Carleton University

Department of Systems and Computer Engineering

SYSC 2310 Fall 2017

Introduction to Digital Systems

Lab #2

Lab Report Due: At **6:00 am** on the day that is one week after your scheduled lab session. (E.G. if your lab is on Tuesday, the report is due on Tuesday one week later.)

Submit the report as a SINGLE PDF FILE. Place the report in a folder named Lab2, along with your lab work as described below. Zip the folder (Lab2.zip) and submit it to the appropriate location in the cuLearn webpage for your lab section. Note: This and future labs will be submitted through your lab section webpage (not the course webpage). **Note that the system will automatically stop accepting submissions at the due date/time for your lab section.**

LATE submissions will NOT be accepted.

Read this document completely and carefully before deciding what to do.

Please bring questions about the lab to class for discussion at the beginning of class.

In this lab you will:

- Use more features of Logisim.
- Design a logic circuit that implements a truth table.
- Enter circuit designs into Logisim.
- Test circuits using Logisim's simulation capability.
- Interpret circuit behaviour under different data representations.

"[Report]" indicates content that should be addressed in the lab report.

This is version 4 of the lab instructions. This version fixes a few typos in Step 3. The revised wording is highlighted. It also includes highlights from earlier versions.

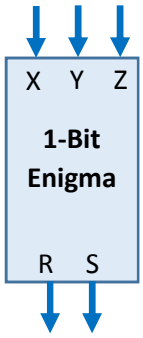
Step 1: Read this entire document before proceeding to Step 2.

Step 2: Download the Lab2.zip file to a persistent work area, and unzip the folder.

The Truth Table for a 1-Bit Enigma component is given below. The component has 3 inputs (X, Y, and Z) and 2 outputs (R and S).

X	Y	Z	R	S
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	1	0
1	0	0	0	1
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

Step 3: a) Open the provided Lab2Start circuit. Extend the circuit to include an implementation of a 1-Bit Enigma circuit. When building the circuit, change the Facing Attribute of all of the gates to South. This will cause the inputs to be oriented towards the top of the canvas and the outputs to be pointing towards the bottom. Keep the gates reasonably close together because you will (eventually) copy and paste multiple instances of the 1-Bit Enigma circuit. Think of the circuit as a component with the inputs and outputs shown below.

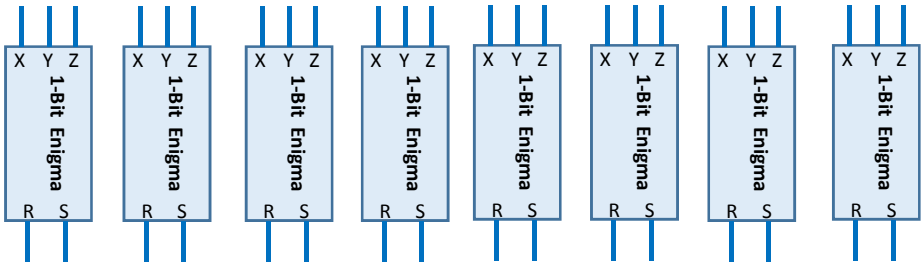


b) Connect the Lab1TestHelper outputs Q2, Q1, Q0 to the X, Y and Z inputs, respectively. Add LEDs to the outputs and Label them (use the Label Attribute) to match the outputs in the table. Log the input/output behaviour of your circuit. Save the circuit in your unzipped Lab2 folder in a circuit file named Lab2Enigma1. [Report] Include the log for your circuit showing that your circuit implements the required behaviour.

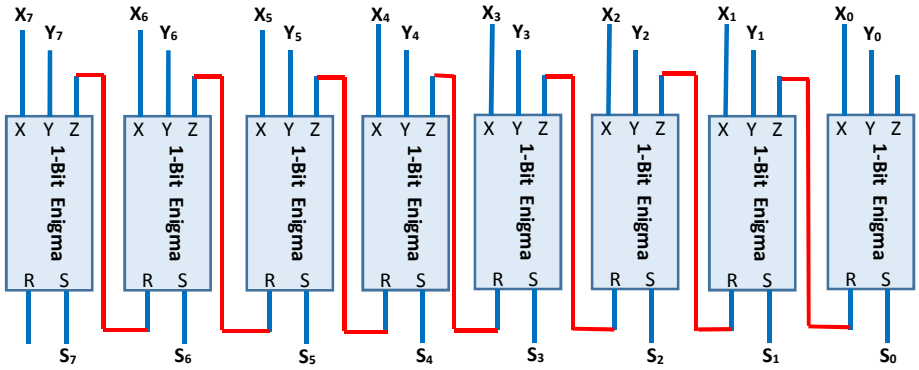
Step 3: Save the file (again) in your unzipped Lab2 folder in a circuit file named Lab2Enigma8. You now have 2 circuit files in your Lab2 folder: Lab2Enigma1 (your circuit from Step 2), and Lab2Enigma8 … you

