Introduction to the Embedded Systems Lab

Welcome to the ***Embedded Systems Lab***.

Since this is your first time here, it is appropriate to remind you of the rules and procedures governing the operation of the lab. Please read these carefully.

In-lab rules:

We have limited space, and you will be working with sensitive electronic components. Therefore:

- ***No food or drinks are allowed inside the lab.*** Be sure to eat properly before your session, you can step out for water if you need to. Notify your TA since he/she is the only person that can grant you access to the lab.
- ***No laptops, notebook computers, tablets, or other electronic gizmos*** allowed during the session.
- ***Bags and backpacks must be stored at the front or back of the room***.
- ***While in the lab, you're responsible for taking good care of all equipment***.
- ***Treat everyone else in the lab with respect and consideration***.
- ***You must listen and follow all instructions provided by your TA***.

How your work will be marked:

Your TA will observe your work during the three hour period.

- 25% of the grade for this lab is given by attending the session and working hard .
- 75% is given for completing your report (both the parts due prior to the start of the session, and all in-lab work).

You will work in pairs, but note:

- Your TA will check both members completed the work labeled ***prior to the lab session.***
- At the end of the lab you will hand in ***a single completed handout per team, be sure to include the student names and student numbers of all team members.***

If you encounter any problems with the software or hardware, bring this to the attention of your TA immediately. If no solution can be found quickly, your TA may have to have you join another team for the duration of the session.

Lab 1 – Implementing Logic Circuits using FPGAs

This lab is designed to allow you to experiment with simple logic circuits and functions. You will study simple Boolean functions first on paper, and then implement these functions on the FPGA board and verify that they behave as predicted.

This will also serve as an introduction to working with the FPGA boards at the lab, and for using the Quartus II software that will allow you to design circuits and program them onto the FPGA.

Learning Objectives:

You will learn to implement simple circuits using the Quartus II software

You will learn to program the FPGA board to implement the circuits you designed

You will learn to test simple logic circuits and verify that they work properly

You will practice the material covered in class regarding Boolean Algebra, truth tables, function simplification, and DNF.

Skills Developed:

Working with truth tables, logic functions, and creating/wiring digital circuits

Working with the Quartus II software and programming the FPGA board

Working as a team in the Embedded Systems lab

Reference material:

This handout. ***Remember that you will hand-in one completed handout at the end of the session.***

The Quartus II handbook (*http://www.altera.com/literature/hb/qts/qts_qii51008.pdf*)

The DE2-115 user manual (inside the Altera System CD directory)

Your lecture notes on Boolean Algebra and logic functions

Acknowledgements: The first part of the handout is based on the Quartus II tutorial from Altera.

Student Names (last, first):

Student Numbers:

We understand that we are responsible for handling the equipment carefully and preserving it in working order

