ELEKTRONICA-ICT

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2EAI-ES2-2324-Depthmonitor

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Abstract

This application note (AN) documents the development of a depth monitoring system using the Arduino Nano BLE Sense microcontroller. The hardware setup integrates various sensors, the details of which will be explained later in this document. The primary objective of this project is to gain insight into different sensor technologies by comparing their performance and accuracy.

The research within this AN give an in-depth examination of the Arduino microcontroller and the diverse array of sensors employed. Additionally, it delves into the programming language utilized for the project. This programming language serves as the foundation for advancing towards a functional product.

A systematic approach has been employed to achieve a working final product, incorporating cost-effective solutions. The in-depth research conducted prior to reaching the original project scope has been instrumental in ensuring the project's success.

Content

Figure list

1 Introduction

This development paper delves deeper into the journey of creating and implementing a monitoring project, undertaken as a crucial part of the academic curriculum at PXL Digital. The project is divided into three key phases: the initial research phase, where we explored hardware and method options; the testing phase, where sensors and tools were put through their paces; and the implementation phase, where everything was brought together into one final product.

In the research phase, we delved into a range of hardware possibilities, including the Arduino Nano BLE Sense, and identified suitable software tools. This phase was pivotal in getting a grasp of what the sensors and tools could do, understanding their strengths and limitations.

Moving on to the testing phase, we conducted direct experiments with the researched sensors and the Arduino Nano BLE Sense. These tests were crucial in making final decisions about the project.

The final implementation phase marked the culmination of our efforts, where we integrated all the tested elements to craft a fully functional monitoring system. Here, our focus was on refining the user experience and ensuring the system's reliability across various conditions.

The paper is organized to walk the reader through each stage of the project development process. Following the introduction, the Materials and methods section provides a detailed description of Hardware and software used. The Results section presents the outcomes of the testing phase. A more in-depth discussion of these results is found in the Discussion section, and the paper concludes with a summary of findings.

