Final Project Report

MMAN4010 Group 5 (Southco)

Mentor: James Stevens

Ethan Athos
BEng (Mechatronics)
z5264626

Lyall Beveridge
BEng (Mechatronics)
z5168048

Udish Davda
BEng (Mechatronics)
z5396986

Martin Deng
BEng (Mechatronics)
z5258975

Aryan Jain
BEng (Mechatronics)
z5395865

Yiqun (Peter) Li
BEng (Mechatronics)
z5329383

Haoran (Charlie) Wen
BEng (Mechatronics)
z5254113

Toby Wright
BEng (Mechatronics)
z5310061

Haoze (Jose) Zhang
BEng (Mechatronics)
z5324144

Jiahuan (Harvey) Zhang
BEng (Aerospace)
z5295911

June 15, 2024

Abstract

This report documents the prototyping of an electronic consumer product for the Australian service body vehicle market, conducted as part of an undergraduate group thesis at the University of New South Wales in conjunction with Southco. The device aims to address the lack of synchronization and communication between central locking systems and service body compartments in vehicles equipped with Southco latches. This lack of integration can lead to various issues, including theft, battery drainage, tool loss, service body damage, and inconvenience. The document details the development process of the final prototype, from scope clarification and background research to the final design and recommendations for market introduction.

The final prototype meets all core requirements including latch control, monitoring, central locking integration and operator warning mechanisms. However, some compromises were made concerning the infrastructure needed for brand-agnostic vehicle integration. This prototype represents the initial phase in an iterative design process, with potential improvements for future versions noted throughout the report. Additionally, the prototype includes advanced features not specifically requested by the client, such as daisy chaining, which allows for optional extension in larger vehicles to control more than the 18 latches the base product manages.

The solution consists of two physical devices: a Door Control Unit (DCU) and a Junction Box. The DCU handles latch monitoring, central locking integration, and power distribution, while the Junction Box serves as a long-distance connection node to reduce installation costs and complexity. Both devices contain a custom printed circuit board and operate on a shared 12.0V to 14.4V supply, with an internal 5V microcontroller managing the logic in the DCU.

Ultimately, this report demonstrates the successful design and development process undertaken by the Southco thesis group, resulting in a prototype that not only meets but exceeds client expectations. Hence, this project serves as a proof of concept for a potentially valuable product that Southco could bring to market.

Contents

List of Figures

List of Tables

1 Introduction

For service body vehicles, efficient and secure access to equipment is paramount. These vehicles are critical to a wide variety of Australian industries, from emergency services to construction, and are equipped with multiple hatches and compartments, often secured by Southco latch products. Whilst these latches provide basic access control via mechanical keys, electronic push buttons, and even Bluetooth mobile applications they lack direct integration with the vehicle's central systems, leading to potential security vulnerabilities and inefficient operation. For many vehicle owners, these service body compartments are not simple storage spaces but are considered extensions of the vehicle's own doors, necessitating a level of security and functionality akin to that of the vehicle's primary access points.

The risk of equipment theft and unauthorised access is heightened when compartments can remain accessible despite the vehicle being locked as the individual latches do not automatically engage alongside the vehicle's central locking mechanism. Current solutions do not provide any form of alert system for hatches left inadvertently open, thus raising the risk of equipment loss, canopy damage, and road accidents, leading to reduced overall safety of the vehicle. Additionally, this lack of integration leads to inefficiencies where the vehicle operator must manually check and secure each hatch when preparing to drive, a time-consuming and error-prone process.

Recognising this issue, Southco, a renowned designer and manufacturer of engineered access solutions, has engaged this thesis group to design and prototype a solution that can be used in conjunction with their access control products to address these issues. This report summarises the development of an innovative electronic door control unit solution aimed at bridging the gap between Southco latches and the central locking systems of modern automotive service body vehicles. Through meticulous design and engineering this thesis group has formulated a solution that ensures harmonious integration, thereby enhancing customer's control over their service body access points and extending the functionality of vehicle doors.

