Note to Instructor:

The FPGA fully synthesizes on the FPGA. It's too big to synthesize on the Github Actions.

Project Report: Linear Regression Calculator

Here is a video of the DEMO to prove it synthesizes:
https://youtube.com/shorts/59fyLhhhODE?si=ylCrKA2hUuUrgr8e

This is the high level datapath:

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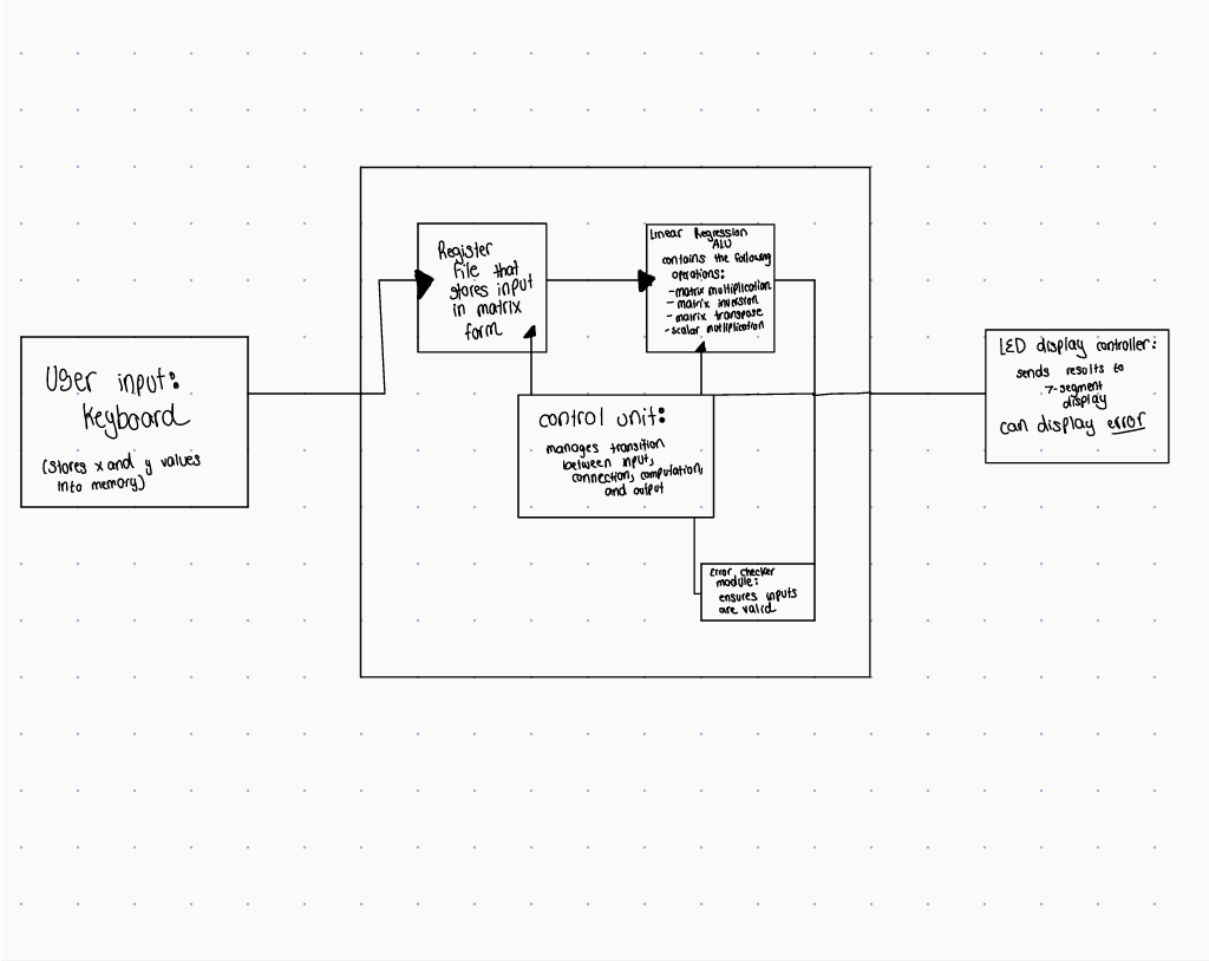


Core Modules

The primary modules in the design are:

1. **Input File Unit** - This is responsible for collecting user input for the X and Y coordinates. For size constraints, it takes 3 x-values (followed by an enter after each) and 3 y-values (followed by an enter after each)

2. **Linear Regression ALU** - This performs the required mathematical operations, including matrix multiplication, matrix inversion, matrix transpose, scalar multiplication, and determinant to compute the best-fit line. Coordinates the sequence of these equations, making sure we only multiply operations in sequence.
    a. It follows the closed form equation for linear regression.

$$\tilde{\mathbf{w}}^{LMS} = \left(\tilde{\mathbf{X}}^{\top}\tilde{\mathbf{X}}\right)^{-1}\tilde{\mathbf{X}}^{\top}\mathbf{y}$$

3. **Error Checker -** The determinant has an error flag (if the error is 0) and the input file module has an error flag if the inputs are wrong.
4. **OLED** module - The OLED module that takes the outputs of the linear regression ALU and outputs it to the OLED using an SPI protocol.
5. **Keyboard** module - The keyboard module that takes the users value and sends them to the input file unit.

