Final Project Report

- **Project Title:** CalcHub – Embedded Based Caulculator
- **Course Title:** Digital Logic Design
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- **Date of Submission:** 21/5/2024

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Abstract

The project, titled "CalcHub – Embedded Based Caulculator" introduces the practical applications of Arduino by building a basic embedded calculator. The project utilizes readily available components such as an Arduino microcontroller, a 4x4 keypad for user input, and an i2c LCD for displaying results. Through CalcHub, hands-on experience in integrating hardware components with software to perform essential arithmetic operations including addition, subtraction,multiplication, and division is mastered. In addition to developing practical skills, CalcHub fosters a deeper understanding of interfacing digital inputs and outputs, while reinforcing software logic concepts essential for programming arithmetic operations.

Introduction

CalcHub: An Interactive Learning Tool for Exploring Embedded Systems

Embedded systems play a pivotal role in our everyday lives, silently powering countless devices from calculators and smartphones to complex industrial automation systems. Understanding the fundamental principles behind embedded systems is crucial for aspiring programmers and anyone interested in the intricate interplay between hardware and software.

Importance and Relevance

This project holds significance for its educational value. It introduces CalcHub, an educational initiative designed to demonstrate the exciting world of embedded systems through the development of a user-friendly, embedded calculator. By leveraging the Arduino platform, CalcHub provides a practical and engaging platform to acquire foundational knowledge and practical skills in embedded system design.

Objectives:

- **Empowering Students through Hands-on Learning:** CalcHub prioritizes experiential learning by guiding the construction of a tangible embedded system – a basic calculator. This hands-on approach fosters a deeper understanding of the subject matter compared to purely theoretical learning.
- **Mastering Hardware-Software Integration:** A core competency in embedded system design is the ability to seamlessly integrate hardware components with software. CalcHub accomplishes this by employing an Arduino microcontroller, a 4x4 keypad for user

input, and an i2c LCD for displaying results. Practical experience is gained in interfacing these elements to achieve a cohesive system.

- **Solidifying Software Logic Fundamentals:** Performing arithmetic operations lies at the heart of any calculator. CalcHub presents an ideal platform to practice and understand software logic by implementing essential mathematical functions like addition, subtraction, multiplication, and division within the Arduino programming environment.

Project Requirements

Hardware Requirements:

- **Microcontroller:** The project will utilize an Arduino Uno. The Arduino serves as the central processing unit for the calculator, handling user input, performing calculations, and controlling the display.
- **Keypad:** A 4x4 matrix keypad will be used for user input. Each key on the keypad will correspond to a numerical digit, mathematical operator (addition, subtraction, multiplication, division), or control function (clear, enter).
- **LCD Display:** An i2c LCD display will provide a visual interface for the calculator. The display will show user input, intermediate calculations, and final results. The i2c interface allows for efficient communication between the Arduino and the LCD.

Software Requirements:

- **Arduino IDE:** The Arduino Integrated Development Environment (IDE) will be the primary software tool for developing and uploading code to the Arduino board.
- **Programming Language:** The project will utilize Arduino's C++ based programming language.
- **Libraries:** Depending on the specific functionalities of the chosen keypad and LCD, additional libraries are required for interfacing with these components. These libraries provide pre-written code for easier communication between the Arduino and the hardware elements.

Project Specifications:

- **Functionality:** The core functionality of the project is to create a basic arithmetic calculator that performs addition,subtraction, multiplication, and division.
- **User Interface:** The user interface will be intuitive and user-friendly. Users should be able to enter numbers and operators using the keypad and view the results on the LCD display.
- **Error Handling:** The project should incorporate basic error handling mechanisms to address invalid user input,such as division by zero.
- **Code Readability and Maintainability:** The code should be well-structured, commented, and easy to understand for future modifications or troubleshooting.

Literature Review

Numerous projects and learning tools exist to introduce the fundamentals of embedded systems.

Existing Solutions:

- **Online Simulators:** Online platforms offer virtual simulations of embedded systems, allowing students to experiment with hardware components and software logic without the need for physical hardware. These platforms provide a convenient and accessible learning environment, but lack the hands-on experience crucial for deeper understanding.
- **Pre-built Development Kits:** Educational development kits often include pre-programmed modules and pre-designed hardware components. While these kits can streamline the building process, they may limit students' creativity and ability to fully grasp the underlying principles.
- **Standalone Microcontroller Projects:** Projects utilizing microcontrollers for tasks like controlling LEDs or reading sensors offer valuable learning experiences. However, these projects often focus on individual components rather than integrating various elements to achieve a complete system with practical applications.

