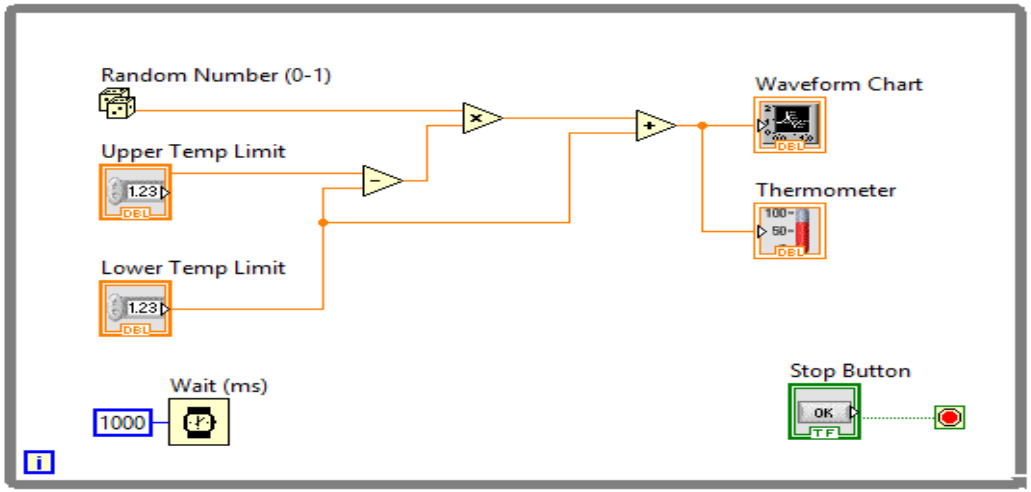
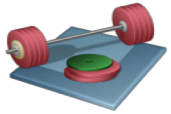
https://www.halvorsen.blog

Introduction to LabVIEW

Basic LabVIEW Programming





with Self-paced Step-by-Step Exercises

Hans-Petter Halvorsen

Contents

LabVIEW Installation

You need the following Software

- LabVIEW (LabVIEW Professional Development System 32-Bit: English)
- NI-DAQmx (Hardware Driver for NI USB-6008, NI TC-01, etc.)
- LabVIEW Control Design and Simulation Module
- LabVIEW MathScript RT Module

Note! These packages are separate downloads!

All LabVIEW Software can be downloaded here: www.ni.com/download

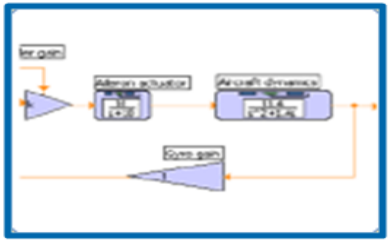
High-Level Design Tools

Configuration

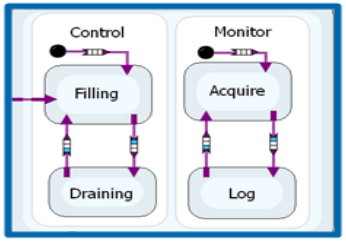
Textual Math

```
1 c = 0.285 + 0.013i;
2 [X Y] = meshgrid(x, y);
3 z = X + i*Y;
4 for k=1:30
5     z = z.^2 + c;
6 end
```

Simulation



Statechart



LabVIEW

Graphical Programming

National Instruments is the vendor of LabVIEW

National Instruments creates both **Hardware** and **Software**

Desktop Platform

Linux®

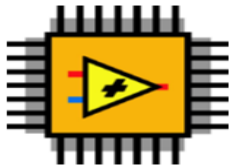
Macintosh

Windows

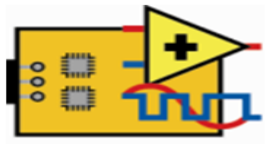
Embedded Platform

Real-Time

FPGA



MPU



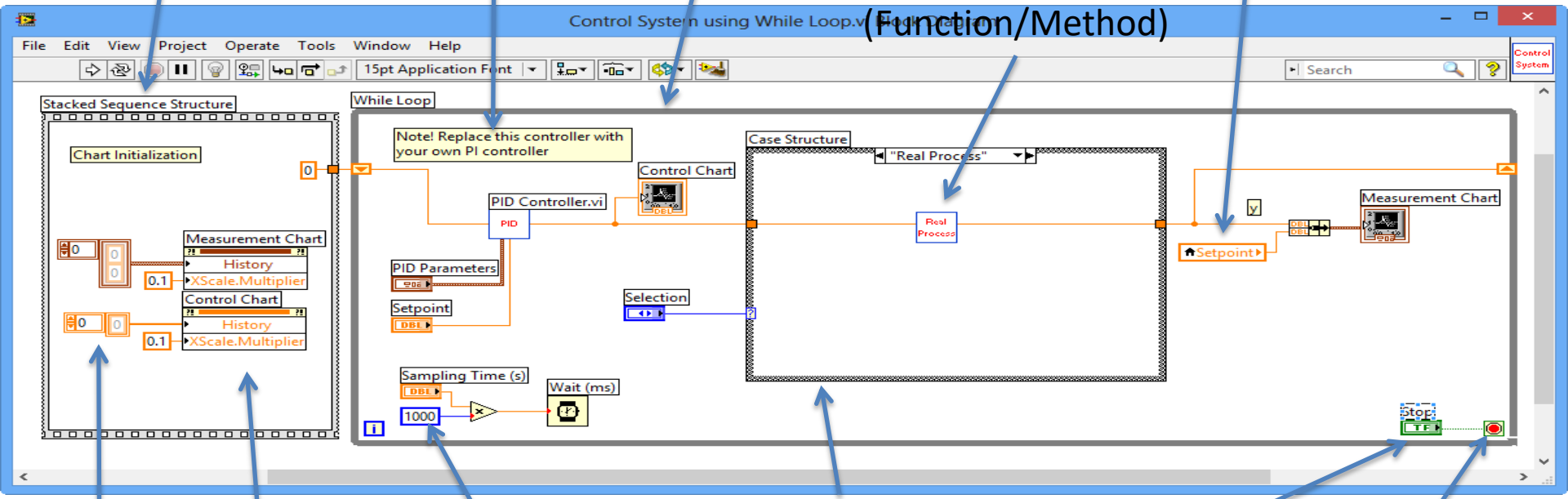
LabVIEW = Fun!

Graphical Programming:

- Very different from traditional programming like VB, C#, Maple, MATLAB, MathScript, etc.
- It is more like a “drawing program” than a Programming Language
- This makes it easy to use for those who are not programmers (or dont like programming ☺)
- Excellent tool when using Hardware, when you need to take Measurements (DAQ), etc.
- It is fun and makes you very creative!

LabVIEW Example

LabVIEW has the same things as other programming languages, but in a graphical way!



Note! To do something with an object – Right-click on it

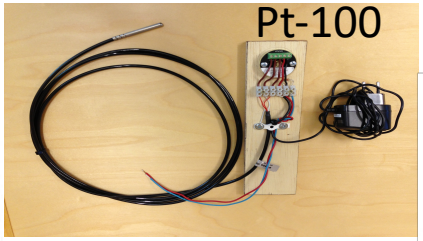
Hardware

Water Tank

USB-6008

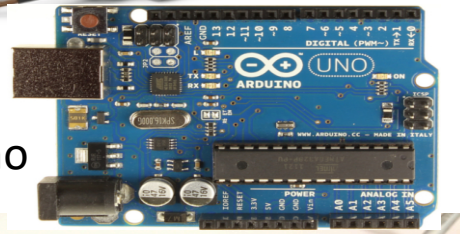

Wi-Fi DAQ

Air Heater


Pt-100


TC-01

ZigBee



Arduino

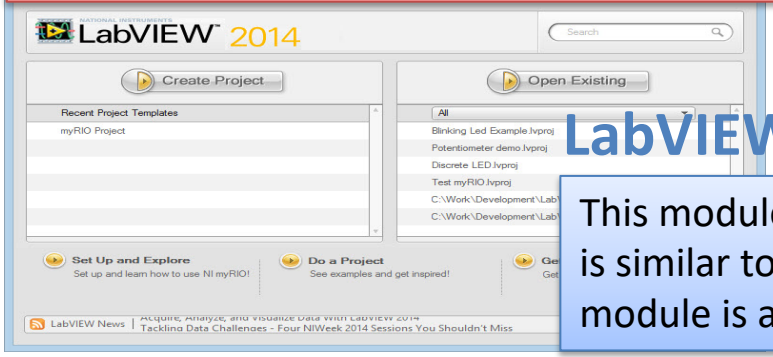
cRIO


NOx Sensor

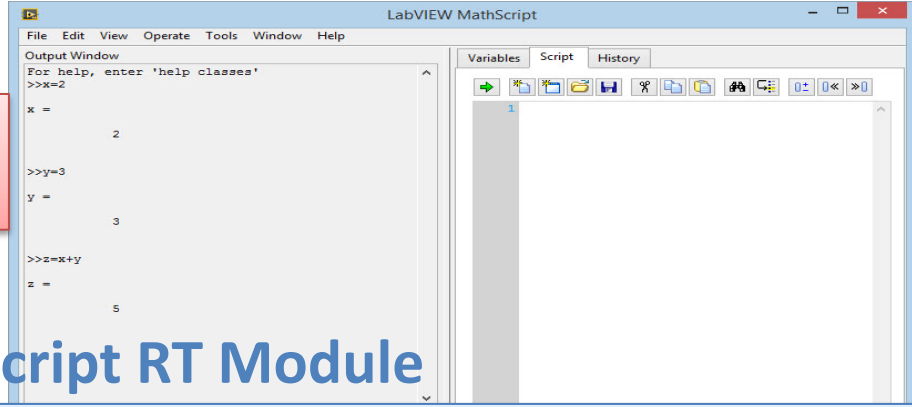
Vision System

LabVIEW

This is the core LabVIEW installation that installs the LabVIEW Programming Environment.



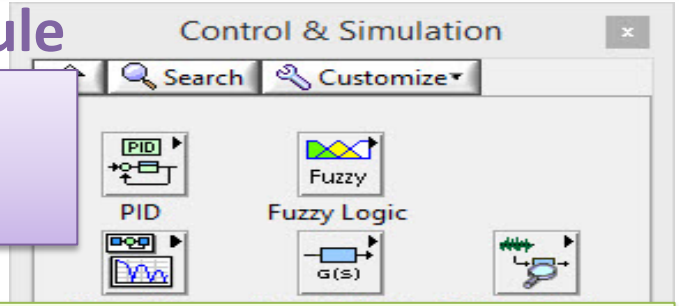
LabVIEW MathScript RT Module



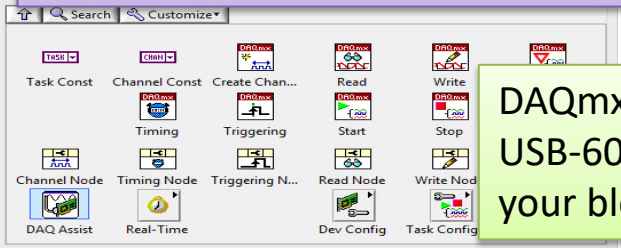
This module is a text-based tool that is very similar to MATLAB. The syntax is similar to MATLAB, you can create and run so-called m files, etc. The module is available from the Tools menu inside LabVIEW.

LabVIEW Control Design and Simulation Module

This module is used for creating Control and Simulation applications with LabVIEW. Here you will find PID controllers, etc. The module is available as a palette on your block diagram.



NI-DAQmx



DAQmx is the Hardware Driver needed in order to use hardware devices like NI USB-6008, NI TC-01, etc. inside LabVIEW. The module is available as a palette on your block diagram.

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The LabVIEW Environment (IDE)

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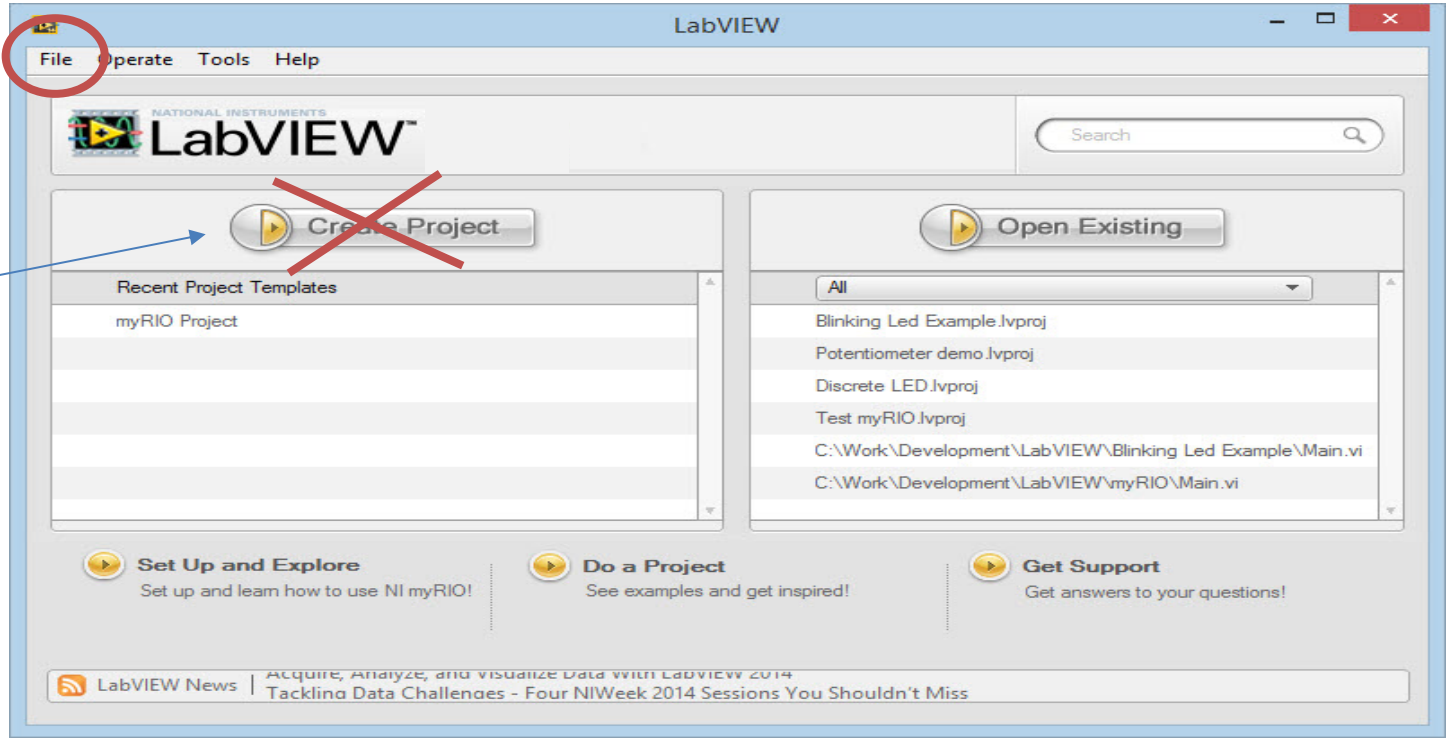
IDE – Integrated Development Environment

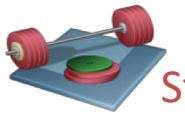
LabVIEW Environment

This window appears when you start LabVIEW:

Select File -> New VI (Ctrl + N) in order to start using LabVIEW

You shall **not** use this one (yet)

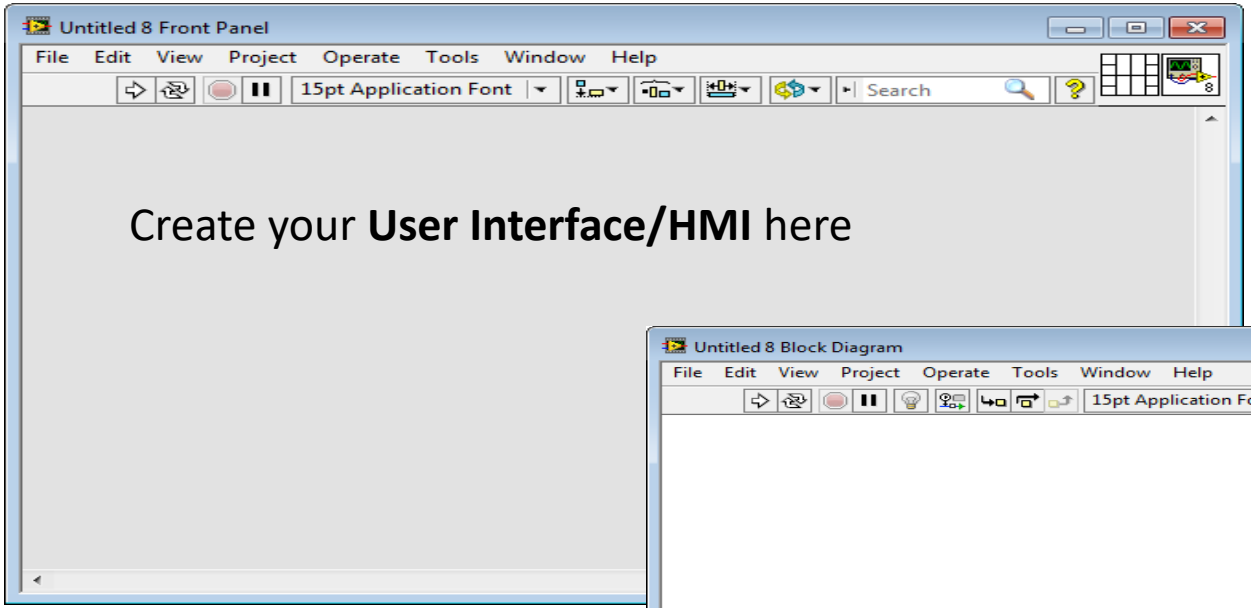




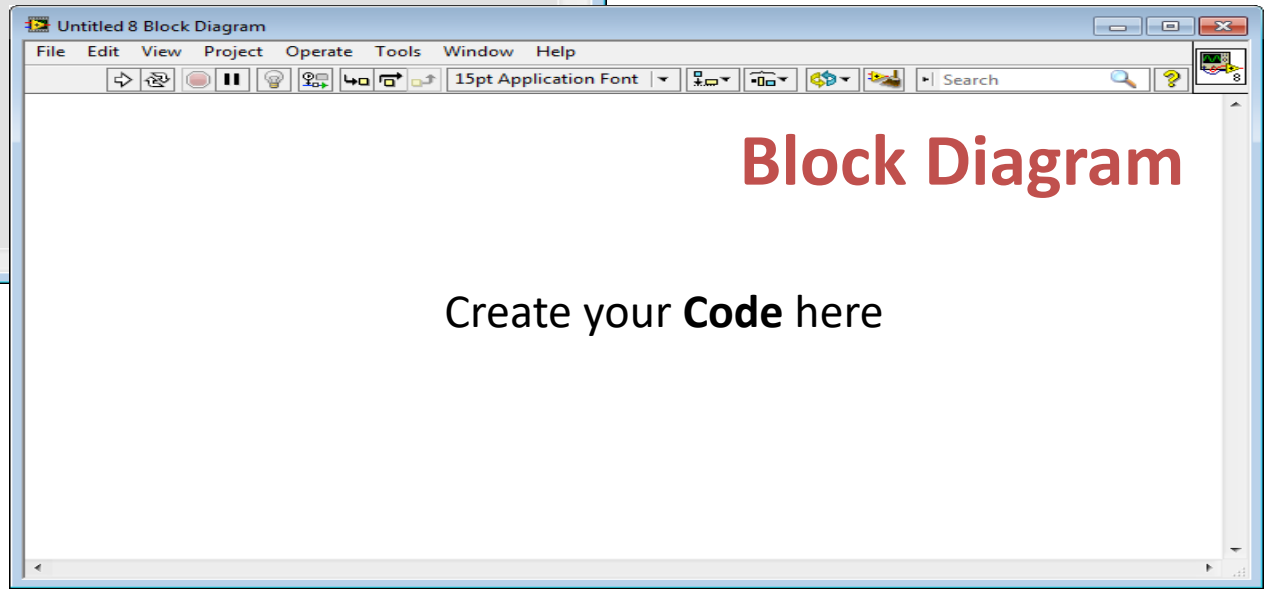
Students: Start LabVIEW in order to get started

LabVIEW Environment

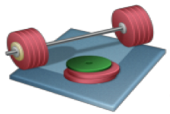
Front Panel



Note! Both the Front Panel and the Block Diagram are stored in one single file. These files are called **VIs** (because the file extension is ".vi"). VI = Virtual Instruments



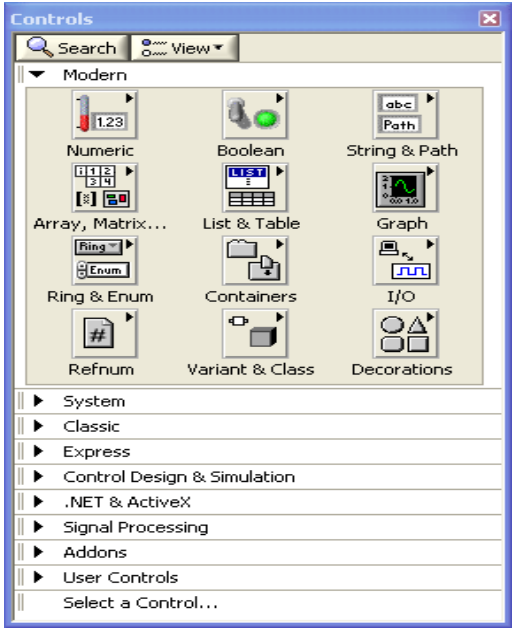
Switch between them: **Ctrl + E**

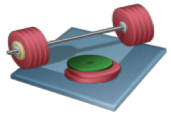


Students: Try this

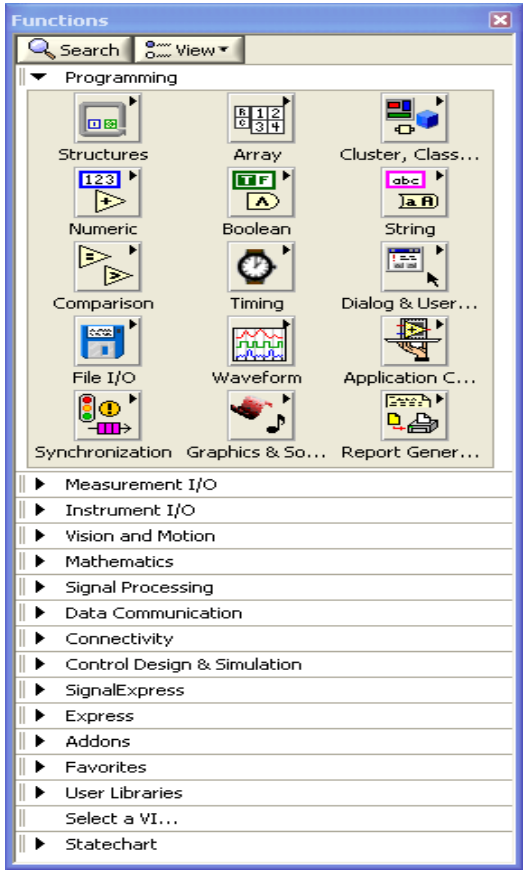
Controls and **Functions** Palette

Controls ← You can "pin" them! → Functions





Students: Open the **Controls** and **Functions** palettes and browse the contents in the different subpalettes



