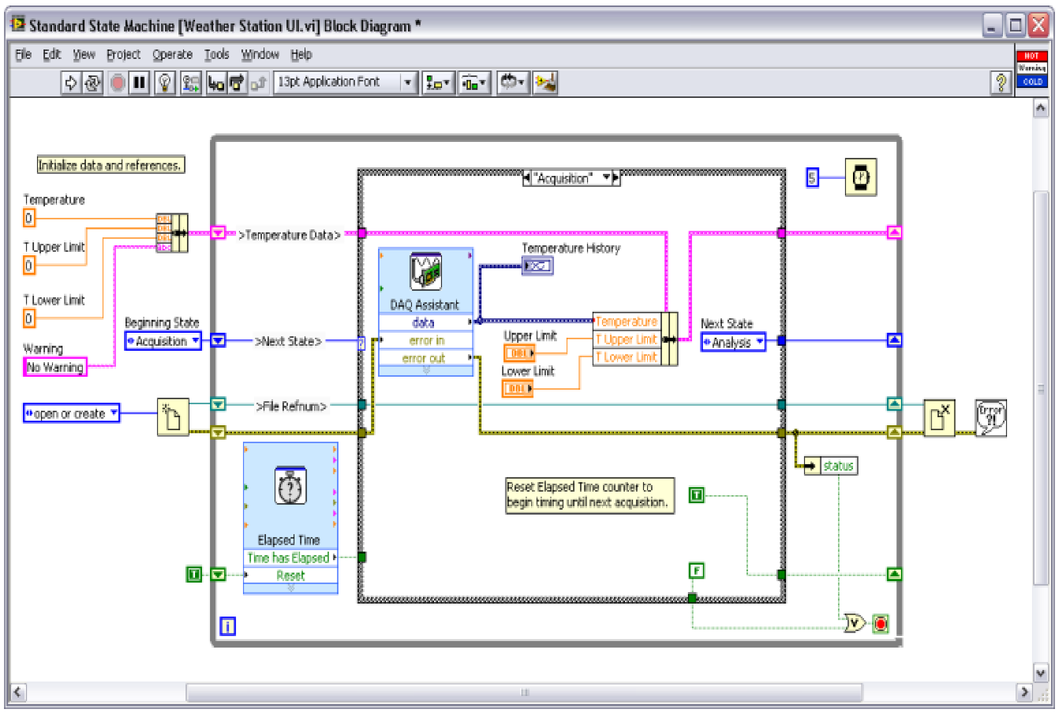
NATIONAL INSTRUMENTS LabVIEW™

Data Acquisition, Instrument Control, Automated Test

What Is LabVIEW?

— A graphical programming environment used to develop sophisticated measurement, test, and control systems.



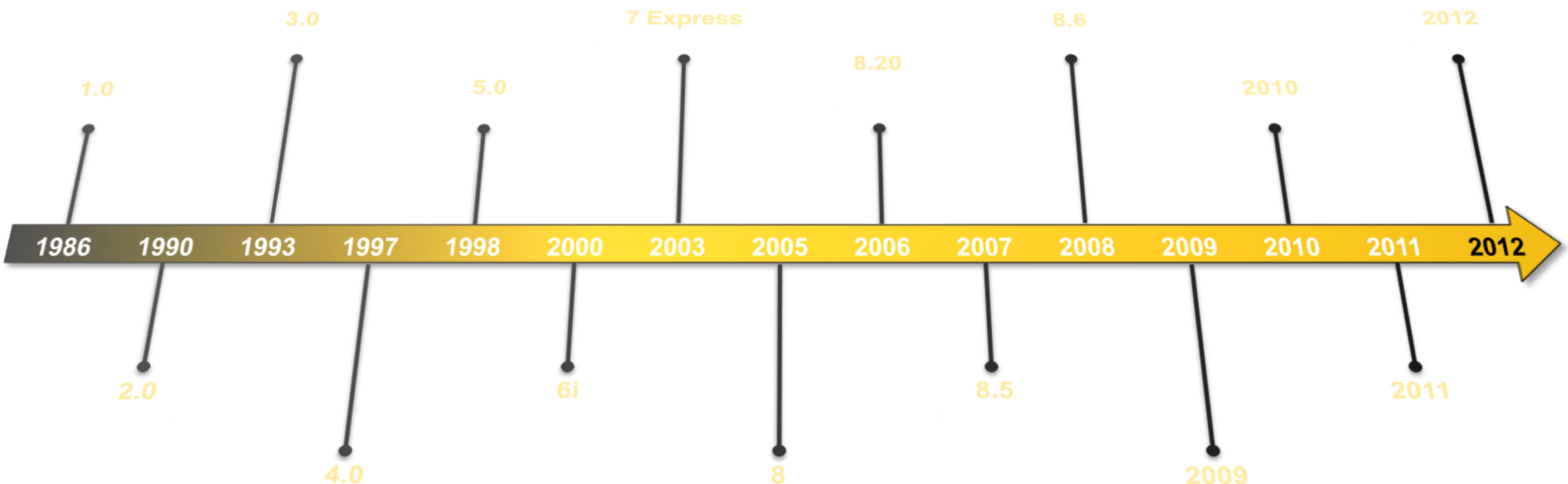
LabVIEW:

- Interfaces with wide variety of hardware
- Scales across different targets and OSs
- Provides built-in analysis libraries

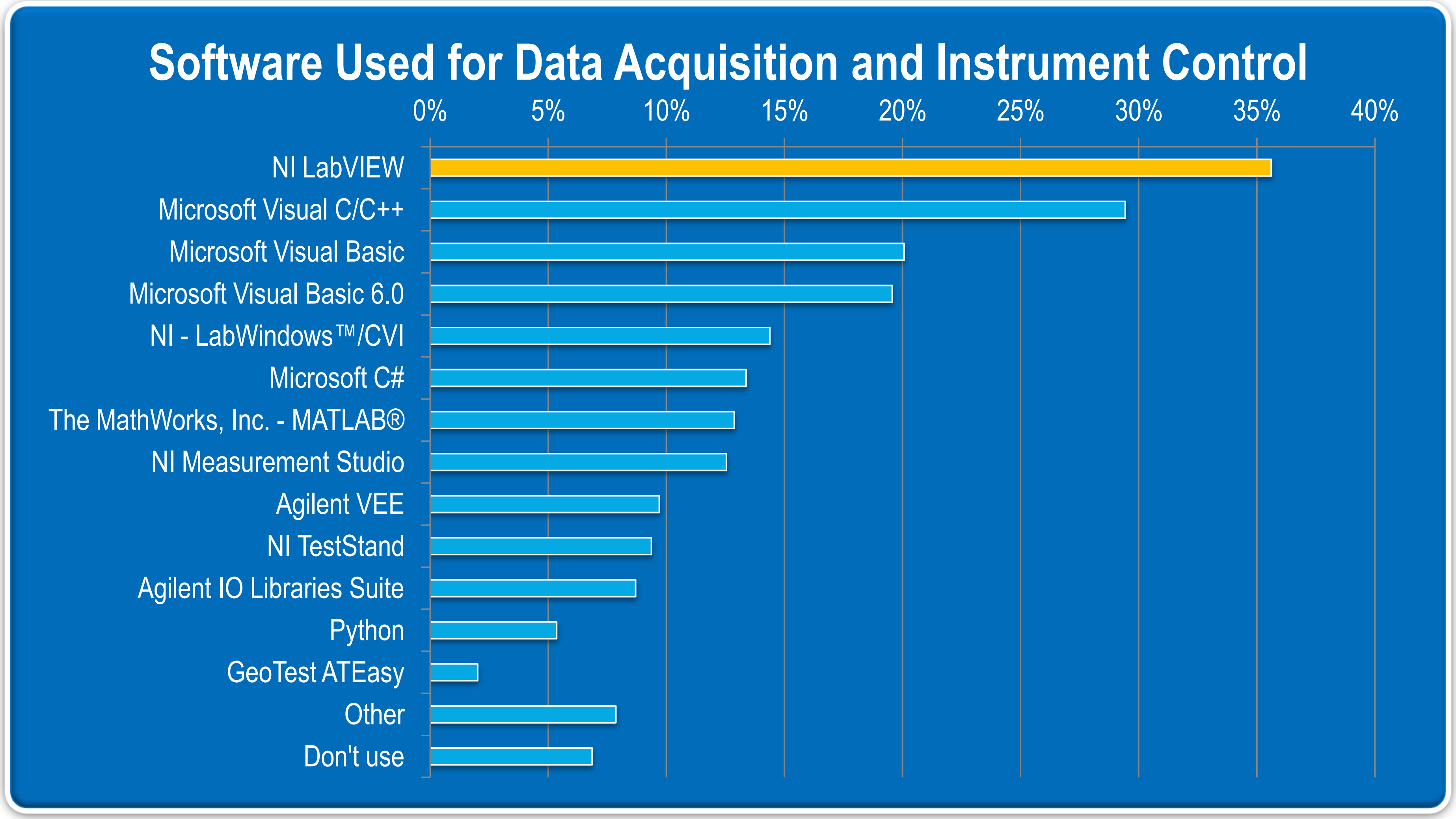
Because It Has Been Proven Over Nearly 30 Years…

Withstanding the test of time across operating systems, buses, technologies, and more

NATIONAL INSTRUMENTS LabVIEW™



…LabVIEW Is the Standard for Making Measurements



Unrivaled Hardware Integration in a Single Environment

- NI hardware
- 200+ data acquisition devices
- 450+ modular instruments
- Cameras
- Motion control

- Third-party hardware
- Instrument Driver Network
  - 10,000+ instrument drivers
  - 350+ instrument vendors
  - 100+ instrument types
- Communicate over any bus

The Foundation of LabVIEW: Virtual Instrumentation

Automation through software led to a realization about fixed-functionality instrumentation…

Redundancy: Power Supplies
Each separate instrument requires its own power supply to run measurement circuitry that captures the real-world signal.

Redundancy: Displays
Instrument vendors provide a limited-quality display per instrument, even though monitor technology is far more advanced.

Redundancy: Processors
Chip manufacturers rapidly enhance processors according to Moore's law, but instruments have fixed processing power.

Redundancy: Memory
PCs can quickly capitalize on a performance boost from a memory upgrade from readily available RAM.

Redundancy: Storage
Each instrument duplicates onboard storage even though PC hard drives are plentiful and cost-effective.

National Instruments’ Strategy: Graphical System Design

Your Investment in a Platform-Based Approach to Measurements Scales Across…

Test

Monitor

Embedded

Control

Cyber Physical

Industries and

NATIONAL INSTRUMENTS
LabVIEW™

Devices

Desktops and PC-Based DAQ

PXI and Modular Instruments

NI CompactRIO

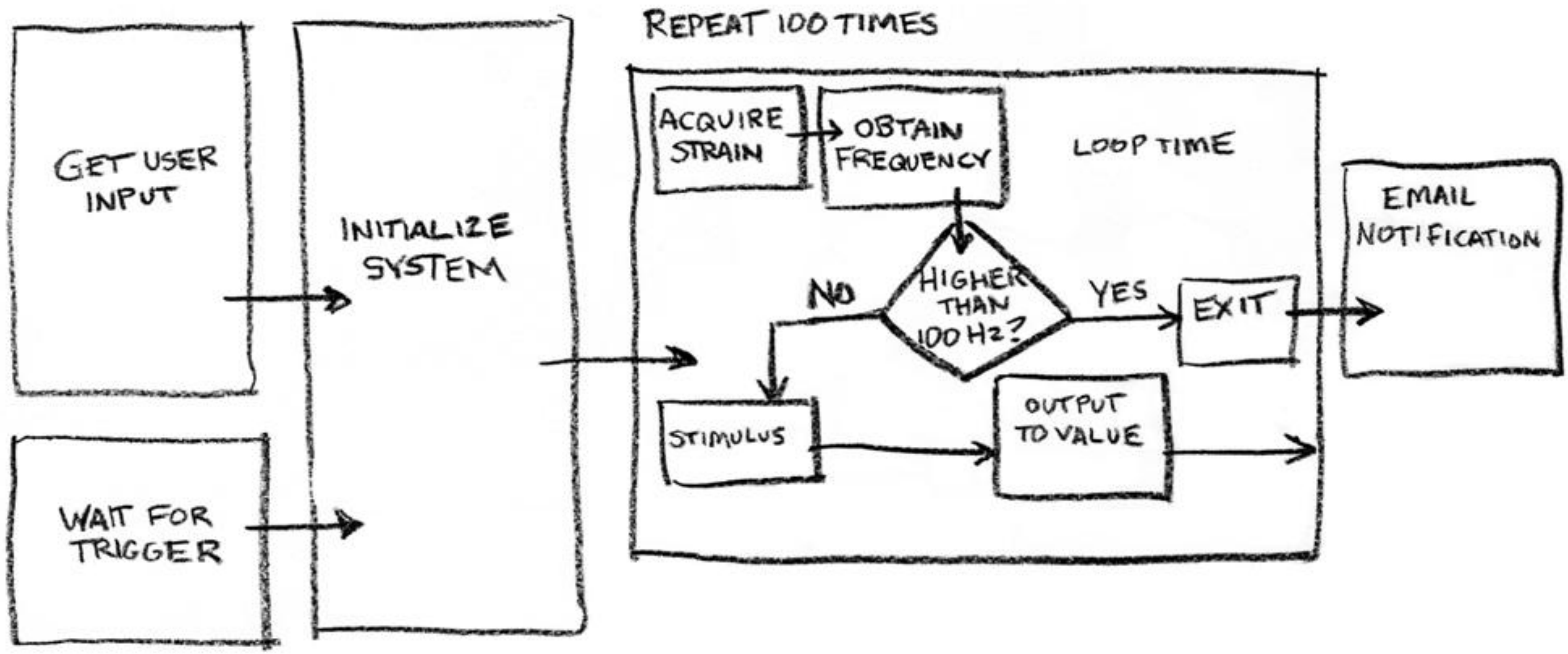
GPIB IEEE-488

ETHERNET

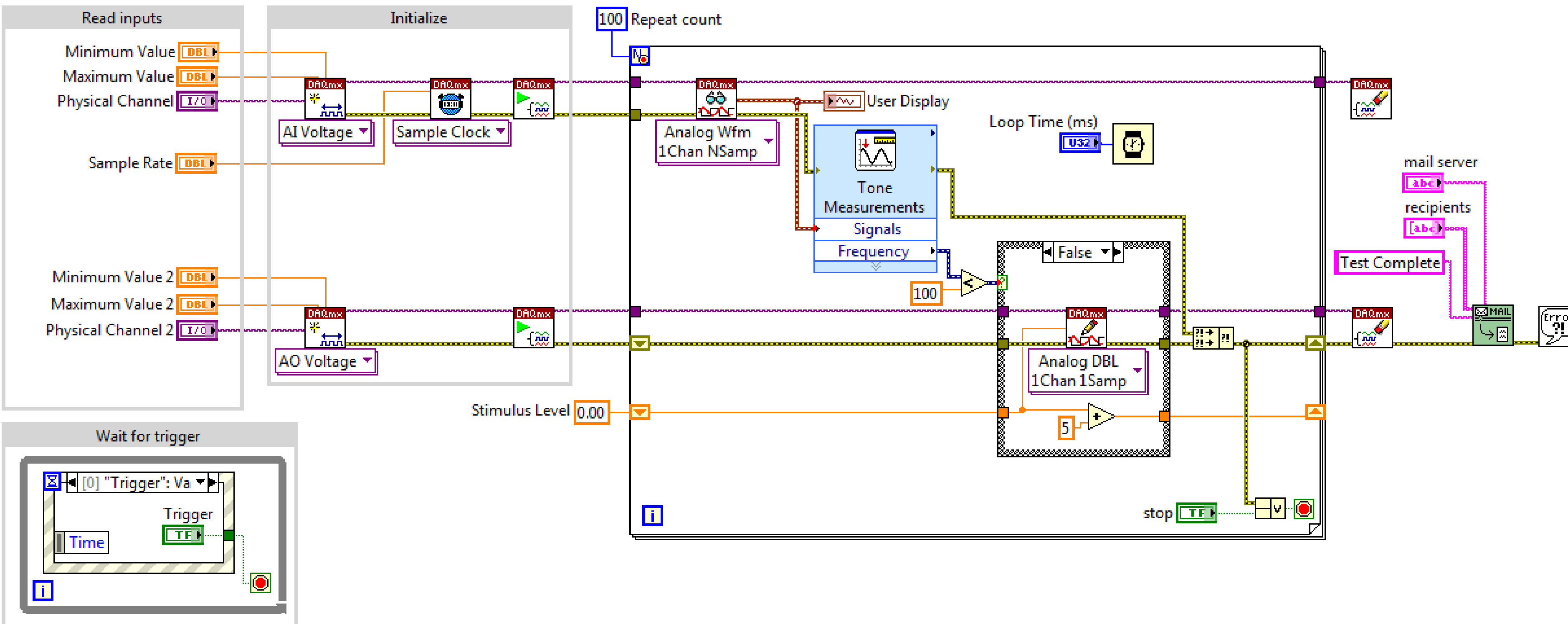
HI-SPEED CERTIFIED USB

Open Connectivity With Third-Party I/O

Graphical Language



Graphical Language



Part 1
Introduction to LabVIEW

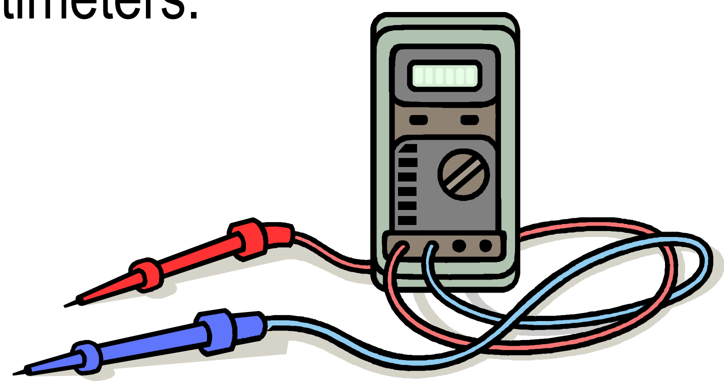
TOPICS

A. Virtual Instruments
B. Parts of a VI
C. Front Panel
D. Block Diagram
E. Dataflow
F. Building a Simple VI

A. Virtual Instruments (VIs)

Virtual Instrument (VI) – A LabVIEW program

The appearance and operation of VIs imitate physical instruments, such as oscilloscopes and digital multimeters.

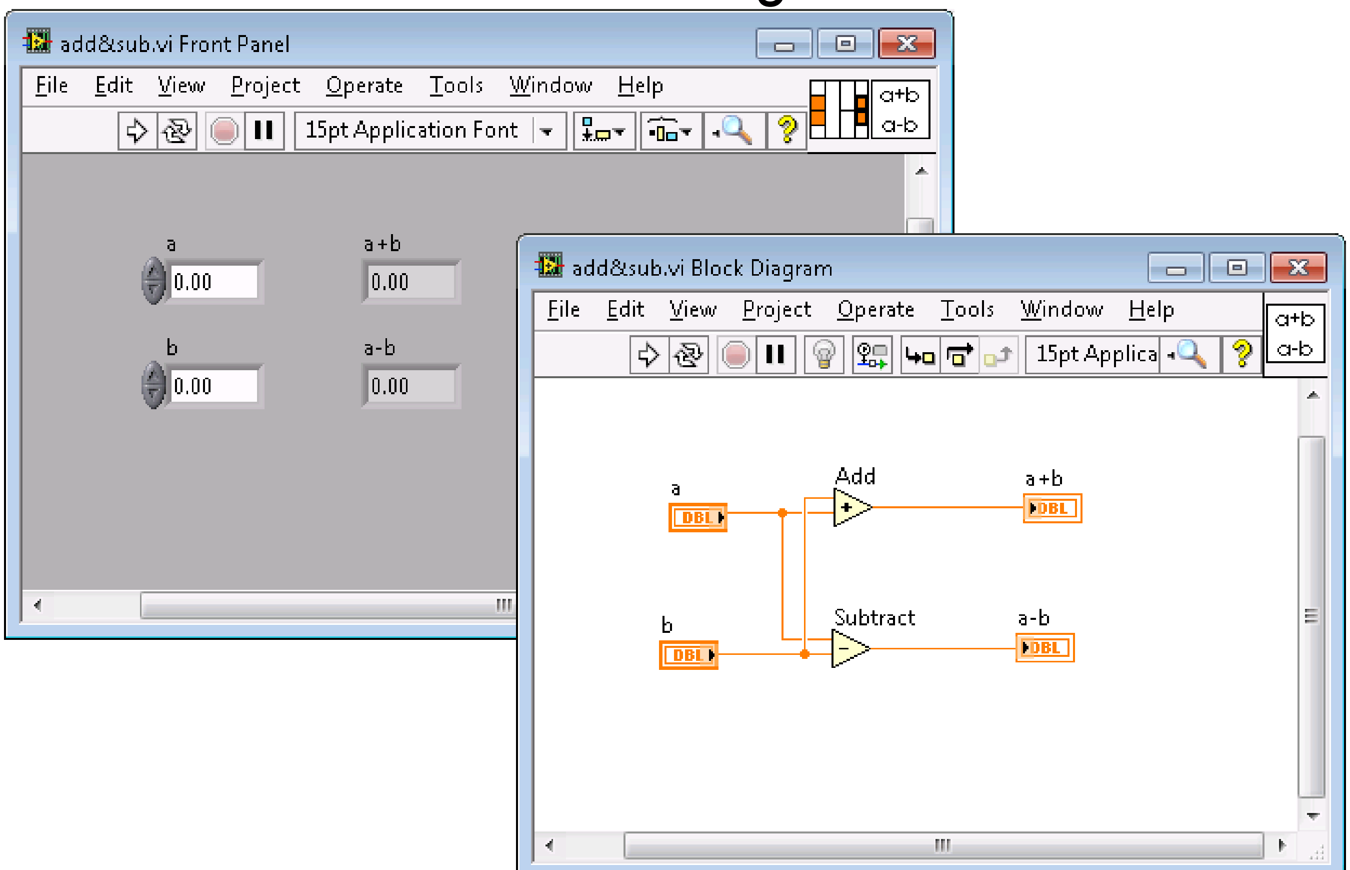


A. Starting a VI

B. Parts of a VI

LabVIEW VIs contain three main components:

