CYBER-PHYSICAL SYSTEM FINAL PROJECT REPORT
DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITAS INDONESIA

DIGITAL COMPASS

GROUP A-3

ZULFIKAR HADZALIC	**2106636224**
MUHAMMAD SUHAILI	**2106731535**
ZAKI ANANDA	**2106636224**
ALIEFYA FIKRI IHSANI	**2106733843**

PREFACE

Praises and thanks are continuously offered to the Almighty God for His blessings and grace, which have enabled us to complete the final project report titled "Digital Compass". This report was prepared to fulfill the requirements of the Physical Cyber Systems practicum at the Faculty of Engineering, Department of Computer Engineering, Universitas Indonesia. Certainly, the preparation and completion of this final project report were not possible without the help and support of various parties. Therefore, we would like to express our heartfelt gratitude to all those involved, especially to:

1. Mr. Fransiskus Astha Ekadiyanto as the lecturer of the Physical Cyber Systems course..
2. The Digital Lab assistant who has assisted and guided us during the Physical Cyber Systems practicum..
3. Our parents and fellow practicum friends who have provided their support, both in terms of material and ideas.

We are fully aware that there are still many mistakes in the preparation of this report, both in terms of vocabulary, grammar, and content. Therefore, we expect the readers to provide their criticisms and suggestions as much as possible regarding this report.

Thus, this final project report on Physical Cyber Systems is completed. Hopefully, this report will be beneficial for us as the authors and also for the readers as an introduction to the computer engineering field.

Depok, May 15th, 2023

Group A-3

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 PROBLEM STATEMENT

In this project, we focus on the issue of obtaining accurate and reliable direction information. To address this challenge, we propose to create a digital compass using Arduino ATmega328P. Our goal is to create a solution that provides consistent and precise direction information in various situations.

The problem we aim to solve is the need for reliable and accurate navigation in various applications, such as outdoor activities, robotics, and mapping. Traditional methods using analog magnetic compasses often suffer from magnetic interference and lack accuracy. Therefore, we want to use more advanced and current digital compass technology to address this issue.

By using Arduino ATmega328P as the development platform, we will integrate accurate magnetic sensors and apply appropriate data processing methods. The aim is to provide a more accurate, reliable, and user-friendly digital compass solution in various conditions. This project aims to address the issue of obtaining accurate direction information through the use of an Arduino ATmega328P-based digital compass.

1.2 PROPOSED SOLUTION

To overcome the challenges of obtaining accurate and reliable direction information, we propose the following approach:

- Design and construction of the digital compass: We will design and build a circuit using Arduino ATmega328P as the main component. This circuit will be equipped with a high-accuracy magnetic sensor to detect the surrounding magnetic field and measure the direction.
- Calibration of the magnetic sensor: We will implement a careful calibration process to eliminate or compensate for magnetic disturbances that can affect reading accuracy. Thus, the readings from the magnetic sensor will correspond to the actual environmental conditions.

- Data processing: We will develop appropriate data processing algorithms to convert raw data from the magnetic sensor into useful direction information. These algorithms will include calculations of angles and relative directions to a reference point, which will be used to display comprehensive direction information to the user.
- Intuitive user interface: We will design a simple, easy-to-understand, and user-friendly user interface to display direction information to the user. This interface can be in the form of clear and easily interpretable text or graphical displays.
- Testing and evaluation: After the digital compass system is built, we will conduct a series of tests to ensure accuracy and reliability. Testing will include verifying the accuracy of readings, responsiveness to direction changes, and testing in various environmental conditions.

By implementing this solution, we hope to create an accurate, reliable, and dependable digital compass. This solution is expected to address the challenges of obtaining consistent and precise direction information in various applications, providing users with an effective and user-friendly navigation tool.

1.3 ACCEPTANCE CRITERIA

Here are the important acceptance criteria for the project report on creating a digital compass using Arduino ATmega328P:

1. Successfully design and build a digital compass circuit using Arduino ATmega328P.
2. Integration of a well-performing magnetic sensor capable of detecting magnetic fields with high accuracy.
3. Calibration of the magnetic sensor to ensure readings align with actual environmental conditions.
4. Successful implementation of data processing algorithms that provide accurate direction information based on raw data from the magnetic sensor.
5. Design of an intuitive and user-friendly user interface.
6. Testing that yields accurate readings and responsiveness to direction changes in the digital compass.

