COM1006/COM1090 Devices and Networks (Autumn)
## Tutorial Sheet #4: Gates and Logic

Getting started with Logisim

In the next tutorials we'll use a digital circuit simulator called Logisim
(http://sourceforge.net/projects/circuit/). Logisim is available from the Software Center on
all CiCS managed desktop machines:
1. Open Software Center from your desktop (if no available software shows, try closing it and reopening)
2. Find "Logisim" and select it
3. Click on "Install Selected" and wait for the installation to finish.
4. To start Logisim at any time after installation, click the start button and select **All Programs > Logisim**. Logisim will start, and you'll be shown a screen that looks like this:
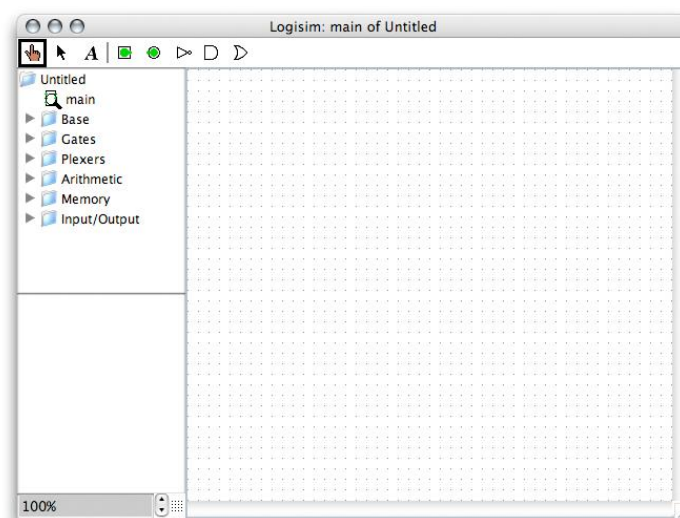
The area full of dots is where you place components to make a circuit. The most commonly used tools and components are shown on a menu bar at the top. The tools (from left to right) are:

Poke tool - use to change the value of a component by clicking on it. Repeatedly clicking on a 1-bit value such an input (see below) will cause it to toggle between 0 and 1.

Edit tool - use to move components and draw wires between them. Wires are drawn by clicking on a dot on a component (a green circle will then be shown around it) and dragging to make a line. You can also click at any point on a wire to make connection with it. To move a component, click inside it and drag.

Text tool - use to add annotations to the diagram. Note that text boxes can only occupy a single line, not multiple lines. **Don't use this tool to add a label to a component; do that using the label field in the component inspector in the bottom left part of the screen**.

Next to the tools are commonly used components:

Pin - use to make an input, which can be altered using the poke tool. Next to it is an output pin, which allows you to see the value generated by a circuit.

**NOT, AND and OR gates**. You should recognise the standard symbols for these. Note that the AND and OR gates have 5 inputs by default. When a component is selected, an inspector panel appears in the bottom left of the screen which you can use to

change the properties of the component (e.g., add a label, change the number of inputs). Note that you can also change the direction in which a component is facing, which is often necessary in order to make a nicely formatted circuit.

To get things started, make a simple circuit by connecting two input pins to an AND gate, and connecting the output of the gate to an output pin. Make sure you **connect the wire to the small dot** (by default on the east side of the square) and the simulation is enabled (**Simulate > Simulation Enabled**). You should get something like the circuit shown below:
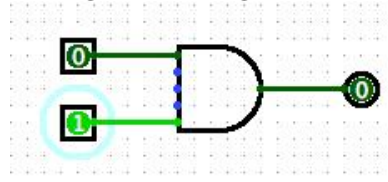
Click on an input with the poke tool and its value will change to 1, and it will light green. Now use the poke tool to click on the second input to change it to 1, and as you would expect the output of the AND gate changes to 1, which is reflected on the output pin:
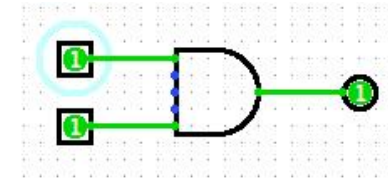
There are other tools and components that you can discover for yourself. Click on the **Base** folder and you will see other commonly used tools. As a final example, let's add a LED output to the circuit that you've made. Using the edit tool, click on the output pin and press Delete (not backspace) on the keyboard. Now click on the **Input/Output** menu and select the LED component, and add an LED to the circuit. Wire the LED to the output of the AND gate. Now you should have something like this; when the two inputs are both 1, the LED will light up.
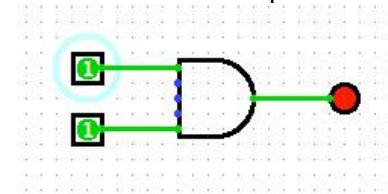
Logisim has a lot of other tricks up its sleeve, which we'll discover as we go through the tutorial sheets. If you need help, there is a comprehensive tutorial and reference guide under the **Help** menu at the top of the Logisim screen.

