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Faculty of Mechanical Engineering

Electrification and implementation of electric unlocking (RFID) at the bike box

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1. Introduction

This seminar paper presents the upgrade of an existing aluminum bicycle shed with an electronic unlocking system (RFID technology) and its electrification for the purpose of charging electric bicycles. The goal of the paper was to develop and implement a system that allows the user to easily and securely access the facility using an RFID card or tag. The project includes several phases, from planning and selecting appropriate components, to wiring, assembling key elements (RFID reader, control unit, electromagnetic lock and power supply system), and final testing and troubleshooting. I paid special attention to protecting the system from external influences, since the facility is located outdoors.

In the theoretical part of the paper, I described the basic principles of RFID technology, types of readers and cards, and the advantages and disadvantages of such systems compared to other methods of electronic access (e.g. Bluetooth, PIN passwords, Wi-Fi access, etc.). I also explained how the system recognizes an authorized user and what are the possible usage scenarios.

In the practical part, I documented in detail the individual steps of electrification and modification of the existing bike rack. This included the selection and connection of components, arrangement of components in the cabinet and programming of the Respbery Pi controller.

The final part of the thesis includes an analysis of the system's efficiency, upgrade options and an assessment of the user experience. The project proves that it is possible to upgrade a home project with relatively simple and affordable technology.

2. Description of the existing situation

The bike shed that I upgraded is a freestanding aluminum bike shed designed to store two bikes and cycling accessories. The construction is simple, made of aluminum square tubes and sheet metal, whose task is to protect against weather conditions and vandals. The bike shed has a door on the front, made of aluminum frame and wooden panels. Originally, the locking was done with a mechanical lock, which means that access is only possible using a classic key. In addition to bikes, other garden tools are also occasionally stored inside, so it is important that all family members have access to the building.

Requirements and limitations for the upgrade:

When planning the electrification, certain spatial and technical limitations were taken into account:

- Power supply: There was no power supply in the immediate vicinity, so the system must be connected to the power source via an extension cord. Weather resistance: All electronic components (reader, control unit, lock and bicycle charging sockets) must be resistant to moisture and temperature fluctuations.

- Ease of use: The system must be easy to use even for less technically savvy members of our family.
- Minimal interventions in the existing structure: Since the bicycle shed was already completed and in use, I wanted minimal interventions in the structure, both for technical and visual reasons.

Based on these requirements, a solution with RFID technology was chosen, i.e. a cabinet with a control unit and two bicycle charging sockets. Unlocking will be done with cards or chips that will be recognized by an external RFID reader. Unlocking or locking will also be indicated by a beeper, which will simplify the user experience.

3. Theoretical foundations

3.1. RFID technology:

RFID (Radio Frequency Identification) is a technology that enables wireless identification of items using radio waves. The system usually consists of three basic components: an RFID transponder, an RFID reader, and a central processing unit.

The RFID transponder contains a microchip with a unique identification code (UID) and an antenna with which it transmits a signal when it comes within range of the reader. The reader sends a radio signal that powers a passive tag, and then receives its response. The received data is then compared with a list of authorized users. If the tag is recognized as valid, the intended action is performed (in my case, unlocking the door).

