

UNIVERSITY OF CALIFORNIA AT BERKELEY
COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Lab 3

Verilog Synthesis & FSMs

1.0 Motivation

In Lab 1, you became acquainted with Synplify as well as the Xilinx Place and Route tools. In Lab 2, you worked with ModelSim and Verilog to produce a working design. This lab is designed to give you a chance to bring those skills together to design, specify and then implement a fully working Finite State Machine in Verilog, using a combination lock as an example.

For this lab we have given you all of the support modules and design that are necessary. Your job is to take our high level design and translate it into working Verilog. To do this you will need to use good Verilog coding style, acquaint yourself with the Verilog language, and become at least somewhat proficient with the CAD tools.

2.0 Introduction

In this lab you will be making a **2-bit, two digit combination lock** such as those sometimes found on secure doors. The inputs to the lock consist of **two code switches** and **three buttons**. The **code switches** (SW9[2:1]) are used to enter the digits in the combination. The three buttons are **Reset** (SW1), which is used to reset the lock, **Enter** (SW2), which is used to enter a digit of the combination, and **ResetCombo** (SW6), which would not be accessible normally and which resets the combination that opens the lock to a default value.

To operate the lock, a user would:

1. **Set the code** on SW9[2:1] to the **first digit** and **press enter** (SW2).
2. **Set the code** on SW9[2:1] to the **second digit** and **press enter** (SW2).
3. The lock will **Open**.
4. The user would then **press enter** (SW2).
5. **Set the code** on SW9[2:1] to the **new first digit** and **press enter** (SW2).
6. **Set the code** on SW9[2:1] to the **new second digit** and **press enter** (SW2).
7. Cycle back to **Step 3** above ...

When someone gets the combo wrong it would go like this:

1. **Set the code** on SW9[2:1] to a **wrong digit** and **press enter** (SW2).
2. **Set the code** on SW9[2:1] to **any digit** (right or wrong) and **press enter** (SW2).
3. The lock will show **Error**
4. The lock will stay in this state until the user **presses Reset** (SW1).

3.0 Prelab

Please make sure to complete the prelab before you attend your lab section. **You will not be able to finish this lab in 3 hrs otherwise!**

1. **Read this handout thoroughly.** Pay particular attention to Section **4.0 Lab Procedure** as it describes in detail the circuits you must create.
2. **Examine the Verilog** provided for this weeks lab.
 - a. Most of the modules you have seen before.
 - b. Make sure you **understand FPGA_TOP2** as it instantiates your module, and **handles the I/O**.
3. **Write your Verilog ahead of time.**
 - a. **Lab3Lock.v**
 - i. Your lock FSM, which instantiates the comparator
 - b. **Lab3Testbench.v**
 - i. A testbench for the lock FSM
 - ii. Make sure that this tests **as much of the lock and comparator as possible**.
 - iii. Refer to **past testbenches** as a starting point.
4. You will need the **entire 3 hr lab** to **test and debug** your Verilog!
 - a. Remember it has to pass **simulation** and **synthesis**

4.0 Lab Procedure

Since we expect you to write your Verilog ahead of time, and Verilog is nothing more than a bunch of standard text in a file with a *.v extension, **you can do this part of the lab entirely from home** in your favorite text editor (we recommend **notepad**). Or you can come into the lab and use the tools there. For those of you who like maintaining a single Xilinx Project Navigator project for each lab, you can even **create the project ahead of time and write your Verilog from within Project Navigator**.

Remember to **manage your Verilog, projects and folders well**. Doing a poor job of managing your files can cost you **hours of rewriting code**, if you accidentally delete your files.

4.1 Lab3Top

The Lab3Top module is very simple and does not need to contain any behavioral Verilog. The Lab3Top module **simply instantiates the Lab3Lock FSM and Lab3Compare modules**, and **ties them together** with the appropriate signals.

