LABVIEW

A Tutorial By

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Note: This tutorial is written specifically for *CET 3464 – Software Applications in Engineering Technology*, a course offered as part of the BSECET program at Valencia College.

LabVIEW was developed in 1986 to make it easier to collect data from laboratory instruments using data acquisition systems and further to process that data to yield important aspects of it. Since then, it has evolved into an extremely useful engineering software that can solve problems from a number of engineering fields. It can not only be used as a data acquisition and processing software but also to control different instruments and equipment.

LabVIEW programming is graphical where you must present a system with different blocks and create logic between those blocks to perform the required tasks. There are many engineering and mathematical applications that you can design using LabVIEW. It can be used to implement simple arithmetic applications, complex integration and differentiation, plots and graphs, statistics, robotics problems, control problems, signal processing problems, and many other problems from different fields.

A LabVIEW program is called *VI*, which stands for *virtual instrument.*

Startup:

When you execute LabVIEW, title screen will show up informing you that LabVIEW is loading its processes and initializing. Once it is done loading its components, *Getting Started* screen will pop-up as shown in *figure* 1 for version 2010. If you are using any other version of LabVIEW, the screen may look different.

To create a LabVIEW program or LabVIEW *VI*, you have to click on *Blank VI* . Once you click it, you will get *Front Panel* and *Block Diagram* windows. *Fornt Panel* displays the *controls* (knobs, buttons, graphs, etc.) and represents the graphical interface for the VI, whereas, *Block Diagram* holds the programming elements, called *blocks*, *functions*, or sometimes *subVIs*, that are wired together to build the graphical program.

Figure 1: LabVIEW 'Getting Started' Screen

Palettes

Palettes in LabVIEW are libraries where you can find useful components to design and edit your program. Two main palettes that are associated with LabVIEW are,

- Function Palette
- Control Palette

Function palette is associated with the Block Diagram window and *Control palette* is associated with the Front Panel Window. If closed, these palettes can be opened from *View* located in the menu bar.

Control palette provides access to the objects like controls, indicators, knobs, and graphs that are placed on the front panel to represent your system. There are many different controls available that are collected into a number of categories and each category can be expanded or collapsed.

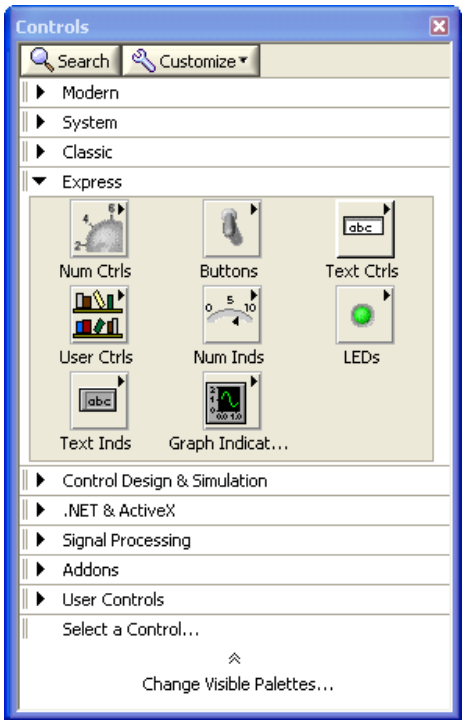


Figure 2: Control Palette Window

Function palette contains *functions, VIs,* and *Express VIs* that can be placed on a block diagram to create the required logic for the system presented in the *control panel*. Like control palette, there are many different functions available in the function palette collected into a number of different categories that can be expanded or collapsed.

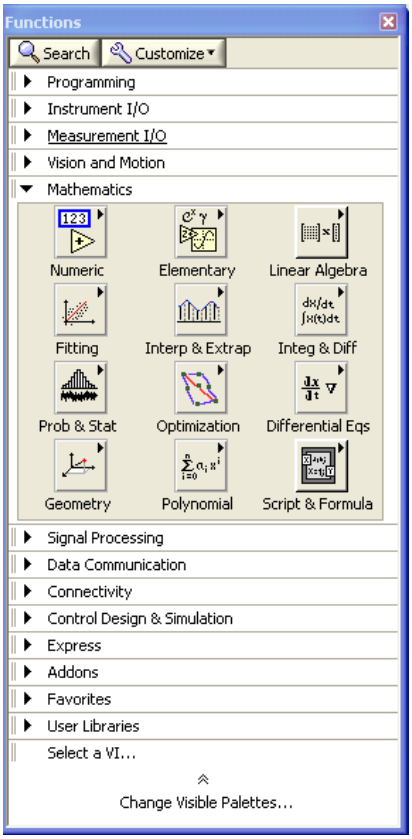


Figure 3: Function Palette Window

EXERCISE – 1

From *function palette* find the group(s) containing the following functions:

(i) Add

(ii) Wait (look for a wristwatch icon)

(iii) Transforms (Laplace, z, Fourier etc.)

From *control palette* find the group(s) containing:

(i) Dial Numeric Control

(ii) Toggle Switch

(iii) Table

There is a third palette called *Tool Palette*, which is used to edit text, position/size/select, probe data and other functions. By default, it is set to *Automatic Tool Selection*, which can be seen by the green light in *figure 4*. You should leave it in the *Automatic Tool Selection* option as it converts the mouse into the desired tool automatically, which is very helpful during programming.

Figure 4: Tool Palette Window

Creating a VI

Let's start with a simple program. Choose a *toggle switch* and an *LED* from the control palette and put them on the *Front Panel*, as shown in *figure 5*. Double click on the names of these controls and change them to *Power Switch* and *LED*.

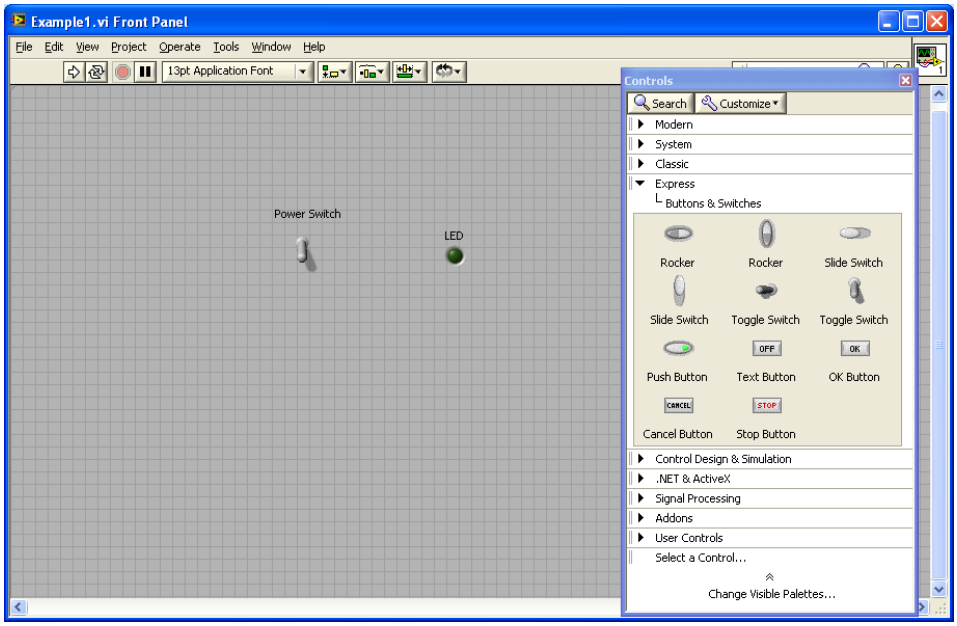


Figure 5: Power Switch and LED on the Front Panel

Next, go to the *Block Diagram* window and observe that the functional blocks of your components shall already be there. Connect the functional blocks in the block diagram through wire(s). You can wire different components in two ways; put your mouse on the connection end of any component and drag it to the connection end of any other component, or just click on the connection end of one of the components and click on the connection end of the other component.

NOTE: If your mouse does not automatically convert into a wiring tool when you place it on the connection end of any component, you are not in the *automatic tool selection* mode. Open *tool palette* and select either *Automatic Tool Selection* (one on the top) or select *Connect Wire* tool. It will be highly recommended that you select *Automatic Tool Selection* and leave that option turned on, as instructed earlier.

When wiring is done, you are ready to simulate your design. Simulation is done in the *front panel* window. Simulation or *Run* buttons are located in the top toolbar menu and can be recognized as shown in *figure 6*

Figure 6: Run Buttons

From left to right, the first button is to run your simulation once, the second one is to run it continuously, the third one is to stop the simulation, and the fourth one is to pause the simulation. Run your simulation continuously and toggle the switch to see your LED turns ON and OFF.

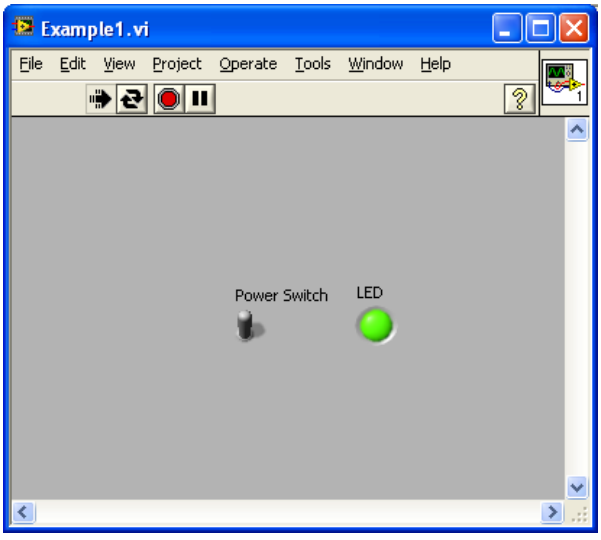


Figure 7: LED Operated by Switch

There are different mechanical properties of the switch that you can select. Select toggle switch, right-click your mouse and go to *Mechanical Action*. Try different types of mechanical actions for the switch.

You can also change color of your LED by selecting LED, going into its properties (right-click), and from there going to the *Appearance* tab.

EXERCISE – 2

Instead of a toggle switch, use a *push-button momentary* switch and operate your LED through it. Change mechanical properties of the switch to try different actions.

