

Introduction to Embedded Systems

Major Project

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Introduction

We have learned the microcontroller architecture and the embedded C programming. We have also learned how to apply on the Arm Cortex M4 TivaC the building process, digital I/O, timers, and interrupts.

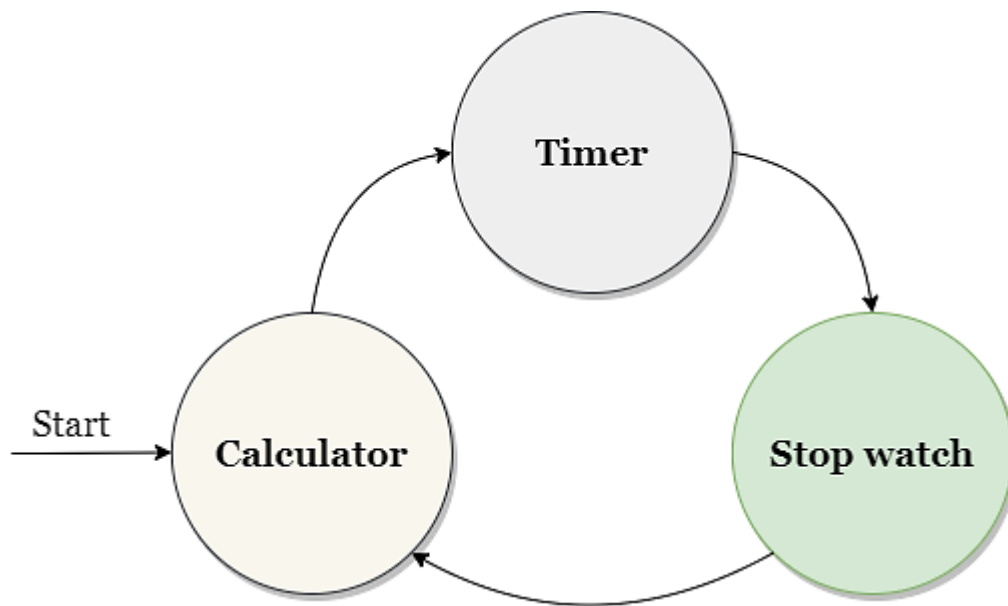
In this project our goal was to design a simple calculator with 2 extra features: a timer and a stopwatch. The calculator is doing the basic operations that are addition, subtraction, multiplication, and division. The timer and stopwatch features will be both handled separately by the hardware.

We have used:

- Two timers one for the **stopwatch mode** and the other for the **timer mode**.
- **GPIO** for the LCD, the keypad, and the pushbuttons
- **Interrupts** for the timers and the push buttons.



