NCF Cleanroom Transponder System Upgrade

University of Illinois at Chicago

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NCF Cleanroom (Team 20)

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ECE 397 - Senior Design

Final Report

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Abstract, Preliminary 1 Design, Product Cost Analysis, Formatting Fixes, Circuit Functionality Description, Reorganizing Preliminary Solution in One Section	Cover Page, Project Goals, Needs Statement, Objective Statement, Marketing Requirements, Engineering Requirements, Conclusions, Final Formatting	Design Alternatives, Background, Abstract, Decision Matrix, Appendix C, D, E, Task Allocation and Timeline, General Report Formatting, Design Evaluation & Justification	Design Alternatives, Decision Matrix, Cost Analysis and Budget, Task Allocation & Timeline, Basic Theory, User Manual, Updated Design Alternative and Evaluation Criteria

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0. Abstract

The NCF (Nanotechnology Core Facility) is an advanced semiconductor device fabrication facility at the University of Illinois at Chicago, accessible by academic, non-profit and industrial researchers. An essential element of NCF operation is its access control system, ensuring that only authorized users with appropriate training are permitted access to the cleanroom space and appropriately billed for the duration of their cleanroom session. Accurate timekeeping of cleanroom usage is especially crucial for accounting purposes as the operational costs for running the cleanroom is costly-all NCF cleanroom users are required to pay a cleanroom access fee which is charged per minute the user is inside the cleanroom area (this includes gowning room); the cleanroom rate for internal users is $34hr and external users $50hr. The total cleanroom access fee is calculated using total cleanroom duration which is defined as the time between user log-in and log-out recorded by the card reader located at the gowning room entrance.

The current access control system, known as the TRS (Time Reporting System), was developed in 2004 by a UIC student team and relies on 127kHz RFID (Radio-Frequency Identification) key fob transponders (a.k.a "tags"). The problem with the current system is that the 127kHz tags are becoming obsolete as they are no longer available for purchase on the market. This presents a significant challenge for the NCF, as they risk depleting their supply of key fobs, potentially preventing new users from accessing the facility and limiting the ability to upgrade existing key fobs. To address this issue, an alternative solution to the 127kHz key fob is urgently required.

Our project focuses on upgrading the existing access control system by replacing the current access key, 127kHz tag, with UIC iCard tap technology. In addition to upgrading the system to support UIC iCards, we plan to enhance its functionality by introducing additional features that will aim to optimize user experience, increase system efficiency, and ensure the system remains scalable for future needs.

A brief description of what the upgraded system does: Upon arriving at the gowning room door, users will tap their iCard at the RFID module. If iCard is properly registered with the TRS system, users will be prompted to select their preferred profile using push button controls. Once the preferred profile has been selected, an audio cue

plays to verify card read (i.e. successful login), and the door unlocks so the user can enter the gowning room. At the end of their cleanroom session, users will tap their iCard when exiting the gowning room to log out; this automatically calculates and records duration of cleanroom session. Additional quality-of-life features, such as a display counter showing the number of users currently in the cleanroom and an icon indicating if the session occurs outside normal operating hours, will be included to enhance the user experience if time permits.

1. Overview

1.1 Project Goals

The aim of our project is to develop and deploy a new transponder system for the UIC Nanotechnology Core Facility (NCF), replacing the current "Time Reporting System (TRS)." This system will be engineered to efficiently manage and monitor User access to the NCF cleanroom, primarily for billing purposes.

The TRS is comprised of four main components: a low-frequency RFID reader that can transmit and receive radio signals via an antenna connected to door locking control circuit, an ethernet connection linking the reader circuit to an interface module for data transmission to a dedicated computer, and 127kHz key fob transponders (also known as "tags").

Each registered User of the NCF cleanroom receives a unique tag. Upon entering the gowning room, the User waves their tag above the TRS RFID reader to unlock the door and automatically log their entry time. After completing their experiment, the User exits the gowning room and waves their tag at the RFID reader again to accurately record the duration of their cleanroom session before leaving the NCF.

There is a significant issue: the 127kHz tags used in the TRS are becoming obsolete and are no longer available on the market, necessitating a new solution. Our project aims to design and implement a new transponder system that uses UIC iCards for room access, replacing the outdated 127kHz key fob transponders.

Main developments include: a new "tap" reader utilizing UIC iCards as access keys, integration of a user-friendly reader display with account management features linked to User iCards, implementation of a lab checkout and receipt system connected to User accounts, and creation of a comprehensive wiki and GIT repository for detailed documentation.

1.2 Needs Statement

The existing "Time Reporting System (TRS)" at the UIC Nanotechnology Core Facility (NCF) relies on outdated 127kHz key fob transponders, which are no longer available on the market. A new transponder system is needed to replace the obsolete hardware to ensure the continued ability to manage and monitor user access for billing and operational efficiency.

The current TRS system uses 127kHz key fobs for access control, which is being phased out. The new system must support modern access control technologies, specifically by utilizing UIC iCards, to ensure compatibility, security, and reliability for users accessing the NCF cleanroom.

The existing TRS lacks an integrated, intuitive user interface for managing access and billing information. A new system is needed to provide a clear, user-friendly reader display that allows for efficient interaction, account management, and real-time data tracking linked to user iCards.

Currently, manual billing processes may be error-prone and inefficient. The new system must include an automated lab checkout system that accurately logs session durations, connects to user accounts, and generates receipts, thereby improving billing accuracy and streamlining operations.

The lack of detailed documentation for the current system hinders troubleshooting and future system upgrades. A comprehensive wiki and GIT repository are needed to provide in-depth technical documentation and support, ensuring the sustainability of the new system for future users and developers.

The new system must be fully integrated with the existing infrastructure at the NCF, ensuring seamless communication between the card readers, user account management, and billing systems. This will provide a smooth transition and avoid disruptions to the facility's operations.

1.3 Objective Statement

The objective of this project is to modernize the Nanotechnology Core Facility's (NCF) Time Reporting System (TRS), currently reliant on a low-frequency RFID reader and obsolete 127kHz key fobs. This system records User entry and exit times for billing purposes by requiring Users to wave their key fobs at the reader.

The upgraded design will replace the existing system with an RFID reader module that utilizes Radio Frequency Identification (RFID) technology to interact with the embedded RFID chips in UIC iCards. This transition will streamline access management by integrating seamlessly with the UIC security ecosystem and eliminating reliance on outdated hardware.

Key advancements include the construction of a lightweight antenna, and a compact, energy-efficient PCB designed to operate at 125 kHz, meeting RFID standards for frequency bandwidth. Additional enhancements include user input capabilities through buttons, an LCD, or a touchscreen interface, enabling Users to select specific funding sources for billing their cleanroom sessions.

1.4 Background

The following subsections provide an overview of typical operation of RFID access control systems, key subsystems within such systems, and novel research that could inform and support our project design.

1.4.1 Basic Theory

A Proximity Reader System is used for access control and identification to secure rooms within a building.

Components which make up a Prox reader system include:

1. Proximity Reader

   Main device that reads information from proximity card or fob. It uses RFID technology to detect and communicate with the card when it comes in range. The data read from the Prox reader is sent to the ACP for processing to determine whether door should unlock and respective feedback response through auditory or visual cue.

2. Proximity Cards or Fobs

   RFID devices that carry identification credentials of the User and when brought into a certain range of the reader (approx. 2-6inch), the reader detects the card.

Prox cards can be categorized into two types:

i. Passive

- Does not have an on-board battery; powered by the electromagnetic field of the reader.

ii. Active

- Battery-powered; has greater read range but will require battery replacement.

3. Access Control Panel (ACP) (Controller)

   The “brain” of the system which processes the data sent from the Prox reader to verify User credentials and then sends signal to door locking mechanism to unlock or keep locked based on User access permissions.

4. Door Lock Mechanism

Hardware which physically secures the door once the access control panel verifies User information.

5. Software

   Manages User data sent from the reader’s microcontroller to the local machine. Allows administrator to set up User hierarchies, add or remove Users, system scheduling, and review access events.

Workflow for Using Proximity Reader System:

- **User Presents Card**: The User brings their Prox card or fob close to the reader.
- **Reader Detects Card**: The reader detects the RFID signal from the card and sends the credential data to the access control panel.
- **Controller Verifies**: The control panel checks the data against its database of authorized Users.
- **Door Unlocks**: If the credentials are valid, the control panel sends a signal to the door lock to unlock the door.

1.4.2 User Survey

Based on the recorded survey responses we found that most Users are internal and have more than two funding sources, would like a touchscreen User display, three note melody reminder, time report after logging out, a one-week notice of reader installation. Additionally, we received some insightful QOL feedback such as displaying the number of Users presently inside the cleanroom, cleanroom hours indicator (normal vs. Afterhours), and admin override in case the RFID reader does not function properly. [Appendix A.1]

1.4.3 Research Survey

Radio frequency identification (RFID) is any technology which uses radio frequencies to transmit data wirelessly for purposes of tracking and identification. Typical components of an RFID system include:

- Radio Receiver *(a.k.a "receiver, wireless, or radio")*
  - A device that receives radio waves and converts the information carried by them into usable form.
- Radio Transmitter *(a.k.a "radio transmitter" and abbreviated as XMTR or TX in technical documents)*
  - An electronic device that produces radio waves for signal transmission to a radio receiver.
- Radio Transponder (a.k.a "tag")
  - A device that upon receiving a signal emits a different signal in response. The term is a blend of transmitter and responder.

RFID systems are designed to work within a specific operating frequency. Selecting an appropriate operating frequency of an RFID system is extremely important as it will limit the capabilities and performance factors of the system such as range and read distance, data rate transfer, material penetration, power consumption, environment interference, and component costs. Each operating frequency also must adhere to security and regulatory guidelines to prevent sensitive information from being compromised and unauthorized wave-space usage which could result in FCC legal intervention.

"Near Field Communication (NFC) is a short-range wireless communication technology. It allows communication between NFC enabled devices. This bidirectional method of communication has a range of around 5-10 cm, with data rates of 106, 212 and 424 kbps" [9].

Typical RFID system types:

Low frequency (LF)

- An RFID system is considered “LF” if it operates with frequencies that range from 30kHz to 500kHz; transmission ranges are short, commonly from a few inches to <6ft. A Typical LF RFID system operates at 125kHz.

High frequency (HF)

- An RFID system is considered “HF” if it operates with frequencies that range from 3MHz to 30MHz; transmission range varies greatly-commonly from a few inches to a couple of feet. A Typical HF RFID system operates at 13.56MHz and goes by the special name of “Near Field Communication” (NFC).

Ultra-High Frequency (UHF)

- An RFID system is considered “UHF” if it operates within frequencies that range from 300MHz to 960MHz; transmission range is far, commonly 25ft or more. A Typical UHF RFID system operates at 433MHz.

Applications of RFID technology can be seen in all facets of humanity including commercial shipping, tap credit/debit card payments, access control security systems, inventory management, pet, and livestock tracking, and much more.

To create a new TRS system which takes advantage of NFC frequency spectrum, the use of a compact NFC antenna will be needed. This could be achieved using a dual-resonance NFC antenna system where an NFC antenna chip with loop is integrated into PCB design [7].

An example of an RFID based access control system is demonstrated in a 2018 paper published by ICCCEEE. The group developing the system used RFID technology for tracking and access control in Sudan Atomic Energy Commission premises. Primary components of the system incorporated control circuit for gate entrance, custom software for user monitoring and recording keeping, GSM modem to send SMS messages to admin phone in case of unauthorized access [18].

Another example of an RFID based access system is described in a 2014 paper published in LACSIT Internation Journal of Engineering and Technology. The project described the use of a 13.56MHz RFID reader and camera to authenticate user access and allow entry, upon failed entry attempt admin is notified via GSM modem [19].

The underlying concept of RFID wireless communication within an access control system can be summarized as follows: The proximity reader powers and communicates with a card in close distance via inductive coupling, data is then transferred between the reader and card to verify credentials resulting in a response signal to the door's locking mechanism to allow User entry.

1.4.4 UIC iCard encoding scheme

UIC iCards are encoded with Binary Frequency Shift Keying (BFSK) technologies. The cards encode binary "0" using 6 pulses of a frequency around 15625Hz, whereas a binary "1" is encoded using 5 pulses of a frequency around 12500Hz. In our code we prefer to capture 5 or 6 high and low pulses defined by their period. A 0 pulse lasts between 60 and 80 microseconds, whereas a 1 pulse lasts about 80 to 100 microseconds. iCards send a total of 96 bits. The first 8 bits are a preamble "00011101" which we check using a method "state_machine." This indicates to us that a card has been read, and data is coming in. After seeing the preamble, the other 88 bits contain the company code, the card format and length, a parity bit, a facility code, and finally the card number. Unlike the preamble, which can be read "as is", the remaining 88 bits are encoded via binary: where "logic 0" is represented with a binary 0 followed by a binary 1, and "logic 1" is represented with a binary 1 followed by a binary 0. Below is a helpful diagram which discusses the encoding process in detail.

1.4.5 Marketing Requirements

Based on our background research and user survey results, we have developed a comprehensive list of marketing requirements to capture the user's needs and define our system's objectives. Below is a list of six engineering requirements that detail what our product should include.