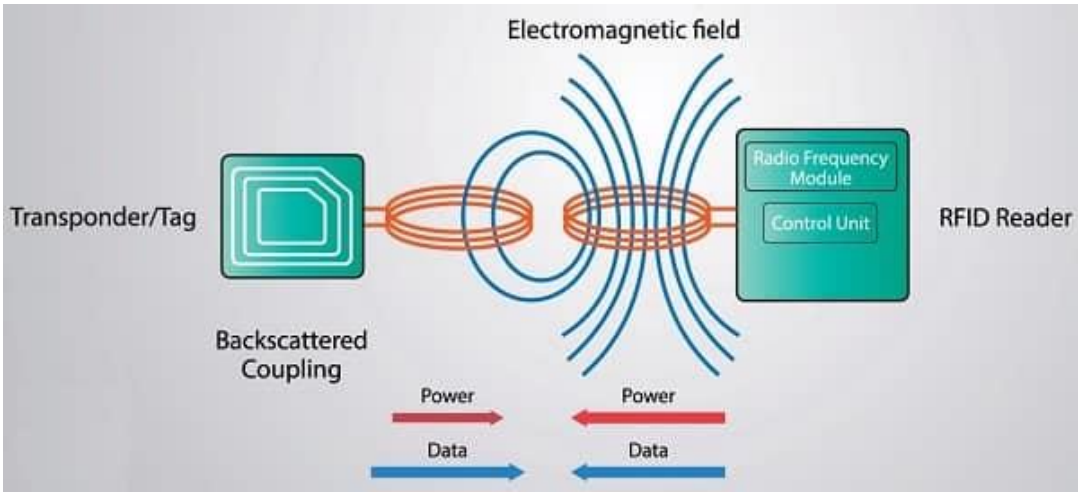


Figure 1: Working of RFID technology

Source: https://www.rfpage.com/components-of-rfid-technology-and-applications/

3.2. Types of RFID systems

LF (Low frequency): operates at around 125kHz. It has a shorter range (up to 10 cm), but is more resistant to external interference. It is most often used in door opening systems such as this one.

HF (High frequency): operates at around 13.56 MHz. It has a medium range (up to 1 m) and is used for public transport cards, access cards, etc.

UHF (Ultra high frequency): operates between 300 MHz and 3 GHz. It allows the longest range (several meters), but is more sensitive to external interference.

3.3. RFID transmitter

These can be in the form of cards (credit card size) or small key chains. Passive transmitters do not have their own power source and are therefore more durable and cheaper.

Figure 2: Types RFID elements

Source: https://blog.flipper.net/rfid/

3.4. Comparison with other systems

The Bluetooth system allows the user to be identified via a smartphone. The advantage is that the user does not need an additional physical card or key fob. The disadvantages depend on the mobile device, the possibility of a dead battery and security vulnerabilities.

The PIN code is a simple method, but it has two disadvantages: the code can be shared with other people and can be easily used, and it is also more difficult to enter and less user-friendly.

Mobile applications do offer more functionality, such as remote unlocking, access logging and internet connection, but they require more complex equipment (Wi-Fi, an application and more knowledge).