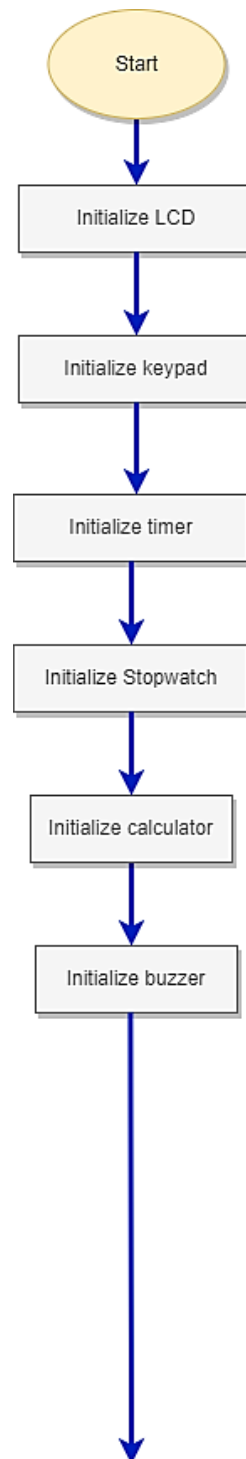
State machine

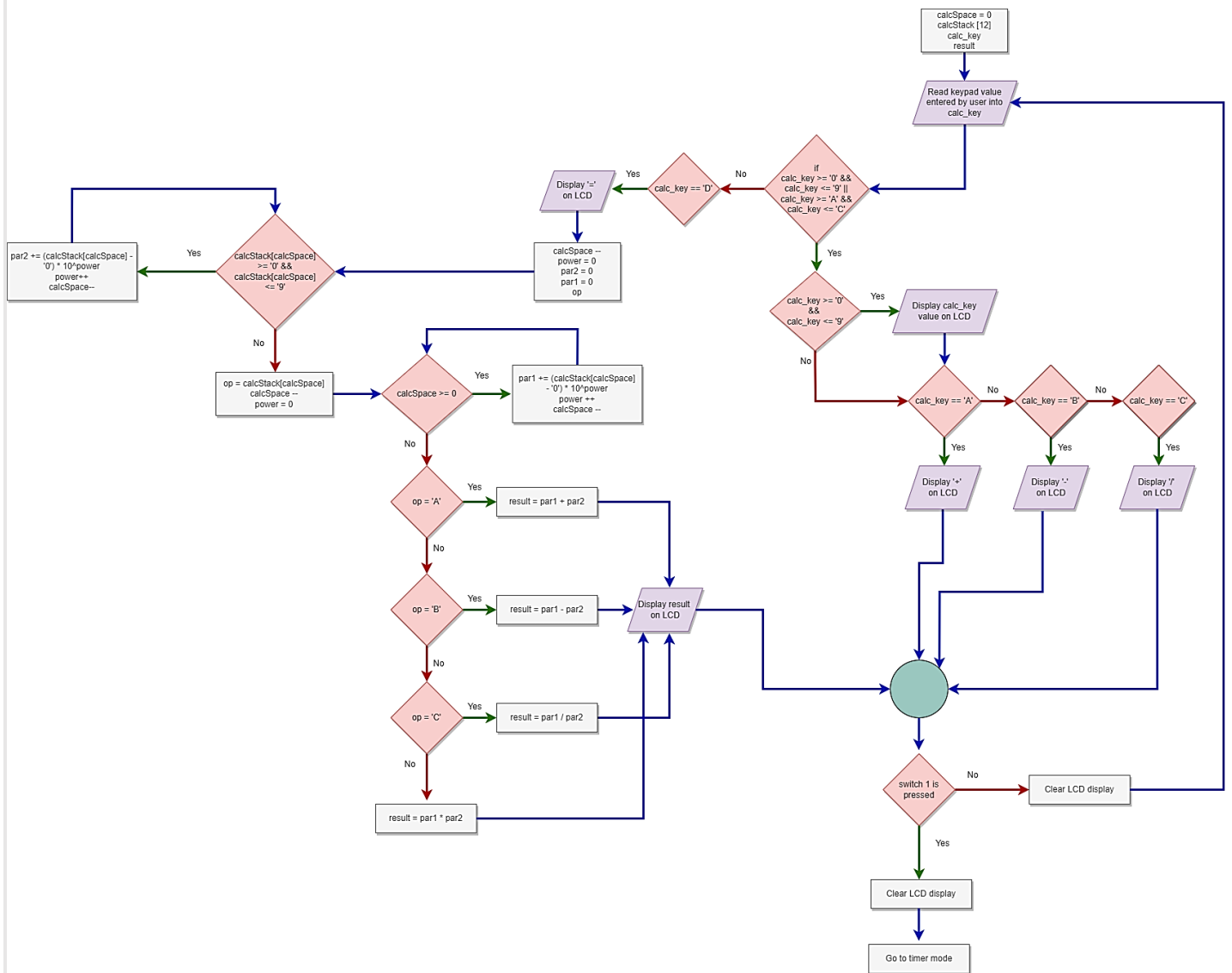


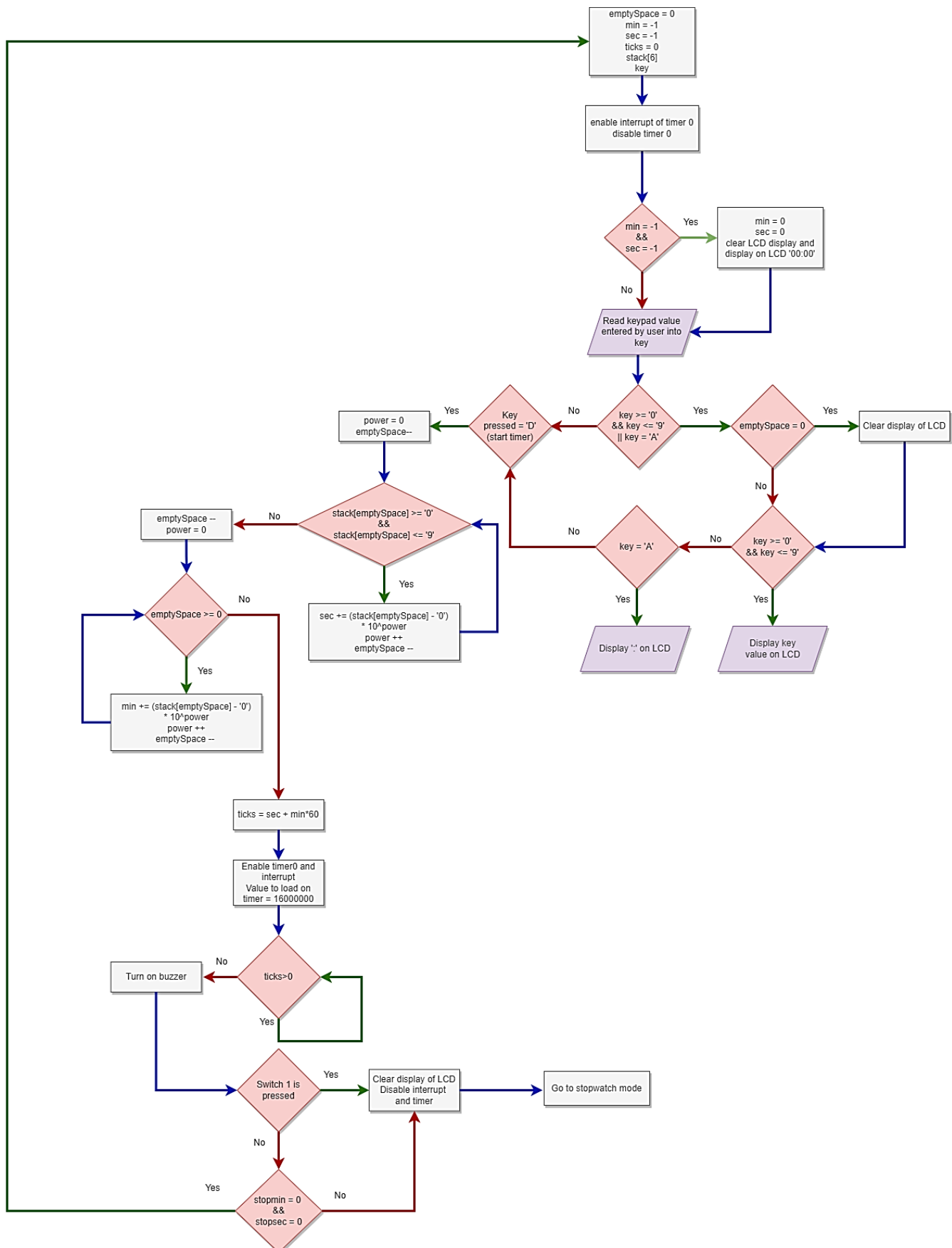


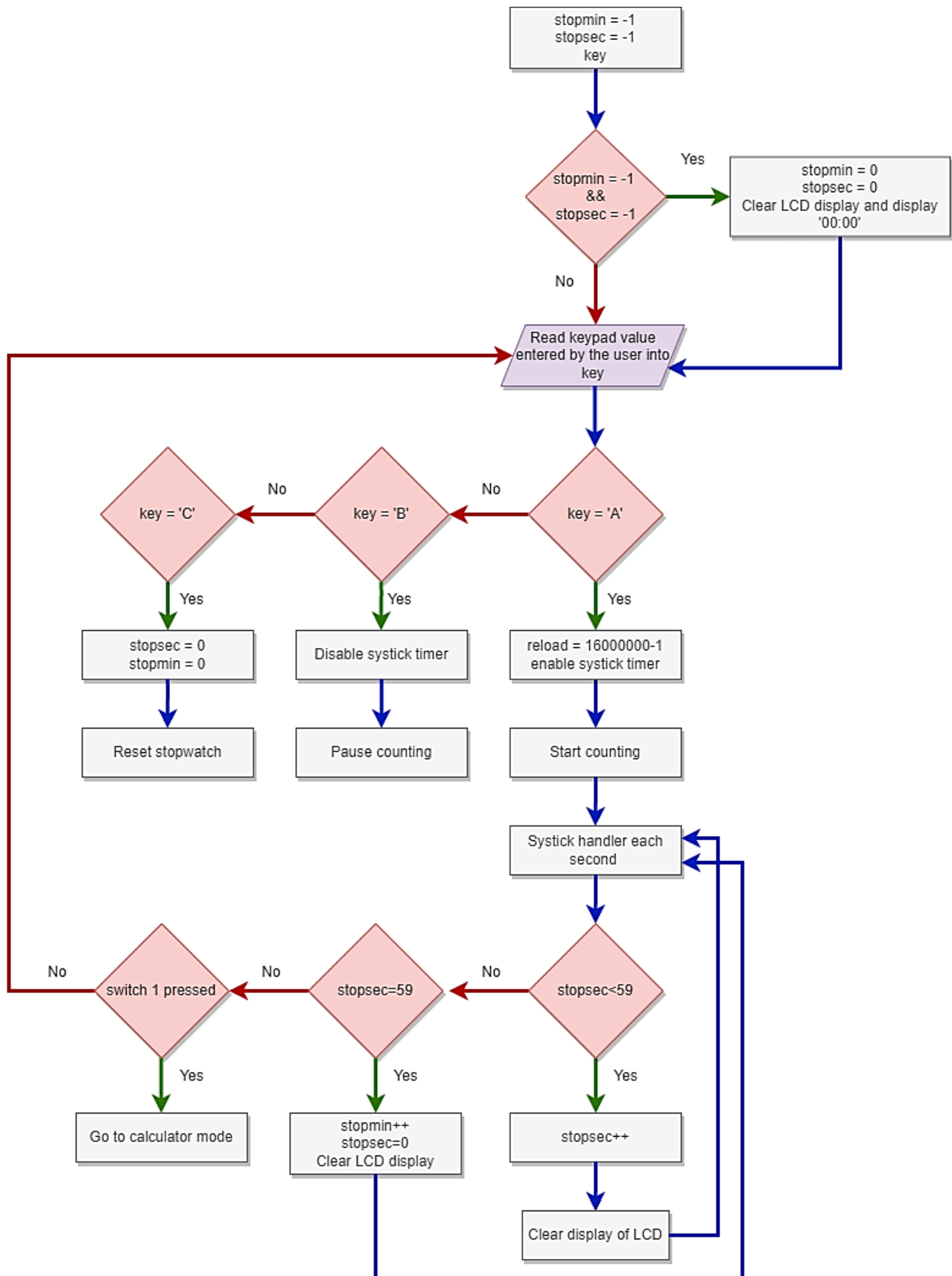
Flowcharts

Calculator

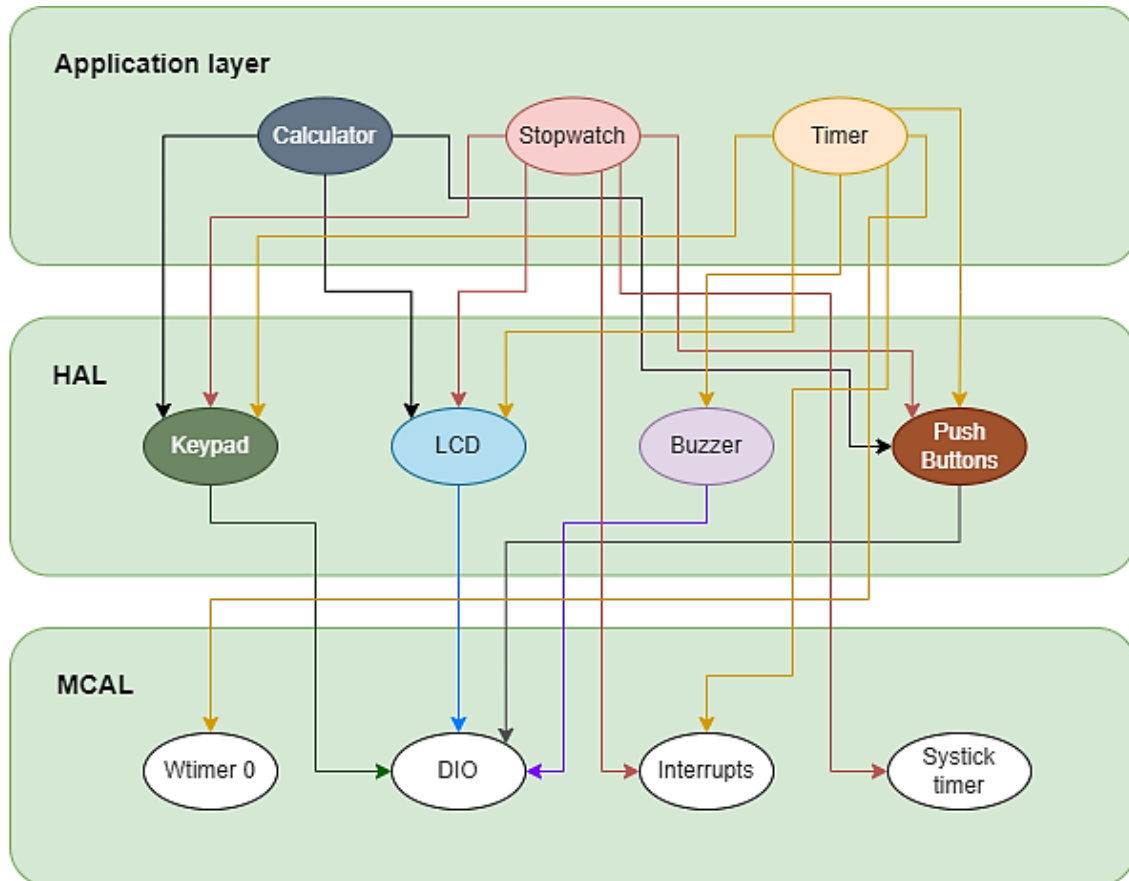




**Timer**

**Stopwatch**

Microcontroller Architecture Layers



Application layer: is the code related to our application. In the application layer we have three components the *Calculator*, *Timer*, and *Stopwatch*.

- Calculator uses the keypad from HAL to enter the operation we want to calculate and uses the LCD from HAL to display the operation and the result. It also uses the push button from HAL to switch to the next mode when button is pressed.
- Timer uses the keypad from HAL to enter the time we want to display and uses the LCD from HAL to display the countdown of the time entered. Uses also the buzzer from HAL to ring when reaching timeout. It uses the push buttons from HAL to switch to the next mode when button is pressed. Uses the interrupts from MCAL to interrupt between each second and the other. And uses Timer0 from MCAL to countdown.
- Stopwatch uses the keypad from HAL to start, pause, and reset counting of time. It uses the LCD from HAL to display time when started counting, when



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Paused, and when reset. Uses the push button from HAL to switch to the next mode when button is pressed. It also uses the interrupts from MCAL to interrupt between each second and the other. And uses the systick timer to from MCAL to count the time.