Mathematical Operations

Many basic and complex mathematical functions can be done with LabVIEW easily. Let's create a VI to add two numbers. Open a blank VI and choose *Num Ctrl* from *Numeric Controls* group. Place two numeric controls (*Addend* and *Augend)* in the front panel as shown in *figure 8.*

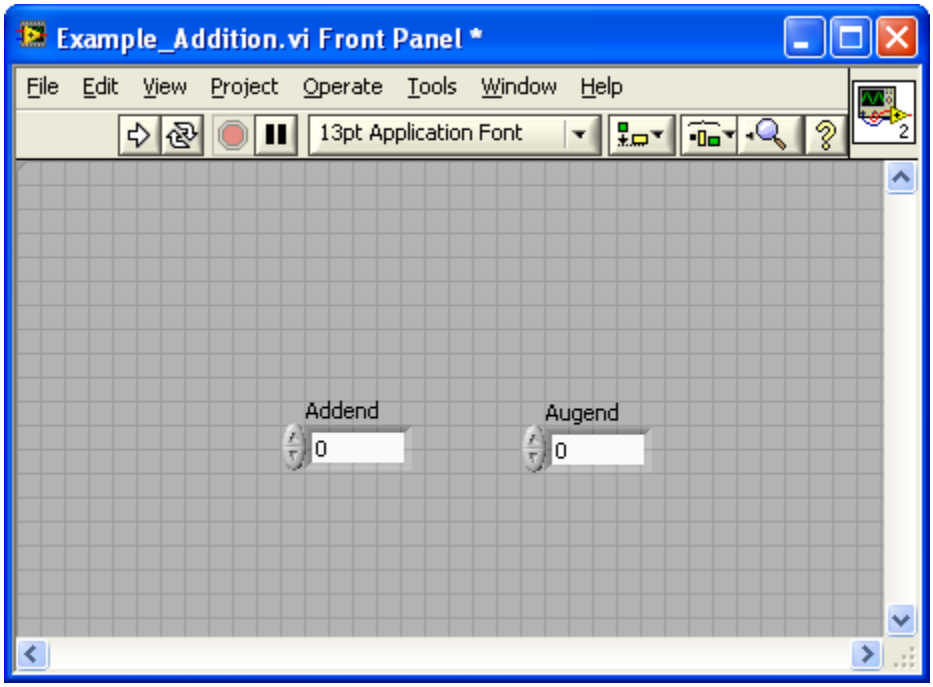


Figure 8: Two Numbers to Add

Next, from the *Numeric Indicators* control group choose *Num Ind* (numeric indicator) and place it in the front panel to display result for the addition operation, as shown in *figure 9*

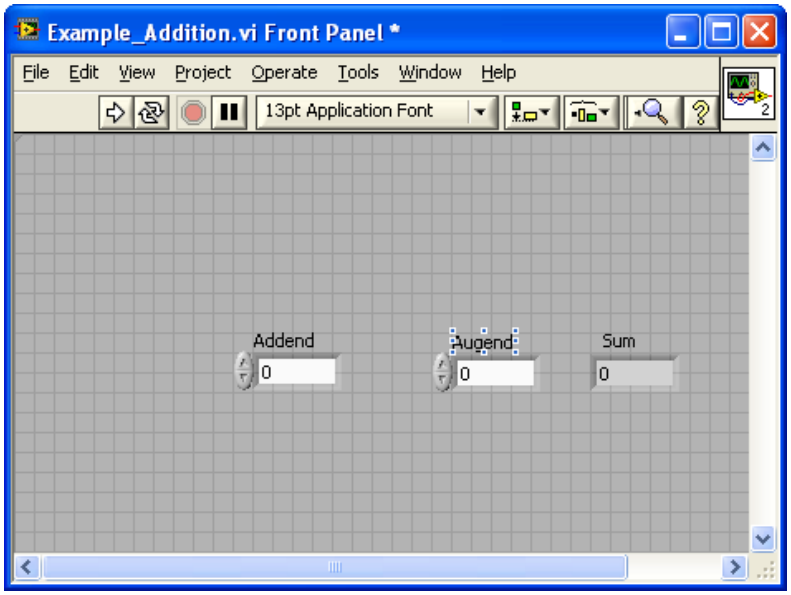


Figure 9: Numeric Controls with Number Indicator

Now, add two labels, a '+' sign between *addend* and *augend*, and an '=' sign between *augend* and *sum*, to properly display the purpose of this control system to the audience. This can be done by double clicking your mouse button where you want to place that text and typing it in the box that appears (if you are in *Automatic Tool Selection* mode).

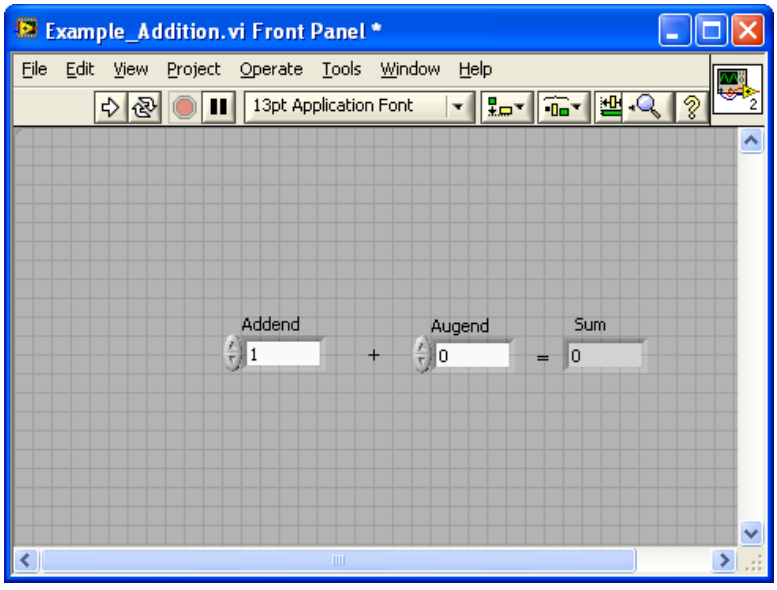


Figure 10: Adding text in Front Panel

Now, go to your block diagram window and from the *function palette*, choose an *ADD* function from *Mathematics* group and place it in the window. Arrange your blocks and wire them as shown in *figure 11*. Run your circuit in the front panel and check results for different number additions.

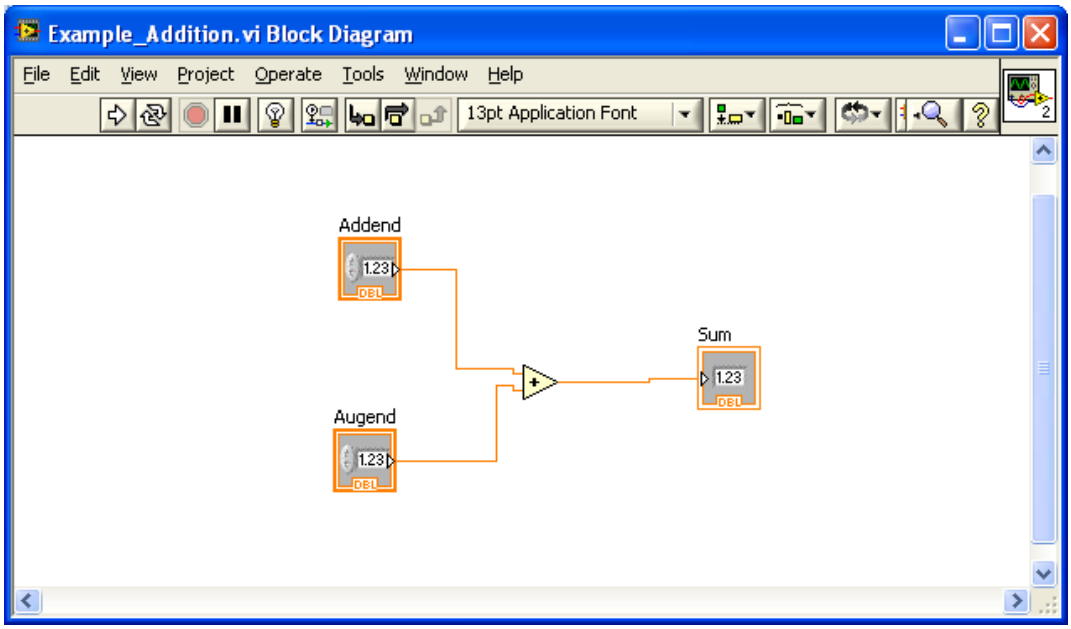


Figure 11: Addition Blocks

There is also a function block called *Compound Arithmetic* under *Numeric* group that can be used to perform multiple additions and multiplications. You can stretch the block to have multiple inputs and you can choose the type of operation by clicking right on the block and choosing *change mode*. Use it when multiple additions or multiplications are required instead of using the single block multiple times that can add or multiply only two inputs.

Helpful Hint: There is a nice option in LabVIEW that can show signal flow while you are simulating your circuit. This can be done by pressing *Highlight Execution* button from the block diagram window (fifth button from left in the toolbar). You can also arrange your two windows right and left, or up and down from *Window* menu bar. Simulate your circuit with *Highlight Execution* button pressed to see how your values are flowing from your addend and augend to your sum block. This option comes very handy while troubleshooting a large system where a lot of data is flowing between different components.

Function Evaluation

Let's evaluate the following function in LabVIEW,

$$f(x, y) = 4x + 3y \tag{1}$$

Place two numerical control blocks for *x* and *y*, and one number indicator block for *f(x,y)*, as you did in the previous design. Place different labels in your front panel to properly represent your system.

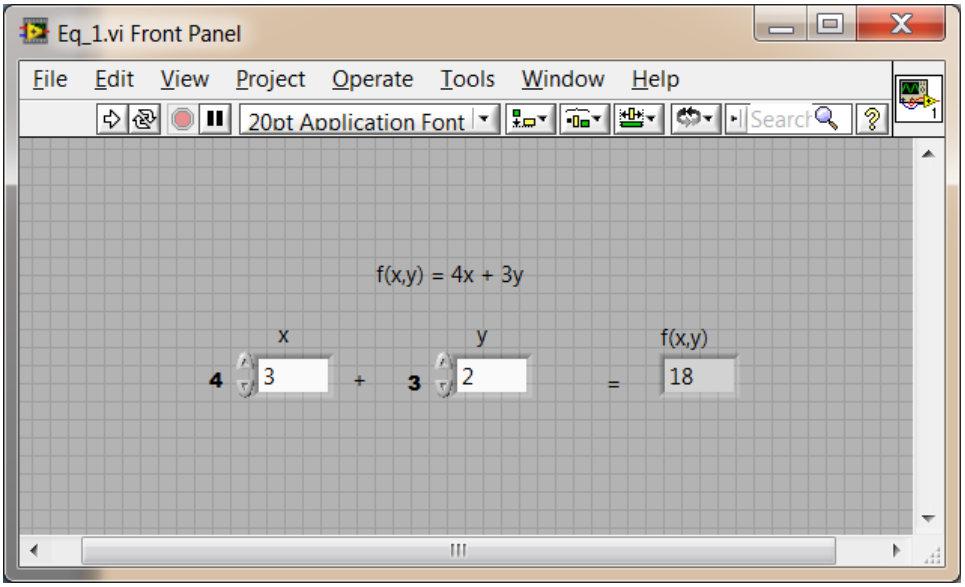


Figure 12: Control Blocks for Equation (1)

To present a constant in the block diagram, choose *Mathematics* under *function palette* and then proceed to *Numeric* and choose either *DBL Numeric Constant* or *Numeric Constant*. Complete block for *equation 1* is shown in *figure 13.*

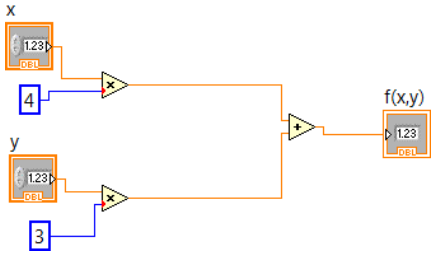


Figure 13: Block Diagram Corresponding to Front Panel from Figure 12

EXERCISE – 3

Implement the mathematical function,

$$f(x, y) = 4x^3 + 3y^2 + 7xy \tag{2}$$

Place proper labels in the front panel to represent your system as well.

