CS 2110 Homework 4
State Machines

Vivian Thiebaut, Soha Jiwani, Joshua Viszlai, Sam Gilson

Fall 2019

Contents

1 Overview

For this assignment, we'll be working with Flip Flops, state machines and K-maps. This will be a 3 part assignment.

Objectives:
1. Understand how information is stored in a computer
2. To learn how to make a state machine
3. To become familiar with different state machine style
4. To understand K-maps and their usefulness

2 Instructions

Part 1: For this part of the assignment you will build your own register from scratch.

- Implement your circuits in the "latches.sim" file

Part 2: Given a simple state diagram, you will build a state machine in CircuitSim using the "one-hot" style of building state machines.

- The circuit will be implemented in the "One-Hot FSM" subcircuit of the "fsm.sim" file

Part 3: Given the same state diagram from part 1, you will be minimizing the logic by using K-Maps.

- Fill out the K-Maps located in the spreadsheet named "kmap.xlsx"
- The reduced circuit will be implemented in the "Reduced FSM" subcircuit of the "fsm.sim" file

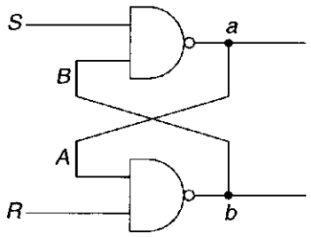
In general, do not change/delete any of the input/output pins.
For parts 2 and 3 of this homework, you must use exactly 1 register. These are found under the Memory tab in CircuitSim. Failure to do so may result in large point deductions.

2.1 Part 1

For this part of the assignment you will build your own register from the ground up. For more information about each subcircuit refer to your textbook.

2.1.1 RS Latch

We will be building a RS latch using NAND gates, as described in your textbook. RS Latch is the basic circuit for sequential logic. It stores one bit of information, and it has 3 important states:
R=1 S=1 (The Quiescent State)
R=1 S=0
R=0 S=1
The Quiescient State is when the latch is storing a value, and nothing is trying to change that value. In order to momentarily change the output to 0 you must change the R input to 0, while keeping the S input as 1. To set the output to 1, you must keep R as 1, and change S to 0. Once you set the bit you wish to store, change back to the Quiescent State to keep that value stored. Notice that the circuit has two output pins; one is the bit the latch is currently storing, and the other is the opposite of that bit. Note: In order for the RS Latch to work properly, both S and R must never be set to 0 at the same time.



- Build your circuit in the "RS Latch" subcircuit in the "latches.sim" file

2.1.2 Gated D Latch

Using your RS latch subcircuit, implement a Gated D Latch as described on the textbook. The Gated D Latch is made up of an RS Latch as well as two additional gates that serve as a control so we can choose when to save the output, and what to save it as. The value of the output can only be changed when Write Enable is set to 1. Notice that the Gated D Latch subcircuit only has one output pin, so you should disregard the inverse output of your RS Latch.

- Implement this circuit in the "Gated D Latch" subcircuit in the "latches.sim" file
- You are not allowed to use the built-in SR Flip-Flop in CircuitSim to build this circuit

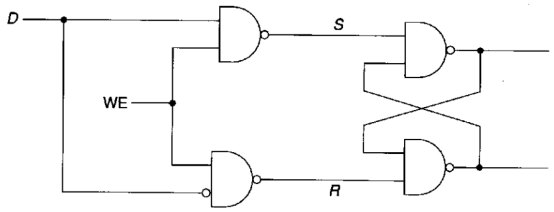
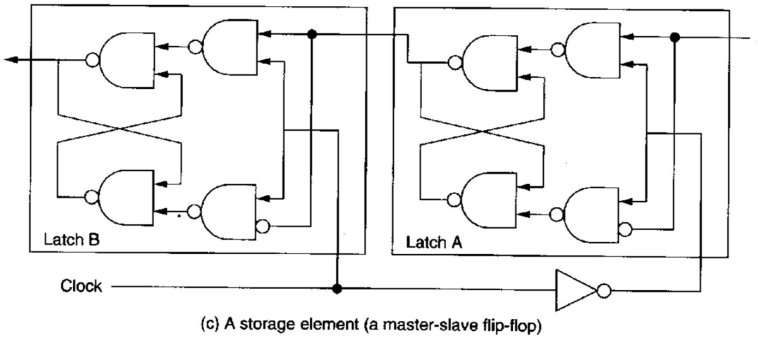


Figure 3.19 A gated D latch

2.1.3 D Flip-Flop

Using the Gated D Latch, create a D Flip-Flop. A D Flip-Flop is composed of two Gated D Latches back to back, and it implements edge triggered logic. Your D Flip-Flop output should be able to change on the **rising edge**, which means that the state of the register should only be able to change at the exact instant the clock goes from 0 to 1.