2 Material and methods

2.1 Materials

2.1.1 Arduino nano 33 BLE sense

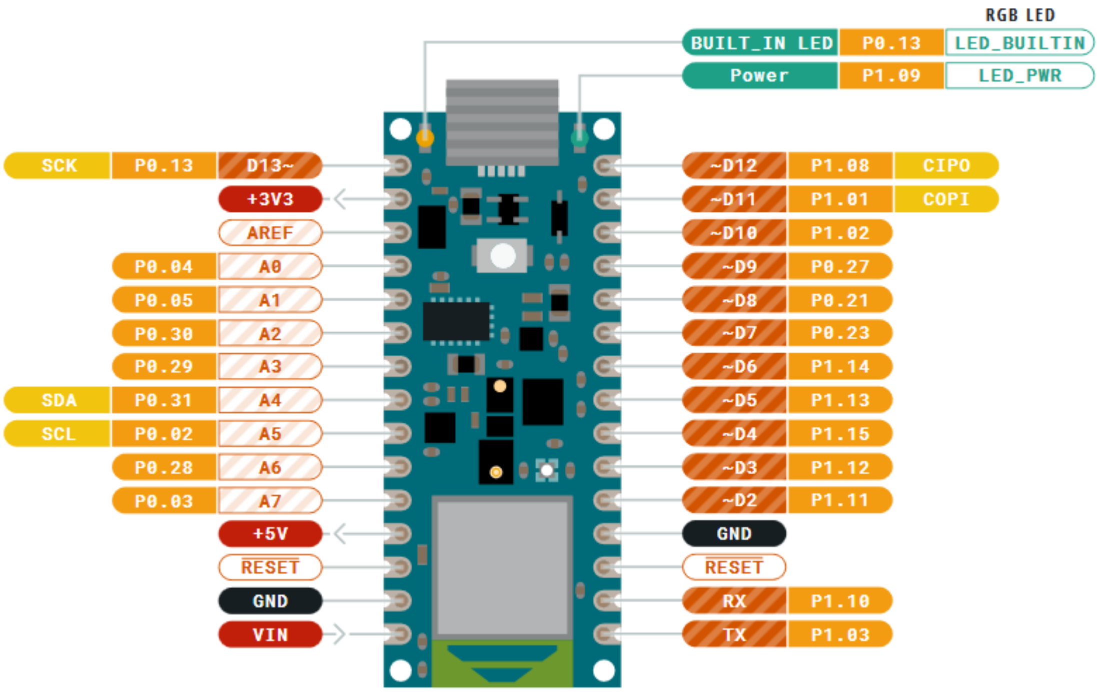

Figure 1 Arduino nano BLE

The Arduino nano served as the main board for driving the project, and to understand the pin layout the manual provided by the company Arduino was consulted. Reading the documentation provided insights into the board's pin configurations, functions, and usage.

Let's delve into the impressive array of features this board offers:

1. Bluetooth Connectivity: Harness the power of a robust 2.4 GHz Bluetooth® 5 Low Energy module, complete with an internal antenna. This feature enables seamless data transmission between various devices.

2. IMU for Motion Detection: With the LSM9DS1 inertial measurement unit onboard, there is access to a 3D accelerometer, gyroscope, and magnetometer.

3. Python Support: The potential of MicroPython, an implementation of the Python® programming language with a subset of the Python® standard library. This enables streamlined programming directly on the board, enhancing development efficiency.

4. Microphone Integration: Utilize the integrated omnidirectional digital microphone (MP34DT05) to capture and analyze real-time sound data.

5. Proximity and Gesture Detection: Leverage the capabilities of the built-in APDS9960 sensor to detect proximity and interpret gesture inputs.

6. Barometric Pressure Sensing: Incorporating the LPS22HB barometric pressure sensor enables precise measurement of atmospheric pressure, ranging from 260 to 1260 hPa. This data can be further processed to calculate accurate altitude above sea level, enriching your project's environmental awareness.

7. Temperature and Humidity Sensing: Benefit from the HTS221 capacitive digital sensor, designed to measure relative humidity and temperature with impressive accuracy (± 0.5 °C).

2.1.2 PEPPERL+FUSHS Ultrasonic sensor

The PEPPERL&FUSHS ultrasonic sensor is an industrial ultrasonic sensor operating at voltages between 17 and 30V. The sensor offers various possibilities and is used in various industrial fields. It is a robust sensor, which is also easily adjustable.

It features the following pinout:

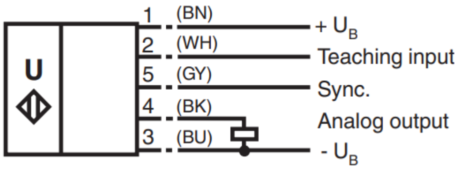

Figure 3: Ultrasonic sensor pinout

Figure 2: PEPPERL+FUSHS ultrasonic sensor

The connections should be made as follows, considering the cable used.

1 Brown cable: connected to 24V source.

2 White cable: not connected.

3 Blue cable: connected to ground of the source.

4 Black cable: connected to voltage divider (to Arduino analog pin)

5 Gray cable: not connected.

The sensor has two main settings. On the one hand, the sensor's operation can be fully set. For example, 'rising amp', 'falling amp', or 'zero line' can be chosen. These are always described as in Figure 4. A1 and A2 can be set using the A1 and A2 buttons (only for the first 5 minutes after a power on), these are the upper, and lower limits. If the sensor is set in 'zero-line' mode, the A1 limit will be set to 0 cm and increase to A2.

The sensor is capable of measuring distances between 350 mm and 6 meters.

Besides setting the behavior of the sensor, the beam width can also be set. This makes this sensor multi-functional.

