Lab 1. Digital Logic on the TM4C123 (Spring 2023)

All students do Lab 1 by themselves (no partner for Lab 1)

Preparation

Read Chapter 1 of the ebook

Step 1 of Install and run Keil uVision 5 on your personal computer (TM4C123)

See "**Instructions for setting up the lab system"** at ECE319K web site

Step 5: Download and run the installer for EE319K

http://users.ece.utexas.edu/~valvano/Volume1/EE319K_Install.exe

Note: You can do steps 2,3,4 when you have your physical LaunchPad board. It is sufficient to perform steps 1 and 5 to perform Labs 1 and 2.

Purpose

The general purpose of this laboratory is to familiarize you with the software development steps using the **uVision** simulator. Starting with Lab 3, we will use uVision for both simulation and debugging on the real board, but for Labs 1 and 2, we will just use just the simulator. In Lab 1, you will learn how to perform digital input/output on parallel ports of the TM4C123. Software skills you will learn include port initialization, logic operations, and unconditional branching. Do not use any conditional branches in your solution. We want you to think of the solution in terms of logical and shift operations. Logical operations include AND ORR and EOR. Shift operations include LSL and LSR.

System Requirements

The objective of this system is to implement a parity system. There are three bits of inputs (Key0, Key1, Key2) and one bit of output (LED). Inputs are positive logic: meaning if the switch is not pressed the input is 0, if the switch is pressed the input is 1. The output is in positive logic: outputting a 1 will turn on the LED, outputting a 0 will turn off the LED.

The exact requirements for your lab will be revealed in the UART window when you enter your EID into the project and then build and run the system.

Students are randomly assigned to solve one of the four possible wiring configurations for Lab 1.

- Port D: Key2, Key1, Key0 input switches on PD2,PD1,PD0 output LED on PD4
- Port D: Key2, Key1, Key0 input switches on PD2,PD1,PD0 output LED on PD5
- Port E: Key2, Key1, Key0 input switches on PE2,PE1,PE0 output LED on PE4
- Port E: Key2, Key1, Key0 input switches on PE2,PE1,PE0 output LED on PE5

Odd parity is an algorithm used in communication systems to detect errors during transmission. Consider the three inputs as a 3-bit data value, such that if the input switch is pressed, that data bit is 1. Your system will have one output bit, creating a 4-bit value, such that the number of ones, considered as one 4-bit value will always be odd. The communication system (if there were one) sends the 4-bit value as a message (containing the 3-bit data plus parity), and the receiver could detect if one of the bits were to be flipped during transmission. The following table illustrates the expected behavior for **odd parity**

Key2	Key1	Key0	LED	
0	0	0	1	0 switches pressed, even
0	0	1	0	1 switch pressed, odd
0	1	0	0	1 switch pressed, odd
0	1	1	1	2 switches pressed, even
1	0	0	0	1 switch pressed, odd
1	0	1	1	2 switches pressed, even
1	1	0	1	2 switches pressed, even
1	1	1	0	3 switches pressed, odd

Odd parity rule: Key2, Key1, Key0, LED always have an odd number of 1's (and an odd number of 0's).

Even parity is an algorithm used in communication systems to detect errors during transmission. Consider the three inputs as a 3-bit data value, such that if the input switch is pressed, that data bit is 1. Your system will have one output bit, creating a 4-bit value, such that the number of ones, considered as one 4-bit value will always be even. The communication system (if there were one) sends the 4-bit value as a message (containing the 3-bit data plus parity), and the receiver could detect if one of the bits were to be flipped during transmission. The following table illustrates the expected behavior for **even parity**

Key2	Key1	Key0	LED	
0	0	0	0	0 switches pressed, even
0	0	1	1	1 switch pressed, odd
0	1	0	1	1 switch pressed, odd
0	1	1	0	2 switches pressed, even
1	0	0	1	1 switch pressed, odd
1	0	1	0	2 switches pressed, even
1	1	0	0	2 switches pressed, even
1	1	1	1	3 switches pressed, odd

Even parity rule: Key2, Key1, Key0, LED always have an even number of 1's (and an even number of 0's).