NOTE: x^2 block is in *Mathematics* → *Numeric* and x^y function block is in *Mathematics*→*Elementary*→*Exponential*. You can also look into using *Compound Arithmetic* block for multiple additions and multiplications.

EXERCISE – 4

Enter temperature in Centigrade (from 0°C, freezing point of water, to 100°C, boiling point of water) with a *knob* and use *thermometer* to display equivalent temperature in Fahrenheit. Conversion formula is,

$$T_F = \frac{9}{5} T_C + 32 \tag{3}$$

NOTE: Use *right-click* → *scale* to set scale for both *knob* and *thermometer* such that the knob shall represent the full range of temperature in Centigrade from 0° to 100° and the thermometer shall represent the equivalent range in Fahrenheit.

EXERCISE – 5

Design a control to find out voltage across resistor R_2 from the following circuit.

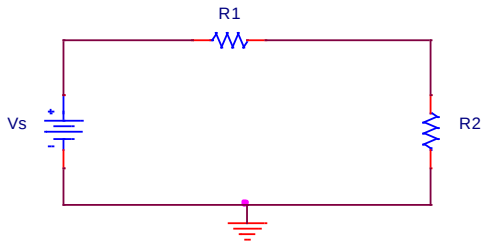


Figure 14: Simple Series Circuit for Exercise - 5

Use *voltage divider rule*,

$$V_{R_2} = \frac{R_2}{R_1 + R_2} Vs \tag{4}$$

Front panel controls are shown as follows:

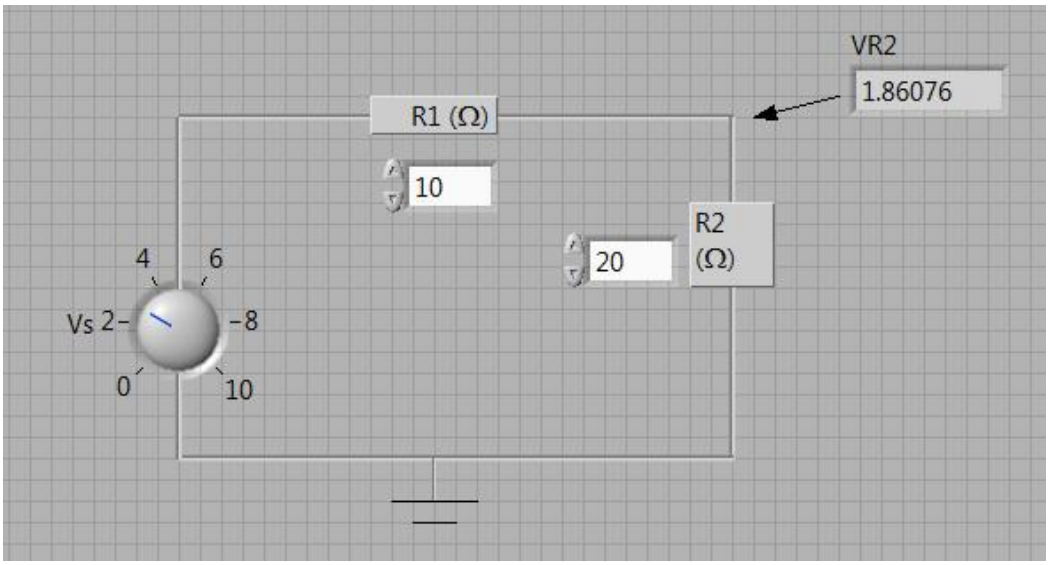


Figure 15: Front Panel Controls for Exercise – 5

NOTE: Use *Modern* → *Decoration* to draw lines and *R1* and *R2* boxes.

Descriptive Information& Block Diagram Labeling

This section discusses how to add a description to your program. Let's create a new *VI* that calculates roots of a quadratic equation, $Ax^2+Bx+C=0$, using quadratic formula,

$$x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \tag{5}$$

Figure 16 shows the controls for the front panel.

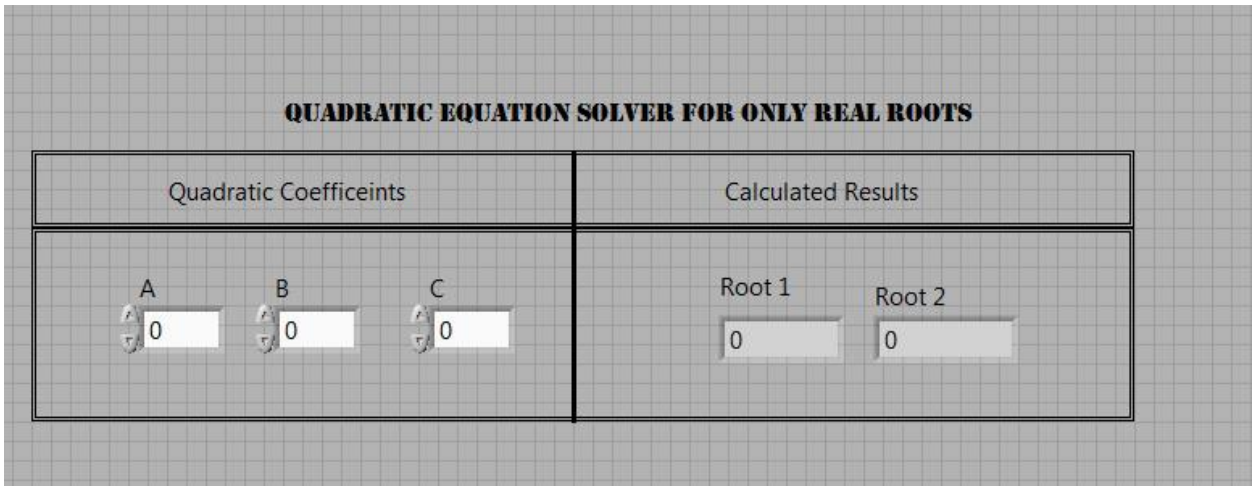


Figure 16: Quadratic Equation Solver for Real Roots

To add a description for this design, go to *File→VI Properties* and choose *Documentation* under *category*. You can also do the same by right clicking on the *LabVIEW* icon in the top right corner of your screen and choosing *VI Properties.* Give *VI* description for your program. One example is shown in *figure 17.*

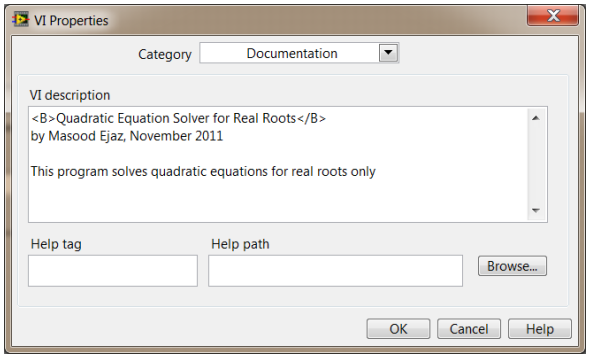


Figure 17: Example of File Description

<B> & </B> are used to print the text written in between them in bold. Press OK to save the description. You can see *context help* about your program by moving your mouse over the *LabVIEW* icon on the top right corner of your screen, if context help is enabled (To enable context help, go to *Help* → *context help* and then move your mouse on the icon).

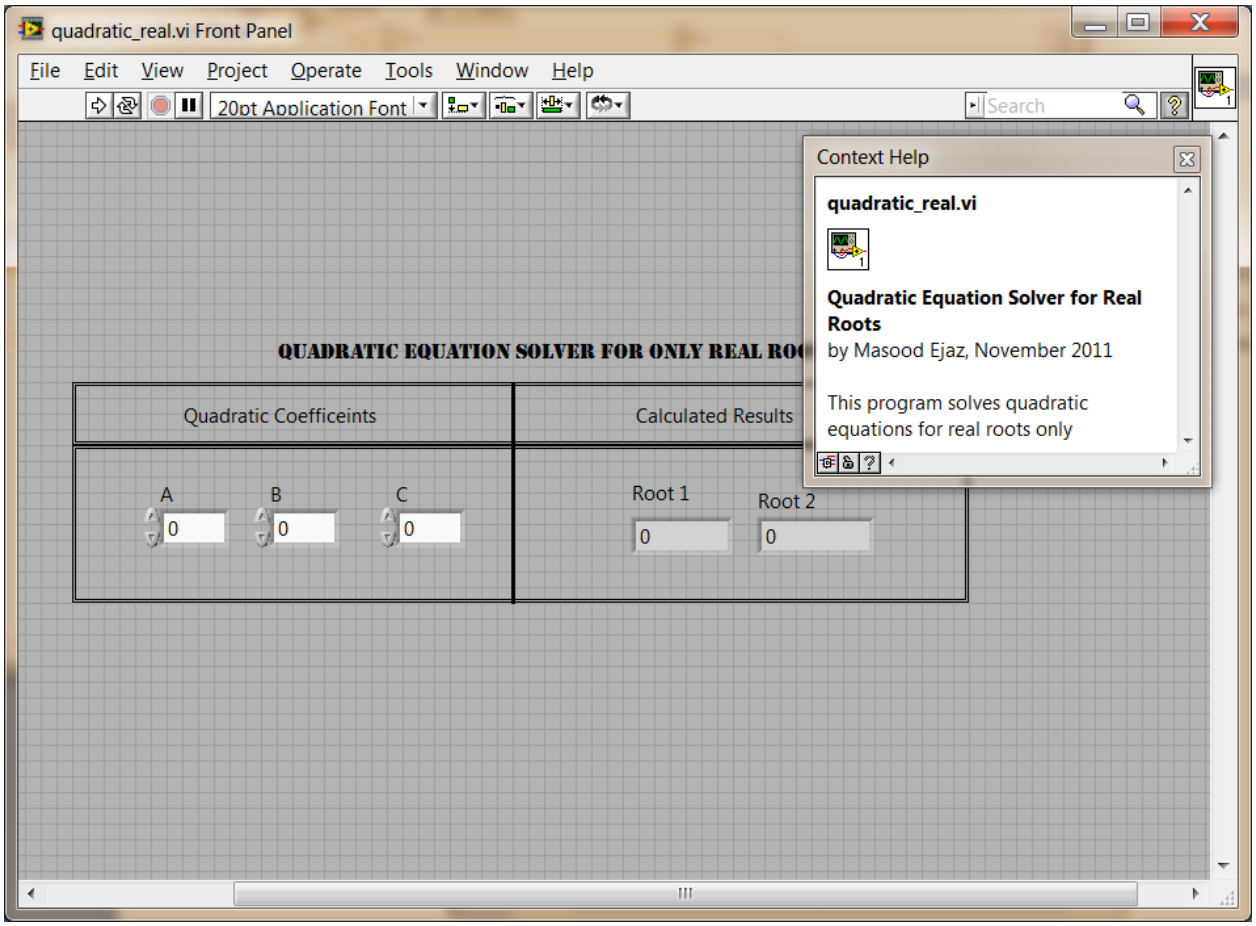


Figure 18: Context Help

The block diagram corresponding to this program is shown in *figure 19.* Observe the proper labeling that shows the signal flowing through a specific connection and makes the block diagram more understandable.