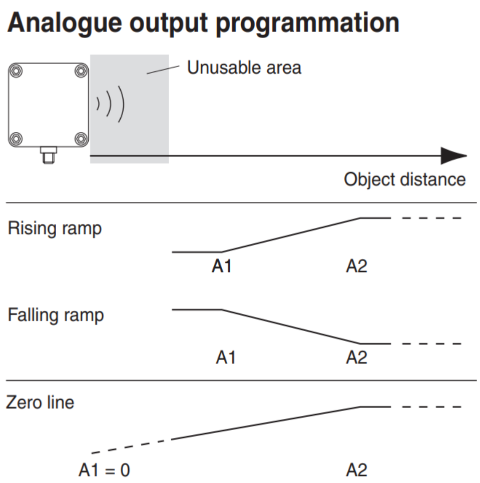

Figure 4: different settings

2.1.3 LV-MaxSonar-EZ

With 2.5V – 5.5V power the LV-MaxSonar-EZ provides very short to long-range detection and ranging in a very small package. The LV-MaxSonar-EZ detects objects from 0-centimeters to 6.45 meters and provides sonar range information from 15 cm to 6.45 meters with 2.5 cm precision.

Figure 5 LV-Maxsonar

This sensor has the following seven pins:

1. BW: This is a pin that can be used to select whether a TX output is required or not. When set high, the sensor is in 'chaining mode'. The TX output will then send a single pulse instead of a serial signal.
2. PW: This pin shows the pulse width representation of the measured distance. The scaling factor is 147uS per inch.
3. AN: this pin outputs an analogue signal with a scaling factor of Vcc/512 per inch. For example, if a voltage of 3.3V is applied to the input, the output voltage at this pin will be 6.5mV per inch. This is roughly equivalent to 2.6 mV per inch. This pin is used in this application to read the analogue distances.
4. RX: When this input is high (or just open), the sensor is in "ranging" mode.
5. TX: a serial signal is output from this pin when BW is low.
6. VCC: input voltage, can range from 3V - 5.5V.
7. GND

2.1.4 PING Ultrasonic Sensor

The PING))) ™ ultrasonic sensor provides an easy method of distance measurement. This sensor is perfect for any numbers of applications that require you to perform measurements between moving or stationary objects.

Figure 6 Ping ultrasonic

Interfacing to a microcontroller is a snap. A single I/O (input/output) pin is used to trigger an ultrasonic burst and then listen for the echo return pulse. The sensor measures the time required for the echo return and returns this value to the microcontroller.

Key features:

- Provides precise, non-contact distance measurements within a 3cm to 3m range.
- Simple pulse in/pulse out communication requires just one I/O pin.

2.1.5 MONOCHROME Display

An OLED (organic light-emitting diode) has many advantages over traditional LCD displays, including a faster response speed, thinner profile, and lower power consumption. An OLED can be widely used in mobile devices for display applications.

Figure 7 Monochrome display

The display areas are 0.96” and uses an IC SSD1306 chip. The screen supports I2C communication and refresh rates up to 60Hz. With a regular operating voltage of 3.3V ~ 5V, this display is easy to work together with a lot of microcontrollers.

2.1.6 Analog distance sensor

Figure 8: SHARP GP2YA21

The Sharp GP2Y0A21 is an analog output distance measuring sensor that utilizes a combination of a position sensitive detector (PSD), an infrared emitting diode (IRED), and a signal processing circuit to measure distances ranging from 10 to 80 cm. It operates on the principle of triangulation, which ensures accuracy despite variations in object reflectivity, ambient temperature, and operational duration. The sensor outputs a voltage corresponding to the measured distance, making it ideal for applications like touch-less switches, robotic cleaners, and energy-saving devices. It typically consumes 30 mA of current and requires a supply voltage between 4.5 and 5.5 V. The sensor features three pins: VCC for power supply, GND for grounding, and Vo for the output voltage, which varies between 0.4V at 80 cm and 2.1V at 10 cm.

2.1.7 Digital distance sensor

Figure 9: SHARP GP2D12

The Sharp GP2D12 is a digital distance measuring sensor with an effective range of 10 to 80 cm. It uses an infrared LED and a position-sensitive detector to determine the presence of an object within this range, outputting a digital signal (0 or VCC). The GP2D12 features a typical response time of 39 ms and an average current consumption of 33 mA. Its three pins are VCC (power supply), GND (ground), and VO (digital output). This sensor is suitable for applications requiring simple presence detection, such as obstacle avoidance in robotics and proximity sensing in automation systems.