The specific operation of this system

1. Initialize your port making the switch pins input and the LED pin an output
2. Input the 3-bit switch value
3. Using AND ORR EOR LSL and/or LSR to calculate the output as a function of the input
4. Output to the LED as specified.
5. Repeat steps 2, 3, and 4 over and over

Procedure

The basic approach to this lab will be to develop and debug your system using the simulator. There is an automated grader for Lab 1. There is no hardware required for Lab 1.

Part a - Verify Keil Project for Lab1 is present and runs

To work on Lab 1, perform these tasks. Find a place on your hard drive to save all your TM4C123 software. In Figure 1 it will be called **EE319KwareSpring2023**, created when you install the .exe. Download and unzip the starter projects. Notice the projects you use for the labs will be folders that begin with "Lab".

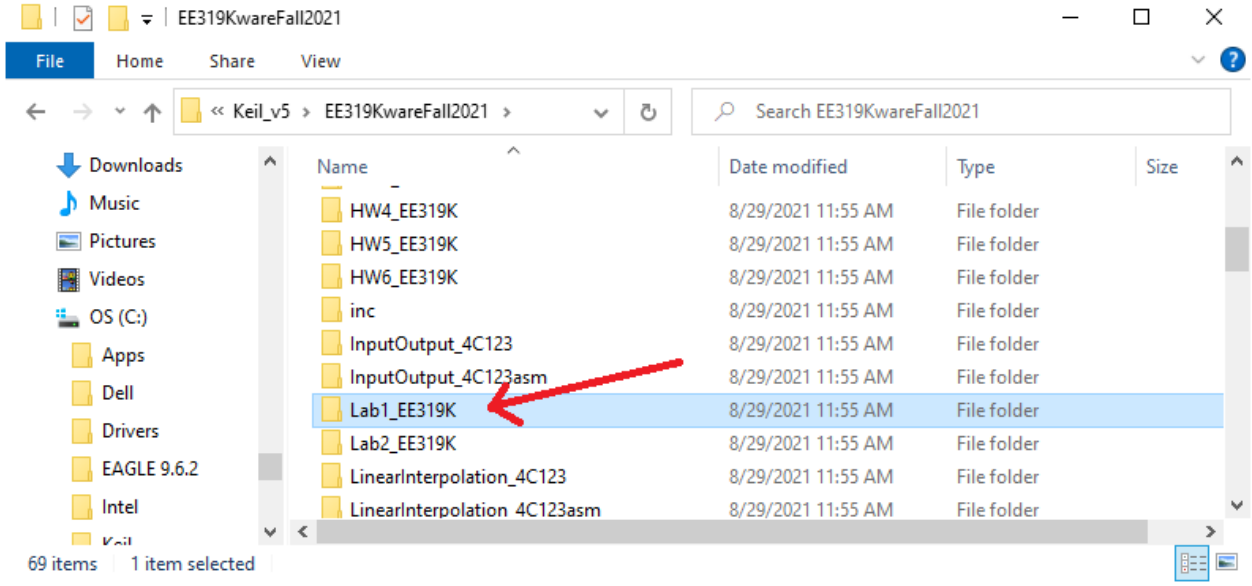


Figure 1. Directory structure with your Lab1.

It is important for the directory structure to look like Figure 1. Notice the directory relationship between the lab folders and the **inc** (include) folder. Begin with the **Lab1_EE319K** project in the folder **EE319KwareSpring2023**. Either double click the **uvprojx** file or open the project from within uVision.

Make sure you can compile it and run on the simulator. Running the system with your EID will reveal the exact requirements for your Lab 1. Please contact your TA if the starter project does not compile or run on the simulator. **Startup.s** contains assembly source code to define the stack, reset vector, and interrupt vectors. All projects in this class will include this file, and you should not need to make any changes to the **Startup.s** file. **Lab1.s** will contain your assembly source code for this lab. You will edit the **Lab1.s** file **(purple arrow)**.