Available only from the **Front Panel**

You create your User Interface with help of these Controls

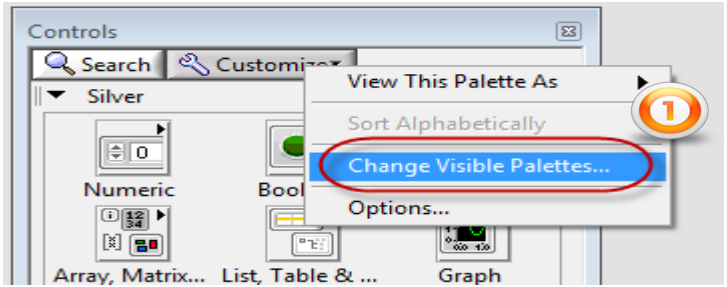
Right-click on the Front Panel

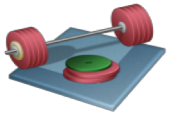
You create your Code with help of these Functions

Available only from the **Block Diagram**

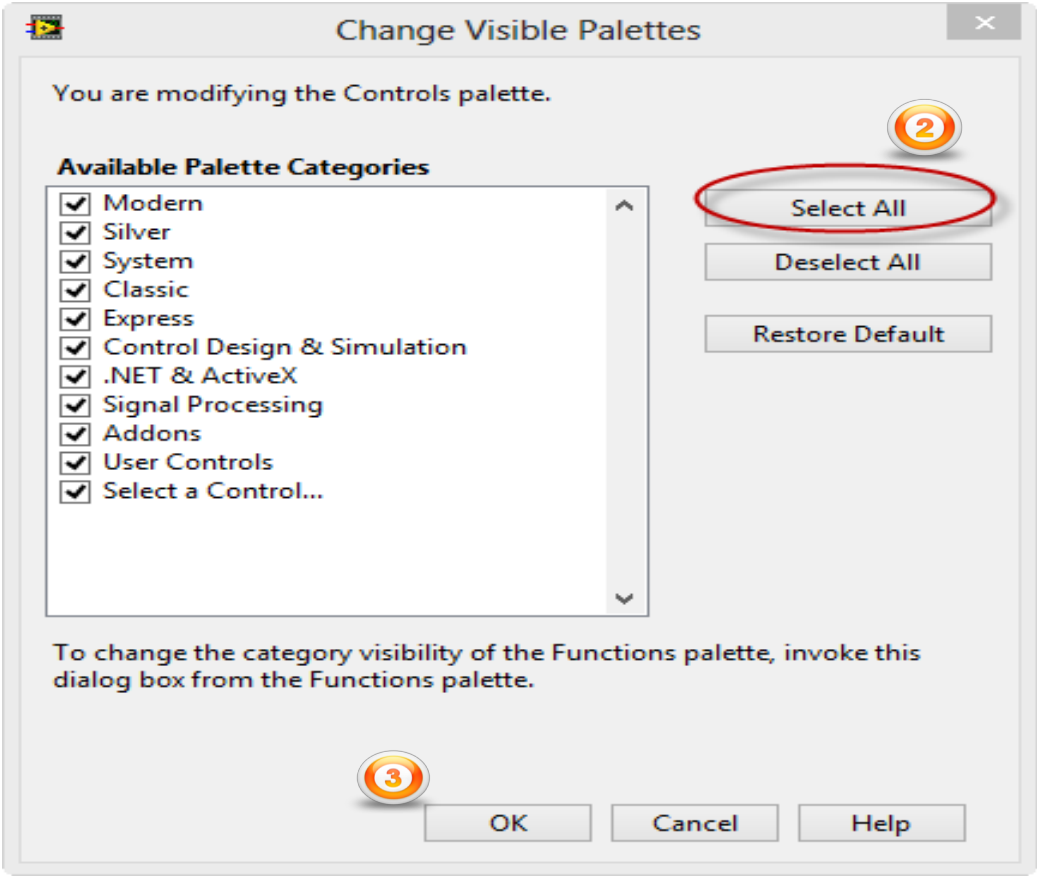
Right-click on the Block Diagram

Customizing Controls and Functions Palettes





Students: Do this for <u>both</u> the **Controls Palette** and the **Functions Palette**



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LabVIEW Programming

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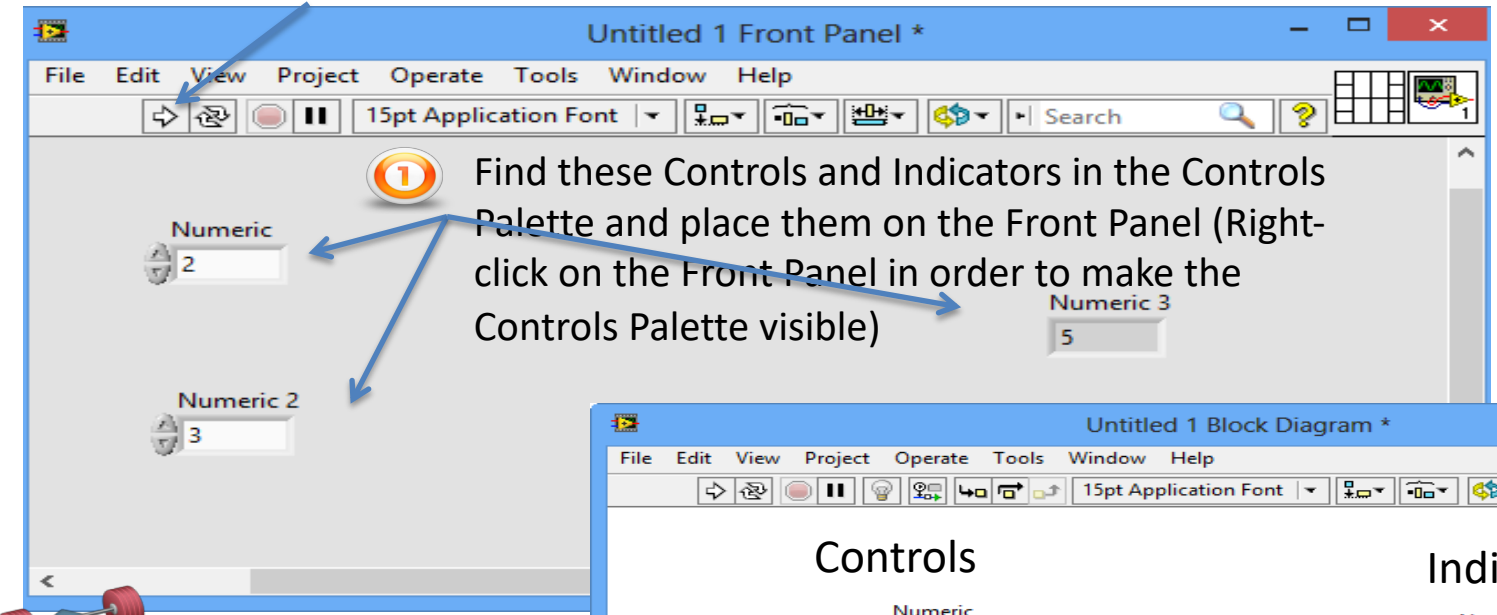
Simple Example

3 Run the Program

Front Panel

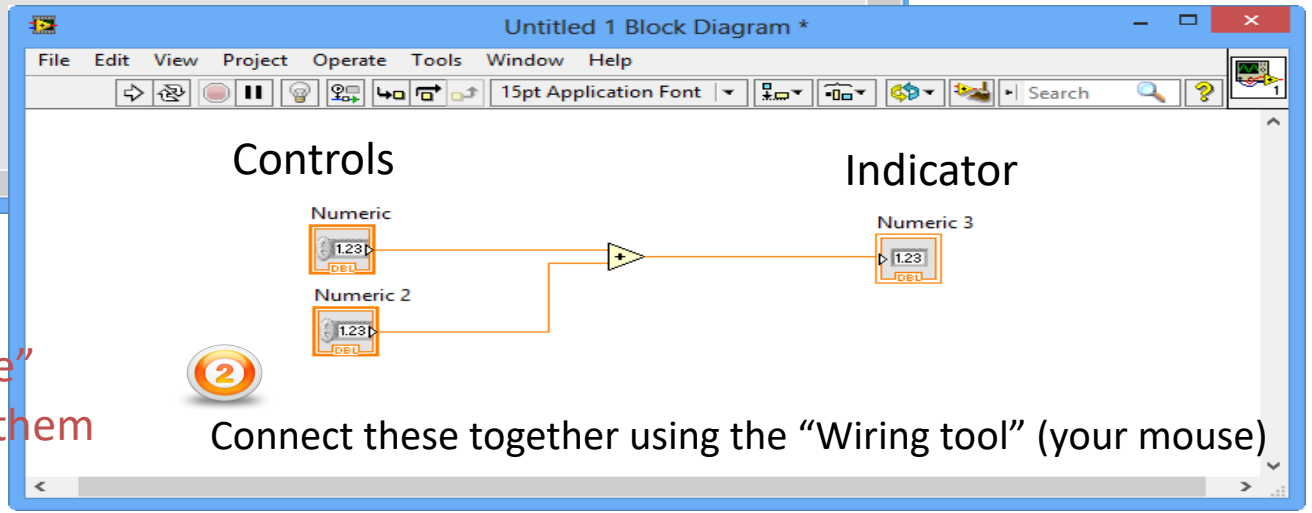


1 Find these Controls and Indicators in the Controls Palette and place them on the Front Panel (Right-click on the Front Panel in order to make the Controls Palette visible)

Controls vs. Indicators

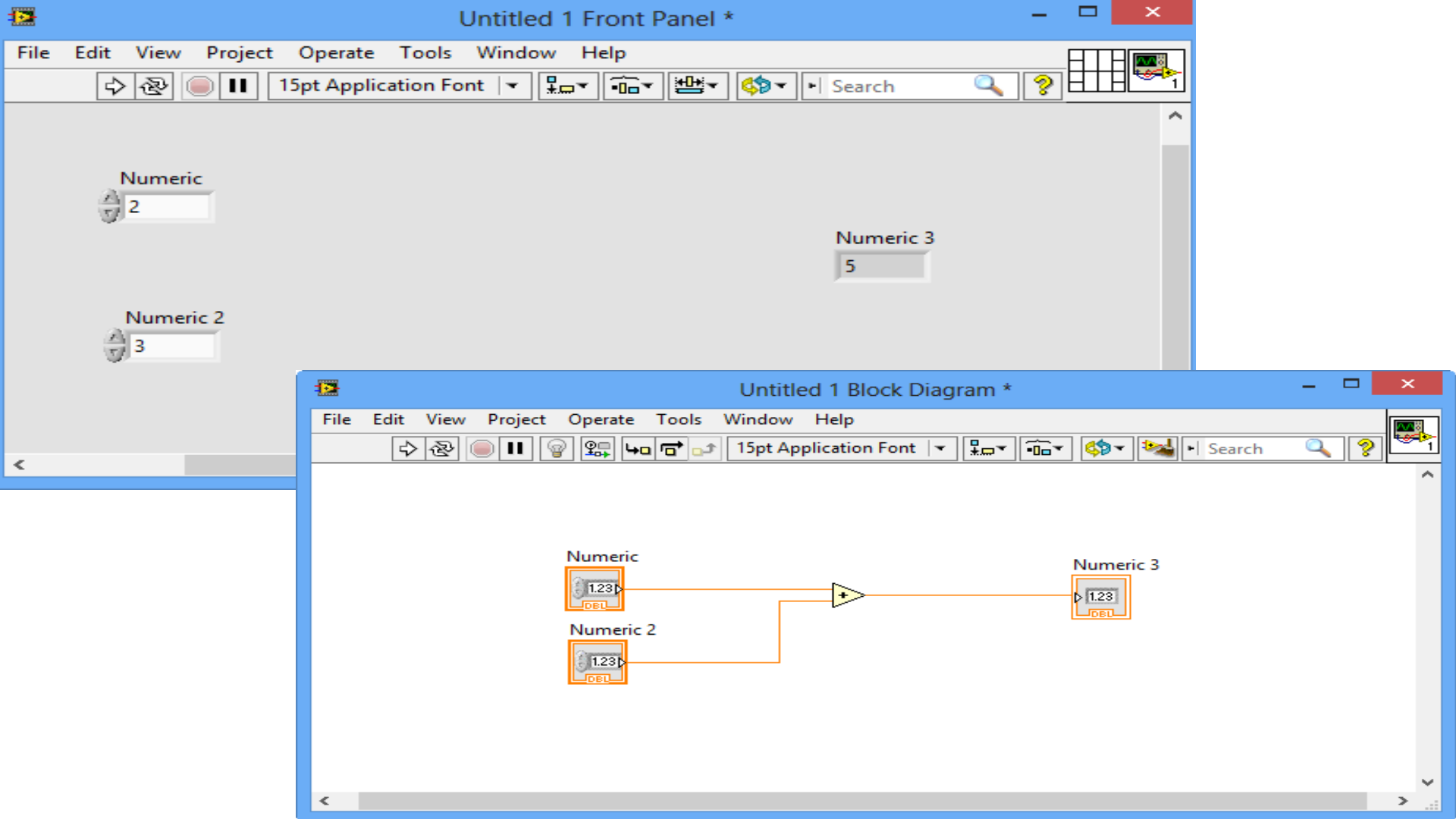
What is the difference?

Block Diagram



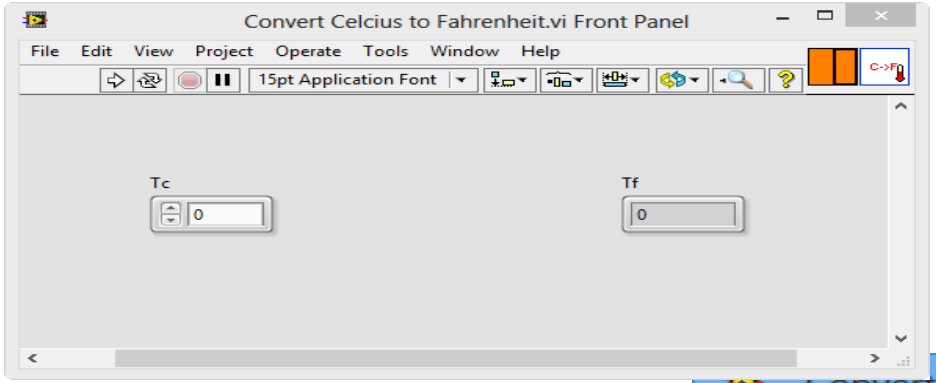
2 Connect these together using the "Wiring tool" (your mouse)

Students: Create this simple example. Try "Minus", "Divide" and "Multiply" as well. Save them as 4 different VIs


Untitled 1 Front Panel *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Numeric
2
Numeric 2
3
Numeric 3
5
Untitled 1 Block Diagram *
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
Numeric
1.23
DBL
Numeric 2
1.23
DBL
Numeric 3
1.23
DBL

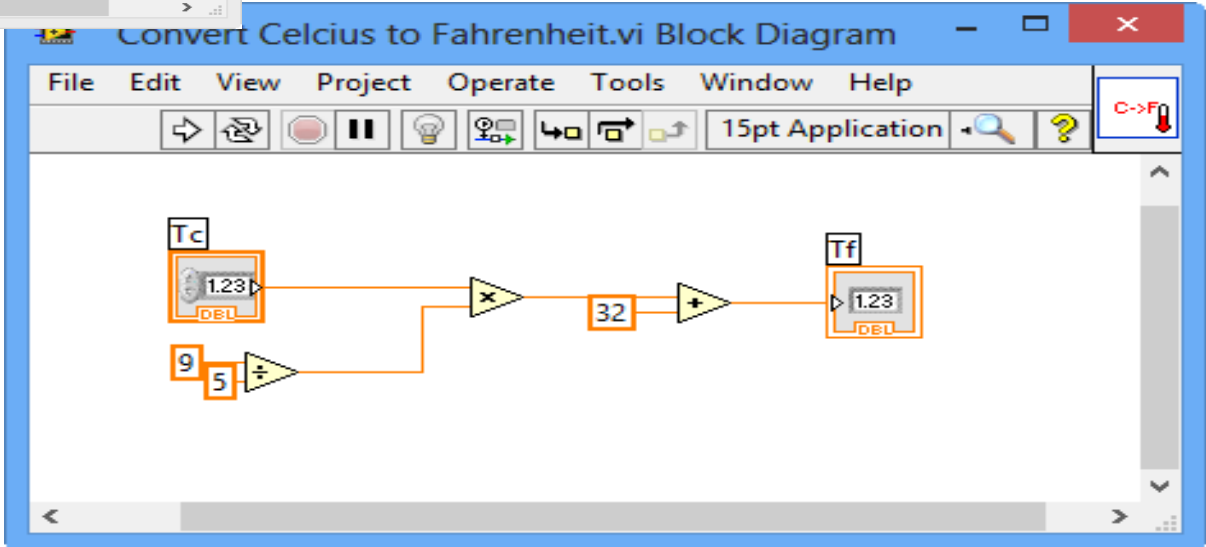
Celcius to Fahrenheit - Example

Front Panel

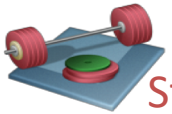


$$T_F = \frac{9}{5}T_C + 32$$

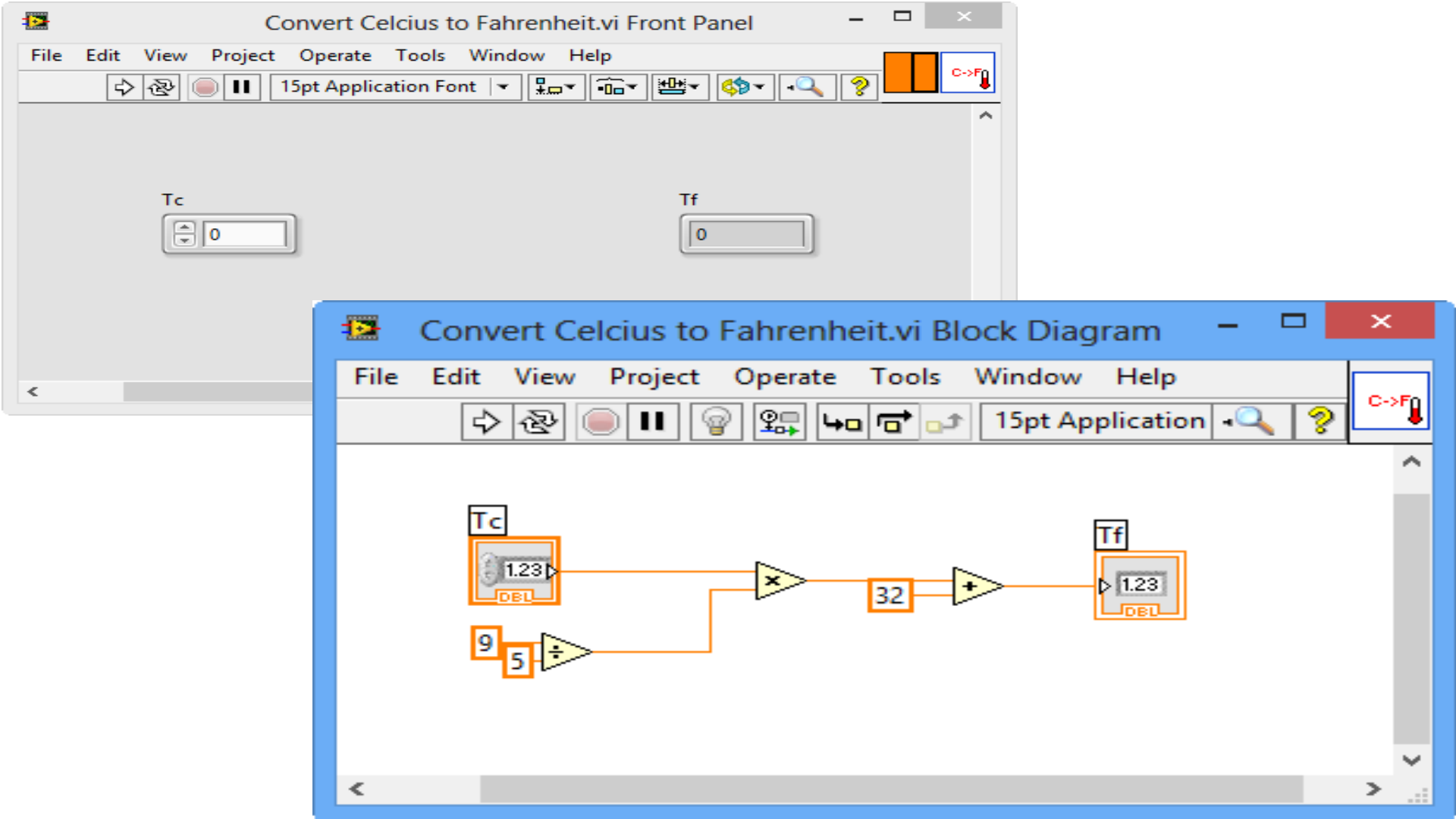
Block Diagram



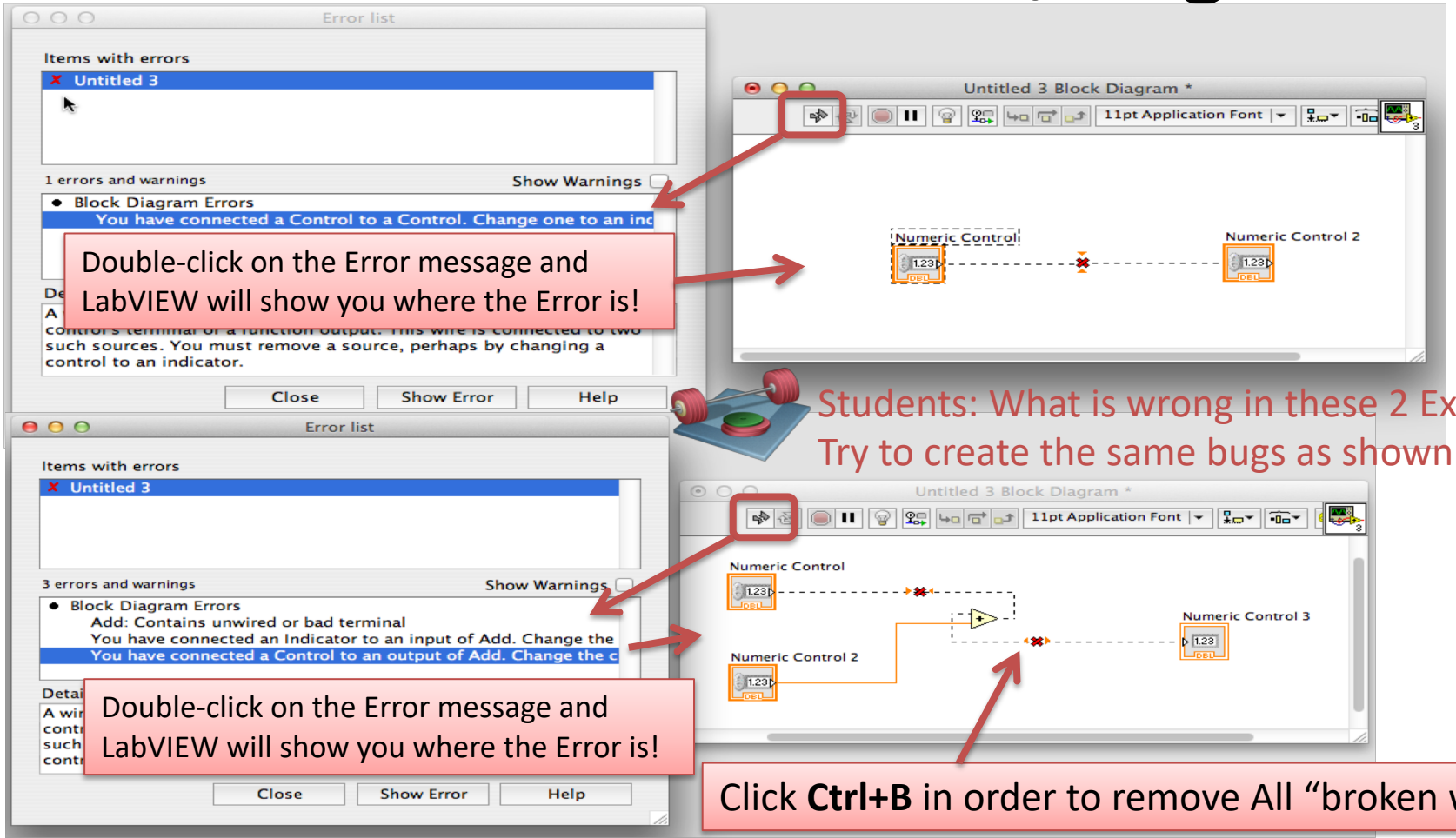
Note! The objects may look different depending on your configuration, but that doesent matter