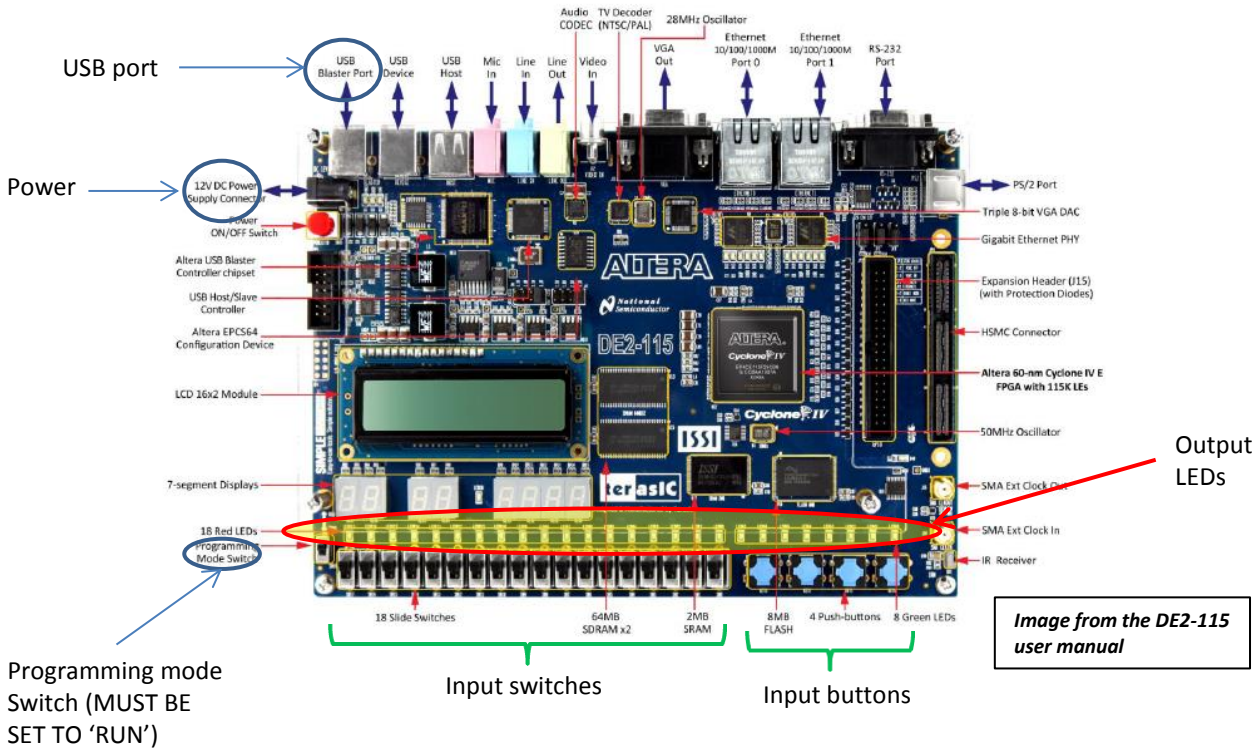
_____ _____

(student's signature 1) ***(student's signature 2)***

You must complete all parts marked as 'prior to the lab session' before your appointed lab section starts. Your TA will check this for each team member at the start of the session.

Part 1 – Getting to know the DE2-115 FPGA board, and implementing a simple logic function using Quartus II

1) Carefully unpack the FPGA board and place is safely on the desk. Connect the power cable to the board and a desk outlet, connect the USB cable to the board's USB 'blaster' port and to a computer USB terminal. ***DO NOT POWER UP THE BOARD yet.***

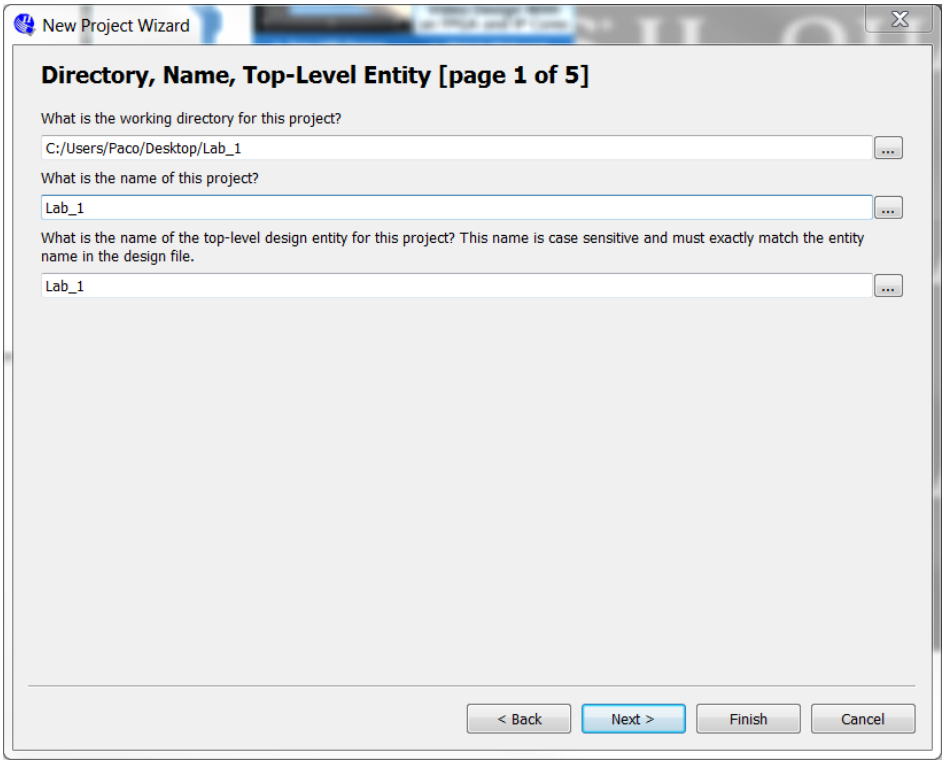


2) Familiarize yourself with the layout of the board, the location of input switches and buttons, output LEDs, and the programming mode switch. This is all we will use for this lab.