Specifically, the following document chronicles the journey from conception to prototype realisation, shedding light on the exhaustive design and development process, commencing with a study of the problem, background research and the project goals it then dives into the strategic approach used, before outlining the progress milestones, plan adherence and outcomes. Finally, this report concludes on how this solution directly solves the problem, coupled with recommendations for future work and implementation guidelines for Southco to bring this product to market.

Ultimately this is a testament to the rigorous engineering processes undertaken by this thesis group to yield a solution which will allow Southco to redefine access control in service body vehicles. It is structured as a compelling narrative of innovation, dedication and problem solving which aims to convince the reader about the potential of this solution to transform service body vehicle access management.

2 Aims

The central aim of this DCU project is to apply accumulated knowledge and skills as UNSW engineering undergraduates to a real-world engineering challenge addressing the inefficiencies and vulnerabilities of service body vehicles as outlined above. The development of a consumer product grounded in a real-world application will serve as a platform to enhance this team's skills in documentation, leadership, industrial problem-solving and engineering design, all of which are fundamental competencies of successful professional engineers.

3 Proposal From Industry

The following Background and Objective subsections aim to summarize initial information provided by the client as well as additional information which was conveyed over the course of the project.

3.1 Background

Southco (Figure 1) sells a range of latches (Figure 2) that are designed to control the access to Service Body Vehicles or Trucks (Figures 3, 4), but there is no controller on the market that is able to communicate with the Central Locking and Latches. This is an ongoing issue that hasn't been resolved. A few workarounds exist, but nothing suited to this application. Canopy and Service Body Vehicles require connectivity to Central Locking, but there is no control unit to power these locks. Everything is wired into the Central Locking via the door which creates communication issues and failures.

Figure 1: Southco Logo

Figure 2: Southco vehicle latches

Figure 3: A utility truck service body vehicle

Figure 4: A cherry picker service body vehicle

3.2 Objectives

The objective of the project is to design and prototype an electronic Door Control Unit which can be installed internally in the car. This DCU should be able to prohibit the operation of Southco latches in the service body to prevent unwanted access. Secondarily, the device should be able to monitor the status of the service body latches and provide features with which to notify car owners about any latches which are opened either when the vehicle is locked or once it has started moving.

In terms of latches, the device should attempt to maximise the number which it can natively support. The specific product line of latches which will be used with this device are all powered at 12V and have a maximum current draw of 1A under load. The device shall also be extendable in a manner which allows customers to purchase further DCUs that can allow support of more than the initial maximum number of latches in their original purchase.

Finally, the DCU should incorporate an interface for secondary devices, being able to control and supply power to other 12V vehicle accessories such as alarms and LED lighting systems.

4 Scope

4.1 Problem Statement

Australia's service body vehicles lack an integrated system that connects compartment latches with central locking systems, leading to increased security risks and operational inefficiencies. This deficiency results in heightened theft risk, potential safety hazards from inadvertently open compartments, and time-consuming manual checks by operators.

4.2 Objective Summary

The primary objective of this project is to design and build a prototype of a consumer grade automotive device which can solve the aforementioned problem by enhancing vehicle security through advanced Southco latch management.

4.3 Goals

Goal	Details
Enhance vehicle security	Implement a system which controls and monitors vehicle latches to prevent unauthorized access and ensure user awareness of compartment open/close status.
Improve user interaction	Provide intuitive and convenient control mechanisms, preferably not requiring any manual interaction at all.
Market compatibility	Ensure the device is compatible with a broad spectrum of vehicle types available in the Australian market.
Inexpensive	Reducing the cost of the product to increase market accessibility.
User friendly	Ensure the device is easily installed, operated and portable, with a minimal physical footprint.
Energy efficiency	Reducing power consumption over existing solutions by only powering Southco locks when necessary.
Equipment safety	Reducing the risk of lost tools and vehicle damage due to handle malfunctions and unintended door openings by automatically locking when the vehicle is in motion.
Operator safety	Minimize physical risk possible to the operator through reduction of potential harm via electrical shock, fire, and/or damage to critical vehicle systems.
Reliability	Maximize consumer confidence by incorporating environmental conditions, fail-safes, and component longevity into the design.
Maintenance of existing supply chains	To encourage ease of manufacture the product should attempt to utilise Southco's existing components wherever possible.
Aesthetics	Increasing the visual appeal of customers' vehicles by allowing flush finishes on service body doors when no handles are required.