1.1 Keyboard

The input register captures the X and Y coordinates entered by the user. The user needs to input 3 x-values (with an enter between each) followed by 3 y-values. The signal goes into the input module.

1.2 Input File Unit

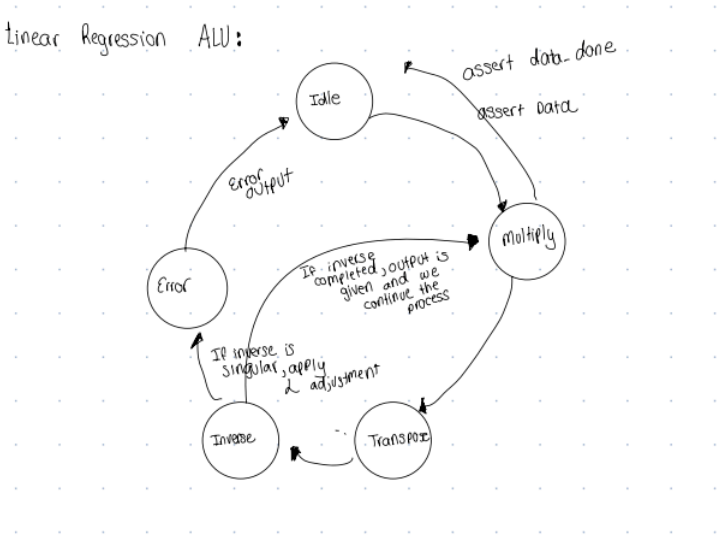
FSM:

1. Read_X: Reads X values 3 times followed by an enter between each
2. Read_Y: Reads Y values 3 times followed by an enter
3. Finish: Sends the data and a done signal to the Linear Regression unit

1.3 Linear Regression ALU (also the control Unit for these modules)

Modules:

1. Matrix Transpose
2. Matrix Inversion
3. Matrix Multiplication
4. Matrix Determinant Calculation



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1.4 OLED Unit

1. Uses the SPI protocol to communicate with the OLED Pmod
2. Takes in the value from linear regression and displays them (or error)

1.5. Keypad PMOD

1. Takes in the values from the keypad and sends it to a linear regression calculator

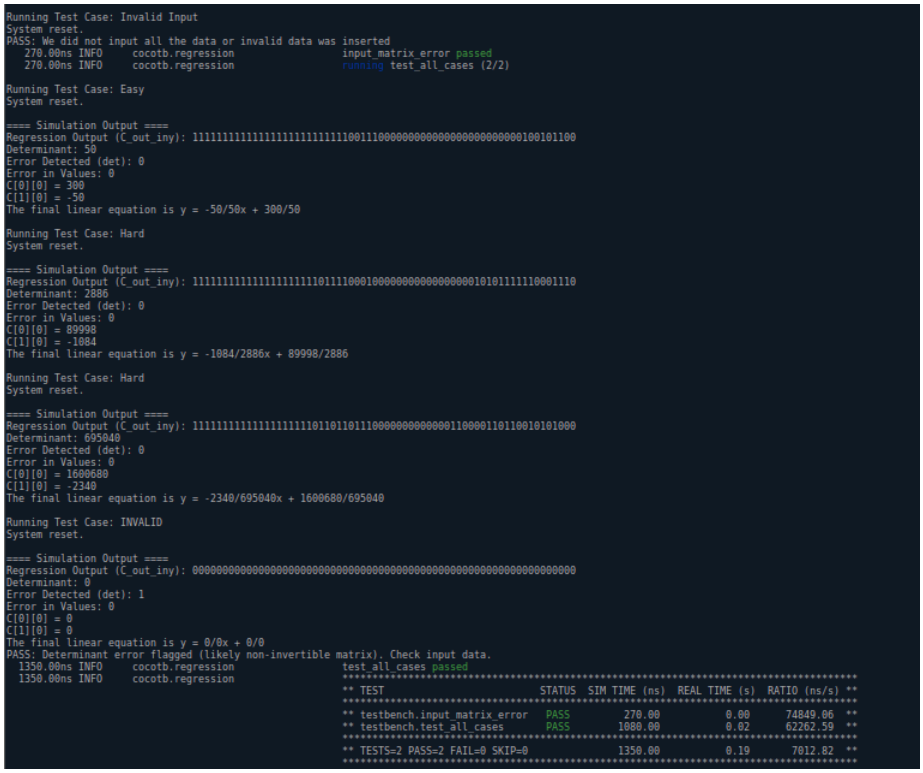
Testbench Verification:

I used cocoTB to verify the errors and the values returned.

Test Cases:

- Multiple Matrices
- Wrong inputs
- Enter asserted wrongly
- Det is 0
- All these test cases passed

Image Below



How to run:

Insert the PMODs in the corresponding pin placements. Toggle the reset button. Insert values into the keypad.