4. Solution planning

4.1. Component selection

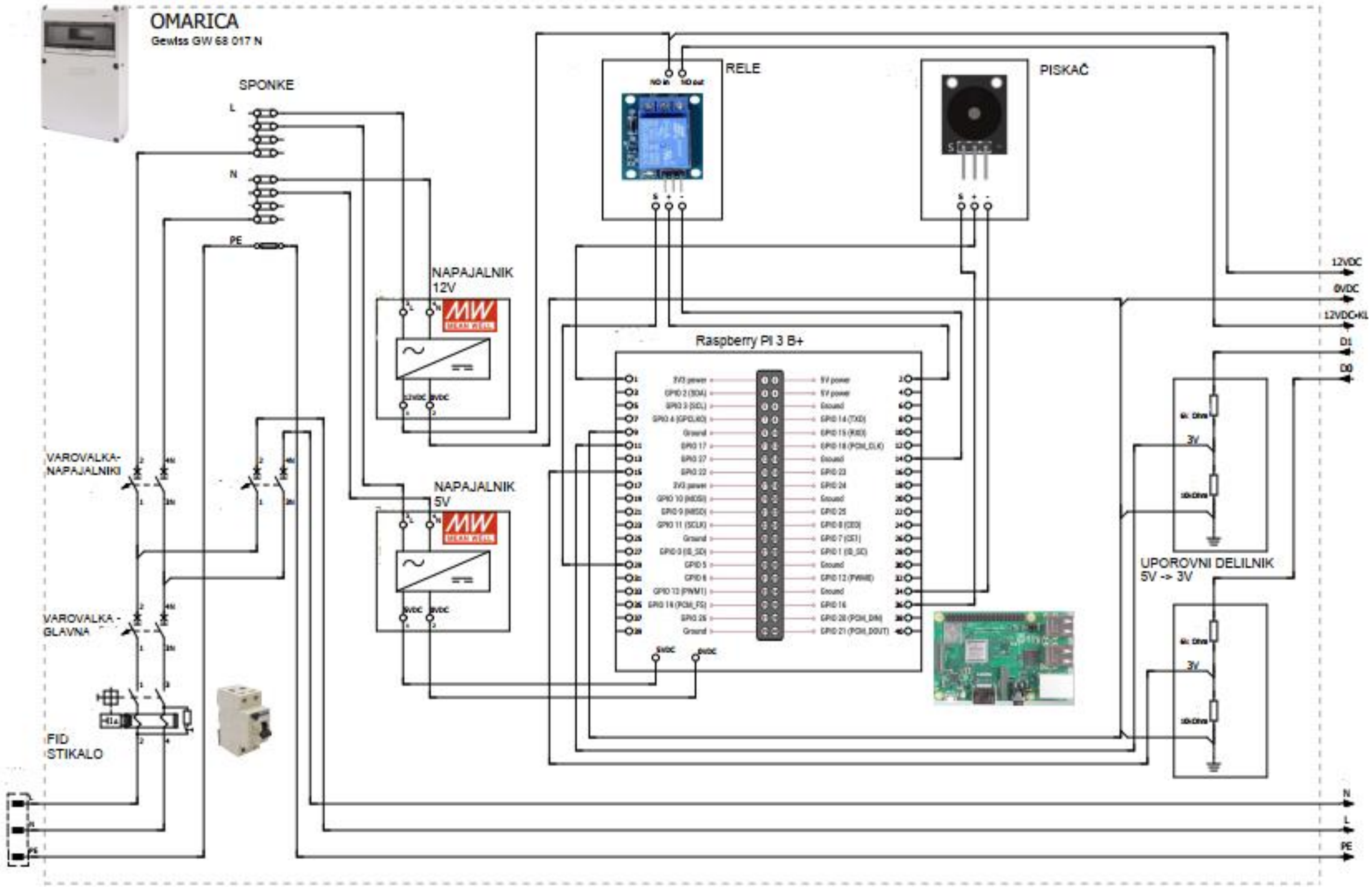
- • **Gewiss GW68007N construction site electrical cabinet.** This one is intended for use in commercial and industrial environments with IP protection 65. The cabinet has dimensions of 320 x 510 x 135 mm and has space inside for 14 circuit breakers (14M).
- • I used the **TRACACON 40A/0.03A 2P RCD** to protect people from electric shock and prevent fire. It is a two-pole version, which allows use in single-phase networks.
- • **Installation circuit breaker** (automatic fuse) with characteristic C, rated current 10A, two-pole (2P) version and short-circuit breaking capacity 6kA. The purpose of this element is to protect the electrical circuit from overload and short circuits.
- • **Tru components TC-9927156 relay.** It is an electromechanical relay with a 5V DC coil and is designed for general use in electronic and industrial applications. According to the manufacturer, it is suitable for use in circuits with low control voltage. The relay has one changeover contact (SPDT). Its advantage is also its size, as it measures only 19 x 15.5 x 15.3 mm.
- • **The buzzer or active piezo buzzer module Joy-it COM-KY012APB** is designed for easy use in Arduino and Respberry Pi projects. The buzzer already contains an internal oscillator, so it only requires a DC power supply to operate, so there is no need for a pwm signal. It requires a voltage of 3.3 to 5V to operate, its sound intensity is around 85 dB, and the tone frequency is 2.3 kHz. It has three inputs: VCC, GND and signal.
- • **Respberry Pi 3b** is equipped with a quad-core 64-bit processor, has built-in Wi-fi and Bluetooth connectivity, and 1 GB of RAM. It requires a 5V power supply via a micro-USB connection to operate. It requires a 5V DC voltage to operate. I

chose the Raspberry Pi because it offers a simpler upgrading my project with WI-Fi or Blutooth connectivity (remote door opening, etc.) like Arduino.