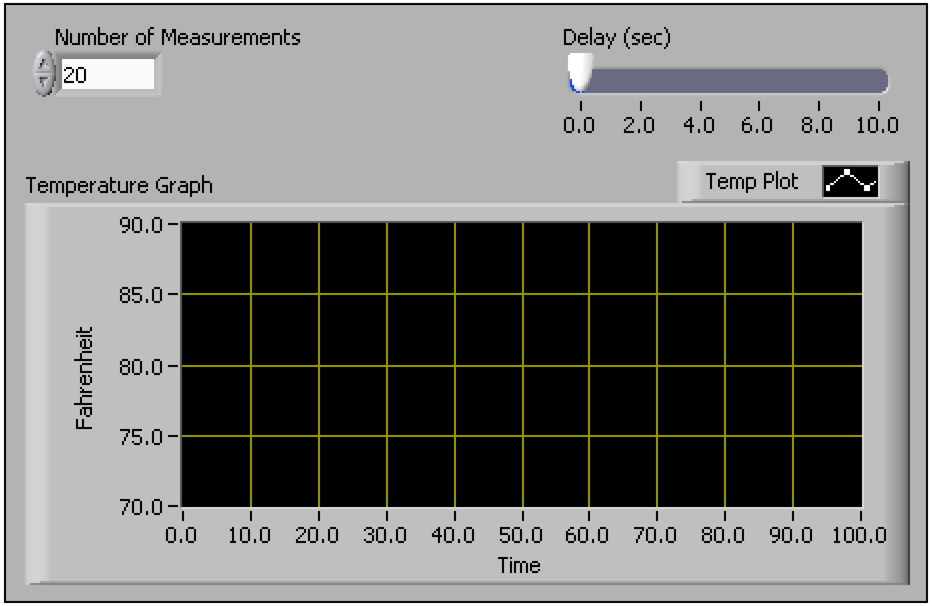
1. Front Panel   2. Block Diagram   3. Icon/Connector Pane



B. Parts of a VI – Front Panel

Front Panel – User interface for the VI

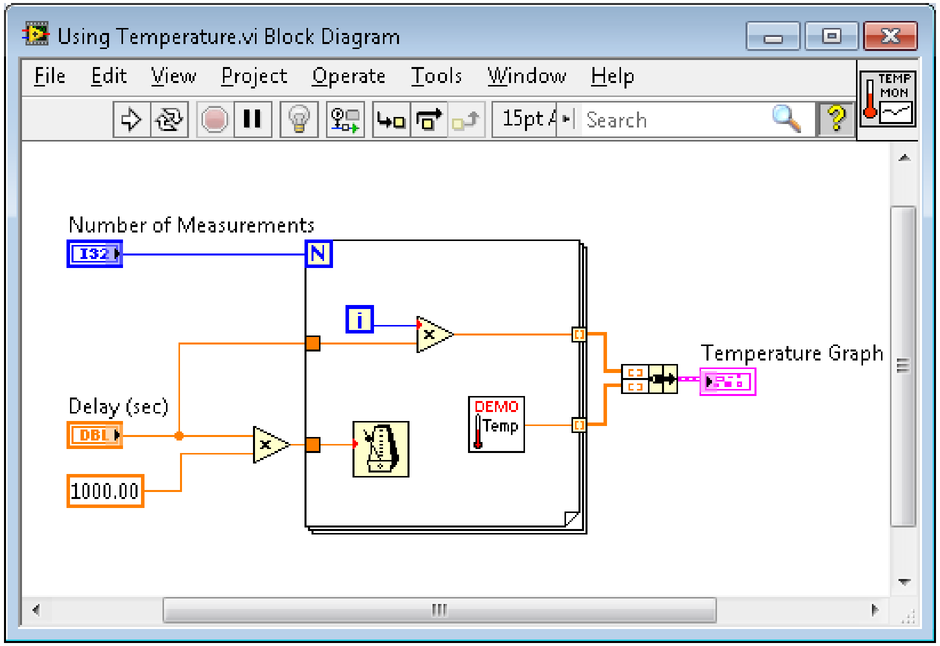
You build the front panel with controls (inputs) and indicators (outputs)



B. Parts of a VI – Block Diagram

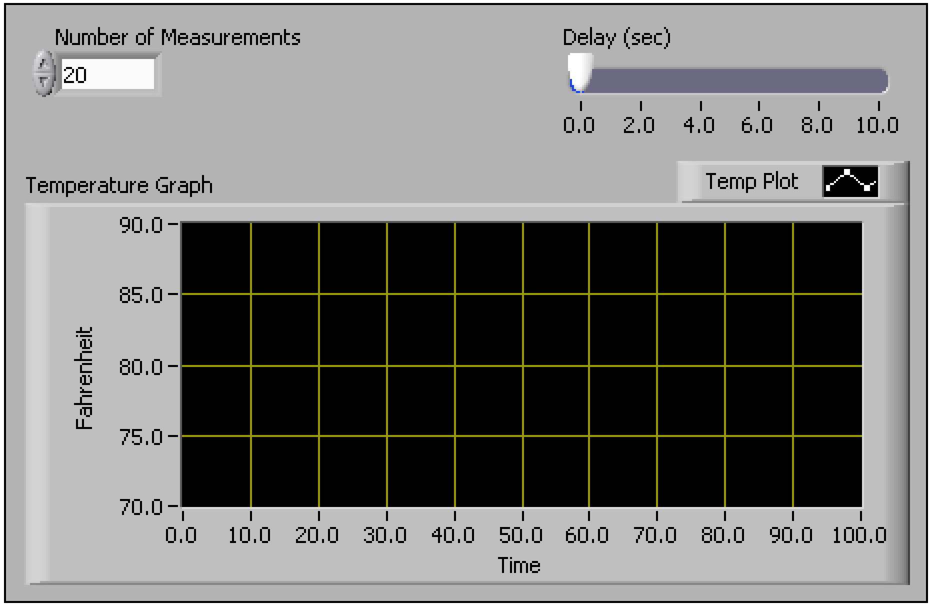
Block Diagram – Contains the graphical source code

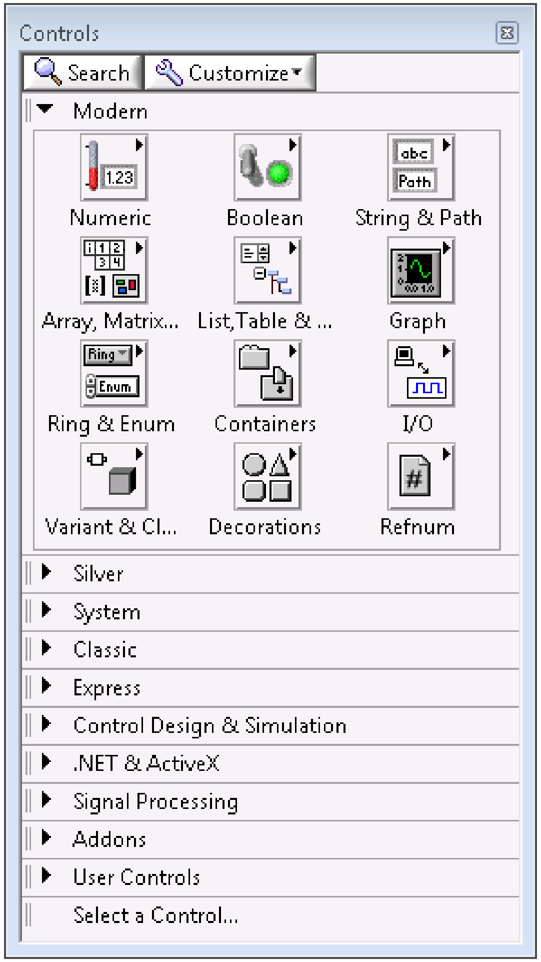
Front panel objects appear as terminals on the block diagram



B. Front Panel – Controls Palette

- Contains the controls and indicators you use to create the front panel
- Access from the front panel by selecting **View»Controls Palette**

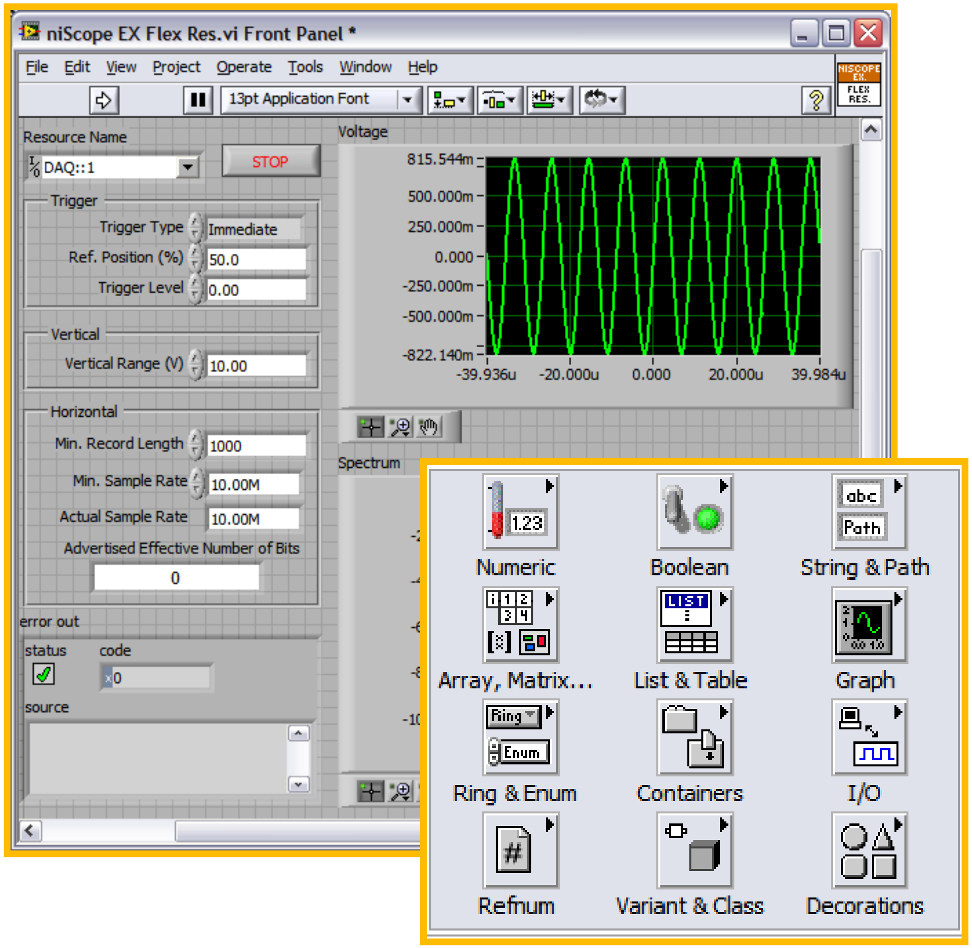




C. Front Panel – Controls & Indicators

- Controls
  - Knobs, push buttons, dials, and other input devices
  - Simulate instrument input devices and supply data to the block diagram of the VI
- Indicators
  - Graphs, LEDs, and other displays
  - Simulate instrument output devices and display data the block diagram acquires or generates

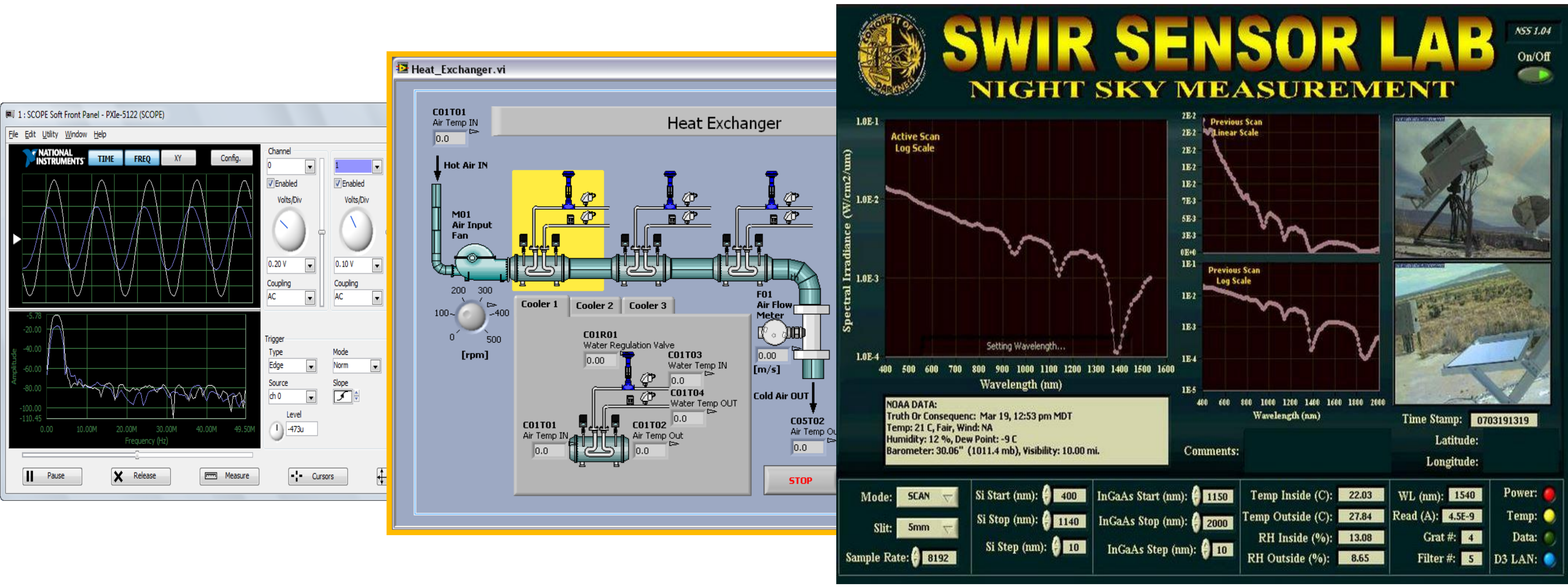
C. Front Panel – Controls & Indicators



- Graphs and strip charts
- Buttons and checkboxes
- Knobs and sliders
- Text and combo boxes
- Tree controls
- Tables
- ActiveX objects
- etc...

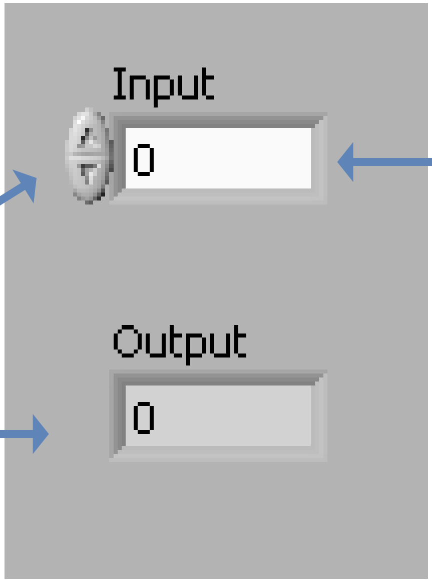
C. LabVIEW Front Panels in Action

C. LabVIEW Front Panels



C. Front Panel – Numeric Controls/Indicators

The numeric data type can represent numbers of various types, such as integer or real



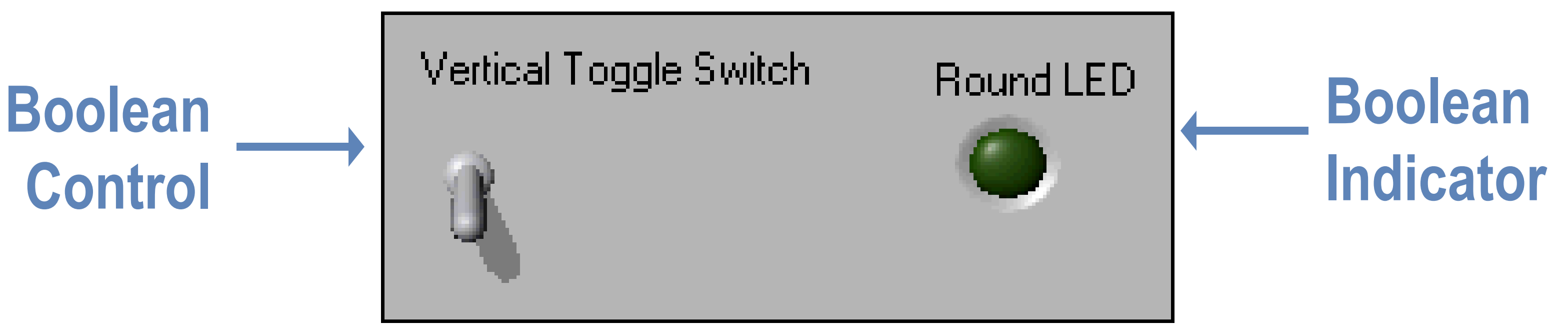
Numeric Control

Increment/Decrement Buttons

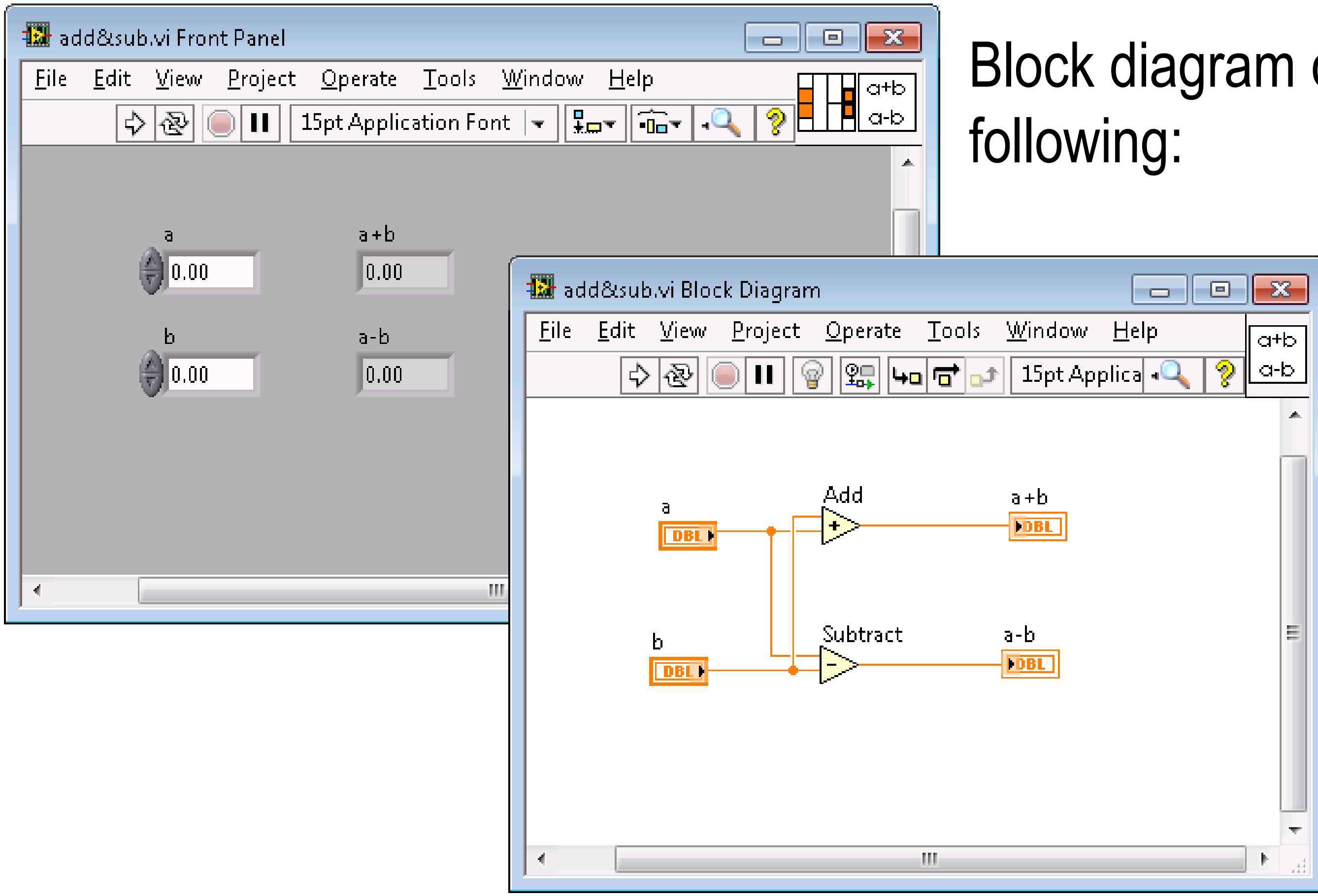
Numeric Indicator

C. Front Panel – Boolean Controls/Indicators

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



D. Block Diagram

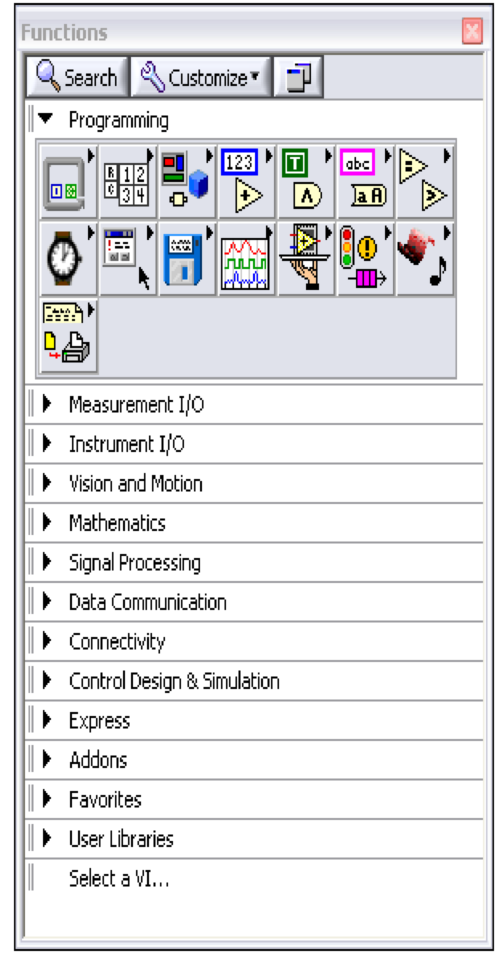


Block diagram objects include the following:

- Terminals
- SubVIs
- Functions
- Constants
- Structures
- Wires

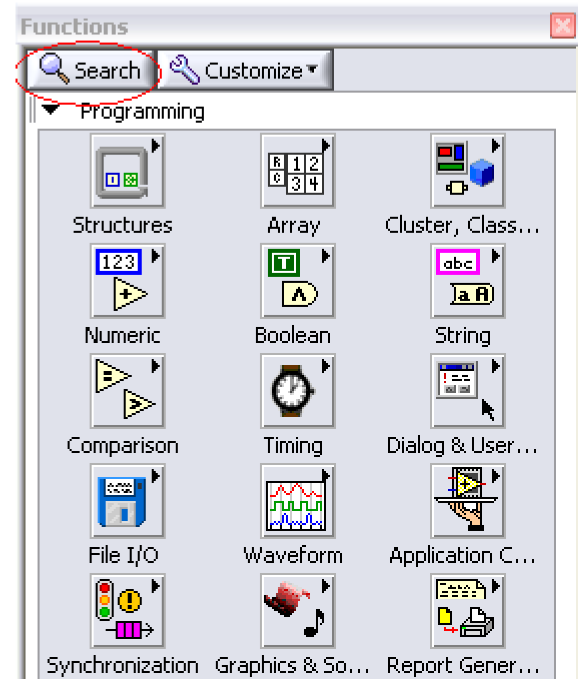
D. Block Diagram – Functions Palette

Contains the VIs, functions, and constants you use to create the block diagram



D. Searching for Controls, VIs & Functions

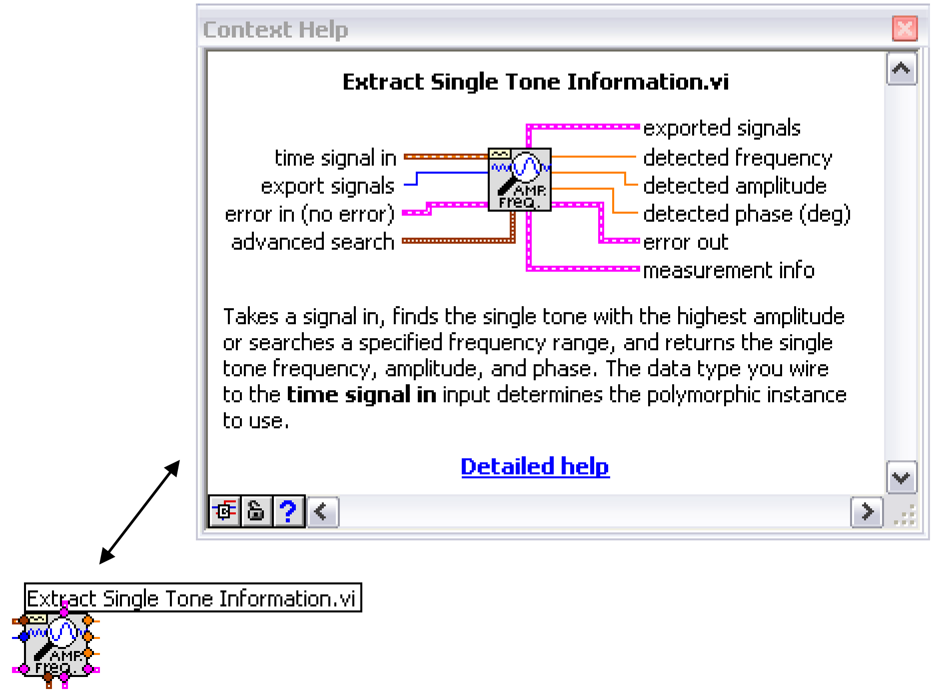
Find controls, functions, and VIs using the **Search** button on the **Controls** and **Functions** palette.



D. Context Help Window

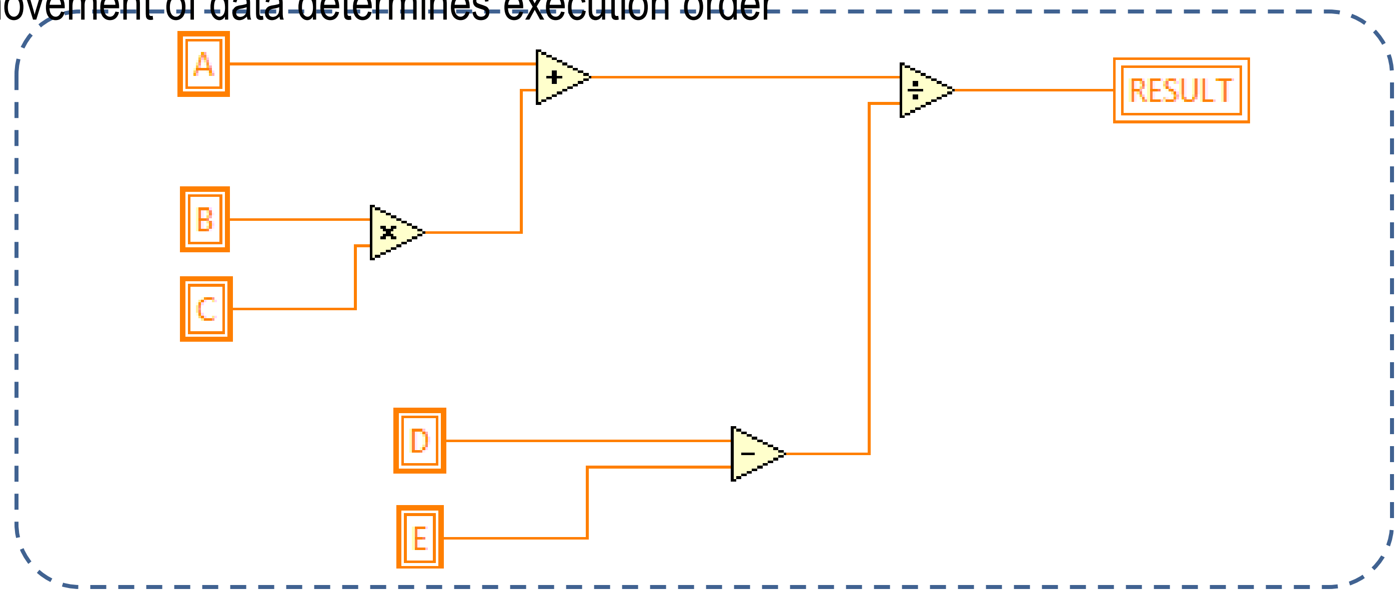
Help»Show Context Help, press the <Ctrl+H> keys

Hover cursor over object to update window



E. What Is Data Flow?

- Each block diagram node executes only when it receives all inputs
- Each node produces output data after execution
- Data flows along a path defined by wires
- The movement of data determines execution order



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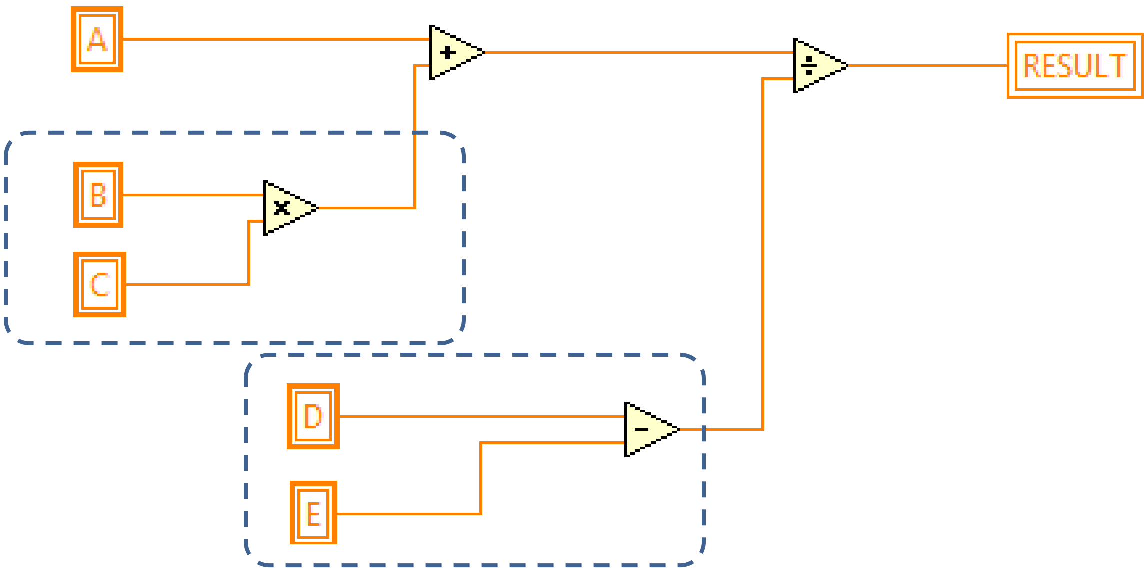
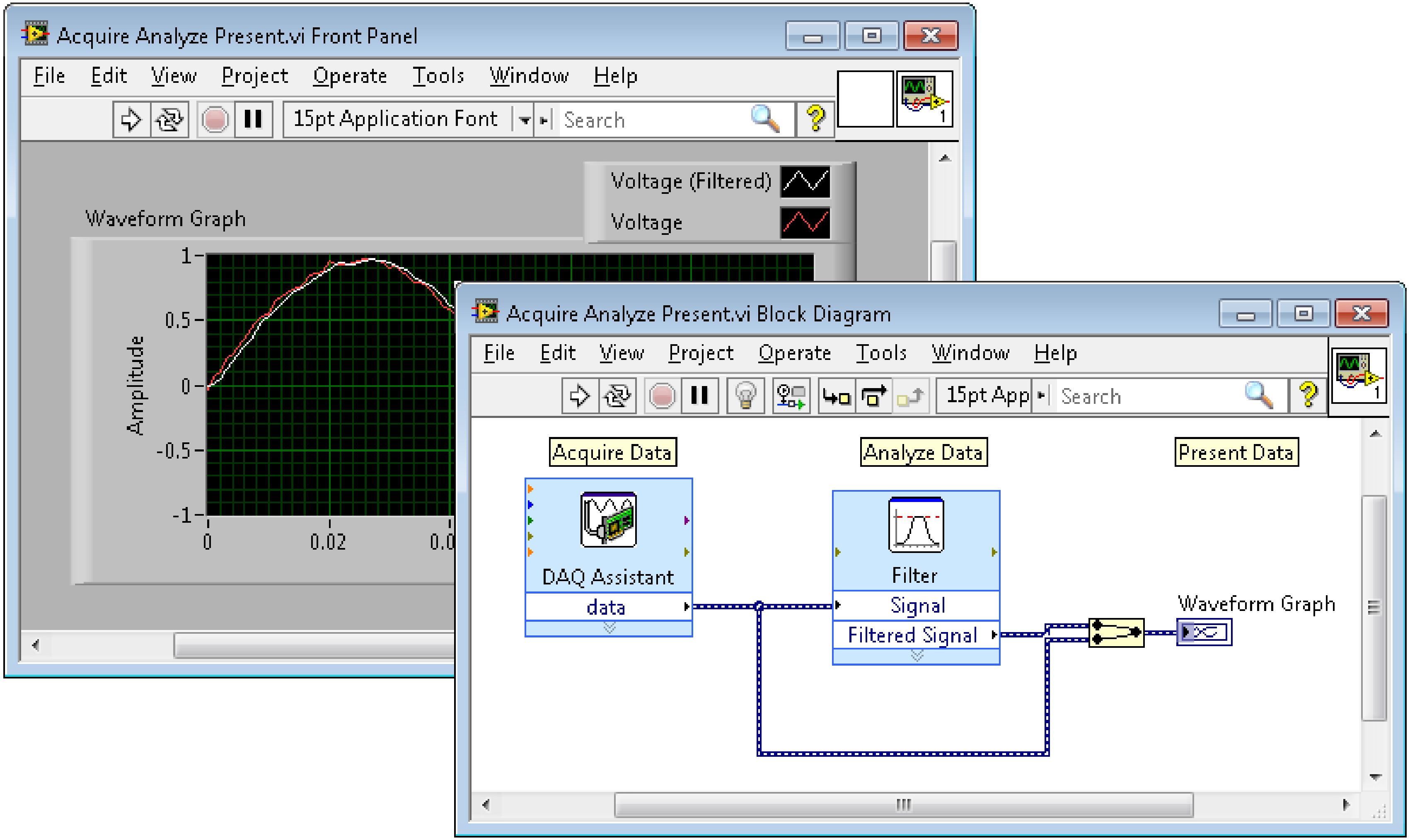


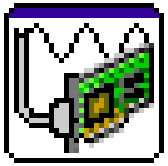
F. Building a Simple VI



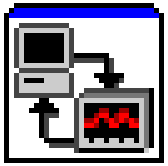
F. Building a Simple VI – Acquire

Acquire Express VIs:

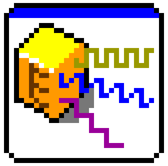
- DAQ Assistant Express VI



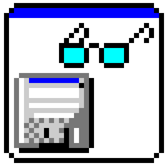
- Instrument I/O Assistant Express VI



- Simulate Signal Express VI

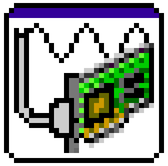


- Read from Measurement File Express VI

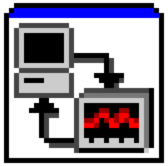


Acquire Express VIs

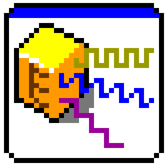
- DAQ Assistant Express VI



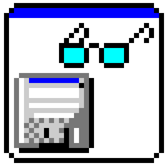
- Instrument I/O Assistant Express VI



- Simulate Signal Express VI

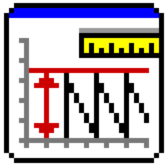
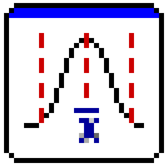
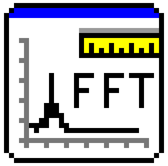


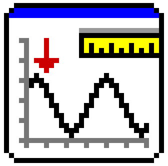
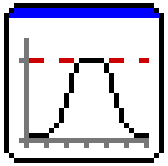
- Read from Measurement File Express VI



Analyze Express VIs

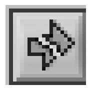
- Amplitude and Level Measurements Express VI
- Statistics Express VI
- Spectral Measurements Express VI
- Tone Measurements Express VI
- Filter Express VI

Debugging Techniques

- **Finding Errors**

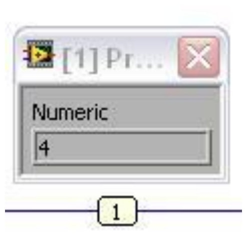


Click on broken **Run** button.
Window showing error appears.

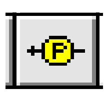
- **Execution Highlighting**

Click on **Execution Highlighting** button; data flow is animated using bubbles. Values are displayed on wires.

- **Probes**



Right-click on wire to display probe and it shows data as it flows through wire segment.



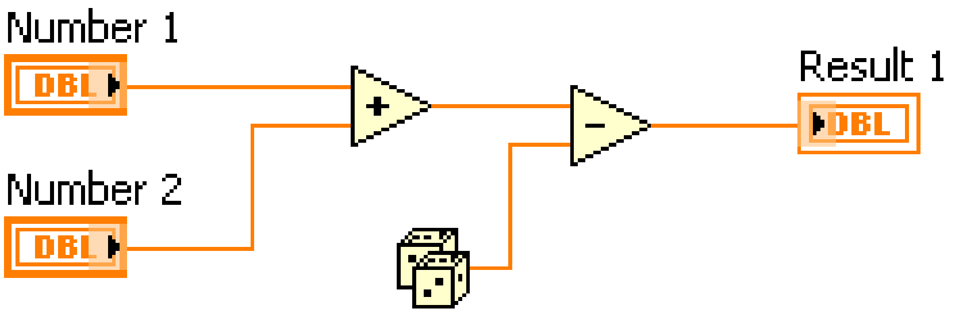
You can also select Probe tool from Tools palette and click on wire.

Exercise 1
Temperature Simulation

Build a simple VI to simulate one temperature data point.

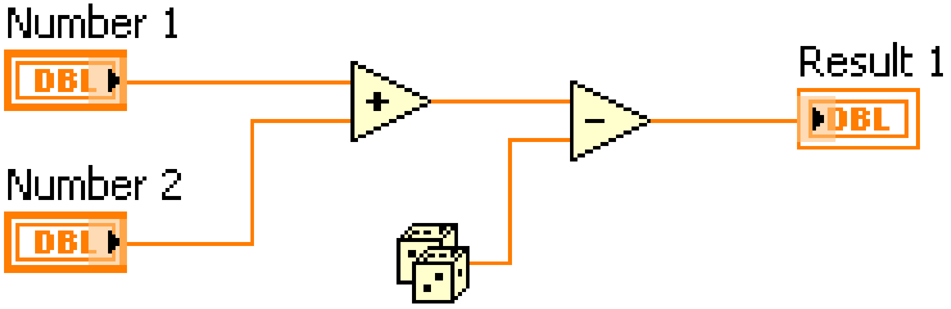
Summary—Quiz

1. Which function executes first: Add or Subtract?
   a) Add
   b) Subtract
   c) Unknown



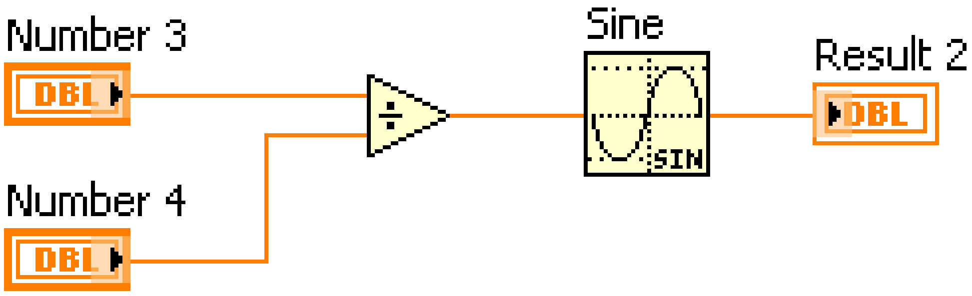
Summary—Quiz Answer

1. Which function executes first: Add or Subtract?
   a) **Add**
   b) Subtract
   c) Unknown



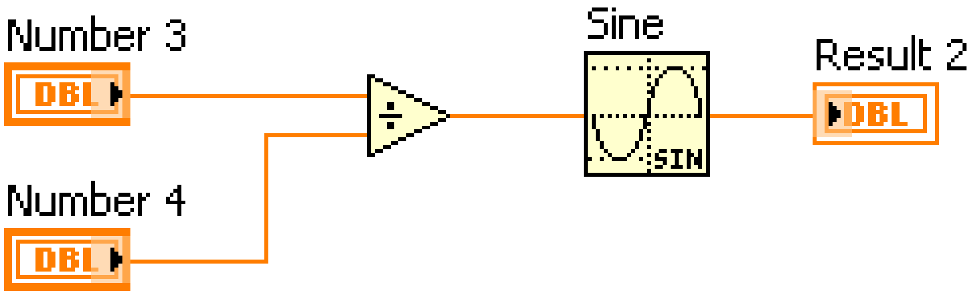
Summary—Quiz

2. Which function executes first: Sine or Divide?
    a) Sine
    b) Divide
    c) Unknown



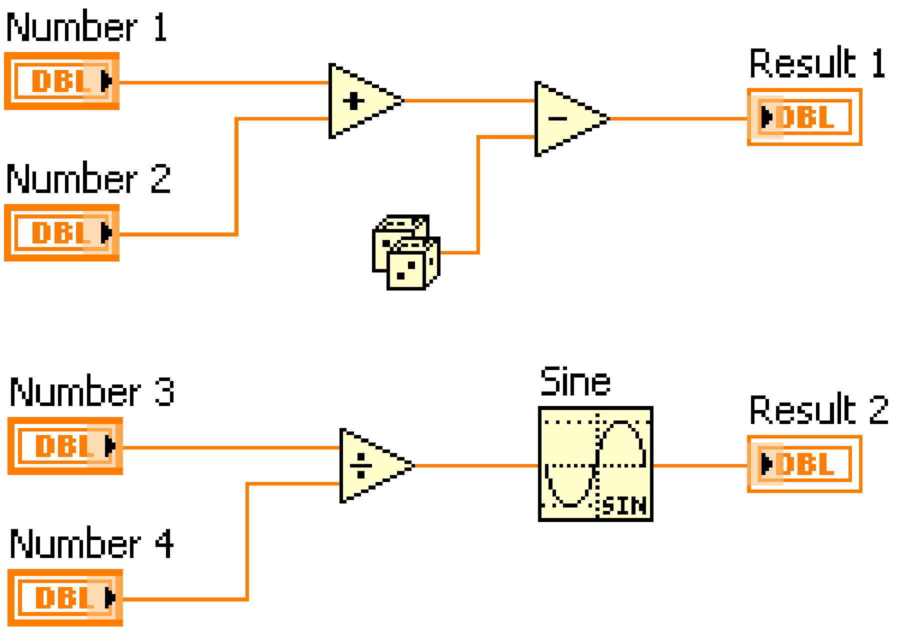
Summary—Quiz Answer

2. Which function executes first: Sine or Divide?
    a) Sine
    b) Divide
    c) Unknown



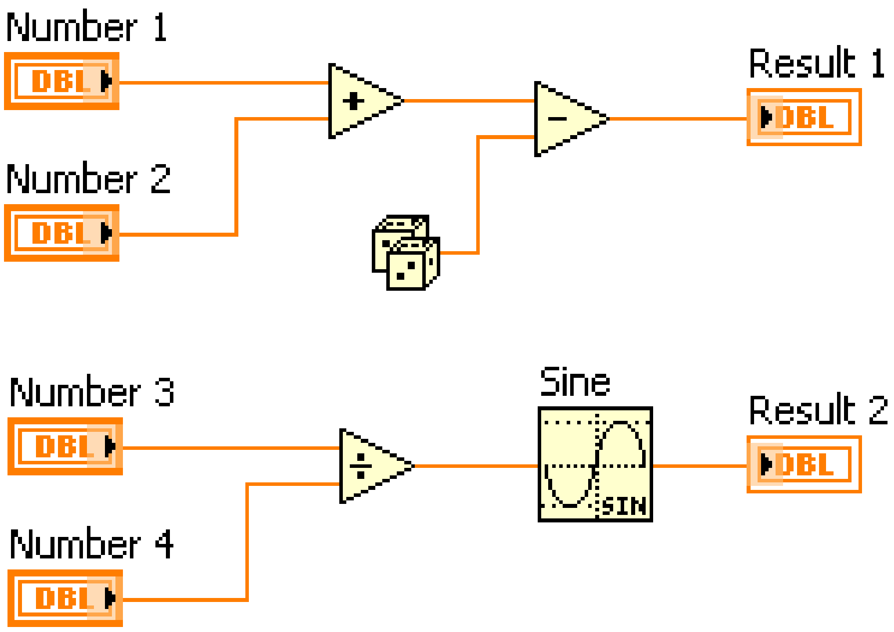
Summary—Quiz

3. Which of the following functions executes first: Random Number, Add or Divide?
   a) Random Number
   b) Divide
   c) Add
   d) Unknown