HAL (hardware abstraction layer): is the device drivers for all the hardware's not inside the microcontroller. The hardware's we are using are the *keypad, LCD, Buzzer, and push button*.

- Keypad uses the DIO from MCAL to read data input from user.
- LCD uses DIO from MCAL to display output data to user.
- Buzzer uses DIO in MCAL to make noise when timer times out.
- Push buttons use DIO from MCAL to read button when pressed by user.

MCAL (microcontroller abstraction layer): is the drivers of the microcontroller peripherals. We are using *timer0, systick timer, interrupts, and DIO*.

Each layer talks with the layer below it only.



Problems faced

- After writing the driver of the LCD it wasn't displaying anything.
- ✔ This was due to the contrast of the screen it requires a certain voltage and we solved this issue by using a potentiometer.
- After using the LCD for a while the cursor stopped appearing
- ✔ It turned out the LCD had a problem itself and we used another one that worked properly.
- When wanting to print more than one digit after each other it used to merge the ASCII of the digits but prints out a totally different ASCII for example: 623 entered and prints 6#
- ✔ We realized that the problem is in the delay method we were using therefore we used a different delay method and it did merging correctly.
- There was overlapping between the timer and stopwatch both were working at the same time by switching between both modes
- ✔ We solved this problem by disabling the timers and interrupts of each module before exiting from it.
- Timer and stopwatch were counting very slowly
- ✔ We were using a lot of printf's in the code therefore when we removed them this fixed the issue.
- We faced some issues regarding the interrupts and the code used to get stuck there
- ✔ We tried solving this issue by disabling the interrupt and timer inside the ISR.
- The buzzer when connected it was making noise continuously non stop
- ✔ This issue was due to that the buzzer was made to make noise for 3 seconds continuous at the meantime, the mode of the timer used is periodic and it does an interrupt each second. Therefore, to make the buzzer to make noise for 3 continuous seconds we had to close the control as long as the buzzer is on so that the buzzer doesn't keep making noise forever.
- Buzzer when making noise it was ringing multiple of times on off on off and so on not just once when reaching time out.
- ✔ We used to initialize the reload register then go to the ISR no matter what is the value of minutes and seconds were at. Therefore, we made it initialize the reload register only when the minutes and seconds are greater than 0 and this solved the issue.