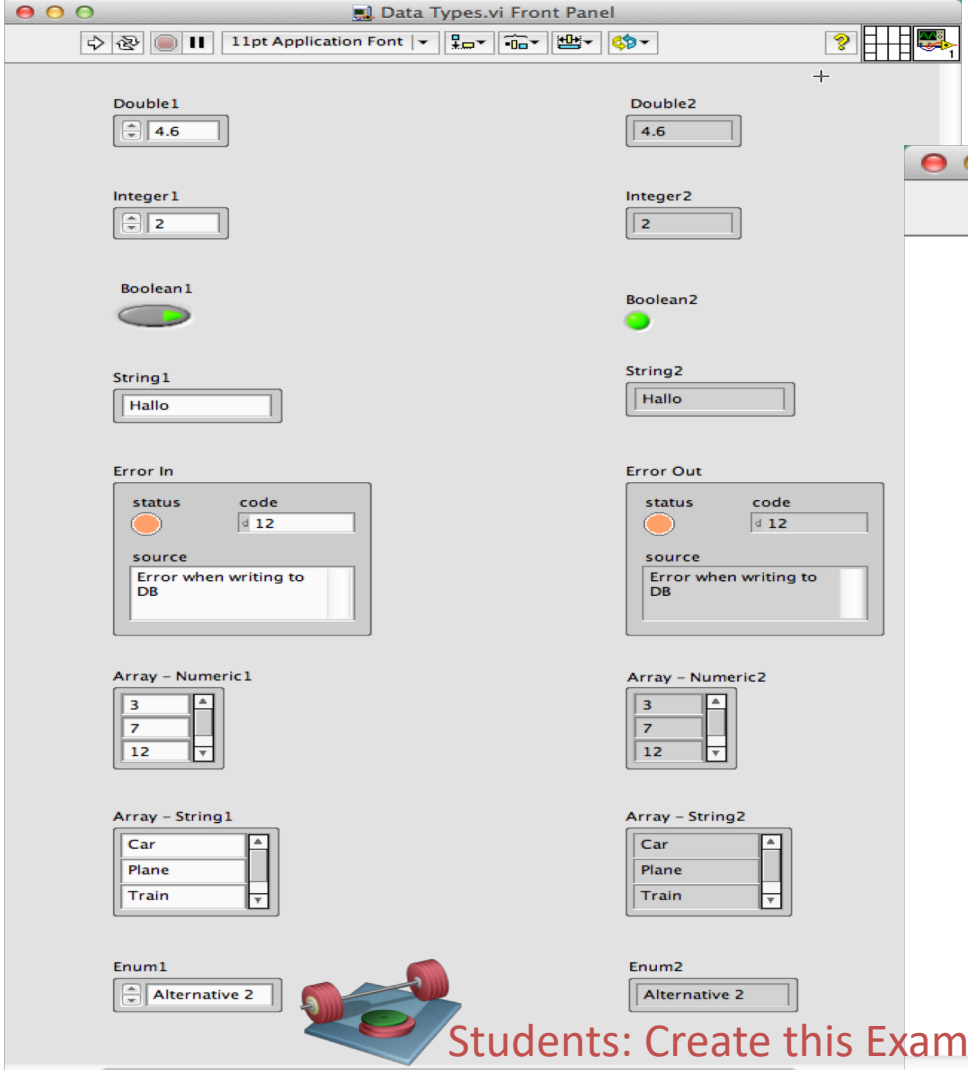
Students: Create the Front Panel and Block Diagram in this example.

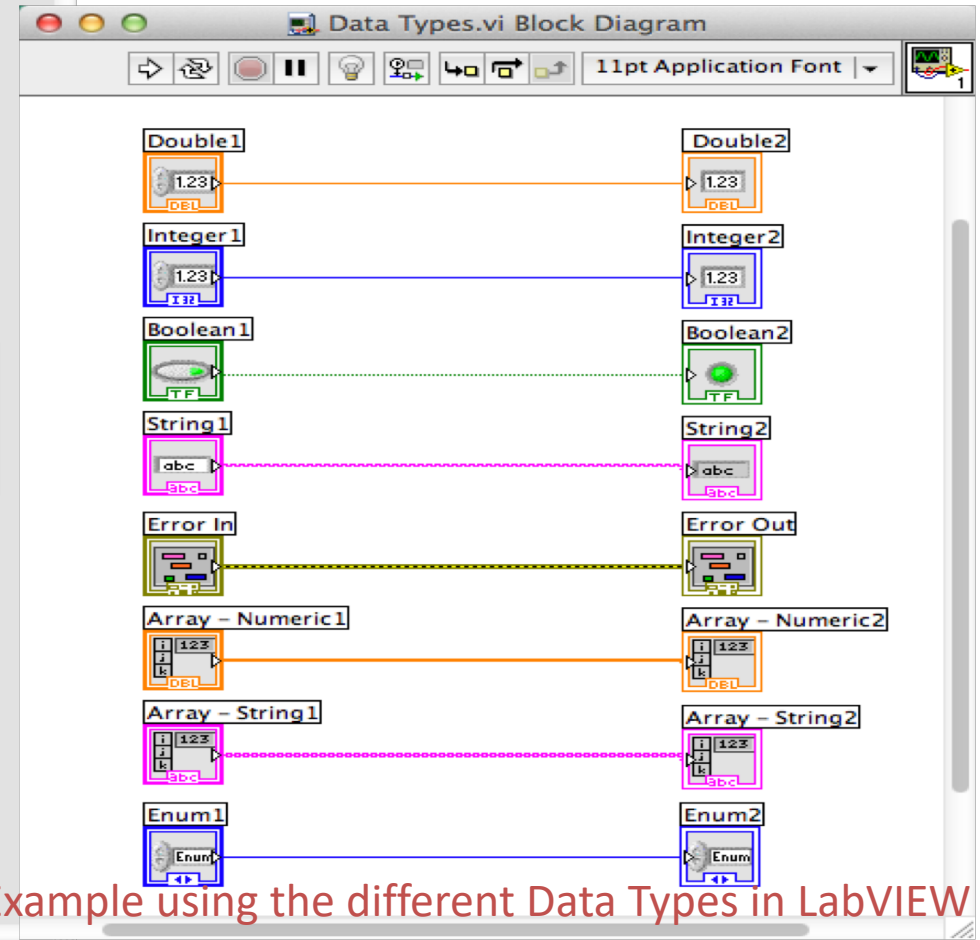

Convert Celcius to Fahrenheit.vi Front Panel
File Edit View Project Operate Tools Window Help
15pt Application Font
C->F
Tc
0
Tf
0
Convert Celcius to Fahrenheit.vi Block Diagram
File Edit View Project Operate Tools Window Help
15pt Application
C->F
Tc
1.23
DBL
9
5
32
Tf
1.23
DBL

How-To Fix Errors/Bugs



Data Types





Students: Create this Example using the different Data Types in LabVIEW

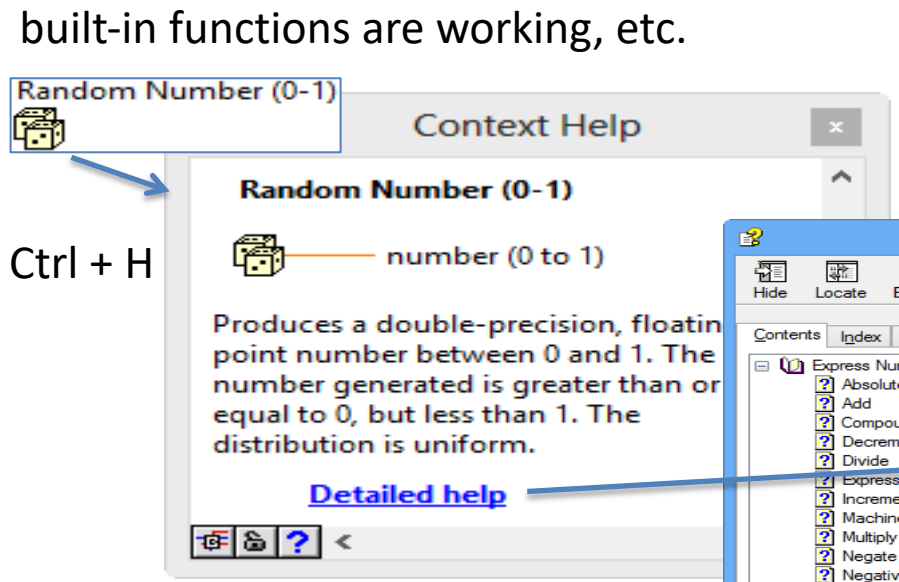
Ctrl + H

I need Help!!

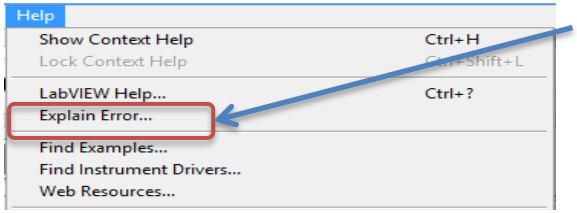
When you use **Ctrl + H**, you may click on all kind of objects (both on Front Panel and Block Diagram) on the screen to get help, e.g., how built-in functions are working, etc.

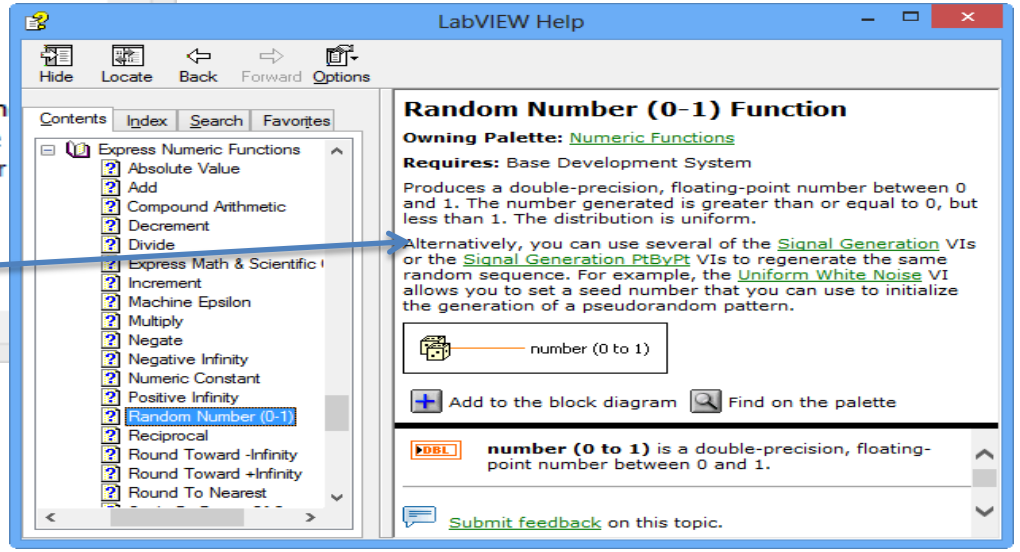
Where can I find it?

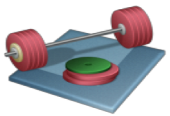
In the Help menu you will find Examples, etc.



Ctrl + H







Students: Try this on different objects on your Block Diagram

http://www.ni.com/pdf/manuals/376039a.pdf

LabVIEW™ Quick Reference Guide

Keyboard Shortcuts

File

Ctrl-N	Create new VI
Ctrl-S	Save VI
Ctrl-P	Print

Edit

Ctrl-V	Paste object
Ctrl-U	Clean up diagram
Ctrl-Space	Activate quick drop
Ctrl-B	Remove broken wires
Ctrl-C	Copy an object
Ctrl-X	Cut object
Ctrl-Z	Undo last action
Ctrl-Shift-Z	Redo last action

Operate

Ctrl-R	Run VI
Ctrl-.	Abort VI

Window

Ctrl-E	Display block diagram/ front panel
Right-Click	Display controls/ functions palette
Shift-Right-Click	Display tools palette
Ctrl-T	Tile block diagram and front panel windows

Help

Ctrl-H	Display context help

Editing Tools

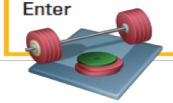
Tool	Icon	Description
Show Context Help		Display the context help window
Text Settings (15pt Application Font)		Change the font setting for the VI, including size, style, and color
Align Objects		Align selected objects
Distribute Objects		Space objects evenly
Resize Objects		Resize multiple front panel objects to the same size
Reorder		Reorder the layers of the objects
Clean Up Diagram		Rearrange wires and objects on the block diagram
Enter		Appears when a new value is available to replace an old value

Debugging Tools

Tool	Icon	Description
Run		Execute the VI
List Errors		List errors that prevent the VI from running
Run Continuously		Execute the VI continuously until abort or pause is pressed
Abort Execution		Stop VI execution immediately
Execution Highlighting		Animate data movement on the block diagram wires
Pause		Temporarily stop execution to debug a portion of the VI
Step Into		Single-step into a subVI or structure to debug it
Step Over		Execute a subVI or structure and pause at the next one
Step Out		Execute a subVI or structure and resume single-stepping

Tools Palette

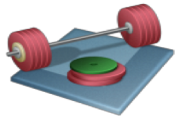
Tool	Icon	Description
Automatic Tool Selection		Automatically choose the appropriate tool
Operating Tool		Change the value of a control or select the text within a control
Positioning Tool		Position, resize, and select objects
Labeling Tool		Edit text and create free labels
Wiring Tool		Wire objects together on a block diagram
Scrolling Tool		Scroll the window without using the scroll bars
Breakpoint Tool (Used for debugging)		Set breakpoints on VIs, functions, wires, loops, sequences, and cases
Probe Tool (Used for debugging)		Create probes on wires and display intermediate values on a wire in a running VI
Get Color Tool		Copy colors for pasting with the Color Tool
Coloring Tool		Set the foreground and background colors



Students: Try some of these Shortcuts and Tools

While Loop

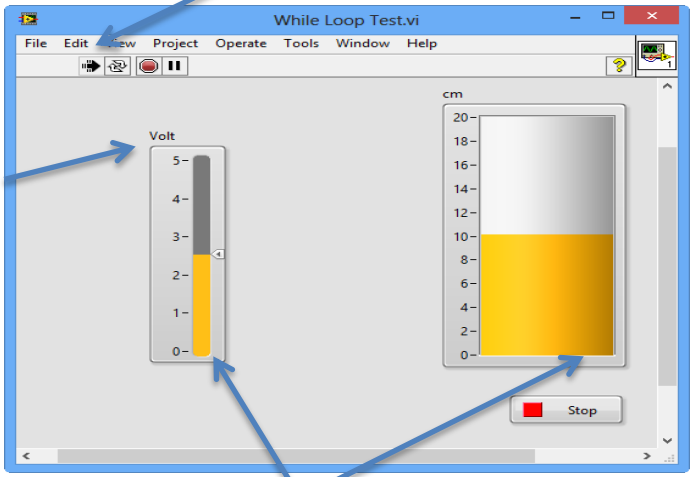
Example: A voltage signal [0-5V] from a DAQ device needs to be converted to the equivalent level values in a water tank [0-20cm]



Students: Create this Example

Front Panel

4 Run the Program



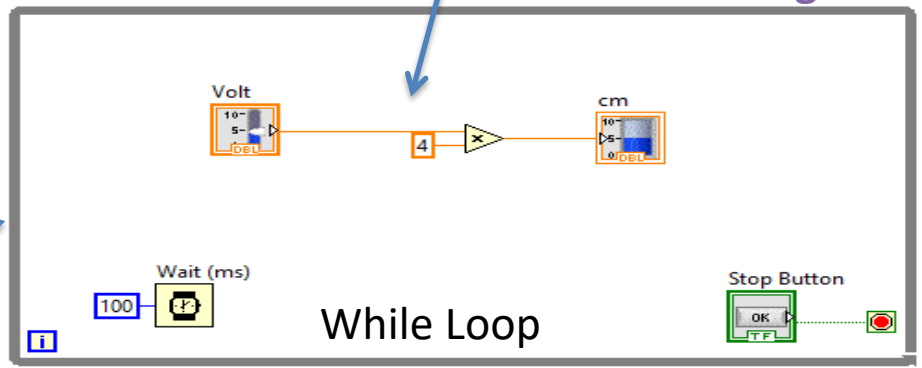
Label

1 **Front Panel**: Find these Controls in the Controls Palette and place them on the Front Panel with proper labels

2 **Block Diagram**: Find the **While Loop** in the Functions Palette and place it on the Block Diagram

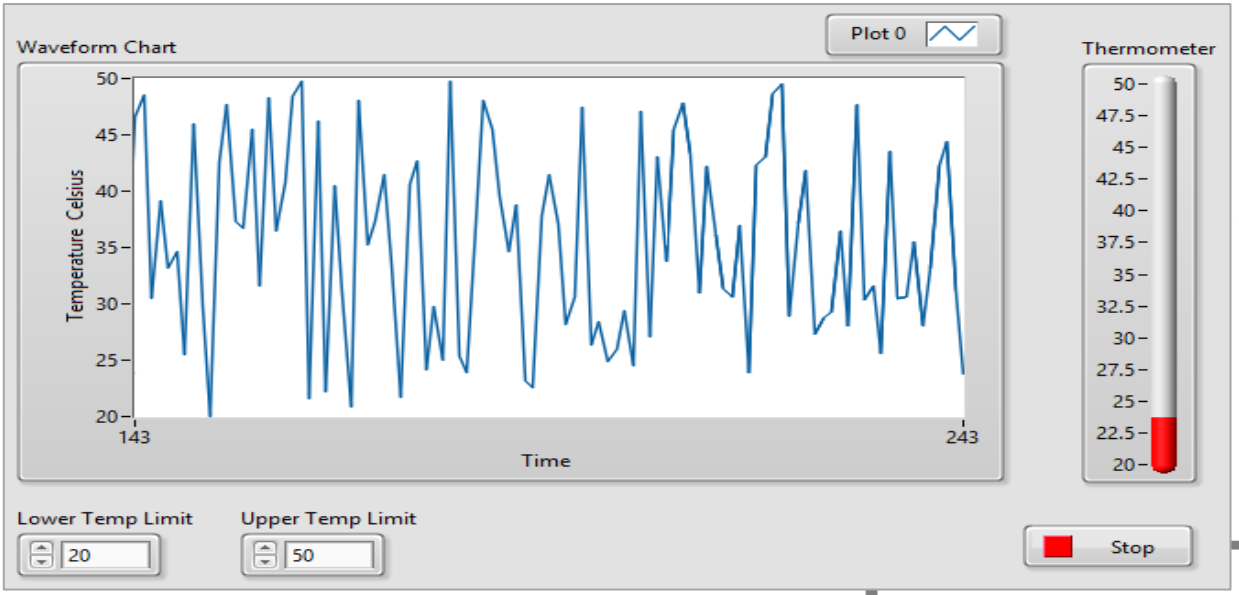
3 **Block Diagram**: Connect these together using the "Wiring tool" (your mouse)

Block Diagram

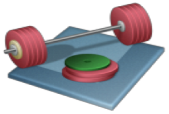


Note! To do something with an object – Right-click on it!