Table 1: Project goals

4.4 Core Requirements

Requirement	Details
Latch control	Can control power to at least 6 latches (12V, 1A per latch) which can be operated in pairs via buttons or other similar 2-wire mechanisms.
Latch monitoring and operator alerting	Must be able to alert the operator using auditory or visual means to notify them of the service body compartments being open whilst the vehicle is locked.
Latch operation	Latches should only be operable once the vehicle is unlocked, with preference for the handbrake engagement included as well.
Vehicle powered	Must be powered at 12V using a host vehicle's existing power distribution systems.

Table 2: Core requirements

4.5 Secondary Objectives

Objective	Details
Handbrake detection	Include the handbrake engagement as a requirement for service body operation.
Vehicle stoppage detection	Incorporate the vehicle movement (rolling versus parked) into the programmed logic for operator alerting.
Ajar sensor integration	Wire the device into the ajar sensor network, to natively alert the user if the a service body compartment is ajar.
Auxiliary device support	Provide optional 12V interfaces which can control and save power for 12V vehicle accessories like LED light bars.
Extensibility	Allow multiple devices to be easily 'daisy chained' to increase the number of latches which can be supported and increase potential product sales.
Redundancy	Have backup operational capability if the vehicle battery fails.

Table 3: Secondary Objectives

4.6 Excluded Scope

Scope	Details
Loom/Wiring harness	The specific method of wiring between the DCU and the Southco locks will be determined by the installer/customer based on their type of vehicle.
Vehicle customization	This product will not have custom variants.
International regulatory compliance	This solution is only intended for the Australian market.

Table 4: Excluded Scope

4.7 Deliverables

Considering the scope of the project outlined above, this project aims to deliver:

- A fully functional prototype of a latch management system.
- Documentation including design specifications, schematics and integration guidelines.
- A roadmap to bring this product to market.

5 Team Overview

The group is organized into two main teams, external and internal DCU, using a cross-functional structure that simplifies management and enhances collaboration by aligning members toward a common goal based on their expertise. The secondary roles were assigned to manage product delivery (Appendix A).

Role	Responsibilities	Assignee
	External DCU Team All engineering related to functionality outside of the core DCU device	
	External Vehicle Integration Portfolio Integration with the vehicle, focusing on universal compatibility	
External Power Supply Engineer	- Find and connect to an appropriate power source for the DCU - Design the required connectors and cables required for installation - Document the installation process - Build a dummy power supply simulator for prototyping and testing - Work with the internal DCU power supply engineer to understand product power requirements	Martin Deng
External Central Locking Engineers (2)	- Design the splicing mechanism to get the central locking signals from the door wires - Design the required cables and connectors for all configurations of locking (positive, negative etc.) - Work with the internal DCU central locking engineer to identify signal types	Udish Davda, Aryan Jain
	Southco Latch Integration Portfolio Powering and controlling up to 20 Southco latches	
External Southco Latch Integration Engineers (2)	- Determine the required cables and cable types required to connect the Southco latches - Ensure that each cable and button setup can be adjusted to work with 1 OR 2 Southco latches - Work with the internal Southco Latch Integration Engineer to understand the power and signal cable requirements - Additional scope: determine how auxiliary devices may be integrated via these cables such as alarms, automatic lights etc	Toby Wright, Yiqun (Peter) Li
	Internal DCU Team Development of the core DCU device, housing and internal electronics	
	Internal Interfacing Portfolio Development of internal interfaces for external signals and power as well as physical device	
Internal Power Supply Engineer	- Manage internal power regulation for DCU - Work with external power supply engineer to understand the incoming power supply from vehicle - Design electronic circuit to step down voltage to power the microcontroller	Ethan Athos
Internal Southco Latch Integration Engineer	- Design the plug interface for Southco latches - Work with internal power supply engineer to pass power and ground lines to the latches - Design the relay mechanisms required to positively control the Southco latches simultaneously - Write microcontroller software to control the relays based on central locking signals	Lyall Beveridge
Internal Central Locking Engineer	- Manage GPIO inputs and signal conditioning circuitry for central locking signals - Work with the external DCU central locking engineers to understand what cables are required and which signals will indicate lock/unlock based on different lock types - Write microcontroller software to process aforementioned GPIO signals	Jiahuan (Harvey) Zhang
	PCB Development Portfolio Manage development of the final PCB	
PCB Engineers (2)	- Design the PCB and review designs with subject matter experts - Source the PCB supplier and components suppliers - Work with all other internal DCU engineers to understand and integrate their designs - Manage microcontroller software and integrate other engineer's code	Haoze (Jose) Zhang, Haoran (Charlie) Wen