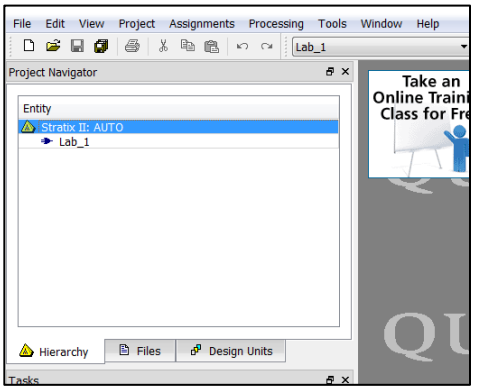
3) Open the Quartus II software. Close the initial information box. Create a new project from ***File -> New Project Wizard***
Create a directory for the project ***on the Desktop***, with name ***Lab_1***
Set the name of the project to ***Lab_1***

Pressing '***next***' at this point would get you advanced configuration options which we will not need for this lab.

Click on '***Finish***' when done.



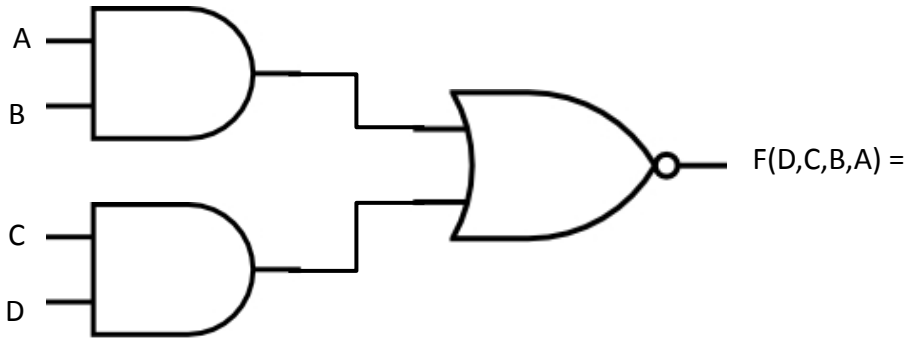
You will see a new project listed on the Quartus II main window:



4) ***To complete prior to the lab session:***

- Write the Boolean Algebra expression for the function whose circuit is shown below
- Complete the truth table for the function

Logic Function #1



Truth Table

D	C	B	A	F(D,C,B,A)

Note the ordering of variables!

Can this function be simplified? (yes/no)

If yes, what is the simplified form? (or N/A)

