Final Project in Electronics

Physics 2371/2372, Electronics for Scientists
Don Heiman and Hari Kumarakuru, Northeastern University, 11/23/2020

The assignment for the Final Project uses Simulink technology from MathWorks. Your results are to be described in a poster format using MS PowerPoint.

Everyone is required to do the 3-bit Multiplier project – or – it can be replaced by one of the more sophisticated optional projects listed below, or replaced by a project that is cleared with the instructors well ahead of time.

Required Project

3-bit Digital Multiplier – Construct a 3-bit multiplier using only the basic gates (AND, OR, NOT, NAND, NOR, XOR, XNOR). Higher-order Simulink functions (blocks) are not allowed. The two inputs to be multiplied are 3-bit binary numbers in the form ABC (e.g. 101), where C corresponds to the least significant bit. The inputs and output of the multiplication must be shown on some type of display, using lamps that turn colors, or on some other more inventive visual device. Optional: use only NAND gates for extra credit.

Suggested Optional Projects

These are some suggested projects that can replace the 3-bit Multiplier. Be creative with them. Expand them if you like, but simplify them if they are turning out to be too difficult. Keep in mind that these projects are more challenging and could require considerable effort, yet should be more rewarding.

Combination Lock – Construct a circuit that produces a hidden digital random number (e.g. 917) and compares it to a number guessed by a user (e.g. 319). The original random number must be saved while the user makes many guesses. For each guess, the circuit should give the user some limited information, such as the total number of digits that were correct (two for this guess), and/or how many of the digits were in the correct place (one for this guess). The guesses must be shown on a display, and the original random number will be display only after it matches a guess. This is a simplified version of the games Mastermind, and Bulls and Cows.

Reaction Timer – Construct a circuit that measures the reaction time of a user, after a user sees a lamp turn color and then presses a button. The reaction time for each trial should be displayed. Another display could show the averaged reaction time for 5 or 10 trials.

Digital Stopwatch – Construct a digital stopwatch displaying minutes and seconds. Use a high frequency (kHz if possible) oscillator/pulser and scale the frequency down to 1 second pulses with flip-flops. Use stop and reset buttons.

Suggest a Project – We are open to suggestions for appropriate projects. If you have a project to suggest, please write it up and email it to us. These projects must be identified ahead of time.

Simulink Tutorial

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I. Introduction

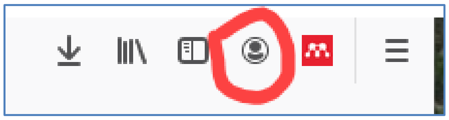
Simulink (Simulation + Link) is a design tool for electronic circuits that was developed by MathWorks and integrated into MathLab. It has a graphical user interface (GUI) that allows you to use various circuit components and connect them by wires, similar to what you would write on a piece of paper.

A very useful property of this tool is that it not only allows you to Design the full circuit, but it also allows you to Simulate (test) its operation to see if it does what you want it to do. Another property is that you can develop Subunits and then Simulate them individually before connecting a number of these Subunits into your final more complex circuit.

II. Get Started with Simulink

You can use Simulink **online** thru your web browser. (You can also **download** MatLab from MathWorks, and run Simulink from inside MatLab.)

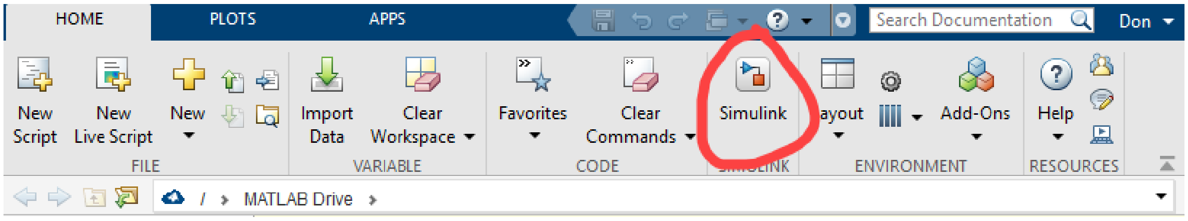
Create a MatLab/MathWorks account - Click on the small circle of a person in the far upper right and use your NU email identity.