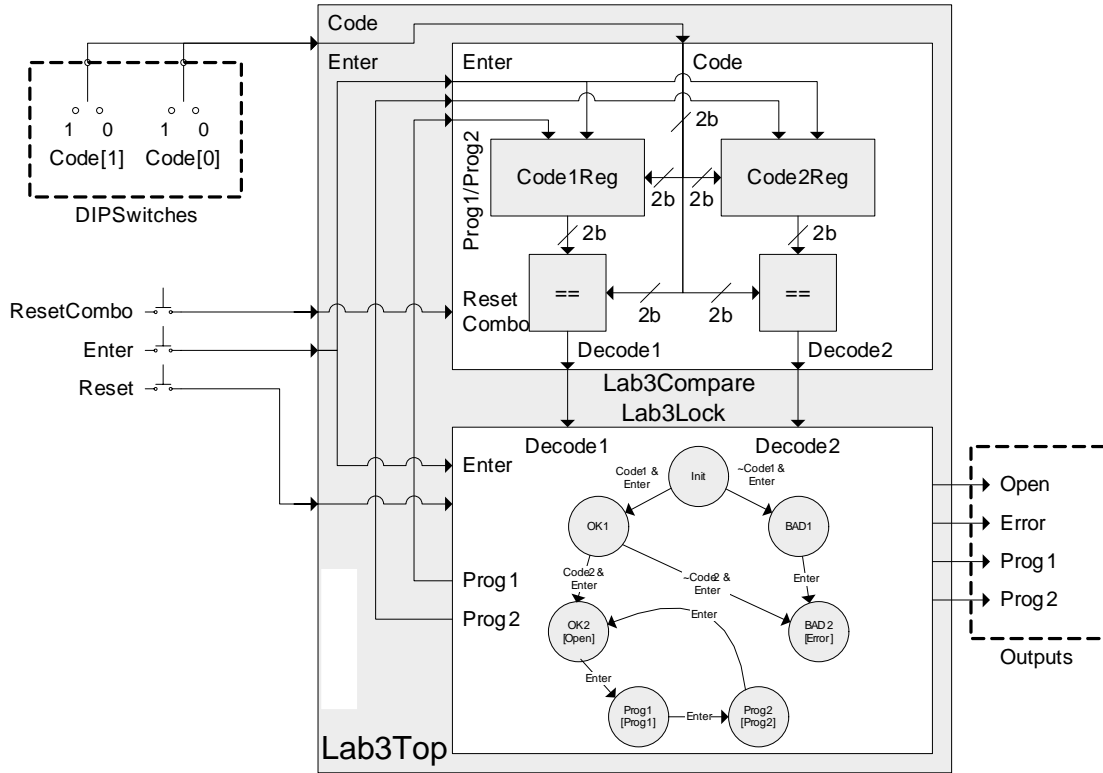


Figure 1: Lab3Top Block Diagram

To **simplify the Lab3Lock FSM** and make the whole lock design more flexible we have separated the FSM and the comparator, which **compares the value on the switches to the digits of the combination**. Essentially the code input from the switches is fed into the Lab3Compare module, which determines the **Decode1** and **Decode2** signals needed by the Lab3Lock FSM. Based on these, and the **Enter** and **Reset** buttons, the Lab3Lock tracks its state and generates the appropriate outputs.

Table 1 below shows the inputs and outputs from the Lab3Top module.

Signal	Width	Dir	Description
Code	2	I	The code value from dipswitch SW9[2:1]
Enter	1	I	The Enter button (SW2)
ResetCombo	1	I	Reset the combination to the default (SW6)
Clock	1	I	The Clock signal
Reset	1	I	Reset the FSM to the Init state (SW1)
Open	1	O	Indicates that the lock is open (OK2 state)
Error	1	O	Indicates that the wrong combo was entered (BAD2 state)
Prog1	1	O	Indicates that the lock will accept a new 1 st digit
Prog2	1	O	Indicates that the lock will accept a new 2 nd digit
LED	8	O	Debug outputs, for your use on the board

Table 1: Port Specification for Lab3Top

4.2 Lab3Lock

In this lab you will be building primarily the Lab3Lock module, a relatively simple FSM. This module is responsible for maintaining the **state of the lock** and generating the **outputs to show the lock's status** to the user.

Below are: a table of the inputs and outputs from the Lab3Lock module and a bubble-and-arc diagram of the finite state machine.

Signal	Width	Dir	Description
Decode1	1	I	Indicates that the switches match the 1 st digit of the combo
Decode2	1	I	Indicates that the switches match the 2 nd digit of the combo
Enter	1	I	The Enter button (SW2)
Clock	1	I	The Clock signal
Reset	1	I	Reset the FSM to the Init state (SW1)
Open	1	O	Indicates that the lock is open (OK2 state)
Error	1	O	Indicates that the wrong combo was entered (BAD2 state)
Prog1	1	O	Indicates that the lock will accept a new 1 st digit
Prog2	1	O	Indicates that the lock will accept a new 2 nd digit
LED	8	O	Debug outputs, for your use on the board