7. Testing in various environmental conditions demonstrating consistent and reliable performance.
8. Compilation of a comprehensive project report with detailed explanations of the design, implementation, and testing results of the digital compass solution.
9. The proposed solution provides accurate and reliable direction information in various applications.
10. Clear and effective communication of the overall project and the proposed solution.

By meeting the above acceptance criteria, the project report can be considered successful in addressing the problem of obtaining accurate direction information through the use of an Arduino ATmega328P-based digital compass.

1.4 ROLES AND RESPONSIBILITIES

The roles and responsibilities assigned to the group members are as follows:

Roles	Responsibilities	Person
Pembuat PPT	Pembuatan PPT dan penulisan laporan, gantt chart, flow chart.	Zulfikar Hadzalic
Penulis laporan	Pembelian barang, penulisan laporan dan readme	Muhammad Suhaili
Programmer	Analisa datasheet dan penulisan kodingan	Zaki Ananda
Role 4	Membuat skematik hardware menggunakan proteus	Aliefya Fikri Ihsani

Table 1. Roles and Responsibilities

1.5 TIMELINE AND MILESTONES

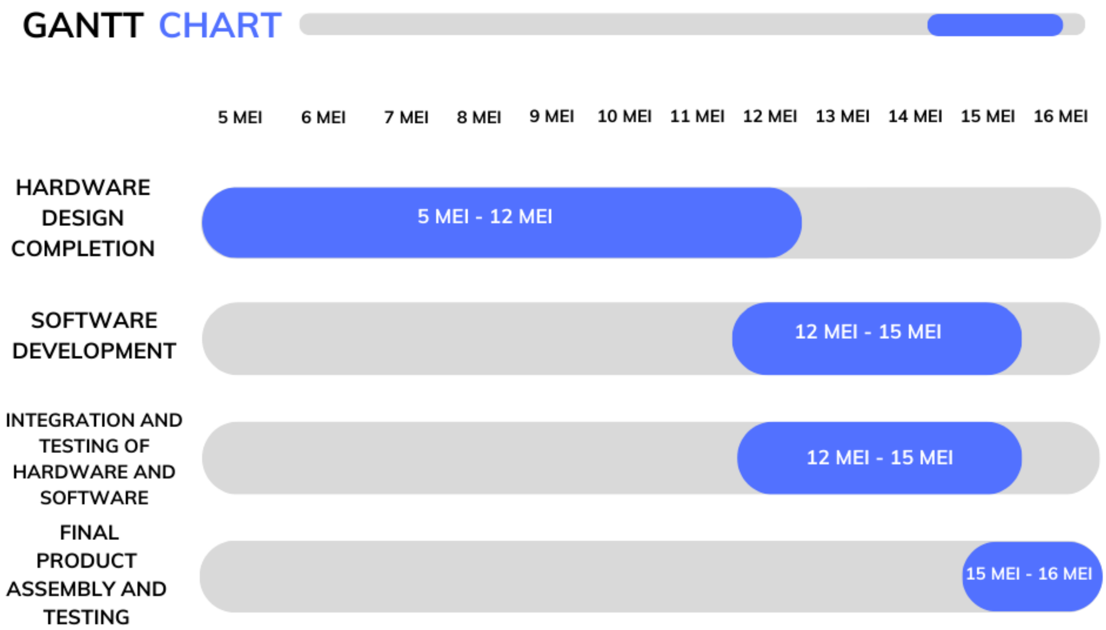


Fig 1. Gannt Chart for Timeline and Milestones

CHAPTER 2

IMPLEMENTATION

2.1 HARDWARE DESIGN AND SCHEMATIC

The hardware design includes an Arduino microcontroller, an OLED display for visual output, an MPU9250 sensor with gyroscope, magnetometer, and accelerometer features, and a logic level converter to ensure voltage compatibility. The connections involve linking the Arduino's SDA and SCL pins to the high voltage side of the logic level converter and the MPU9250 and the OLED's respective I2C pins to the low voltage side. Meanwhile, the MPU9250 and the OLED's VCC and GND pins are connected to the Arduino's 5V and GND pins. This hardware setup serves as the foundation for implementing a digital compass system using these components.