CalcHub's Differentiators:

CalcHub addresses the limitations of existing solutions by offering a unique approach:

- **Focus on Practical Application:** By constructing a functional calculator, CalcHub allows the experience of the outcomes of embedded system design. This practical application fosters a deeper understanding compared to solely theoretical exercises.
- **Emphasis on User Interaction:** The user-friendly interface with a keypad and LCD display allows interaction with the calculator, simulating real-world use cases. This interactive element enhances the learning experience and reinforces the practical value of embedded systems.
- **Customization and Learning Progression:** While providing a core framework, CalcHub offers opportunities for customization such as utilizing more complex calculations or exploreing different hardware components, fostering independent learning and project ownership.

CalcHub builds upon existing solutions by offering a hands-on, interactive, and customizable platform.

Design Methodology

Calchub utilizes an Arduino for code development, and LCD for display, and a keypad for input. These component are connected together to ultimately develop the calculator.

Hardware Component Selection:

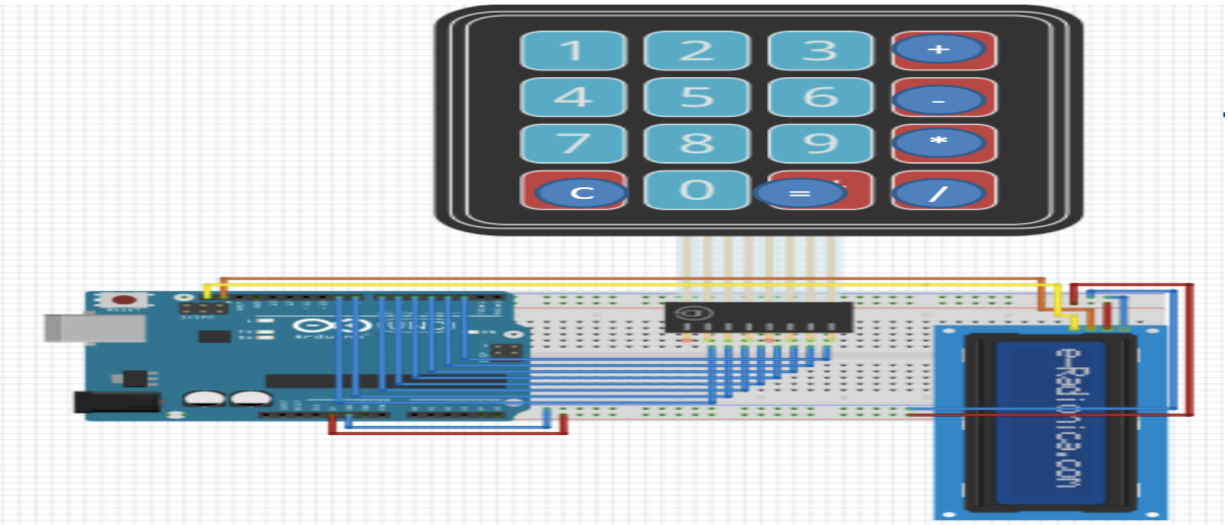
- **Microcontroller:** The Arduino Uno is chosen for its user-friendly platform, readily available libraries, and extensive online support resources.
- **Keypad:** A 4x4 matrix keypad provides a cost-effective and intuitive way for users to input numbers and operators.Specific models may have varying pin configurations that need to be considered during code development.
- **LCD Display:** An i2c LCD display simplifies communication with the Arduino through the i2c protocol. The chosen display's resolution (e.g., 16x2 characters) and character size will influence the information layout on the screen.

Logic Design and Software Development:

- **Input Handling:** The software is deesigned to scan the keypad matrix to detect pressed keys. Row and column scanning techniques will be implemented to determine the corresponding number or operator entered by the user.
- **Calculation Logic:** The core functionality of the calculator involves performing arithmetic operations. The code is structured to handle addition, subtraction, multiplication, and division, incorporating error handling for invalid inputs like division by zero.

- **Output Control:** The code controls the i2c LCD display to show user input, intermediate results, and the final calculated answer. Libraries specific to the chosen LCD model show proper display control.