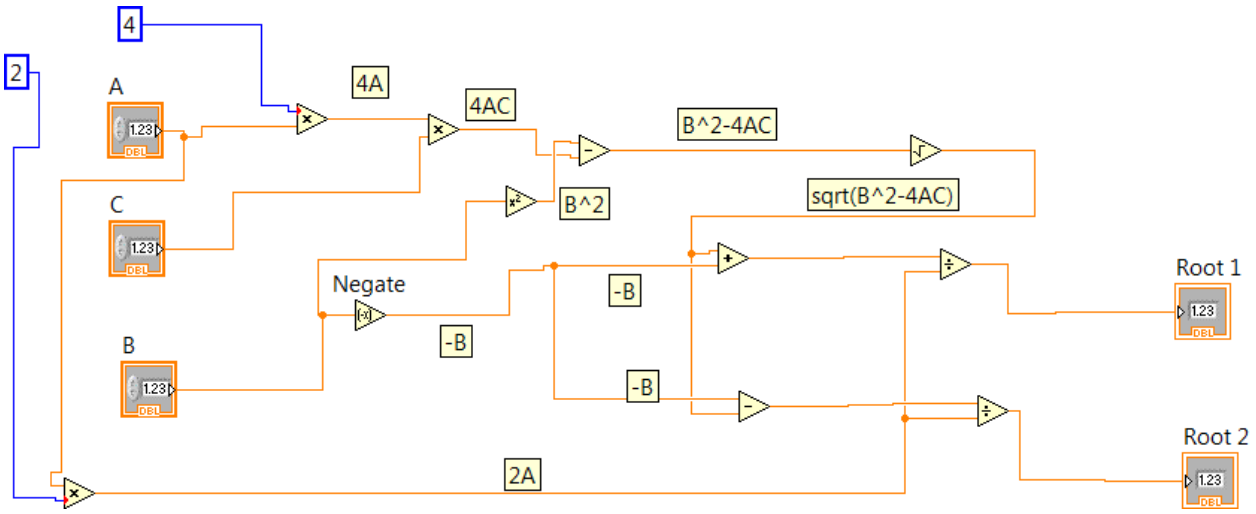


Figure 19: Block Diagram Corresponding to the Quadratic Equation Solver for Real Roots

To convert this program into a quadratic equation solver for both real and complex roots, all you have to do is to choose proper data type associated with the square root function block and the output *number indicator* blocks. This data type is *complex double* and you can choose it by right clicking the output number indicator blocks and going to *Representation* → *CDB*. Likewise, change the data type for the square root block from *Double* to *Complex Double (right-click* → *Properties* → *Output Configuration*). A proper quadratic equation solver that can solve for both types of roots, real and complex, is shown in *figure 20*.

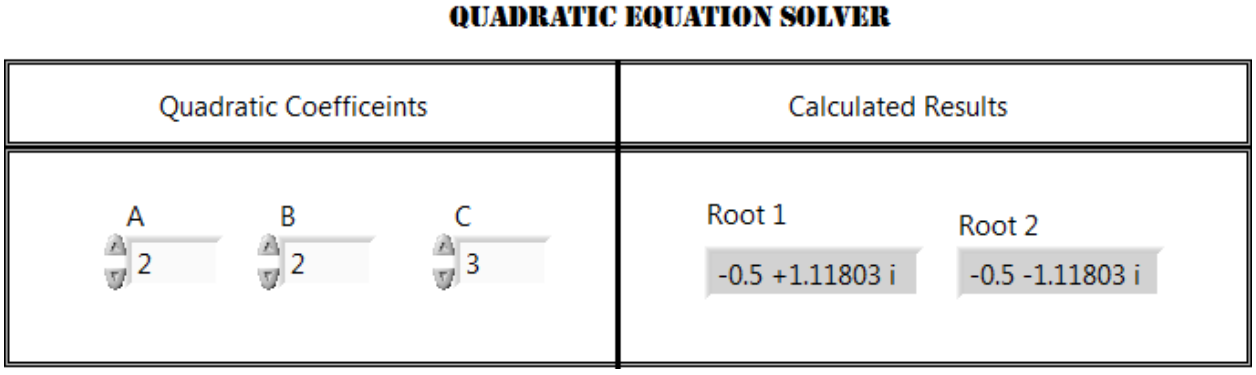


Figure 20: Quadratic Equation Solver for all Types of Roots

Equation Evaluation using *Formula* Block

There are many function blocks given under *Mathematics* → *Script & Formulas*. Let's analyze one of them to see how we can evaluate equations and formulae without using basic mathematical function blocks.

Suppose we want to implement the equation $f(x, y) = 4x^3 + 3y^2 + 7xy$ from *Exercise 3* without using individual functional blocks. In your front panel arrange numeric controls for *x* and *y* and number indicator for *f(x,y)*. In the block diagram window, pull *formula* block from *Mathematics* → *Script & Formulas* and arrange the blocks, as shown in *figure 21*.

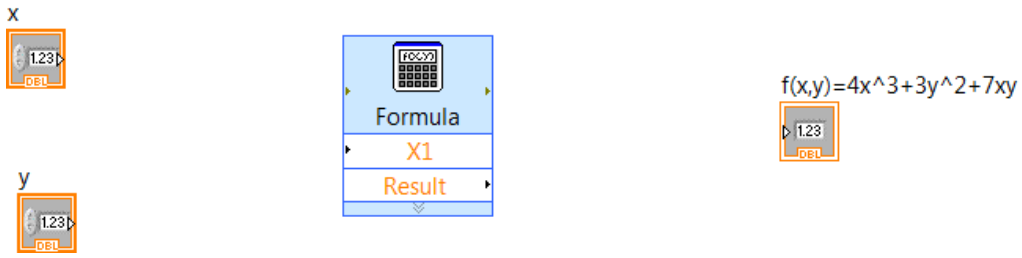


Figure 21: Arrangement of Blocks to Implement Equation (2) Using Formula Block

When you put the formula block, its *properties* window will open up that looks like a calculator. Type your formula in this calculator using the variables *X1* for *x* and *X2* for *y*. Make sure to use '**' button for power. Once you are done entering your formula, change the label of *X1* to *x* and *X2* to *y*. Press *OK* to exit from the formula block properties. In the block diagram, your formula block will expand to show you two input connections, *x* and *y*. Connect inputs and outputs as shown in *figure 22*. Your control is ready to work!

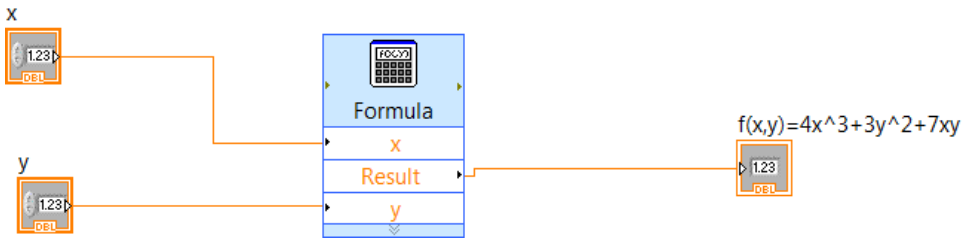


Figure 22: Circuit to Implement Equation 2

WARNING: Make sure not to use formula block to evaluate any expression or implement any type of function control unless you are asked to do so.

EXERCISE– 6

Design a binary to decimal number converter that converts a 3-bit binary number into its decimal equivalent. Take *C* as the most significant bit and *A* as the least significant bit. Front panel controls are shown in *figure 23*. When a toggle switch is *ON* assume a *1* and when it is *OFF* assume a *0,* for the binary number. Choose different colors for switches to show On and OFF state.

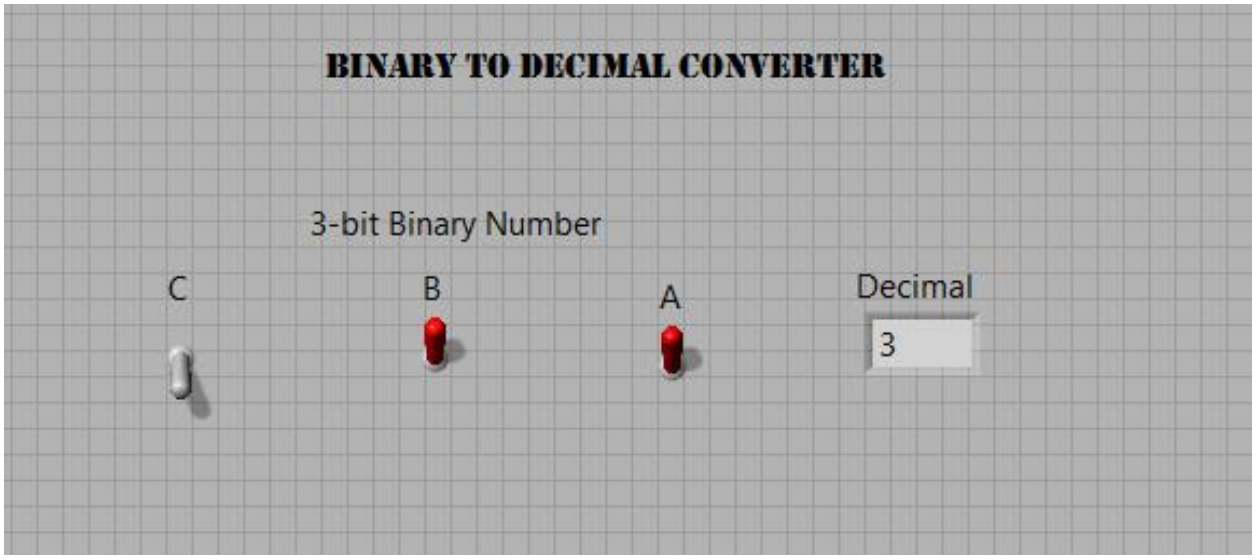


Figure 23: Binary-to-Decimal Converter

NOTES:

(i) You will need to convert *Boolean* logic of switches into equivalent decimal *0* and *1* before you create the conversion circuit. To do so, right-click on any switch in the block diagram and choose *Boolean palette* →*Boolean to (0,1)*. This is important to match input and output data types.

(ii) If you do not know how to convert a binary number into decimal, learn! It will be helpful for your future classes as well.

Comparison Functions

Let's look at another important class of functions, *comparison functions*. Comparison functions compare different conditions at the input and generate an output based on the comparative result. These functions are located in *Express* → *Arithmetic & Comparison* → *Comparison*. You must be familiar with most of the functions in this group. Let's use a less familiar function, *Select*, to create a program. Functionality of *select* block is similar to *if-else* routine in other programming languages.