2.2 Methods

2.2.1 Altium Designer

The electrical wiring schematics were created using Altium Designer, a professional-grade software widely used in the industry. Fortunately, our school provided us access to this powerful tool, enabling us to produce detailed designs for our project.

2.2.2 Arduino IDE

The open-source Arduino software (IDE) is a powerful tool designed to simplify the development and deployment of code for Arduino boards. It provides an easy-to-use, user-friendly interface that allows both beginners and experienced developers to write, edit and upload code seamlessly.

3 Results

3.1 Components

3.1.1 PEPPERL & FUSHS Ultrasonic sensor

The ultrasonic sensor depicted is utilized as the 'main sensor'. It is configured with a zero-line and a maximum range of 6 meters, enabling easy calculation of the measured distance in the software. The sensor outputs a value from 0 to 10V, so a voltage divider was implemented to reduce this range to 0 to 3.3V using 1K and 2K2 ohm resistors. Currently, the sensor is used with a small beam in a prototype setup within a narrow environment. The convenient configuration allows for easy adjustments later.

The image below illustrates that when the sensor detects a short range, it returns a low voltage. This voltage is sent to the Arduino microcontroller, where further calculations are performed to determine the correct distances. The sensor's response varies with different settings. This characteristic is utilized in the current project.

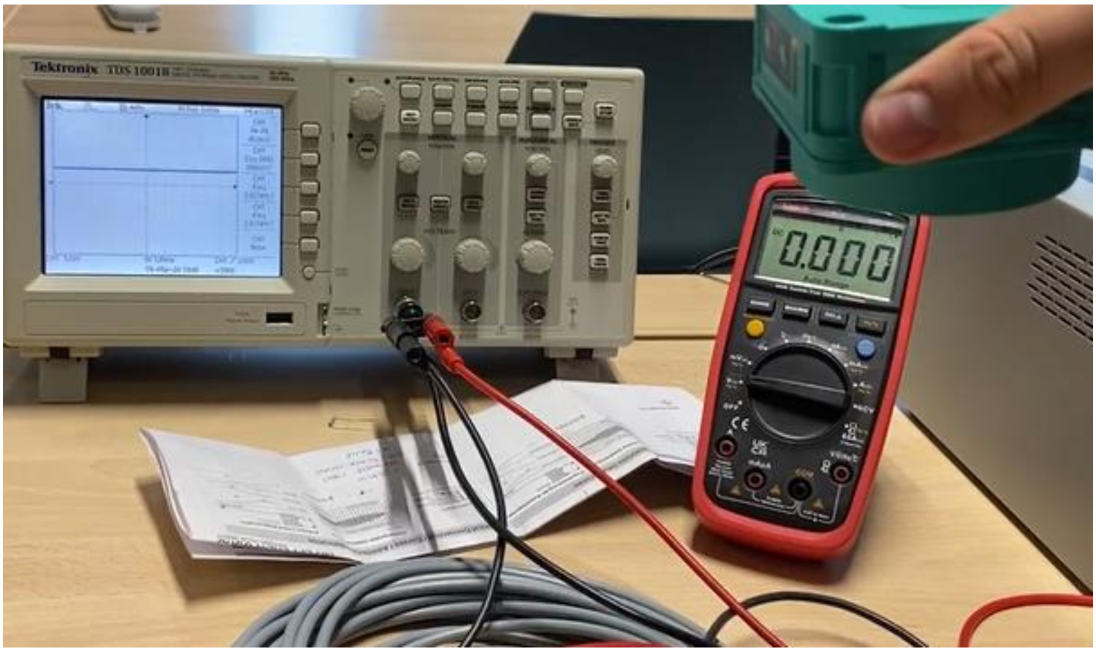

Figure 10 Pepperl & Fushs close range

The image below illustrates that when the sensor detects a greater distance, it returns a higher voltage, with a maximum output of 10V. This voltage is converted using a voltage divider, corresponding to approximately 6 meters, which is the maximum distance the sensor can measure.