TA check: Students completed this prior to the session

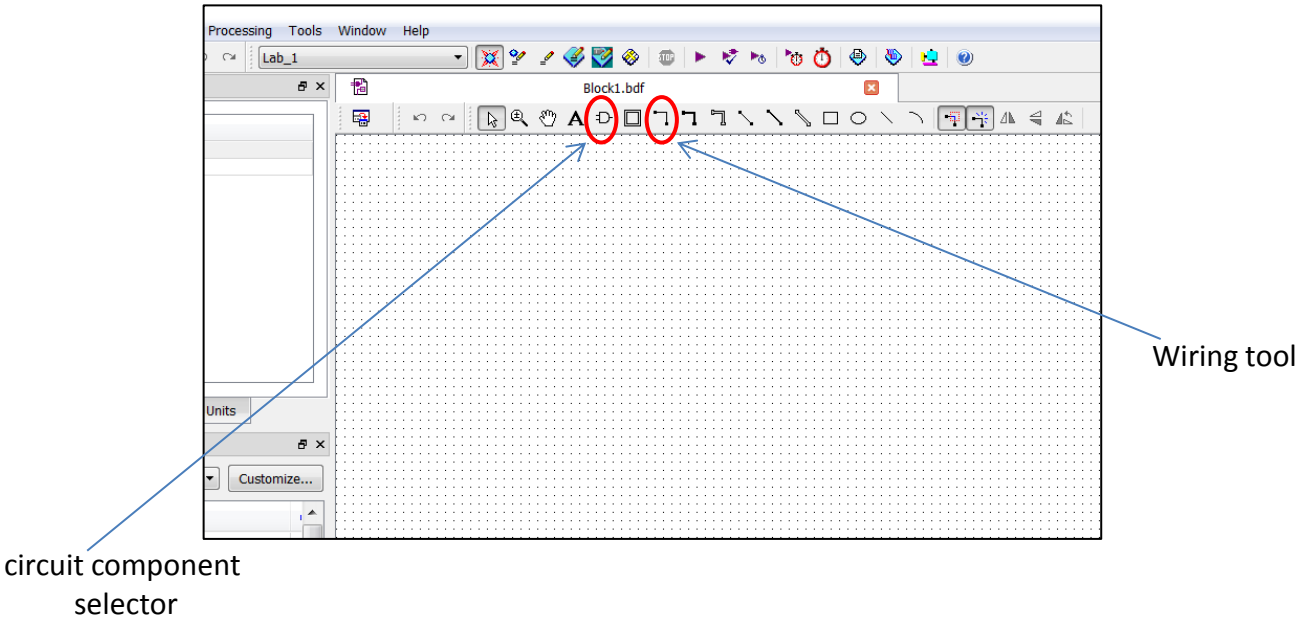
Student 1: ☐

Student 2: ☐

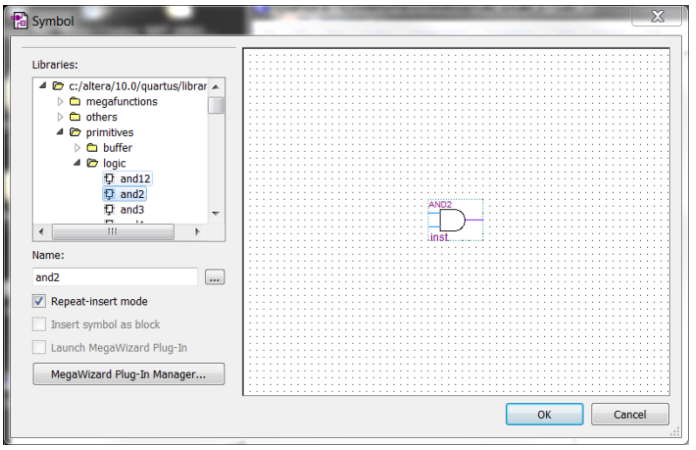
5) Use the Quartus II graphical editor to implement the logic function from the previous page.

To start the graphical editor, use ***File -> New -> Block Diagram/Schematic File***

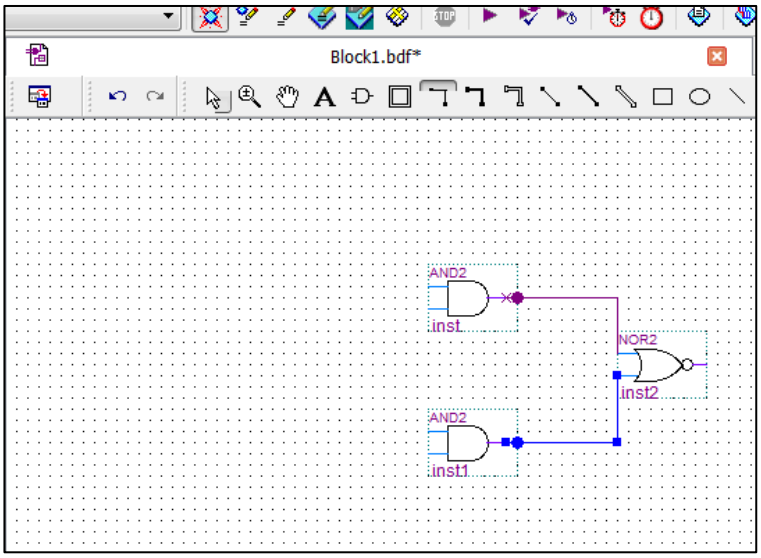
The graphical editor allows you to select and connect all sorts of logic functions and circuit components



For now, we will need only the circuit component selector, and the wiring tool. Click on the circuit component selector, this will bring up a menu with circuit components. Expand the contents of the Altera libraries, and find ***'primitives -> Logic'***. There you will find a list of logic gates. Select and place on the graphical editor the gates needed for the circuit.