Table 5: Primary role descriptions

6 Literature Review

6.1 Automotive Battery Specifications

Vehicle batteries are generally available in three types: flooded lead acid (wet cell), sealed lead acid (SLA), and absorbed glass mat (AGM) batteries [4, 5]. The standard nominal voltage for these batteries in most vehicles is 12V, but this can increase to between 13.5V and 14.0V during operation due to the alternator charging the battery [5]. Larger vehicles might use 24V batteries, but 12V batteries are common in most general-purpose or commercial vehicles.

The capacity of vehicle batteries varies, depending on the vehicle's requirements. Their ampere rating typically ranges from about 550A to 1000A. Battery capacity is measured in Amp Hours (Ah), indicating the number of amps a battery can supply per hour over a period of approximately 20 hours, until the voltage drops to the cut-off point, usually around 10.5V for SLA batteries [5, 6].

Considering the use of a vehicle battery to power Southco latches, we can assume a typical service body vehicle has a 12V battery with around 85Ah capacity. For example, a Toyota Landcruiser will require a 12V battery [7]. A Southco latch needs 25 milliamps (mA) [2] to operate. If 10-12 latches are used simultaneously, the total idle current draw would be around 600mA. Given that the proposed device needs to be operational at all times, it would draw a maximum of 600mA from the battery. This consumption is minimal and would have a negligible impact on the battery's lifespan.

6.2 Methods for Powering Third Party Vehicle Accessories

Battery Powering Methods		
Locking System Type	**Description**	**Usage/Prevalence**
Positive	Operates on a simple principle where a positive voltage is applied to the lock actuator, causing it to move and either engage or disengage the locking mechanism. Typically —requires a switch mechanism and basic electrical wiring.	Commonly found in older cars; usage has decreased with the advent of more advanced technologies in modern domestic automobiles.
Negative	Utilizes a negative voltage to control the lock and unlock mechanisms. The system comprises actuators, a control module, and a switch powered by a negative source.	Widely used in contemporary vehicles due to its effectiveness, ease of integration with electronic control modules, and compatibility with advanced vehicle security systems.
Reverse Polarity	Changes the state of the door lock by alternating the polarity of the electrical current, causing the door lock to switch between locked and unlocked states. Includes actuators, a control module, and relays.	Popular in various vehicles, adaptable and reliable, commonly used for aftermarket installations.
Vacuum	Operated by an actuator driven by vacuum pressure. The state of the lock is controlled by applying or releasing vacuum pressure. Consists of actuators, check valves, vacuum lines, and vacuum pumps.	Was common in older vehicles, now less prevalent in modern domestic cars due to the rise of electronic door locking mechanisms that offer more precise control.

Table 6: Auxiliary automotive device power supply methods

6.3 Automotive Power Distribution Systems

In all automotive vehicles that utilise electricity a power distribution system (PDS) is required to properly allocate the appropriate amount of energy to each component. The PDS can be broken down into three main sections, namely the primary power distribution (PPD), the secondary power distribution (SPD), and the electronic control units (ECUs). As shown in Figure 5 a battery supplies the required power for each distribution center or domain (PPD, SPD, ECU).