Figure 11 Pepperl & Fushs wide range

3.1.2 Analog distance sensor

The SHARP GP2Y0A21 is used in the final design. The analogue value is read and converted to a distance using a similar technique to the large ultrasonic sensor. This sensor only works up to 80 cm, so it will be deployed within its range. The digital IR sensor is not used, because it is of no importance that we can detect whether there is anything within the range of the sensor.

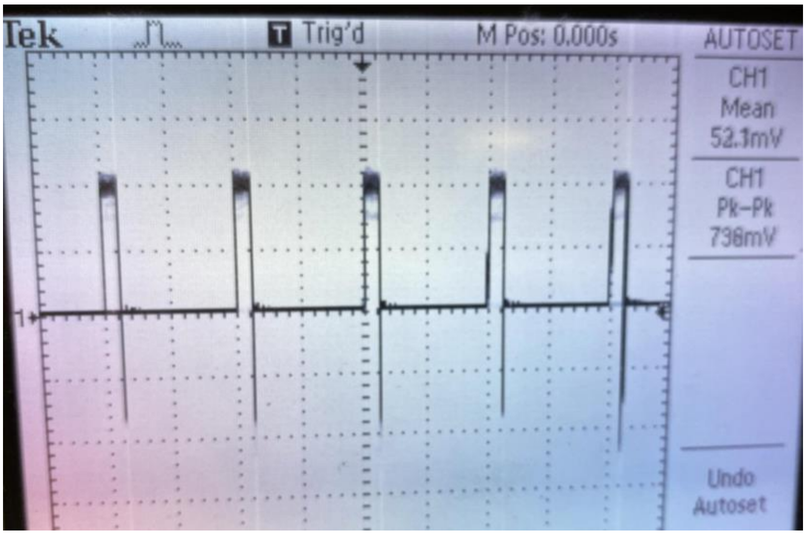

Figure 12 Analog sensor range

In the image above, it is shown that when an object is held at a consistent distance above the sensor, the voltage output increases. As the distance between the sensor and the object increases, the voltage output increases further. Conversely, when the object is held at a lower height, the voltage from the sensor decreases. These voltage readings can be used to perform calculations to measure the volume in liters.

3.1.3 LV-MaxSonar-EZ

The LV-MaxSonar-EZ range finder is a high-performance sonar sensor capable of detecting objects from 0 to 254 inches (6.45 meters), providing accurate range information with a resolution of 1 inch. This sensor operates with a power supply between 2.5V to 5.5V and is designed for indoor use, making it ideal for applications such as UAVs, bin level measurement, proximity detection, and robotic navigation.

The LV-MaxSonar-EZ offers multiple output formats: pulse width output, analog voltage output, and RS232 serial output. In our project, we utilize the analog voltage output, which allows us to convert the voltage readings directly into distance measurements using an Arduino. This interface provides a simple and effective way to integrate the sensor into our system, ensuring reliable and continuous distance measurement.

Key features of the LV-MaxSonar-EZ include continuously variable gain control, side lobe suppression, and the ability to operate in free-run or triggered modes. The sensor also boasts a fast measurement cycle, with readings available every 50 milliseconds (20-Hz rate), and it functions within an actual operating temperature range from –40°C to +65°C.

Figure 13: All sensors, respectively: range finder, ultrasonic sensor, infrared sensor

3.2 Total project

The final project is designed to read the current contents of a vessel or barrel on a display. As an exercise, different sensors are used for this purpose. For instance, both an infrared sensor and an ultrasonic sensor are used. By switching a lever, the user is able to switch between different sensors. When the sensor is activated, the calculated content is shown on the OLED display. In this way, the user can read the contents based on different measurements, making the outcome a lot more accurate. The process is shown in the image below.