Let's create a program that selects and calculates *natural log* or *base-10 log* of a number with a toggle switch. Front panel controls are shown in *figure 24.*

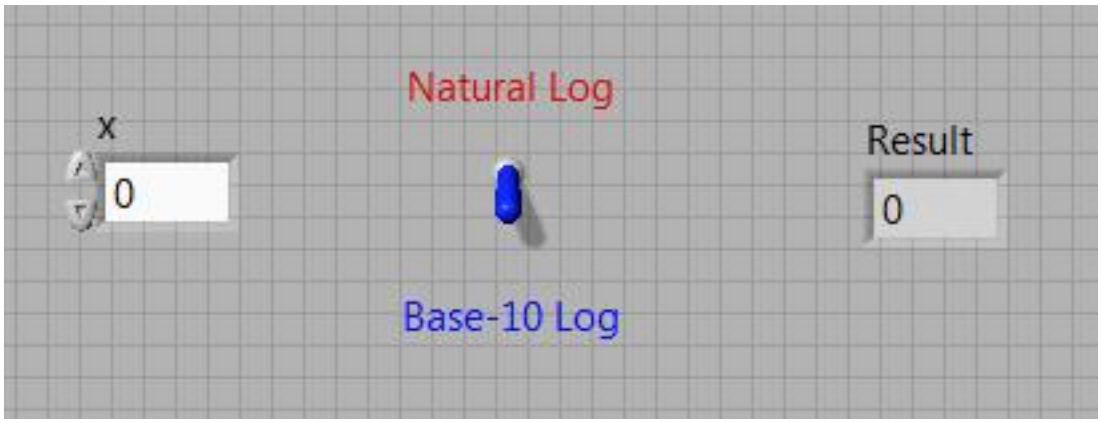


Figure 24: Toggle Switch to Calculate Corresponding Results for x

Pull *Select*, *log10*, and *ln* blocks to the block diagram. Logarithmic blocks are located under *Mathematics* → *Elementary* → *Exponential* library. Check *Select* block's *help* to understand its operation. Wire them together as shown in *figure 25* and test your circuit. Test your system with different values on *x*.

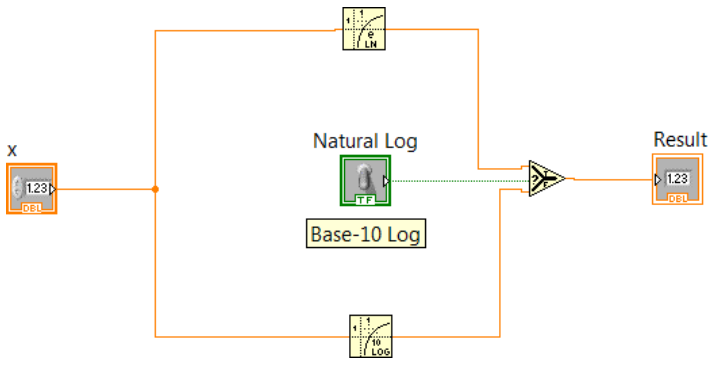


Figure 25: Block Diagram Corresponding to the Problem

EXERCISE – 7

Create a design to select one of the following functions with a toggle switch and calculate its output for different input values.

$$f(x,y) = 2x + 3y$$
$$g(x,y) = 4x + 5y \quad (6)$$

Incorporating Other Comparison Functions with Select:

Let's create a program based on *Exercise -7* such that if input $x > y$, output will be calculated according to *f(x,y)*, otherwise, it will be calculated according to *g(x,y)*. We are going to use two comparison function blocks; *greater than* and *less or equal to* along with the *select* block. Make sure to check their help to see the data types associated with their inputs and output.

Open the front panel for *Exercise – 7*, remove the switch and rearrange the controls as shown in *figure 26*. Add two LEDs, one to show when result will be calculated using *f* and other when it will be calculated using *g*.

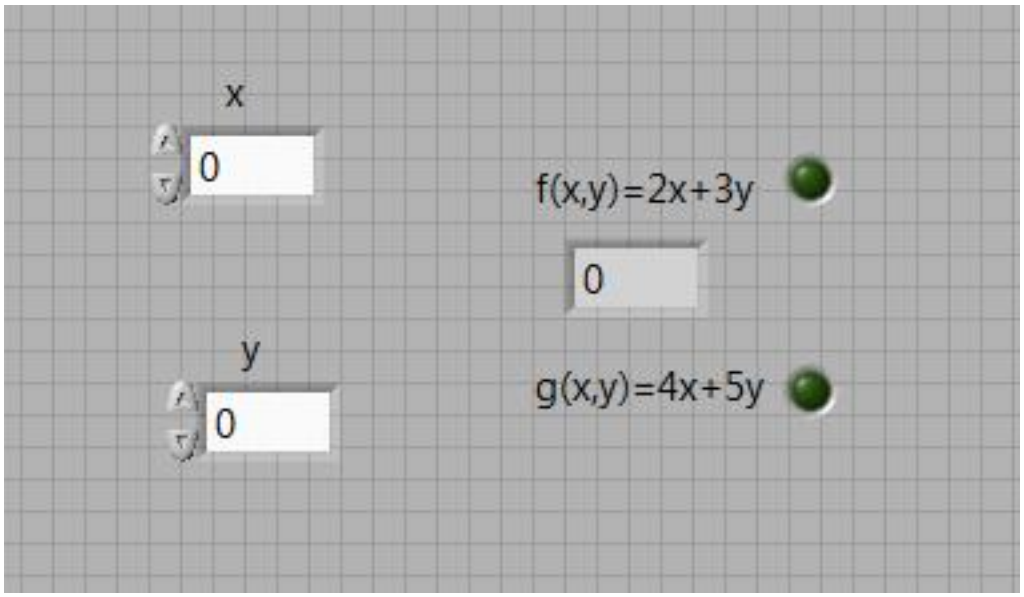


Figure 26: Calculation of Two Different Functions Based on the Input Values

Block diagram of the control is shown in *figure 27*. Note how the output of *greater than* block is connected to both of the LEDs directly. Practically, you will need an inverter circuit (*NOT* gate) connected to the LED of *g(x,y)* function but just for the demonstration purpose, you do not need to connect any gate between the output of comparison block and LEDs. How you are going to make sure that only one LED will light up when the corresponding function is calculated, as shown in *figure 28*? (Just by cheating a little bit and changing the color of LEDs when they are ON and OFF)

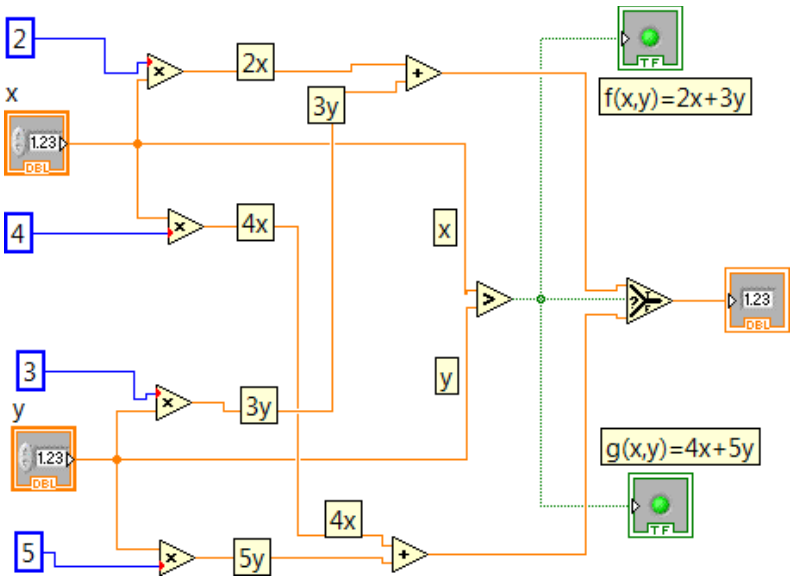


Figure 27: Block Diagram for Figure 26 Circuit Control

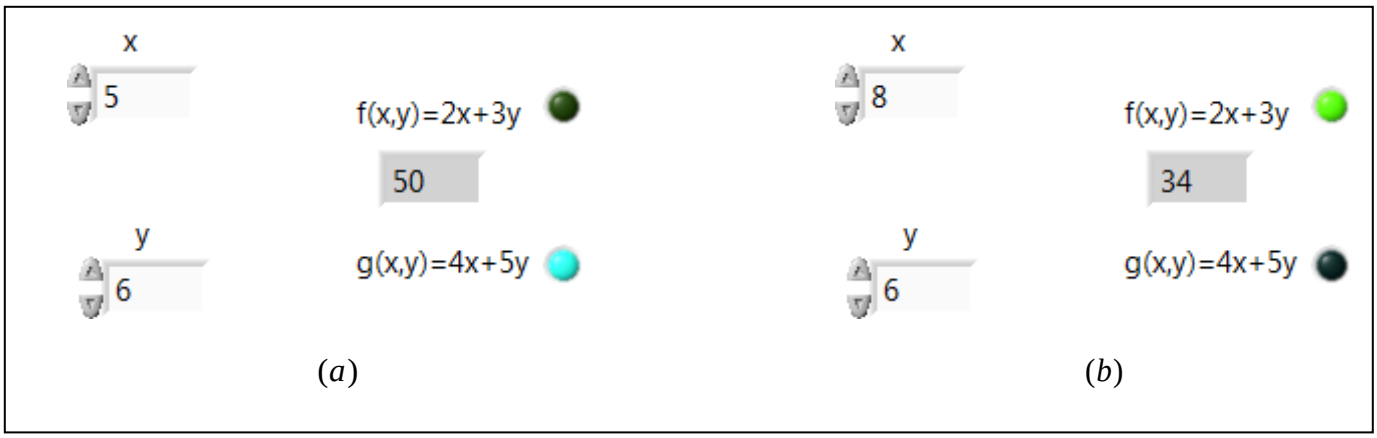


Figure 28: Output of Two Functions, Selected One at a Time, Base on the Input Values (a) Output is Calculated for g(x,y), since x < y (b) Output is Calculated for f(x,y), since x > y

Random Number Generation:

There are two random number generator blocks in the *function palette* under *Mathematics* → *Numeric*. The first block is *Random Number (0-1)*, which generates a floating-point number randomly using a *uniform distribution function* between 0 and 1. If you want to generate any number between a specific range, say 0 to 10, all you have to do is to multiply the output of the random number generator by the upper limit of your range. If you want output to be only random integers instead of floating-point numbers, round them off to the closest integer using the appropriate function block.

The second random number generator is *Random Numbers (Range)*, which generates a random integer between an upper and lower limit.

EXERCISE – 8

Use both random number generators to generate a pair of random **integers** between 1 and 10. Your front panel should have two numeric indicators, one to represent the random number generated through *Random Number (0-1)* block and the other to represent the random number through *Random Numbers (Range)* block.

WHILE Loops

Suppose we want to create a program in which a user has to guess a randomly generated number between 0 and 10. This calls for the user to keep guessing until the number matches with the one that is randomly generated. This situation can be handled with a *WHILE* loop. WHILE loops perform a set of functions as long as comparison of one or more set of conditions result in a *true* or *false* output.

WHILE loop function block is present under *Programming* → *Structure*. Pull the function block on the block diagram. It looks like a box that can be resized. Anything that you enclose inside this box will be repeated until the condition of the WHILE loop becomes *true* or *false*, however you set it. Make sure to check the help of WHILE loops to fully understand its function.

Let's create a program that let a user guess a randomly generated number between 0 and 10. Front panel will contain a *numeric control* (disable *increment/decrement* control so that user can only enter the number by typing it) and an *LED*, as shown in *figure 29*.