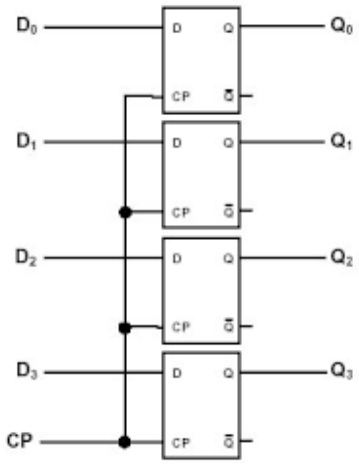
- Implement this circuit in the "D Flip-Flop" subcircuit in the "latches.sim" file.



(c) A storage element (a master-slave flip-flop)

2.1.4 Register

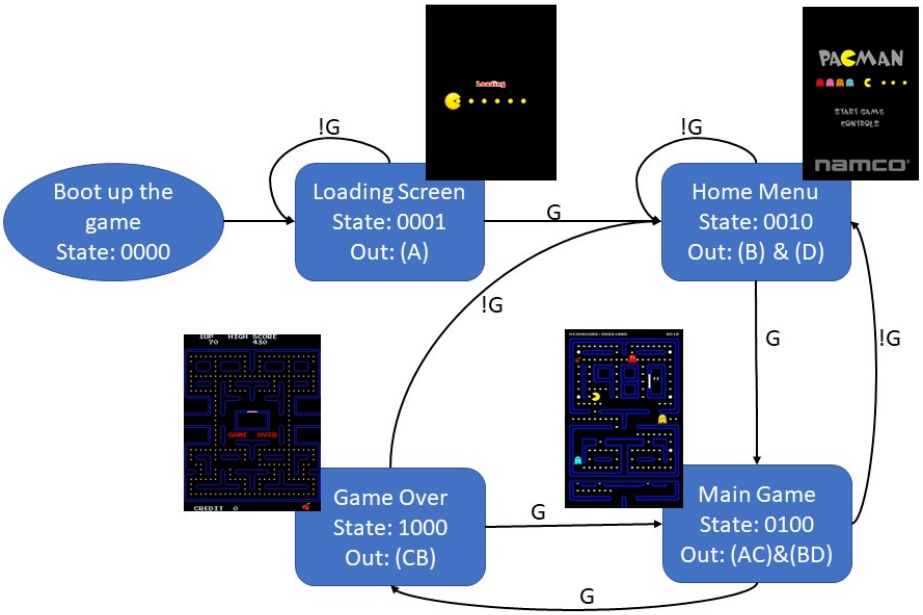
Using the D Flip-Flop you just created, build a 4-bit Register. Your register should also use edge-triggered logic.



- This circuit will be implemented in the "Register" subcircuit in the "latches.sim" file

2.2 Part 2

Take a look at this state machine transition diagram. We are using an example of a game to explain the diagram. The input G represents some event that carries the player through all the game states. The outputs A, B, C, D represent different game attributes that occur based on the current game state (Ex. Output D represents the theme song of the game being played).