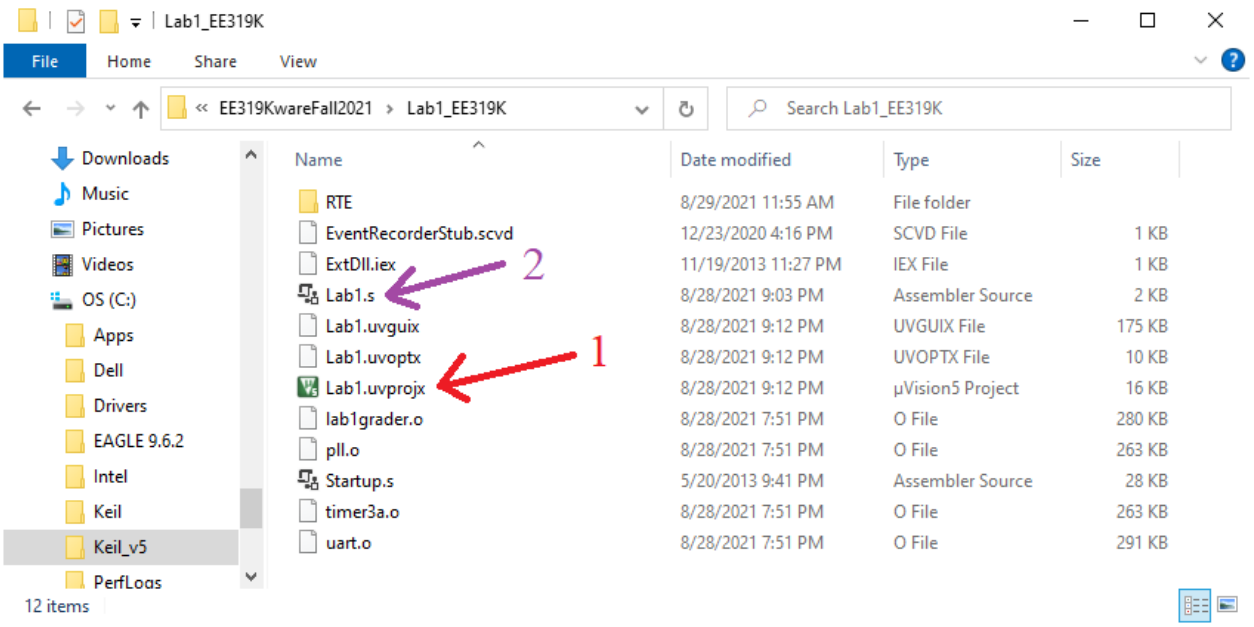


*Figure 2. Start Keil by opening the **Lab1.uvprojx** file (red arrow). It should say Fall2022.*

Please enter your EID into the **Lab1.s** file as shown with the red arrow in Figure 3. You EID is used by a random number generator to select the pins you need to implement. During initial development leave the **RunGrader** flag as 0 (false) so the grader will not run (purple arrow).

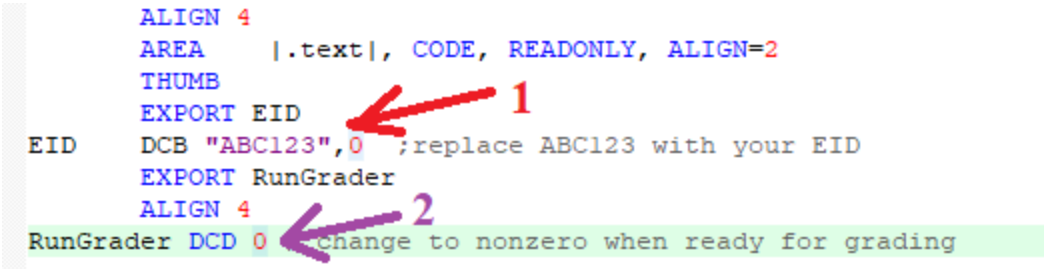


Figure 3. Put your EID into your Lab1.s file.