1. The RFID reader must reliably scan UIC iCards and accurately identify each User.
2. Upon tapping a UIC iCard, the system must authenticate the User and provide an interface for selecting from available profiles.
3. The project is sponsored by NCF management, ensuring alignment with organizational goals and priorities.
4. The new system must be designed to reduce operational costs.
5. The system must operate on a dependable and energy-efficient power source.
6. The system must maintain accurate records of User activity and safeguard all personal and billing information in compliance with UIC's privacy and security.

2. Engineering Requirements

In our Requirements Specification, we strive to deliver the best TRS experience for our users by converting our marketing requirements into precise engineering requirements for our system. In [Table I] we outline these engineering requirements and provide justifications based on the necessity for modern access control technologies, user-friendly features for efficient session management, energy-efficient hardware design, objective tree [Appendix E] and robust data privacy to comply with institutional security standards.

Table I
Engineering Requirements

Marketing Requirements	Engineering Requirements	Justification
1 and 2	The RFID reader module must include an antenna capable of reading the serial number embedded in a User's iCard, operating at a frequency of 125kHz, in 2 seconds.	This ensures fast and reliable authentication, meeting the User's need for efficient access to the cleanroom without delays. IEEE 291, IEC 62022, ISO/IEC 18000-2
2	The PCB must utilize surface-mounted devices (SMDs) to transmit the User's iCard serial number from the receiver to the admin computer, retrieve the User's profile from the cleanroom database, forward the profile information to a microcontroller, and interface with a touchscreen display to allow the User to select a funding source for their cleanroom session.	This allows seamless communication between system components, supporting a user-friendly interface and efficient session management for billing. IEEE 1621, IEEE 1680, ISO 9241-420, ISO 9241-410, ISO 9241-110
3	The project design must adhere to a $250 budget constraint, with the flexibility to exceed this budget for a more robust solution. PCB fabrication will be performed in-house and covered by NCF resources.	Cost-effectiveness is critical for project viability, and in-house fabrication reduces expenses while allowing for flexibility in achieving a reliable design. (3) ISO/IEC 18000, ISO/IEC 19762, IEEE 1058, ISO 27001
4	The system will utilize the	Leveraging existing iCards

		existing coils embedded in UIC iCards for verification and access control, removing the need to purchase, program, and issue new key fobs for Users.	minimizes costs and simplifies the transition, providing a modern and efficient solution without additional hardware for Users. ISO/IEC 18000-2, ISO/IEC 11784, ISO/IEC 11785
5		The system must be compatible with the existing 24V, 15V, and 5V DC power sources while maintaining similar or lower power consumption.	Ensuring compatibility with current power sources and optimizing energy usage supports sustainable operation and reduces long-term costs. IPC-7351, IPC-A-600, IPC-2221, IEEE 2401
6		The new TRS system will remain completely disconnected from wireless networks, with access restricted to authorized NCF administrators only.	This guarantees data security and privacy, aligning with institutional standards to protect sensitive User credentials and billing information. ISO/IEC 18000-2, IEEE 802.3

3. Engineering Design Alternatives

The following engineering design alternatives section takes into account the marketing requirements, engineering requirements and objective tree weights discussed in previous sections to create three unique design solutions. Each design alternative includes a level 0 schematic, design inputs and outputs, and a brief description of tradeoffs inherent to each design.

3.1 Design Alternative I

(User Profile selection via touchscreen display, iCard access key, 125 kHz-based reader)

Features:

- Touchscreen display
- iCard reading capability
- 125kHz based RF data transmission
- User account selection
- Custom PC software to log and calculate user metrics

Description:

The current 127kHz key fob will be replaced by the User's assigned iCard to function as access key. The User presents their iCard to touchscreen display of reader module on entry which will trigger a prompt for the User to select a profile to bill for cleanroom session; additional display indicators such as current in-lab cleanroom User count and normal/after-hours will also appear on touchscreen display. Once the user has made their profile selection, the start time of their session will be taken, door to gowning room will open, and "successful log in" message will pop-up on touchscreen display. After User is done with their cleanroom session, they must tap their iCard at the reader again upon exiting the gowning room to log their end time. New PC software will be written so PC can communicate with the microcontroller to implement this new digital logic. Pros and cons of design alternative I are listed in [Table II] for the purpose of providing concise evaluation of design features. The I/O signals of alternative I are illustrated in [Fig. 1]. Components we could use to achieve design alternative I can be found by combining parts listed in our concept map [Appendix C]: ATM0700M61K-CT(touchscreen display) , PIC18F452 (MCU), ID-12LA (125kHz Reader IC), TS0010D: 2 channel 5V Relay (DigiKey) (Door relay), MAX223 (Computer module IC) [Appendix C].

Table II
Advantages and disadvantages of design alternative I

Advantages	Disadvantages
NCF administrator can manage cleanroom access using iCards without having to connect to Wi-Fi network.	125kHz based reader is not as secure as HF solution.
User profile selection via touchscreen display.	Larger hardware footprint and power draw due to touchscreen display.
No third-party fobs required.	Users with older iCards may need to replace their iCard for it to work as an access key to the new reader system.

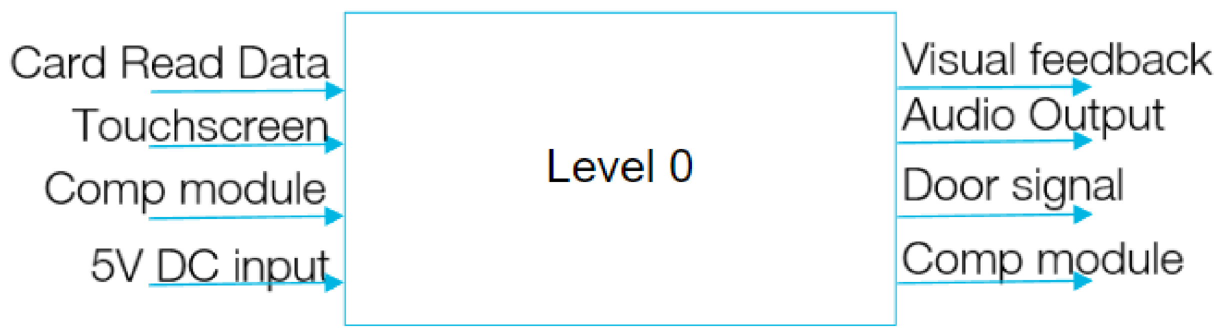

Fig. 1. Level 0 Input/Output flow diagram for design alternative 1

3.2 Design Alternative II {REVISED} (Selected)

(User profile selection done via pushbuttons, simple backlit 16x02 LCD display, still have iCard access key and 125 kHz-based reader)

- Features:
- iCard reading capability
- 125kHz based RF data transmission
- Backlit LCD display
- Push-button controls so user can select profile

Description:

The current 127kHz key fob transponders will be replaced by the User's assigned iCard to function as an access key into the gowning room. A brief description of how the new system will work: the User presents their iCard to TRS reader module's new 125kHz RF antenna on entry and exit to log their cleanroom time; a message will appear on LCD along with LED blink to provide feedback to User about their log-in attempt. This addition will be programmed in such that it maintains the same serial communication format that exists in the 2004 TRS system. Pros and cons of design alternative II are listed in [Table III] for the purpose of providing concise evaluation of design features. The I/O signals of alternative I are illustrated in [Fig. 2]. Components we could use to achieve design alternative II can be found by combining parts listed in our concept map [Appendix C]: HDA500-2S-IPS (LCD display), ATtiny85 (MCU), EM4095 (125kHz) (Reader IC), Weidmüller RCM570012 (Mouser), SP3232 (Cptr IC) [Appendix C].

Continue to next page >>

Design Alternative ii continued...

Table III
Advantages and disadvantages of design alternative II

Advantages	Disadvantages
No third-party fobs needed.	Basing our design on 125kHz reader will not be as secure as using HF 13.56MHz reader solution.
Streamlined hardware design improves user ease of use.	Users with older iCards may need to replace their iCard for it to work as an access key to the new reader system.
Less plastic and electrical components are used to build the final product to reduce environmental impact.	Admin must manually verify user cleanroom session billing.

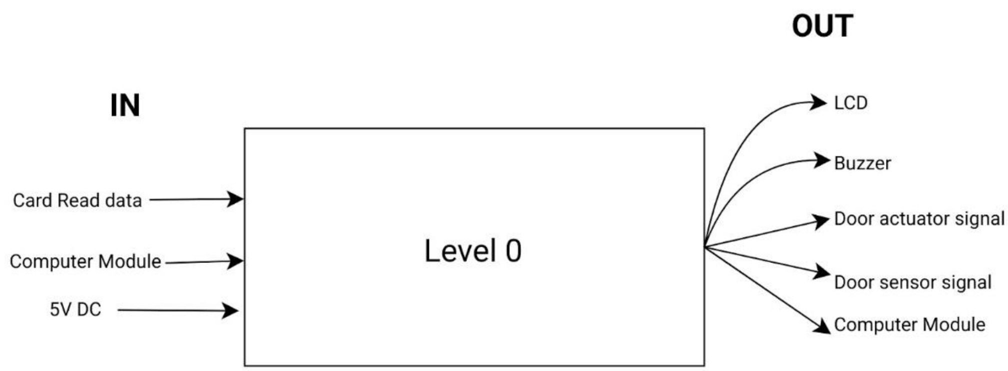

Fig. 2. Level 0 Input/Output Flow Diagram for Design Alternative 2

NOTE: We revised design alternative II to include pushbutton functionality.

3.3 Design Alternative III

(Replace current reader and transponder system with a new one that operates at 13.56Mhz)

Features:

- Key fobs and reader operate at 13.56 MHz
- Backlit LCD display
- Custom PC software to log and calculate user metrics

Description:

Current 127kHz key fob transponders will be replaced by 13.56MHz transponders which can be purchased from third party vendor. The User presents their HF transponder to the reader on entry and exit to log their cleanroom time. General functionality is maintained from legacy system to maintain user familiarity. New PC software is written so it can communicate with the microcontroller. Pros and cons of design alternative III are listed in [Table IV] for the purpose of providing concise evaluation of design features. The I/O signals of alternative I are illustrated in [Fig. 3]. Components we could use to achieve design alternative III can be found by combining parts listed in our concept map [Appendix C]: NHD-5.0-800480AF-ASXP-CTP (LCD display), STM32G0 (MCU), MFRC522 (13.56MHz Reader IC), 103020012: 5V electromechanical relay (Digi key/Mouser), SP3232 (Compter IC) [Appendix C].

Continue to next page >>

Design Alternative iii continued...

Table IV
Advantages and disadvantages of design alternative III

Advantages	Disadvantages
13.56MHz key fobs are widely available for purchase and fob programming can be done "in-house" for greater access control.	Does not support existing key fob transponders or User iCards
Uses higher frequency 13.56 MHz instead of 125 kHz.	Higher power consumption and computation demand on MCU
Higher frequency allows for more data to be transferred and at faster rates	Higher cost due sophisticated parts needed to produce/receive HF signal
Shorter read distance for fob to be recognized which improves security.	Frequent device contact

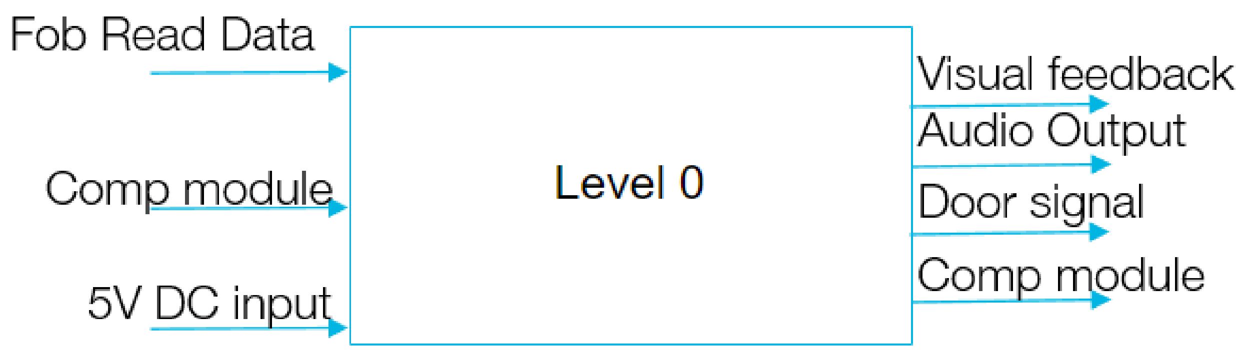

Fig. 3. Level 0 Input/Output Flow Diagram for Design Alternative 3

4. Design Alternative Evaluation Criteria

After producing three design alternatives as a group, we needed to narrow down our options to a single design alternative to use as a framework for our final senior design project. To make this selection as impartial and objectively focused as possible we followed a structured decision-making process through the help of a decision matrix, a tool meant to select the best option among different choices by quantitatively analyzing each option based on defined selection criteria.

The whole decision process involved agreeing on six design criteria as a group, individually performing a pair-wise comparison to determine criteria weights [Appendix D] [Tables IX-XII] and finally calculating averaged weights for each of the six criteria to create finalized selection criteria weights [Appendix D] [Table XIII].