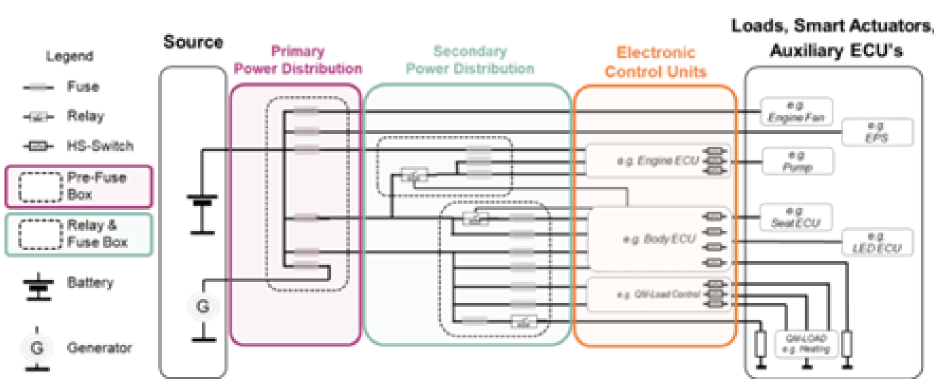


Figure 5: Power Distribution System (PDS) of an automotive vehicle [1]

Automotive vehicles are designed using two possible control system architectures with the most recently developed architecture being the centralised power distribution (CPD). This method incorporates most of the vehicle's system functionalities into very few controllers and ECUs and instead opts to utilise a body control module (BCM). With the implementation of a centralised control system, it may be easier to manage functions, reduce complexity and maintenance costs. However, with more wires required it may limit troubleshooting capabilities and make debugging difficult [8].

Decentralised power distribution (DPD) separates individual control systems into domains, namely ECUs. Unlike the CPD, DPD powers multiple ECUs directly from the battery to control each function of the vehicle instead of distributing the power through a BCM. A benefit of DPD is that the components can enable such that the number of wires is reduced. This, however, poses a scalability issue as more ECUs result in more complex wiring harnesses and troubleshooting difficulty [9] [10].

6.4 Lock Actuators

An actuator uses a set of pistons and gears that work together to lower the shaft connected to the lock of the door. The cable or shaft extends to operate the lock. Thus, it becomes one of the most crucial parts of a vehicle's locking system. These actuators convert electrical signals into mechanical actions after receiving them. Depending on the manufacturer's preferences and the architecture of the vehicle, they may be solenoid-based or motor-driven [11].

6.5 Types of Automotive Door Locks

The following list (Table 7) of door locking strategies have been identified as the most common methods relevant to this project [12].

Locking System Type	Description	Usage/Prevalence
Positive	Operates on a simple principle where a positive voltage is applied to the lock actuator, causing it to move and either engage or disengage the locking mechanism. Typically —requires a switch mechanism and basic electrical wiring.	Commonly found in older cars; usage has decreased with the advent of more advanced technologies in modern domestic automobiles.
Negative	Utilizes a negative voltage to control the lock and unlock mechanisms. The system comprises actuators, a control module, and a switch powered by a negative source.	Widely used in contemporary vehicles due to its effectiveness, ease of integration with electronic control modules, and compatibility with advanced vehicle security systems.
Reverse Polarity	Changes the state of the door lock by alternating the polarity of the electrical current, causing the door lock to switch between locked and unlocked states. Includes actuators, a control module, and relays.	Popular in various vehicles, adaptable and reliable, commonly used for aftermarket installations.
Vacuum	Operated by an actuator driven by vacuum pressure. The state of the lock is controlled by applying or releasing vacuum pressure. Consists of actuators, check valves, vacuum lines, and vacuum pumps.	Was common in older vehicles, now less prevalent in modern domestic cars due to the rise of electronic door locking mechanisms that offer more precise control.

Table 7: Automotive central locking types

6.6 Methods of Central Locking Status Detection

In traditional vehicle door locks, activating the handle or key starts a process where a capacitor discharges, energising a relay that turns on a motor to move the lock. This process stops once the capacitor discharges completely, completing the unlocking [13]. The lock status is typically monitored through this mechanism.

A vehicle's central locking system includes a control switch, key control switch, lock assembly, luggage door opener, and a controller, all overseen by the vehicle's onboard computers, which may include lock status information [14]. Directly accessing the ECU could provide real-time lock status.

Modern cars often have an indicator light on the control panel, linked to a door sensor. This light illuminates when a door is open or unlocked, offering a visual alert to the driver.

Detecting central locking status might be complex through direct circuit integration. Instead, a Hall effect sensor on the door frame, which detects magnetic fields, can generate a signal when a magnet approaches, indicating lock status [15].