Circuits and Diagrams:



Character on Keypad	**Assumed to be**
“A”	Addition (+)
“B”	Subtraction (-)
“C”	Multiplication (*)
“D”	Division (/)
“*”	Clear (C)
“#”	Equals (=)

Implementation

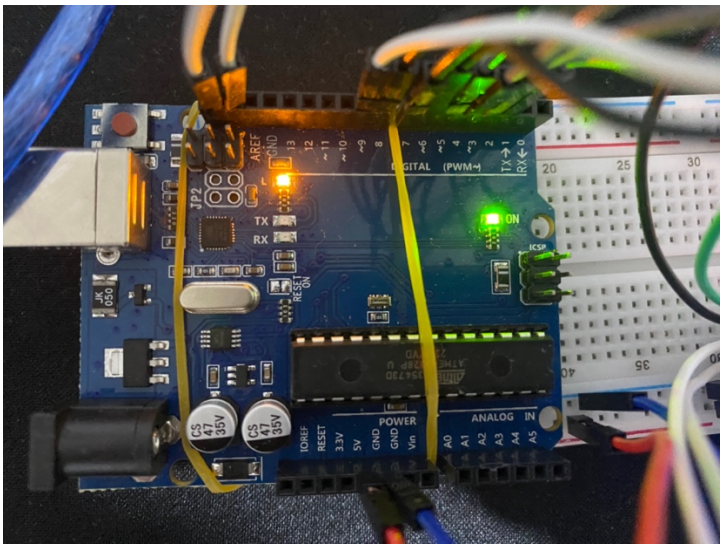
Implementation Process:

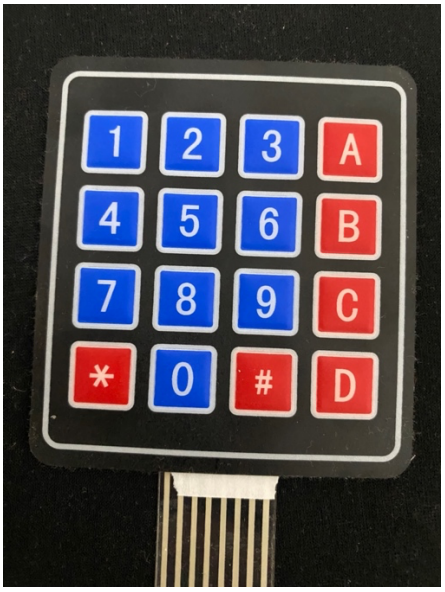
First, we built the hardware by utillizing Dr. Ahmed ElShaefaee's playlist demonstrating the step by step building of the system. We connected the components consisting of Arduino microcontroller, 4x4 keypad, and i2c LCD together through jumper wires and then provided power using the USB C cable connected to the laptop. Then, we downloaded the Arduino IDE and the needed libraries and wrote the code and uploaded it to the Arduino Uno.

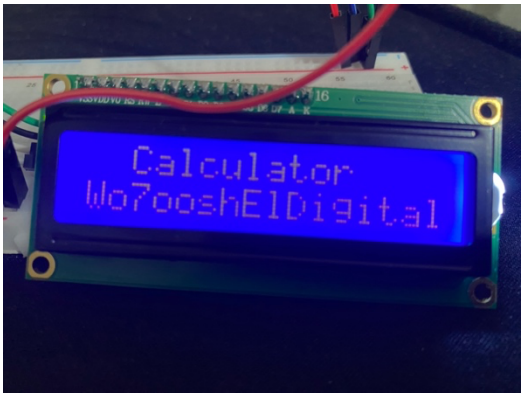
Challenges Faced:

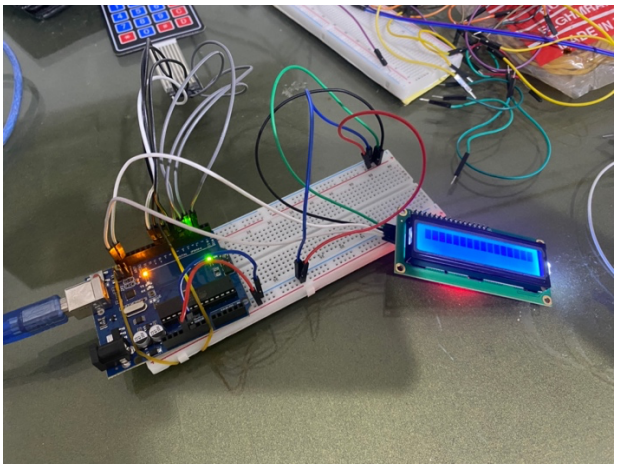
There were many challenges that we encountered as we built and coded the project. These challenges were mainly software related. For example, one of the main challenges we faced was performing three arithmetic calculations. To do so, we had to update the given code and add variables and if statements. We kept getting errors and wrong calculations untill we finally executed the code correctly and uploaded it to the Arduino. These challenges were overcome by understanding every line of code given and updating it to our desired outputs.