Our group decided to have “Part Availability” as a criterion since it is important that our design use parts which can arrive by next semester or sooner. By selecting parts which can ship quickly, it will give us a reasonable amount of time to perform tests and redesign if needed. “Ease of Use, Effective Product, and Satisfying technical requirements” were all criteria that we also wanted to include in our decision matrix. The primary goal of our sponsored project is to build a functioning and improved replacement reader module that allows for User iCard to be used as a transponder while integrating software and hardware features as described in our user survey and outlined by our project sponsor. We believe making the reader both easier and more effective to use would satisfy the need to improve the existing system, and satisfying all technical requirements listed here gives our project the best chance of being well received by its users. The final criteria of "Time to Complete" was included in our decision matrix to account for design complexity such as learning curves associated with picking up new software and understanding hardware connections; doing so will help us be more contentious of the time needed to complete the design alternative in order to finish this project by the end of semester two.

5. Selection of Design Alternative & Justification

The following selection is a continuation of the decision matrix process which began in the previous section.

After criteria weights had been determined, each group member then individually ranked the three design alternatives with respect to how well they satisfied our selection criteria [Appendix D] [Tables XIV-XVII]. The final decision matrix containing each design alternative score [Table V] was calculated using Equation (1) below.

*Design Score = Sum (Mean (ranking of alternative w.r.t criteria) * weight of criteria* (1)

Based on the computed design alternative scores in [Table V], design alternative one proved to be our most promising design based on our selection criteria. Our group discussed and agreed with the decision matrix's selection of design alternative as it is best suited for satisfying the desired functionality outlined by our project sponsor and integrating additional QOL features as mentioned in user survey.

Table V
Computed Scores for Each Design Alternative

Criteria	Weight	Design Alt 1	Design Alt 2	Design Alt 3
Part Availability	0.28	4.5	4.5	4
Time to Complete	0.36	3	3.25	3.75
Ease of Use	0.15	4	2.75	3.75
Effective Product	0.11	4.75	2.5	3.5
Satisfy Tech Requirements	0.10	4.75	3.75	4.25
Score		3.93	3.49	3.84

NOTE: Due to time constraints, our team had no time to develop the touchscreen functionality and instead opted to build our system according to Design Alternative 2.

6. Preliminary Design

Our initial design has been adapted from the 2004 team's work. To meet new engineering requirements, we will implement an upgraded reader with a new antenna, along with an updated interface that enables users to select which profile should be charged for the time spent in the lab.

The previous system required users to carry multiple fobs, each linked to a different fund. For example, if a user worked with three different funds, they would need to carry three separate fobs.

The fobs will be replaced by the UIC i-card, and the display will allow users to select their fund. This solution will cut costs by utilizing the existing i-card issued to all faculty and students at UIC, while also minimizing the time staff spend managing multiple profiles.

Our preliminary design will get some modifications as we test it. The current system must integrate with the latest changes to not affect the lab's schedule or current work being developed. Also, users requested through survey a couple of weeks of heads up to update the new i-card in case they still have the old one without NFC chip.

The system is being updated to work as simple as possible, as well to reduce the amount of time and purchased of fobs that are being done by our faculty who runs the NCF facility. Our report will present the level 1 diagram [Fig. 4], preliminary circuit [Fig. 5] and operation, and software design [Fig. 6] in the following pages. A draft of the user manual is provided in [Appendix I].

6.1 Level 1 Diagram

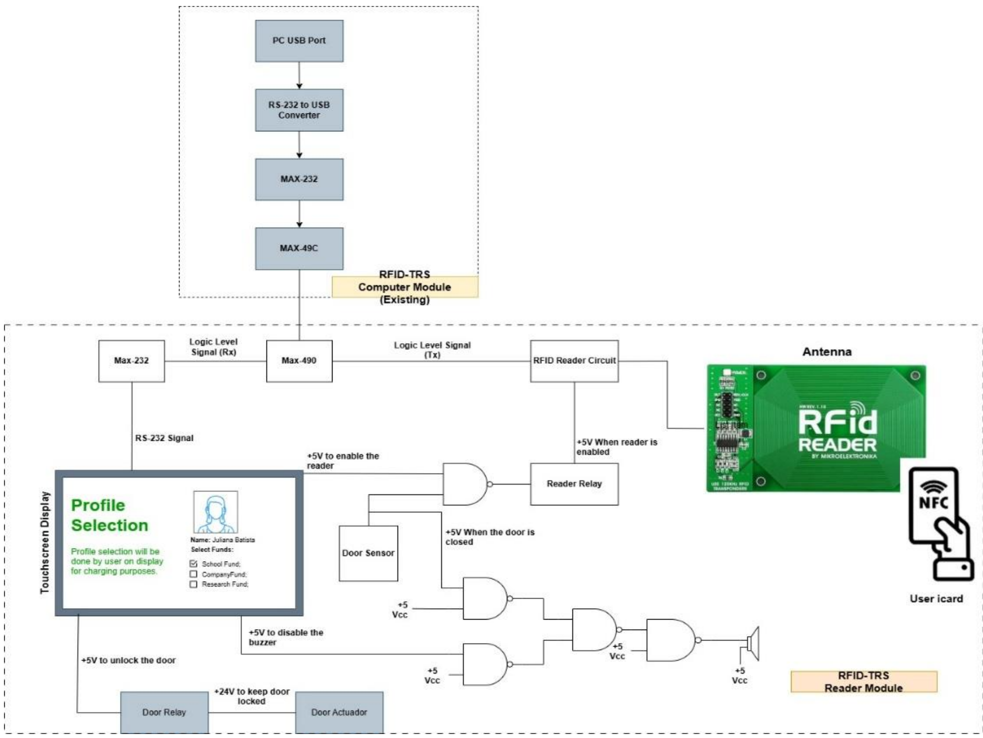

Fig. 4.1 Level 1 Diagram for best design alternative for ECE 396

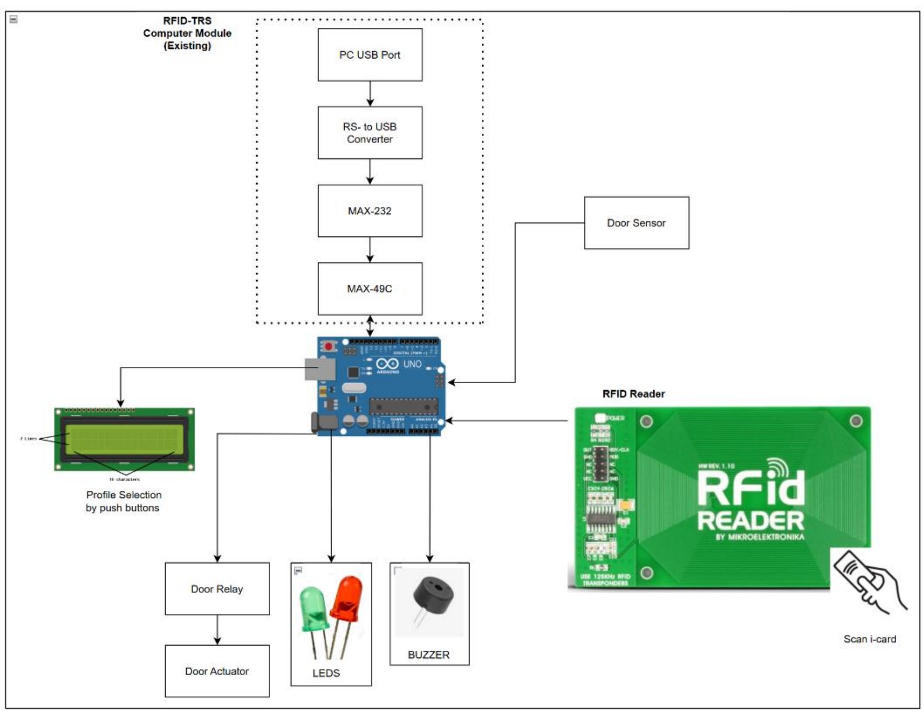

Fig. 4.2 Level 1 Diagram for final design alternative for ECE 397

6.2 Design Operation

Log-in:

- The door must be closed. The reader will not allow the user to log in if the door is open. This logic will be handled by a sensor relay with a NO (normally open) contact.
- The RFID reader reads the i-card.
- The RFID reader sends a signal to the computer module to verify if the user is in the system:
- If the user is not recognized, the display will inform the user to verify their identity with staff.
- If the user is identified, the computer module will send the information back to the display for profile selection.
- After profile selection, the display will send a signal to a relay that will activate the solenoid and door sensor, allowing the door to open.
- A buzzer will sound, notifying the user that the door is open.
- After profile selection, the display will also send a signal back to the computer module to start tracking time.

Log-out:

- The user will open the door. A buzzer will sound to indicate that the door was opened without any scan. The buzzer will continue to beep until the user logs out.
- The door must be closed for log-out as well. The reader will not allow the user to log out if the door is open. This logic will be handled by a sensor relay with a NO (normally open) contact.
- The RFID reader reads the i-card.
- The RFID reader sends a signal to the computer module to verify if the user is in the system.
- The computer module will identify the user's login and automatically log the user out.
- Hours of system use will be recorded for lab usage.

7. Testing

This section outlines the testing parameters and results necessary to ensure the system meets functionality and operational requirements based on the established engineering criteria.

7.1 Unit Testing

Description

Individual components verify they meet performance expectations.

Table VI
Unit Testing Results Table

Component	Test Objective	Setup Description	Variables Tested	Results
RFID Reader	Verify iCard detection at 125 kHz within 2 sec	Reader + iCard on test bench	Read time, detection rate	Passed: Avg 1.8 sec
LCD Display	Verify correct text display and refresh time	LCD connected to microcontroller	Text accuracy, refresh lag	Passed: <0.5 sec lag
Pushbuttons	Verify input response for selection menu	Buttons wired to microcontroller	Input recognition, bounce	Passed: Reliable input, debounce successful
Door Sensor	Detect door open/closed state	Sensor installed on door	State detection accuracy	Passed: 100% accuracy
LEDs (Red/Green)	Indicate access status	LEDs connected to MCU outputs	On/off control, brightness	Passed: Correct signaling
Relay & Actuator	Trigger door unlock	Relay wired to actuator	Actuation time, power draw	Passed: Unlock <1 sec
Buzzer	Provide audio feedback	Buzzer connected to MCU	Sound on/off, duration	Passed: Audible alert

7.2 Integration Testing

Description

The full system integration testing to ensure all components worked together smoothly.

Table VII
Integration Testing Results Table

Test Objective	Setup Description	Variables Tested	Results
Complete login/logout flow	Full hardware setup with admin server + iCard + User	Read time, display prompt, button input, relay trigger, LED signal, buzzer sound	Passed: Login 1.9 sec, logout accurate, access granted
Account selection with buttons + LCD	System connected to admin DB, LCD shows profiles, buttons used to scroll/select	Display clarity, button response, selection accuracy	Passed: Smooth profile selection, no input lag
Door control + access logging	RFID + sensor + relay tested under repeated access cycles	Door unlock time, lock after logout, data log accuracy	Passed: Unlock <1 sec, logs 100% correct

7.3 Acceptance Testing

Description

Final system-level tests were conducted to verify compliance with engineering requirements.

Table VIII
Acceptance Testing Comparison Table

Engineering Requirement	Acceptance Test Result	Pass/Fail
Read iCard serial number at 125 kHz within 2 sec	Avg 1.8 sec read time	Pass
Display user profile + allow funding selection via buttons + LCD	Correct profiles displayed, selection completed <2 sec	Pass
Total system cost ≤ $250 (with flexibility)	Materials cost $240; in-house PCB covered by NCF	Pass
Compatible with 24V, 15V, 5V DC power, optimized consumption	Measured power draw: 4.1W (below old system)	Pass
Wired system, no wireless; admin-only configuration access	Fully wired; admin credentials required for system access	Pass

7.4 Arduino Code Repository

Our final Arduino code can be accessed at this GitHub repository for review. Comments within the code are fairly comprehensive, otherwise our code follows the methodologies discussed in this report.

8. Final Design

Our final project goal was to redesign the RFID reader circuit for the existing TRS system with all SMD (Surface Mount Device) components to reduce circuit footprint, improve reliability, and modernize outdated hardware. Our prototyping and final product design utilized an UNO development board as the foundation to fast-track testing since we did not have the time nor the expertise to work at the bare microcontroller level as initially planned.

We first built a working prototype on a breadboard using TH (Through-hole) components and jumpers which we then condensed into a PCB peripheral shield for an Arduino UNO using Altium digital software; we decided to create a shield to facilitate future testing since we could not get down to low level microcontroller design within our given time frame. This final PCB shield consists of several subsystem circuits each with their own set of hardware which is described below.

- LED: Consists of x2 LEDs, resistor, and control signal from microcontroller to provide visual feedback to user about door lock status.
- Buzzer: Consists of a small buzzer, diode, resistor, and transistor to provide auditory feedback to the user about door lock status.
- Antenna: Consists of 125kHz antenna to transmit and receive card data stored on user iCard to microcontroller for further data processing.
- MAX490 driver circuit: Consists of a MAX490 IC, x2 resistors, and bypass capacitor to simulate computer module functionality without having to take it offline.
- Motion sensor: To enable detection of users in proximity to the reader.
- LCD power: Consists of respective resistors and potentiometer to boot up the LCD.
- Door Actuation: Control logic signals and door power.

The following pages illustrate the circuit connections used in the final design. Fabricated PCB images can be found in [Appendix H].