Plotting

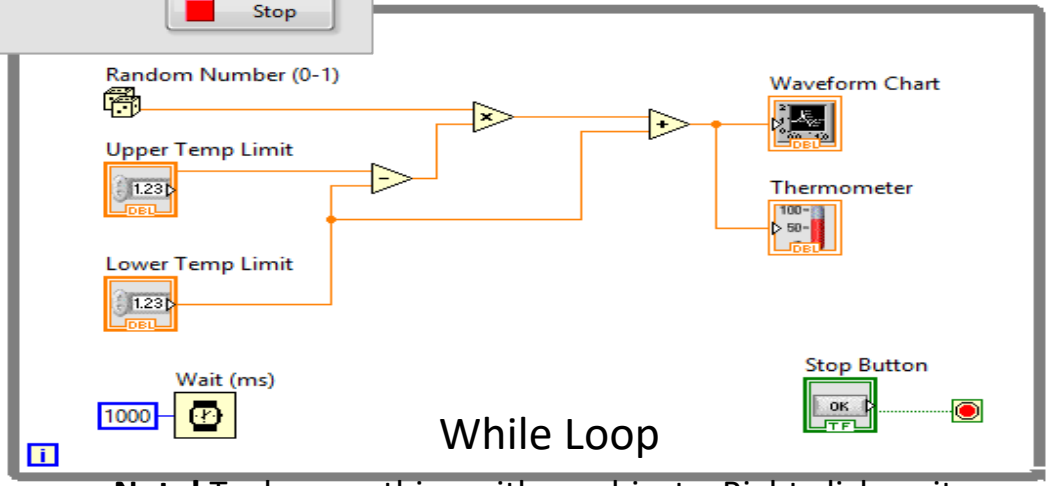


This example simulates the Temperature in an "Air Heater" system. The Temperature in the Air Heater should be between 20 and 50 degrees Celsius. We use the **Random Generator** in LabVIEW in this Example



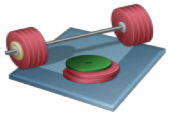
Students:

- Create this Example
- Try out different options on the Chart, e.g. Autoscale, different Modes, Grid, Layout, Colors, etc. (Right-click on the Chart)

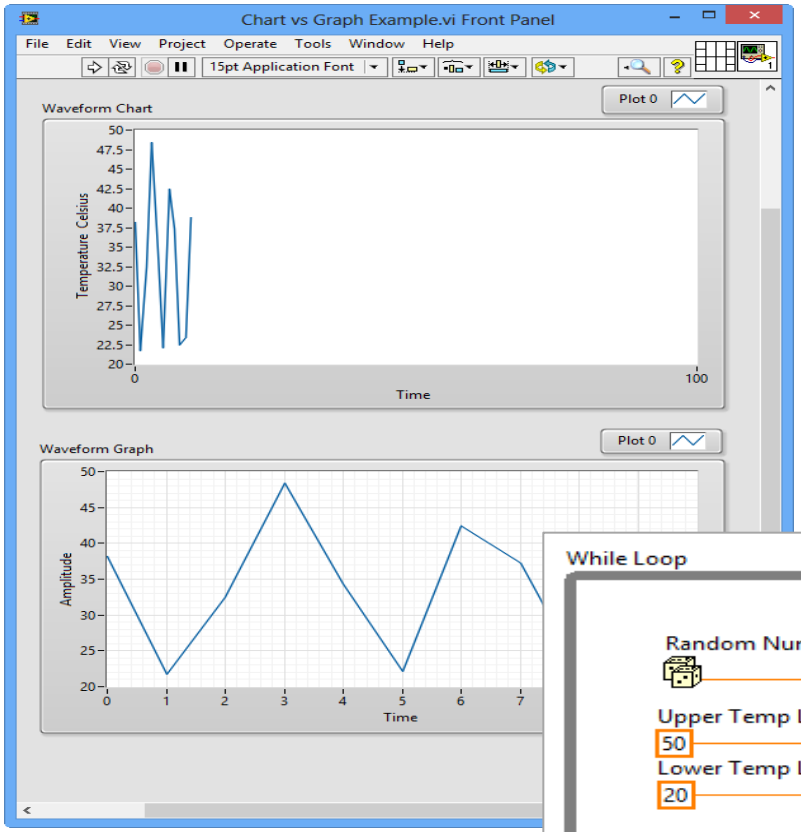


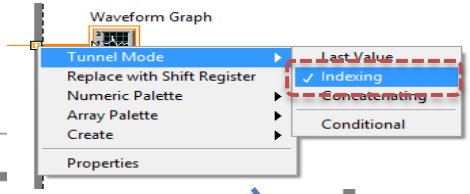
Note! To do something with an object – Right-click on it

Charts vs. Graphs - Example

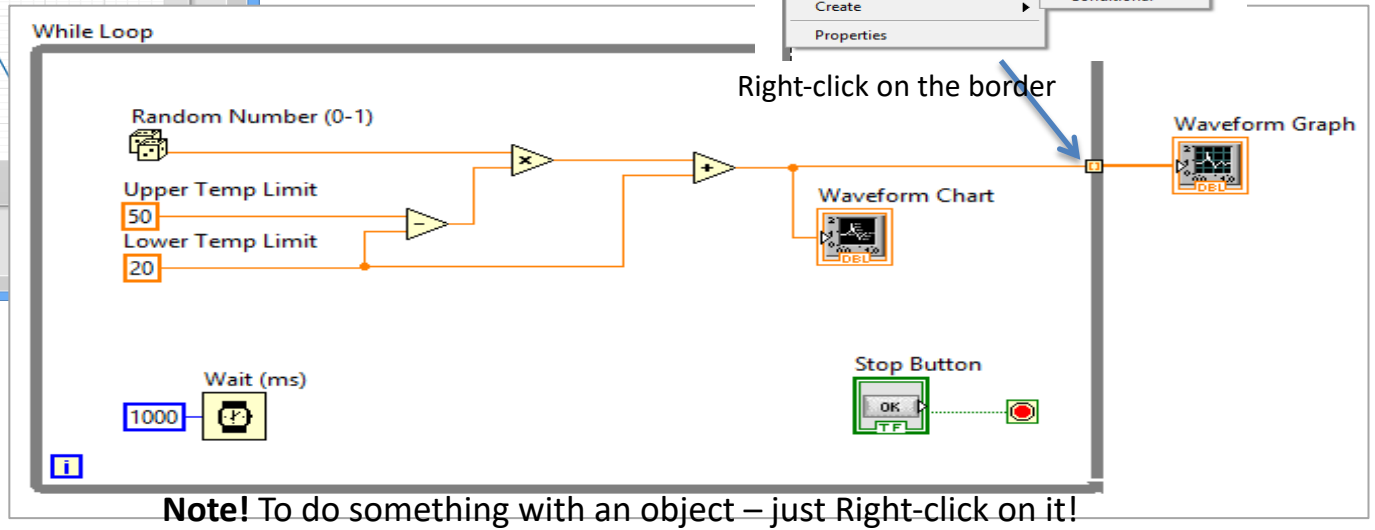


Students: Create this VI in order to see the difference between a **Chart** and a **Graph**





Right-click on the border



Note! To do something with an object – just Right-click on it!

Charts vs. Graphs

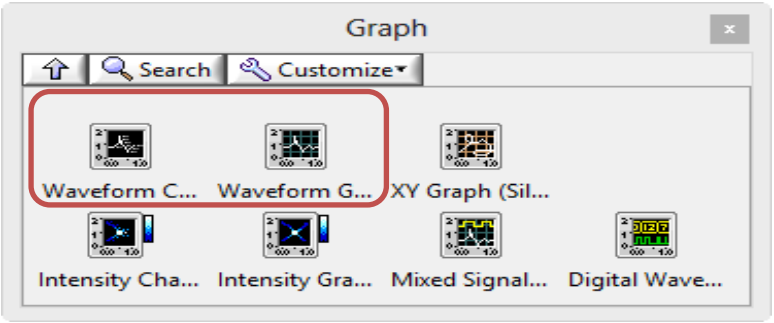


Chart:

- Remembers history – New point added to end of the plot
- Used inside a While Loop/For Loop
- One new point is added each time

Graph:

- You plot all the data at once – typically an array with data
- Used outside a While Loop/For Loop

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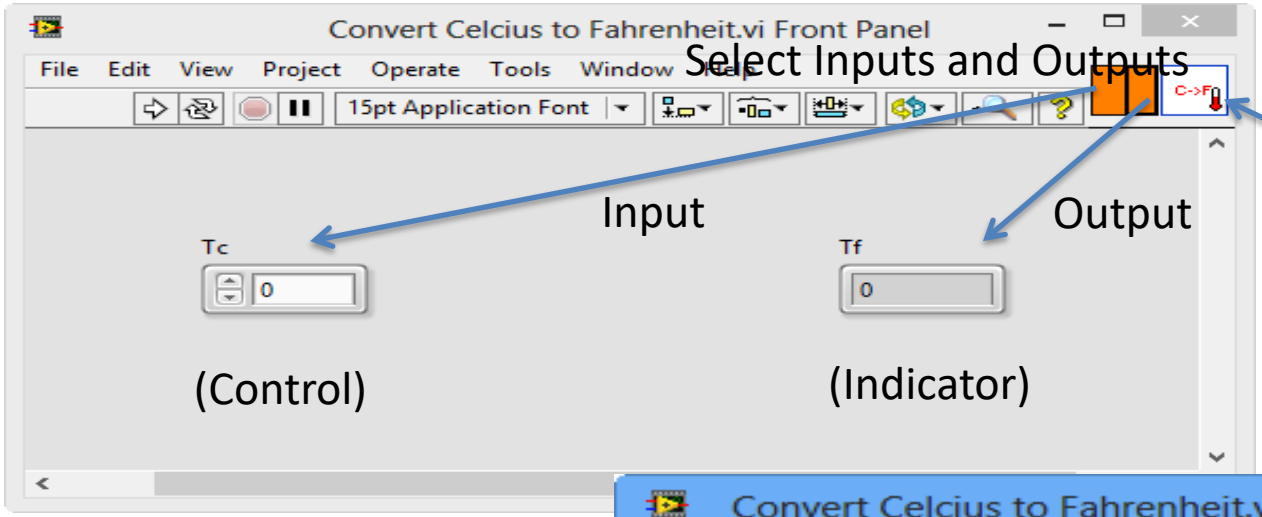
SubVIs

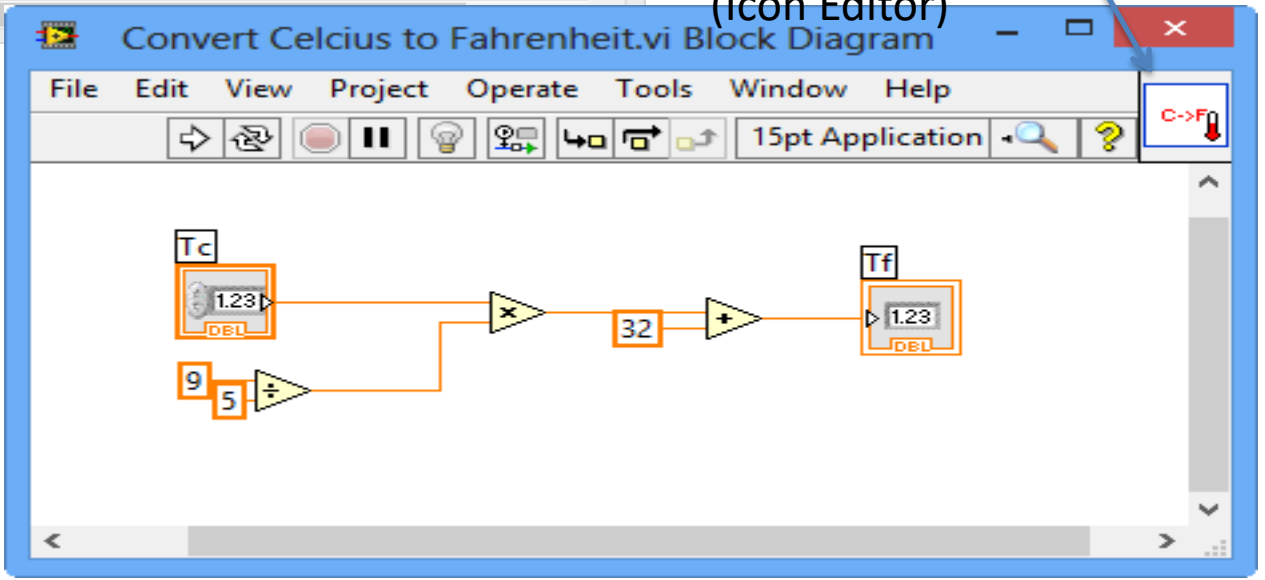
Hans-Petter Halvorsen

SubVIs



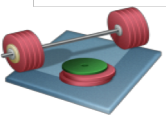
Icon that makes it easier to understand what the SubVI is doing

Create a nice icon as well (Icon Editor)



A SubVI is the same as a function or a method used in other languages

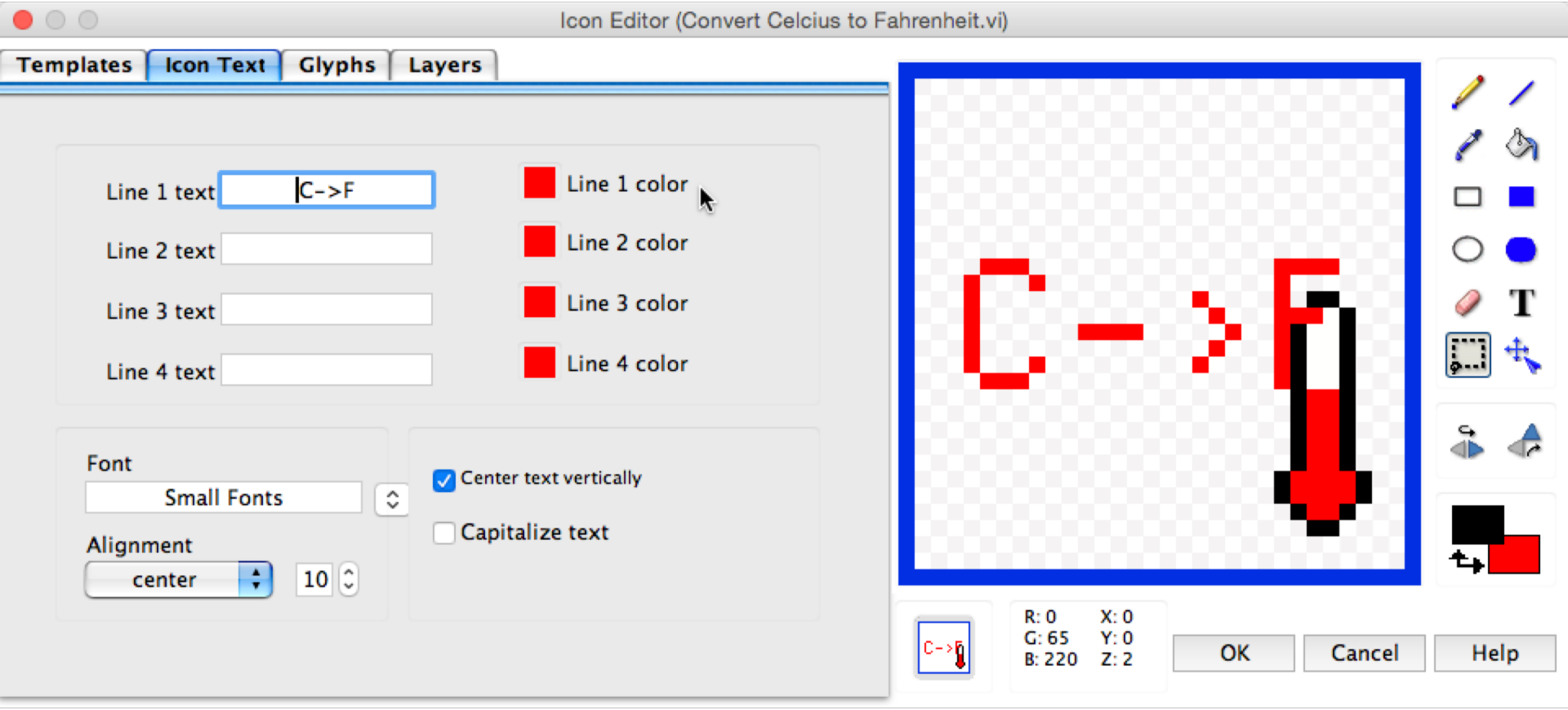
$$T_F = \frac{9}{5} T_C + 32$$



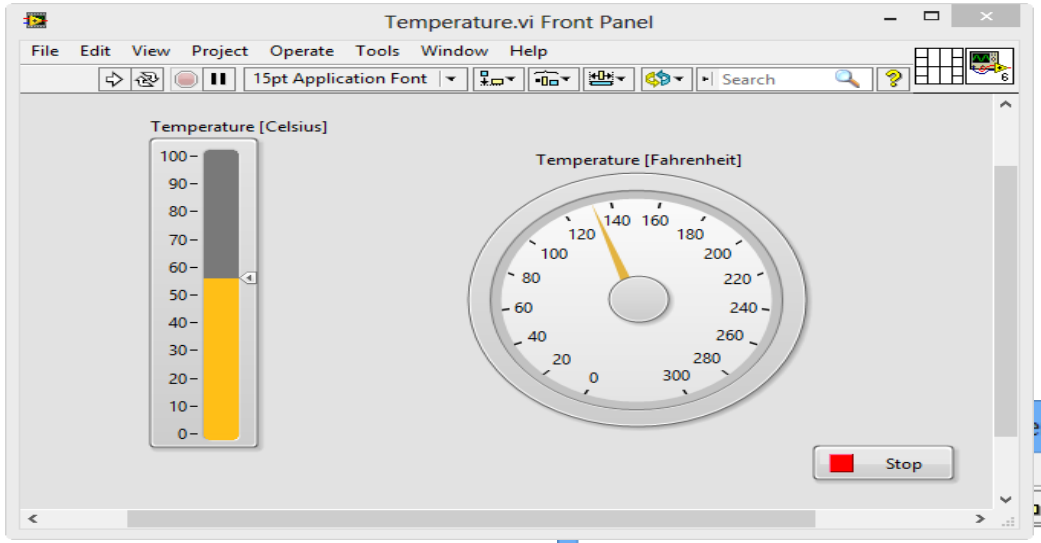
Students: Create this SubVI

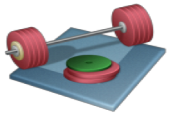
Icon Editor

Use the Icon Editor in order to create a descriptive icon for your SubVI.

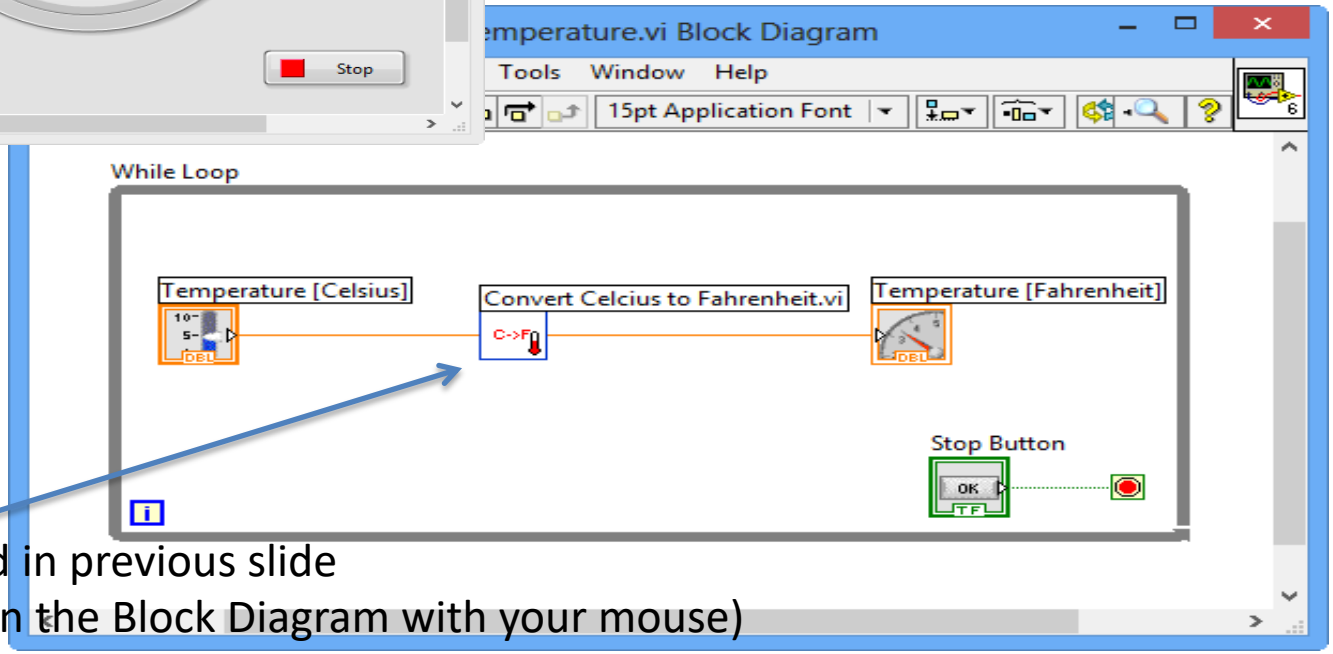


Using SubVIs





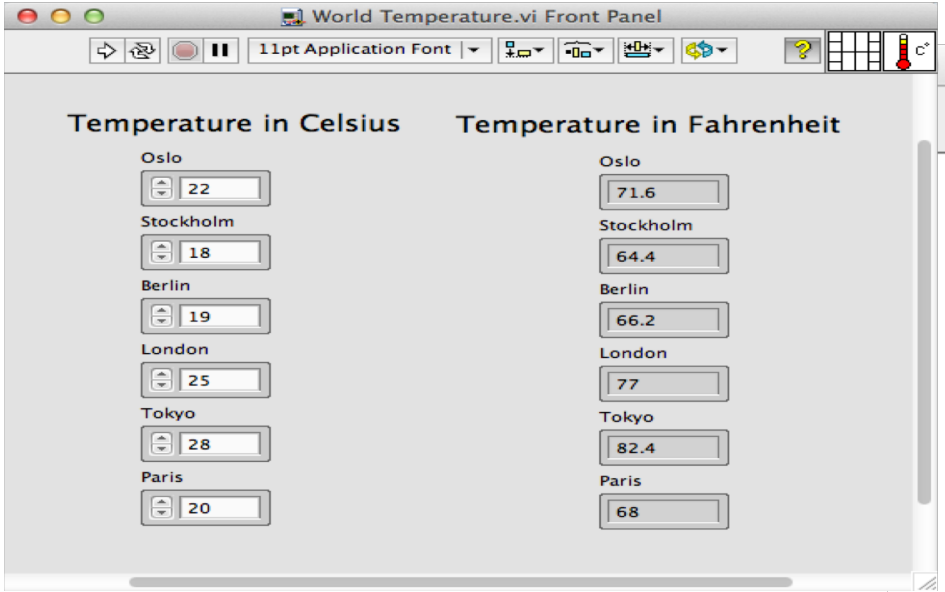
Students: Create this VI

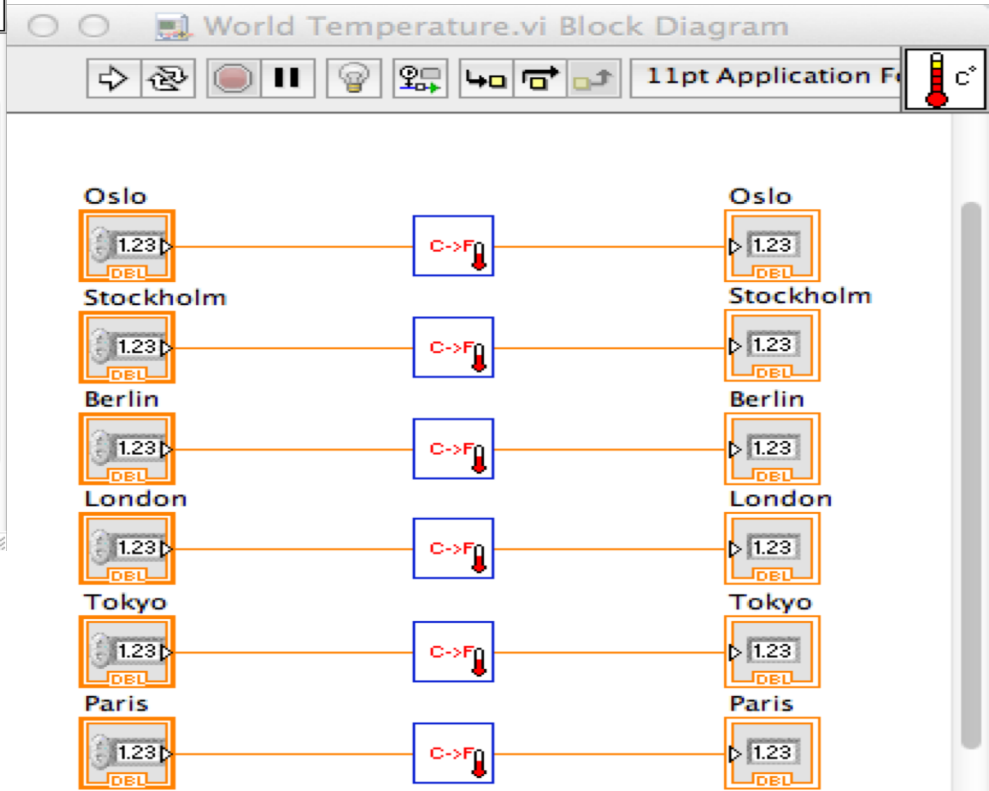


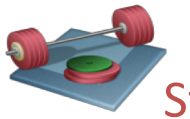
SubVI created in previous slide
(just drag it on the Block Diagram with your mouse)

SubVIs

Here you see some of the advantages with using SubVIs.