Keyless entry systems, which intercept and interpret lock actuation signals, offer insights into central locking status. These systems, compatible with various vehicle models, translate signals from devices like keyfobs into commands for the car's locking system.

These keyless systems adapt to different locking mechanisms, from simple electrical circuits to complex digital commands. Their universality is crucial for this project's needs. Installation guides and technical specifications, like those from Summit Racing Equipment [16], provide valuable information for developing a DCU subsystem to detect central locking status.

6.7 Microcontroller Platforms

This review examines microcontroller platforms suitable for low-power automotive applications, focusing on electronic latch control in service vehicles. Various platforms were assessed based on criteria such as power consumption, size, installation ease, compatibility, automotive-grade components, wireless capabilities, cost, programming, development support, and security. The study aimed to identify and analyze the most suitable microcontrollers, evaluate their compatibility with electronic latches and vehicle systems, and provide recommendations to guide prototyping and development.

Power Consumption

Minimising power consumption is critical, as Southco's EM latches only require a low trigger current (5-20mA typical) to operate their internal relays [2]. The microcontroller's GPIOs need to source this small trigger current. The MCU must operate at ultra-low currents of 5-10mA to adhere to Southco's power efficiency standards to reduce car battery consumption. As a result, sleep mode currents below 10μA are preferred.

Size Constraints, Installation, and Compatibility

A compact MCU footprint is crucial for ideal in-cabin installations. Microcontrollers with small Quad Flat No-leads (QFN) packages are particularly desirable. These QFN packages, characterised by their lack of protruding leads or pins and featuring metal pads on the bottom, are optimal for space-constrained applications, allowing for compact, streamlined, and efficient solutions with minimal material usage. For example, the ESP32 has a dedicated CAN bus shield communicating via the OBD2 port with an adapter, allowing for a cohesive and minimal solution.

Automotive Grade Components

MCUs must meet AEC-Q100 standards for automotive reliability which include: an industrial -40°C to 105°C rating, vibration and shock durability, and EMI protection [17].

Criteria	Arduino Nano [18]	PIC32MX [19]	STM32F411 [20]	ESP32 [21]
Active mode power	7.71mA	1 mA	1mA	10mA
Sleep mode power	0.47mA	1A	9A	150A
Installation & Compatibility	Basic vehicle integration with addon shields	Basic vehicle integration with addon shields	Integrated CAN bus support	Basic vehicle integration with add-on shields
QFN shields (i.e. compact & wireless)	Yes	Inbuilt CAN communication	Inbuilt CAN communication	Yes
Wireless Functionality	NO — requires additional modules	NO — requires additional modules	NO — requires additional modules	Yes - inbuilt
Operating Temperature (degrees Celsius)	-40 to 85	-40 to 85	-40 to 105	-40 to 105
Automotive Grade	NO	AEC-Q100 approved	AEC-Q100 approved	NO
Security	Basic, requires addon shields	Excellent with flash encryption, hardware cryptographic accelerators etc.	Excellent with flash encryption and hardware cryptographic accelerators etc.	Good with inbuilt Wi-Fi security
Development Support	Excellent support and examples	Moderate	Moderate	Large support and examples
Price & availability	$7	$40	$29.85	$32

Table 8: MCU Comparison

Conclusion

The ESP32 is an ideal microcontroller for prototyping low-power automotive applications, due to its extensive community support and wide range of available add-on modules which facilitate a smoother development process. Its proven reliability and functionality, as evidenced in various automotive projects, make it suitable for the initial phases of our project. However, as the ESP32 does not meet AEC-Q100 standards, a transition to the a PIC microcontroller should be planned for the manufacturing phase. For example, the PIC16F630-I/SL [22] is AEC-Q100 certified, which is crucial for automotive applications. It features an 8-bit CMOS architecture and is known for high performance and low power consumption. This microcontroller's operational characteristics, with 2.0V and 8.5µA at 32 kHz and 2.0V and 1nA in standby mode, align well with the requirements for Southco's EM latches [22, 23]. A transition to a suitable PIC microcontroller would ensure the product meets stringent automotive standards and enhances reliability for service body vehicles.