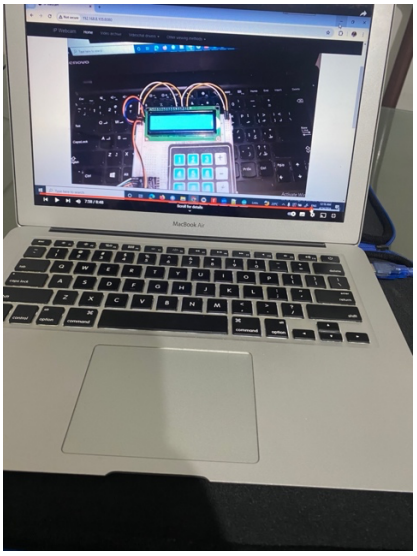
Stages of Development:

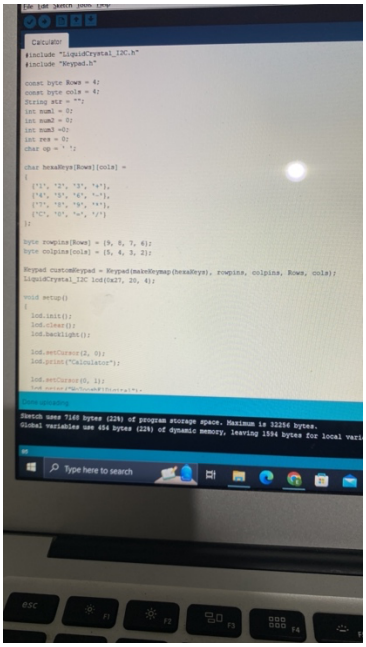
1. 

2. 

3. 

4. 

5. 

6. 
Calculator
#include "LiquidCrystal_I2C.h"
#include "Keypad.h"
Sketch uses 7140 bytes (22%) of program storage space. Maximum is 32256 bytes.
Global variables use 454 bytes (22%) of dynamic memory, leaving 1594 bytes for local vari
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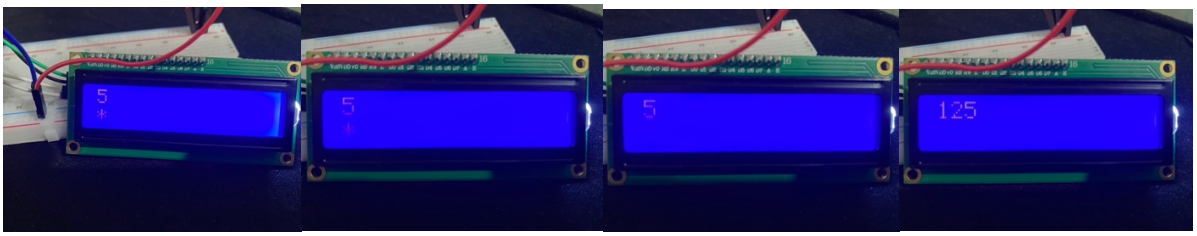
Testing and Results

Thorough testing is crucial to ensure CalcHub's functionality and identify any potential issues. A combination of unit testing and functional testing were employed:

- **Unit Testing:** Individual modules of the code, were tested such as the keypad scanning function or a single arithmetic operation, in isolation. This helps isolate errors in specific code sections.
- **Functional Testing:** The overall functionality of the calculator was tested with various user inputs and scenarios. Test cases were designed to cover:
    - Basic arithmetic operations (addition, subtraction, multiplication, division) with various numerical inputs.
    - Handling edge cases like entering large numbers exceeding the display capacity.
    - Testing for division by zero and implementing appropriate error messages.
    - Verifying the user interface and ensuring clear display of input, intermediate results, and final answers.

Presentation of Results:



Analysis and Discussion:

By successfully passing a comprehensive test suite, CalcHub meets the project objectives.

- **Functional Calculator:** Passing functional tests involving various arithmetic operations confirms CalcHub's ability to perform basic calculations as intended.
- **User-friendly Interface:** Testing user interaction with the keypad and LCD display ensure intuitive input methods and clear output presentation.
- **Error Handling:** Tests designed for edge cases and invalid inputs verify that CalcHub implements appropriate error handling mechanisms for scenarios like division by zero.