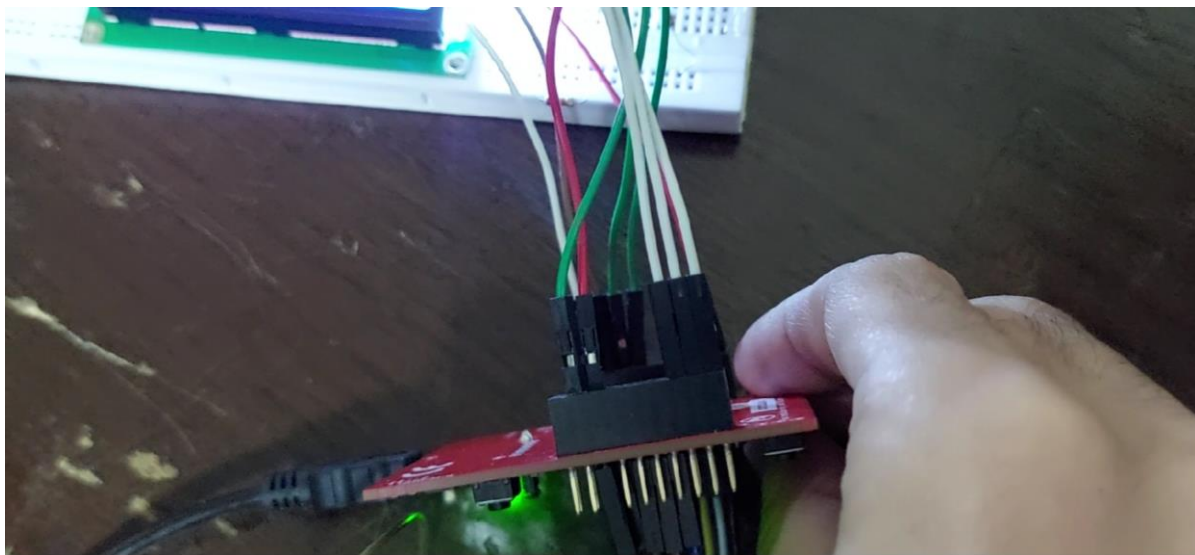
User Guide

Calculator mode

ADDITION EX:

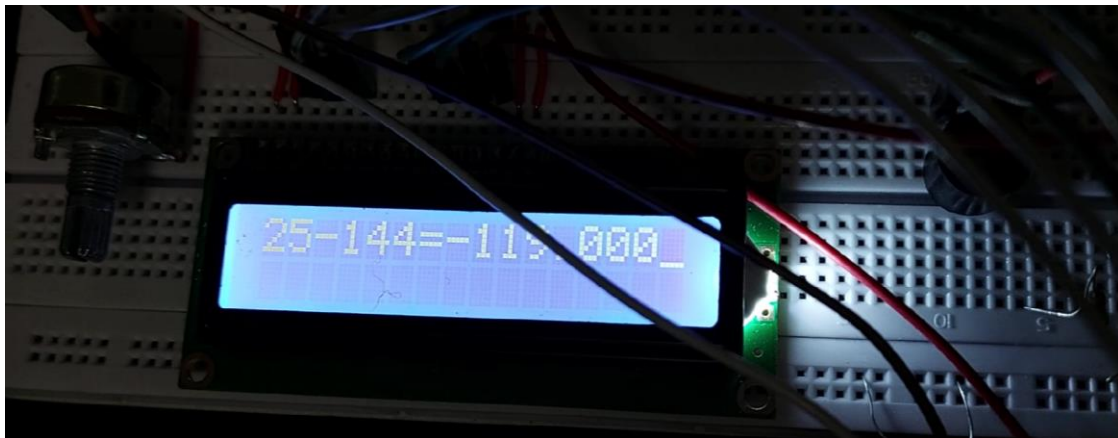


Press switch to try another operation:





SUBTRACTION ex:



MULTIPLICATION EX:

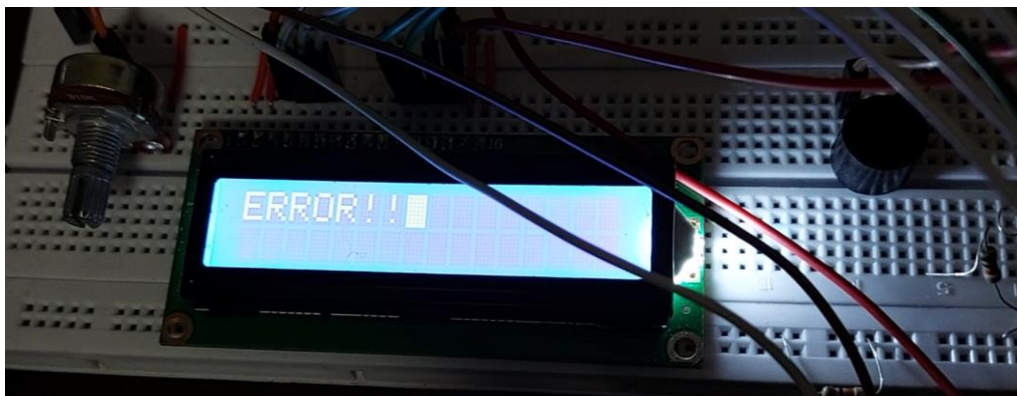


DIVISION EX:

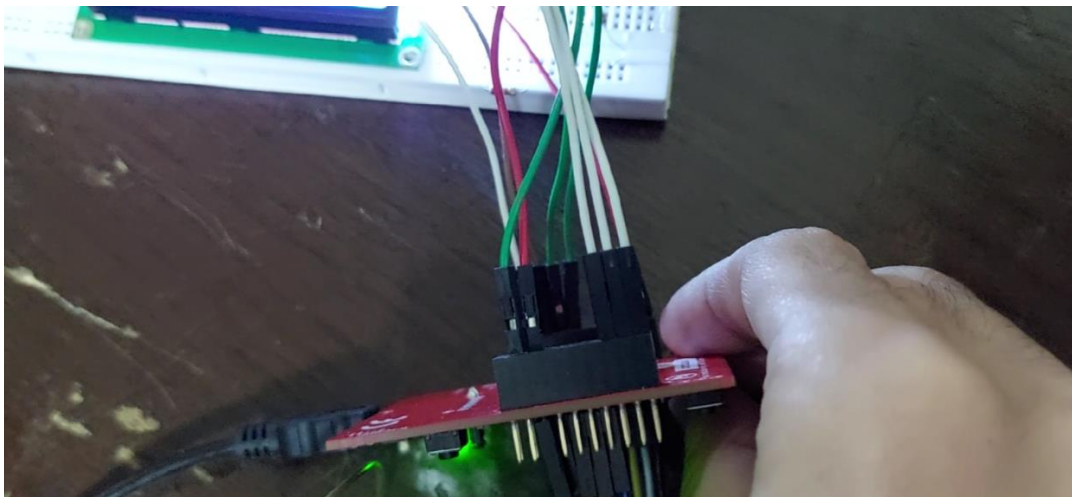




MATH ERROR EX:

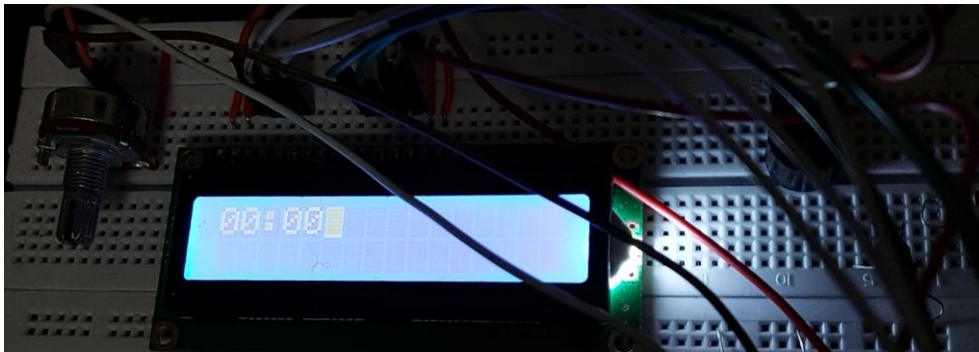


Press switch 1 to go to timer mode:

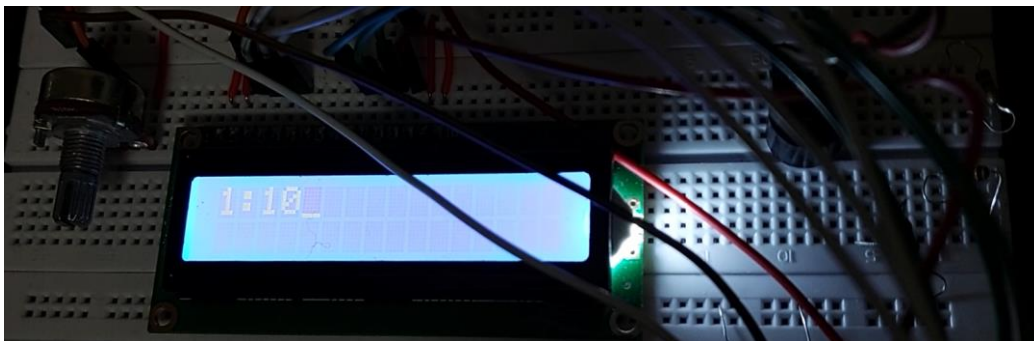




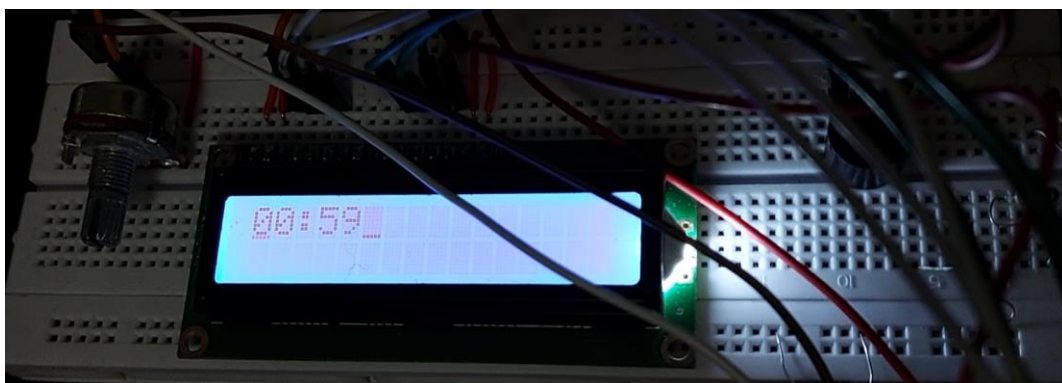
Timer mode

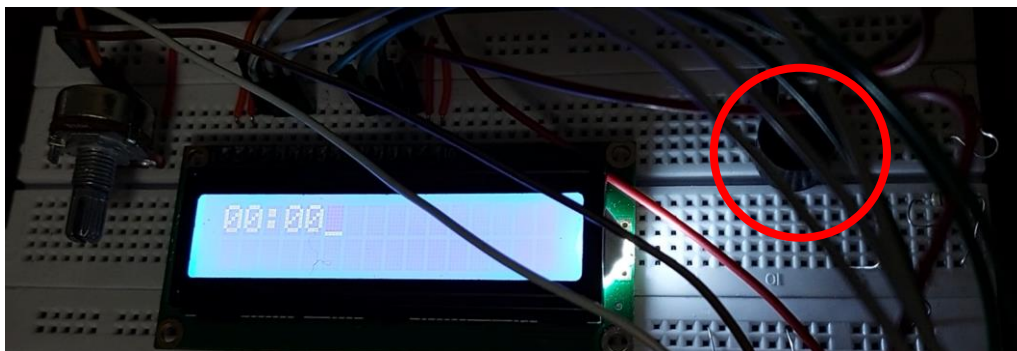


Write in a time for example 1:10



Counting down...