8.1 Breadboard Prototype, Altium Schematics, Pinouts, etc.

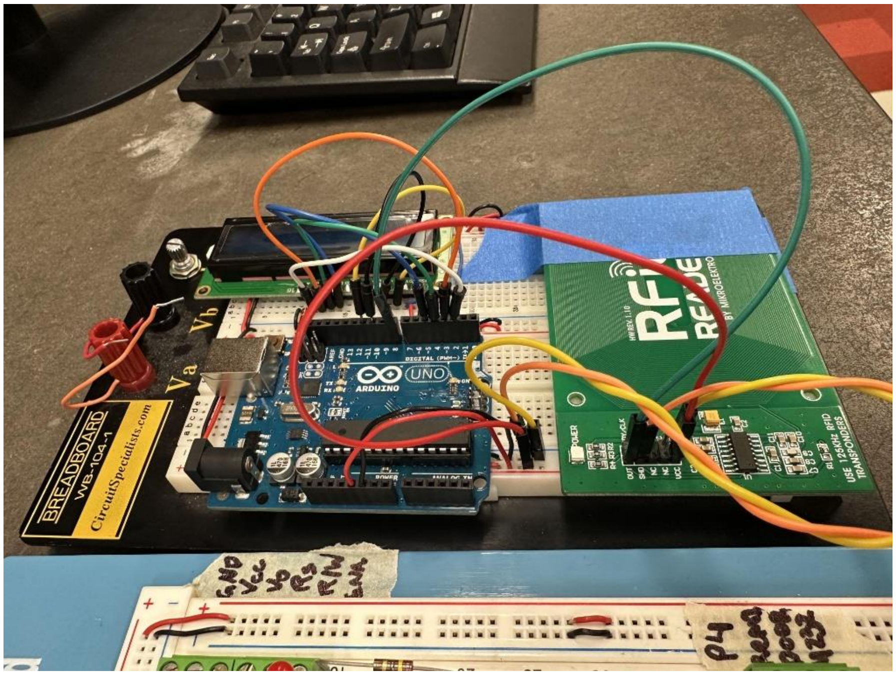

Fig. 5.1 Image of working breadboard prototype

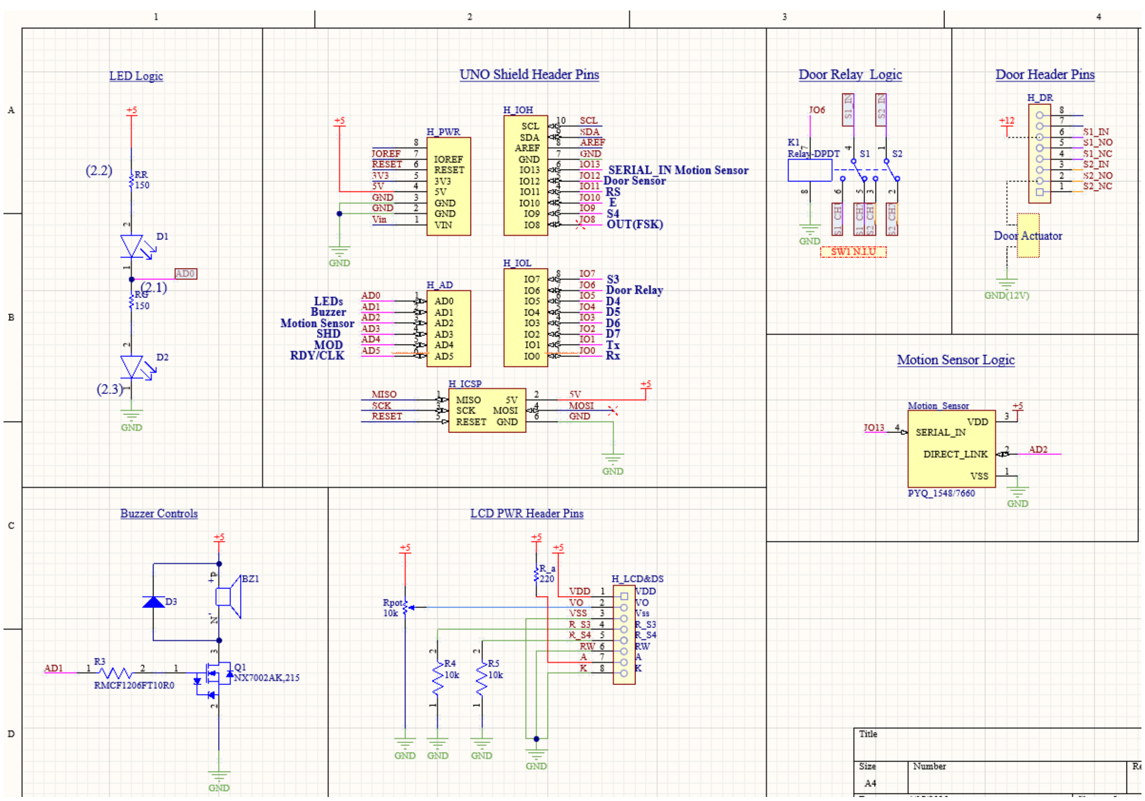

Fig. 5.2 Hardware schematic for control logic subsystems (LEDs, Buzzer, LCD, Door actuation and Motion Sensor)

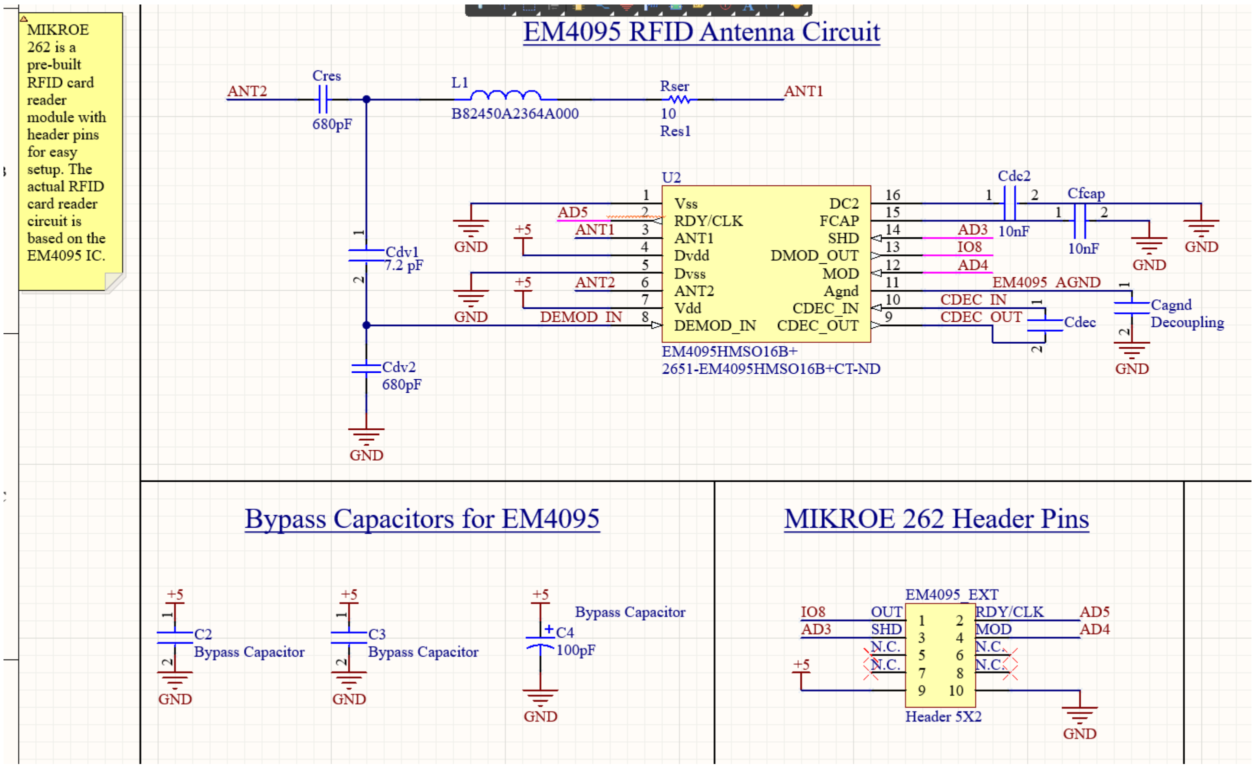

Fig. 5.3 Hardware schematic of antenna circuit copied from MIKROE262 datasheet

(Design based on EM4095 Integrated Circuit)

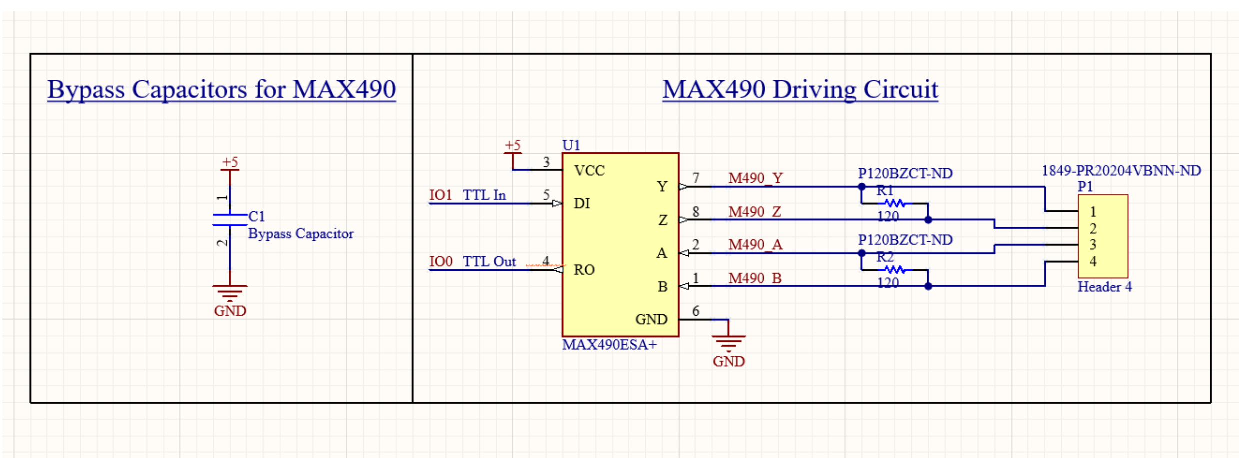

Fig. 5.4 Hardware schematic of driving circuit to simulate computer module

(Design based on MAX 490 Integrated Circuit)