Table 2: Port Specification for Lab3Lock

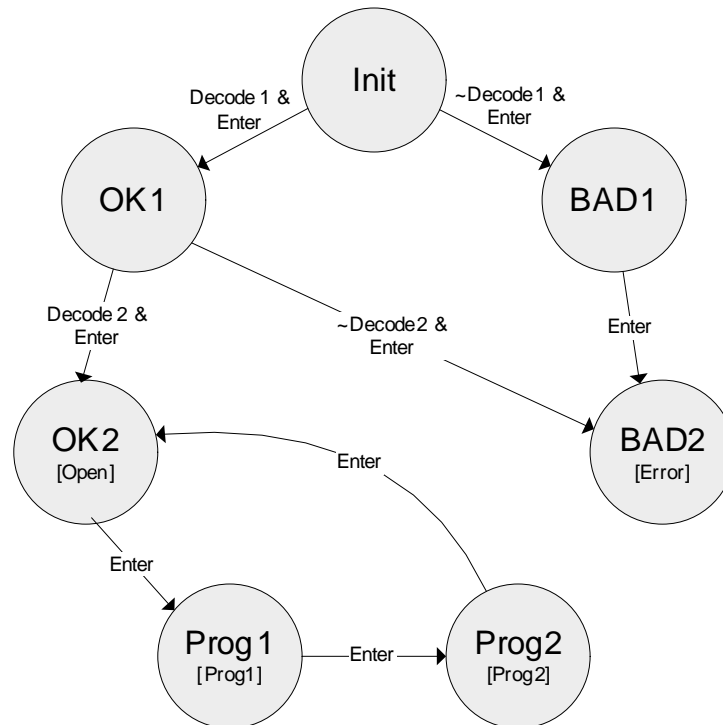


Figure 2: Bubble-and-Arc Diagram for Lab3Lock

Notice that Figure 2 uses some **shorthand notation**. First, there are no arcs labeled **Reset**. That is because a high on the **Reset** input will **ALWAYS return the FSM to the Init state**. Also of note is the output specifications in [], where only the outputs which are actually **asserted in a given state** are shown.

As a note on **optimization**, you should examine the relationship between state changes and the **Enter signal**. You may be able to **simplify your Verilog** if you are clever.

4.3 Lab3Compare

You should keep in mind that this module has been built for you. We are providing this documentation to make the operation of this module very clear.

It is the responsibility of the Lab3Compare module to **generate the Decode1 and Decode2 signals**, which indicate that the Code **input matches the 1st and 2nd digits** of the combination respectively. Therefore the Lab3Compare module is **essentially a pair of combinational comparators**.

However to **make the combination on our lock programmable**, this module has a **pair of registers** to remember what the 1st and 2nd digits of the combination actually are. **To set up a default combination** the ResetCombo input will **forcibly set these registers to 2'b11 and 2'b01 respectively**.

In order to program new combinations, when the Prog1 and Enter signals are high, the register for the **1st digit will store whatever value is on the Code input as the new 1st digit**. Similarly, when the Prog2 and Enter signals are high the register for the **2nd digit will store the new 2nd digit**.

Signal	Width	Dir	Description
Code	2	I	The code value from dipswitch SW9[2:1]
Decode1	1	O	Indicate that that Code matches the 1 st digit of the lock
Decode2	1	O	Indicate that that Code matches the 2 nd digit of the lock
Prog1	1	I	Indicates that the lock will accept a new 1 st digit
Prog2	1	I	Indicates that the lock will accept a new 2 nd digit
Enable	1	I	Enable the loading of new combination digits (driven by the Enter button, SW2)
Clock	1	I	The Clock signal
Reset	1	I	Reset the combination to 2'b11, 2'b01 (SW6)

Table 3: Port Specification for Lab3Compare

5.0 Lab 3 Checkoff

Name: _____ SID: _____
 Name: _____ SID: _____
 Section: _____

I Quality of Verilog
 1 Lab3Top _____ (8%)
 2 Lab3Lock _____ (12%)
 II Full Simulation _____ (40%)
 III Working Synthesized Lock _____ (40%)

IV Hours Spent: _____

V Total: _____

VI TA: _____

RevD – 8/14/2005	Randy Katz	Various edits and grammatical corrections
RevC – 1/18/2005	Greg Gibeling	Added errata from Fall 2004 Migrated to Lab4
RevB – 7/10/2004	Greg Gibeling	Complete Rewrite of Lab4 Based on the old Lab4
RevA	Multiple	Original Lab4 from Fa02-Sp04 Spring 2004: Greg Gibeling Fall 2003: Greg Gibeling Spring 2003: Sandro Pintz Fall 2002: John Wawrzynek & L.T. Pang