are working in Lab2Enigma8. Disconnect and delete the Lab1TestHelper sub-circuit and delete the LEDs you added in Step 2 above.

Extend the Lab2Enigma8 circuit by duplicating your 1-Bit Enigma circuit 8 times and placing the 8 copies in a row across the canvas. (Hint: you can left-click and drag the mouse on the canvas to create a selection box that encloses multiple gates and wires, and then use the (Edit) Copy and Paste functions.) Leave some space above the copies to put some more components. (Hint: If necessary, it is easy to select all of your 1-Bit Enigma components at once (by drawing a selection box around them) and then move them all as a group.) Conceptually, the result should look as shown below. Think of this as the start of an 8-Bit Enigma circuit, with the most significant bit being the left-most 1-Bit Enigma sub-circuit, and the least significant being the right-most 1-Bit Enigma sub-circuit.

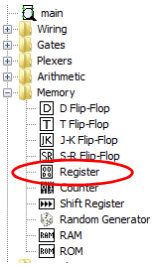


For each 1-Bit sub-circuit (except for the most-significant sub-circuit), connect its R output to the Z input of its next more significant neighbour. The result should look like this 8-Bit Enigma circuit:



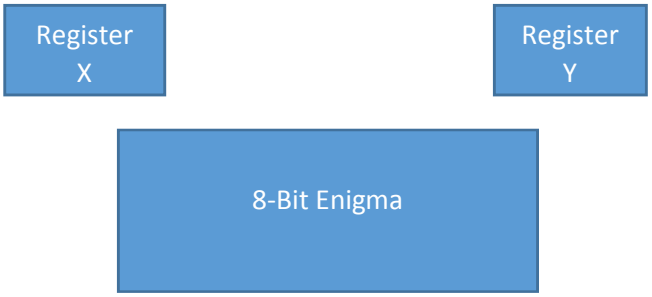
Now connect a constant 0 to the Z input on the least significant 1-Bit Enigma circuit. (this line was added in V2)

This lab will use Logisim's Register component (you can find the Register component in the Memory circuit Library in the Explorer pane):



The Register component defaults to hold 8 bit values. For this lab, ignore all of the Register's connections except the Q outputs. The single Q output connection consists of 8 output bits: Q_7 .. Q_0 (more on this later). The hexadecimal contents of the register are displayed as part of the register icon (the default contents are 0x00). Register contents can be modified using the Poke tool.

Add one Register above and on the left side of your 8-Bit Enigma circuit. Label this Register X. Add another Register above and on the right side of your 8-Bit Enigma circuit. Label this Register Y. Conceptually, your circuit should look like this,



Save your circuit (saving work often is always a good idea).

Connect the outputs from Register X to the X inputs on the 8-Bit Enigma sub-circuit (be sure to get Q_7 from Register X connected to X_7 on the 8-Bit Enigma circuit, etc.). This will require knowledge of how to use Logisim's Wire Bundles. The output of the X Register is an 8-wire bundle. Wire Bundles are often used in circuit diagrams to simplify multi-bit connections among components. (For more about Wire Bundles: open the Help Tutorial and expand the Wire Bundles entry in the left-side pane). You will also need to know about the use of a Wire Splitter (available from the Wiring Library, and discussed in the Wire Bundle documentation … pay particular attention to the discussion of the Splitter's Attributes … you may need to explore as part of a circuit to really understand them.)

Connect the outputs from Register Y to the Y inputs on the 8-Bit Enigma sub-circuit (again, be sure to get Q_7 from Register Y connected to Y_7 on the 8-Bit Enigma circuit, etc.).

Save your circuit (saving work often is always a good idea).