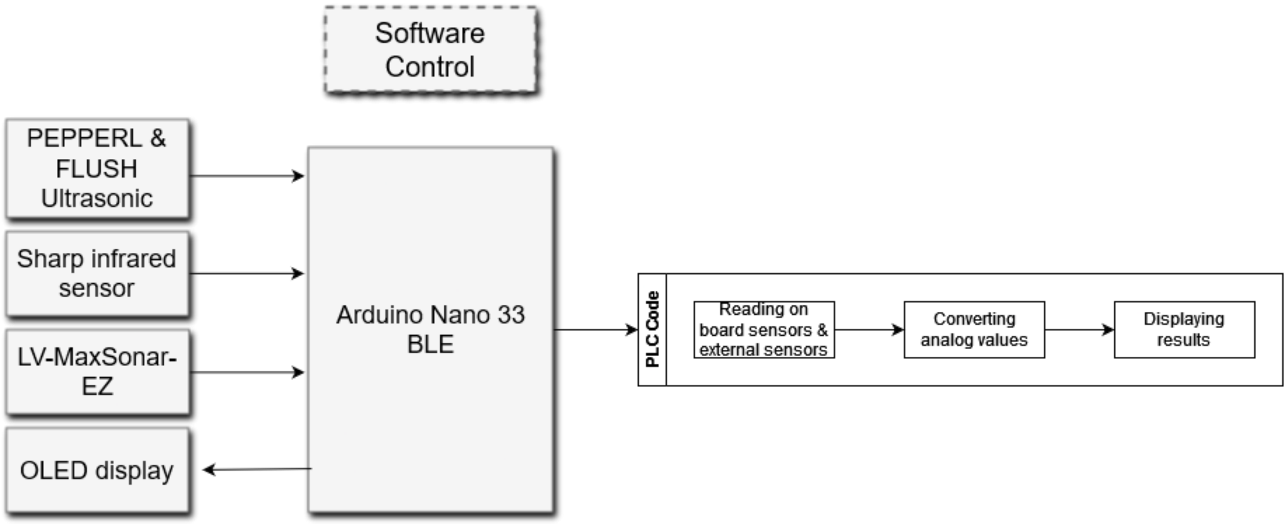

Figure 14 Software overview

For the setup, a simple rectangular wooden plate is utilized, allowing easy placement of the entire setup on various vessels or barrels. All electronic components are mounted on a basic pertinax plate. Given the simplicity of the setup, consisting only of an Arduino and a few resistors, the cost of developing and purchasing a PCB is unnecessary. Utilizing the pertinax print plate makes the project cost-effective and environmentally friendly. To complete the setup, an external 5V power supply is required to power the OLED display and the Arduino microcontroller, while a separate 24V power supply is necessary to power the PEPPERL&FUSHS ultrasonic sensor.

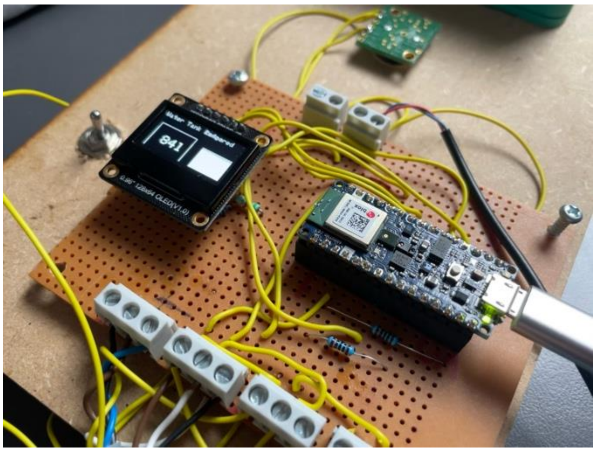

Figure 15: Working program - OLED display shows volume

3.2.1 Component list

The components for this project were graciously provided by the lecturer from PXL meaning as a student, there were minimal expenses except for the PCB costs. Utilizing a simple printed circuit board (PCB) kept additional expenses at bay. Maintaining a component list is invaluable for assessing the cost of the components utilized in the project.