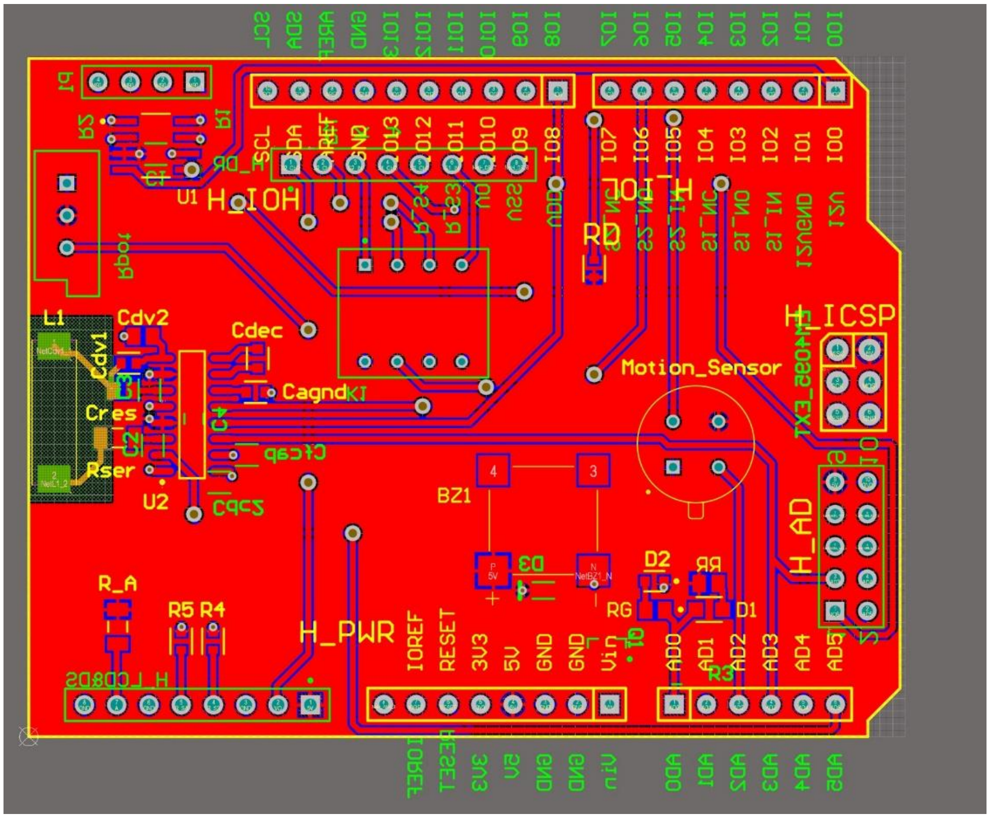

Fig. 5.4 Altium 2D render of PCB metal trace connection layout for UNO shield

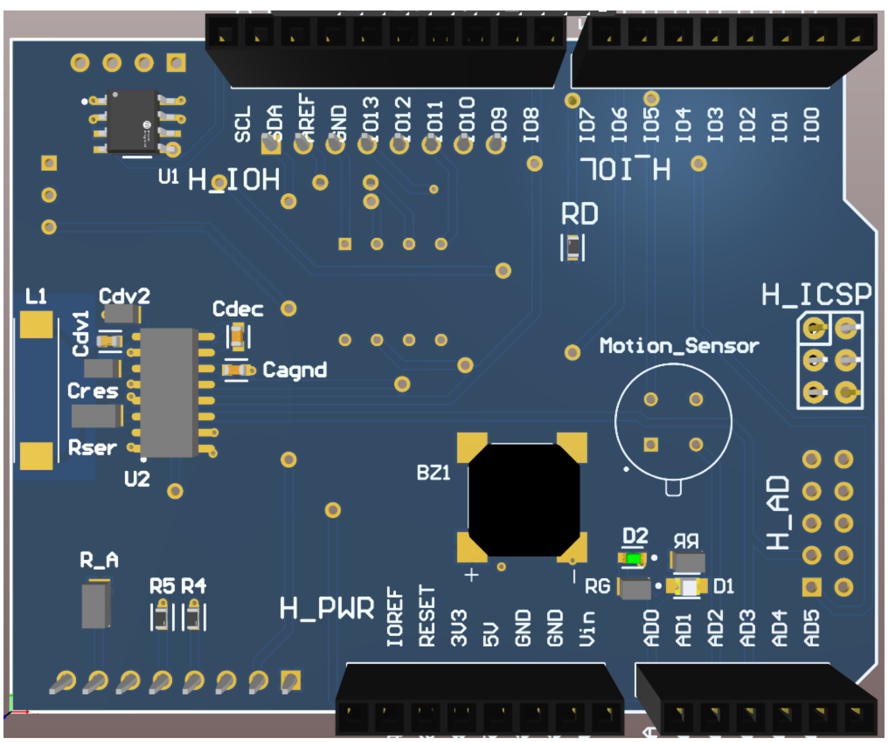

Fig. 5.5 Altium 3D rendering

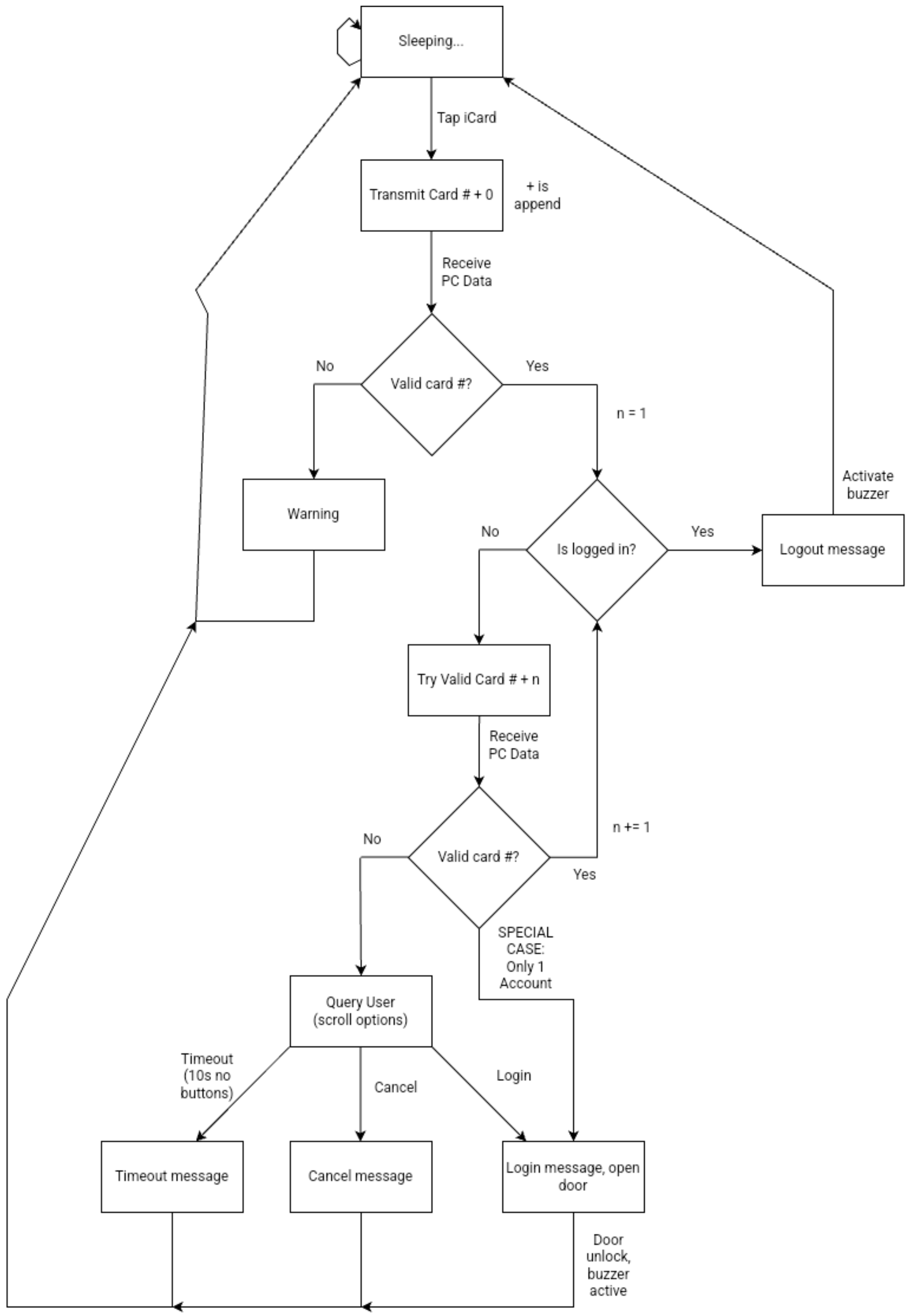

Fig. 5.6   Software design flow for upgraded TRS system

GPIO Arduino UNO	Input/Output	I/O	Checked
AD0	LED CTRL Pin	Tmer0 PWM	Y
AD1	BZR CTRL Pin	OUPUT or PWM	Y
IO0	Rx	USART0	Y
IO1	Tx	USART0	Y
IO2	D7 (LCD Data)	OUTPUT	Y
IO3	D6 (LCD Data)	OUTPUT	Y
IO4	D5 (LCD Data)	OUTPUT	Y
IO5	D4 (LCD Data)	OUTPUT	Y
IO6	SHD	OUTPUT	Y
IO7	BTN 1	INPUT	Y
IO8	OUT (FSK signal)	TIMER1 iCP	Y
IO9	BTN 2	INPUT	Y
IO10	E	OUTPUT	Y
IO11	RS	OUTPUT	Y
IO12	DOOR SNSR	INPUT	Y
IO13	DOOR RELAY CNTRL	OUTPUT	Y

Color Key
Arduino
MIKROE262
LCD
OTHER

LCD HPIN #	LCD HPIN Label	Connection	Checked
1	VSS	GND	Y
2	VDD	5V	Y
3	VO	Wiper of 10k pot	Y
4	RS	IO11	Y
5	RW	GND	Y
6	E	IO10	Y
7	D0	NC	Y
8	D1	NC	Y
9	D2	NC	Y
10	D3	NC	Y
11	D4	IO5	Y
12	D5	IO4	Y
13	D6	IO3	Y
14	D7	IO2	Y
15	A	220 to 5V	Y
16	K	GND	Y

MIKROE 262 HPIN #	MIKROE 262 HPIN Lab	Connection	Checked
1	OUT	IO8	Y
2	SHD	IO6	Y
3	NC	NC	Y
4	NC	NC	Y
5	VCC	5V	Y
6	GND	GND	Y
7	NC	NC	Y
8	NC	NC	Y
9	MOD	GND	Y
10	CLK	NC	Y

Fig 5.7 Pin Connections for LCD, UNO, and MIKROE 262 RFID Reader

8.2 Bill of Materials

For our project, the following equipment would be required to be purchased:

Table IX
Hardware list for final design

QTY	Equipment	Model	Manufacturer	Price
1	PCB	Quote #: 6232568 Order #: 10356510	Advanced PCB	$119.00
1	Reader + Antenna	MIKROE-262	MikroElektronika	$29.00
1	Arduino Uno	Arduino Uno Rev3	Arduino	$27.60
1	PCB Components	-	Digikey	$46.51
1	Relay	DPDT Relay DC 5V 2NO 2 NC (12Pcs)	Amazon	$13.98
1	Display	HDM16216H-B-S00S	Hantronix	$12.31
			Total	$248.80

Table X
PCB Components - Ordered from Digikey

TAG	Description	Manufacturer	Model
BZ1	Buzzer	PUIaudio	SMT-0823-S-R
C1, C2, C3, Cagnd, Cdec	Capacitor	Yageo	CC0603KRX7R6BB104
C4	Bypass Capacitor	Kyocera	TAJA106K016SNJ
Cdc2, Cfcap	Capacitor	Yageo	C0603C103K8RACTU
Cdv1	Capacitor	Kemet	CBR06C729BAGAC
Cdv2, Cres	Capacitor	Yageo	CC0805KRX7RBBB681
D1	LED RED	Osram	LSR976-NR-1-0-20-R18
D2	LED GREEN	Liteon	LTST-C191KGKT
D3	DIODE	DIODES	1N4148WS-7-F
L1	RFID ANTENNA	TDK	B82450A2364A000
Motion Sensor	Motion Sensor	EXCELITAS	PYQ 1548/7660
P1	PIN HEADER	METZ	PR20204VBNN
Q1	MOSFET	NEXPERIA	NX7002AK,215
R1, R2	RESISTOR 120 Ohm	PANASONIC	ERJ-PA3J121V
R3	RESISTOR 10 Ohm	STACKPOLE	RMCF1206FT10R0
R4, R5, RD	RESISTOR 10 kOhm	Yageo	RC0603FR-0710KL
R_a	RESISTOR 20 Ohm	Yageo	RC1206FR-10220RL
RG, RR	RESISTOR 150 Ohm	VISHAI	RCS1206150RJNEA
Rser	RESISTOR 10 Ohm	SSSUSUMU	HRG3216Q-10R0-D-T1

U1	IC TRANSCEIVER FULL 1/1 8SOIC	MAXIM	MAX490ESA+
U2	125KHZ - 134KHZ, READ/WRITE ANALOG	EM MICROELECTR.	EM4095HMSO16B+
HD-AD	CONN RCPT 6POS 0.1 GOLD PCB	SAMTEC	SSQ-106-03-G-S
H_ICSP	CONN RCPT 12POS 0.1 GOLD PCB	SAMTEC	SSQ-106-02-G-D
H_IOH	CONN RCPT 10POS 0.1 GOLD PCB	SAMTEC	SSQ-110-03-G-S
H_IOL	CONN RCPT 8POS 0.1 GOLD PCB	SAMTEC	SSQ-108-03-G-S
H_DR, H_LCD&DS	CONN HDR 8POS 0.1 GOLD PCB	SAMTEC	PPPC081LFBN-RC
H_PWR	CONN RCPT 8POS 0.1 GOLD PCB	SAMTEC	SSQ-108-03-G-S
Rpot	TRIMMER 10K OHM 0.5W PC PIN SIDE	BOURNS	3386W-1-103
EM4095_EXT	CONN HEADER VERT 18POS 2.54MM	ADAM TECH	PH2-18-UA

The total Bill of Materials (BOM) for our project amounted to $248.80, as detailed in [Table IX]. While a significant portion of our expenses was supported by the NCF facility, we successfully remained within the allocated budget. Throughout the course, we made several purchases for testing and prototyping purposes; however, this report only includes the final costs associated with the completed project. Notably, although we initially purchased the reader MIK_ROE 262, we ultimately chose to replicate its functionality directly on our custom PCB to better optimize space and improve integration.

9. Task Allocation and Timeline

This final section outlines tasks that each group member was responsible for as well as a rough estimate of when each process step should be completed. The project timeline as shown in [Appendix F] served as idealized project development timeline for ECE397 to ensure steady progress is being made towards realizing our selected design alternative, while the timeline shown in [Table XI] is the real project development timeline for our team.

Table XI
Actual Timeline

Phase	Week	Leader	Tasks	Descriptions
A	1	Juliana	Research and Manuals	This week was used to look over component manuals and to study the legacy system
	2	Tony	Elevator Pitch & Legacy System Testing	Our elevator pitch was completed and further study into the legacy system took place
B	3	Julian	Part Ordering and Reader Configuration	We begin ordering various components and working with one of the various readers we developed with
	4	Moody	Part Ordering, PCB drafting, unit testing & debugging	Continued purchasing of components while starting to develop our Altium designs and testing individual components.
	5	Juliana	Continuation of 4	See above
	6	Tony	PCB Digital Logic, expo work, inventory, and continued testing	Logic for working with door relays, work on our expo posters and handouts, an updating of our inventory, and continued component testing took place
	7	Julian	Continuation of 6	See above
	8	Moody	Microcontroller development and Altium modeling	Code to begin integration testing starts development and Altium work is accelerated
C	9	Juliana	Reader Troubleshooting	Working with the readers was giving the team trouble, it was here that time investment increased drastically and extensive work on decoding iCards began.
	10	Tony	Week 9 + New Display implementation	Above, as well as integrating the LCD display to start integration testing
	11	Julian	Integration testing and microcontroller development	Full scale integration testing begins and Arduino code is developed

	12	Moody	Final integration testing and PCB design	This week made final adjustments to the various systems of our project, getting it expo ready
D	13	Juliana	Continuation of 12	See above

10. Contribution of Work

Moody Ekladios

I contributed to the project by working on testing various RFID card readers and encoding methods to determine the specific encoding used by UIC iCards. I worked with Tony to simulate the serial communication between the computer module and the reader module, successfully receiving messages from the computer module and displaying them on the LCD display. We also sent card data using serial commands formatted to be compatible with the current TRS system. Additionally, I developed a software simulation of the computer module and user database, which supported multiple profiles and accurately tracked login/logout information for quick access. I assisted Tony in writing and debugging the full system code, which handled card reading, displayed messages, checked the door sensor, and controlled the system components, including the LEDs, door relay, and buzzer. I also contributed to preparing the project poster for the EXPO and kept detailed records of all material purchases by maintaining an inventory of parts.

