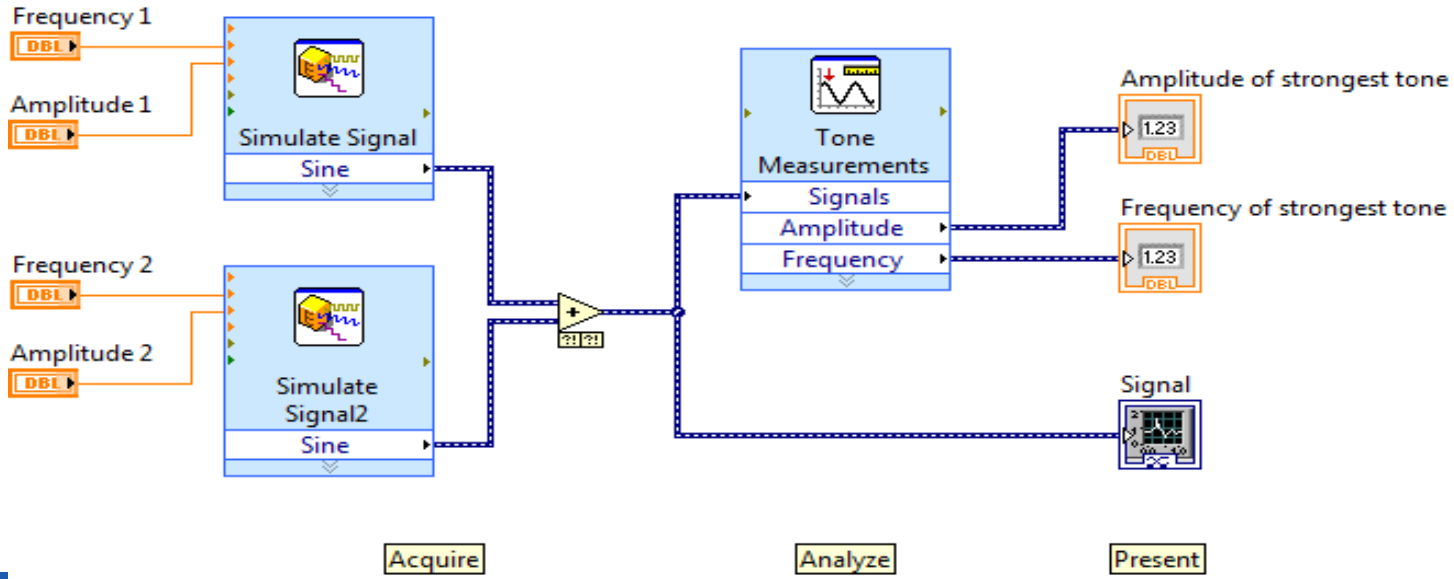
- Practice navigating the LabVIEW environment - add things to the front panel and block diagram, align and resize objects, use simple functions.

# Homework:
# Simple AAP VI

- Build a simple Acquire-Analyze-Present VI.
- You may use some of the Express VIs mentioned on the slides or different VIs that can be found in LabVIEW palettes.
- To find a function or VI, use ‘Search’ button on the palette or use Quick Drop window (<Ctrl+space>).

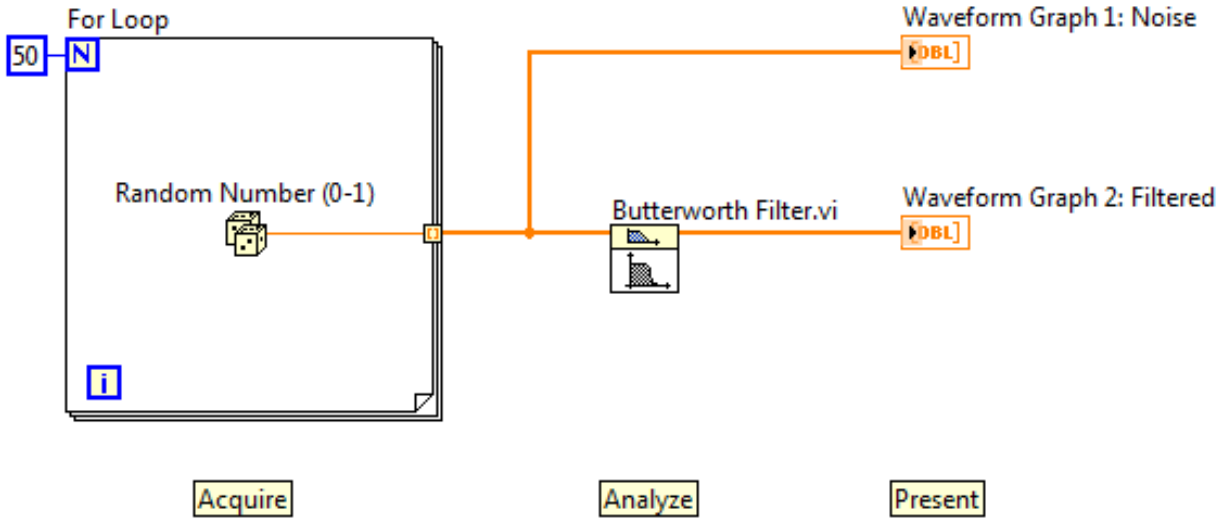
# Homework: Simple AAP VI

- Example: using Express VIs



# Homework:
# Simple AAP VI

- Example: without Express VIs



# Homework:
# Simple AAP VI

## Example – scenario:

- Acquire a sine waveform for 0.1 seconds.
- Determine the average value of the waveform.
- Log the data to a file.
- Display the data to a graph.