Fig 2. Microcontroller yang digunakan

Fig 3. LED yang digunakan

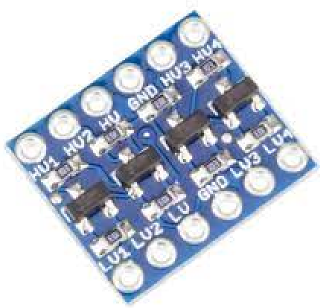


Fig 4. MPU9250 yang digunakan

Fig 5. Logic Level Converter yang digunakan

In the schematic diagram for the digital compass, we have four main components: Arduino, OLED display, MPU9250, and logic level converter. The Arduino acts as the central controller, coordinating the operations of the other components. The OLED display provides a visual interface to present compass readings and other relevant information. The MPU9250 is a sensor module that combines gyroscope, accelerometer, and magnetometer in one package, offering precise orientation and motion data. To ensure compatibility, the logic level converter adjusts the voltage levels between the components, as the Arduino typically functions at 5V, while the OLED display and MPU9250 module require 3.3V.

The schematic showcases the interconnections between these components, including the I2C communication lines for data exchange between the Arduino and MPU9250. Additionally, it illustrates the power connections, guaranteeing appropriate voltage supply to each component. The schematic serves as a visual guide, aiding in comprehending the electrical connections and facilitating understanding of the interrelationships among the components in the digital compass system.

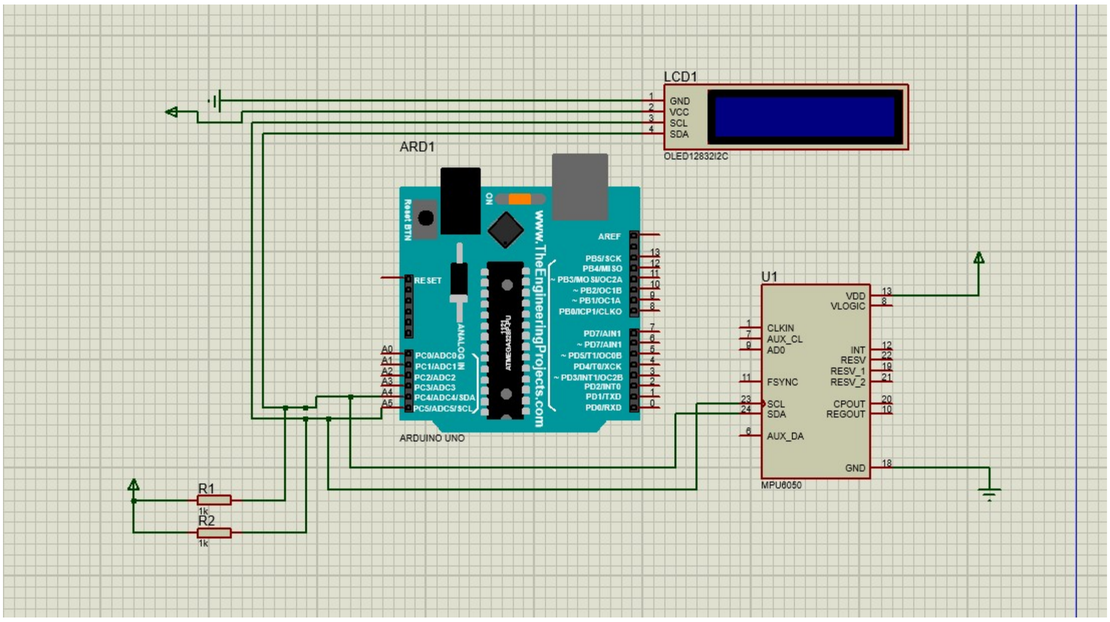
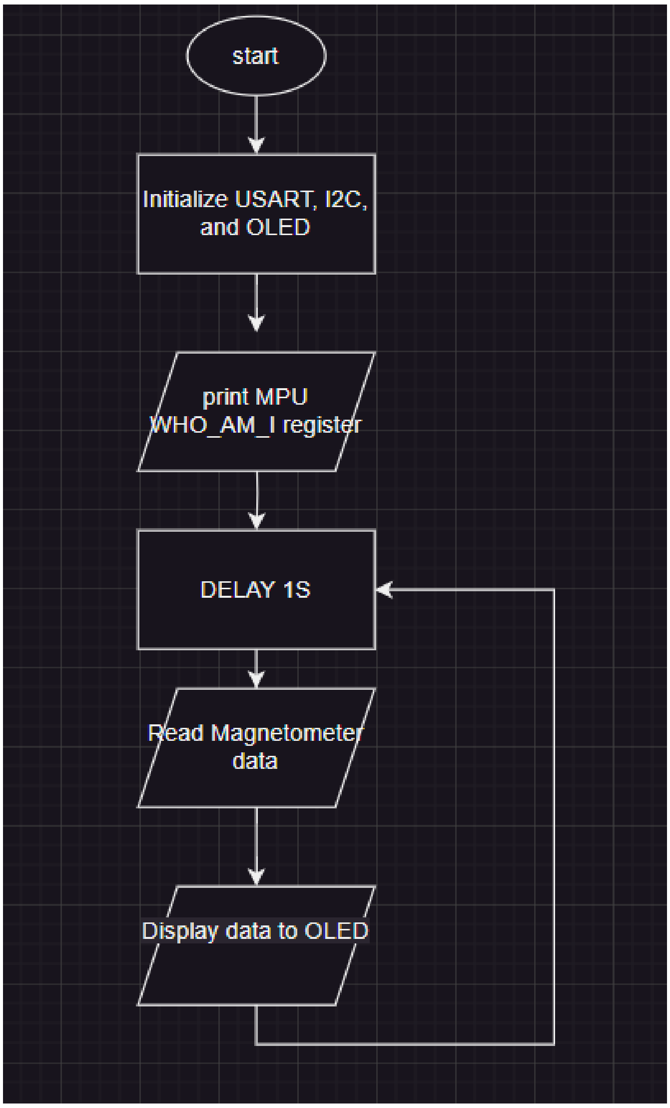