5) (cont…) You should see something like the image shown below.



You can use the arrow tool to select and move components around.

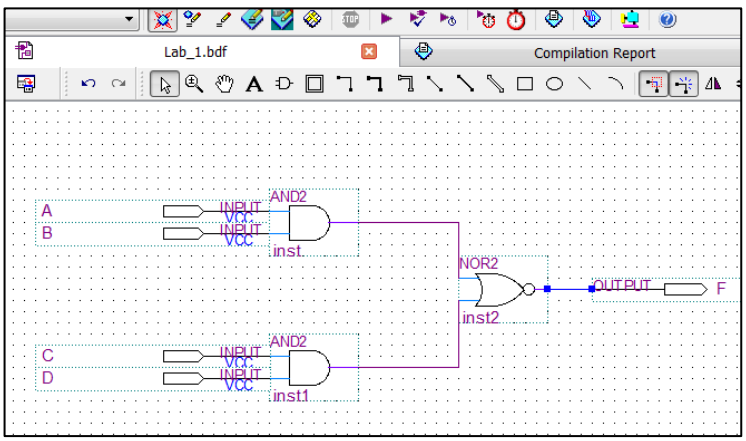
To delete a component simply select it and press 'Delete'

Use the wiring tool to connect the two AND gates to the NOR gate, but do nothing to inputs and outputs for now.

Make sure that the connections are properly set. The graphical editor will mark with a small 'x' any wire that is not properly connected to anything.

6) Set the inputs and outputs for the circuit

Use the circuit components selector, and go to '***primitives -> pin***'. You will need one input pin for each input variable, and one output pin for the output function. Set the pin names to the correct variable names.



Make sure the inputs and output are properly connected to the gates

At this point, save your work using ***File -> Save All***

Then go to
Processing ->
Start Compilation

If you did everything correctly your circuit will compile. If you get errors, check wiring and connections and compile again. ***You can not proceed until your circuit compiles successfully.***

7) ***Do not start this part until you have a circuit that compiles successfully.***

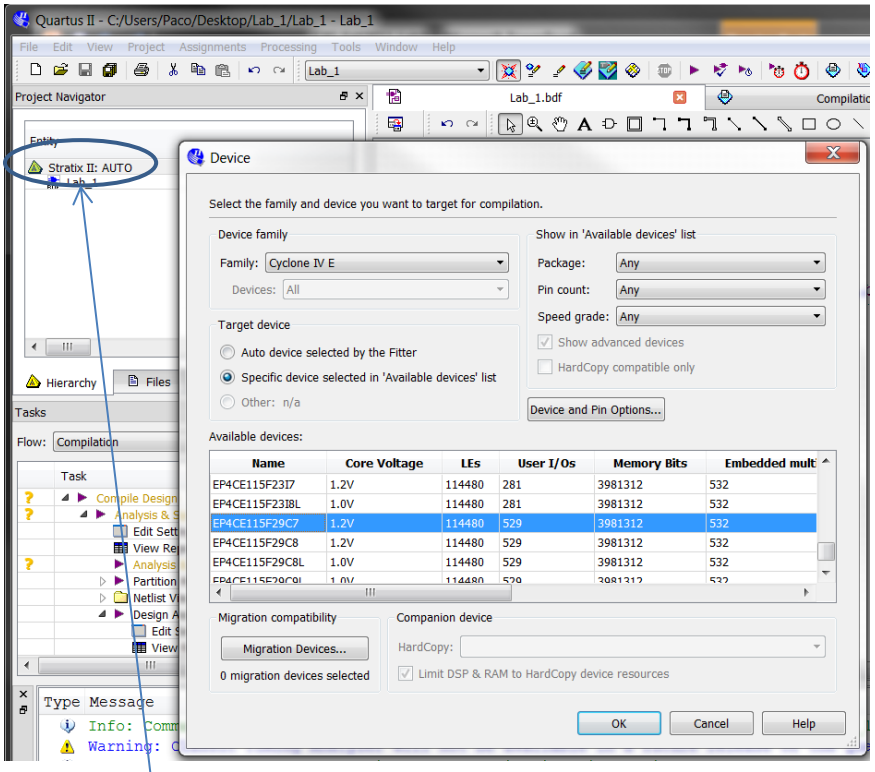
Before programming the FPGA, we have to map inputs and outputs in our circuit to input and output elements in the DE2-115 board.