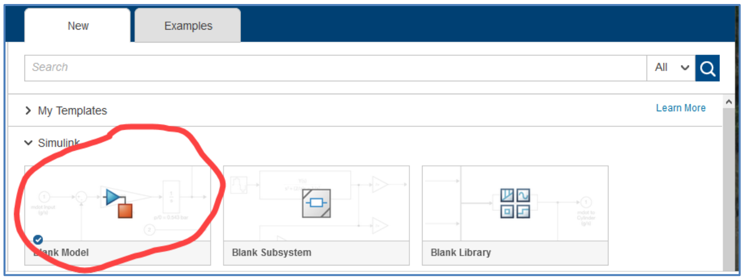
III. Run Simulink Online

For online use, go to Simulink Online, sign into your account and click on to blue button "Start using Simulink Online."

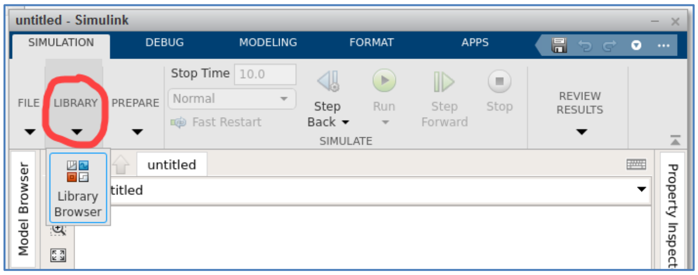
If you get into the MatLab page, click on the **Simulink** button at the top. You may have to do this often.



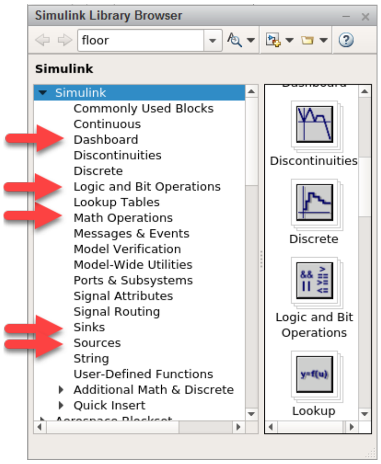
You should now see the Simulink page containing boxes, like the "Blank Model" box. Click on the **Blank Model** box as shown to open a new window.



IV. Creating a Model – Examples



To begin creating your project you need to first open the Simulink **Library Browser**. Locate the Simulink Library button in the grey toolbar and open it. This will open a list of sub-libraries. In the Library you will find your most important items, the **Blocks**. As you might expect, the Blocks do specific functions and you can use **Lines** to connect the inputs and outputs to the Blocks. You can find specific information about a Block by right-clicking on it. You can also get details of any Block in the online Help button at the top. There, you can type in the name of a Block to **search** for it.



A. *Example – Simple NAND Gate*

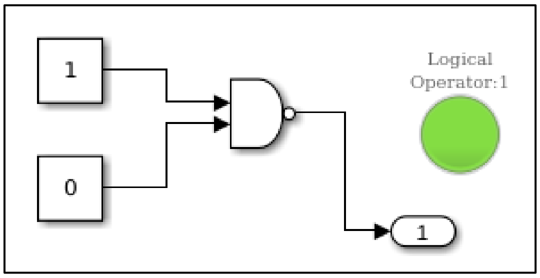
The most basic sub-libraries are shown here, **Dashboard**, **Logic and Bit Operations**, **Math Operations**, **Sinks** and **Sources**.

Open the Logic and Bit Operations sub-library. Locate the **Logical Operator** block and drag it into the Simulink workspace. Double click on it to open its window. Make it a 2-input NAND gate, then you can change the Icon shape to “distinctive” and press OK. The block will then have the “Do” shape of a NAND gate.