Fig 6. Schematic of the hardware

2.2 SOFTWARE DEVELOPMENT

The software development process for the digital compass involves programming the Arduino microcontroller to interact with the MPU9250 sensor and OLED display. To begin, the Arduino development environment is set up, and the necessary libraries for the MPU9250 sensor and OLED display are installed. In addition, various file formats such as .S (assembly) and .h (header) are utilized. The main.S file serves as the starting point, handling low-level initialization and main loop routine. The i2c.h file provides functions and definitions for communication using the I2C protocol, enabling data retrieval from the MPU9250 sensor and data transmission to OLED display. The registerMap.h file contains specific register addresses and bit definitions, improving program readability. For serial communication and debugging, the usart.h file is used. The oled.h file takes care of controlling the OLED display, including initialization and text display. By combining these .S and .h files with user interface features, the digital compass system can deliver accurate and dependable compass functionality. Detailed documentation accompanies the software development process, providing explanations of the code, algorithms, and user instructions to ensure a comprehensive understanding of the digital compass system.



2.3 HARDWARE AND SOFTWARE INTEGRATION

The successful integration of hardware and software components is vital for implementing the digital compass system. The process begins with assembling the hardware components based on the schematic design, ensuring proper connections and power supply. Simultaneously, the software development phase involves programming the Arduino microcontroller using specific files, configuring communication protocols, and implementing compass calculations and display functionalities. Once the hardware and software are ready, the integration phase focuses on establishing communication between the components, and testing the system's functionality.

Comprehensive documentation is essential, covering hardware assembly, software implementation, calibration procedures, and user instructions. This documentation serves as a valuable guide for effectively utilizing and maintaining the digital compass system. The successful integration of hardware and software components enables smooth operation and ensures a reliable and precise digital compass system.