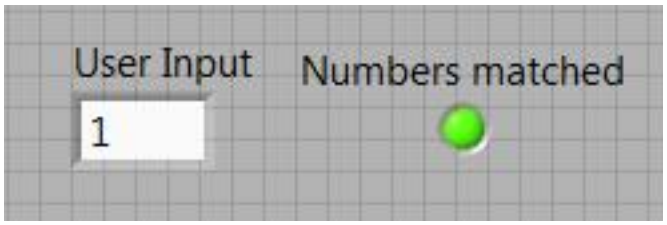


Figure 29: Front Panel for Number Guessing Program

We will enclose *user input* and comparison block inside the WHILE loop and randomly generated number control outside the WHILE loop, since random number has to be generated only once. LED will also be outside the WHILE loop, connected to the output of the comparison block. It will turn *ON* when the WHILE loop condition will be satisfied, i.e., when the input number will be matched with the random number. Any indicator outside the WHILE block will only demonstrate its status once the WHILE condition is satisfied. Block diagram of the program is shown in *figure 30.*

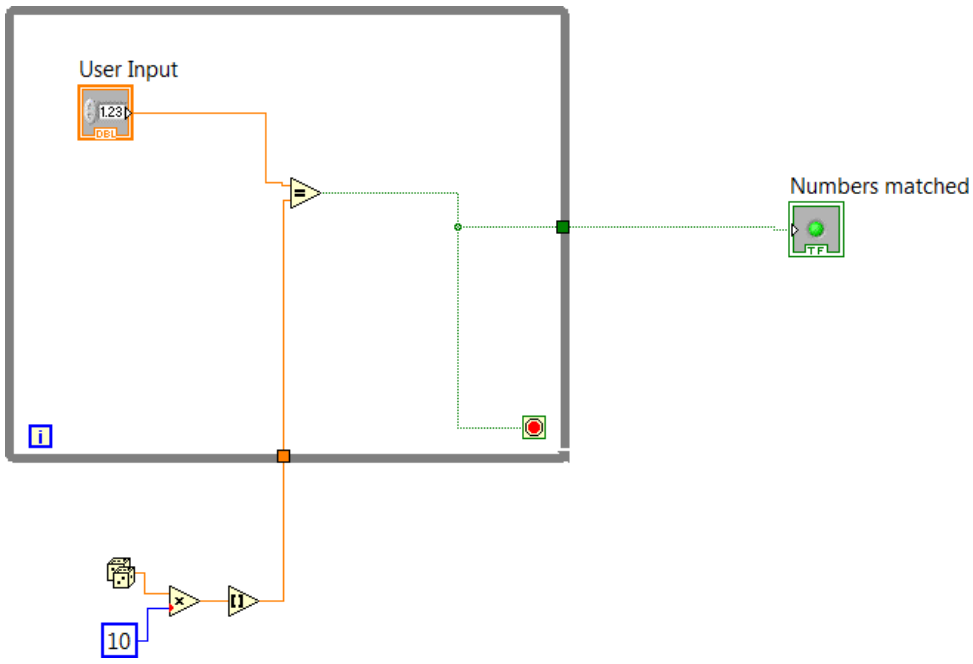


Figure 30: Block Diagram for Number Guessing Program

Condition for the WHILE loop that is used is *Stop if True*. You can change the condition to *Continue if True* (right-click WHILE block) and change *equal to* block to *not equal to*, to get the same result.

Boolean Functions:

Boolean or *Logic* functions are comprised of basic logic gates (*NOT, AND, OR)* and advanced logic gates (*NOR, NAND, XOR, XNOR)*. Boolean function group also has some other function blocks that can be used as required. A brief description of the function of different logic gates are as follows:

- *NOT:* Output is opposite of the input
- *AND:* Output is high only if all the inputs are high
- *OR:* Output is low only if all the inputs are low
- *NAND:* Opposite of *AND.* Output is low only if all the inputs are high
- *NOR:* Opposite of *OR.* Output is high only if all the inputs are low
- *XOR:* Output is high if both of the inputs are opposite
- *XNOR:* Output is high if both of the inputs are same

Let's start with an easy example. Choose two dials *A* and *B*, each with the range from zero to ten. Choose two LEDs, one for each dial. If A > B, turn LED for dial *A* ON else turn LED for dial *B* ON. This can be made with a simple *NOT* gate. The front panel of the program is shown in *figure 31* and the block diagram is shown in *figure 32*.

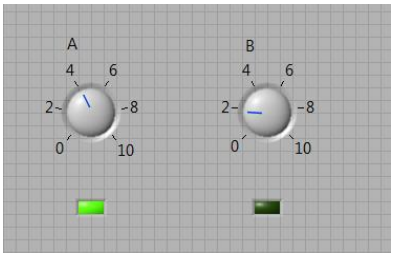


Figure 31: Two Dials Controlling Two LEDs

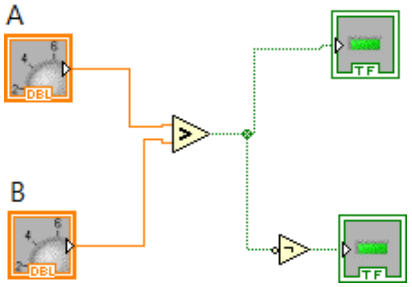


Figure 32: Block Diagram for Two-Dial Circuit from Figure 31

EXERCISE – 9

Create a program that can generate random integers from 3 to 8. Your front panel will have only one numeric indicator to show random integer.

Note: Your logic must be based on the use of While loops and you must use Random Number (0-1) block to generate random numbers.

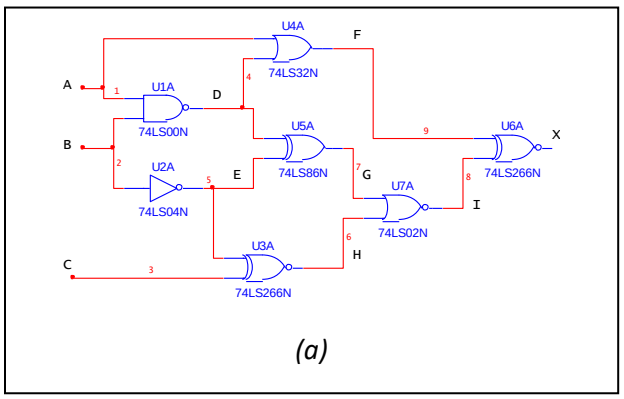
EXERCISE – 10

Choose three dials *A, B,* and *C,* each with a range from zero to ten. Also choose three *LEDs* (different colors), one for each dial. Design a control circuit that shows you which dial has the highest value by turning ON the corresponding LED.

Hint: One way to design this control is to use *AND* gates as part of the design.

EXERCISE – 11

Create the logic circuit shown in *figure 33* and fill out the corresponding truth table. Use three switches for the inputs and an LED for the output.



A	B	C	X
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

(b)

Figure 33: (a) Logic Circuit (b) Truth Table

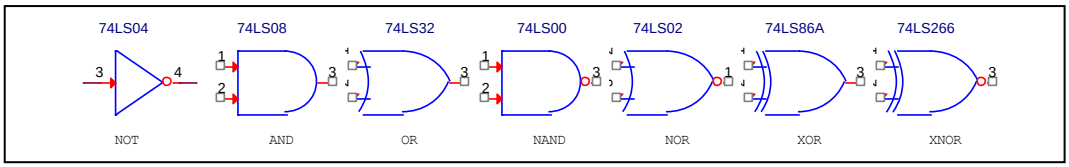


Figure 34: Symbols for Different Gates

Matrices & Arrays

In LabVIEW, matrices represent data arrangement in *2D* while arrays represent data arrangement in any dimension. In arrays you can store data with only one data type (double floating, Boolean, integer etc.). If you want to store data with different data types (for example, a mix of floating, image, integer etc.), *clusters* are used instead of arrays.

To define a matrix, go to *Array, Matrix, and Cluster* control group and choose *RealMatrix*. Let's add two matrices as follows,

$$\begin{bmatrix} 2 & 3 & 9 \\ 1 & 6 & 4 \\ 8 & 5 & 2 \end{bmatrix} + \begin{bmatrix} 3 & 3 & 8 \\ 2 & 5 & 2 \\ 1 & 3 & 2 \end{bmatrix}$$

Pull two matrix controls on the front panel, name them *A* and *B*. First index of the matrix control represents row number and second one represents column number. Note that both row and column numbers start at *0*. You can remove vertical and horizontal scroll bars and index control by going into the properties of the matrix block. Also, you can stretch matrix block to accommodate visible number of rows and columns. Front panel is shown in *figure 35.* Make sure to change *A+B* matrix from *control* to *indicator* (*right-click → change to indicator*).

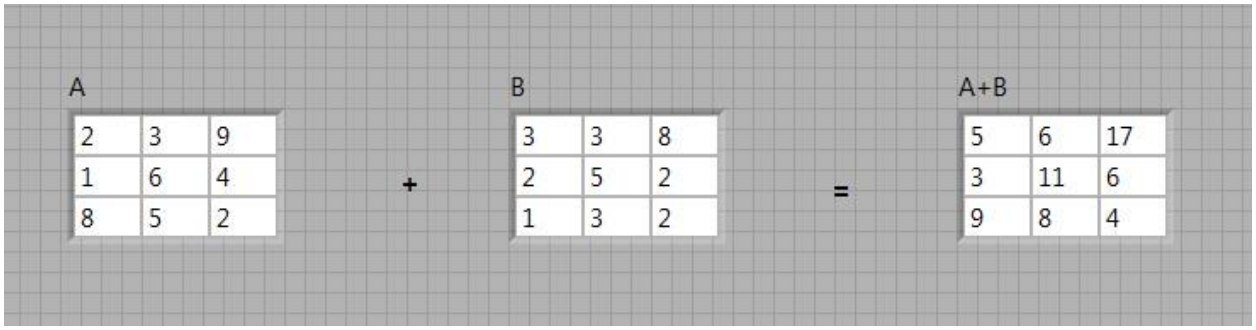


Figure 35: Matrix Addition

Explore different functions of matrix block by highlighting and right-clicking it.

Now, let's define an array. Pull *array* block from the corresponding control group. It will look like an empty box. Insert a *numeric indicator* in the box and stretch it to control the number of rows with one column. To increase the number of columns, right-click the block and click on *Add Dimension*. Column dimension will appear. Stretch the array block to adjust the number of columns.

When you use matrix block to do matrix multiplication, LabVIEW carries out *cross product*. Hence, number of columns of the first matrix should be equal to number of rows of the second matrix. With arrays, you can either do element-by-element multiplication (array multiplication) or cross multiplication by using the corresponding block from *Mathematics* → *Linear Algebra* → *A* × *B*.

EXERCISE – 12

In circuit analysis, when *KVL* (Kirchhoff's Voltage Law) or *KCL (*Kirchhoff's Current Law) equations are set up to solve for either loop currents or node voltages, it results in a set of simultaneous linear equations. Solve the following set of simultaneous linear equations using matrix manipulation as given below.

$$2x + 5y + 6z = 2$$
$$3x + 6y + 2z = 1$$
$$8x - 5y + z = 4$$

This set of linear equations can be represented in terms of matrices as follows,

$$\begin{bmatrix} 2 & 5 & 6 \\ 3 & 6 & 2 \\ 8 & -5 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 2 \\ 1 \\ 4 \end{bmatrix}$$

Values of unknown variables can be found out as follows,

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 2 & 5 & 6 \\ 3 & 6 & 2 \\ 8 & -5 & 1 \end{bmatrix}^{-1} \begin{bmatrix} 2 \\ 1 \\ 4 \end{bmatrix}$$

where $\mathbf{A}^{-1}$ represents matrix inverse. There is an *inverse matrix* function block in LabVIEW (find it!). To keep your values intact in any matrix, right click on the matrix, go to *data operations* and select *make current values default*. If you do not make them default then they will be lost once you close your file.