Discussion

Interpretation of Results:

A successful testing phase signifies that CalcHub effectively fulfills its intended purpose as an educational tool for embedded system design. By passing a variety of test cases encompassing basic arithmetic operations, user interaction scenarios, and error handling, CalcHub demonstrates its ability to:

- **Perform calculations accurately:** The core functionality of the project, performing addition, subtraction,multiplication, and division, functions as intended across a range of numerical inputs.
- **Provide a user-friendly interface:** The keypad allows for intuitive input of numbers and operators, while the LCD display clearly presents the entered values, intermediate results (optional), and final calculated answers.
- **Handle errors gracefully:** In cases of invalid user input, such as division by zero, CalcHub implements appropriate error handling mechanisms, preventing unexpected behavior and ensuring system stability.

Assessment of Performance and Reliability:

The testing process not only verifies functionality but also provides insights into the project's performance and reliability.Through comprehensive testing, the project demonstrates:

- **Reliable functionality:** Consistent passing of test cases across various scenarios indicates the project's reliability in performing its intended calculations.

- **Limited errors:** Any errors encountered during testing can be addressed through code modifications, further enhancing the project's reliability.

Comparison with Initial Objectives:

The project's outcomes are directly aligned with the initial objectives outlined earlier:

- **Develop an embedded calculator:** CalcHub successfully functions as a basic embedded calculator, performing essential arithmetic operations.
- **Implement user input and display:** The user-friendly keypad facilitates input, and the LCD display effectively presents information.
- **Enhance understanding of hardware-software integration:** Practical experience is achieved through integrating hardware components (keypad, LCD) with software to achieve a cohesive system.
- **Solidify software logic fundamentals:** By implementing the core logic behind arithmetic operations in code, understanding of software logic concepts is solidified.

Overall, CalcHub achieves its initial objectives, serving as a valuable educational tool for acquiring foundational knowledge and practical skills in embedded system design.

Conclusion

CalcHub stands as a successful educational initiative designed to introduce world of embedded systems. This project aided in the development of a user-friendly, embedded calculator built using an Arduino microcontroller, a 4x4 keypad for input, and an i2c LCD for display.

Major Findings:

- Through the hands-on experience of constructing CalcHub, a deeper understanding of embedded system design principles is achieved compared to purely theoretical learning.
- The project fosters crucial skills in hardware-software integration.
- Implementing the core mathematical logic within the Arduino programming environment allows grasp of software logic fundamentals to solidify.
- Testing confirms CalcHub's functionality as a basic calculator, providing a user-friendly interface and handling errors gracefully. These outcomes directly align with the project's initial objectives.

Future Work and Improvements:

While CalcHub serves as a valuable learning tool in its current form, several avenues exist for potential improvements and future work:

- **Expanding Functionality:** The project can be extended to include more complex calculations (e.g., exponents,logarithms) or incorporate additional functionalities like memory storage.

- **Advanced Hardware Integration:** Integrating different hardware components like sensors can enhance the calculator's capabilities.
- **Wireless Communication:** Implementing wireless communication protocols (e.g., Bluetooth) could allow the calculator to connect with other devices or mobile applications.
- **Mobile App Integration:** A mobile application could be developed to interact with the calculator, providing a visual interface for calculations or offering more advanced features.

References

ElShafee, A. (2024). *CalcHub – Embedded Based Caulculator(Embedded) Playlist* [YouTube Channel]. YouTube. https://youtube.com/playlist?list=PLzIiZDNBNt9yfdpPPJHs3Ki7enHg7dhH-&si=aE0icbiP8-1sQ49H

ElShafee, A. (2024). *Embedded and Discrete Logic Design Projects Spring 2024*. Prof. Ahmed Elshafee - Homepage. https://aelshafee.net/LogicDesignCourse/

Raj, A. (n.d.). *Arduino calculator using 4x4 Keypad*. Circuit Digest - Electronics Engineering News, Latest Products, Articles and Projects. https://circuitdigest.com/microcontroller-projects/arduino-calculator-using-4x4-keypad

Appendices

Appendix A: *Arduino IDE*

Appendix B: *Libraries – LiquidCrystal_I2X.h, Keypad.h*

https://aelshafee.net/LogicDesignCourse/Calc_lib.zip

Appendix B: *Detailed Circuit Diagram*