CHAPTER 3

TESTING AND EVALUATION

3.1 TESTING

To ensure the accuracy and functionality of the digital compass system, a series of tests are conducted:

1. Hardware Verification: The hardware components, including Arduino, MPU9250 sensor, OLED display, and logic level converter, undergo thorough inspection to ensure proper functionality. This involves checking the connections, power supply, and overall integrity of the hardware.
2. Orientation Sensitivity: The system's performance under different orientations is evaluated. By rotating the digital compass in various directions, the corresponding compass readings are examined to ensure accurate representation of orientation changes.
3. Environmental Interference: The system's resistance to environmental factors, such as reading value at rest, is tested. The digital compass is exposed to different environmental conditions to verify its ability to maintain accurate readings despite external influences.
4. Display Functionality: The functionality of the OLED display is assessed to ensure proper initialization, clear visibility of compass readings, and real-time updates. The display is evaluated under different lighting conditions to ensure optimal readability.
5. User Interaction: The user interface is evaluated to assess its ease of use and responsiveness. This includes the user-friendliness of the displayed value
6. System Reliability: A comprehensive system test is conducted to evaluate the overall reliability and stability of the digital compass system. The system is operated continuously for an extended period to detect any performance issues or inconsistencies.

3.2 RESULT

The digital compass system, consisting of Arduino, MPU9250 sensor, OLED display, and logic level converter, has been implemented and tested. The evaluation yielded the following key findings:

1. Hardware Functionality: The hardware components, including Arduino, MPU9250 sensor, OLED display, and logic level converter, functioned correctly. The connections were established accurately, ensuring reliable communication and power distribution to each component.
2. Orientation Sensitivity: The system performed effectively under various orientations. As the digital compass was rotated in different directions, the compass readings accurately reflected the changes in orientation, providing real-time updates with minimal delay.
3. Environmental Interference Resilience: The digital compass system's displayed value changes significantly even at rest, suggesting that the data as it is displayed still needs to be processed
4. Display Functionality: The OLED display functioned excellently, providing clear visibility of angular rate measurements and real-time updates. The display remained legible under different lighting conditions, ensuring readability in various environments.
5. User Interaction: The result displayed in the OLED has yet to fulfill our expectation, as it only displays angular rate measurements in hexadecimal format, so it's not easily understandable by non-experts users when using the device.
6. System Reliability: The digital compass system showcased high reliability and stability during extended operation. It consistently performed its task without any significant issues or inconsistencies.

The successful integration of hardware and software components, along with rigorous testing, has resulted in a somewhat successful attempt to make a rudimentary device to display sensor readings. Though, we are still not able to achieve our initial objective that is to make a usable digital compass that serves its purpose to show proper directions and such.

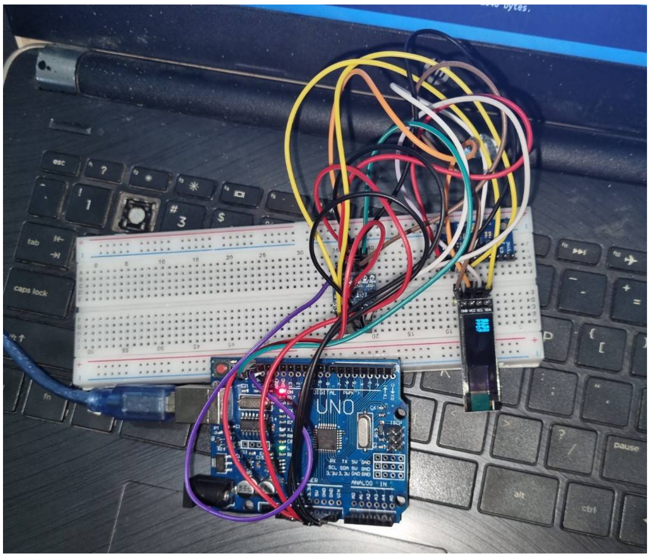


Fig 2. Testing Result

3.3 EVALUATION

As explained in the previous subsection, the digital compass we have created has not fully met its function as a typical digital compass. This is because the values displayed on the OLED screen are readings from the gyroscope that are divided into three types:

- Yaw: the horizontal rotation on a flat surface when seen from above the object.
- Pitch: vertical rotation as seen from the front of the object.
- Roll: horizontal rotation as seen from the front of the object.

We have not yet succeeded in converting these values into compass readings that are generally understandable, such as indicating the cardinal directions and their inclination to the Earth's magnetic field. This is because the conversion process is more difficult and complex than we anticipated, requiring additional variables to be included in the program such as reading the sensor calibration and the inclination value of the magnetic field.

CHAPTER 4

CONCLUSION

In conclusion, the project to make a digital compass was not quite successful, as it is still not what we quite expected. The digital compass is a useful tool for navigation, and the project involved the use of various electronic components such as an Arduino Uno, MPU-9250 sensor module, and OLED to display the result.