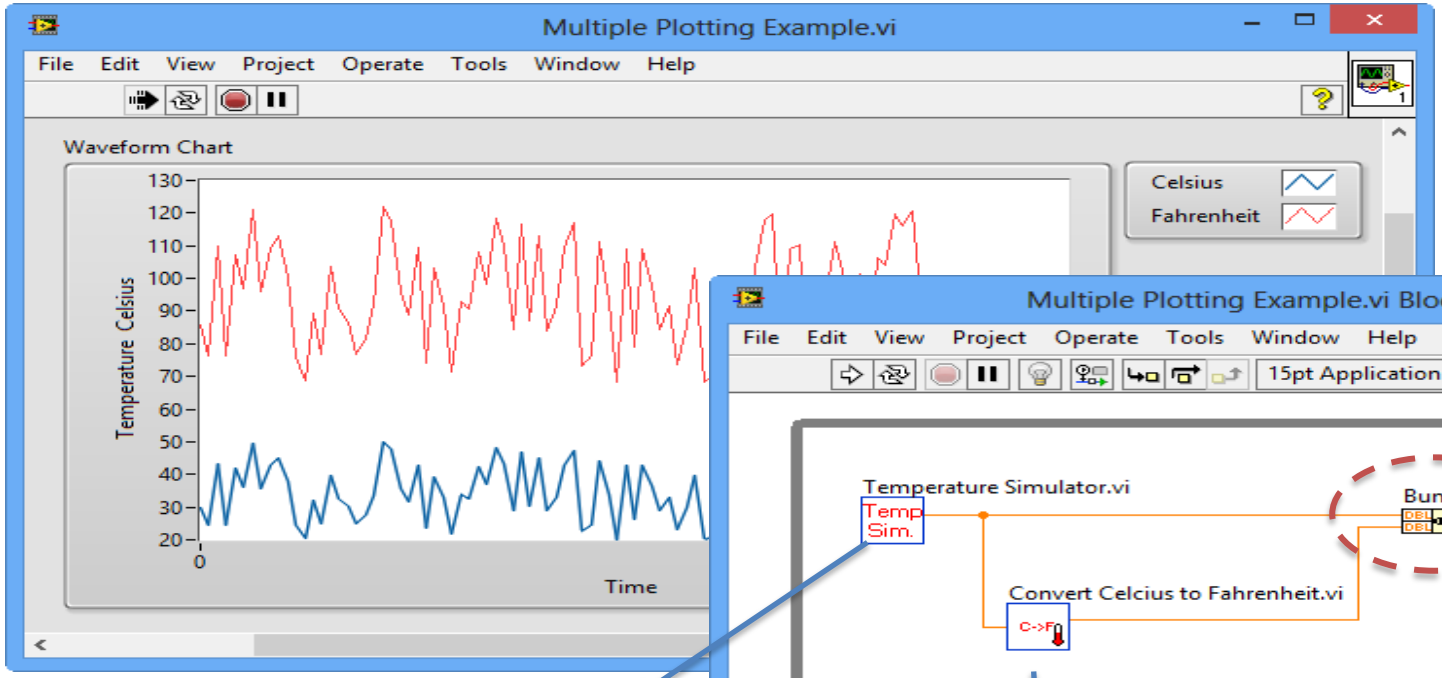




Students: Create this Example

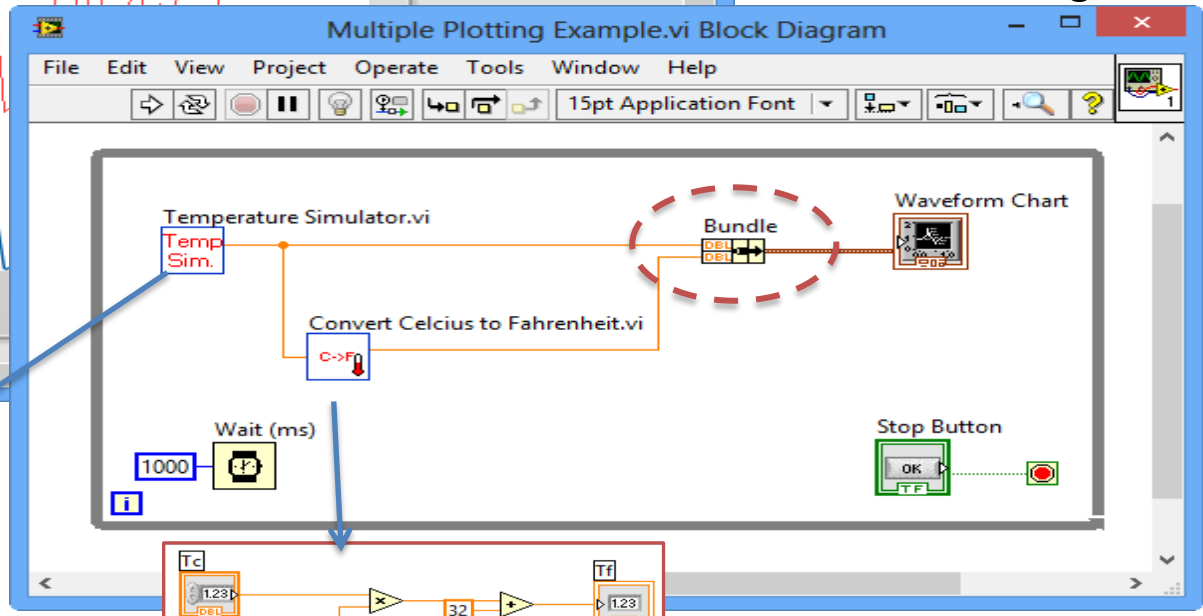
Multiple Plotting and SubVIs

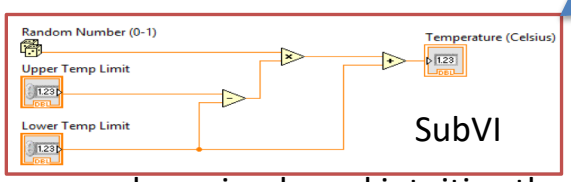
Front Panel



Students:
Create this program

Block Diagram





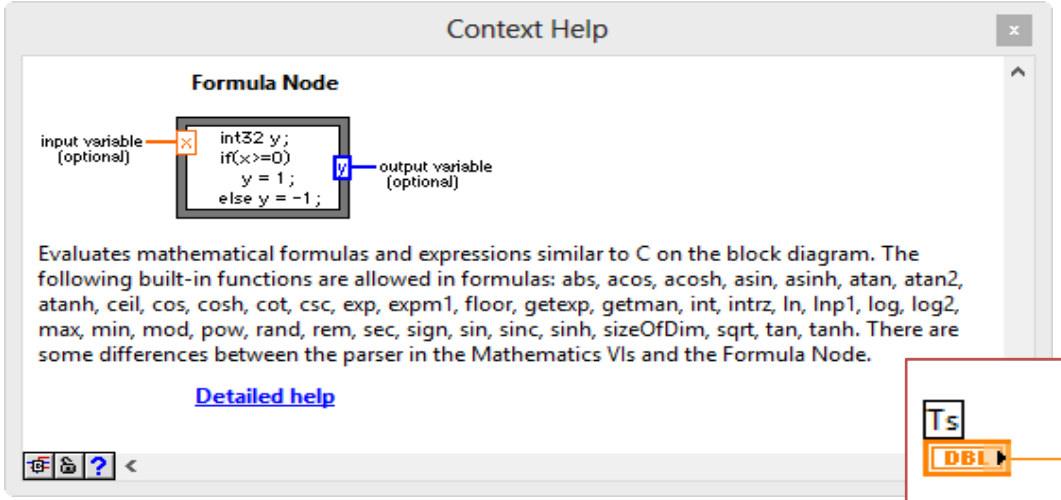
Do you see how simple and intuitive the code becomes when using SubVIs?

SubVI

Writing Formulas

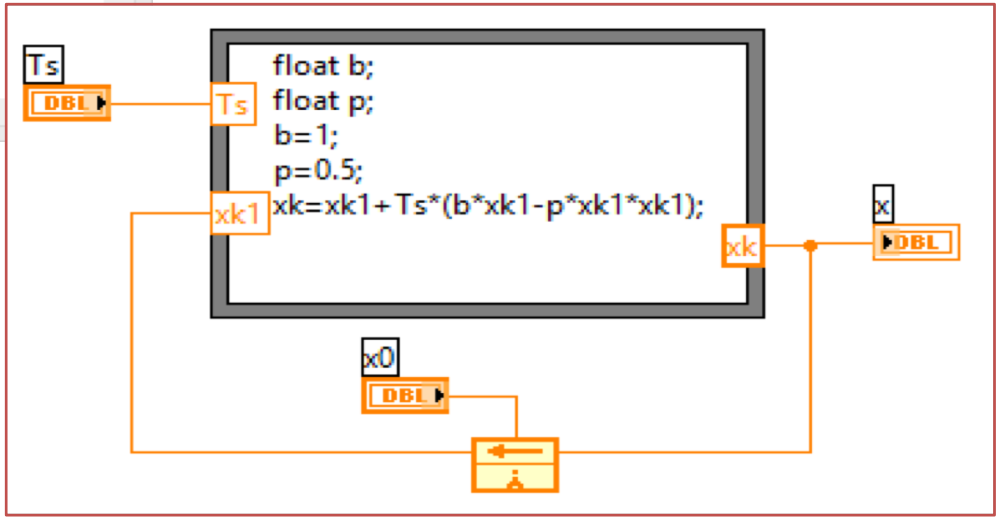
Hans-Petter Halvorsen

LabVIEW Formula Node



Formula Node: Create and use C code within LabVIEW

Example:



Very useful for mathematical expressions and simulations!

LabVIEW Formula Node

Celsius to Fahrenheit:

$$T_F = \frac{9}{5} T_C + 32$$

Students: Use the LabVIEW Formula Node in order to implement this formula

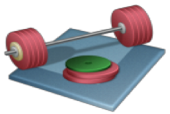
Advanced Mathematical Formula:

$$f(x) = \frac{\ln(ax^2 + bx + c) - \sin(ax^2 + bx + c)}{4\pi x^2 + \cos(x - 2)(ax^2 + bx + c)}$$

Given $a = 1, b = 3, c = 5$

Find $f(9)$

Try also with other values for a, b, c



Students: Use the LabVIEW Formula Node in order to implement this formula

Try also to implement this function with ordinary LabVIEW blocks. What is easiest to implement?

(The answer should be $f(9) = 0.0044$)

Solutions

$$f(x) = \frac{\ln(ax^2 + bx + c) - \sin(ax^2 + bx + c)}{4\pi x^2 + \cos(x-2)(ax^2 + bx + c)}$$

Formula Node Example.vi Block Diagram

File Edit View Project Operate Tools Window Help

15pt Application Font

```
f = (ln(a*x*x + b*x +c) - sin(a*x*x + b*x +c)) /(4*pi*x*x + cos(x-2)*(a*x*x + b*x +c));
```

Note!

Alternative Solution:

Formula Node Example2.vi Block Diagram

File Edit View Project Operate Tools Window Help

15pt Application Font

```
float g;
g = a*x*x + b*x +c;
f  = (ln(g) - sin(g)) /(4*pi*x*x + cos(x-2)*(g));
```

Which Solution do you think is best?

Formula Node Example.vi Front Panel

File Edit View Project Operate Tools Window He

15pt Application Font

a: 1

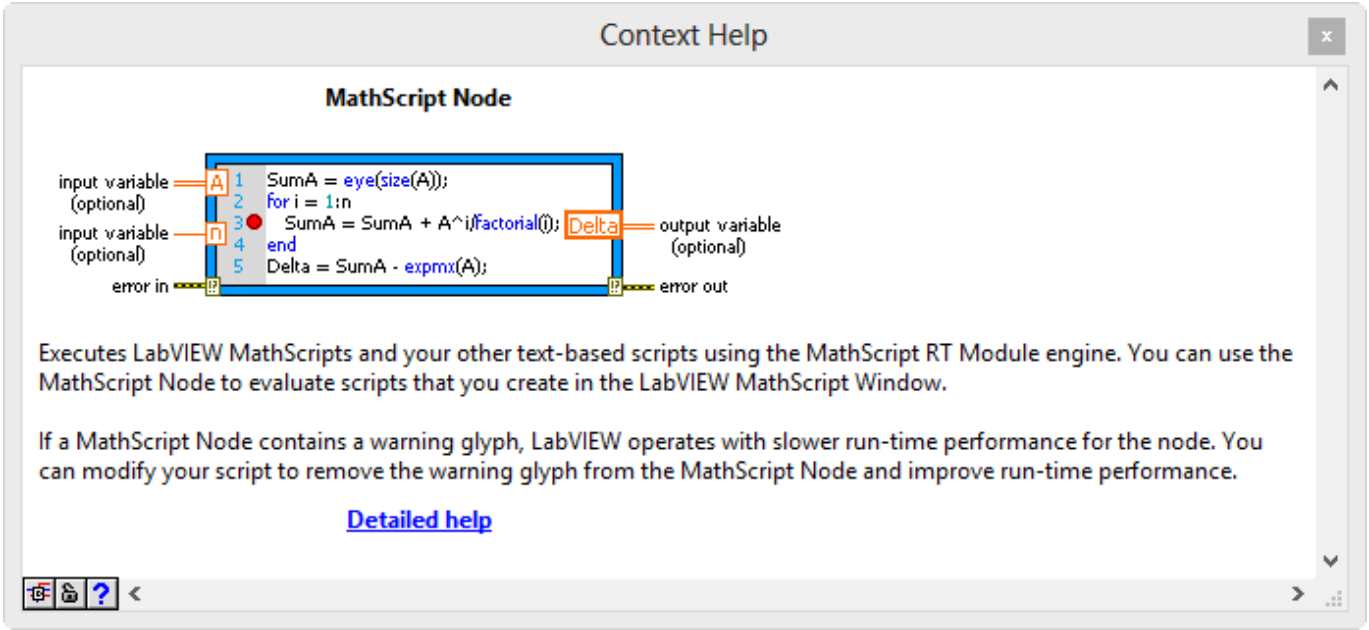
b: 3

c: 5

x: 9

f: 0,00437378

LabVIEW MathScript Node



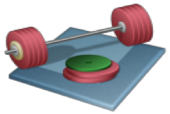
Very useful for mathematical expressions and simulations!

MathScript Node: You can create and use MathScript/MATLAB code within LabVIEW

LabVIEW MathScript Node

Celcius to Fahrenheit:

$$T_F = \frac{9}{5} T_C + 32$$



Students: Use the LabVIEW MathScript Node in order to implement this formula

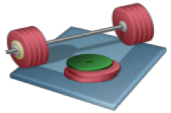
Advanced Mathematical Formula:

$$f(x) = \frac{\ln(ax^2 + bx + c) - \sin(ax^2 + bx + c)}{4\pi x^2 + \cos(x - 2)(ax^2 + bx + c)}$$

Given $a = 1, b = 3, c = 5$

Find $f(9)$

Try also with other values for a, b, c

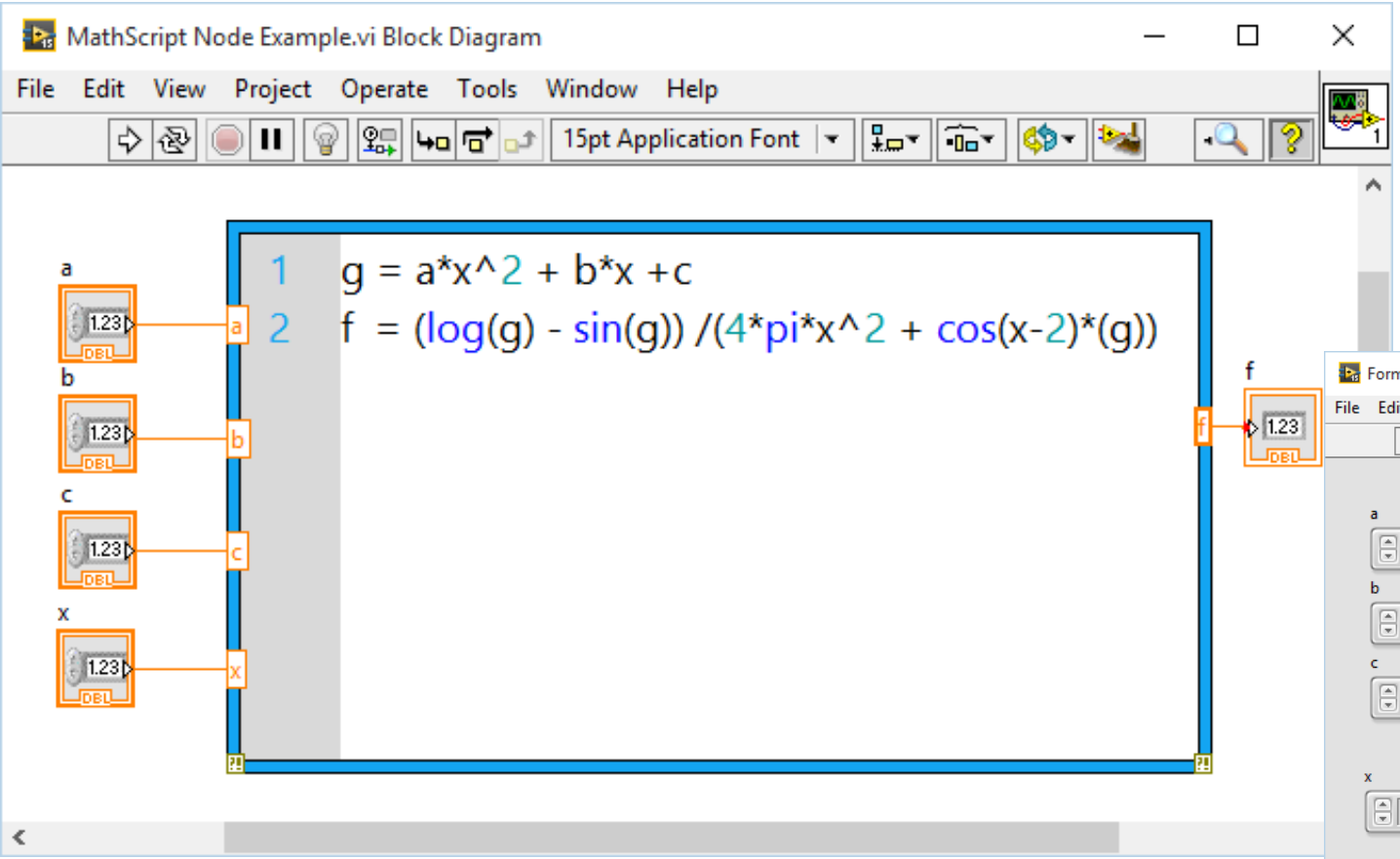


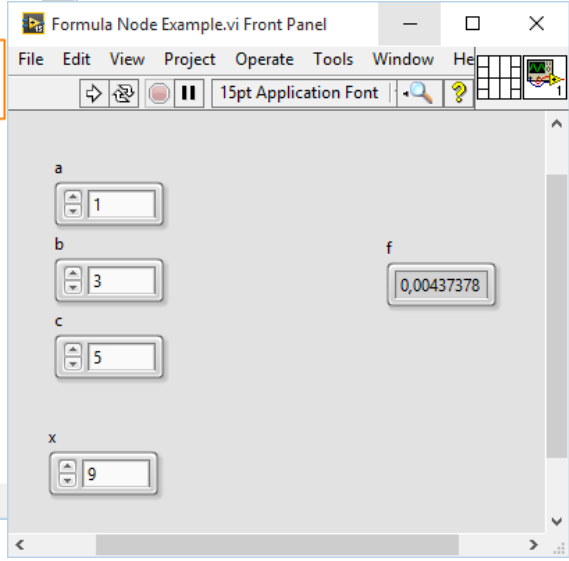
Students: Use the LabVIEW MathScript Node in order to implement this formula

(The answer should be $f(9) = 0.0044$)

Solutions

$$f(x) = \frac{\ln(ax^2 + bx + c) - \sin(ax^2 + bx + c)}{4\pi x^2 + \cos(x - 2)(ax^2 + bx + c)}$$

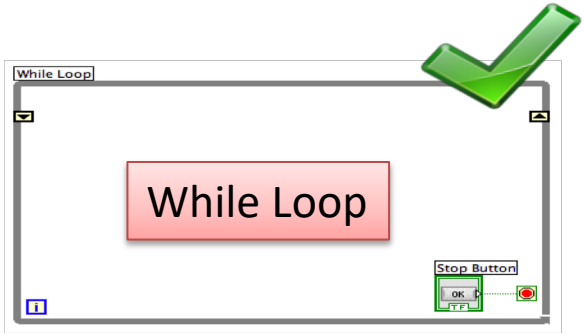


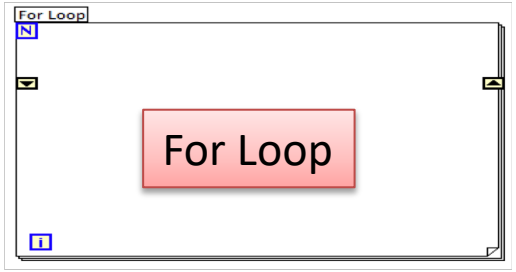


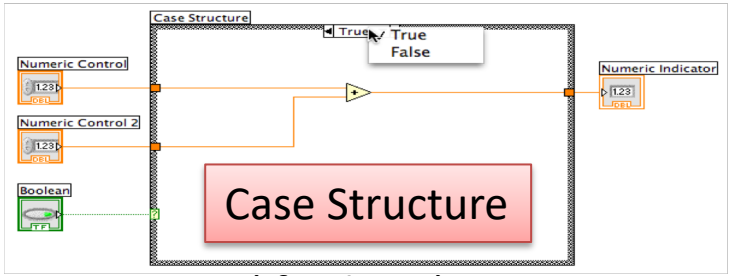
More Loops & Structures

Hans-Petter Halvorsen

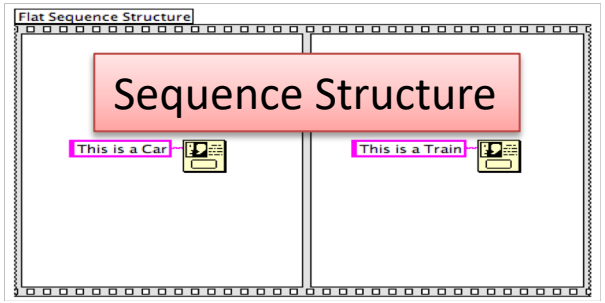
Loops & Structures







(if...else...)