You should rename the Lab1 starter folder to include your EID. You will not need global variables in Lab 1.

To run the Lab 1 simulator, you must check two things. First, execute Project->Options and select the Debug tab. The debug parameter field must include **-dLaunchPadDLL**. Second, the **LaunchPadDLL.dll** file must be present in your Keil\ARM\BIN folder (the EE319K DLLs should have been put there by the installer).

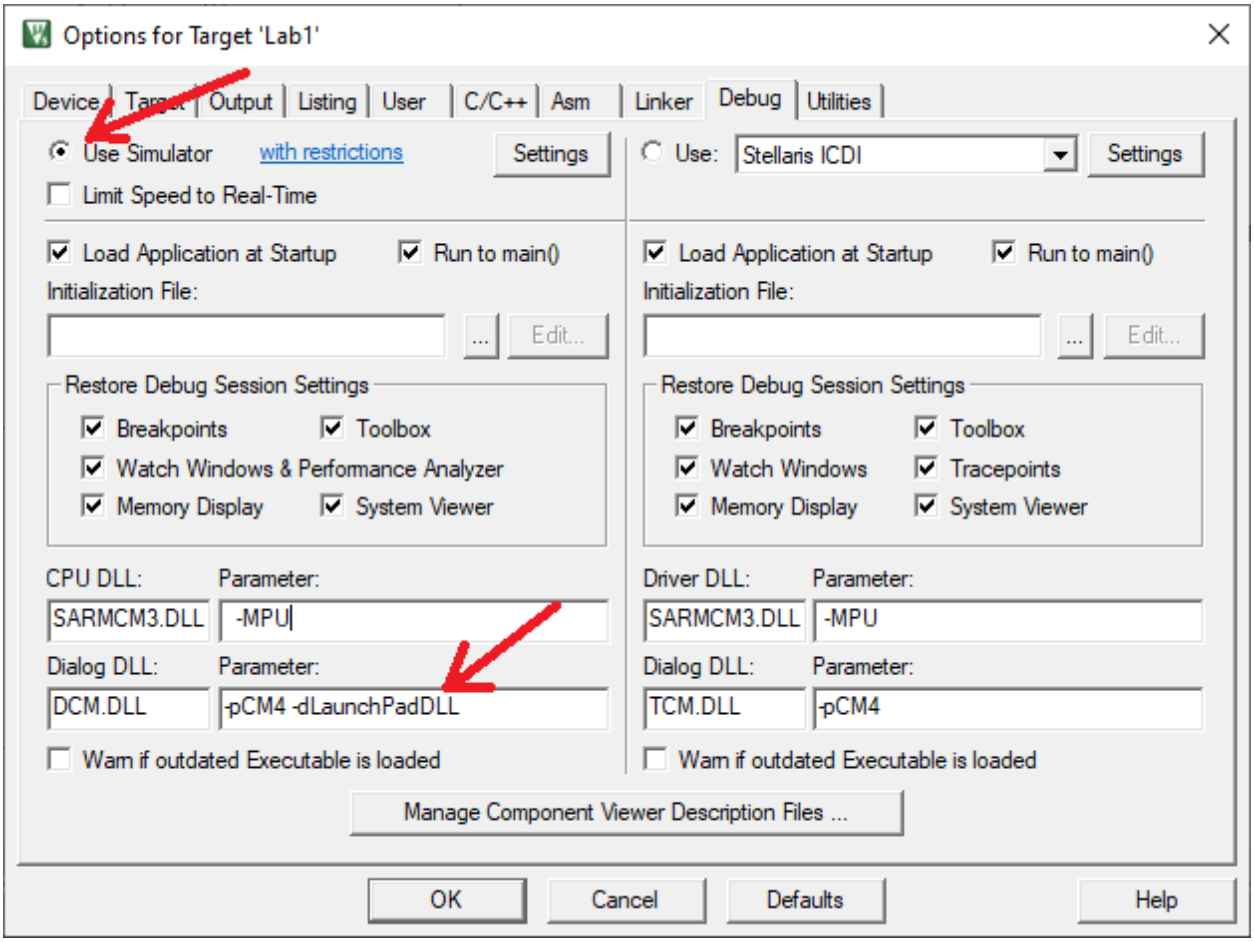


Figure 4. Debug the software using the simulator (DCM.DLL -pCM4 -dLaunchPadDLL).