- • **Non-pulse electric cam mini 1410RF**, which operates on a voltage of 12V and is intended for a constant electrical signal. It is mainly suitable for unlocking and mechanical movement indoors, covers, access mechanisms, etc.
- • **Mean Well LRS-35-12 is a power supply** with a 12V DC output voltage and a power of 30W. It has built-in protection against overvoltage, overload and short circuit. It allows mounting on a DIN rail. In the project, I used it to power a non-pulse electric cam and an RFID card reader.
- • **Mean Well HDR-15-5 is a power supply** with a 5V DC output voltage and a power of 15W. It has built-in protection against overvoltage, overload and short circuit. It allows mounting on a DIN rail. In the project, I used it to power the Raspberry Pi.
- • **Resistor divider from 5V -> 3V,** which I made myself. I used a breadboard on which I made a divider with a 6 kOhm and 10 kOhm resistor.
- • **Two surface mount sockets**, with an IP54 protection level. I will use these to charge electric bikes.
- • **RFID reader** - waterproof (IP68) 125 kHz RFID Wiegand reader for access control. It allows easy connection to access control systems such as electronic locks, door controllers, time and attendance systems, etc. It is suitable for outdoor or indoor installation. It requires a voltage of 9 - 16V DC to operate (I used 12V DC, just like for the electric cam).
- • **Small materials**: this includes wires, clips, etc. Wires with a cross-section of 2.5mm2 were used to connect sockets and components to power supplies, while wires with a diameter of 0.75 mm2 were used for other low-voltage connections.

4.2. Wiring diagram:

After selecting the appropriate components, I made a component connection diagram. Immediately after the supply cable enters, it is first connected to the RCD switch, and then it is divided into two branches, each of which goes to its own installation circuit breaker (fuse). One branch goes directly to the sockets on the outside of the electrical box. The branch after the second fuse is divided into two power supplies (12V and 5V) at the connection terminals. The 5V power supply is used to power the Raspberry Pi controller, and the 12V is used to power the non-pulse electric cam and reader. The diagram was drawn in the Canva design platform


OMARICA
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Raspberry PI 3 B+
VAROVALKA-
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VAROVALKA -
GLAVNA
FID
STIKALO
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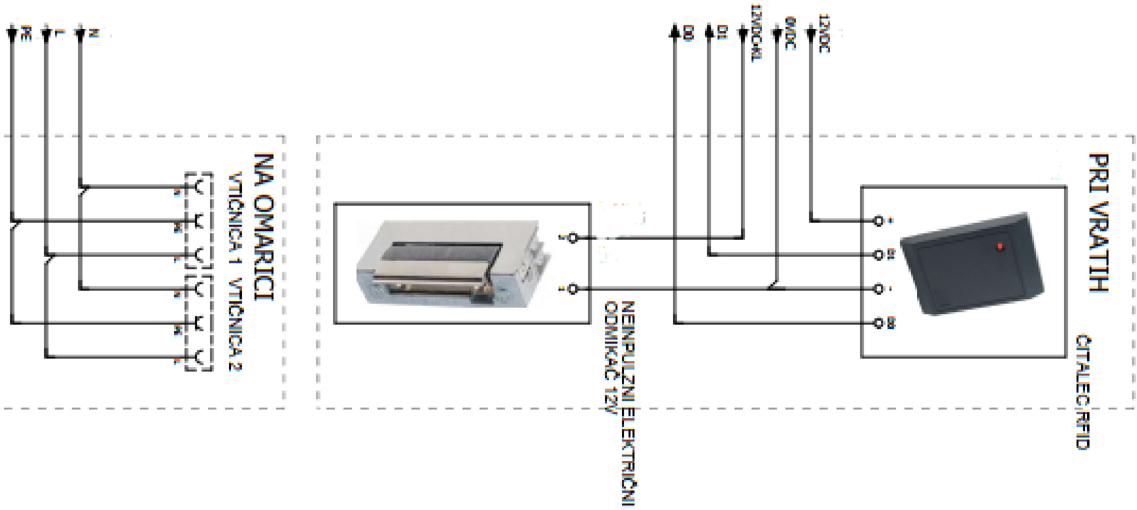

5. Physical implementation of the project

5.1. Component building

Next came the physical implementation of the project. I bought the necessary components and some small accessories (wires, clamps, ...) and started connecting the components. I had no problems during the connection itself, since it was not my first time doing this. The result of the connection is shown in the picture below.