Juliana Jade Batista

As part of our project team, I contributed to several important aspects of the design and presentation. I was involved in the preliminary design phase and performed the product cost analysis to keep our solution within budget. I also made the necessary material purchases to support our development and testing. In addition, I took care of formatting fixes and reorganized the preliminary solution into a clear and structured section. On the technical side, I created the Altium schematic and performed the PCB trace routing in 3D for our custom UNO shield, ensuring accurate layout and functionality. I also prepared the bill of materials (BOM) for the shield. I wired the demo board for the door actuator, relay, and sensor, and helped integrate the door sensor and door relay hardware variables into the system’s logic to ensure proper operation. Lastly, I helped design both the poster board and the handout to effectively communicate our work.

Tony Weidel

My work on this project centered around first understanding how UIC cards are encoded. I did extensive work with John and Moody to gather sample data and test for various encoding types. Moody and I also managed to develop our Arduino code which replicates the functioning of the previous reader system and adds new account functionality and quality of life improvements. I worked on developing the software flowchart at the beginning of the code development process and also did much of the initial testing on our components. I did also have some part in integration testing some components in collaboration with Moody. I also managed much of the paperwork and archiving for this project, such as work on design alternatives, decision matrices, developing the user manual, and significant portions of our posterboard.

Julian Porro

I collaborated with Juliana to develop a breadboard prototype by modernizing and simplifying a 2004 RFID reader circuit using updated components and optimized connections (resistors, transistors, buzzers). Conducted unit testing for 16x2 LCD display and enabled data readability from mikro262 reader antenna using the Saleae logic analyzer. Assisted in building and documenting hardware schematics for Arduino UNO shield and PCB trace layouts. Contributed significantly to the final report, authoring key sections including the abstract, background, design alternatives, decision matrix, task allocation, and design justification. Supported Altium schematic creation, LCD/reader demo board wiring, and report formatting including labeled tables, figures, and appendices.

11. Lessons Learned

Moody Ekladios

The most valuable takeaway from my senior design experience was understanding the importance of collaboration and teamwork in completing complex tasks. Working together as a team allowed us to divide responsibilities, combine our strengths, and support each other through challenges. Having a supportive mentor and staff available to answer questions and provide guidance made a huge difference throughout the project. I also learned the value of persistence, facing challenges head-on and not giving up too quickly. With consistent effort and perseverance, results eventually come, even if progress seems slow at first. For instance, while trying to decode the iCard's encoding method, we tested multiple card readers and different encoding techniques. Each failure brought us closer to a solution by revealing new directions to explore. On the technical side, I gained practical experience integrating hardware and software to create a fully functional system. I learned how to read datasheets, understand component functionality, and connect various hardware modules. I also improved my coding practices by dividing my code into smaller, organized functions, which made debugging much easier. This project significantly strengthened my problem-solving and troubleshooting skills and taught me the importance of patience and adaptability when working with real-world systems.

Juliana Jade Batista

I believe one of the lessons I got is that a project is never as easy as you think. To fully develop a product, there are so many components behind it. So much planning and research is required, and the troubleshooting takes a lot of time too. I also learned the importance of evaluating each component and its variables, as well as understanding their impacts on the circuit. Another takeaway I got was teamwork and understanding how everyone operates. I believe this was the hardest part for me. My work style is different than the rest of the group, and many times I had to adjust to the group's needs, which also helped me for the future when I am working in the corporative environment. I also want to point out that it was nice to learn different software that I haven't used before. It was challenging at first, and not always organic to understand how to use, but I believe if I had more time to devote myself to it I would've learned quicker. It was also great the opportunity of presenting our project to the public and getting experience in "sales". I learned so much from the judges' questions. Sometimes when you are too involved in the project it is difficult to look at other variables, and through their questions I got some feedback on what we could work on in the future.

Tony Weidel

One of the greatest takeaways I'm leaving with includes the ability to pivot priorities when action is needed. Our team benefitted greatly from the careful planning and execution of our prototype ideas. Had we taken our plan as gospel, we likely never would have finished the project as our ambitions were simply unnecessarily high in developing systems not critical to the project's functioning. I also learned that building as early as possible is an absolute necessity. The more time can be dedicated to seeing problems as one moves through the development process, the better. Another key takeaway I'm leaving with includes the ability to collaborate with team members with differing values and assumptions. There were many points in this project where the ideas I had didn't match those of my teammates, and the ability to compromise on decisions and future expectations is necessary in order to achieve a common goal. Lastly, I can't stress enough the importance of allowing oneself to embrace the void of questions, doubts, and ignorance. This project, as well as many of the projects I saw working in the senior design lab, were technically advanced and well outside of the engineering knowledge I've accrued in college. This project was daunting to ponder over, even more so when hit with the realization that the project may never get finished in time. So much of the design process can be frustrating or difficult to understand, and it's easy to fall into the trap that one can't accomplish their goals. It was through the perseverance and drive of myself and my team that this project was finally realized. Never stop asking questions and never stop trying to understand the people and problems you encounter. Problems provide you with a wealth of experience, and people provide you with a wealth of wonderful experiences.

Julian Porro

One key lesson I learned is that stalled progress in a technical project often points to a mismatch between the team's current skill set and the complexity of the hardware or software involved. It's important to reassess the scope and simplify where necessary. I also realized the value of collaboration—it's neither practical nor effective to handle everything alone. Trusting teammates and seeking guidance from those with relevant expertise can significantly improve outcomes. Finally, I learned that striving for perfection in the early stages of design can hinder progress. It's better to focus on building a functional prototype first, then iterate and refine the design as new skills, concepts, and resources become available.

12. Conclusions

The final TRS design successfully meets the core objectives of the project. We were able to determine the encoding method used by UIC iCards and developed code to accurately decode the card data into the six-digit serial number printed on the back of the card. The system reliably supports multiple user profiles, allowing users to select their desired funding source during each session. It reads iCards quickly, identifies users accurately, and enables seamless login and logout, providing a smooth and efficient experience. Importantly, the system also solves the NCF's long-standing issue of running out of key fobs, as it now relies solely on the iCards for access. For future improvements, replacing the LCD display and pushbuttons with a touchscreen interface, as originally preferred in the user survey, would improve usability and streamline the interface. Additionally, adding a self-service feature that allows users to register, add, or remove their profiles independently, without the need for NCF administrator intervention, would greatly enhance flexibility and user autonomy.

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14. Appendices

Appendix A – Surveys, Outline, and Manuals

Appendix A.1 - User Survey

NCF Cleanroom Time Reporting System (TRS) Upgrade _ Senior Design Survey(1-10).xlsx

Appendix A.2 – Project Outline

Faculty Project Submission Form (Responses).xlsx //NCF transponder upgrade is listed as project #10 in this spreadsheet

Appendix A.3 - Component Manuals

- Display:
  NHD-5.0-800480AF-ASXP.pdf
- Reader + Antenna:
  rfid-reader-manual.pdf
- Relays:
  AZ822-2C-12DSE.pdf
- Buzzer:
  WT-1205.pdf
- NAND:
  IC GATE NAND 4CH 2-INP 14SOIC.pdf

Appendix B: BFSK Encoding

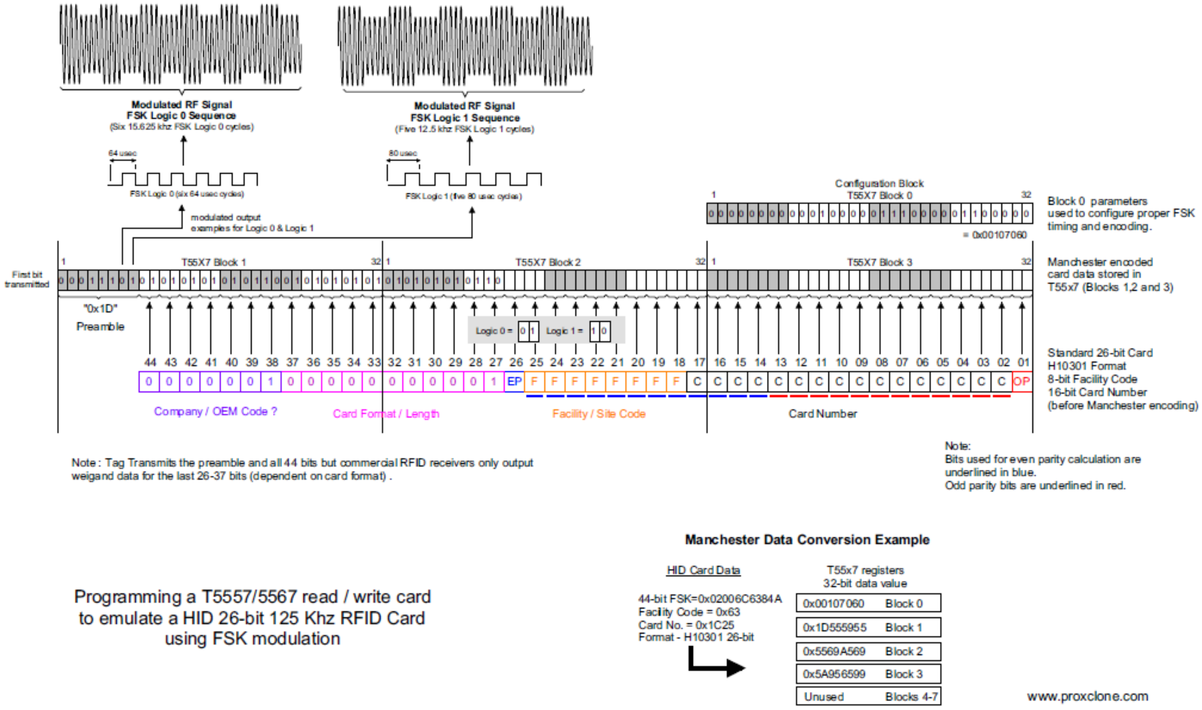
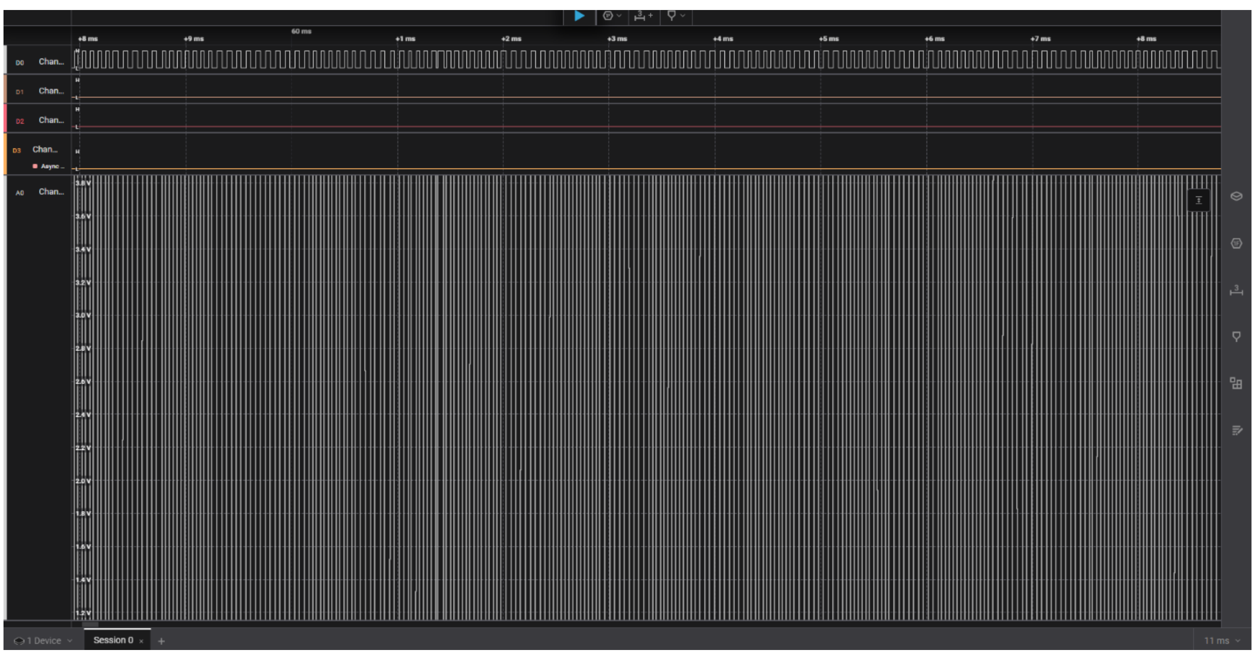


Fig. 7. BFSK Encoding/Decoding process [20]