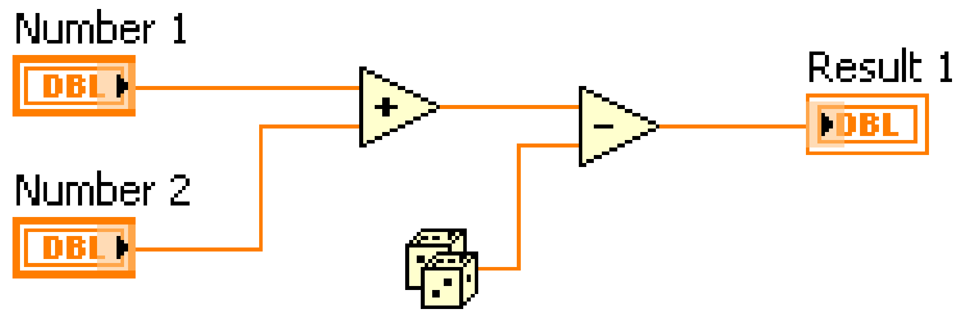
Summary—Quiz Answer

3. Which of the following functions executes first: Random Number, Add or Divide?
   a) Random Number
   b) Divide
   c) Add
   d) Unknown



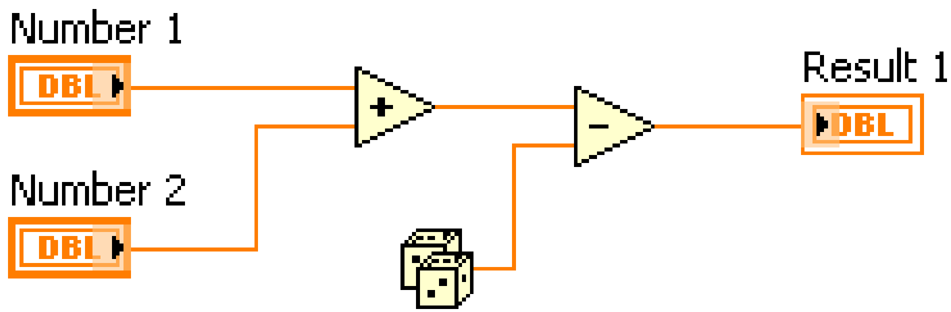
Summary—Quiz

4. Which of the following functions execute last: Random Number, Subtract or Add?
   a) Random Number
   b) Subtract
   c) Add
   d) Unknown



Summary—Quiz Answer

4. Which of the following functions execute last: Random Number, Subtract or Add?
   a) Random Number
   b) Subtract
   c) Add
   d) Unknown



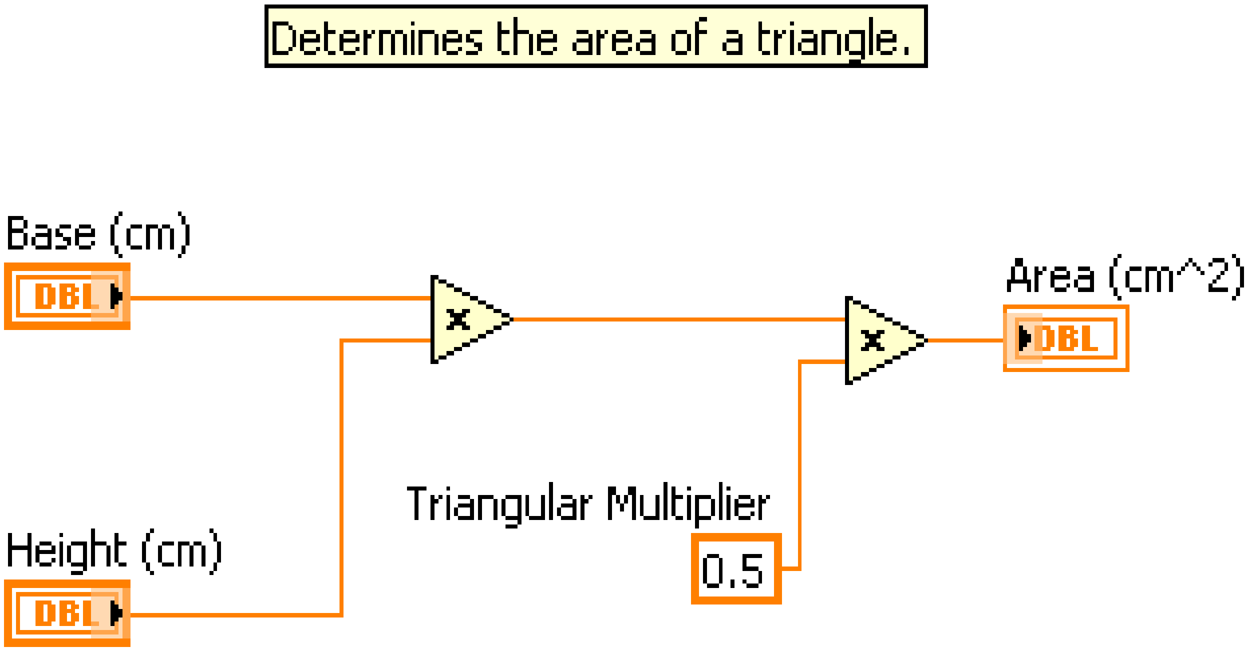
Part 2
Implementing a VI

TOPICS

A. LabVIEW Data Types
B. Structures - While Loops
C. Structures - For Loops
G. Timing
H. Grouping Data – Arrays
I. Grouping Data - Clusters

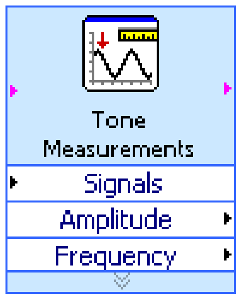
A. LabVIEW Data Types – Terminals

Terminals visually communicate information about the data type represented

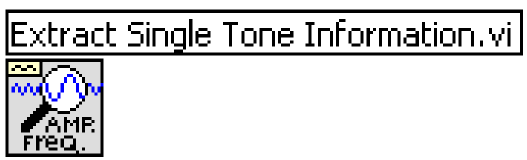


3 Types of Functions (from the Functions Palette)

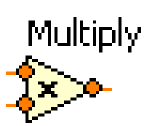
Express VIs: interactive VIs with configurable dialog page **(blue border)**



Standard VIs: modularized VIs customized by wiring **(customizable)**



Functions: fundamental operating elements of LabVIEW; no front panel or block diagram **(yellow)**



What Types of Functions are Available?

Input and Output

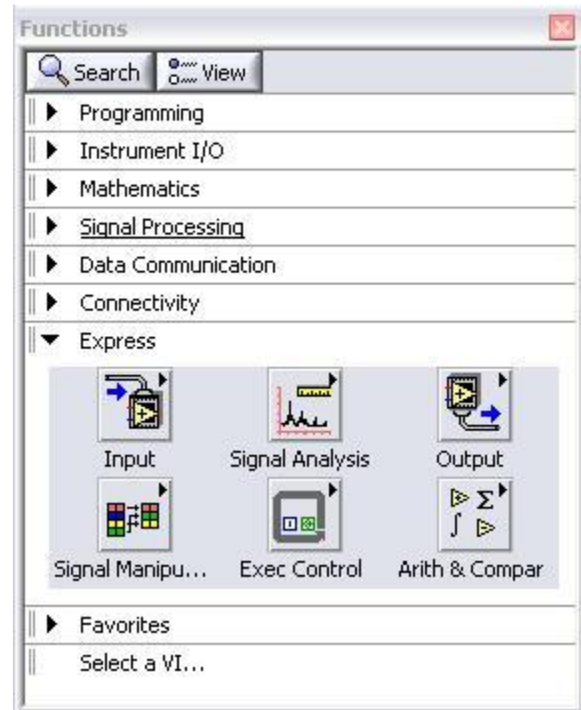
- Signal and Data Simulation
- Acquire and Generate Real Signals with DAQ
- Instrument I/O Assistant (Serial & GPIB)
- ActiveX for communication with other programs

Analysis

- Signal Processing
- Statistics
- Advanced Math and Formulas
- Continuous Time Solver

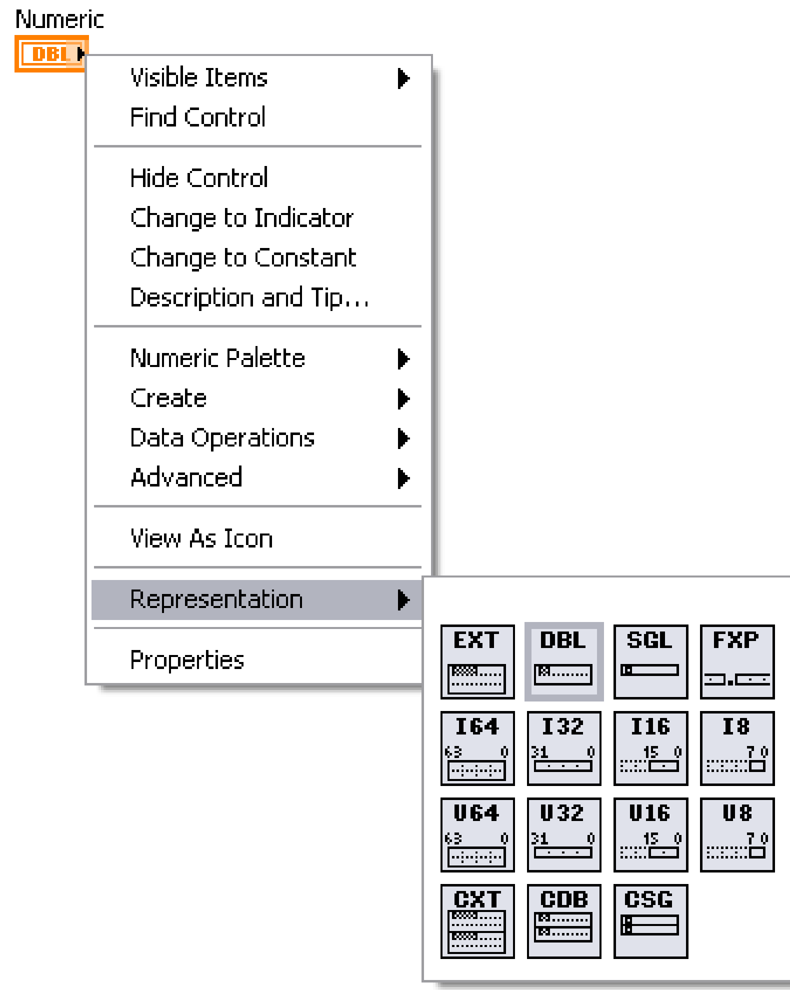
Storage

- File I/O



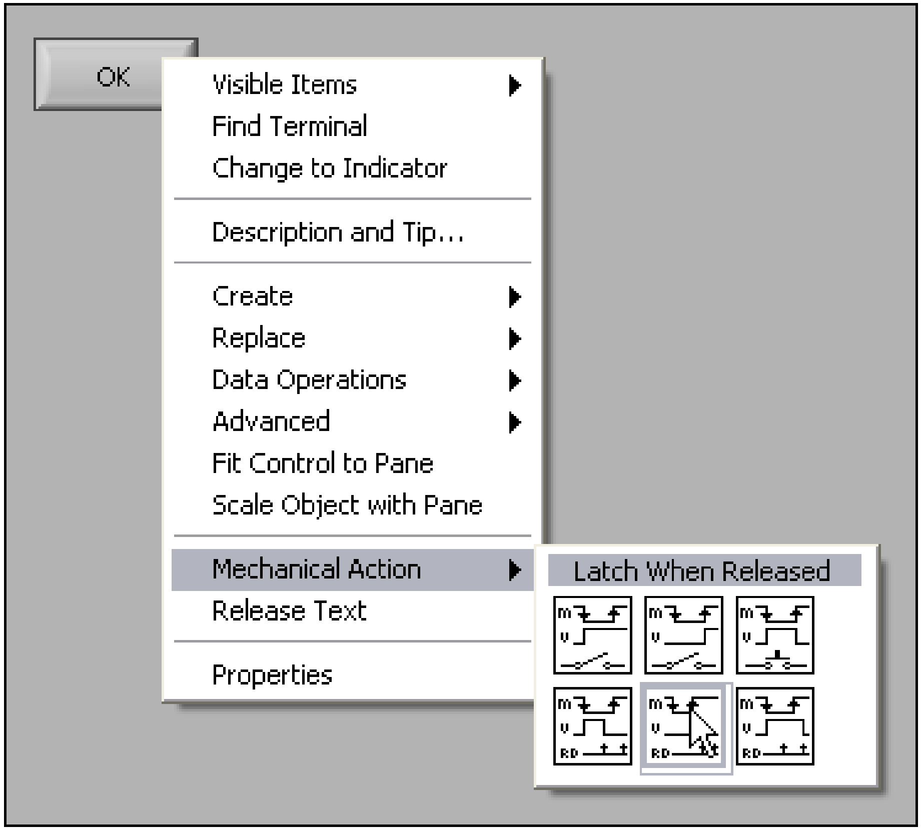
A. LabVIEW Data Types – Numerics

- The numeric data type represents numbers of various types
- To change the representation of a numeric, right-click the control, indicator, or constant, and select **Representation** from the shortcut menu

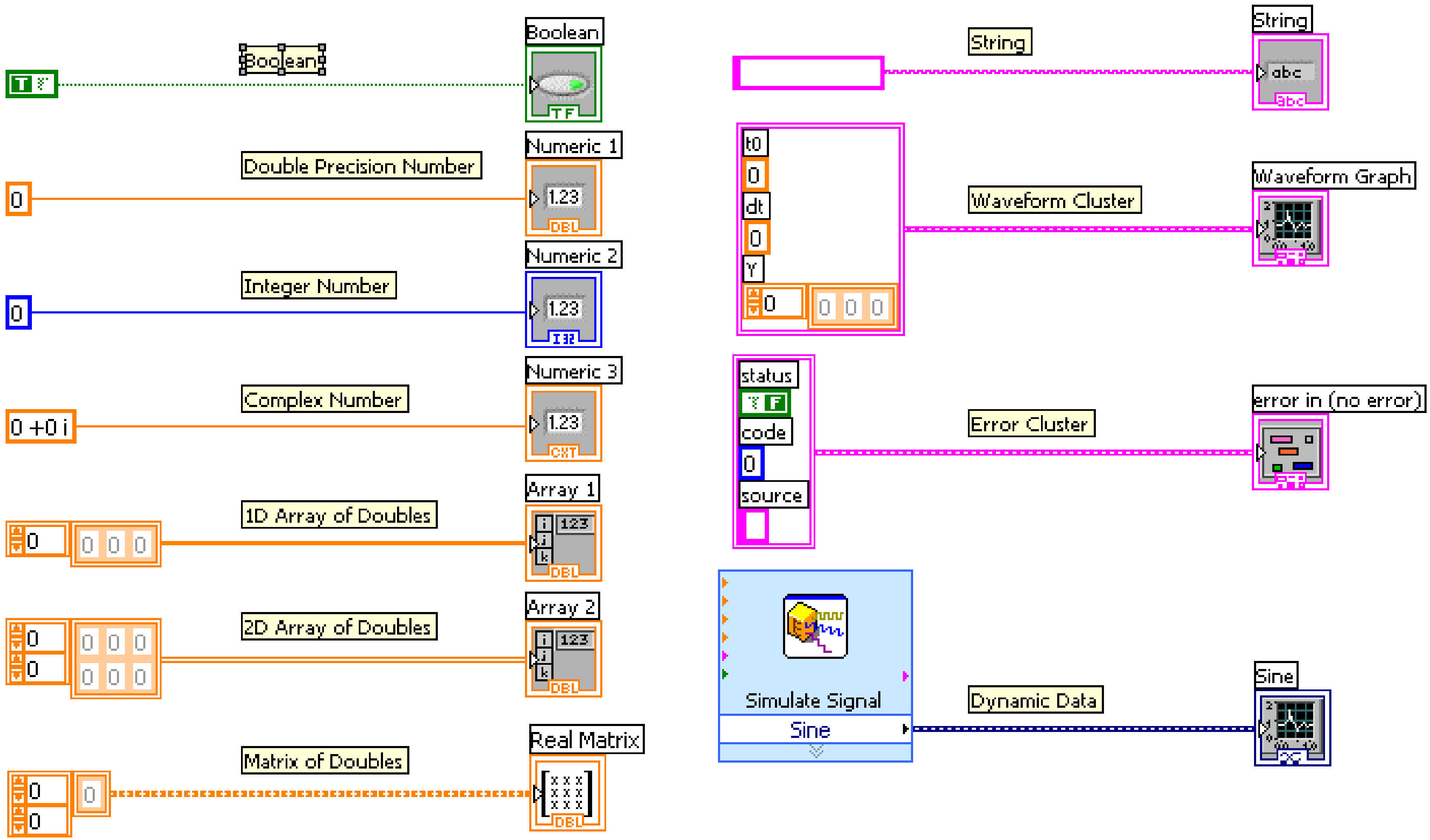


A. LabVIEW Data Types – Boolean

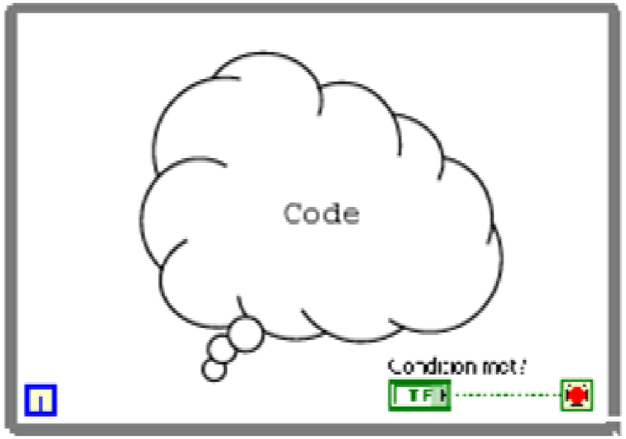
- Behavior of Boolean controls is specified by the mechanical action
- In LabVIEW, the Boolean data type is represented with the color green

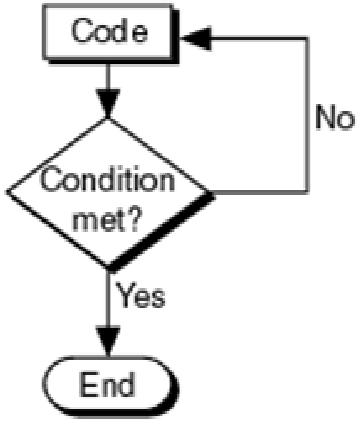


A. LabVIEW Data Types – Other Data Types



B. Structures - While Loops



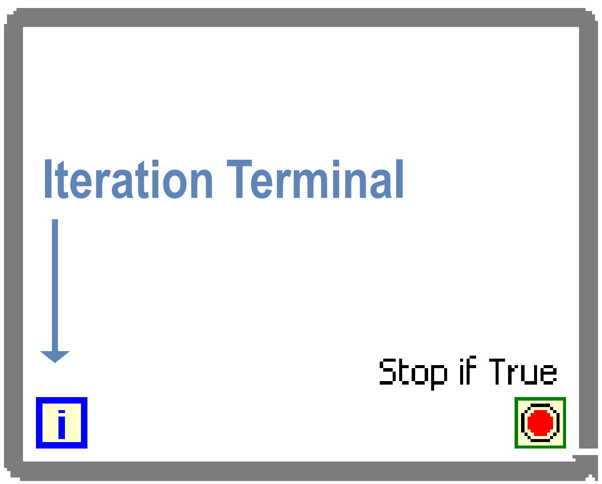


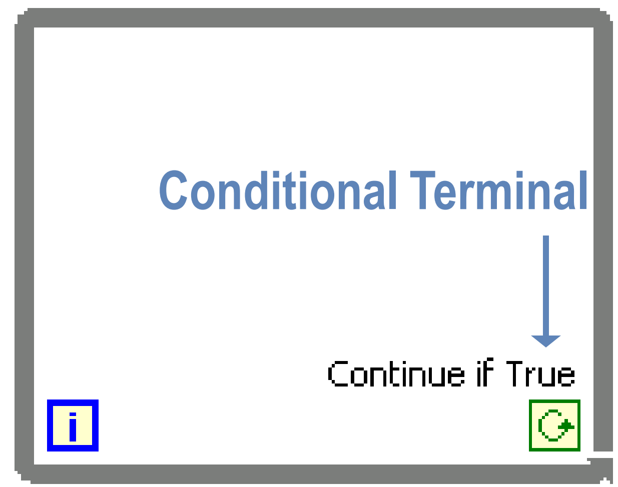

```
Repeat (code);
Until Condition met;
End;
```