There is also a linear equations solution function block under *Mathematics* → *Linear Algebra* → *Solve Linear Equations*. Use this block and work on *Exercise – 12* again.

Another important function related to matrices and arrays is to extract different columns and rows and create new matrices or arrays out of them. The function that is used to do this job is

Array Subset (find it!). Function block is shown in *figure 36* with description of its inputs and outputs. As with any array control block, by default *Array Subset* block is one-dimensional (only rows). You can always add more dimensions by selecting *Add Dimension* through right-click or as soon as you will connect a matrix to the input of function block, it will automatically extend its input dimension. In *figure 36*, both rows and columns dimensions are shown (blue inputs)

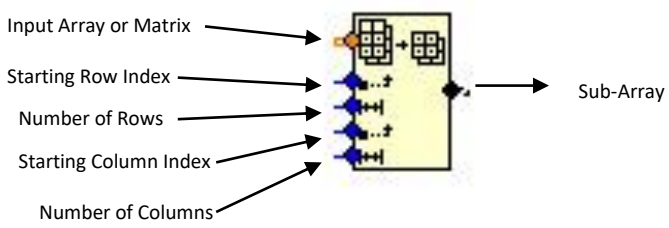


Figure 36: Array Subset Block

Create a 3-by-3 matrix or array and use *array subset* block to extract a two-by-two matrix with rows 2 & 3 and columns 2 & 3 as shown below. Remember the first column and row indices in LabVIEW are zero.

$$\begin{bmatrix} 2 & 3 & 4 \\ 5 & 6 & 7 \\ 8 & 9 & 10 \end{bmatrix} \Rightarrow \begin{bmatrix} 6 & 7 \\ 9 & 10 \end{bmatrix}$$

Origianl matrix *Extracted matrix*

Figure 37: Matrix and Sub-Matrix

There is also a very useful function to find out maximum and minimum value (s) of a matrix or array and indices of the first maximum values. This function is *Programming → Array → Max & Min*

Two-Dimensional Graphs:

Graphs utilize arrays to hold the values of coordinates. Let's start with a simple line plot of equation $y = 2x + 1$ for $x = 1$ to 10,

$x = 1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6 \quad 7 \quad 8 \quad 9 \quad 10$

$y = 3 \quad 5 \quad 7 \quad 9 \quad 11 \quad 13 \quad 15 \quad 17 \quad 19 \quad 21$

Create two arrays, one for *x* and one for *y*. There are two types of *X-Y* plot functions that you can use: *XY Graphs* and *Express XY Graphs*. Let's start with *ExpressXY Graphs* (*Modern → Graphs → Express XY Graphs* or *Express → Graph Indicators → XY Graph)*. Click on the *x* and *y* axes range to set initial and final values for both the axes. You can also click on the *x* and *y* labels to change them as well as the title of the plot. The front panel is shown in *figure 38* and block diagram is shown in *figure 39*.

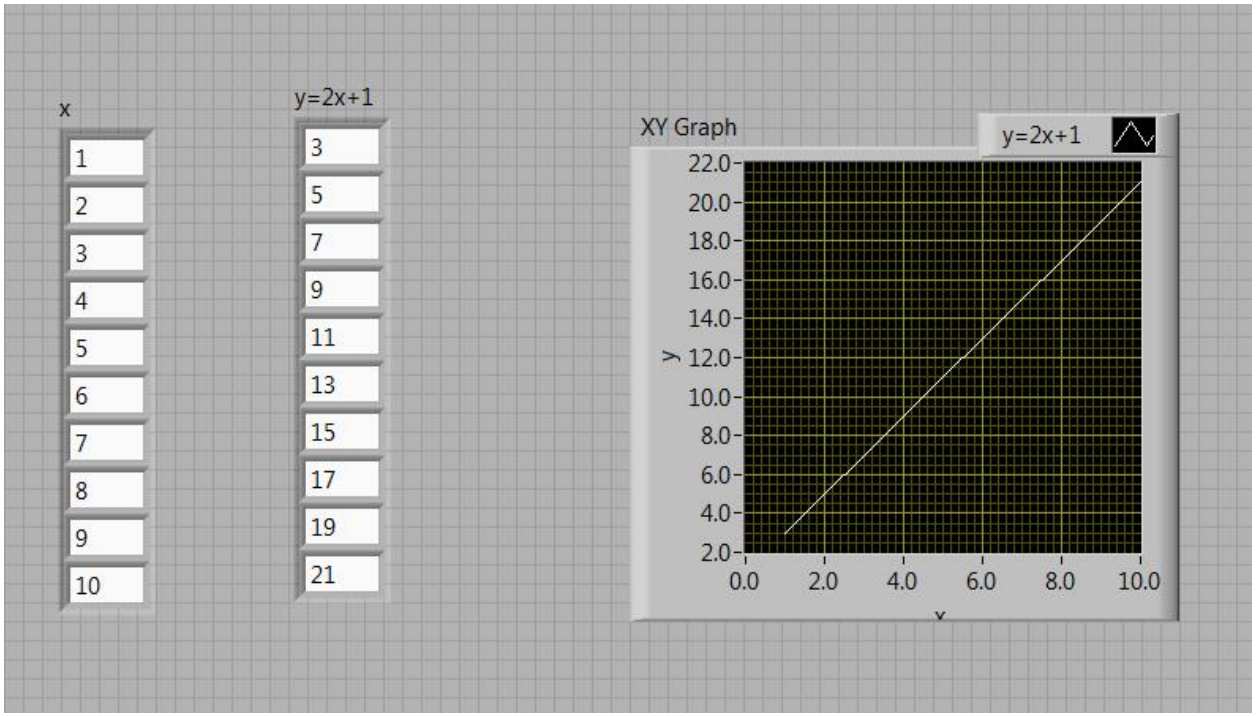


Figure 38: Simple Line Function Graph

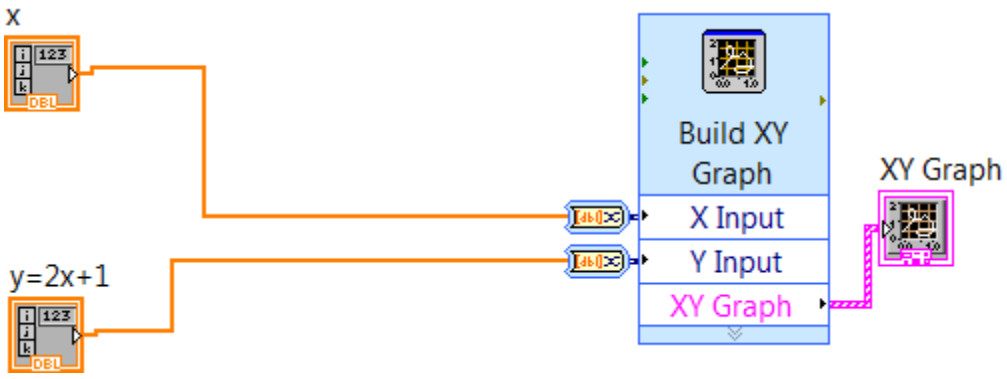


Figure 39: Block Connection for Line Graph from Figure 38

As shown in *figure 39*, express graphs have a *Build XY Graph* function added to them that lets you put two input arrays as *x* and *y* and generates an *XY Graph* between them.

If you use *XY Graph (Modern → Graphs → XY Graphs)* instead of *Express XY Graph*, you have to create an *array bundle (Programming → Cluster, Class, and Variant → Bundle)* for input arrays *x* and *y* such that output is a single array going into the graph function. Recreate the line function graph using *XY Graphs* and *Bundle* function. Block diagram is shown in *figure 40.*

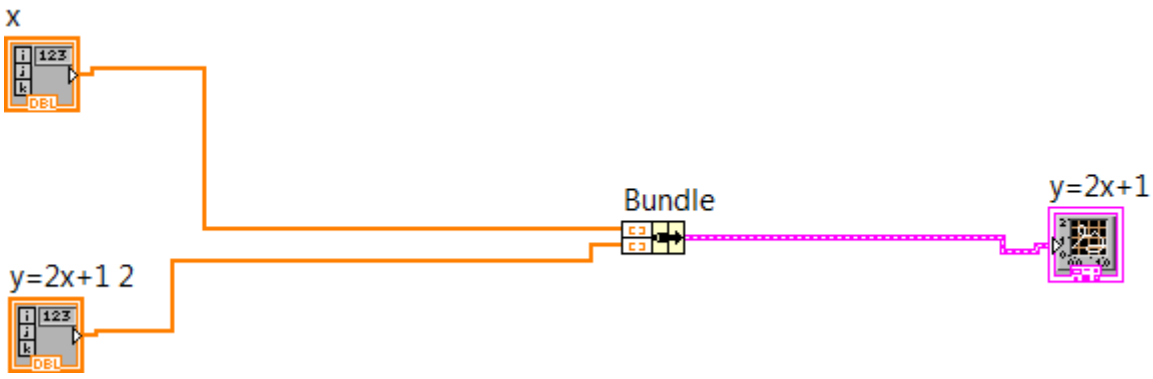


Figure 40: Graph of the Straight Line Function using XY Graphs and Bundle Function

For Loops:

For loops are used to generate values for a function for a range of its input variable(s). For loop function block is located under *Programming* → *Structures* and shown in *figure 41*. Operation of this block is very simple; loop is going to run for *N* times, with *i* being the current iteration value from 0 to *N-1*. Arrays are generally used to hold the values and results generated from the loop.

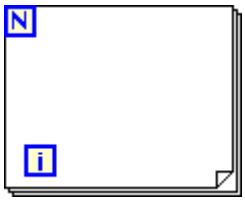


Figure 41: For Loop Function Block

Let's create a very simple program; build an array with values from 1 to 100. This can be done easily using a *for loop* as shown in *figure 42*. Note that '1' is added in the iteration value *i* to generate an output from 1 to 100, since *i* goes from 0 to *N*-1 (0 to 99 in this case)

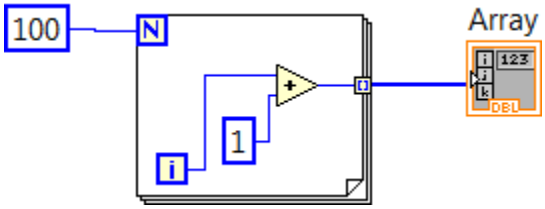


Figure 42: Using For Loop to Create an Array from 1 to 100

EXERCISE – 13

Use a *for loop* to generate a multiplication table from 1 to 10 for an integer *n*. Front panel is shown in *figure 43*.