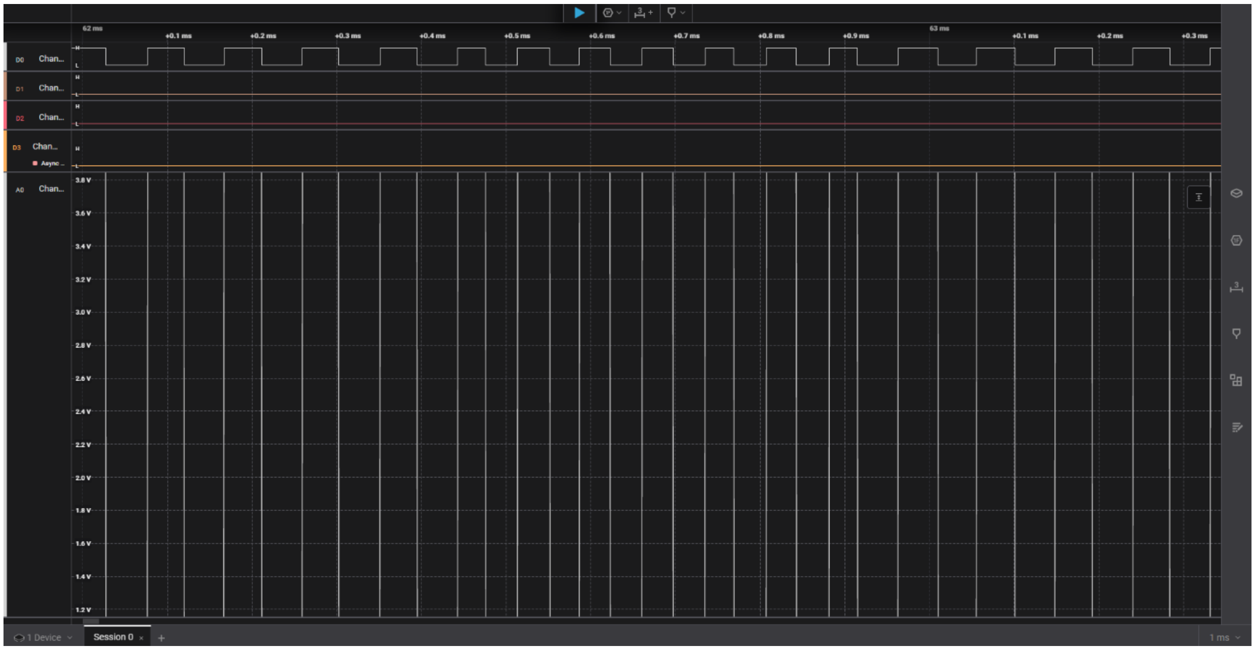


Fig. 8. ICard BFSK Signal Read with Logical Analyzer

Appendix C: Concept Map

Table XII
Concept Map

Function 1: User Input	**Function 1: Microcontroller**	**Function 1: Reader IC/Module**	**Function 1: Door Relay**	**Function 1: Computer Module IC**
Softkeys and LCD	PIC18F452	ID-12LA (125kHz)	TS0010D: 2 channel 5V Relay (digikey)	MAX223
Touchscreen	ATmega328P	EM4095 (125kHz)	103020012: 5V electromechanical relay (digikey/mouser)	MAX202
Keypad and LCD	ATtiny85	MFRC522 (13.56Mhz)	Weidmüller RCM570012 (mouser)	SP3232
	STM32G0	PN532 (13.56Mhz)	Songle SRD-05VDC-SL-C (amazon)	ST3232

Appendix D: Decision Matrix

Link to spreadsheet calculations [week12_Decision Making Matrix.xlsx]

Decision Matrix Steps

i.) Pairwise comparison of selection criteria

Julian	Part Availability	Time to Complete	Ease of Use	Effective Product	Satisfy Tech requirements	Geometric Mean	Weights
Part Availability	1	1/7	7	9	1/3	1.25	0.23
Time to Complete	7	1	1/7	1/3	1/9	0.52	0.09
Ease of Use	1/7	7	1	1	1/3	0.80	0.15
Effective Product	1/9	3	1	1	3	1.00	0.18
Satisfy Tech Requirments	3	9	3	1/3	1	1.93	0.35

Table XIII: Pairwise comparison of selection criteria (Julian)

Juliana	Part Availability	Time to Complete	Ease of Use	Effective Product	Satisfy Tech requirements	Geometric Mean	Weights
Part Availability	1	6	8	9	7	4.97	0.55
Time to Complete	1/6	1	8	9	8	2.49	0.28
Ease of Use	1/8	1/8	1	8	8	1.00	0.11
Effective Product	1/9	1/9	1/8	1	3	0.34	0.04
Satisfy Tech Requirments	1/7	1/7	1/8	1/3	1	0.24	0.03

Table XIV: Pairwise comparison of selection criteria (Juliana)

Moody	Part Availability	Time to Complete	Ease of Use	Effective Product	Satisfy Tech requirements	Geometric Mean	Weights
Part Availability	1	1/5	1	3	5	1.25	0.18
Time to Complete	5	1	5	3	7	3.50	0.51
Ease of Use	1	1/5	1	1	3	0.90	0.13
Effective Product	1/3	1/3	1	1	5	0.89	0.13
Satisfy Tech Requirments	1/5	1/7	1/3	1/5	1	0.29	0.04

Table XV: Pairwise comparison of selection criteria (Moody)

Tony	Part Availability	Time to Complete	Ease of Use	Effective Product	Satisfy Tech requirements	Geometric Mean	Weights
Part Availability	1	1/3	1/5	1/5	4	0.56	0.08
Time to Complete	3	1	6	6	9	3.96	0.53
Ease of Use	5	1/6	1	3	4	1.58	0.21
Effective Product	5	1/6	1/3	1	4	1.02	0.14
Satisfy Tech Requirments	1/4	1/9	1/4	1/4	1	0.28	0.04

Table XVI: Pairwise comparison of selection criteria (Tony)

Selection Criteria	Average Geometric Mean	Weights
Part Availability	2.00	0.278623699
Time to Complete	2.62	0.363855213
Ease of Use	1.07	0.149147791
Effective Product	0.81	0.113035026
Satisfy Tech Requirments	0.69	0.095338271

Table XVII: Pairwise comparison of selection criteria (Weighted)

ii.) Ranking design alternatives with respect to criteria

Julian	Part Availability	Time to Complete	Ease of Use	Effective Product	Satisfy Tech requirements
Alternative 1 (125kHz, w/t Touc	5	2	3	4	5
Alternative 2 (125kHz, w/o Tou	5	2	2	1	5
Alternative 3 (13.56MHz, w/o T	5	3	4	4	5

Table XVIII: Ranking design alternatives with respect to criteria (Julian)

Juliana	Part Availability	Time to Complete	Ease of Use	Effective Product	Satisfy Tech requirements
Alternative 1 (125kHz, w/t Touc	5	5	3	5	5
Alternative 2 (125kHz, w/o Touc	5	4	3	4	4
Alternative 3 (13.56MHz, w/o T	5	3	4	2	4

Table XIX: Ranking design alternatives with respect to criteria (Juliana)

Moody	Part Availability	Time to Complete	Ease of Use	Effective Product	Satisfy Tech requirements
Alternative 1 (125kHz, w/t Touc	3	2	5	5	4
Alternative 2 (125kHz, w/o Tou	4	3	4	3	3
Alternative 3 (13.56MHz, w/o T	4	4	3	4	4

Table XX: Ranking design alternatives with respect to criteria (Moody)

Tony	Part Availability	Time to Complete	Ease of Use	Effective Product	Satisfy Tech requirements
Alternative 1 (125kHz, w/t Touch	5	3	5	5	5
Alternative 2 (125kHz, w/o Touch	4	4	2	2	3
Alternative 3 (13.56MHz, w/o To	2	5	4	4	4

Table XXI: Ranking design alternatives with respect to criteria (Tony)

iii.) Calculated score for each design alternative

Table XXII
Ranking design alternatives with respect to criteria (Weighted)

Criteria	Weight	Design Alt 1	Design Alt 2	Design Alt 3
Part Availability	0.28	4.5	4.5	4
Time to Complete	0.36	3	3.25	3.75
Ease of Use	0.15	4	2.75	3.75
Effective Product	0.11	4.75	2.5	3.5
Satisfy Tech Requirements	0.10	4.75	3.75	4.25
Score		3.93	3.49	3.84

Appendix E: Objective Tree

Description:

An *Objective tree* is a visual tool used to represent desired project parameters in a hierarchical manner via transforming problem statements given by client into positive objectives. Each node is given weight of importance based on collective agreement amongst team members to determine the most important aspects of the project (i.e. minimum required features).

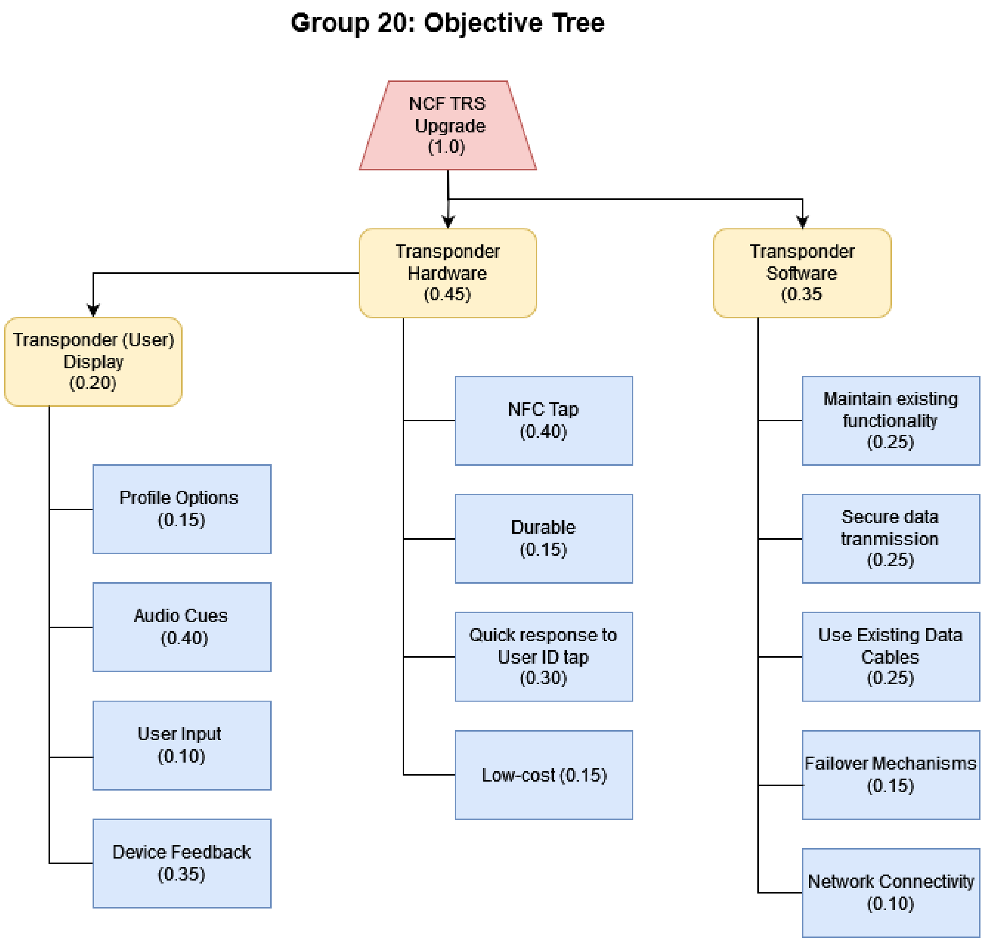


Fig. 9. Objective Tree for TRS upgrade

Appendix F: Initial Project Timeline

Table XXIII: Initially planned Project Timeline for ECE397 spring 2025 drafted during fall 2025

Phase	Week	Estimated Wks to Complete	Leader	Task	Description
A	1	4	Julian	Order Parts	Order necessary materials for project.
	2	2	Moody	Verify Serial Data	Plug personal laptop into admin computer to observe the serial data fed into the computer apon scanning keyfob at the reader to understand data encoding/decoding and how it is stored in custom software.
	3	8	Tony	C/C++ for µC	Draft programs for reader control: remove override, access sequency, deny sequence, setup, time setup, text output to display.
	4	4	Juliana	Finalize PCB schematic	Design trace antenna to meet the 125kHz freq. spec to communicate iCard serial number
B	5	2	Julian	Verify touchscreen functionality	Test touch screen display to ensure that it works with desired functionality using dev connections
	6	4	Moody	Touch screen menu	Test and debugg software to get touch screen UI to navigate properly via touch
	7	4	Tony	Touch screen user accounts	Test and debug software to get touch screen UI to allow account selection
	8	3	Juliana	Enclosure design	Design a 3D enclosure used to house RFID circuit using AutoCAD model
C	9	2	Juliana	PCB Connetion Verification	Verify connections via testbench and wired connections to debug setup
	10	6	Moody	Verify ethernet data transfer	Test data sent from reader circuit PCB is properly sent over ethernet channel to ensure compatibility with existing system.
	11	6	Tony	Verify µC functionality when connected to PCB	programming to ensure door lock and unlock logic works properly
	12	2	Julian	PCB Assembly	Assemble PCB via reflow soldering.
D	13	3	all	Prototype completion	Iterate & fix any issues that arise in hardware or software
	14				
	15				

Appendix G: Card Reading and User Authentication

Fig. 10. Reading and displaying card serial number

```
Valid 12-byte message received:
01 09 0C 14 0C 42 00 00 00 00 5F 20
User ID: 201266
User Profile #0
User found: Moody Ekladios
Profile: ECE 397
```