Although this project still lacks a lot of refinement, there is potential for future improvements and developments in this project. One possible improvement is to read more sensor readings, so that the OLED could display a more proper compass reading. Additionally, we could process the data as it is displayed into a human-readable data so that it is more understandable by non-expert people to read the compass direction.

REFERENCES

[1] ‘MPU-9250 Register Map and Descriptions’, *Tdk.com*. [Online]. Available: https://invensense.tdk.com/wp-content/uploads/2015/02/RM-MPU-9250A-00-v1.6.pdf. [Diakses: 16 Mei 2023]

[2] ‘MPU-9250 Product Specification Revision 1.1’, *Tdk.com*. [Online]. Available: https://invensense.tdk.com/wp-content/uploads/2015/02/PS-MPU-9250A-01-v1.1.pdf. [Diakses: 16 Mei 2023]

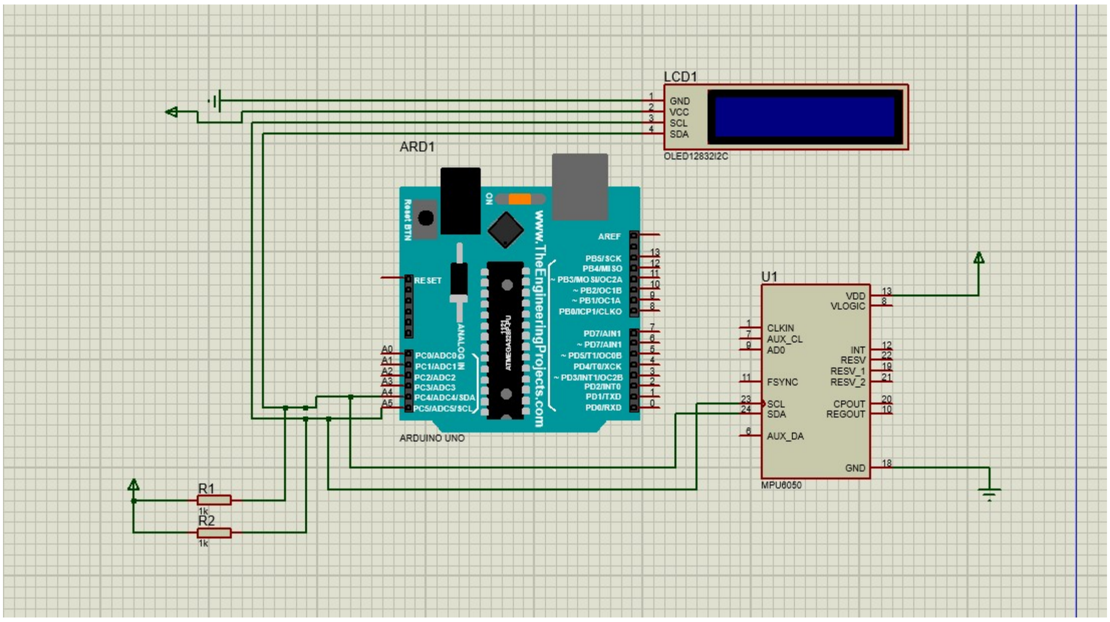
[3] S. Systech, ‘28 x 64 dot matrix OLED/PLED segment/common driver with controller’, *Adafruit.com*, 2008. [Online]. Available: https://cdn-shop.adafruit.com/datasheets/SSD1306.pdf. [Diakses: 16 Mei 2023]

[4] Anas Kuzechie. "Assembly via Arduino (part 21) - HC SR04 Sensor". (Dec. 6, 2021). [Video Online]. Available: https://www.youtube.com/watch?v=dIIBG7Qz-_E. [Diakses: 16 Mei 2023].

[5] Tim Penyusun Modul. “Modul 8 SSF : I2C & SPI”. [Online]. Digital Laboratory FTUI. 2023. Available: https://emas2.ui.ac.id/pluginfile.php/3797142/mod_resource/content/1/ModSRul%208%20SSF_%20I2C%20_%20SPI.pdf. [Accessed: 15 May 2023].

APPENDICES

Appendix A: Project Schematic



Appendix B: Documentation