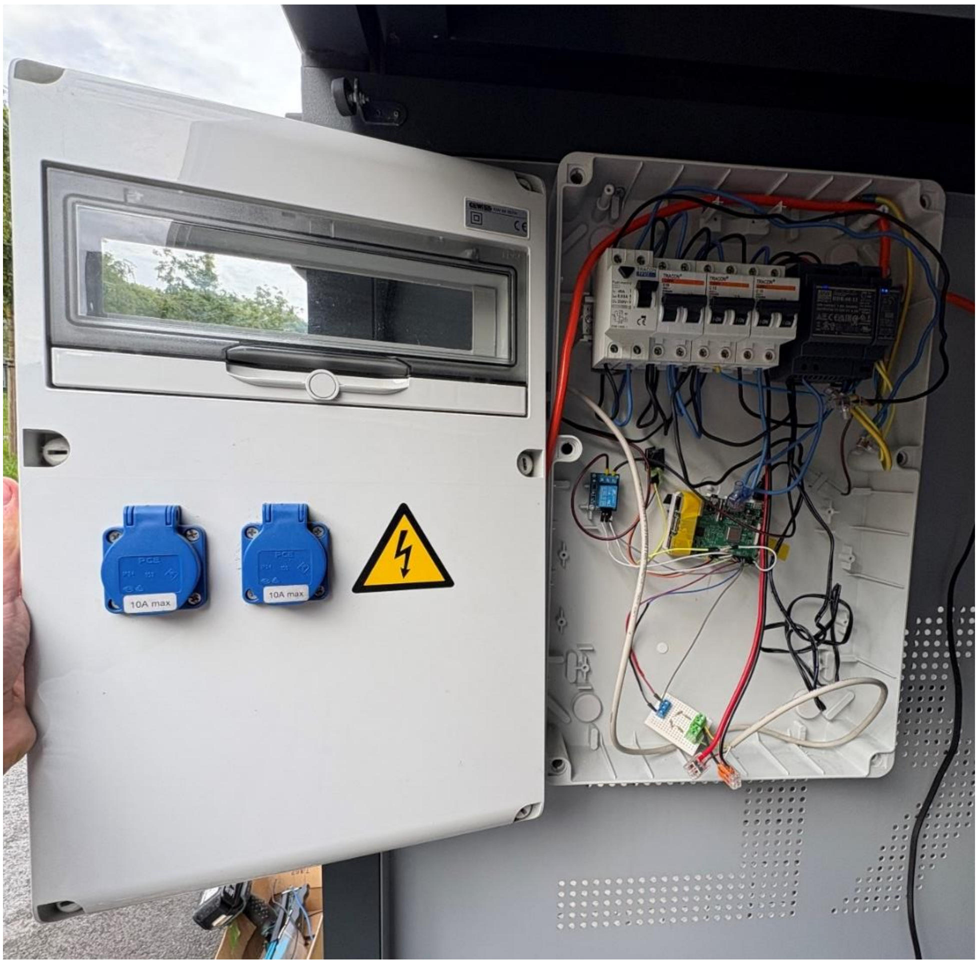

Figure 3: Electrical box

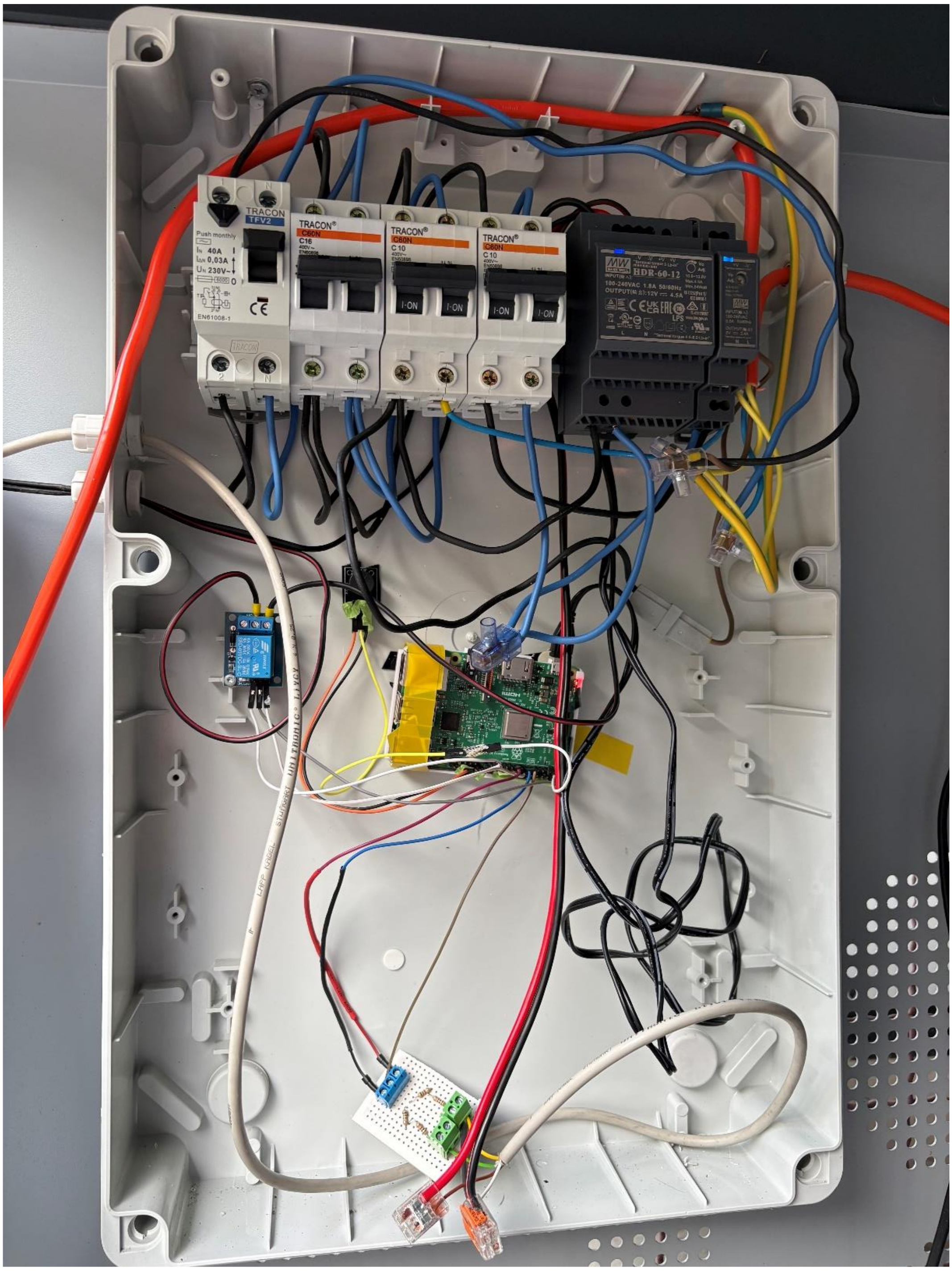

Figure 4: Interior of electrical box

5.2. Controller programming:

Script for adding new cards to the system:

This Python script is intended for use on a Raspberry Pi in conjunction with a Wiegand RFID reader. The program allows you to easily add RFID cards to a file that stores information about all authorized users and their cards. Script reads data from the card via the reader and GPIO pins on the controller. This checks whether the card has already been added and if not, saves it to a local file. In practice, this means that the program allows the user to easily add a new card by bringing the RFID card closer to the reader. Each card is recorded with a unique ID and additional attributes rent (whether it has the right to use it) and admin (whether the user is an administrator).

```
import os
import json
import pigpio
import time

# Ime datoteke kjer bodo shranjene kartice
cards_file = "cards.json"

# Inicializiraj pigpio knjiznico
pi = pigpio.pi()

# Definiraj pine GPIO za podatkovne linije Wiegand
D0_pin = 17  # GPIO pin za D0 (zelena zica)
D1_pin = 22  # GPIO pin za D1 (bela zica)

# Branje obstoječih dovoljenih kartic
#če je datoteka obstaja, jo poskusi prebrati kot JSON, če pa je poškodovana ali ne obstaja vrne prazno knjižnico
def load_card_permissions():
    if os.path.exists(cards_file):
        with open(cards_file, 'r') as f:
            try:
                return json.load(f)
            except json.decoder.JSONDecodeError:
                print("Error: Invalid JSON content in 'cards.json'. Initializing with empty data.")
                return {}
    else:
        print("Warning: 'cards.json' not found. Initializing with empty data.")
        return {}

# shranjevanje novih kartic: shrani slovar z dovoljenimi karticami
def save_card_permissions(card_permissions):
    with open(cards_file, 'w') as f:
        json.dump(card_permissions, f, indent=4)

# dodajanje nove kartice:
#ko je prebrana nova kartica, preveri če že obstaja, če ne jo doda v datoteko(rent in admin = FALSE)
def add_card(bits, value):
    card_data = str(value)  # Convert the value to a string
    if card_data:
        card_permissions = load_card_permissions()
        if all(user_data["id"] != card_data for user_data in card_permissions.values()):
            user = f"user{len(card_permissions) + 1}"
            card_permissions[user] = {"id": card_data, "rent": False, "admin": False}
            save_card_permissions(card_permissions)
            print(f"Card with ID '{card_data}' added successfully.")
        else:
            print(f"Card with ID '{card_data}' already exists.")

# Glavbna funkcija za začetek branja kartic - teče v neskoncni zanki
def main():
    print("Scan a card to add it to the cards file (cards.json).")
    w = decoder(pi, D0_pin, D1_pin, add_card)  # Initialize the Wiegand decoder
    try:
        while True:
            time.sleep(1)
    except KeyboardInterrupt:
        w.cancel()
        pi.stop()
        print("\nProgram terminated by user.")

if __name__ == "__main__":
    main()
```