We have at our disposal a set of 18 switches, and four push buttons to use as input. We also have 18 LEDs to use for output purposes.

For this part we will use the four switches (***SW0*** to ***SW3***) and one green LED (***LEDG0***). Locate these components on the FPGA board.

Be very careful here, choosing the wrong device will void your design and possibly cause problems when attempting to program the device.

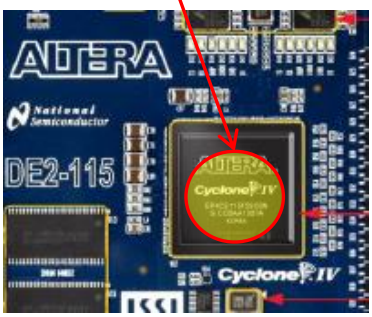
On the '***Entity***' window, ***right-click*** on 'Stratix II (AUTO)', select '***device***'.



Right-click here

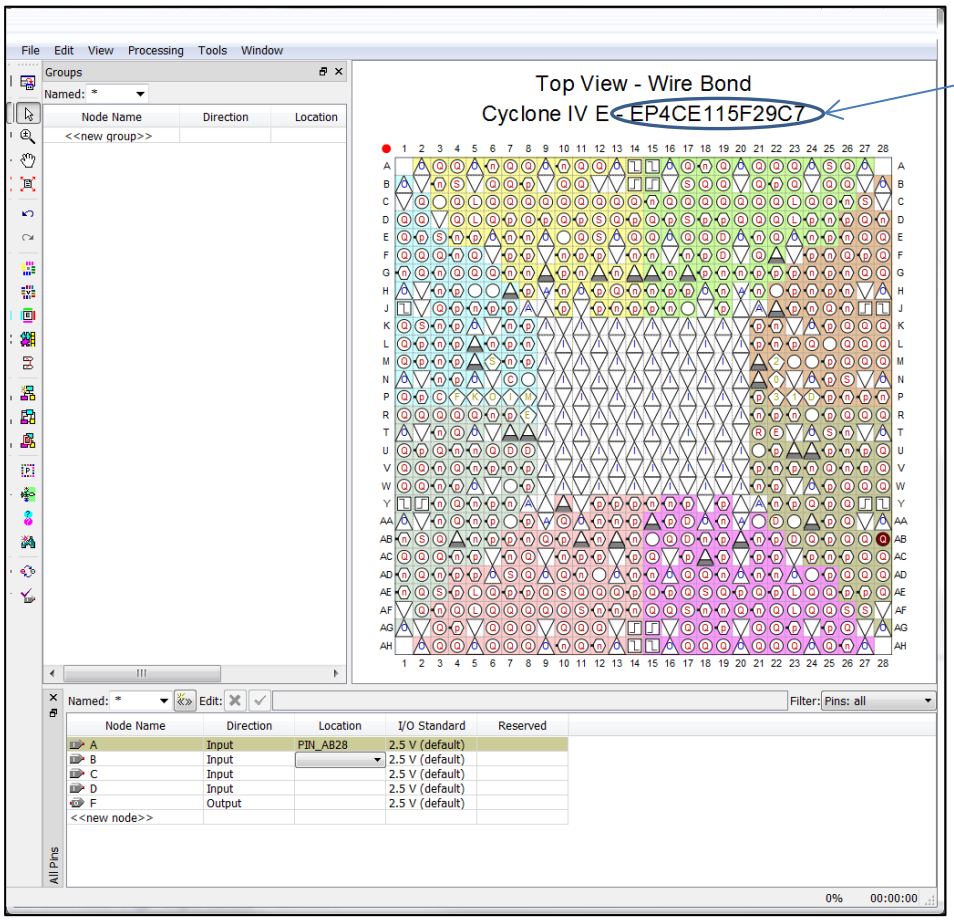
Select ***Cyclone IV E*** for 'family', click on '***Specific device selected…***' and choose **EP4CE115F29C7** as the device.