Part b - Draw Flowchart

Write a flowchart for this program. We expect 5 to 15 symbols in the flowchart. A flowchart describes the algorithm used to solve the problem and is a visual equivalent of pseudocode. See Section 1.7 in the book for example flowcharts.

Part c - Write Pseudocode

Write pseudocode for this program. We expect 5 to 10 steps in the pseudocode. You may use any syntax you wish, but the algorithm should be clear. See Examples 1.14.1 and 1.14.2 in the book (Section 1.14) for an instance of what pseudocode might look like. Note, pseudocode ought to embody the algorithm and therefore be language blind. The pseudocode will become comments when developing the solution in either assembly or C (or any other language).

Part d - Write Assembly

You will write assembly code that inputs from Key0, Key1, Key2 and outputs to the LED. The address definitions for Ports D and E are placed in the starter file **Lab1.s**:

The opening comments include: filename, overall objectives, hardware connections, specific functions, author name, TA, and date. The **equ** pseudo-op is used to define port addresses. Global variables are declared in RAM, and the main program is placed in EEPROM. The 32-bit contents at ROM address 0x00000004 define where the computer will begin execution after a power is turned on or after the reset button is pressed.

```
;****************** Lab1.s ***************
; Program initially written by: Yerraballi and Valvano
; Author:                  <-- Place your name here
; Date Created: 1/15/2018
; Last Modified: 1/10/2023  <-- put the date here
; Brief description of the program: Solution to Lab1
; The objective of this system is to implement a parity system
; Hardware connections:
;  Output is positive logic, 1 turns on the LED, 0 turns off the LED
;  Inputs are positive logic, meaning switch not pressed is 0, pressed is 1
;       PE0 is an input   <-- change this to match your assignment
;       PE1 is an input   <-- change this to match your assignment
;       PE2 is an input   <-- change this to match your assignment
;       PE4 is the output <-- change this to match your assignment
```

Program 2. Required comments at the top of every file.

To interact with the I/O during simulation, make sure that **View->Periodic Window Update** is checked or the simulator will not update! See Figure 5. Execute the **Peripherals->TExaS DAC** command to get access to input switches. 1) Set the input pins as needed for your Lab1. Execute the **Peripherals->TExaS ADC** command to get access to output LED. 2) Set the output pins as needed for your Lab1. When running the simulator, 3) we check and uncheck bits in the I/O Port box to change input pins. 4) We observe the output pin in the window.