Figure 5: Script for adding new cards to the system

The code below represents a list of users or RFID cards in the system. Each user is recorded with three parameters: ID, rent information and admin access. The goal of these parameters is:

- Checking whether the card is allowed in the system
- Authenticating users based on their card ID

• Defining user roles (regular user, administrator, tenant)

I added 10 users myself, since I also bought that many cards.

This part could be upgraded by assigning usernames (i.e. card holders) or by adding additional parameters such as registration date, last access time, etc.).


```
#Shranjene kartice
{
    "user1": {
        "id": "58637207",
        "rent": false,
        "admin": false
    },
    "user2": {
        "id": "58636992",
        "rent": false,
        "admin": false
    },
    "user3": {
        "id": "58636975",
        "rent": false,
        "admin": false
    },
    "user4": {
        "id": "58640474",
        "rent": false,
        "admin": false
    },
    "user5": {
        "id": "58640230",
        "rent": false,
        "admin": false
    },
    "user6": {
        "id": "58640408",
        "rent": false,
        "admin": false
    },
    "user7": {
        "id": "25106753",
        "rent": false,
        "admin": false
    },
    "user8": {
        "id": "25094522",
        "rent": false,
        "admin": false
    },
    "user9": {
        "id": "25106685",
        "rent": false,
        "admin": false
    },
    "user10": {
        "id": "352912",
        "rent": false,
        "admin": false
    },
}
```


Figure 6: Card base

It is a system that uses RFID cards to authenticate users and consequently unlock the door (via an electromagnetic lock) and an audio signal (beeper). The list of authorized cards is stored in a local file (explained in the previous chapter).