6.8 Southco R4-EM Latches

Locking and Unlocking Operations

The Southco R4-EM latch system operates at 12V DC and 600 mA and is designed to utilise a rotary cam and striker interaction to achieve secure door closure [2]. Upon closing, the striker makes contact with the cam, which prompts it to rotate. This rotation enables the cam to capture the striker, thereby effectively locking the door. The latch's design in series models 1 and 2, which we have been provided with, features immediate engagement, where the cam instantly secures the door. Alternatively, series models 4 and 6 and above are equipped with a delayed engagement, providing a short grace period before the lock activates. This delayed option enables quick, unimpeded access if the door needs to be reopened immediately, meeting various operational demands with adaptable security solutions [2].

For unlocking, there are two primary methods that ensure accessibility and convenience. The manual override trigger option is a manual fail-safe that allows the latch to be disengaged without electrical power. By applying force to the side trigger, the cam is manually rotated to unlock the latch, ensuring access even during power outages or electronic failures. This signal is sent to the internal DC motor via pin 3 (Orange: Control Signal 8 to 26 Volts DC), while pin 1 (Brown: Ground) and pin 2 (Red: Power 8 to 26 Volts DC) supply the necessary power to the system. Activating these connections causes the motor to rotate the cam, unlocking the latch [2].

The operational instructions detail both auto relock and delayed relock modes, respectively, as the delayed locking functionality mentioned earlier. In auto relock mode, an electronic signal initiates the disengagement of the latch (step 1), activating the spring-loaded cam which pushes open a lightweight door. This mode allows for the door to automatically re-secure itself once the signal is removed, as the striker re-engages the cam back into the locked position (step 2). On the other hand, the delayed relock mode leaves the latch unlocked while leaving the door in a closed position (step 3). The duration of the unlocked state is controlled by DCU, allowing manual operation of the door without immediate relocking. Once the persistent control signal has stopped, the door can be re-locked in either the open or closed position (step 4).

Real Time Status Feedback

A notable feature of the Southco R4-EM latch is its ability to provide real-time status feedback through an integrated microswitch which similarly operates at 12V DC with a maximum current rating of 3A. This microswitch plays a crucial role in the DCU by monitoring the lock status of each door. This real-time information, coupled with an LED indicator, provides users with clear visual cues about the security status of each door, aligning with the project's objective of developing a user-friendly and safe access control system.

The microswitch operates through three specific pins named PIN 4 (Black), 5 (Blue) and 6 (Grey) [2] as illustrated in Figure 6. PIN 4, known as the Microswitch Common, is connected to the latch's internal microswitch. It acts as the common terminal and provides feedback on the latch status. When the latch is in a locked position, this microswitch is closed, grounding the Microswitch Common wire. Conversely, when the latch is unlocked, the microswitch opens, leaving the Microswitch Common wire ungrounded.

PIN 5 serves as the Microswitch N.O. (Normally Open) contact. Linked to the latch's internal microswitch, this contact remains open when the latch is locked and closes when the latch is unlocked, signaling a change in status.

Lastly, PIN 6 functions as the Microswitch N.C. (Normally Closed) contact. Also connected to the internal microswitch, this contact maintains a closed state when the latch is locked and opens upon unlocking, providing another layer of status indication. These integrated features make the Southco R4-EM latch an effective component in ensuring secure and efficient access control.

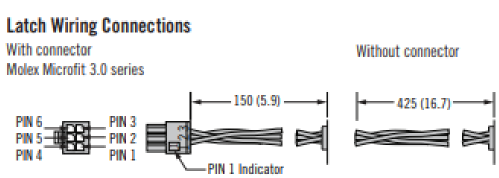


Figure 6: R4-EM pin layout [2]

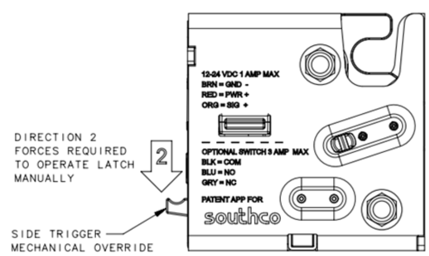


Figure 7: R4-EM Diagram [2]

6.9 Vehicle Warranty After Modification

As the proposed product is only designed for service body vehicles in Australia, the information in this section will be tailored to Australian law and consumer rights only.