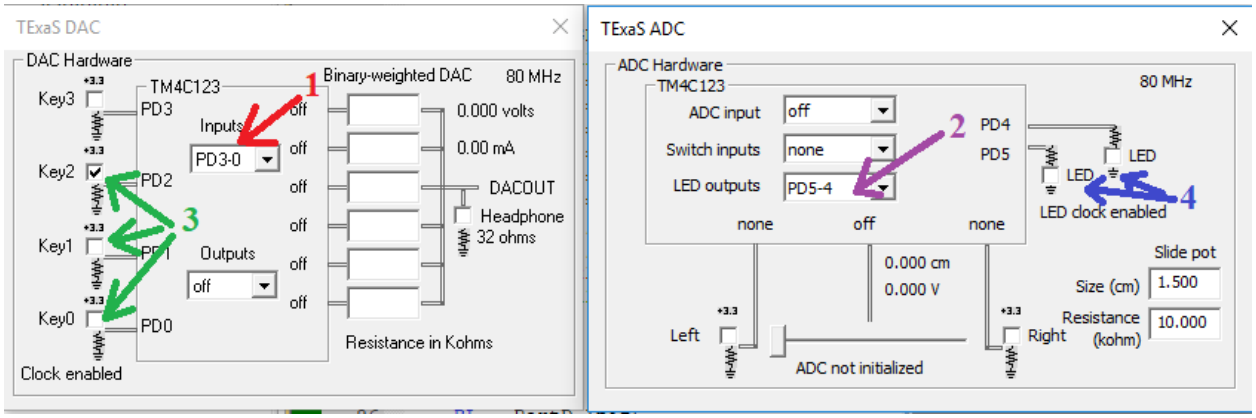


Figure 5. In simulation mode, we interact with virtual hardware. Notice the switch on PD2 is pressed and the other switches are not pressed. You choose Port D or Port E (shown as 1,2 arrows) as needed.

Part e - Debug

Please debug your system before running the grader. When you are ready to run the grader set the **RunGrader** flag to 1 (true) so the grader will run (purple arrow in Figure 3). To get points you will create the 8 possible input values (green arrow 3 in Figure 5). Full credit is a score of 25 as shown in Figure 6.

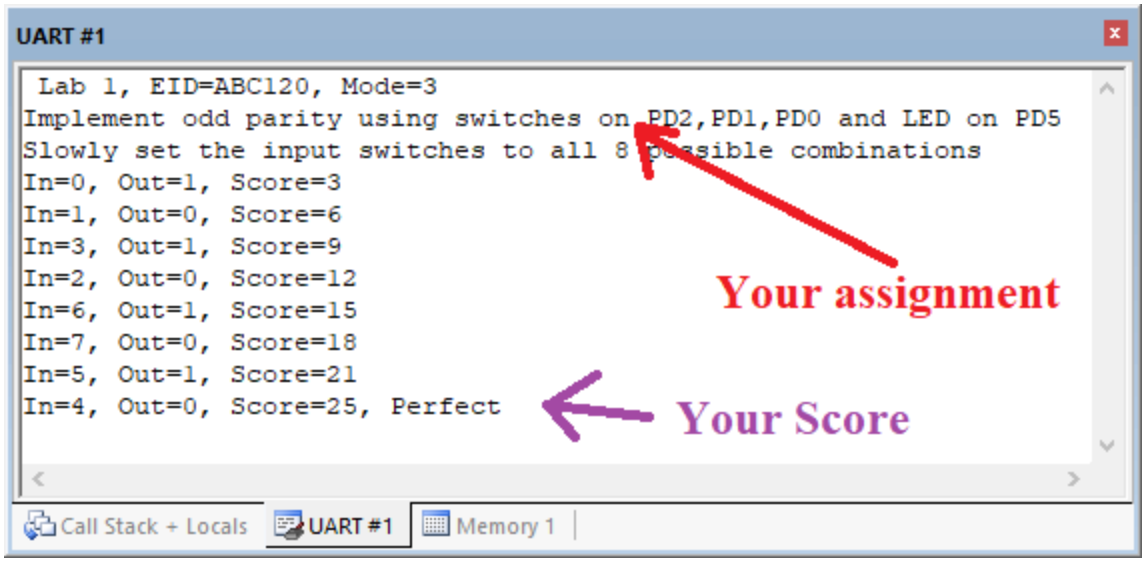
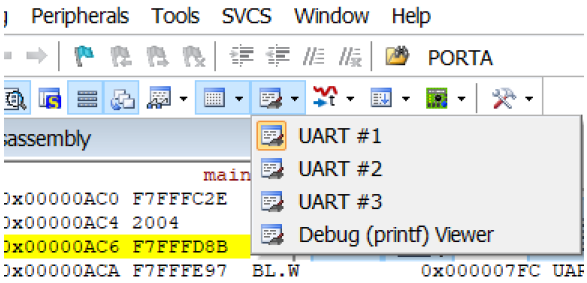


Figure 6. The UART window showing the full score.