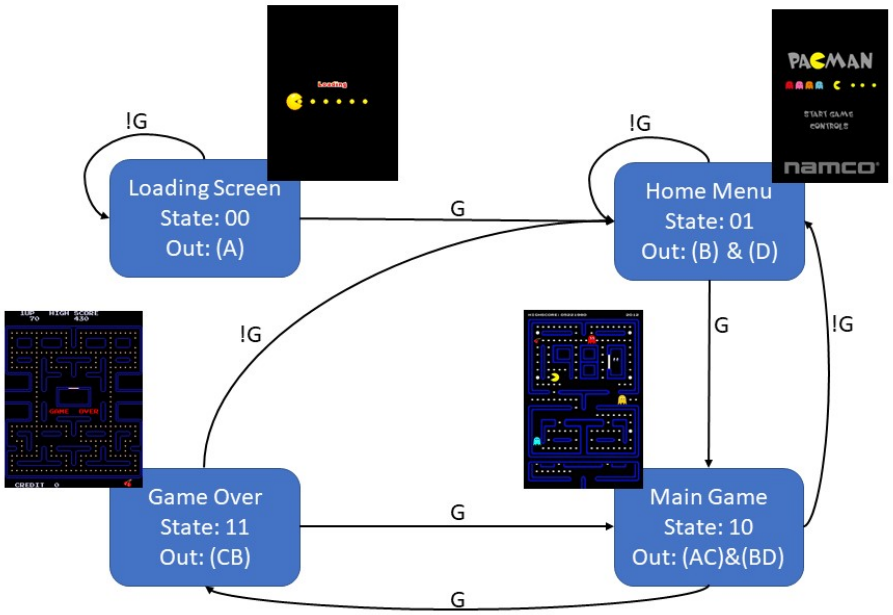
OUTPUT	SCREEN
A	Load Screen
B	Start Screen
AC	Main Game Screen

OUTPUT	MUSIC
D	Theme Song
BD	Main Game Song
CB	Defeat Song

- You will be implementing this state transition diagram as a circuit using the one-hot style. Remember for one-hot you will have a register with the number of bits being the number of states you have. Each bit corresponds to a state, and you are in that state if the corresponding bit is a 1. Only one of these bits will be on at a time (the only exception being when the state machine starts up). At most, one of the inputs will be turned on.
- You must implement this using one-hot. A template file fsm.sim has been given to you. Implement the state machine in the provided "one-hot state machine" subcircuit.
- Note that there are 3 inputs to the "one-hot state machine" subcircuit: CLK, G, and RST. The CLK input turning off and on repeatedly will be used to represent clock ticks in your circuit. The G input corresponds to whether or not G is on, as in the diagram above. RST corresponds to an attempt to reset your circuit.

2.3 Part 3

Take a look at this state machine transition diagram. Again, we are using an example of a game to explain the diagram. The input G represents some event that carries the player through all the game states. The outputs A, B, C, D represent different game attributes that occur based on the current game state (Ex. Output D represents the theme song of the game being played).



OUTPUT	SCREEN
A	Load Screen
B	Start Screen
AC	Main Game Screen
OUTPUT	**MUSIC**
D	Theme Song
BD	Main Game Song
CB	Defeat Song

- First, produce the k-maps for the state diagram above on the provided spreadsheet named "kmap.xlsx". Use the k-maps to produce the reduced boolean expressions for the state machine.

  The inputs for the k are:

  - $S0$ = Current State 0th bit (least significant)
  - $S1$ = Current State 1st bit (most significant)
  - G

  The outputs for the k-maps are:

  - $N0$ = Next State 0th bit (least significant)
  - $N1$ = Next State 1st bit (most significant)
  - A, B, C, D

  Please Note: This State Machine is a Moore State Machine, meaning that the output values are determined solely by the current state (you should not use the N_1 and N_0 outputs for determining the values for A, B, C, D.

  - You will fill out one K-map per output and one per next state bit for a total of 6 K-maps ($N1$, $N0$, A, B, C, D). The respective K-maps are located in the kmap.xlsx file.
  - Your K-map must give the BEST minimization possible to receive full credit. This means you must select the BEST values for the don't cares in your K-maps to do this.
  - It may be helpful to check with others on piazza to see if your circuit is optimal. In order to do this without giving away your answer you may share the number of AND and OR gates used.
  - **IMPORTANT:**The k-maps are gonna be autograded, and because of that there are a set of restrictions to how you must fill your k-maps to ensure you get full credit:

    * When you fill the row and column headers for your k-maps you must only use the following variable names: $S0$, $S1$, G. They must be capitalized and have no space between them. To negate a variable you must use an apostrophe.
      Example: $S0'G$
    * When writing the boolean expresions resulted from your k-map groupings, you must use the same rules as the previous bullet point, but also use "+" for OR with no spaces between and no space between variable for AND.
      Example: S0'+S1G

- Implement this circuit in the "reduced state machine" subcircuit of the provided fsm.sim file. You will lose points if your circuit does not correspond to your K-map or if your circuit is not minimal. You should use only the minimal components possible to implement the state machine.
- **HINT:** We recommend you make a truth table for the state machine to help organize the logic, and then transfer it to the k-maps. We've provided truthtable.xlsx to help with this.
  Note: you do not need to submit truthtable.xlsx anywhere, it's just for your use in helping make K-maps.