LabVIEW While Loop **Flowchart** **Pseudo Code**

B. Structures - While Loops

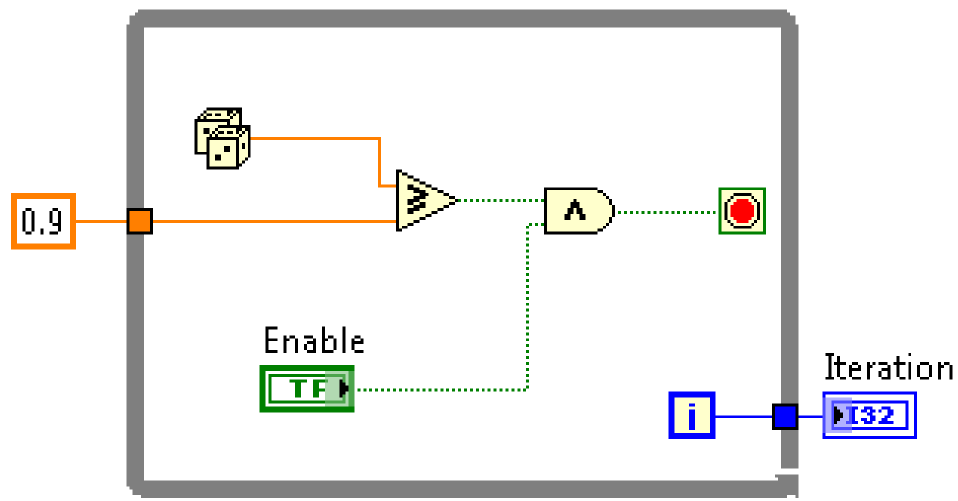
- Iteration terminal: returns number of times loop has executed; zero indexed
- Conditional terminal: defines when the loop stops



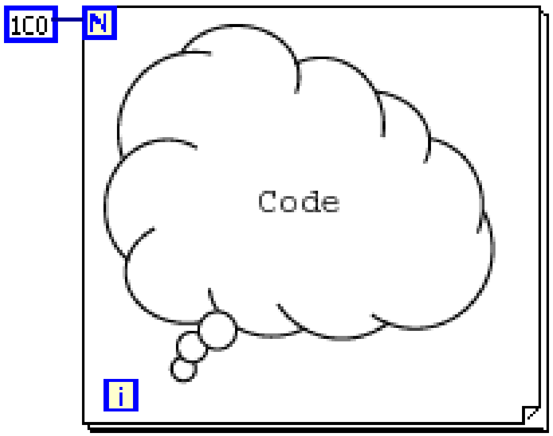


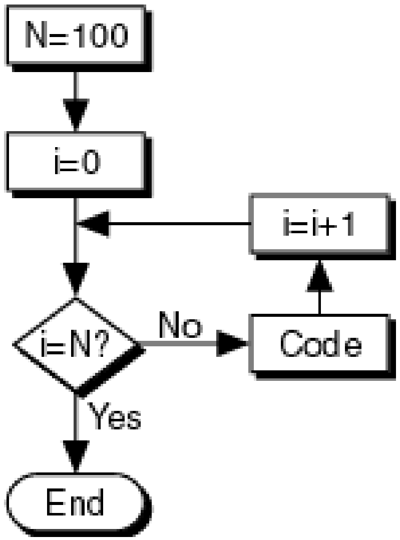
B. Structures - While Loops

- Tunnels transfer data into and out of structures
- Data pass out of a loop after the loop terminates
- When a tunnel passes data into a loop, the loop executes only after data arrive at the tunnel



C. Structures – For Loops



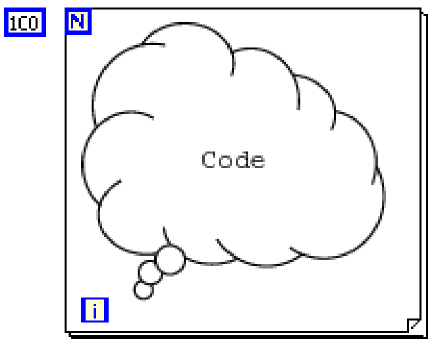


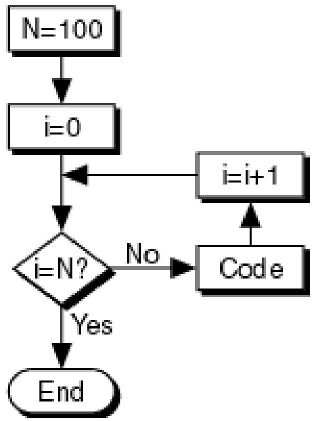

```
N=100;
i=0;
Until i=N:
  Repeat (code;i=i+1);
End;
```

LabVIEW For Loop **Flowchart** **Pseudo Code**

C. Structures – For Loops

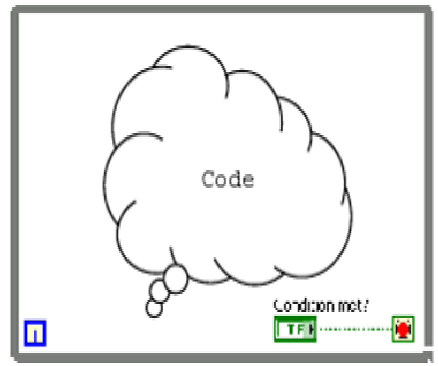
For Loop

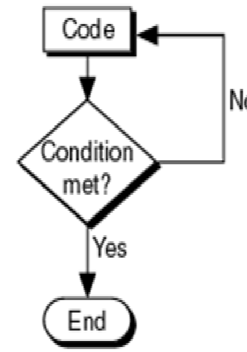




- Executes a set number of times unless a conditional terminal is added
- Can execute zero times
- Tunnels automatically output an array of data

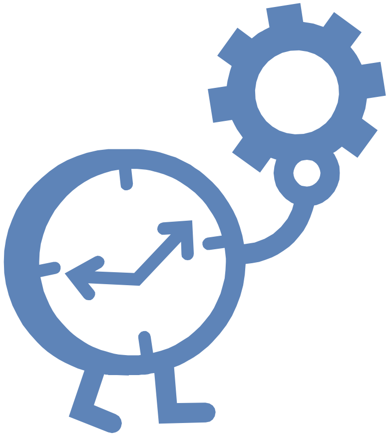
While Loop





- Stops executing only if the value at the conditional terminal meets the condition
- Must execute at least once
- Tunnels automatically output the last value

D. Timing a VI



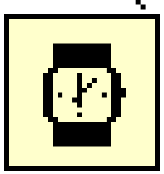
Why do you need timing in a VI?

- Control the frequency at which a loop executes
- Provide the processor with time to complete other tasks, such as processing the user interface

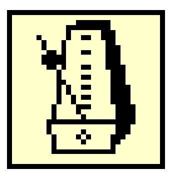
D. Timing a VI – Wait Functions

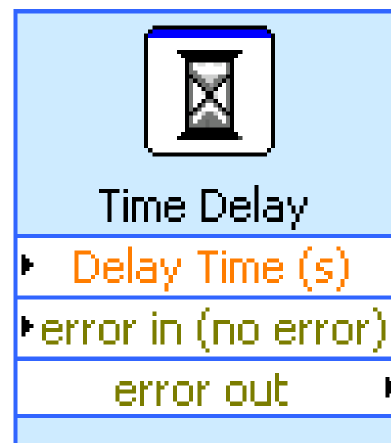
- A wait function inside a loop allows the VI to sleep for a set amount of time
- Allows the processor to address other tasks during the wait time
- Uses the operating system millisecond clock

Wait (ms)



Wait Until
Next ms Multiple





D. Timing a VI – Elapsed Time Express VI

- Determines how much time elapses after some point in your VI
- Keep track of time while the VI continues to execute
- Does not provide the processor with time to complete other tasks

Wait Chart VI

Compare and contrast using a Wait function and the Elapsed Time Express VI for software timing.

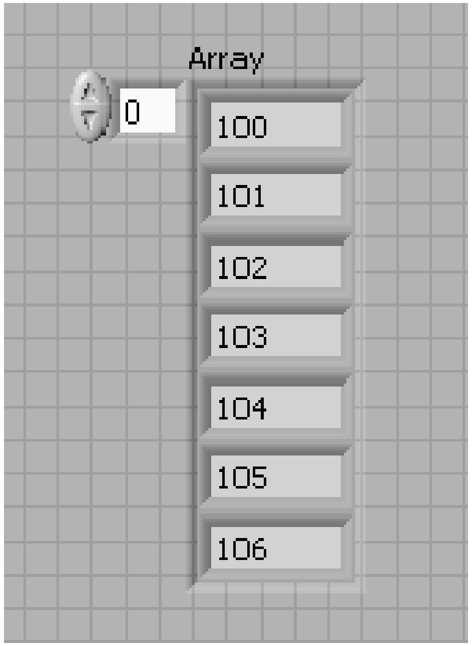
Exercise 2
Continuous Temperature Acquisition

Modify the temperature simulation VI to execute continuously.

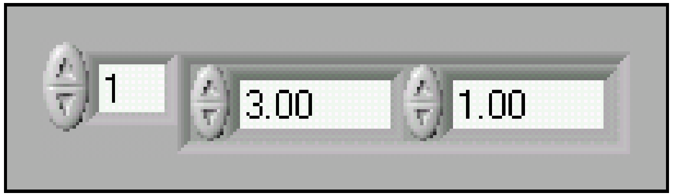
E. Grouping Data - Arrays

- An array consists of elements and dimensions
  - Elements: data that make up the array

- Consider using arrays when you work with a collection of similar data and when you perform repetitive computations



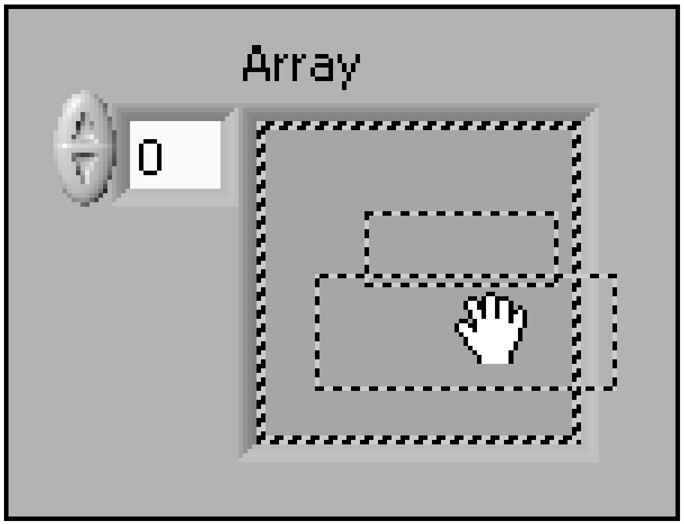
E. Grouping Data - Arrays



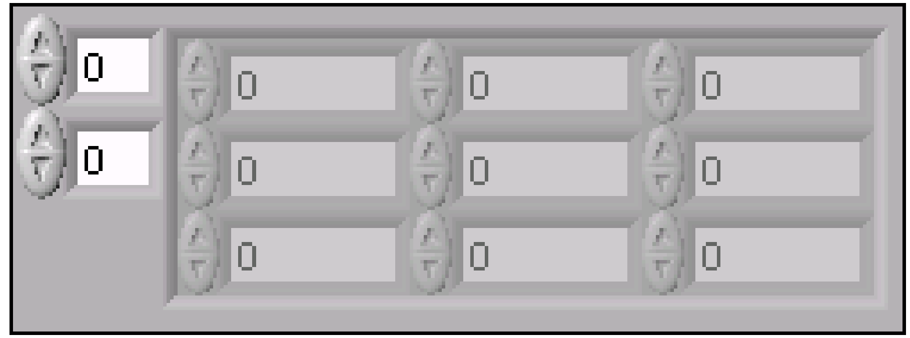
- The first element shown in the array (3.00) is at index 1 and the second element (1.00) is at index 2
- The element at index 0 is not shown in this image, because element 1 is selected in the index display
- The element selected in the index display always refers to the element shown in the upper left corner of the element display

E. Arrays – Creating

1. Place an array shell on the front panel
2. Drag a data object or element into the array shell



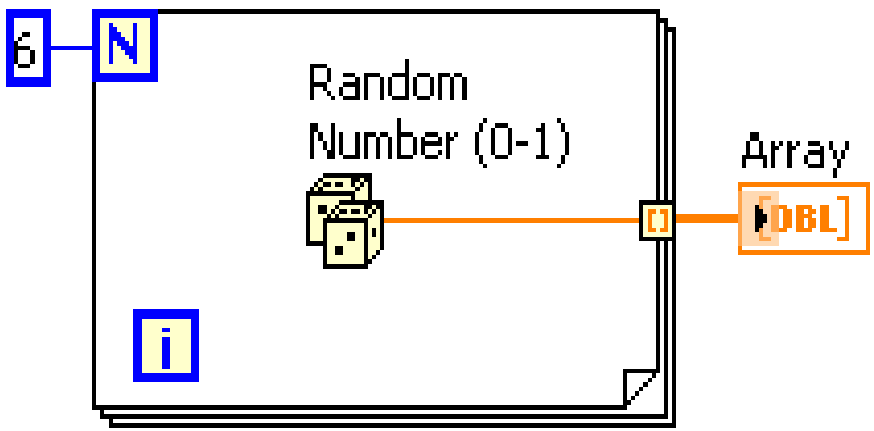
E. Arrays – 2D Array



- Stores elements in a grid
- Requires a column index and a row index to locate an element, both of which are zero-based
- To create a multidimensional array on the front panel, right-click the index display and select **Add Dimension** from the shortcut menu
- You also can resize the index display until you have as many dimensions as you want

E. Arrays – Auto-indexing Output

- When you auto-index an array output tunnel, the output array receives a new element from every iteration of the loop
- Auto-indexed output arrays are always equal in size to the number of iterations

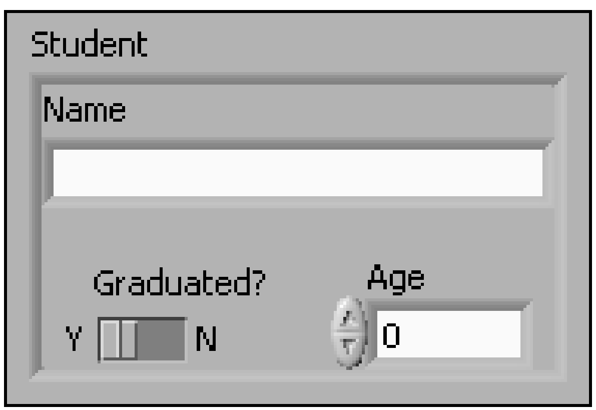


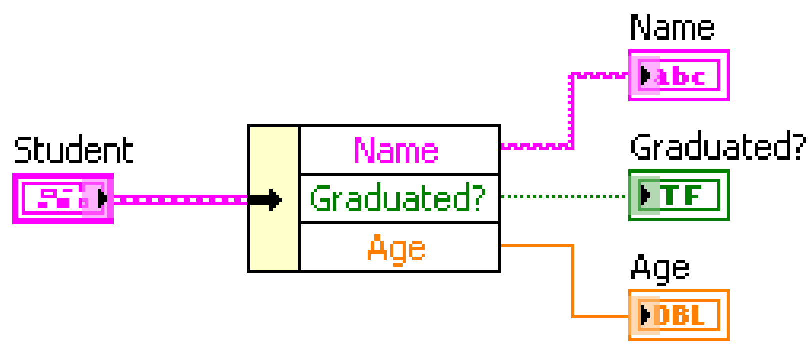
Exercise 3
Arrays

Store multiple data points in a single array using the indexing option.

F. Grouping Data - Clusters

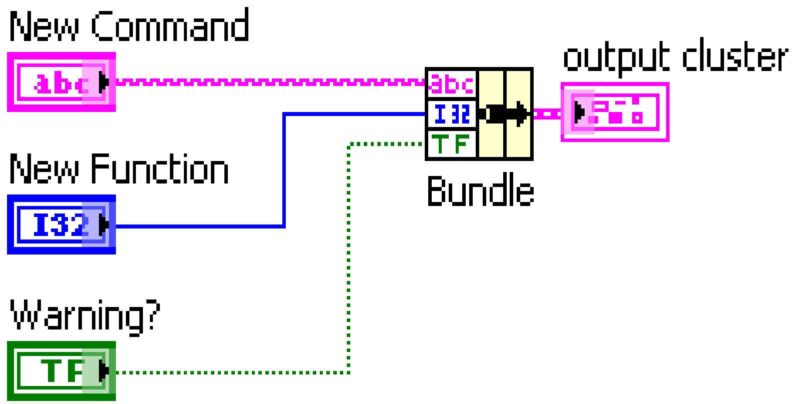
- Clusters group data elements of mixed types
- Similar to a record or a struct in text-based programming languages





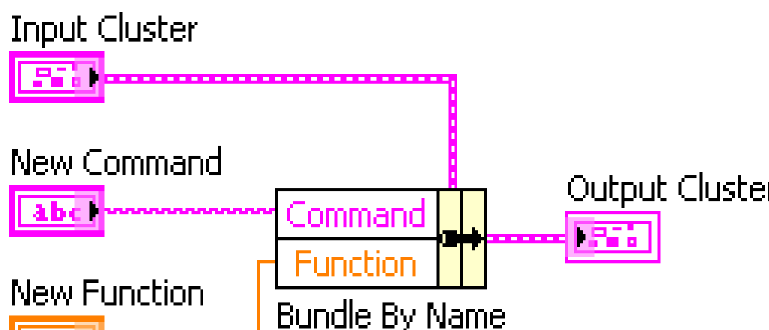
F. Clusters – Assembling a Cluster

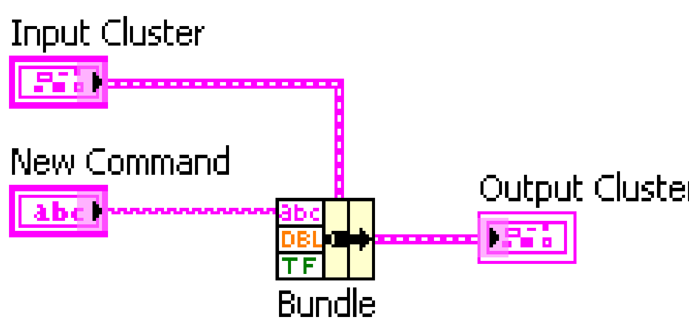
Use the Bundle function to assemble a new cluster



F. Clusters – Modifying a Cluster

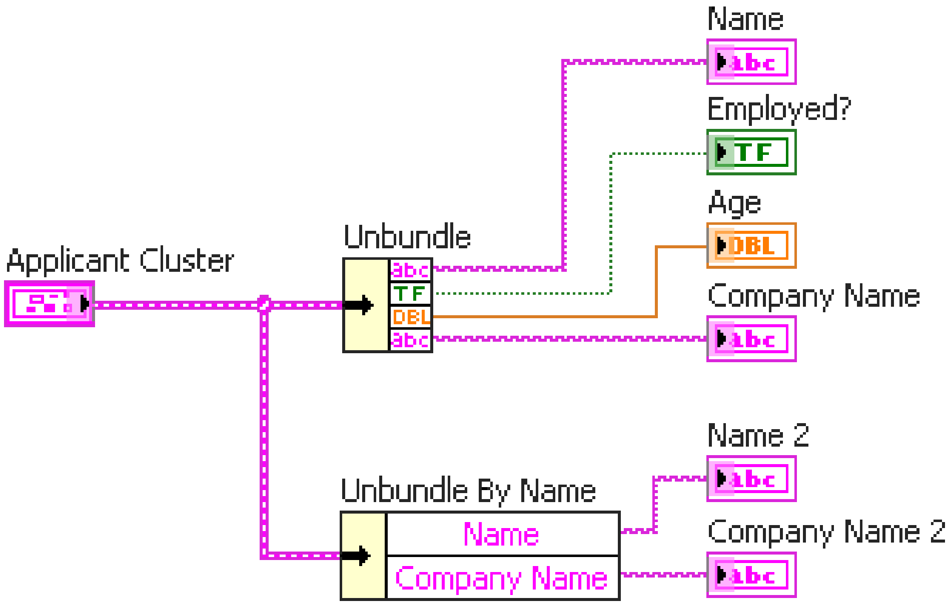
Use the Bundle By Name or the Bundle function to modify an existing cluster





F. Clusters – Disassembling a Cluster

Use the Unbundle By Name or Unbundle function to use individual items in a cluster