Fig. 11. Received encoded card serial number and identifying user from card reader to computer

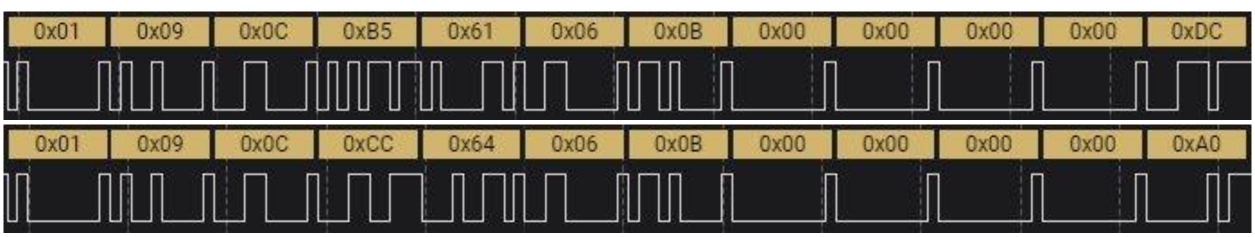
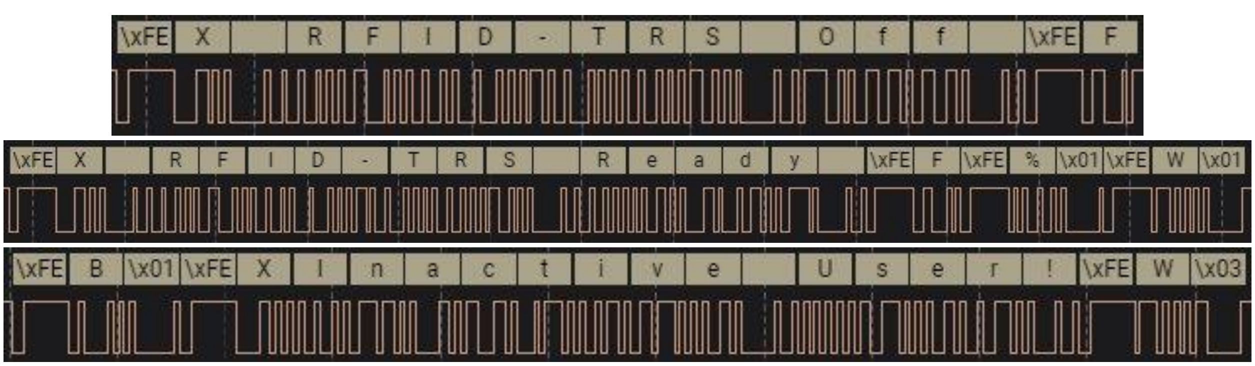


Fig. 12. Decoded key fobs data send sent from card reader to computer module



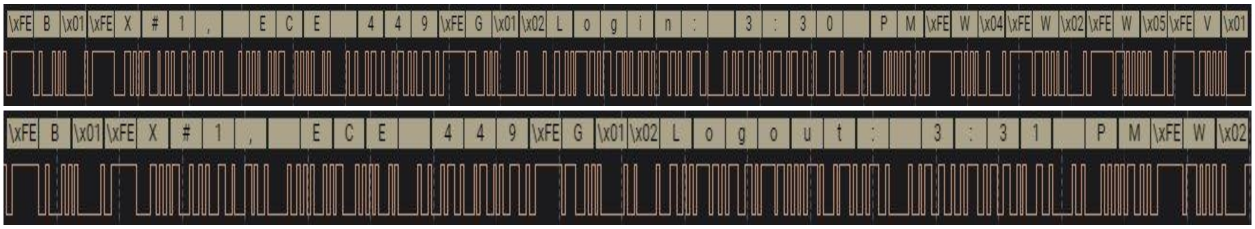


Fig. 13. Decoded messages and serial commands sent from computer module to card reader

Fig. 14. Display messages sent from computer module to card reader

Appendix H: PCB Shield

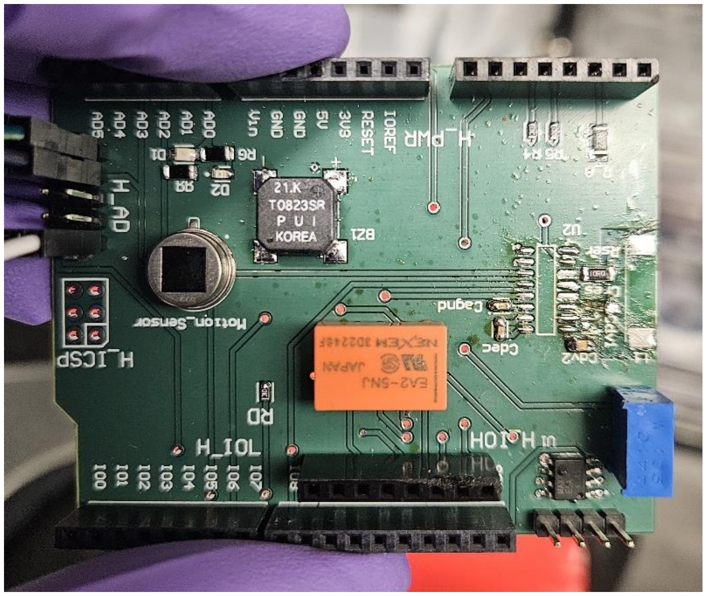


Fig. 15. (Top view) Fabricated PCB shield with SMD components soldered on

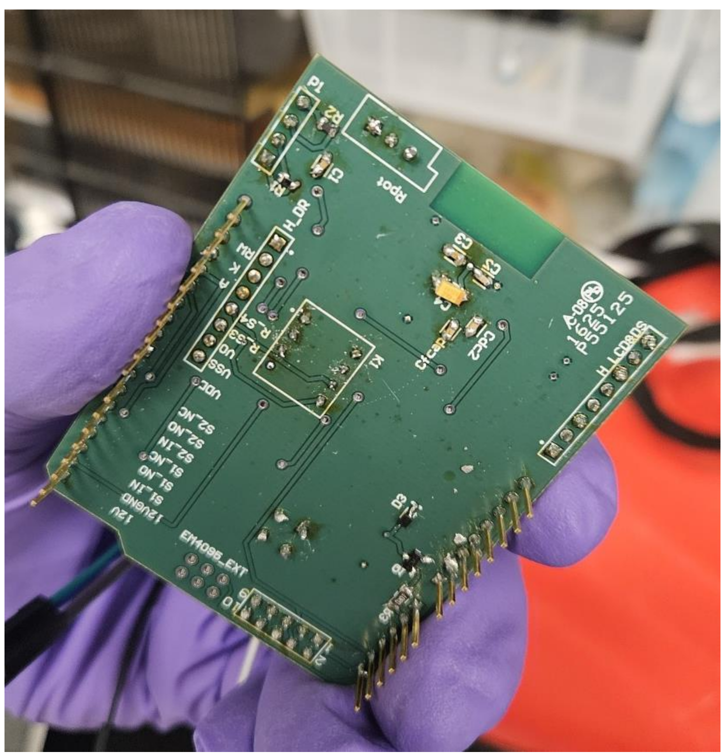


Fig. 16. (Bottom view) Fabricated PCB shield with SMD components soldered on

Appendix I: NCF Cleanroom User Manual

The reader system is fairly simple to work with. Assuming all components are connected properly to the PCB, the system simply needs to be plugged into a power source. After a short boot sequence, the reader will display "RFID TRS Ready" indicating to the user that the card reader is functioning and ready to transmit card data when a card is placed in range of the PCB's antenna. Upon scanning a UIC iCard, either 1 of 4 things will occur:

1. Invalid User

   The card that's been tapped contains user data not registered with the cleanroom. This indicates to the user that they do not have any accounts registered with the NCF Cleanroom. Card data will have been stored in the computer module database and Dr. An will be able to make a profile for you.
2. One Account (Login success)

   When you tap your card, the buzzer sounds, and you are cleared to enter the cleanroom. You should see your account on the display for charging purposes.

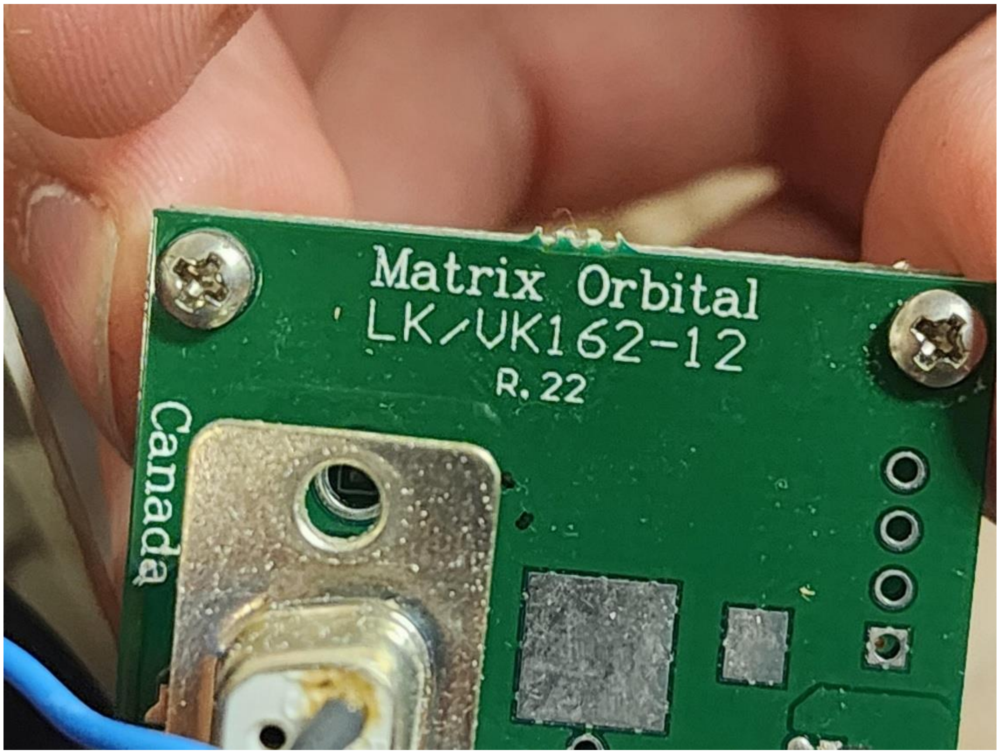
3. Multiple Accounts

   Because your card has multiple accounts associated with it, you'll need to select the account you want to use. The accounts will display one at a time in a rotating list. You'll have two buttons available to you, one for "scroll" and one for "select." The "scroll" button will move down the list of available accounts. When the "select" button is pressed, whichever account was displayed on the LCD will be logged in. The buzzer will sound and the door to the cleanroom will open.

4. Logout success

   This is an indication that one of your accounts (or the only account if you have only one) was previously logged into the system. The account will be displayed on the LCD and a logout confirmation will show. This is your indicator that you are no longer being charged for lab usage.

Once you've exhausted these options, or after a timeout duration, the display will return to



"RFID TRS Ready" and the user can tap another card. For any troubleshooting of the system, please refer to the final report documentation or the code repository linked here.

Appendix J : Notes about 2004 TRS documentation

Fig. 17. The TRS uses a Matrix Orbital VK162-12 LCD

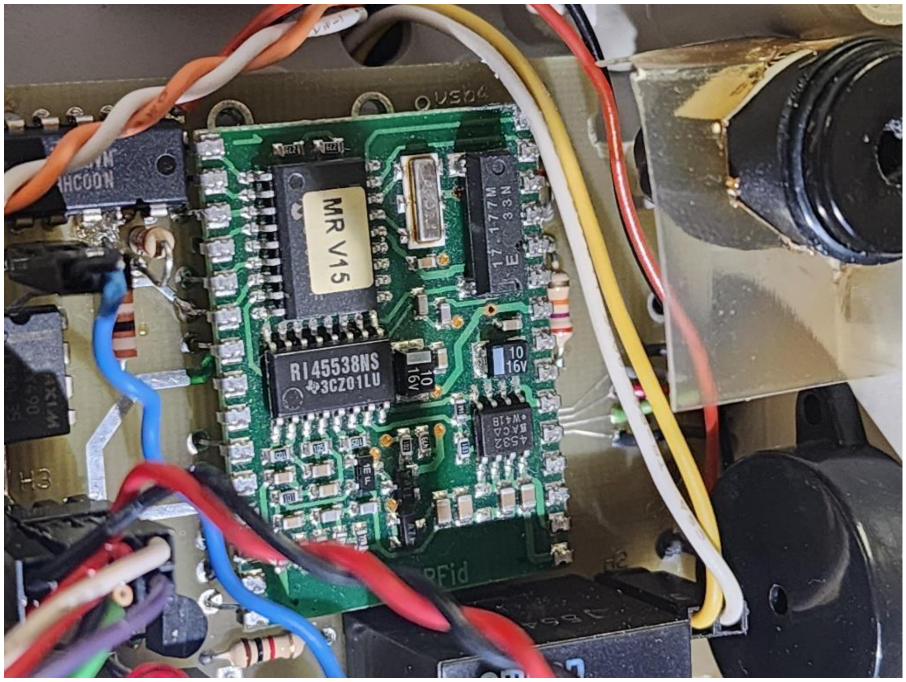


Fig. 18. The TRS uses a RI-STU-MRD1 Micro-reader (2000 series reader system)