Connect an 8-bit Hexadecimal Probe to the 8-bit wire bundle output from Register X. This will require setting the Radix Attribute of the Probe before you can complete the connection (correctly). Label the Probe "X Hex" (choose a Label Location that helps readability).

Connect an 8-bit Hexadecimal Probe to the 8-bit wire bundle output from Register Y. This will require setting the appropriate Attributes of the Probe. Label the Probe "Y Hex" (choose a Label Location that helps readability).

Connect an 8-bit Hexadecimal Probe to the S outputs of the 8-Bit Enigma sub-circuit. This will require setting the appropriate Attributes of the Probe (and you will need another wire splitter to form a wire bundle ☺). Label the Probe "S Hex" (choose a Label Location that helps readability).

Connect an 8-bit Unsigned Decimal Probe to the 8-bit wire bundle output from Register X. This will require setting the appropriate Attributes of the Probe. Label the Probe "X Unsigned" (choose a Label Location that helps readability).

Connect an 8-bit Unsigned Decimal Probe to the 8-bit wire bundle output from Register Y. This will require setting the appropriate Attributes of the Probe. Label the Probe "Y Unsigned" (choose a Label Location that helps readability).

Connect an 8-bit Unsigned Decimal Probe to the 8-bit wire bundle associate with the S outputs. This will require setting the appropriate Attributes of the Probe. Label the Probe "S Unsigned" (choose a Label Location that helps readability).

Connect an 8-bit Signed Decimal Probe to the 8-bit wire bundle output from Register X. This will require setting the appropriate Attributes of the Probe. Label the Probe "X Signed" (choose a Label Location that helps readability).

Connect an 8-bit Signed Decimal Probe to the 8-bit wire bundle output from Register Y. This will require setting the appropriate Attributes of the Probe. Label the Probe "Y Signed" (choose a Label Location that helps readability).

Connect an 8-bit Signed Decimal Probe to the 8-bit wire bundle associate with the S outputs. This will require setting the appropriate Attributes of the Probe. Label the Probe "S Signed" (choose a Label Location that helps readability).

Save your circuit (saving work often is always a good idea).

Set up logging to record the values of all of the Probes, and save the log in your unzipped Lab2 folder in a file named Step3Test.txt.

(this paragraph was added in V3) The Change Radix button in the Logging tool can be used to select how the Logging tool will record data from a particular component. The tool supports Binary (2), Hex (16), and Unsigned Decimal (10) data formats. Unfortunately, the tool does not support Signed Decimal. To deal with Signed Decimal values: 1) log the data as unsigned using the tool and manually record the signed values, then 2) manually edit the log file to replace the logged unsigned vales with the signed values.

Using the Poke tool, enter the following values (in hexadecimal)

Test Pair 1) X: 10 Y: 6

Test Pair 2) X: 5A Y: 1B

Test Pair 3) X: 7F Y: 6D

Based on your log results: what function do you think is implemented by the 8-Bit Enigma circuit?

[Report] Include the log for these test pairs, and state the function you think is implemented by the 8-Bit Enigma circuit, and why.

Step 4: Set up logging to record the values of all of the Probes, and save the log in your unzipped Lab2 folder in a file named Step4Test.txt. (If you just finished Step 3, all you need to change is the name of the logging file ☺)

Using the Poke tool, enter the following values (in hexadecimal)

Test Pair 4) X: 9C Y: 6

Test Pair 5) X: 80 Y: 1

Test Pair 6) X: 23 Y: 24

[Report] Include the log for these test pairs, and a brief discussion of why the answers are "correct" for the logged values and the function you identified in Step 3.

Step 5: The lab is done! ☺ If you could not complete the lab during the scheduled lab time … that's OK … finish up the lab on your own time.

Before you leave the lab (even if you could not complete the lab), show the TA what you have completed. [Attendance marks are associated with this.]

Bonus: [Report] Pick an appropriate test pair from Step 4, and describe (briefly) why the result is correct for both the Unsigned and Signed cases, and why the hex (binary) values are the same for both cases.

Step 6: Before the due date for your lab section (i.e. does not have to be done during the scheduled lab). Prepare your report and place the single pdf in the unzipped Lab2 folder containing your lab work. Name the report "Lab2Report".PDF (the folder should retain the name "Lab2"). Zip and submit the Lab2 folder to the appropriate place in your lab section's cuLearn page.