Summary—Quiz

1. Which structure must run at least one time?
   a) While Loop
   b) For Loop

Summary—Quiz Answer

1. Which structure must run at least one time?
   a) **While Loop**
   b) For Loop

Summary—Quiz

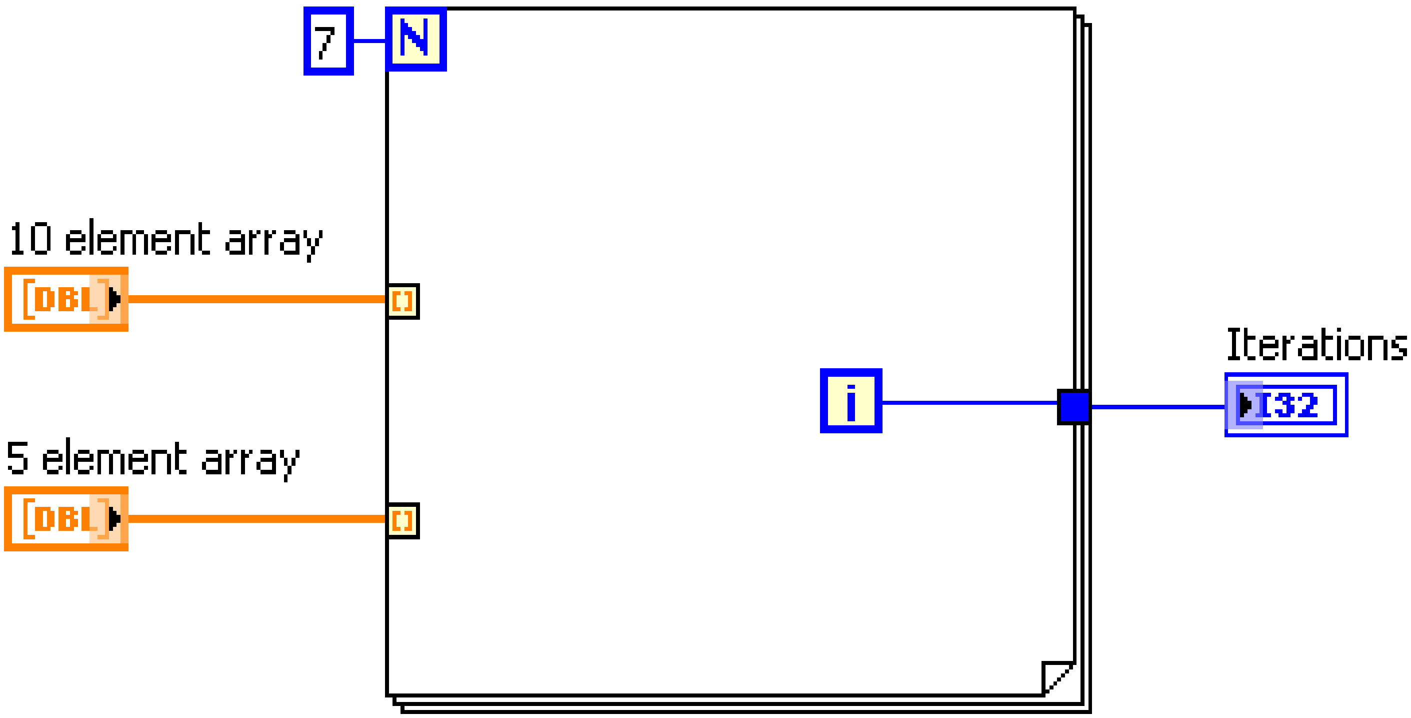
2. Which is only available on the block diagram?
   a) Control
   b) Constant
   c) Indicator
   d) Connector Pane

Summary—Quiz Answer

2. Which is only available on the block diagram?
   a) Control
   b) Constant
   c) Indicator
   d) Connector Pane

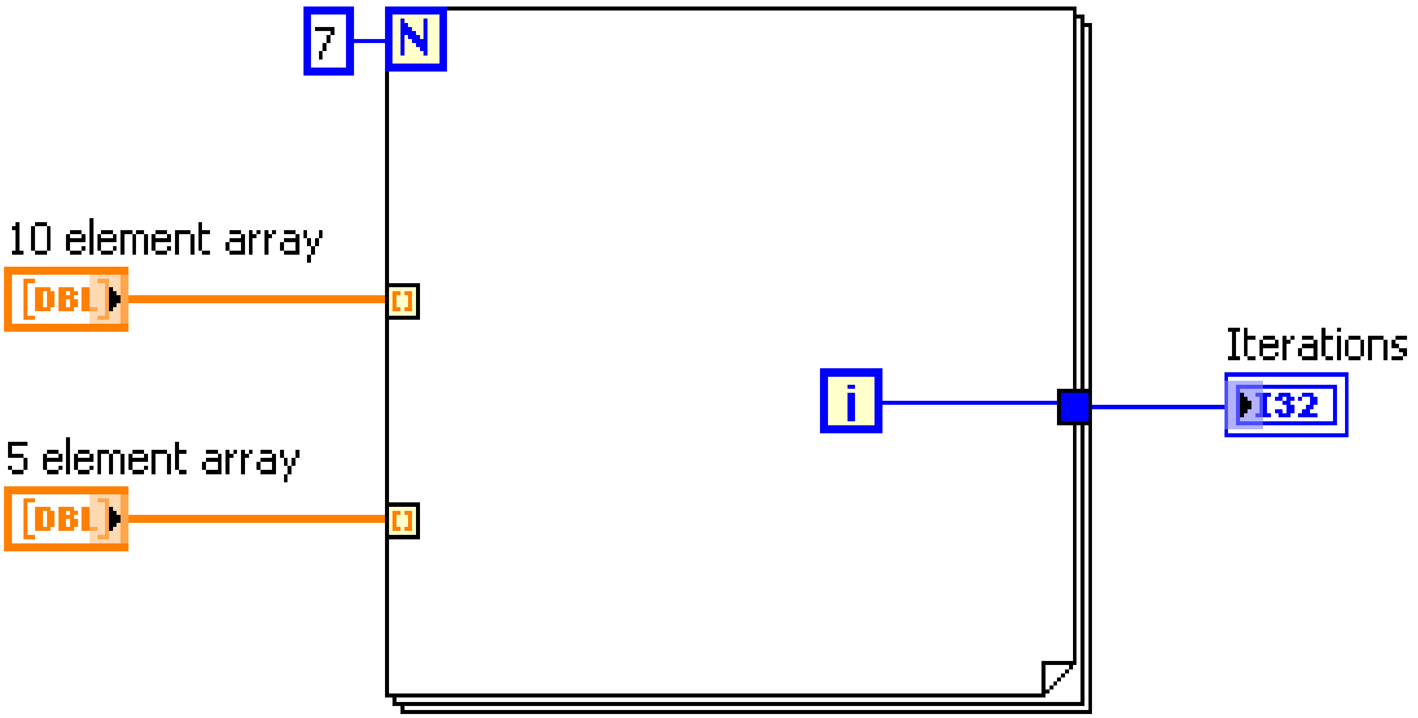
Summary—Quiz

3. What is the value of the Iterations indicator after running this VI?



Summary—Quiz Answer

3. What is the value of the Iterations indicator after running this VI? **Value of Iterations = 4**



Part 3
Presenting Data

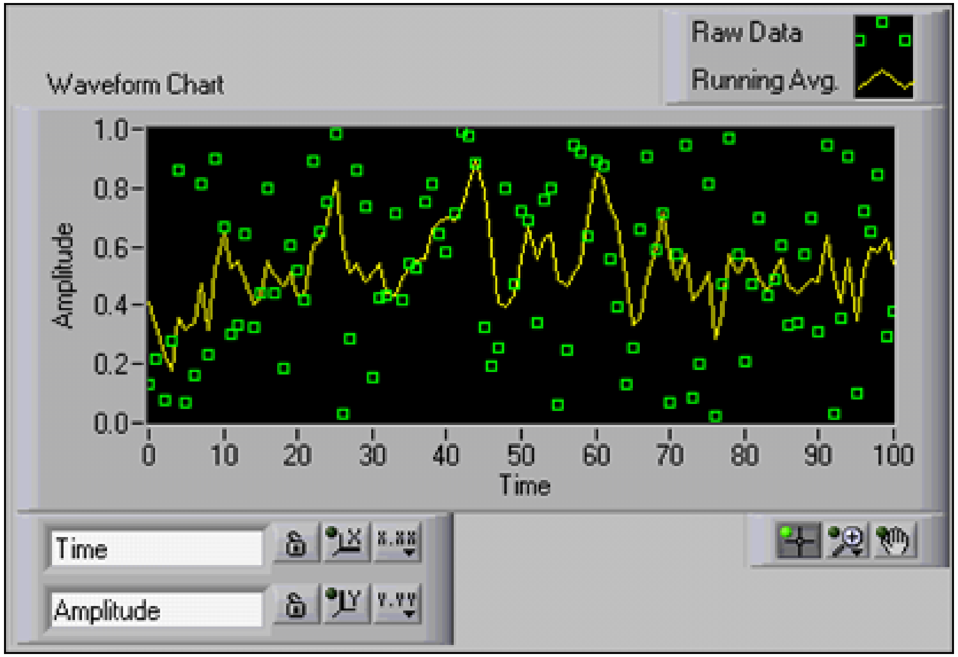
TOPICS

A. Front Panel Design

- Inputs and outputs lead to front panel design
- Retrieve the inputs by the following methods:
  - Acquiring from a device
  - Reading directly from a file
  - Manipulating controls
- Output data by the following methods:
  - Displaying with indicators
  - Logging to a file
  - Outputting to a device

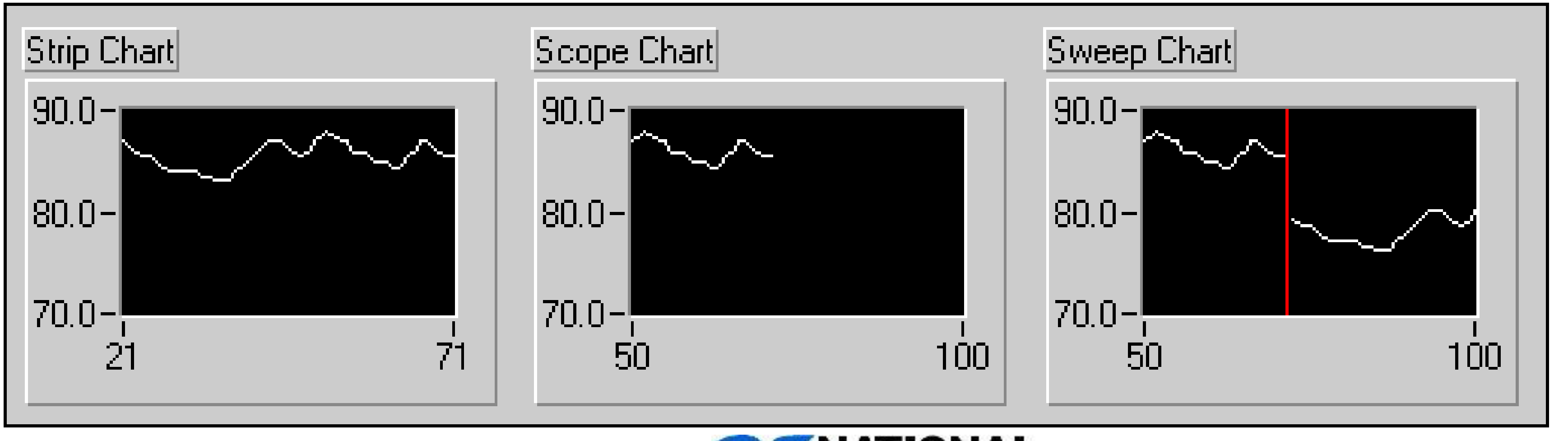
B. Plotting Data – Waveform Chart

- Special type of numeric indicator that displays one or more plots of data, typically acquired at a constant rate
- Displays single or multiple plots

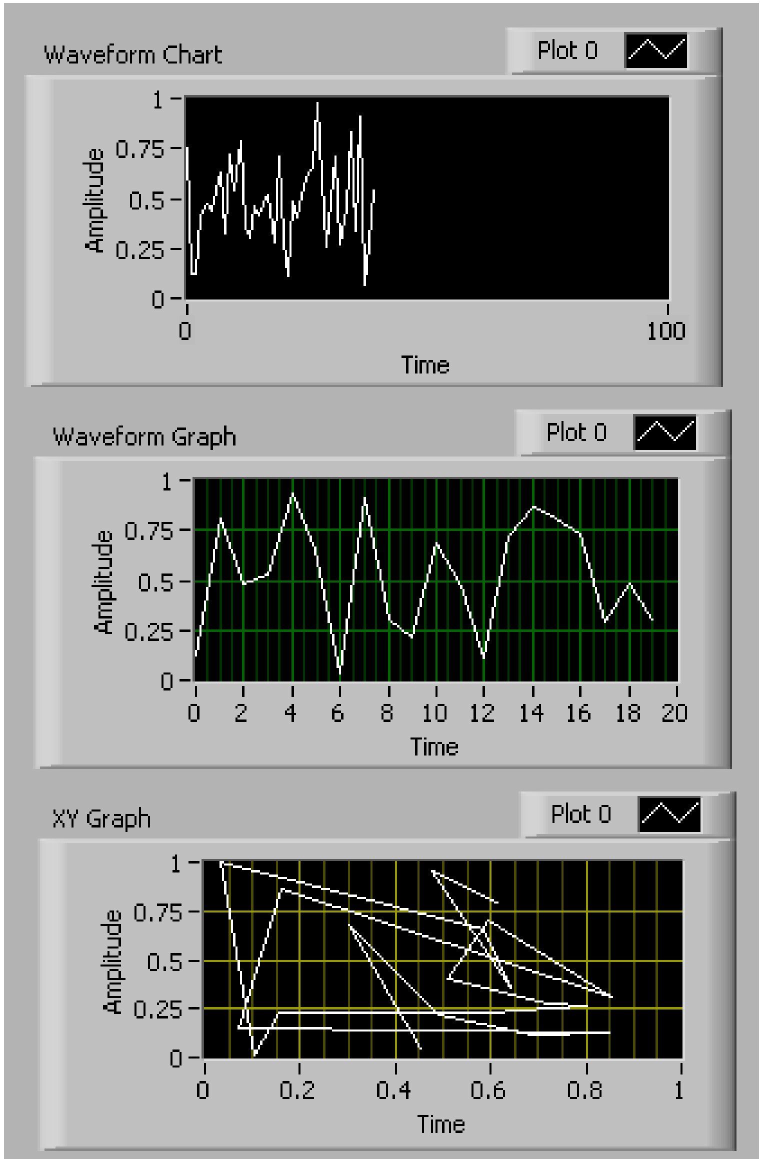


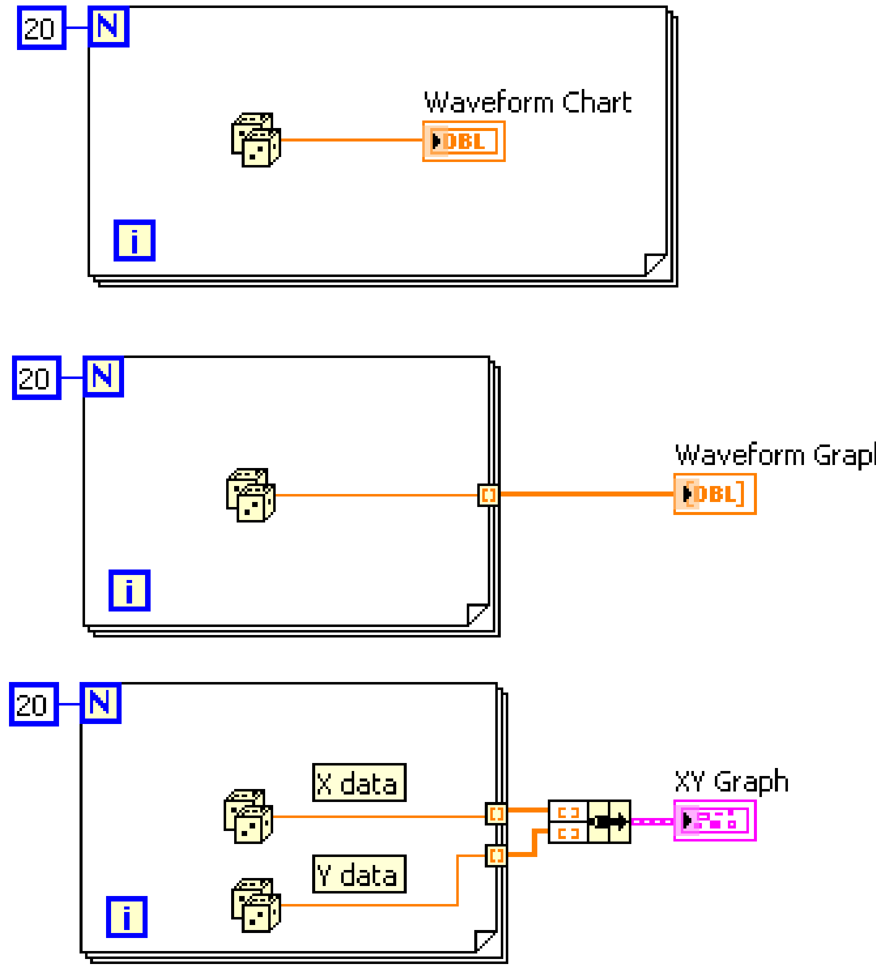
B. Plotting Data – Chart Update Modes

- Right-click the chart and select **Advanced»Update Mode** from the shortcut menu
- Strip chart is the default update mode
- Scope chart and Sweep chart modes display plots significantly faster than the strip chart mode



B. Plotting Data



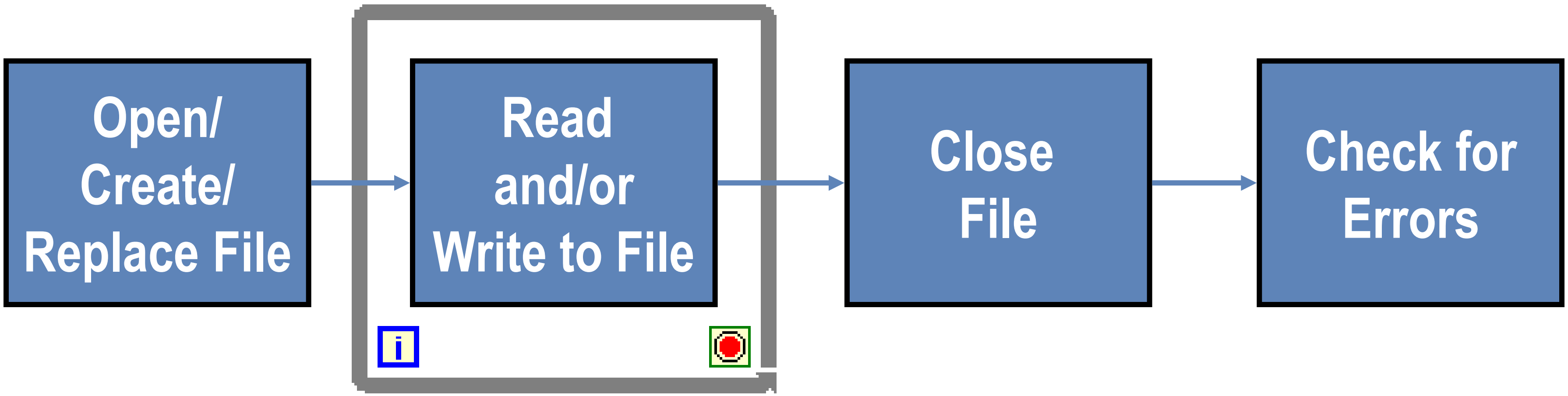


Exercise 4
Graphs and Charts

- For this exercise, is it better to use a chart or a graph?

C. Understanding File I/O

- File I/O writes to or reads from a file
- A typical file I/O operation involves the following process:



C. Understanding File I/O – File Formats

LabVIEW can use or create the following file formats:

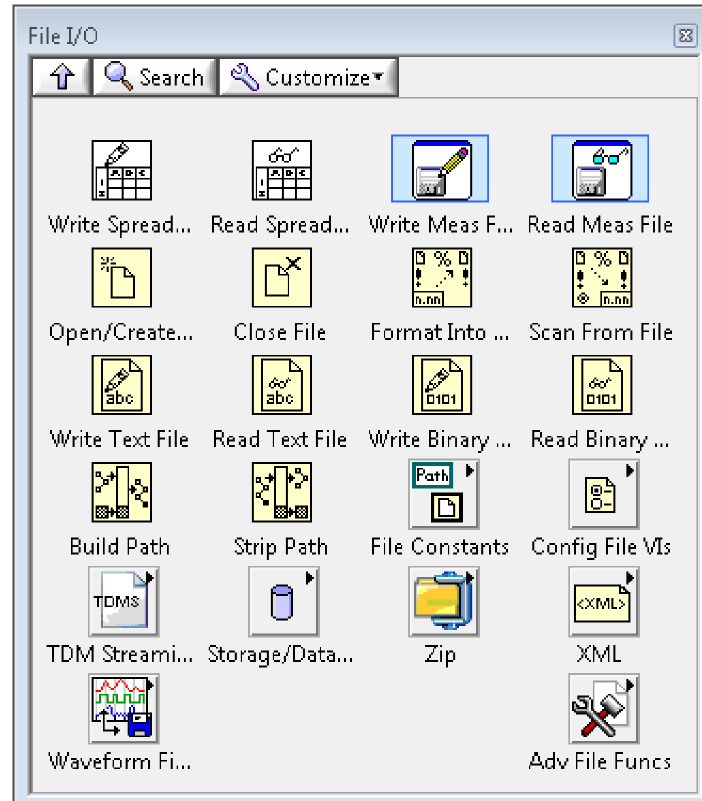
- **Binary**—Underlying file format of all other file formats
- **ASCII**—Specific type of binary file that is a standard used by most programs
- **LVM**— The LabVIEW measurement data file (.lvm) is a tab-delimited text file you can open with a spreadsheet application or a text-editing application
- **TDMS**—Type of binary file created for NI products consisting of two separate files: a binary file and a binary index file

C. Understanding File I/O – File Formats

- In this course, you learn about creating text (ASCII) files
- Use text files in the following situations:
  - You want to access the file from another application
  - Disk space and file I/O speed are not crucial
  - You must not perform random access reads or writes
  - Numeric precision is not important

D. Understanding High-level File I/O

- High-level VIs
  - Perform all three steps (open, read/write, close) for common file I/O operations
  - Might not be as efficient as the functions configured or designed for individual operations
- Low-level VIs
  - Individual VI for each step
  - If you are writing to a file in a loop, use low-level file I/O functions



D. Understanding High-Level File I/O

Write to Spreadsheet File

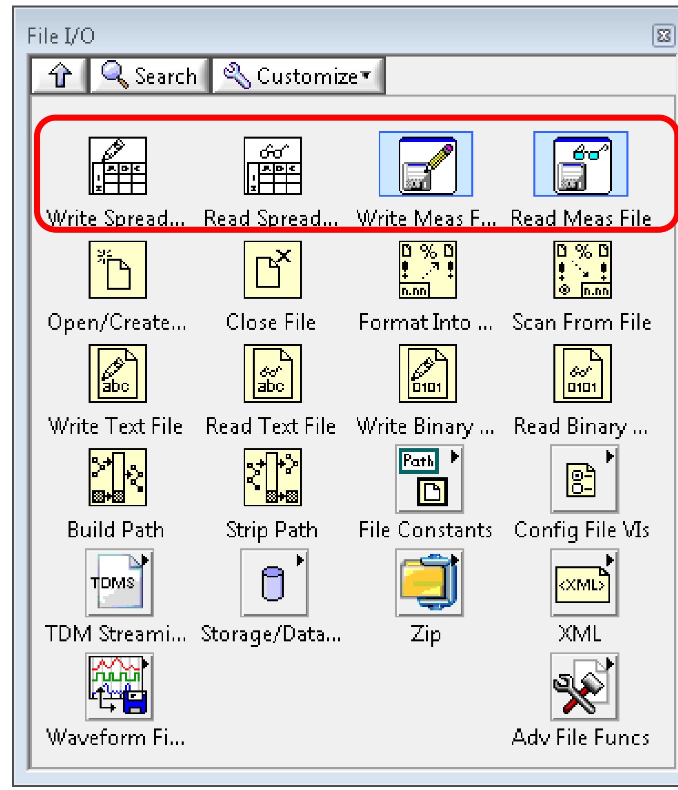
- Converts an array of double-precision numbers to a text string and writes the string to an ASCII file