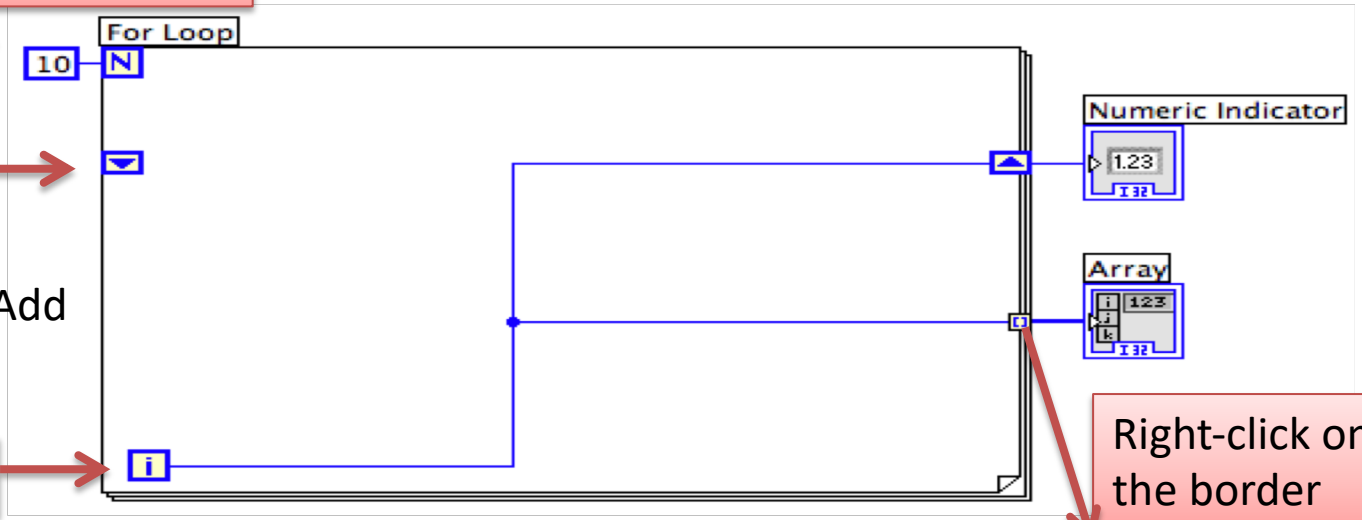
For Loop

Specify Number of Iterations

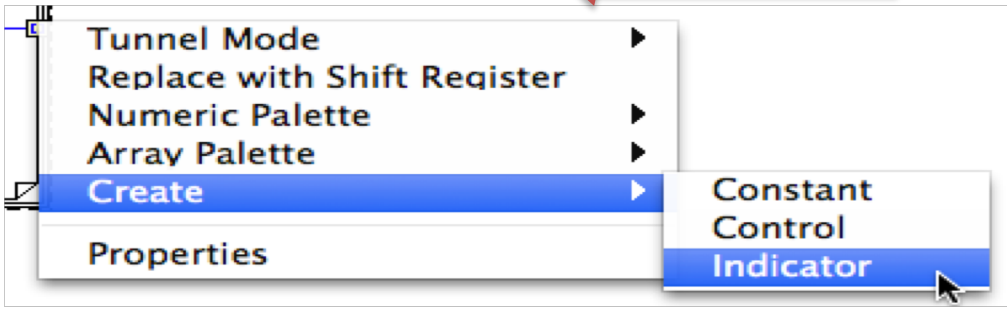
Shift Register

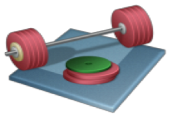
Right-click on the border and select “Add Shift Register”

Current Iteration



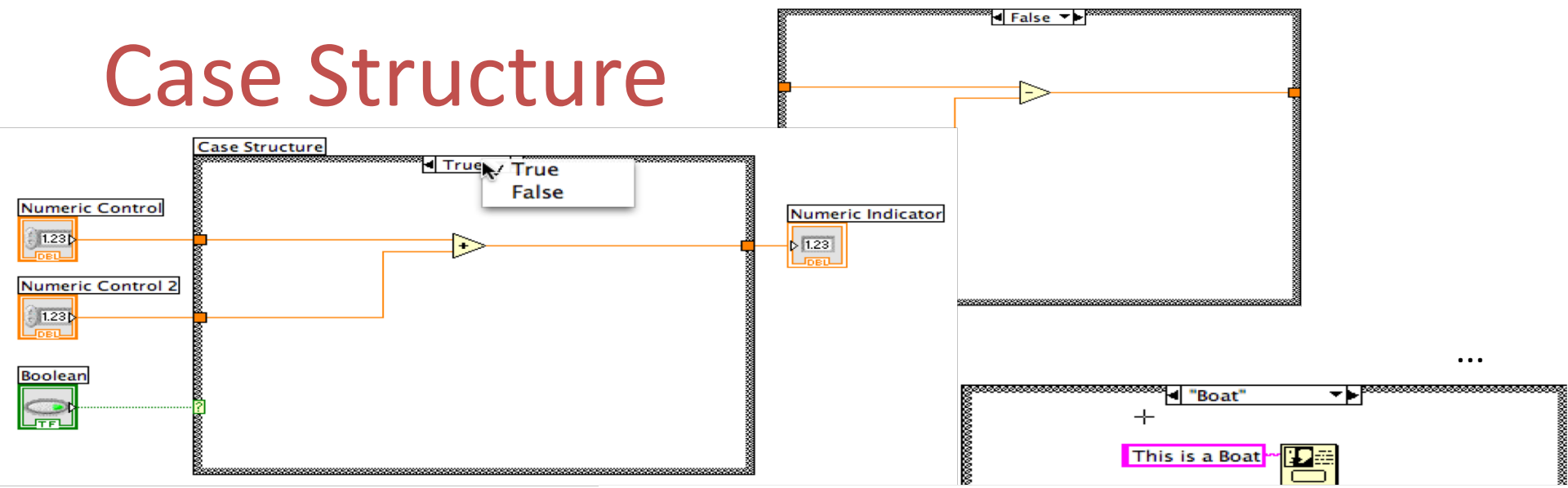
Right-click on the border





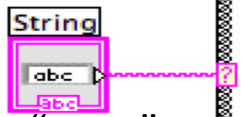
Students: Create this Example

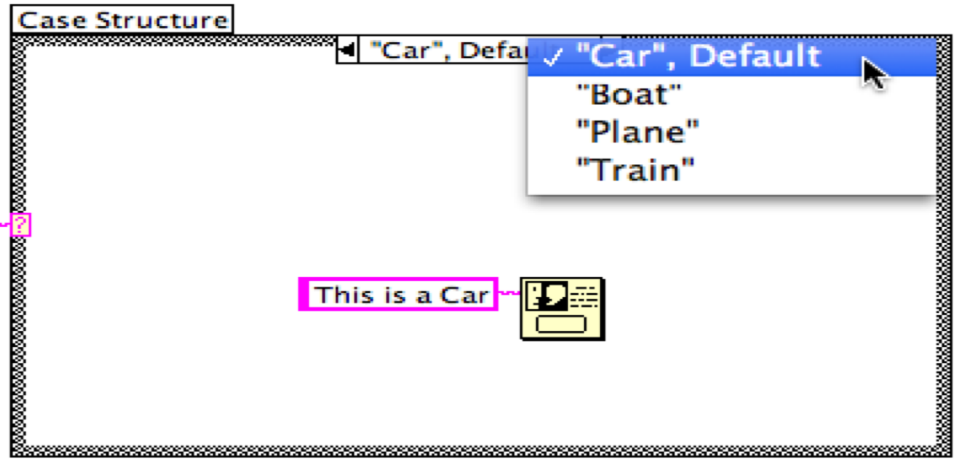
Case Structure

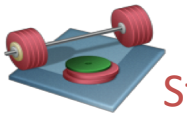


The Case structure is the same as **if... else...** used in other programming languages like C#, etc.

Write either “Car” or “Boat” and see what happens

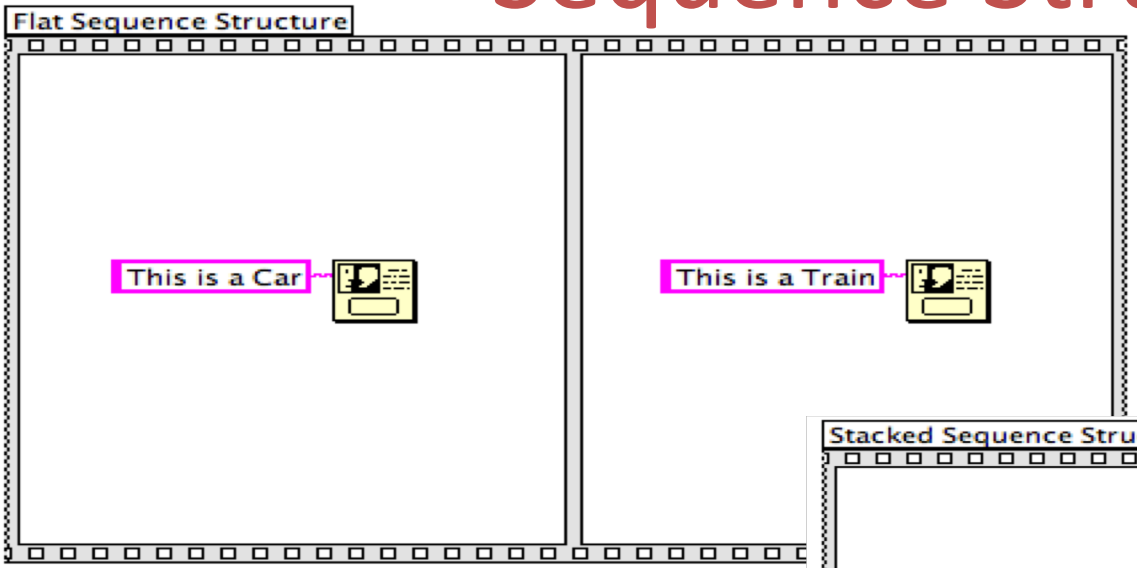






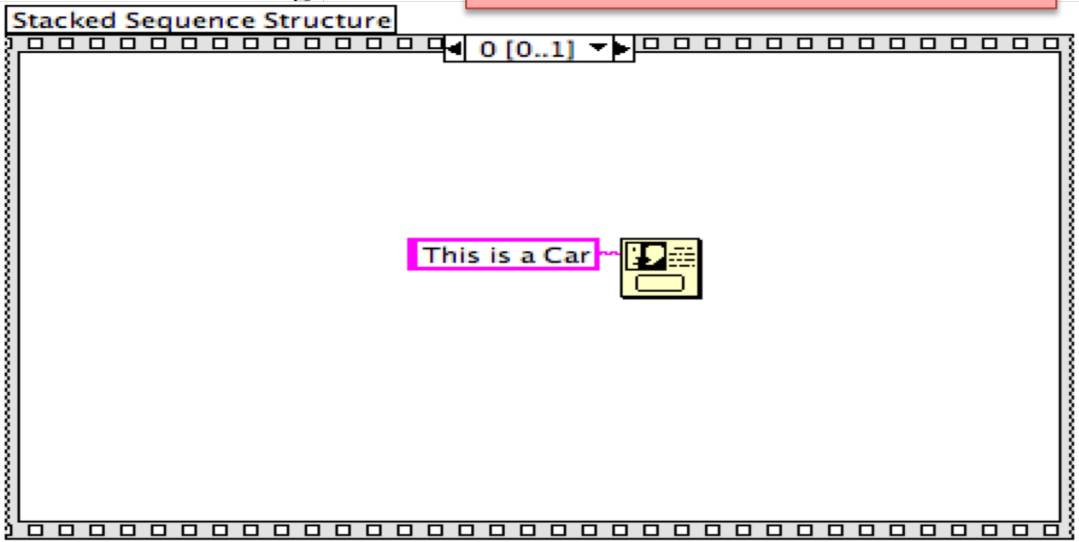
Students: Create these Examples

Sequence Structure

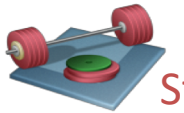


Flat Sequence Structure

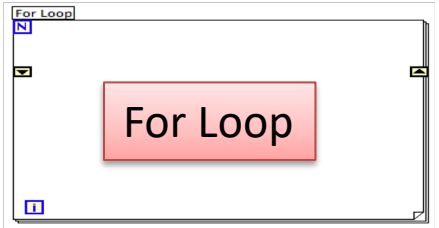
Stacked Sequence Structure

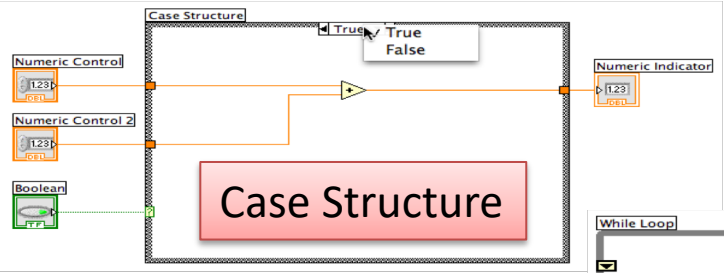


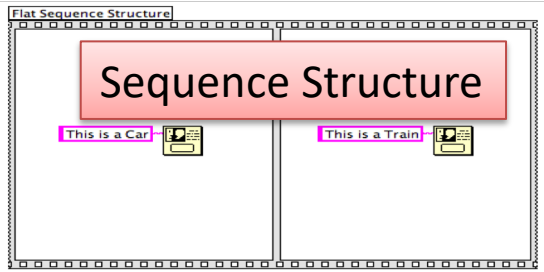
The “One Button Dialog” can be used to give a popup message to the user



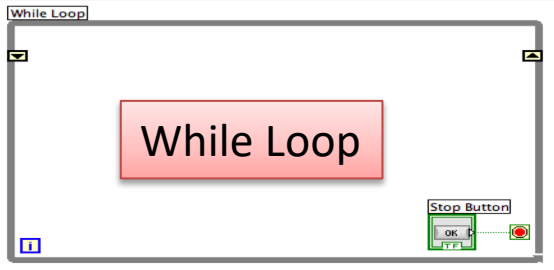
Students: Create these Examples

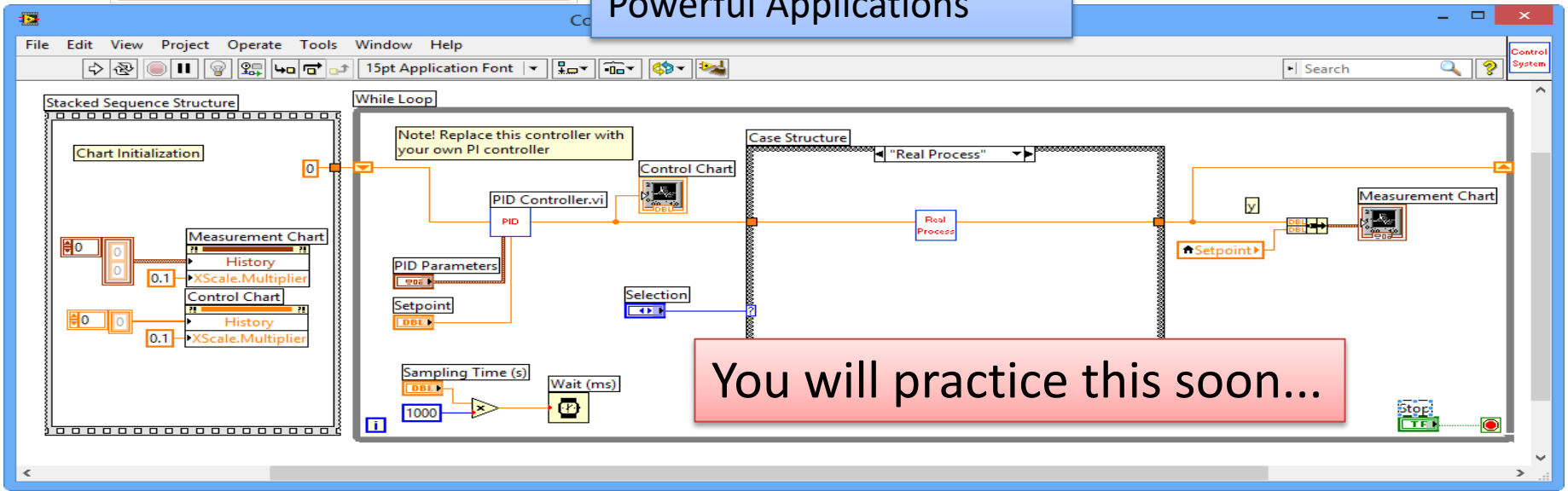






When Combining Loops and Structures, you can create Advanced and Powerful Applications





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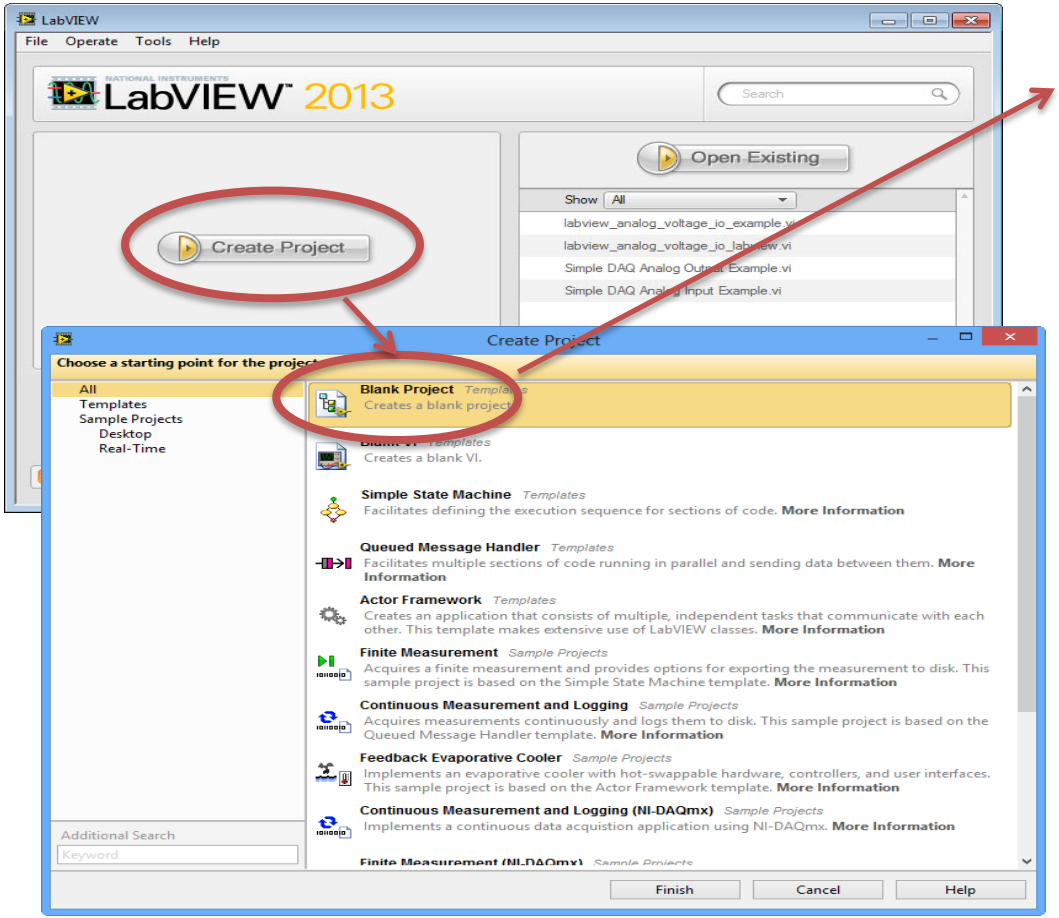
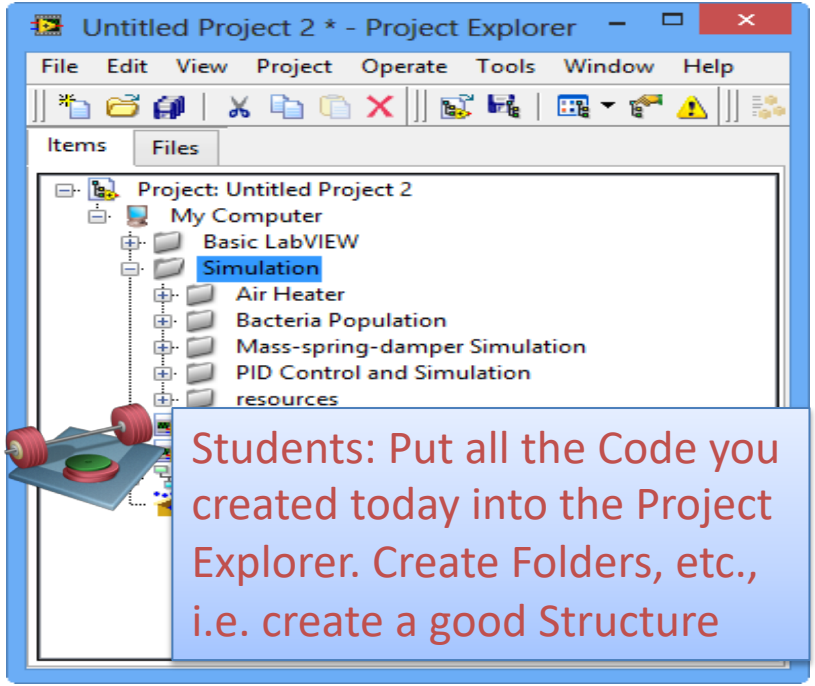
Tips & Tricks

Hans-Petter Halvorsen

Project Explorer

Similar to “Solutions Explorer” in Visual Studio. It Keeps all your Files for a spesific project in one place.