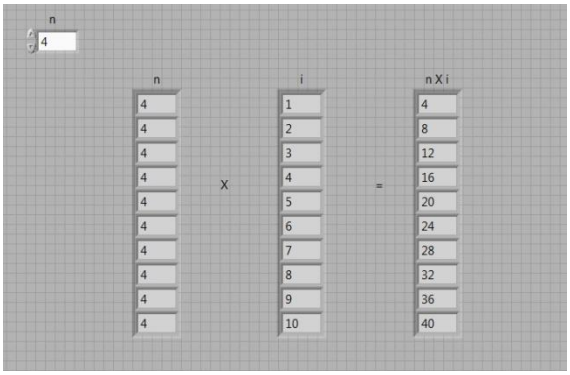


Figure 43: Front Panel for Multiplication table

Graphs Using For Loops:

One of the most important functions of *for loops* is to generate arrays to plot graphs. Let's create a plot for a quadratic function, $y = 2x + 3x^2 + 1$ for $x = 0$ *to* 20. Loop is going to run for *21* times (*N = 21)*. Block diagram of the program is shown in *figure 44* and the plot is shown in *figure 45*. *Formula* block is used to write the required quadratic equation.

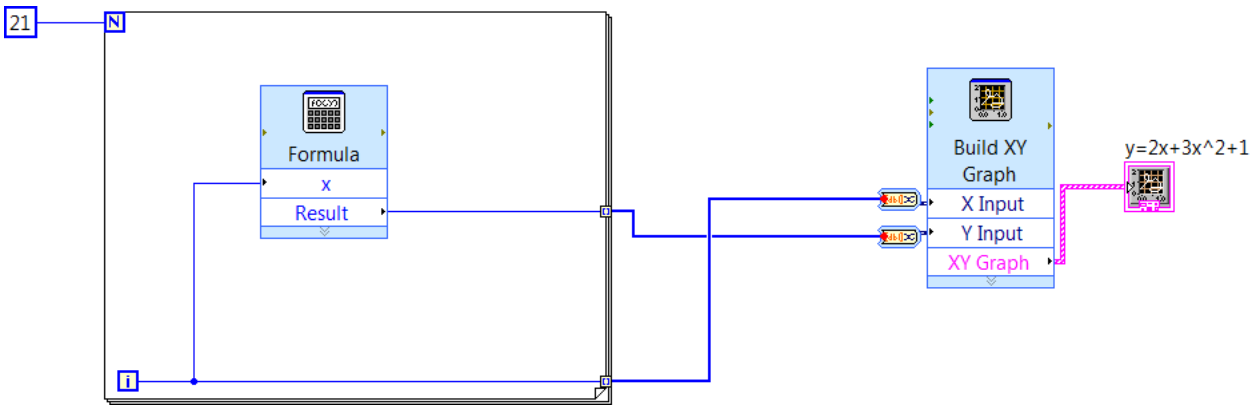


Figure 44: Block Diagram for the Quadratic Function Plot

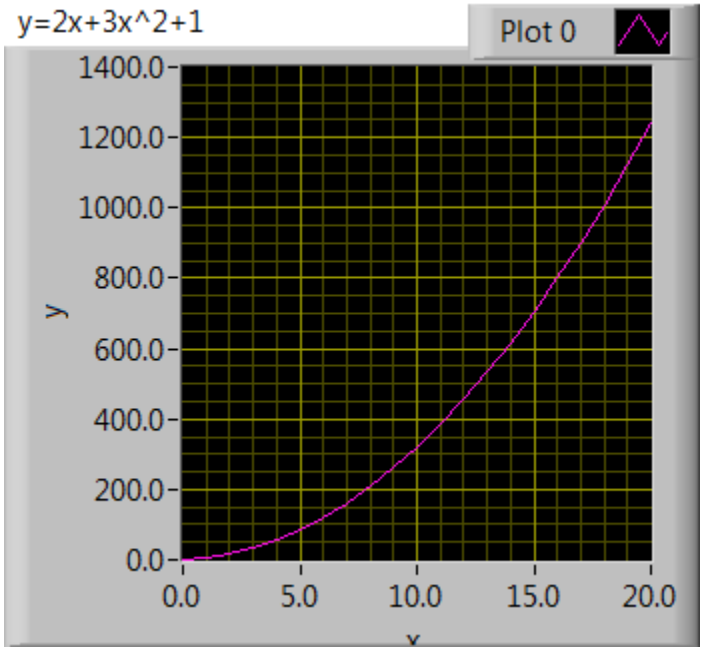


Figure 45: Plot of Quadratic Function $y = 2x + 3x^2 + 1$

EXERCISE – 14

Create a graph for $y = 2sin(x)cos(5x)$ for $x = 0^o$ *to* 360^o. Make sure your *x-axis* should be in degrees. Remember that all trigonometric functions in LabVIEW take their argument in radian.

Multiple Graphs

In this section we will look at how to graph multiple functions on the same plot. Let's start with *Express XY* graphs and plot two functions, $y_1 = 2sin(t)$ and $y_2 = cos(t)$, on the same plot. Let's plot both the functions from 0 to 4π with 100 points distributed evenly in the range. The front panel set-up will be the same as shown in *figure 45*. In the block diagram, you will have to run the FOR loop for 100 times such that it produces input to the trigonometric functions that starts at time $t = 0$ and ends at $t = 4\pi$. This can easily be done by dividing 4π by 99 (maximum value of *i*) and then multiplying it by *i*, as shown in *figure 46*. This value will go to the inputs of both *sin* and *cos* blocks.

To get multiple graphs on the same plot, we will use a function block called *Build Array*. This is located under *Programming* → *Array*. You will need two of these blocks, one to build array for *x* (time) and the other to build array for *y1* and *y2*. Output of respective blocks will go to the *x* and *y* inputs of *Build XY Graph* block. Complete block diagram is shown in *figure 46* and front panel shot is shown in *figure 47*. Note that by default *Build Array* block has a single input; stretch it down to produce more inputs (two in this case).

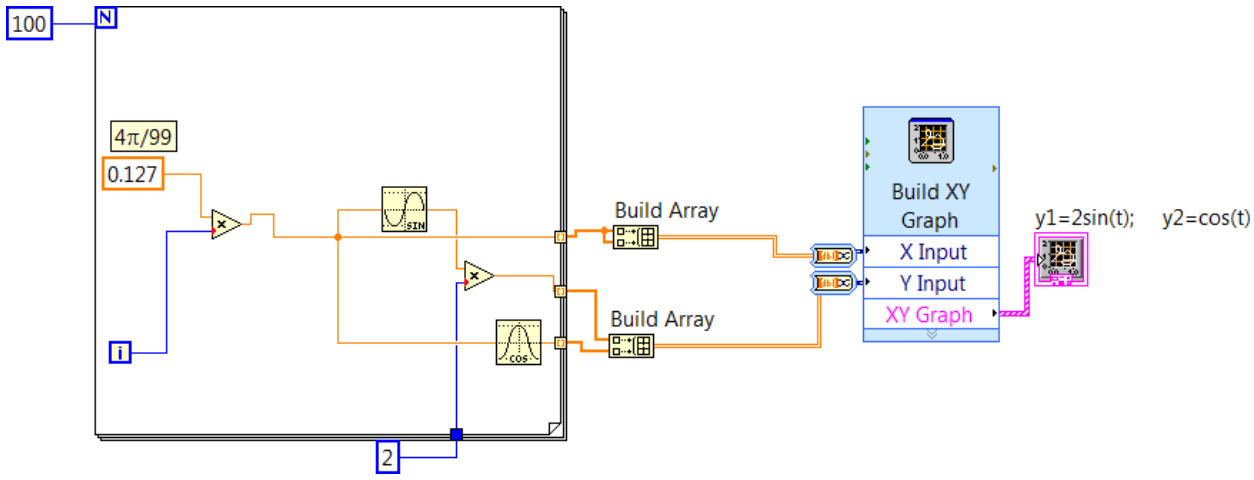


Figure 46: Block Diagram to Graph Two Functions on the Same Plot

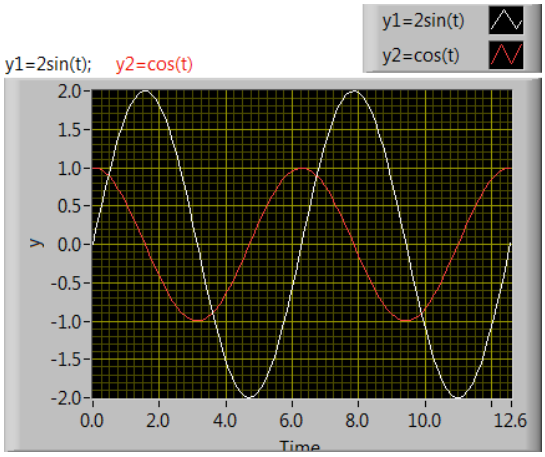


Figure 47: Multiple Graphs on the Same Plot

Cursors

You can add cursors to check the (*x*,*y*) coordinates of each graph. Turn the cursor on by right clicking the graph and selecting *Visible Items* → *Cursor Legend*. By default there is only one cursor. To add more cursors, right click on the graph again, go to *Properties* → *Cursors* → *Add.* You can change the color of each cursor lines to differentiate from one another. An example is shown in *figure 48* that shows coordinate values of two graphs at two different points.

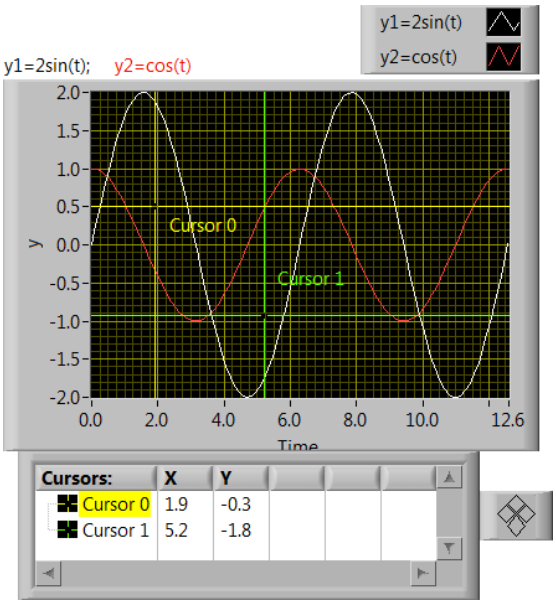


Figure 48: An Example of using Cursors

EXERCISE – 15

Plot two functions, $y_1 = 6cos(5x)sin(8x)$ and $y_2 = 7sin(7x)cos(9x)$, *using XY Graph* (not *Express XY Graph*) from the *modern* library. The range of *x* is from 0 to 8 and the step-size is 0.01. Place two cursors, one for each function, and measure the output for *y1* at $x = 2$ and *y2* at $x = 3$. Also, use three arrays to display the generated values of *x*, *y1*, and *y2*. Hence, your control panel should have three arrays to display the generated values (numerical indicators), one graph, and one cursor screen.

Hints:

- You will have to use a *bundle* block to make pairs of **(x, y_1)** and (**x**, **y_2**) first**,** followed by a *build array* block.
- Right click on the graph window, go to *Data Operations* and choose *Make current values default* to keep your graph intact once you close the file.
- Under *Properties* of the graph when you go to *cursors*, choose *single-point* for each cursor under *Allow Dragging* to move your cursors along the plot.

EXERCISE – 16

Graph a function $y = Ax^2+Bx+C$, where values of *A, B,* and *C* shall be controlled by three *dials* or *knobs*, each with a range from -5 to 10. The range of *x* is from 0 to 10 divided into 100 points. You can use either *XY Plot* or *Express XY Plot.*