B. *Example – Inputs, Push Button and Lamp*

Open the **Sources** sub-library. Drag in a **Constant** Block. Create a second **Constant** Block by first **right** clicking and holding the key down on the block, press and hold down the control key, then drag the block to a new position. Connect the two **Constant** blocks to the NAND gate inputs by wires. Do this by left clicking on the **Constant** caret then click onto the NAND input. Close the yellow window clicking on the “X” at the upper right of the large window.

In order to use the **Lamp** block,you must first connect the NAND output into an output Block. Drag in the **Out1** block from the Sink sub-library. Connect **Out1** to the NAND output. Now drag in a **Lamp** Block from the **Dashboard** sub-library. It will be highlighted so you can click on the small connect symbol at the top, then click on the NAND output wire. When the small “Connect” window pops up, click on the small circle at the left and the circle will fill. Then close the window by clicking on the “X.”



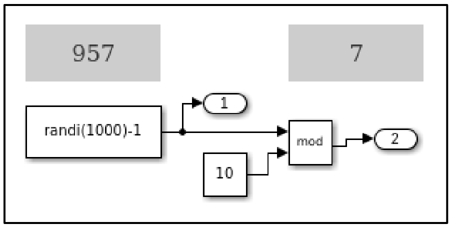
To change the colors for different NAND outputs, double right click the Lamp to open the **Block Parameters** window. Set the 0 to the red color. Click the “+” sign to make a 1 into the color green. It is important to click “OK” at the very bottom, which may be hidden until you move the window up. Click the green **Run** button.

Test the circuit by changing one of the inputs to 0, then to 1 by double left clicking on the Constant block. Press the Run button to see the Lamp output change.

Save the Model under FILE/SAVE AS/filename. It appears that the filename cannot be a dictionary word, but can be a non-dictionary word like "lamptest" for example.

C. Example – Random Number Generator and Display

Drag in a **Constant** block from the Sources sub-library. Double click on it and type "randi(1000)-1" as the value, then OK. Change the "-C-" designation to "randi(1000)-1" by grabbing a corner to pull the box longer. Drag in an **Out1** block from the Sinks sub-library and connect the random number output. Drag in a **Display** block from the Dashboard sub-library. Click on the small connect symbol at the top, then click on the previous output wire. When the small window pops up, click on the small circle at the left and the circle will fill. Then close the window by clicking on the "X" at the upper right of the large window. Press the Run button several times to see the random number displayed.



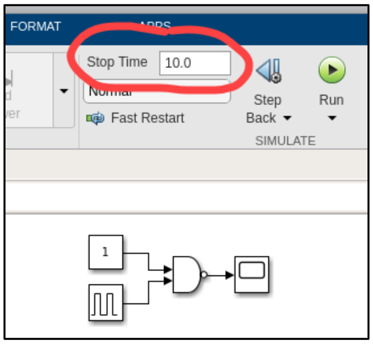
From the **Math Operations** sub-library, drag in a **Math Functions** block. Double click on it to change to a MOD function. Use this to select out the least significant bit from the random number.

D. Example – Pulses and Scope Output

Open the **Sources** sub-library. Drag in a **Constant** block and a **Pulse Generator** block. Next, open the **Sinks** sub-library and drag in a **Scope** block. Wire the two Sources to the inputs of the NAND gate and the output of the NAND gate to the scope. Set the Constant block output=1.

Double click on the **Pulse Generator** block. Set the Amplitude=1, Period=1, Pulse width=80%, then click OK.

Make sure the Stop Time =10, then press the green **Run** button. To see the results, double click on the **Scope** block. There you will see a train of 10 pulses of amplitude=1. Note that the time is shortened a large amount. Next, you can set the Constant block output=0. After Running it, you can see that the pulses are gone and the Scope output=1.


Stop Time 10.0

V. Useful Items

Save – Save your Model under FILE/SAVE AS/filename. It appears that the filename cannot be a dictionary word, but can be a non-dictionary word like "lamptest" for example.

Copy - Create a second Block by first **right** clicking and holding the key down on the block, press and hold down the control key, then drag the block to a new position.

Displays – Many display blocks require the output to first be wired into a sink, such as the **Out1** block.