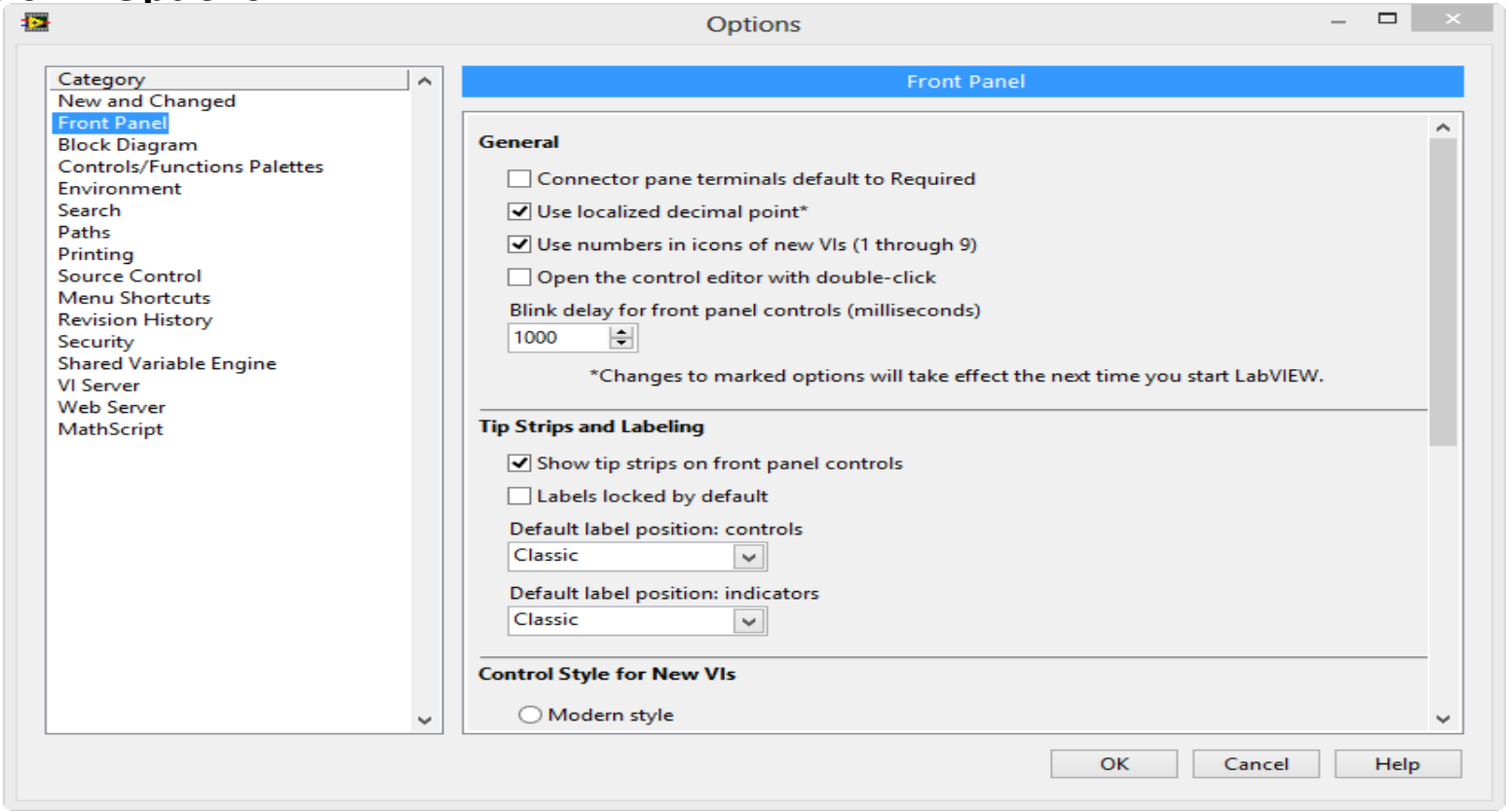


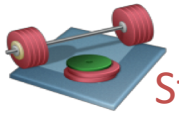


It is recommended to use this when you create larger applications that contains lots of VIs and other files, etc.

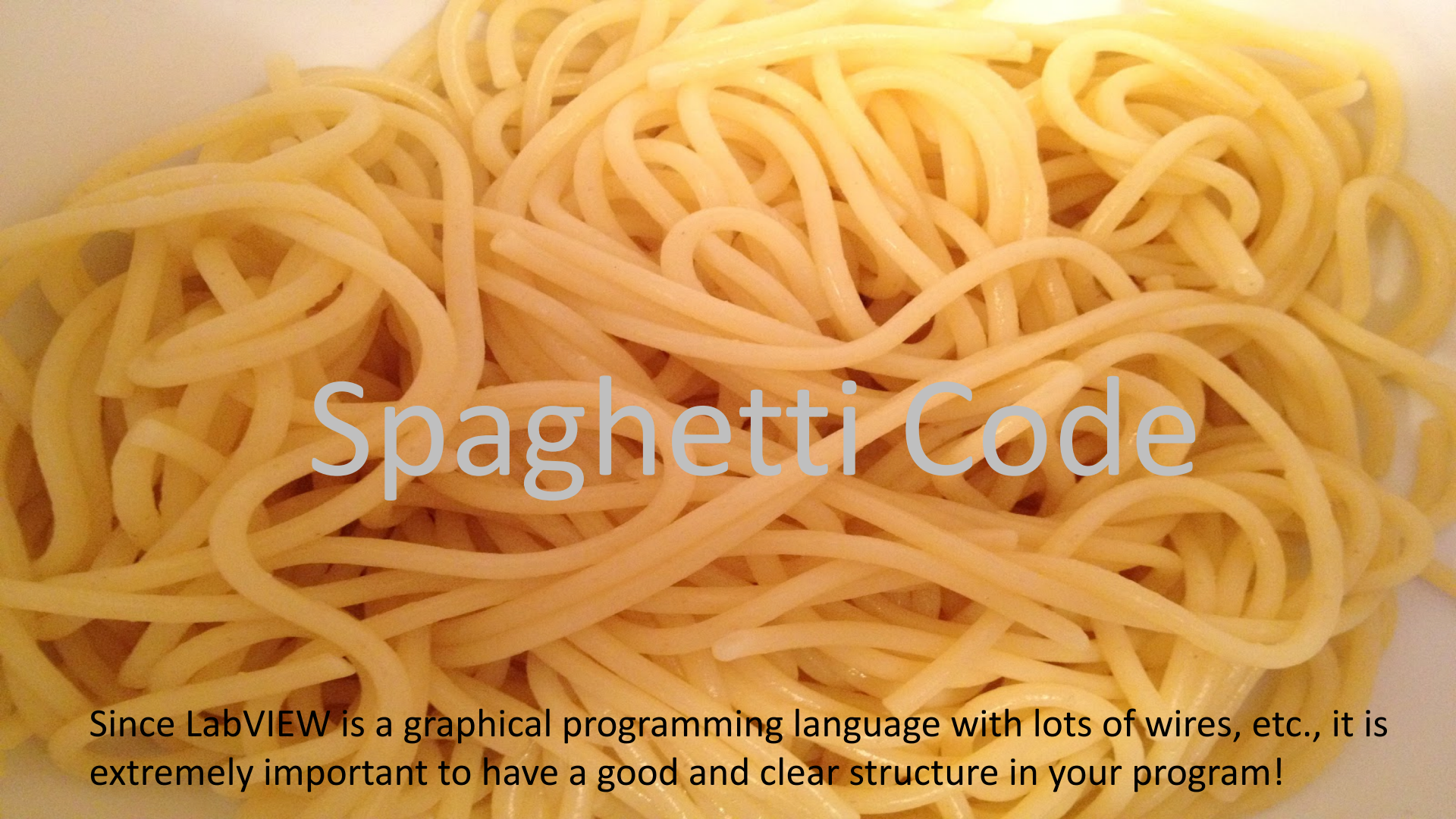
Customizing LabVIEW IDE

Select **Tools ➔ Options…**



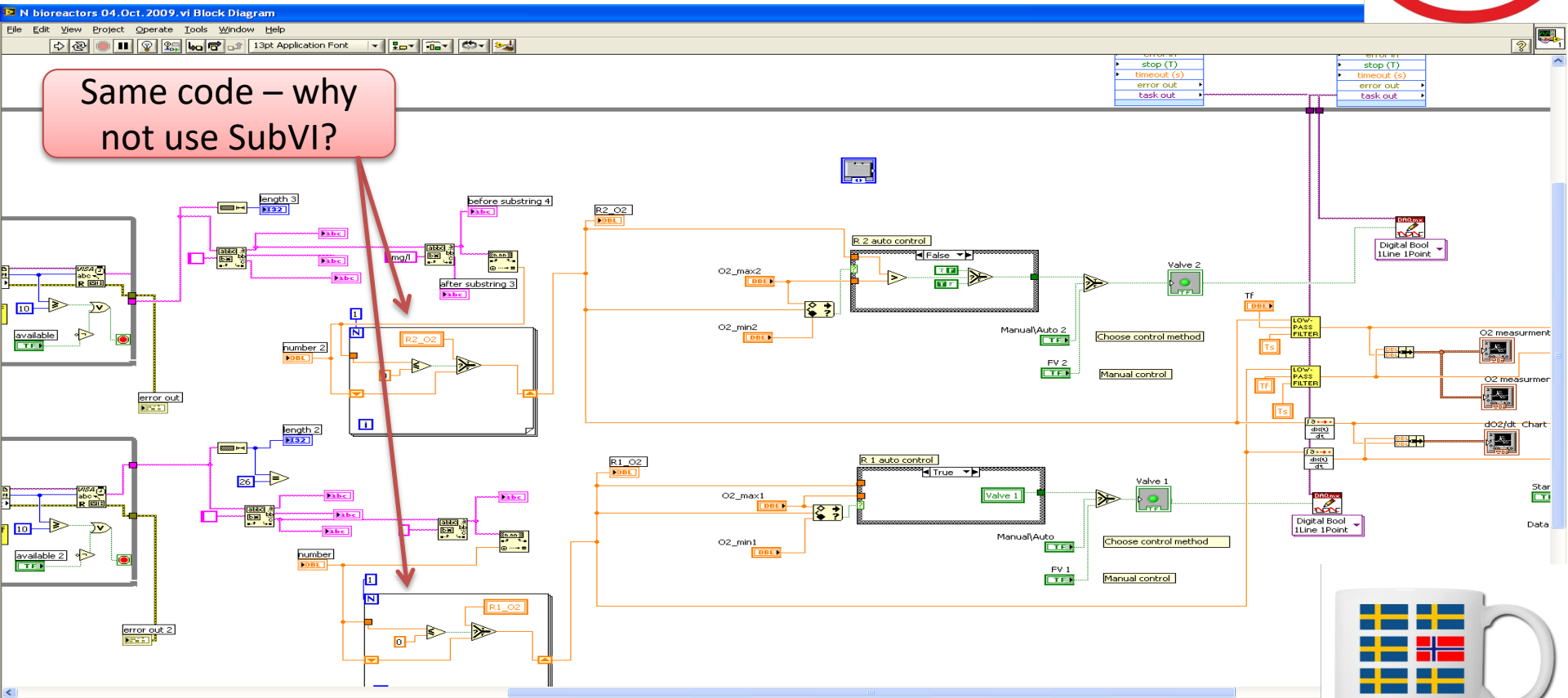


Students: Change the different options according to how you want to use LabVIEW



Since LabVIEW is a graphical programming language with lots of wires, etc., it is extremely important to have a good and clear structure in your program!

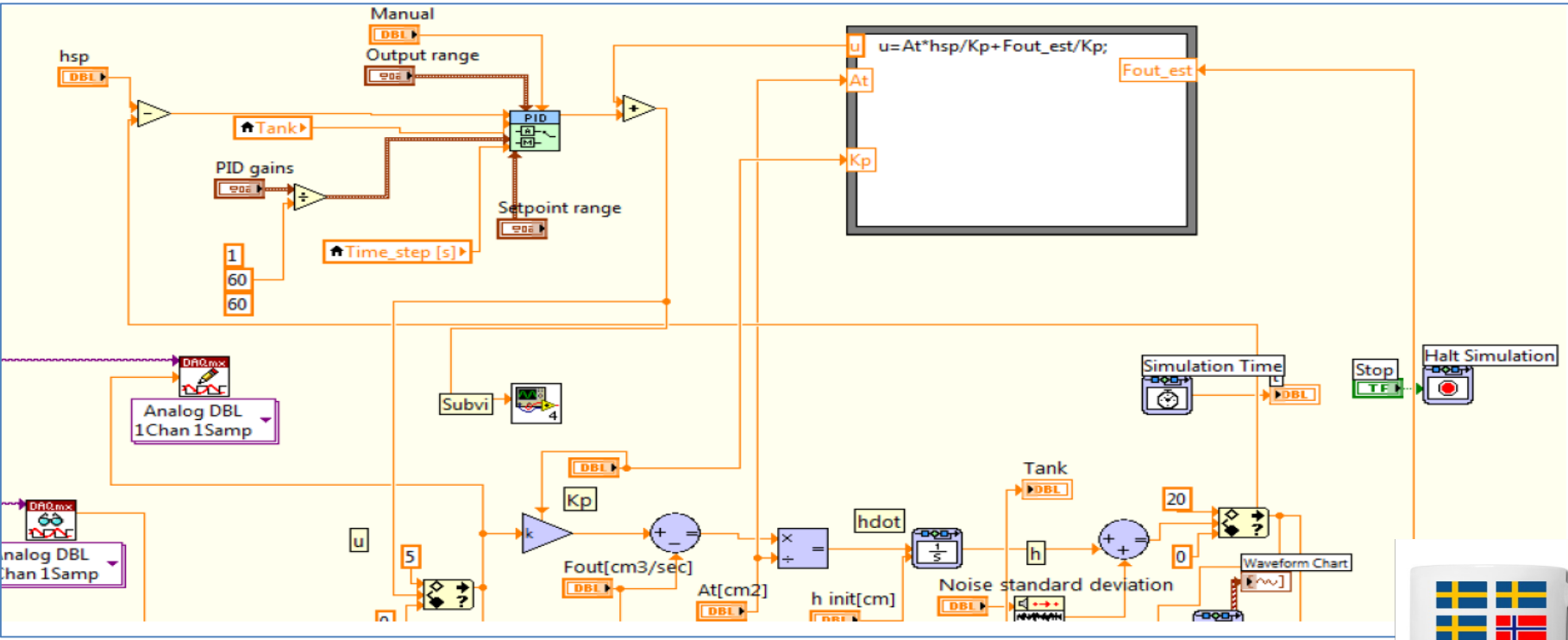
Spaghetti Code – Bad Example 1



Structure your code! Use SubVIs, Avoid Spaghetti Code, Document your Code, etc.

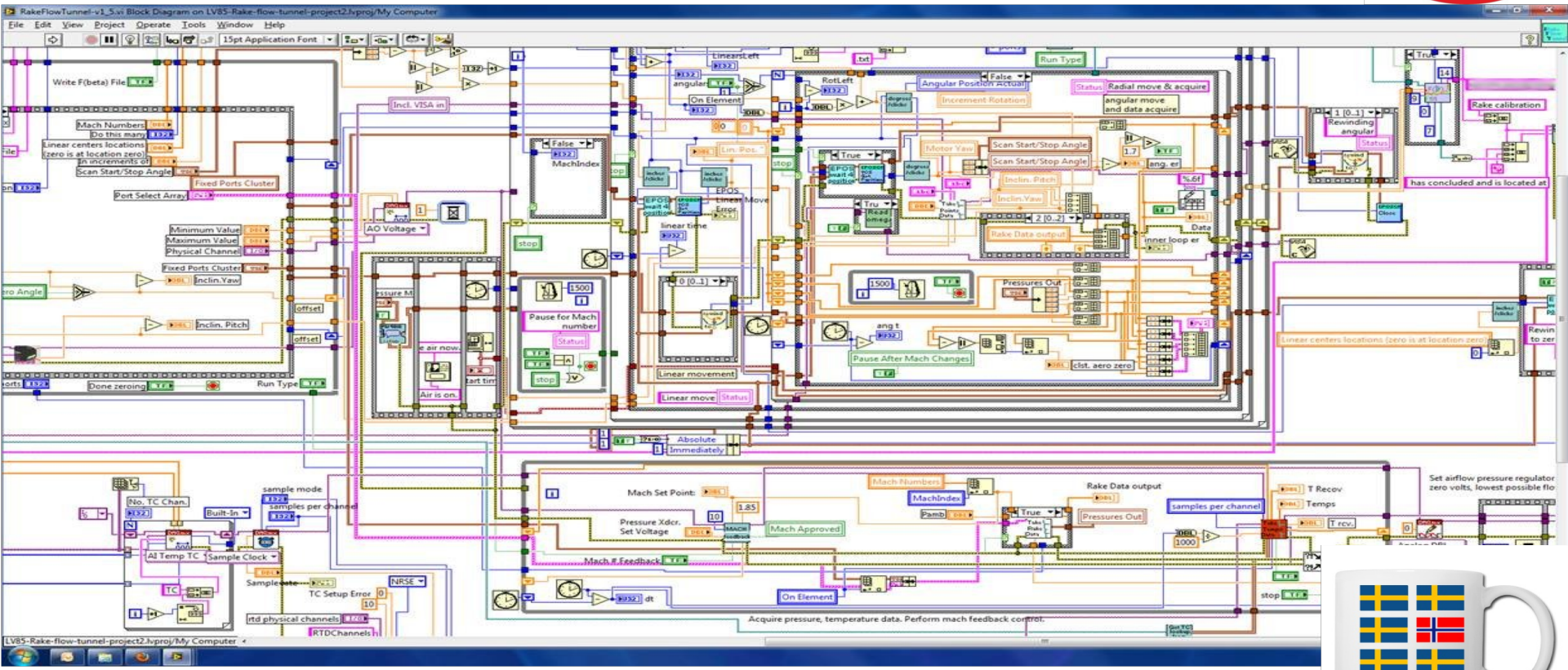
Spaghetti Code – Bad Example 2

Make sure your code fits into your screen size – scrolling to see code is not good!



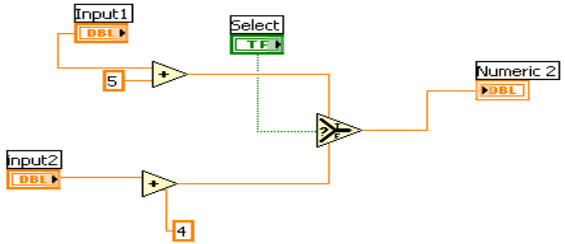
Structure your code! Use SubVIs, Avoid Spaghetti Code, Document your Code, etc.

Spaghetti Code – Very Bad Example

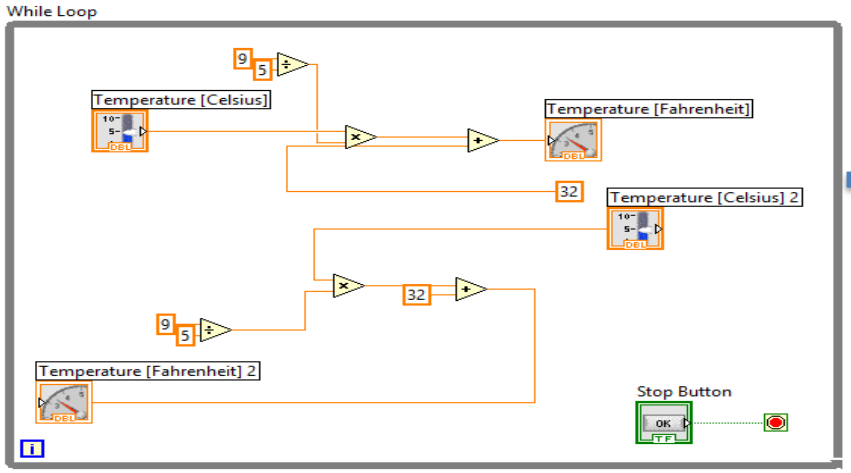


Structure your code! Use SubVIs, Avoid Spaghetti Code, Document your Code, etc.