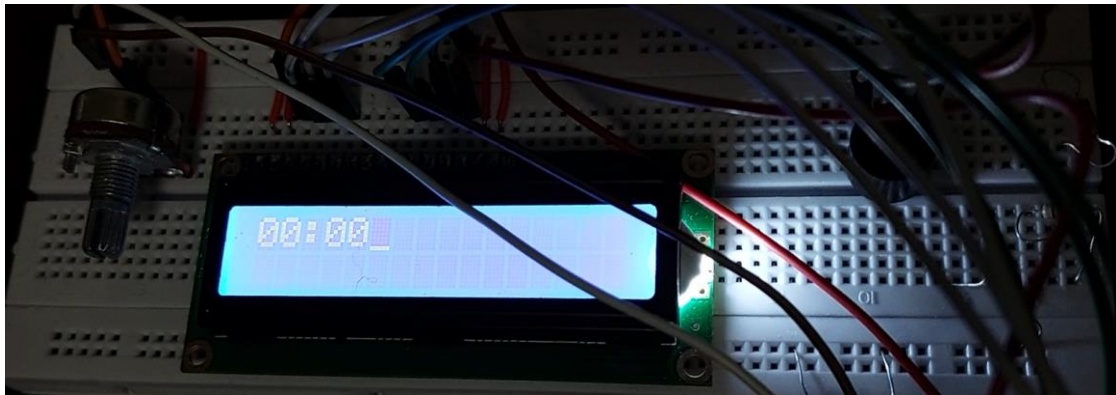


BUZZER RINGS!

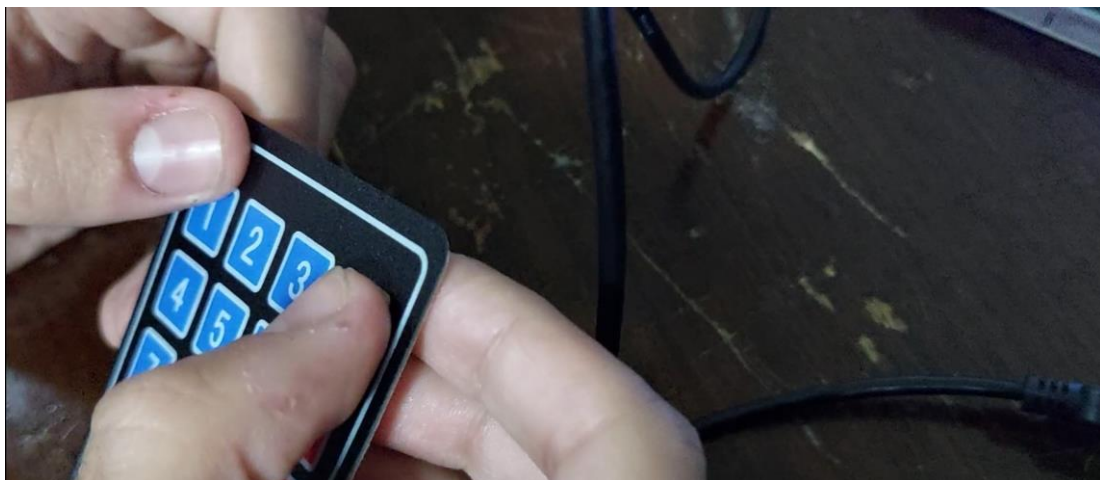
Then, press switch 1 to go to stopwatch mode:



Stopwatch mode

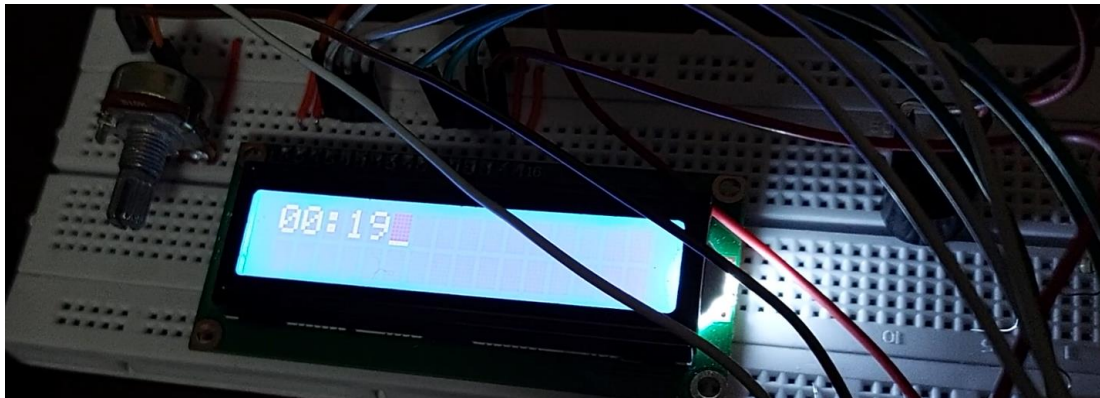


Press 'A' on keypad to start stopwatch:

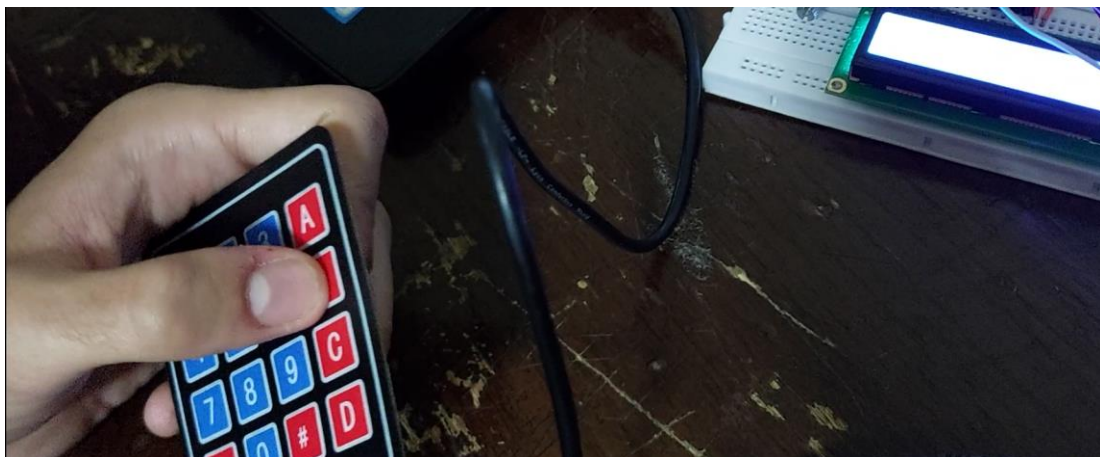


Starts counting ...



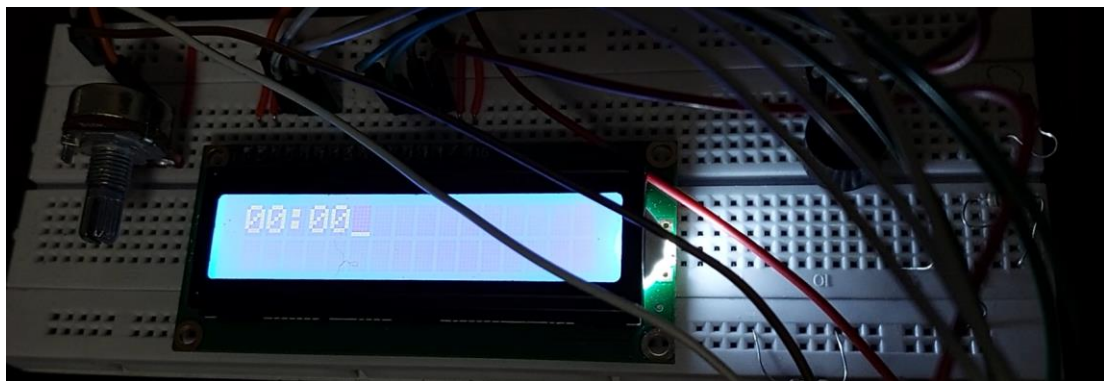
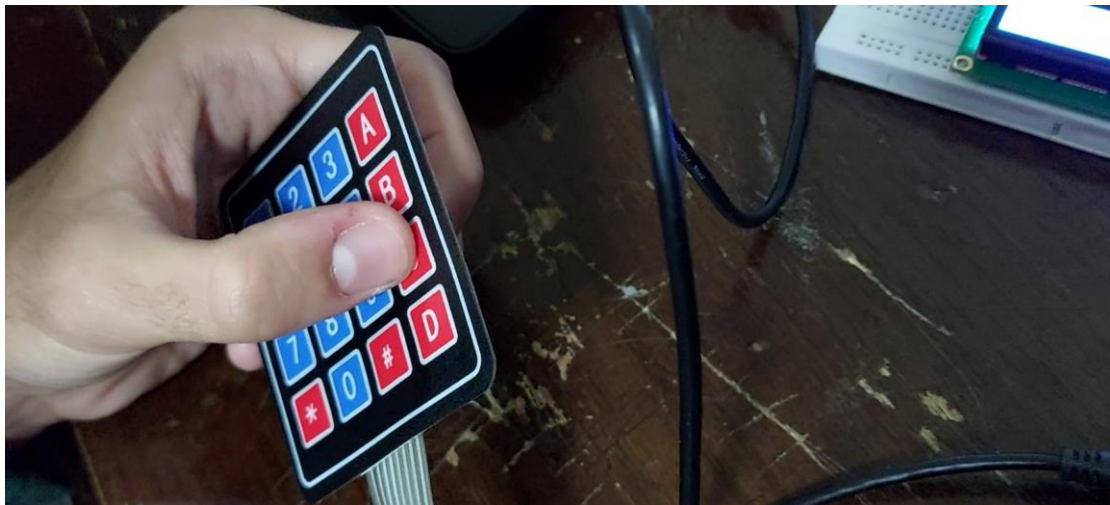


Press 'B' to pause counting:



To reset stopwatch press 'B' first to pause first then press 'C' to reset:





Press switch 1 to go back to calculator mode.



GOOGLE DRIVE LINK:

https://drive.google.com/drive/folders/1ero6NMHcRcAYt6zxIf1I-tG5oaAUN-eY?usp=share_link