BOM: Depthmonitor

Description	Supplier	Reference	Qnt	Delivery date	Package Qnt	prices
Resistor			*2*		*2*	*€ 0,00000*
1 kΩ	provided by PXL		1	Always available	1	€ ,000
500 Ω	Document is voor het laatst opgeslagen: Zojuist PXL		1	Always available	1	€ ,000
Print plate			*1*		*1*	*€ 0,00000*
Print plate	provided by PXL		1	Always available	1	€ ,000
Microcontroller			*1*		*1*	*€ 22,80000*
Arduino Nano 33 BLE	Arduino store	ABX00030	1	SOLD OUT	1	€ 22,8000
Sensors			*5*		*5*	*€ 401,43000*
PING))) Ultrasonic Distance Sensor	provided by PXL	28015	1	Available	1	€ 23,11000
Ultrasonic sensor UB6000-F42-U-V15	provided by PXL		1	Available	1	€ 330,32000
MB1000 LV-MaxSonar-EZ0	provided by PXL		1	Available	1	€ 28,95000
Sharp Optical Distance Sensor	provided by PXL		1	Available	1	€ 5,5000
GP2D12 Sharp Infrared Distance Sensor	provided by PXL	381000055	1	Available	1	€ 13,55000
Display			*1*		*1*	*€ 13,40000*
Monochrome 0.96" 128x64 I2C/SPI OLED Display (Breakout)	provided by PXL	DFR0650	1	Available	1	€ 13,4000
					Total	*€ 437,63000*
					Total setup	*€ 400,97000*

Figure 16 Component List

3.2.2 Electrical schematic

In the picture below the connections are as follows:

All sensors are connected using the same power source to reduce the amount of wiring, only the UB6000 (PEPPERL & FUSHS) sensor is connected to the 24V power supply. The setup also requires an external 5V power supply to power the microcontroller and its component.