When the card is detected, the system checks the permissions and unlocks the door for 3 seconds. Simultaneously with the unlocked door, a beeper also works, which additionally warns of the unlocked door. The beeper triggers a pwm signal at a frequency of 900Hz 3 times after 0.5 s (on/off). I only implemented this for a more user-friendly experience. After this time, the electromagnetic lock locks again and the beeper turns off. The program also records events in the RFID reading file.

```
import os
import time
import json
import pigpio
import wiegand  #modul dekodita Wiegand signal iz RFID čitalnika
import logging
from threading import Timer #omogoča izvajanje funkcij z zamikom (npr. zaklepanje po 3 s)


# določitev GPIO pinov
solenoid_lock_pin = 5 #elektromagnetna kljucavnica
buzzer_pin = 16 #piskac

# pot do datoteke s seznamom kartic
cards_file = "/home/Desktop/cards.json"

# nastavitve logiranja
logging.basicConfig(filename='/home/Desktop/RFID_reader.log'

# nastavitev GPIO (zacetno stanje)
pi = pigpio.pi()
if not pi.connected:
    logging.error("Failed to initialize GPIO. Exiting...")
    exit()

pi.set_mode(solenoid_lock_pin, pigpio.OUTPUT)
pi.write(solenoid_lock_pin, 0)

pi.set_mode(buzzer_pin, pigpio.OUTPUT)
pi.write(buzzer_pin, 0)
busy = False

# Odklepanje vrat
def unlock_door():
    pi.write(solenoid_lock_pin, 1)
    logging.info("Door unlocked")

# Zaklepanje vrat
def lock_door():
    pi.write(solenoid_lock_pin, 0)
    logging.info("Door locked")
    busy = False

# zvočni signal buzzer
def start_buzzer():
    f=900
    pi.set_PWM_frequency(buzzer_pin, f)
    pi.set_PWM_dutycycle(buzzer_pin, 128)
    for _ in range(3):  # Beep for 10 seconds
        #pi.write(buzzer_pin, 1)  # Turn on the buzzer
        time.sleep(0.5)  # Beep for 0.5 seconds
        #pi.write(buzzer_pin, 0)  # Turn off the buzzer
        pi.set_PWM_dutycycle(buzzer_pin, 128)
        time.sleep(0.5)  # Pause for 0.5 seconds
    pi.set_PWM_dutycycle(buzzer_pin, 0)

# branje in zapis kartic
def load_card_permissions():
    try:
        with open(cards_file, 'r') as f:
            return json.load(f)
    except FileNotFoundError:
        logging.error(f"Error: '{cards_file}' not found.")
        return {}
    except json.decoder.JSONDecodeError:
        logging.error(f"Error: Invalid JSON content in '{cards_file}'.")
        return {}
```

```python
def handle_card(bits, value):
    global busy
    if busy:
        return
    try:
        card_data = str(value)  # Convert card ID to string
        card_permissions = load_card_permissions()
        logging.info(f"Card ID: {card_data}")

        if any(user_data['id'] == card_data for user_data in card_permissions.values()):
            logging.info(f"Authorized card detected: ID='{card_data}'")
            busy = True
            unlock_door()
            Timer(0, start_buzzer).start()  # Start beeping for 10 seconds
            Timer(3, lock_door).start()  # Lock the door after 10 seconds
            Timer(3, clear_busy).start()

        else:
            logging.info(f"Unauthorized card detected: ID='{card_data}'.")
    except Exception as e:
        logging.error(f"An error occurred: {e}")

def clear_busy():
    global busy
    busy =False

def callback(bits, value):
    handle_card(bits, value)

# poveže GPIO pina z Wiegand citalnikom
w = wiegand.decoder(pi, 17, 22, callback)

# čakanje na kartice
while True:
    time.sleep(0.1)
```

Figure 7: Main program

The codes were publicly available from the manufacturer Wiegand, which I then adapted/modified for my task. I used artificial intelligence (Chat GPT) to help me with this.

6. Performance testing RFID

During the testing phase of the RFID system for unlocking the bike rack, the functionality, responsiveness and reliability were checked in various weather conditions. No significant shortcomings were detected; I only had a few problems with poor wiring contacts. This was mainly a result of purchasing cheap wires from China with male and female collectors, which were not all well made. But I was most worried about operation in a humid environment, which turned out to be stable due to the purchase of the right components with the appropriate IP rating.

I was also satisfied with the "logic" of the system's operation. I only tested this on my family members, who tested the operation, and none of them had problems with what to do at a certain point in the process. So, I left the logic as I had imagined it at the beginning.

7. Conclusion

In this seminar work, I presented the entire process of upgrading an existing bicycle shed, electrifying it and implementing an electronic unlocking system using RFID technology. The main goal of the project was to improve the user experience and simplify access for my family members. I analyzed possible electronic unlocking systems, among which RFID technology proved to be the most useful and affordable, as well as easy to install and implement. It enables contactless identification, fast operation, easy use and a high level of flexibility.

As part of the project, I designed the system, selected the appropriate components (I did not pay attention to the manufacturing costs, as my goal was to make the product as I imagined it), and connected them into a whole. This was followed by the implementation of the operating logic with program code. During testing, I did not detect any major shortcomings, only a few problems with the wiring contacts, which I soon identified and fixed. The system works reliably, is weatherproof, and resets itself in the event of a power outage. During the project implementation, I gained practical experience in the field of electrical engineering, programming, and the permanent modification of the bicycle shed. An important part was also considering the protection of components from external influences.

The system could be further upgraded in the future. One option is to introduce access recording, where each entry would be automatically recorded, which would enable control over use. Another option would be integration into the existing smart home system, which would further modernize the system.

In conclusion, I can say that I am satisfied with the project and that it was successfully implemented. The goal of electrifying and modernizing the bicycle shed has been achieved, and the solution has already proven to be useful and reliable in practice. The project proves that it is possible to practically improve the operation of home systems with little effort and minimal investment.

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