Double-check that the above matches the device type printed on the FPGA on the DE2-115 board



8) In Quartus II, go to ***Assignments -> Pin Planner***

If you selected the device correctly, you will see a pin diagram for the FPGA, along with a list of the input and output pins in your circuit.



Check you have the correct device

Check the DE2-115 user user manual for the mapping of switches and LEDs to pins, this can be found in ***Table 4-1***, on page 35.

For example, to assign input ***A*** to switch ***SW0***, the manual indicates we should use ***PIN_AB28***. Double-click on the ***'Location'*** column for input ***A***, and select ***PIN_AB28*** for this input.

Repeat the process for the remaining variables, and ***complete the table below with the correct pin assignments as given by the DE2-115 user manual.***

Variable	*Assigned to*	*Type (Input/Output)*	*PIN on FPGA*
A	SW0		
B	SW1		
C	SW2		
D	SW3		
F	LEDG0		

9) Programming the FPGA

Save your work, compile the project and fix any errors found at this stage.

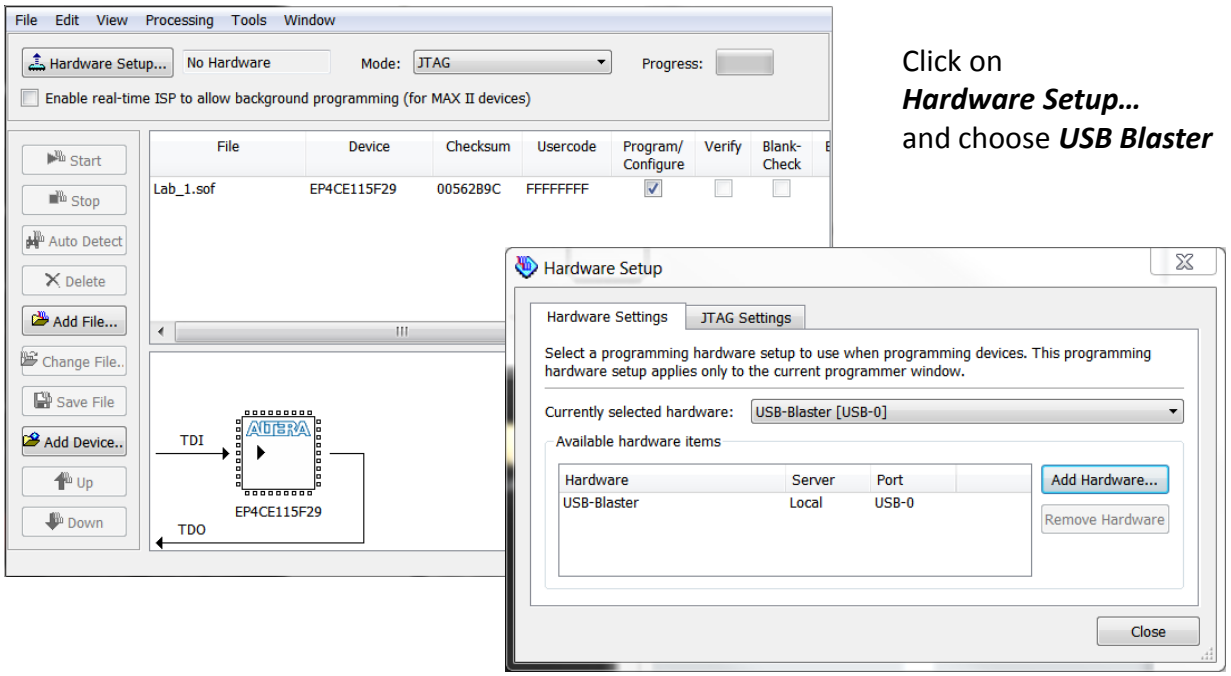
Turn your attention now to the DE2-115 board

- Make sure power and USB connections are set up properly
- Make sure the programming mode switch is set to '***RUN***' (see page 2)

Turn on the FPGA board by pressing the red power button.