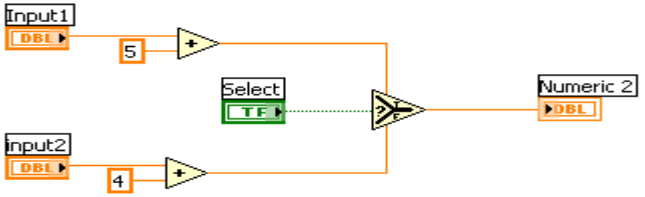
Bad vs. Good Code



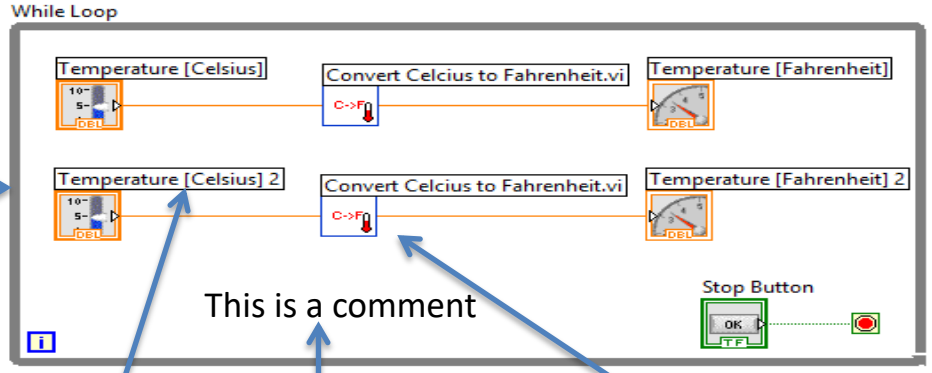
Avoid Spaghetti Code!



The Flow should go from left to right



Make your code readable for others!



Use SubVIs!!!

Use Labels and Comment your Code

NATIONAL INSTRUMENTS

LabVIEW™ Quick Reference Guide

Keyboard Shortcuts

File

Ctrl-N	Create new VI
Ctrl-S	Save VI
Ctrl-P	Print

Edit

Ctrl-V	Paste object
Ctrl-U	Clean up diagram
Ctrl-Space	Activate quick drop
Ctrl-B	Remove broken wires
Ctrl-C	Copy an object
Ctrl-X	Cut object
Ctrl-Z	Undo last action
Ctrl-Shift-Z	Redo last action

Operate

Ctrl-R	Run VI
Ctrl-.	Abort VI

Window

Ctrl-E	Display block diagram/ front panel
Right-Click	Display controls/ functions palette
Shift-Right-Click	Display tools palette
Ctrl-T	Tile block diagram and front panel windows

Help

Ctrl-H	Display context help

Editing Tools

Tool	Icon	Description
Show Context Help		Display the context help window
Text Settings 15pt Application Font		Change the font setting for the VI, including size, style, and color
Align Objects		Align selected objects
Distribute Objects		Space objects evenly
Resize Objects		Resize multiple front panel objects to the same size
Reorder		Reorder the layers of the objects
Clean Up Diagram		Rearrange wires and objects on the block diagram
Enter		Appears when a new value is available to replace an old value

Debugging Tools

Tool	Icon	Description
Run		Execute the VI
List Errors		List errors that prevent the VI from running
Run Continuously		Execute the VI continuously until abort or pause is pressed
Abort Execution		Stop VI execution immediately
Execution Highlighting		Animate data movement on the block diagram wires
Pause		Temporarily stop execution to debug a portion of the VI
Step Into		Single-step into a subVI or structure to debug it
Step Over		Execute a subVI or structure and pause at the next one
Step Out		Execute a subVI or structure and resume single-stepping

Tools Palette

Tool	Icon	Description
Automatic Tool Selection		Automatically choose the appropriate tool
Operating Tool		Change the value of a control or select the text within a control
Positioning Tool		Position, resize, and select objects
Labeling Tool		Edit text and create free labels
Wiring Tool		Wire objects together on a block diagram
Scrolling Tool		Scroll the window without using the scroll bars
Breakpoint Tool (Used for debugging)		Set breakpoints on VIs, functions, wires, loops, sequences, and cases
Probe Tool (Used for debugging)		Create probes on wires and display intermediate values on a wire in a running VI
Get Color Tool		Copy colors for pasting with the Color Tool
Coloring Tool		Set the foreground and background colors

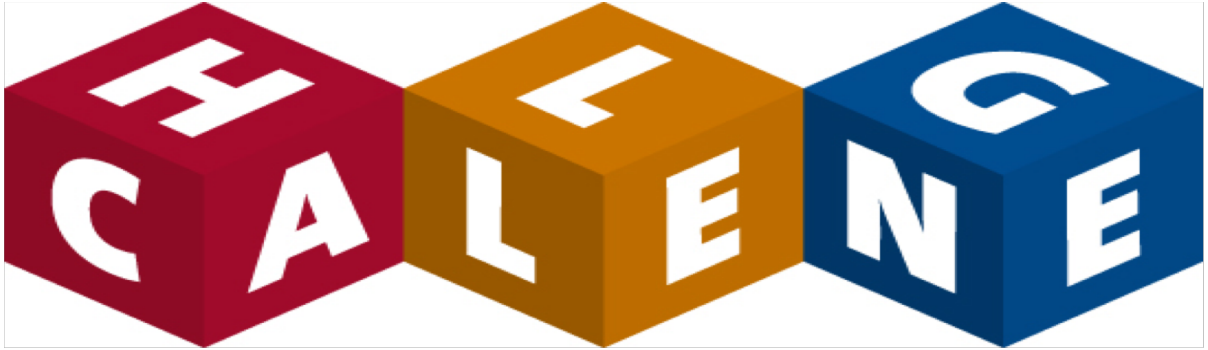
http://www.ni.com/pdf/manuals/376039a.pdf

Short-Cuts that you must know!

Short-Cut	Description
Ctrl + B	Deletes all broken wires in a VI
Ctrl + .	Stops the Running VI
Ctrl + E	Toggle between the Front Panel and Block Diagram
Tab	Cycles through the most common Tools (Automatic Tool Selection should be disabled!)
Ctrl + Mouse wheel	Scrolls through subdiagrams in Case, Event or Sequence structures
Ctrl + H	Displays the Context Help window
Ctrl + Mouse Double-click on a SubVI	Opens the Block Diagram directly
Ctrl + Arrows (→←←↓)	Move faster. You first have to select a SubVI, a Function, Object, etc
Ctrl + W	Close the SubVI
Double-click on a wire	Selects the hole wire

Ctrl + drag objects with your mouse: Copy objects (easier than Ctrl + C and Ctrl + V)

https://www.halvorsen.blog



Do you need more Practice? - Select a Challenge

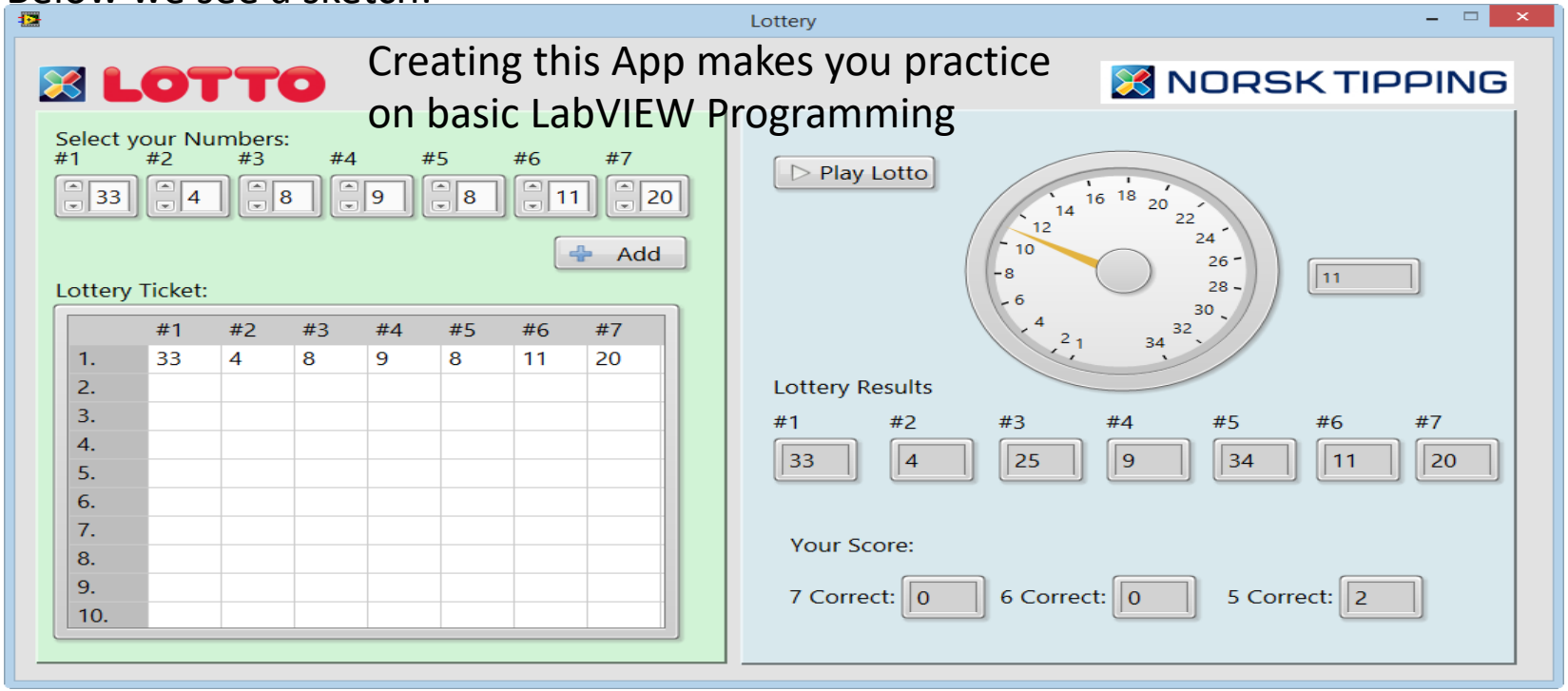
Hans-Petter Halvorsen

Note! This is just an example to illustrate the assignment. You can create your own User Interface with your own features.
The code should include a While Loop, Case structures, SubVIs, etc. You can use the built-in Random Generator when playing Lottery.

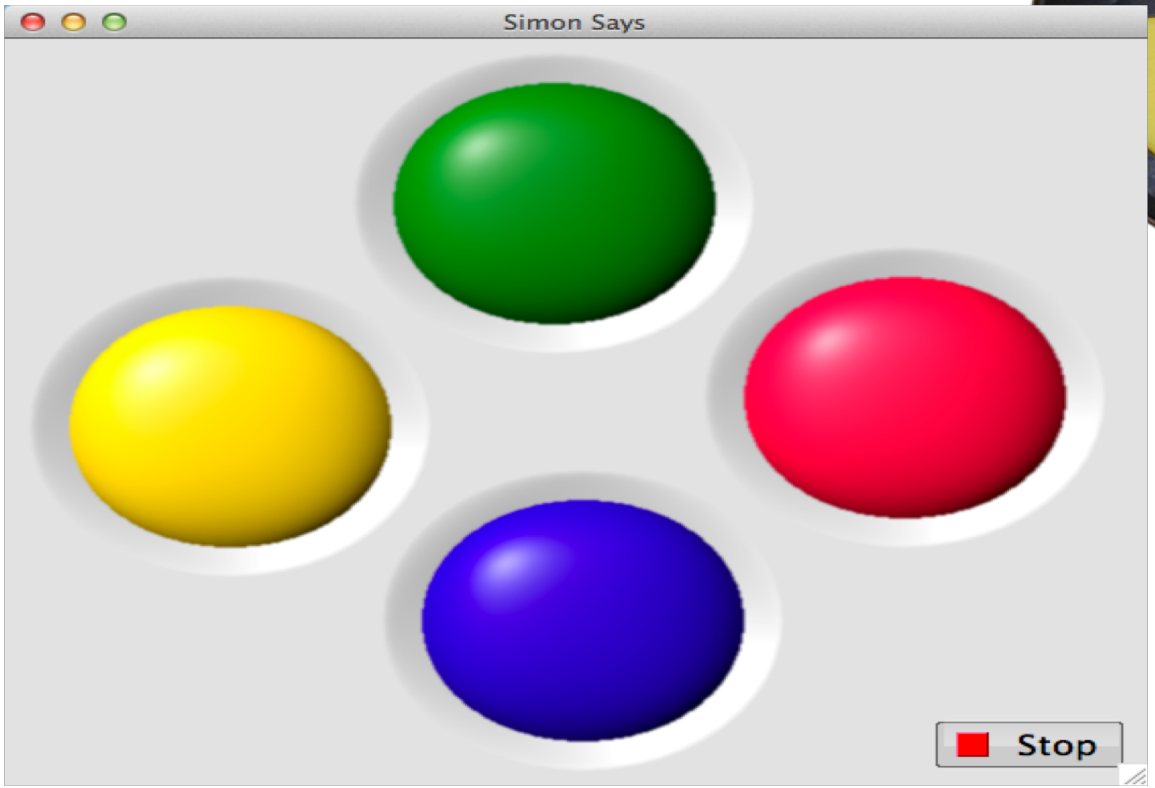
1

Create a Lottery App in LabVIEW

Below we see a sketch:



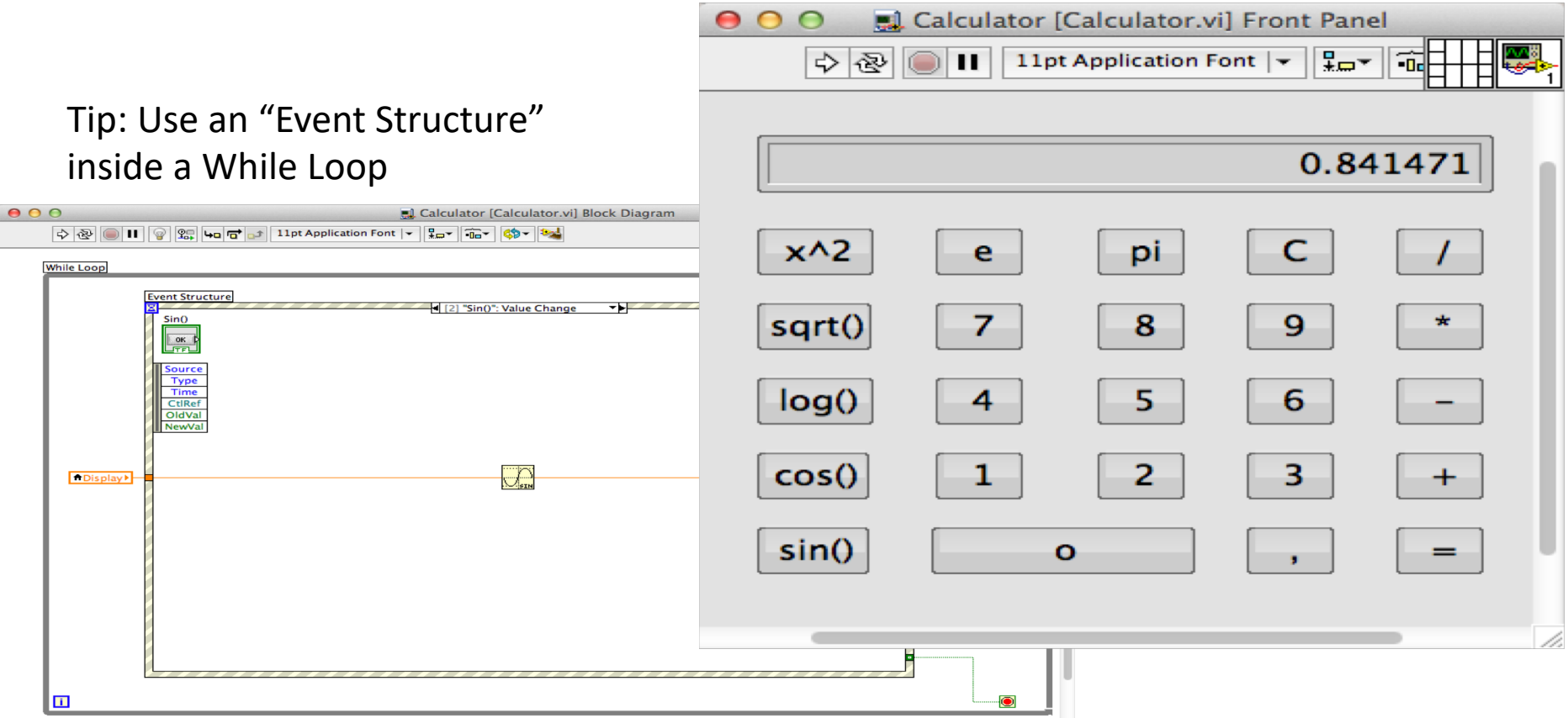
Simon Says



Creating this App makes you practice on basic LabVIEW Programming

LabVIEW Calculator

Tip: Use an “Event Structure” inside a While Loop



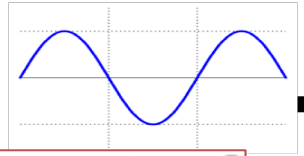
Level Tank

4

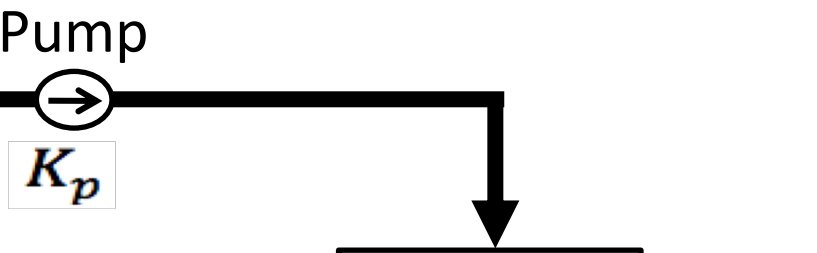
Assignment: Control the Level (close to the setpoint) in the Tank manually by adjusting the outflow of the tank with a manual Valve. Plot Level and Flow.

Flow into the Tank:

$$F_{in}(t_k) = K_p \sin(\omega t_k)$$



$$\omega = 2\pi f$$

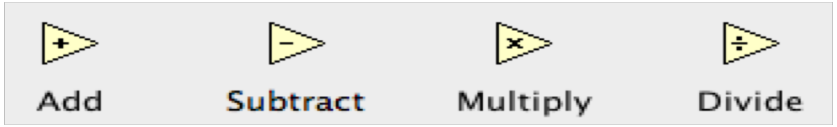


Level formula:

$$h(t_{k+1}) = h(t_k) + \frac{T_s}{A}[F_{in}(t_k) - F_{out}(t_k)]$$

Previous Level

Implement the Equations using standard LabVIEW operators like:



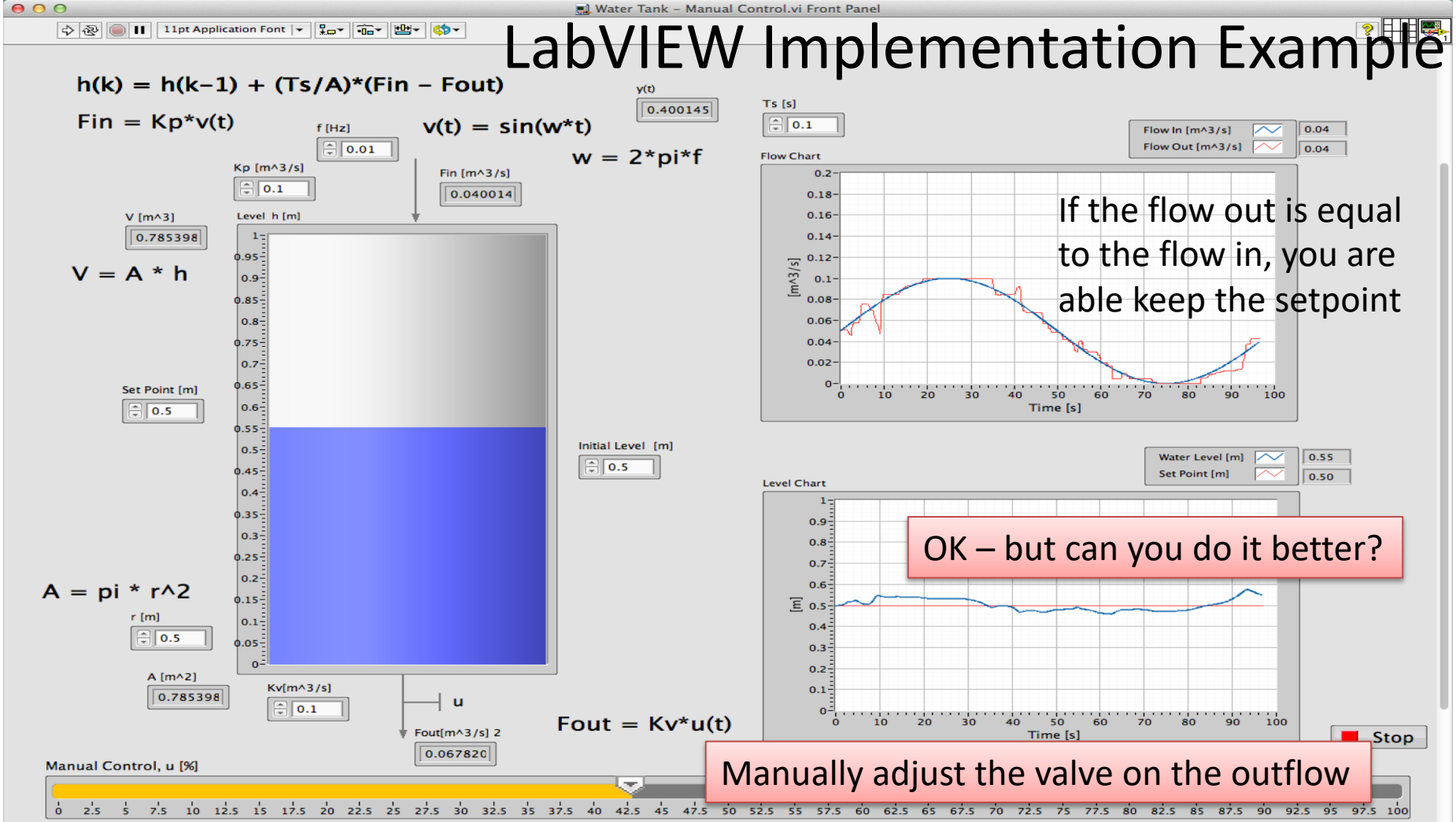
etc.

Using SubVIs are recommended!

Flow out of the Tank:

$$F_{out}(t_k) = K_v u(t_k)$$

LabVIEW Implementation Example



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