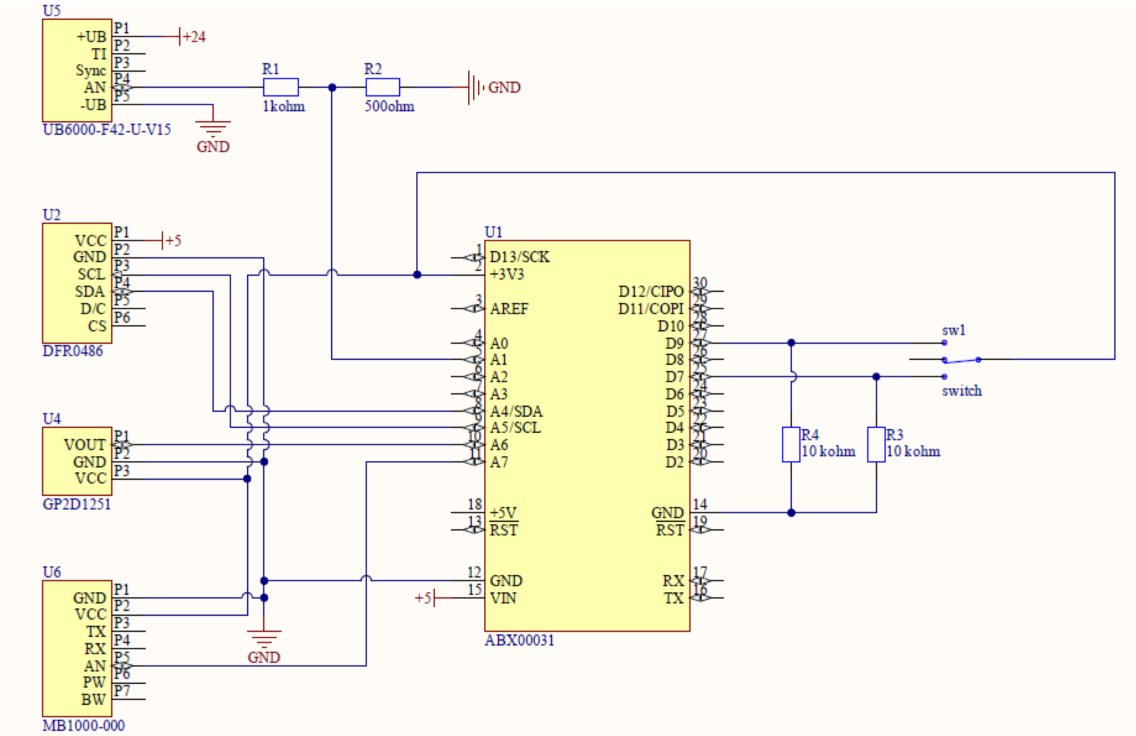

Figure 17 Electrical connections

4 User Experience

From a user perspective, the current setup offers convenience and ease of use. The wooden plate, placed atop a vessel or barrel, provides ample space between the electronics and any water contact. All connections are conveniently made on top of the plate, with non-water-resistant sensors positioned flush with the plate's edge. Notably, the PEPPER&FLUSHS sensor boasts complete water resistance, eliminating concerns about water contact.

Starting the process is straightforward for users: simply connect the external 5V and 24V power supplies, and the microcontroller initiates everything automatically. The inclusion of a switch enhances user control, allowing easy switching between the OLED display sources. By default, the PEPPER&FLUSHS sensor data is displayed, but activating the switch enables viewing data from other sensors.

To enhance the setup further, improvements can be made to the print plate by ensuring better connections. Current connections serve as temporary solutions, implemented due to time constraints. Additionally, upgrading to better water resistance and implementing enhanced security protocols are potential avenues for improvement.

Consideration for user experience during development is evident in the setup's design. Users will appreciate the straightforward setup process and the ability to easily switch between sensor data. The user interface is intuitive, reducing the likelihood of confusion or misuse. Safety measures are implemented, particularly with water resistance and power supply connections, ensuring user protection. While the learning curve for operating the setup is minimal, users may benefit from basic knowledge of power supply connections and sensor operation. Overall, the setup caters to users of varying abilities, offering a user-friendly experience with room for further improvement.

5 Discussion

The goal of this project was to learn the difference between sensors, with the final touch being an application using the Arduino as a microcontroller. By placing the better sensor together, a project for analyzing the differences could be made.

The beginning of the project involved studying the different sensors by looking at each data sheet and testing the sensors with an oscilloscope and function generator. With these instruments, the sensors could be tested by manually changing amplitudes and frequencies.

Most of the time was spent on the working process of the PEPPERL & FUCHS sensor. This sensor was a little bit complicated to understand due to its programmed features and settings. Once this was learned, the sensor became our main component to test other sensors in the project. This sensor is also the most expensive and water-resistant of all the others.

6 Conclusion

Throughout this project, we have done thorough research on various sensors and the Arduino Nano to build our complete solution. Working with new sensors has helped each team member learn more about hardware. Exploring how different sensors work has been a valuable learning experience for everyone involved. We have encountered challenges and discovered new things along the way, which has made us more knowledgeable about hardware systems. As we move forward, we are excited to use what we have learned in future projects.

7 Reference list

- Arduino nano 33 BLE documentation. [Online]Arduino. https://www.arduino.cc/en/Guide/NANO33BLE.
- Arduino nano 33 BLE datasheet. [Online]https://github.com/JonasVanhulst/DepthMonitor/blob/main/Datasheets/ABX00031-datasheet.pdf.
- MB1000 Datasheet. [Online]https://github.com/JonasVanhulst/DepthMonitor/blob/main/Datasheets/MB1000.pdf.
- UB6000-F42-U-V15 Ultrasonic sensor Datasheet. [Online]https://github.com/JonasVanhulst/DepthMonitor/blob/main/Datasheets/UB6000-F42-U-V15%20Ultrasonic.pdf.
- gp2d12 IR sensor datasheet. [Online]https://github.com/JonasVanhulst/DepthMonitor/blob/main/Datasheets/gp2d12.pdf.
- gp2y0a02yk_e Datasheet. [Online]https://github.com/JonasVanhulst/DepthMonitor/blob/main/Datasheets/gp2y0a02yk_e.pdf.
- i2c_Display datasheet. [Online]https://github.com/JonasVanhulst/DepthMonitor/blob/main/Datasheets/i2c_Display.pdf.