3 Testing

To test your **circuits** locally, navigate to the directory with the latches.sim and fsm.sim files and run the tester jar file via

```
java -jar hw04-checker.jar
```

To test your K-maps, please submit your kmap.xlsx to the Homework 04 K-maps assignment on Gradescope.

4 Deliverables

You will need to submit latches.sim, fsm.sim, and kmaps.xlsx to the Homework 04 assignment on Gradescope.

The sim files and the kmaps will be autograded on gradescope.

Note: The checker may not reflect your actual grade on this assignment. We reserve the right to update the checker as we see fit when grading.

5 Demos

This homework will be demoed.
The demos will be ten minutes long and will occur in the CS2110 TA lab - COC 104b during the week of September 23rd - September 27th.

- Demo signups will go up by September 20th and you can sign up for a demo via the calendar on Canvas
- You must sign up for your demo at least 24 hours in advance
- If you cannot make any of the available demo signups, email the Head TA at viszlai@gatech.edu **by Monday September 23rd**. This is the only way you can ensure you will have a demo.
- Your demo is 30 points of your Homework 04 grade. If you miss your demo you will not receive these points and the maximum you can receive on the homework is a 70%.

- You cannot cancel your demo within 24 hours or else you will lose all 30 of your demo points.
- You will be able to makeup one of your demos at the end of the semester for 50% of the demo grade.

6 Rules and Regulations

6.1 General Rules

1. Starting with the assembly homeworks, any code you write must be meaningfully commented. You should comment your code in terms of the algorithm you are implementing; we all know what each line of code does.
2. Although you may ask TAs for clarification, you are ultimately responsible for what you submit. This means that (in the case of demos) you should come prepared to explain to the TA how any piece of code you submitted works, even if you copied it from the book or read about it on the internet.
3. Please read the assignment in its entirety before asking questions.
4. Please start assignments early, and ask for help early. Do not email us the night the assignment is due with questions.
5. If you find any problems with the assignment it would be greatly appreciated if you reported them to the author (which can be found at the top of the assignment). Announcements will be posted if the assignment changes.

6.2 Submission Conventions

1. All files you submit for assignments in this course should have your name at the top of the file as a comment for any source code file, and somewhere in the file, near the top, for other files unless otherwise noted.
2. When preparing your submission you may either submit the files individually to Canvas/Gradescope or you may submit an archive (zip or tar.gz only please) of the files. You can create an archive by right clicking on files and selecting the appropriate compress option on your system. Both ways (uploading raw files or an archive) are exactly equivalent, so choose whichever is most convenient for you.
3. Do not submit compiled files, that is .class files for Java code and .o files for C code. Only submit the files we ask for in the assignment.
4. Do not submit links to files. The autograder does not understand it, and we will not manually grade assignments submitted this way as it is easy to change the files after the submission period ends.

6.3 Submission Guidelines

1. You are responsible for turning in assignments on time. This includes allowing for unforeseen circumstances. If you have an emergency let us know **IN ADVANCE** of the due time supplying documentation (i.e. note from the dean, doctor's note, etc). Extensions will only be granted to those who contact us in advance of the deadline and no extensions will be made after the due date.
2. You are also responsible for ensuring that what you turned in is what you meant to turn in. After submitting you should be sure to download your submission into a brand new folder and test if it works. No excuses if you submit the wrong files, what you turn in is what we grade. In addition, your assignment must be turned in via Canvas/Gradescope. Under no circumstances whatsoever we will accept any email submission of an assignment. Note: if you were granted an extension you will still turn in the assignment over Canvas/Gradescope.