Read From Spreadsheet File

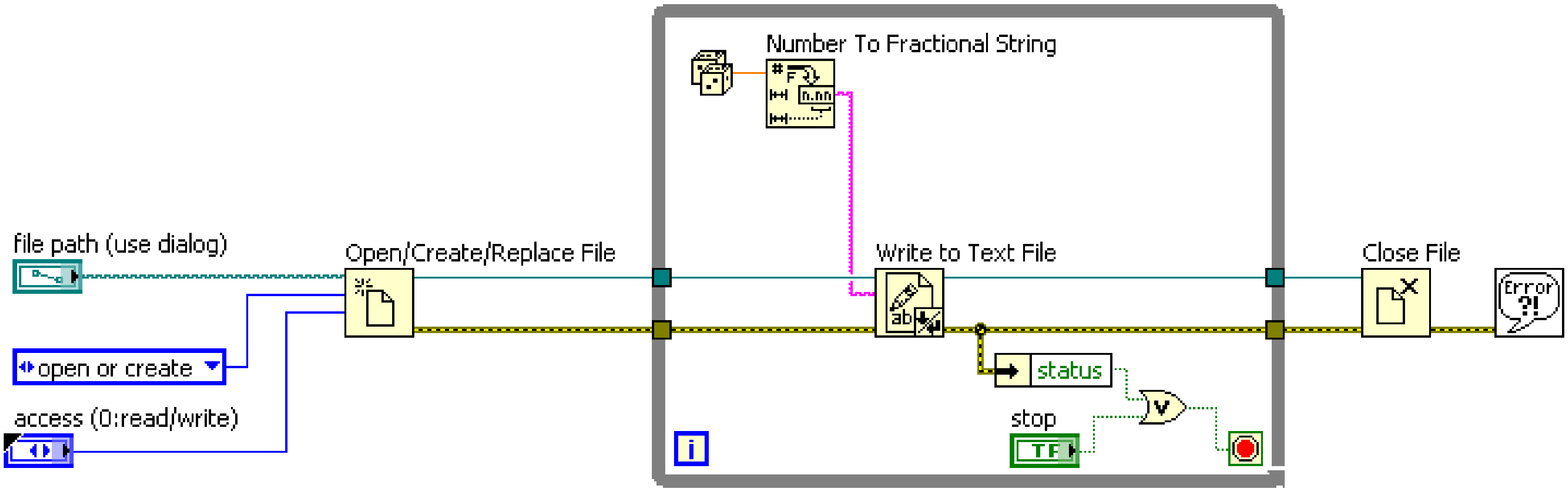
- Reads a specified number of lines or rows from a numeric text file and outputs a 2D array of double-precision numbers

Write to/Read from Measurement File

- Express VIs that write data to or read data from an LVM or TDMS file format



E. Understanding Low-Level File I/O VIs



Exercise 5
File I/O

- For this exercise, is it better to use a chart or a graph?

Summary—Quiz

1. Your continuously running test program logs to a single file the results of all tests that occur in one hour as they are calculated. If you are concerned about the execution speed of your program, should you use low-level or high-level File I/O VIs?
   a) Low-level file I/O VIs
   b) High-level file I/O VIs

Summary—Quiz Answer

1. Your continuously running test program logs to a single file the results of all tests that occur in one hour as they are calculated. If you are concerned about the execution speed of your program, should you use low-level or high-level File I/O VIs?
   a) Low-level file I/O VIs
   b) High-level file I/O VIs

Summary—Quiz

2. If you want to view data in a text editor like Notepad, what file format should you use to save the data?
   a) ASCII
   b) TDMS

Summary—Quiz Answer

2. If you want to view data in a text editor like Notepad, what file format should you use to save the data?
   - **a) ASCII**
   - b) TDMS

Part 4
Developing Modular Applications

TOPICS

A. Understanding Modularity
B. Icon and Connector Pane
C. Using SubVIs

A. Understanding Modularity

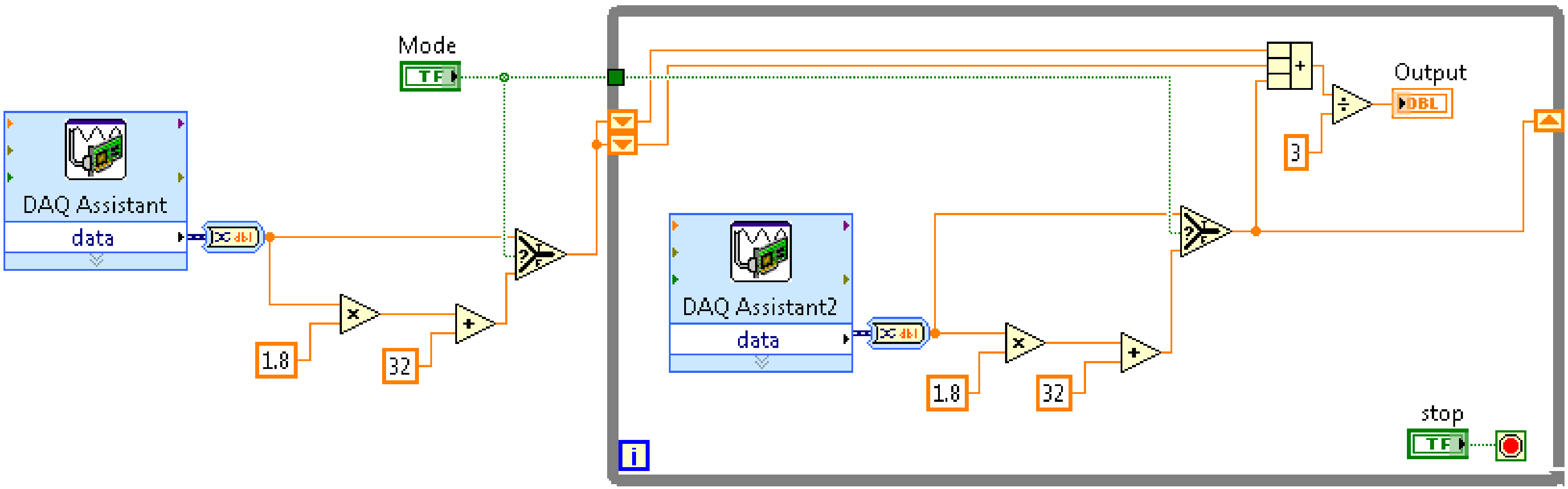
Modularity - The degree to which a program is composed of discrete modules such that a change to one module has minimal impact on other modules

A. Understanding Modularity – SubVIs

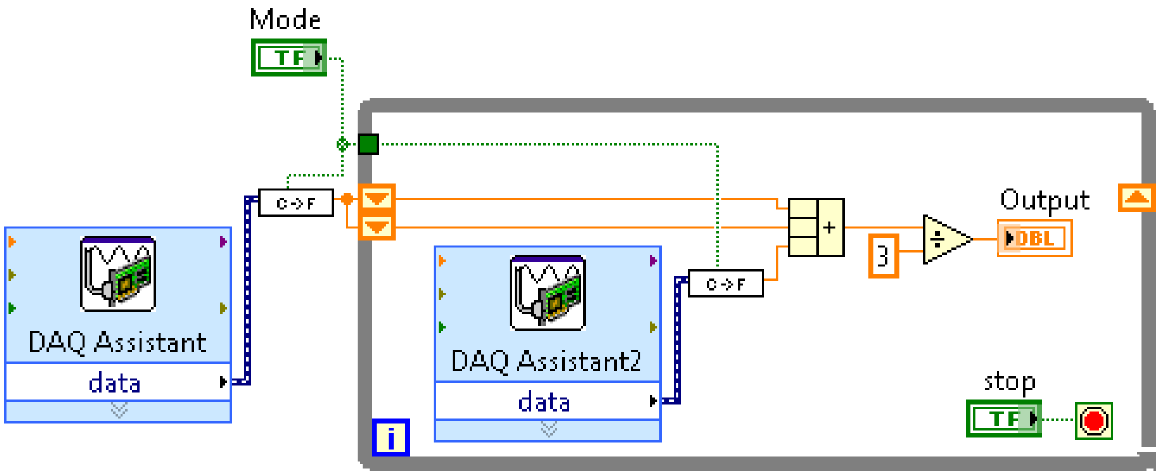
SubVI- A VI within another VI

- The upper right corner of the front panel and block diagram displays the icon for the VI
- This icon identifies the VI when you place the VI on the block diagram

A. Understanding Modularity – SubVIs



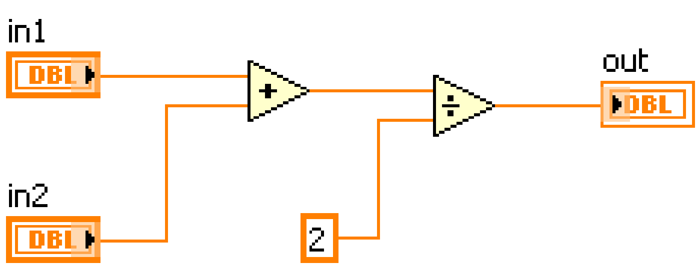
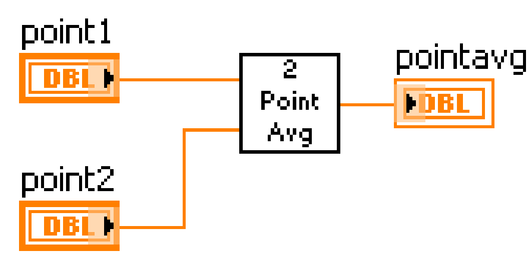
A. Understanding Modularity – SubVIs



A. Understanding Modularity – SubVIs

Function Code	Calling Program Code

`function average (in1, in2, out)`
`{`
`out = (in1 + in2)/2.0;`
`}`
	`main`
	`{`
	`average (point1, point2, pointavg)`
	`}`

SubVI Block Diagram	**Calling VI Block Diagram**
	

Exercise 6
SubVI

Change a piece of code into a subVI to increase modularity.

Summary—Quiz

1. On a subVI, which terminal setting causes an error if the terminal is not wired?
   a) Required
   b) Recommended
   c) Optional

Summary—Quiz Answer

1. On a subVI, which terminal setting causes an error if the terminal is not wired?
   a) Required
   b) Recommended
   c) Optional

Summary—Quiz

2. You must create a custom icon to use a VI as a subVI.
   a) True
   b) False

Summary—Quiz Answer

2. You must create a custom icon to use a VI as a subVI.
   a) True
   b) False

   You do not need to create a custom icon to use a VI as a subVI, but it is highly recommended to increase the readability of your code.

Part 5
Decision Making and Data Access

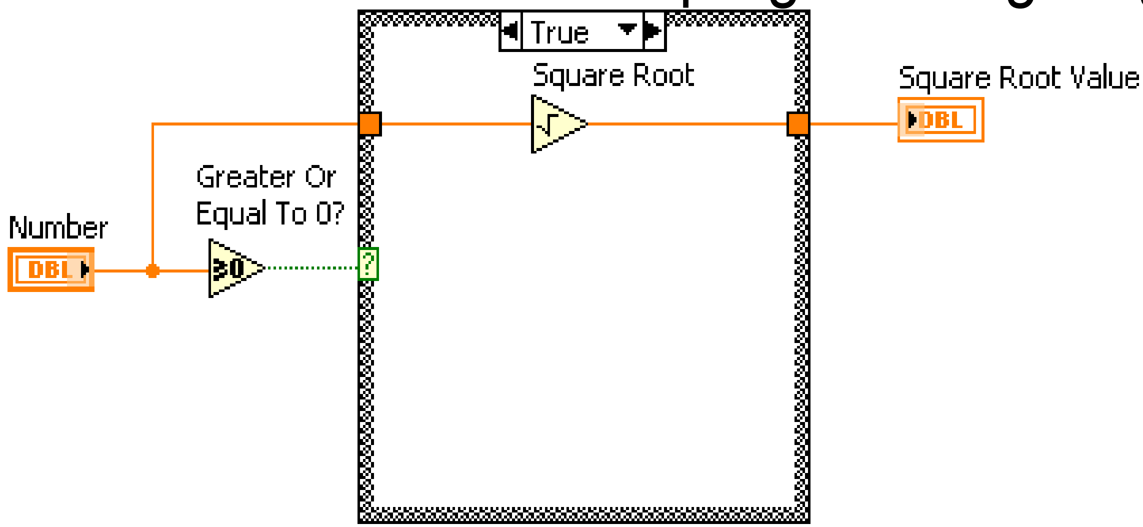
TOPICS

A. Case Structures

B. Iterative Data Transfer

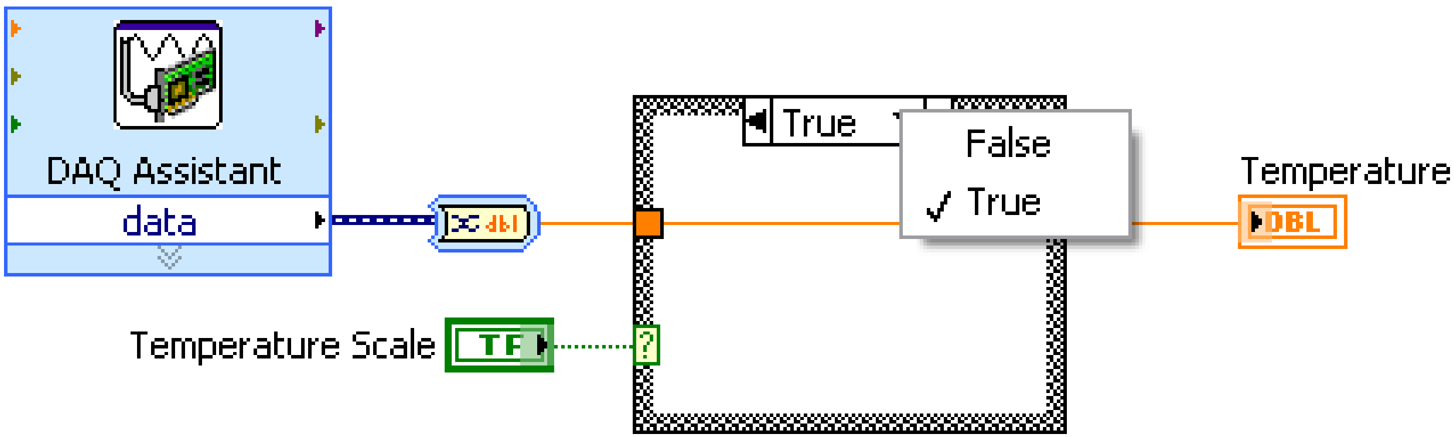
A. Case Structures

- Have two or more subdiagrams or cases
- Execute and displays only one case at a time
- An input value determines which subdiagram to execute
- Similar to `case` statements or `if...then...else` statements in text-based programming languages



A. Case Structures

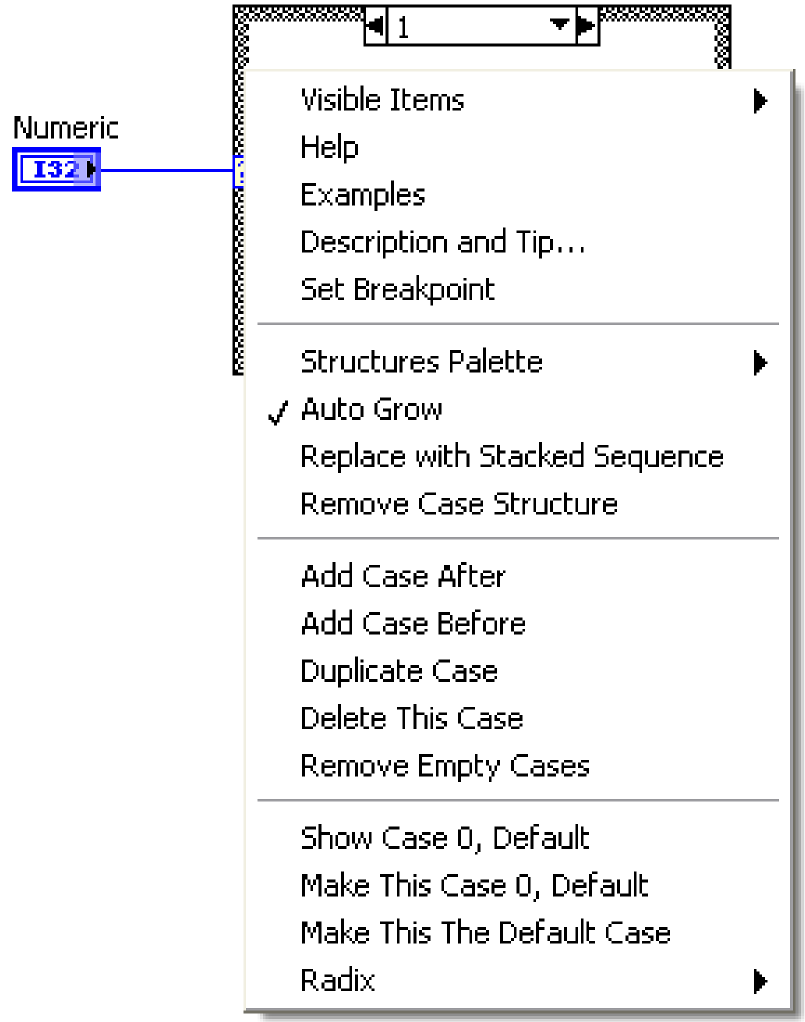
- Case Selector Label: contains the name of the current case and decrement and increment buttons on each side



- Selector Terminal: Wire an input value, or selector, to determine which case executes

A. Case Structures – Default Case

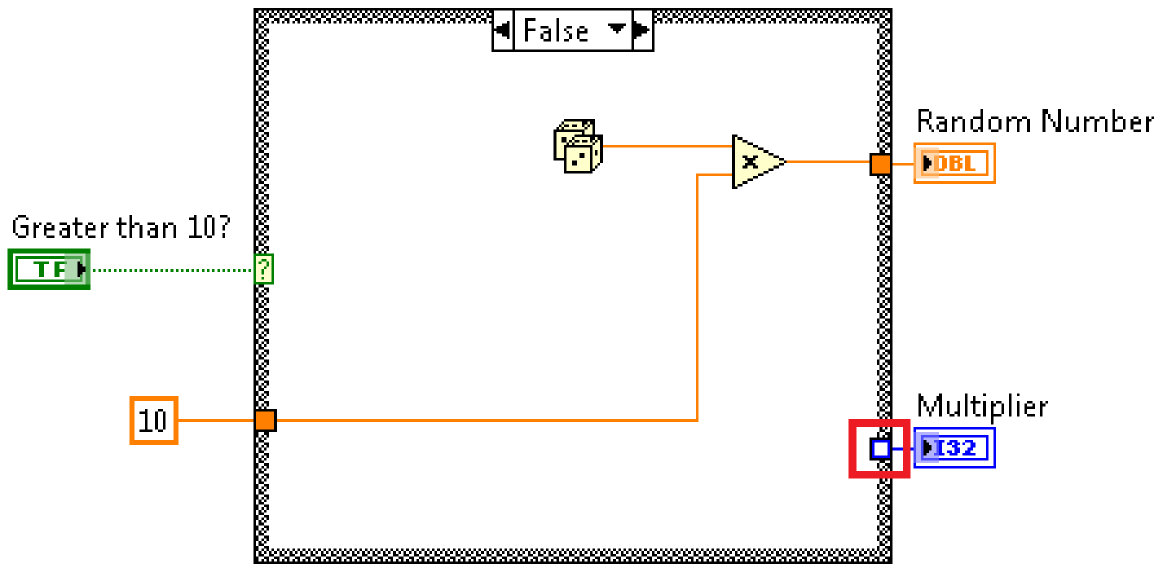
- You can specify a default case for the Case structure
  - If you specified cases for 1, 2, and 3, but you get an input of 4, the Case structure executes the default case
- Right-click the Case structure border to add, duplicate, remove, or rearrange cases and to select a default case



A. Case Structures – Input & Output Tunnels

You can create multiple input and output tunnels

- Inputs are available to all cases if needed
- You must define each output tunnel for each case



A. Case Structures – Use Default if Unwired

Default values are:

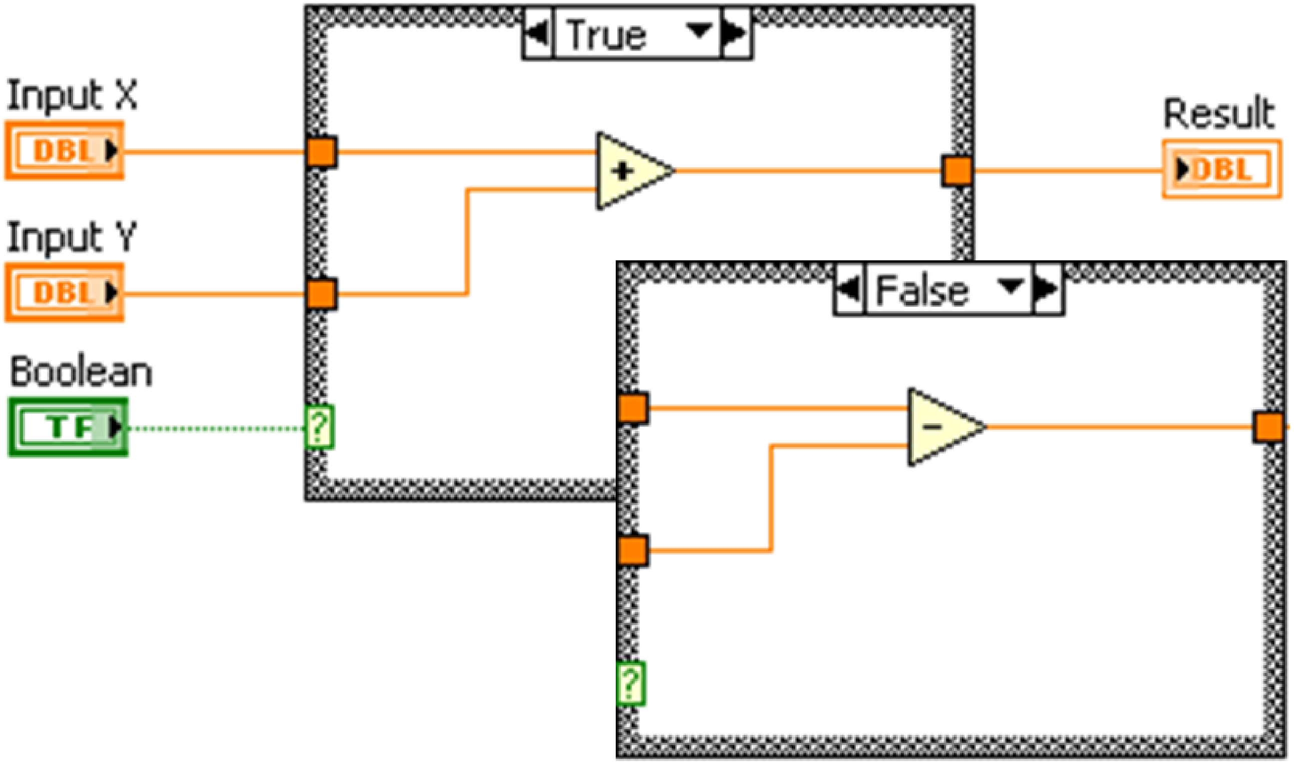
Data Type	Default Value
Numeric	0
Boolean	FALSE
String	Empty

Avoid using the Use Default If Unwired option on Case structure tunnels

- Adds a level of complexity to your code
- Complicates debugging your code

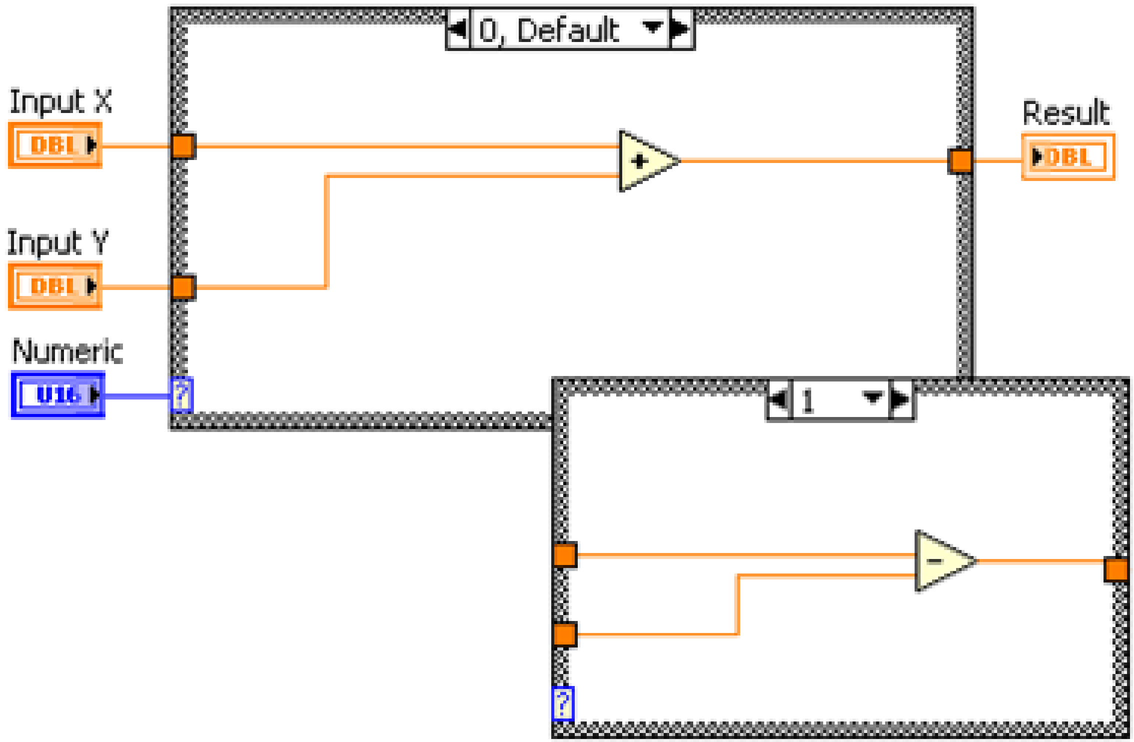
A. Case Structures – Boolean

Boolean input creates two cases: True and False



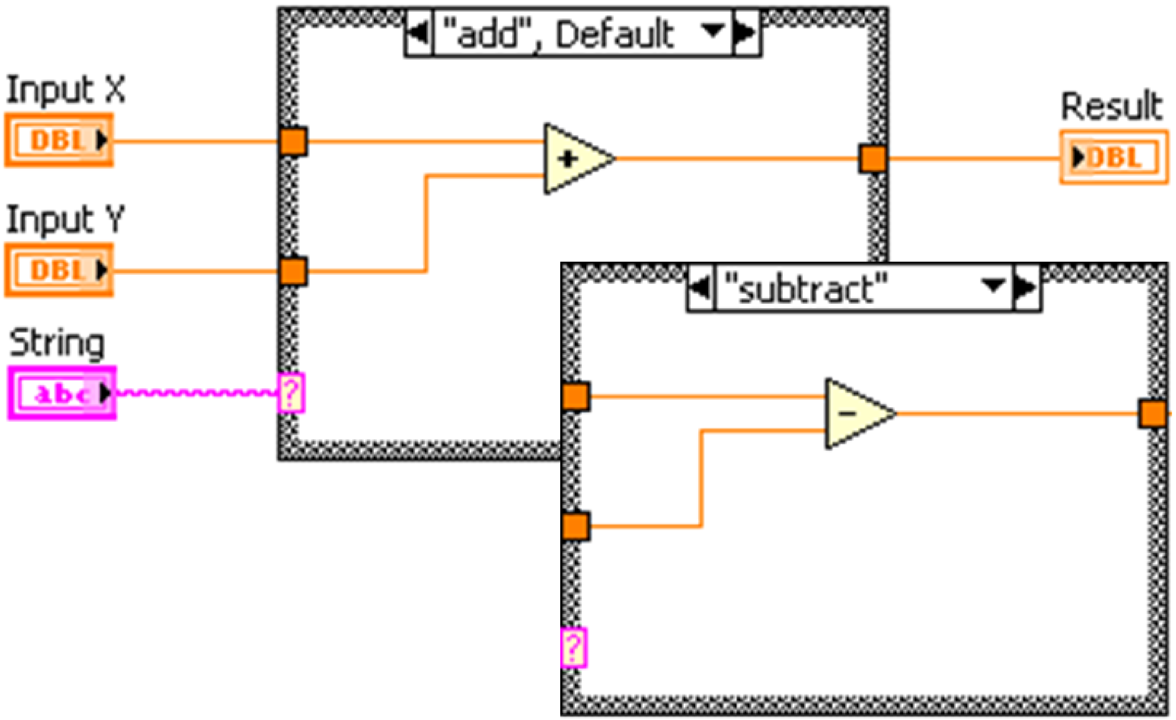
A. Case Structures – Integer

- Add a case for each integer as necessary
- Integers without a defined case use the default case



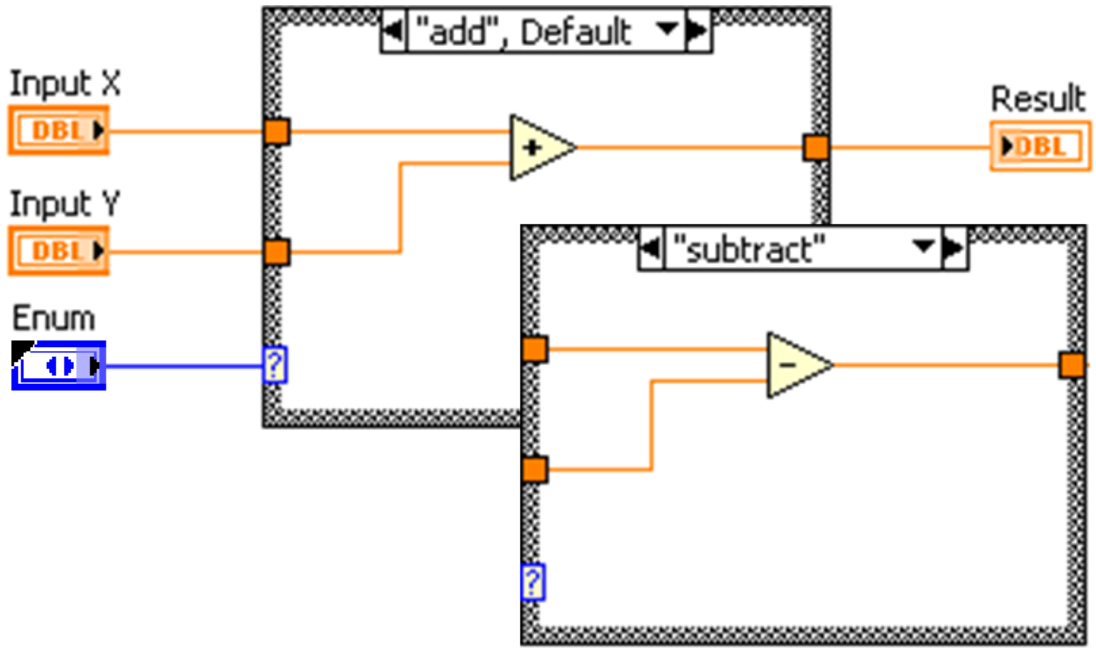
A. Case Structures – String

- Add a case for each string as necessary
- Strings without a defined case use the default case



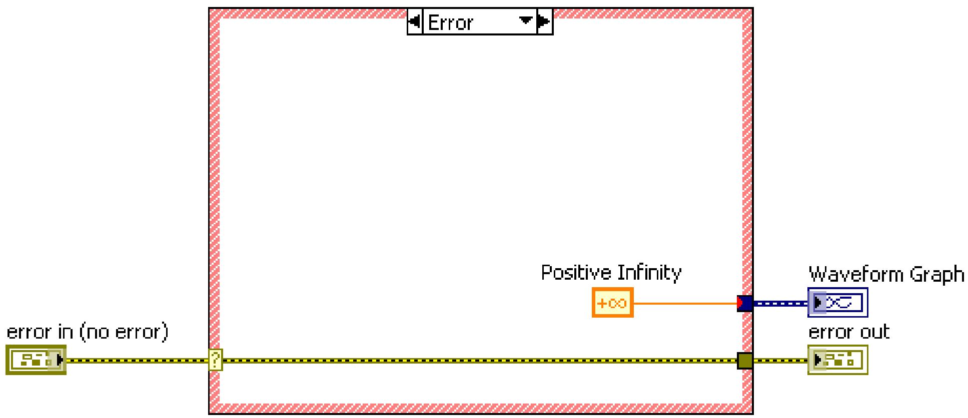
A. Case Structures – Enum

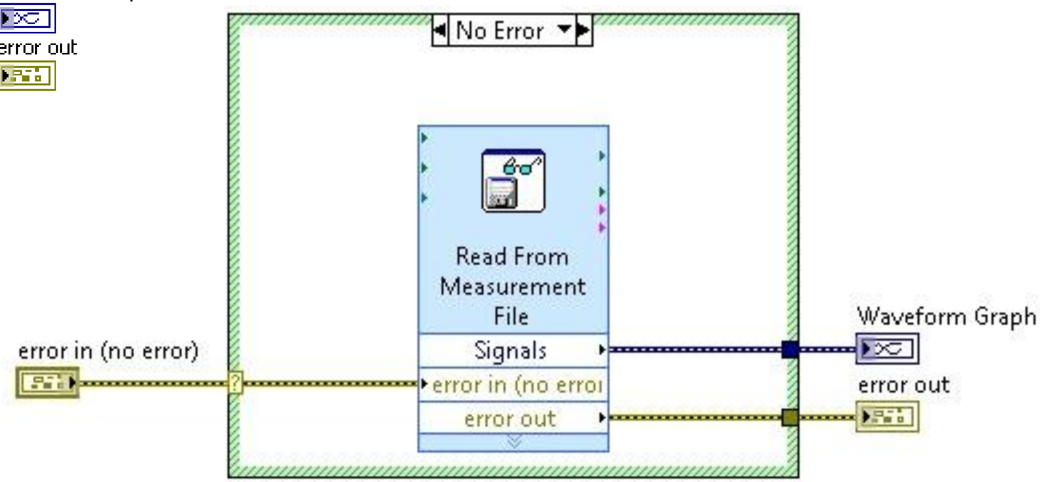
- Gives users a list of items from which to select
- The case selector displays a case for each item in the enumerated type control



A. Case Structures - Error Checking and Error Handling

Use Case Structures inside VIs to execute the code if there is no error and skip the code if there is an error



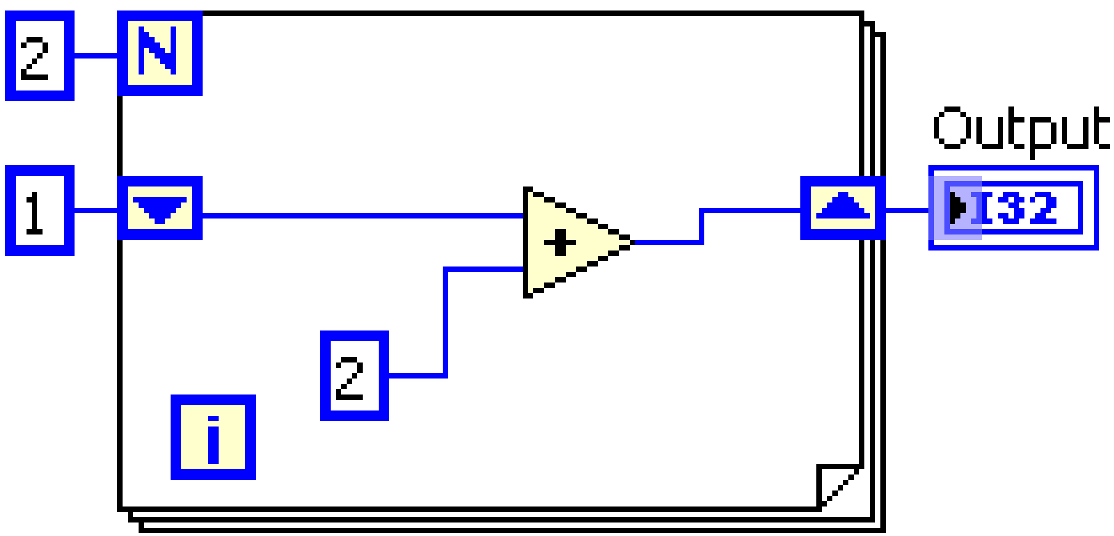


Exercise 7
Case Structures

Use Case Structures to change the temperature unit.

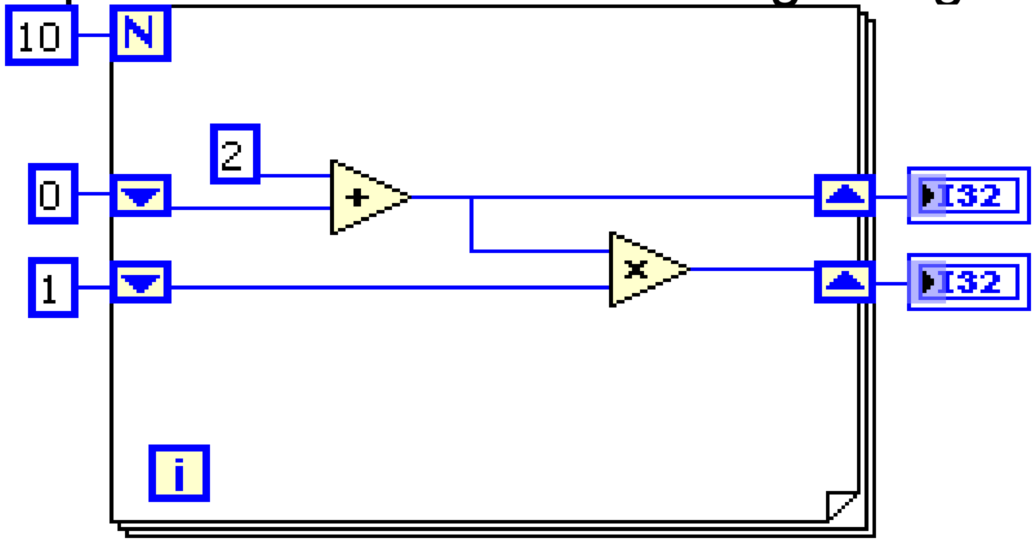
B. Iterative Data Transfer

- When programming with loops, you often need to know the values of data from previous iterations of the loop
- Shift registers transfer values from one loop iteration to the next



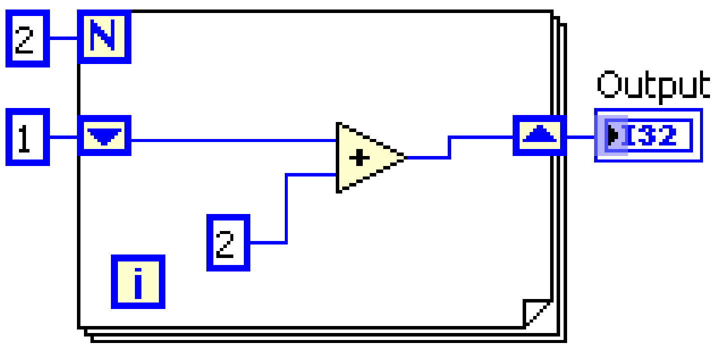
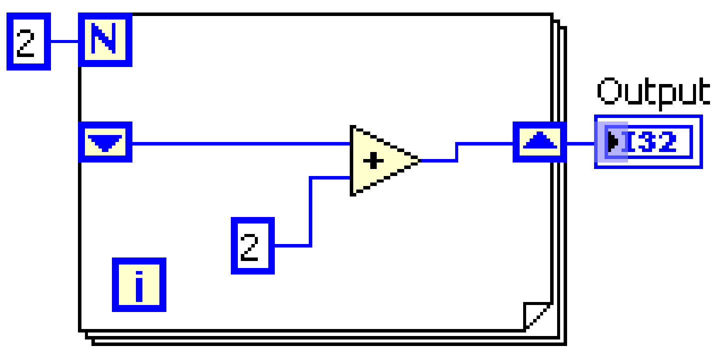
B. Iterative Data Transfer – Shift Registers

- Right-click the border and select **Add Shift Register** from the shortcut menu
- Right shift register stores data on completion of an iteration
- Left shift register provides stored data at beginning of the next iteration



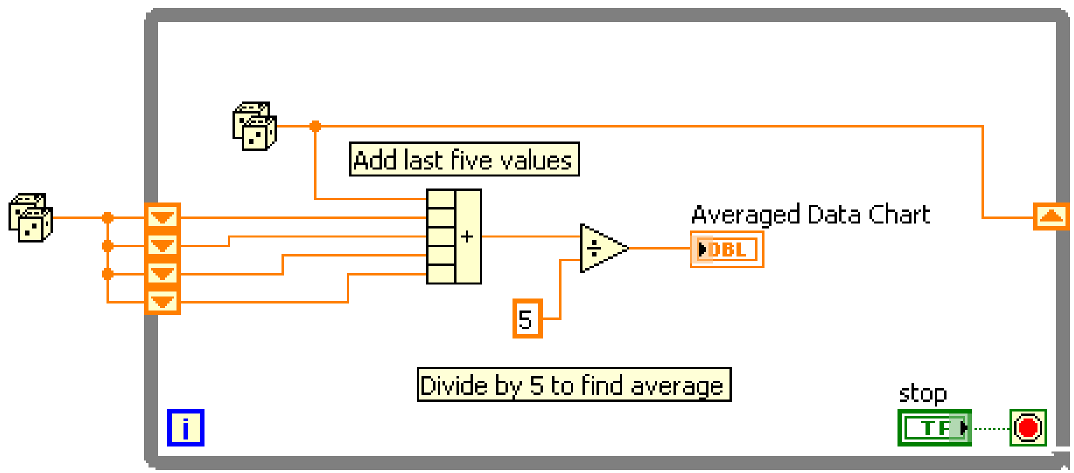
B. Iterative Data Transfer – Initializing

Run once → VI finishes → Run again

Block Diagram		1st run	2nd run
Initialized Shift Register		Output = 5	Output = 5
Not Initialized Shift Register		Output = 4	Output = 8

B. Iterative Data Transfer – Stacked Shift Registers

- Stacked shift registers remember values from multiple previous iterations and carry those values to the next iterations
- Right-click the left shift register and select **Add Element** from the shortcut menu



Exercise 8
Shift Registers

Use shift registers to calculate the average temperature from previous iterations.

Summary—Quiz

1. Which of the followings data types will generate an error if wired to the input of the case structure?
   a) Numeric Double
   b) Cluster
   c) Error Cluster
   d) Enum

Summary—Quiz Answer

1. Which of the followings data types will generate an error if wired to the input of the case structure?
   a) Numeric Double
   b) Cluster
   c) Error Cluster
   d) Enum

Summary—Quiz

2. Shift registers only allow you to retrieve the data from the last iteration.
   a) True
   b) False

Summary—Quiz Answer

2. Shift registers only allow you to retrieve the data from the last iteration.
   a) True
   b) False

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Thank you!