Common mistakes: make sure you **always connect wires to pins (small dots)**. In the circuit below, the top input is connected correctly, but for the bottom one the wire does not connect to the pin. Note how blue/red wiring shows that something is wrong.
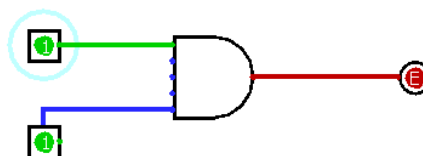
Exercises

1. In Lecture 4 we saw the following circuit. Implement it in Logisim, using appropriate labels of the inputs and outputs.
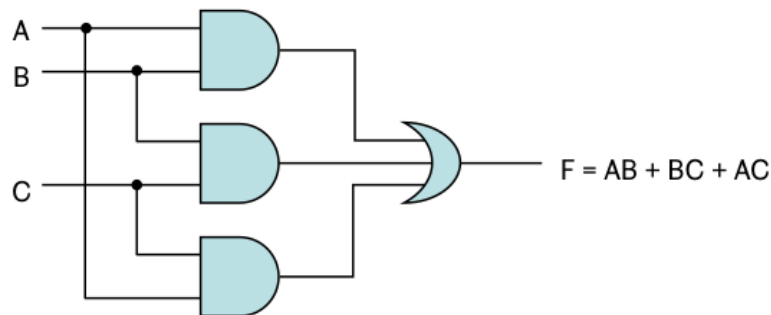
    A nice feature of Logisim is that it can analyse circuits for us. From the Logisim menu, select **Project > Analyse Circuit**. Then click on the **Expression** tab. You should see that the output is F = AB+BC+AC as above (assuming that you have correctly labelled the input and output pins). Now click on the **Table** tab and you will see the truth table for F. Check that it matches the one in the notes.

2. Tabulate the values of the variables, P, Q, R, S, T and U in the circuit below, for all possible input variables A, B, C and D. **Do this by hand**. Lay out the truth table for this question as shown in the lecture slides.
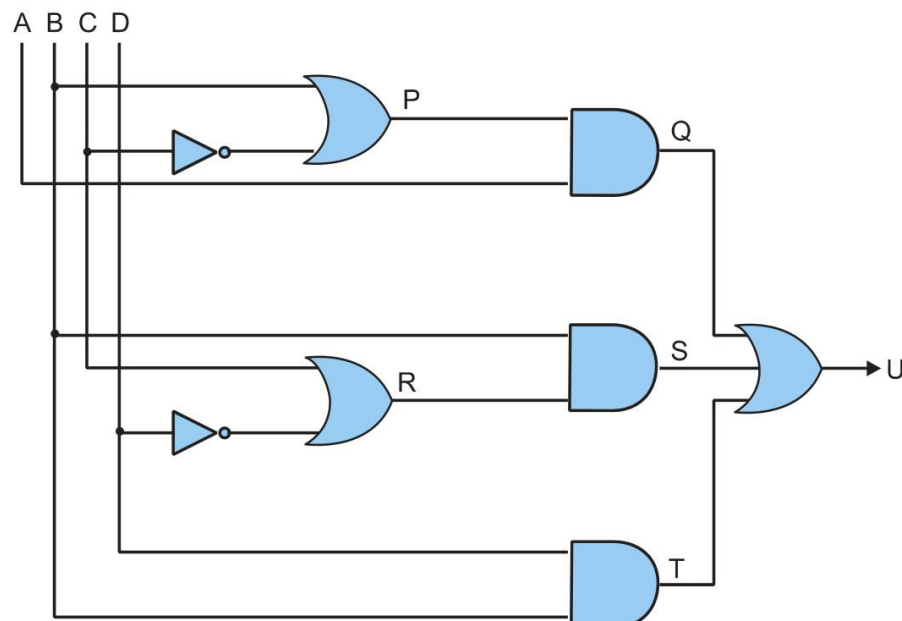
3. Now implement the circuit above in Logisim and check your answer to question 2 by analysing the circuit and displaying the truth table.

4. Using the truth table that you wrote in question 2, write down a sum-of-products expression for U.

5. For the circuit of question 2, obtain a Boolean expression for the output U in terms of the inputs A, B, C and D. **Do this by hand**, by writing down the logic function of each gate.

6. Use Logisim to draw logic diagrams, using AND, OR and NOT gates only, to implement the following Boolean expressions. In each case draw the diagrams directly from the equations and do not attempt to simplify the expressions.

   a) $F = \overline{A}B + \overline{A\overline{B}}$

   b) $F = (A+B+C)\cdot(AB+AC)$

   c) $F = (A+\overline{C})\cdot(A+B\overline{D})$

   For each circuit, check you answer by analysing the circuit in Logisim (do **Project > Analyse Circuit** and click on the **Expression** tab).