If you do not see the UART window, execute **View->SerialWindows->UART1** when in the debugger. You can also find **UART1** as shown in the screenshot below:



Demonstration

There are grading sheets for every lab so you know exactly how you will be evaluated. During the demonstration, you will be asked to run your program to verify proper operation. You should be able to single-step your program and explain what your program is doing and why. You need to know how to set and clear breakpoints. You should know how to visualize Port E input/output in the simulator.

Do all these well in advance of your checkout

1. **Signup for a time with a TA. All students do Lab 1 by themselves**
2. **Upload your software to canvas, make sure your name is on your software**
3. **Upload your one pdf with deliverables to Canvas**

Do all these during checkout meeting

1. **Have your one pdf with deliverables open on your computer**
2. **Have Keil Lab 1 open so TA can ask about your code**
3. **Start promptly, because we are on a schedule.**
4. **Demonstrate lab to TA**
5. **Answer questions from TA to determine your understanding**
6. **TA tells you your score (later the TA will upload scores to Canvas)**

Deliverables

Upload your **Lab1.s** file to Canvas. Combine the following components into one pdf file and upload this file also to Canvas. Have the pdf file and Keil open on the computer during demonstration.

0) Your name, professor, and EID
1) Flowchart of the system
2) Pseudo-code for the algorithm
3) A screenshot of the UART window, one showing EID and score.

Optional Feedback : http://goo.gl/forms/rBsP9NTxSy

FAQ

The list of FAQ below are populated from Piazza over the semesters (thanks to the contributions of all past TAs and students). More questions may be posted so please check back regularly.

1. Should the program keep checking for inputs and update the LEDs continuously?
   Your program should loop, so yes.
2. Our program works as expected when stepping through but when it is run through it does not. What could be causing this? What is an effective way to debug when our debugging method says that the program is working fine but the actual running of the program says otherwise?
   First check if the “Periodic Window Update” under the “View" tab is on when you are in debugging mode. Also, some run-time errors can occur when setting up the clock register which don't appear when single stepping. Look over and ensure you are writing to the correct register and only affecting those bits required to activate Port E, as well as give enough time for it to start up.
3. What is the best way to include the source code for the main.s into the pdf file?
   One way to include the source code for the main.s into the pdf file is to copy / paste the code into a Word document and then combine that with all of your other deliverables, depending on the lab, and then converting that file to a PDF. Please do not only include a screenshot.
4. For the flowchart and pseudocode, do we need to start at the very beginning with all the initialization tasks, or just at the actual logic for locking and unlocking the lock?
   Your flowchart should cover the entire program that you write. Therefore, initialization should be included. How you represent initialization is up to you.
5. Are we allowed to branch?
   Only unconditional branches are allowed in this lab. You are required to implement this lab using only Boolean logic and shift operations such as AND, OR, EOR, LSL and LSR.
6. Do both members of our lab group need to turn in a pdf, or do we just turn in one for the two of us?
   Labs 1 and 2 are done individually. For Labs 3-10 both partners should submit the same pdf on Canvas.
7. When I try to run the debugger, I get: Error: Could not load file 'C:\Keil\EE319Kware\Lab1_EE319K\Lab1.axf'. Debugger aborted! What should I do?
   You most likely forgot to build your project before running the debugger. The other possibility is the code has a syntax error. If that doesn’t solve the problem, try running Keil as an administrator.

8. When I try to build, it gives the errors: Build target 'Lab1', error - cannot create command input file '.\startup._ia', error - cannot create command input file '.\main._ia', Target not created! What should I do?
   Try running Keil as an administrator
9. Where can I find the addresses for the different ports?
   Register definitions for the microcontroller may be found here:
   http://users.ece.utexas.edu/~valvano/arm/tm4c123gh6pm.s
10. I edited my code but nothing changes when I re-run it in the debugger!
    If you made changes to your code “in debug mode”, you most likely have not re-built your project and therefore your debugger is running the old version of your code. Exit out of debug mode and rebuild your code for the changes to take effect.
11. Keil tells me I have tons of build errors but nothing seems to be wrong with my assembly code.
    Make sure you instructions are indented. Only the labels are aligned all the way to the left.