3. There is a 6-hour grace period added to all assignments. You may submit your assignment without penalty up until 11:55PM, or with 25% penalty up until 5:55AM. So what you should take from this is not to start assignments on the last day and plan to submit right at 11:54AM. You alone are responsible for submitting your homework before the grace period begins or ends; neither Canvas/Gradescope, nor your flaky internet are to blame if you are unable to submit because you banked on your computer working up until 11:54PM. The penalty for submitting during the grace period (25%) or after (no credit) is non-negotiable.

6.4 Syllabus Excerpt on Academic Misconduct

Academic misconduct is taken very seriously in this class. Quizzes, timed labs and the final examination are individual work.

Homework assignments are collaborative, In addition many if not all homework assignments will be evaluated via demo or code review. During this evaluation, you will be expected to be able to explain every aspect of your submission. Homework assignments will also be examined using computer programs to find evidence of unauthorized collaboration.

What is unauthorized collaboration? Each individual programming assignment should be coded by you. You may work with others, but each student should be turning in their own version of the assignment. Submissions that are essentially identical will receive a zero and will be sent to the Dean of Students' Office of Academic Integrity. Submissions that are copies that have been superficially modified to conceal that they are copies are also considered unauthorized collaboration.

You are expressly forbidden to supply a copy of your homework to another student via electronic means. This includes simply e-mailing it to them so they can look at it. If you supply an electronic copy of your homework to another student and they are charged with copying, you will also be charged. This includes storing your code on any site which would allow other parties to obtain your code such as but not limited to public repositories (Github), pastebin, etc. If you would like to use version control, use github.gatech.edu

6.5 Is collaboration allowed?

Collaboration is allowed on a high level, meaning that you may discuss design points and concepts relevant to the homework with your peers, share algorithms and pseudo-code, as well as help each other debug code. What you shouldn't be doing, however, is pair programming where you collaborate with each other on a single instance of the code. Furthermore, sending an electronic copy of your homework to another student for them to look at and figure out what is wrong with their code is not an acceptable way to help them, because it is frequently the case that the recipient will simply modify the code and submit it as their own. Consider instead using a screen-sharing collaboration app, such as `http://webex.gatech.edu/`, to help someone with debugging if you're not in the same room.

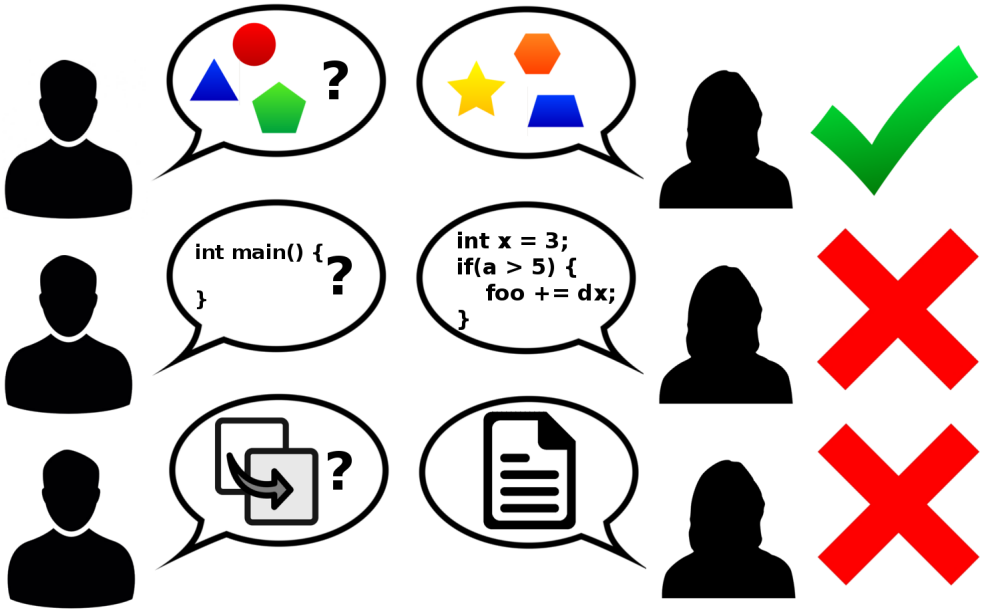


Figure 1: Collaboration rules, explained colorfully