You should see the welcome message on the LCD display, the numeric displays will be cycling digits, and the LEDs will be flashing. Wait a few seconds for the computer to recognize the board and load the appropriate drivers.

Now in Quartus II go to ***Tools -> Programmer*** which brings up the window shown below



Click on
Hardware Setup…
and choose ***USB Blaster***

To program your design onto the FPGA board, press ***Start***.

After the operation completes, the DE2-115 will have turned into the circuit you designed!

10) Testing

Now proceed to test that the circuit is indeed working to implement the logic function you designed.

Use SW0-SW3, to provide values for A, B, C, and D. The ordering of the variables should be such that A is the least-significant bit, and D is the most-significant bit.

Write the value of the output corresponding to all possible inputs (i.e. the truth table for the circuit) below.

Circuit Output

D	C	B	A	Output

Does this output table agree with the truth table you obtained for the circuit in Page 4? (yes/no)

Once you have completed your testing, call your TA to check your work so far

Reviewed by TA and found correct curing lab session

☐

TA check mark and initials

11) Part 2 – Implementing a function in DNF using the DE2-115.

To complete prior to the lab session:

Analyze the truth table before, and write the function in DNF form that implements it.

Truth Table

D	C	B	A	F(D,C,B,A)
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	0	0	0
0	1	0	1	1
0	1	1	0	0
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	0
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0

TA check: Students completed this prior to the session

Student 1: ☐

Student 2: ☐

The DNF form for the function shown above is:

F(D,C,B,A) =

This function can be implemented using 2 levels of NAND gates plus a handful of inverters. How many NAND gates are required to implement the function shown above?

Can the function above be simplified (yes/no), if yes, show the simplification process and simplified function.

12) Implement the function on the DE2-115 board

Close the project for the previous part, and create a new project on the Desktop called ***Lab_1b***.

Use the graphical designer to implement the function from the previous page using NAND gates and inverters.

Just like for the first part, we will assign:

- ***A*** to ***SW0***
- ***B*** to ***SW1***
- ***C*** to ***SW2***
- ***D*** to ***SW3***
- ***F(D,C,B,A)*** to ***LEDG0***

You can use the same pin assignments you recorded on page 8

Be careful and double-check all your wiring, input and output connections, and pin assignments.

Once you have a complete design that compiles without errors, program it onto the FPGA and test it. Record the output of your circuit in the table below.

Circuit Output

D	C	B	A	F(D,C,B,A)

Does this table agree with the truth table shown in the previous page?

If you found any disagreements, what procedure would you follow to find and correct 'bugs' in your circuit design?

Once you're done testing, call your TA to verify your work.

☐ ***TA please check and initial if the circuit is correct***

13) Wrapping up (10 minutes before the end of the session)

Power-down and carefully store the DE2-115 board, bring the boards and cables to the storage locker your TA will indicate.

On the Desktop. Locate the folders for ***Lab_1***, and ***Lab_1b***. Select ***both*** folders and create a .zip file containing all your work.

e-mail this .zip file to the ***course instructor*** with the following subject:

'***CSCB58, Lab 1'*** (without the quotes!)

Inside the email, note the name and student numbers of each team member.

Don't forget to attach the .zip file! It is a good idea to send a copy to yourselves for backup.

14) Post-session feedback. ***You must complete this prior to handing-in this report to your TA and leaving the lab. There are no incorrect answers, but writing thoughtful/useful feedback will be part of your grade for this session.***

- Briefly comment on what learned during this session

- Did this exercise improve your understanding of (circle as appropriate):
  - Logic circuits (yes/no)
  - Truth tables (yes/no)
  - DNF and implementing DNF functions with NAND gates (yes/no)

- Do you find this lab to have provided you with a worthwhile learning experience? (comment briefly on your answer please)

- Any other thoughts or comments:

TA Check: Team handed back a complete, properly packed FPGA board set. ☐