Under Australian Consumer Laws (ACL) a supplier and manufacturer must guarantee that they will honor any express warranties. In this case, a 'supplier' refers to a dealer or manufacturer if they sell directly to consumers. ACL also provides automatic guarantees to consumers who purchase a service or product. Warranties apply to these services or products and can be enforced under contract law.

There are various types of new car warranties, including the manufacturer's warranty, which guarantees products or services will be free from defects for a certain period, and express warranties, which cover additional promises made about the product. Extended warranties offer similar coverage at an additional cost. Contrary to common belief, vehicle modifications do not necessarily void new car warranties. The Australian Automotive Aftermarket Association (AAAA) states that a car fitted with a fit for purpose part will not void a warranty [24], and issues arising from modifications are covered by the part manufacturer or fitter's warranty. The Australian Competition and Consumer Commission (ACCC) clarifies that a manufacturing defect causing a vehicle to become immobile constitutes a major failure under consumer guarantees. However, defects due to third-party accessories or modifications are not covered, implying that modifications causing major failures can void the warranty. The ACCC also notes that consumers are responsible for problems caused by their actions or inactions [25]. Therefore, to maintain the new car warranty, the proposed product must not diminish the vehicle's functionality or quality or cause any major failures as defined by the ACCC and Australian Consumer Law (ACL).

7 Budget

The total expenditure for the project was calculated at $810.56 (AppendixB), which exceeded the original budget by $72.52, set at $738.04. This overrun is largely due to the project's experimental nature, which led to significant deviations from the anticipated costs outlined in the initial plan. A notable instance of this was the purchase of optocouplers, used to experiment with the isolation and conditioning of central locking signals.

It's also important to note that many of the items initially budgeted were already owned by team members. These items were returned upon project completion, incurring no cost to the project. This category primarily included smaller components such as LEDs, resistors, and cabling. Although these items appear in the final bill of materials (Appendix C), they were not factored into the initial budget, further underestimating the total cost of the project. This miscalculation distorted the expected cost and will serve as a learning experience for future projects.

The most substantial expense was the manufacturing of the PCB, which cost $353.87, significantly surpassing the expected $220. This increase was partly due to the high cost of expedited shipping.

In retrospect, the project concluded over budget with just one completed prototype instead of the planned two, suggesting that the initial budget was significantly underestimated. This underestimation was likely due to incorrect assumptions and a lack of experience, as well as members not taking stock of already-owned items. Further analysis on how to better accommodate experimental projects in budget planning could be beneficial for all team members.

8 Approach and Methodology

This section details and critically evaluates the cutting-edge tools, methods and strategies which were used in the implementation of this project, linking these approaches to current challenges and justifying the chosen methods. Given the nature of the project, this section is divided based on the internal, PCB and external development portfolios, each responsible for developing specific components of the final solution. This organization greatly accelerated the development process by balancing team coordination with individual expertise.

8.1 Internal Interfacing

8.1.1 Microcontroller Selection

The internal DCU team was tasked with selecting a microcontroller after previous assessments showed the necessity for one to meet project demands. The chosen microcontroller required not just basic memory and GPIO pins but also needed to support both DIP and SMD packaging types for development and production and possess energy-efficient power characteristics capable of operating 12V relays or transistors for latch control. Microchip's product range, known for its suitability in automotive applications, met these criteria by offering extended temperature tolerance, vibration and shock resistance, regulatory compliance, and long-term support.

Initially, the PIC16F630 chip [22], already being used in existing Southco accessory products like the EA-R02 [26], was selected. However, the challenge of requiring external programming peripherals lead to the subsitution of the PIC16F630 with a more reliable solution when the PICKit 3 [27] programmer proved unreliable and lacked proper documentation. This lead to the adoption of the more official and dependable MPLAB Snap ICSP programmer [28] which cost approximately $65.

Ultimately, the PIC16F18324-I/SL [29] was selected for its superior memory, enhanced features and programmer compatibility. This microcontroller was used throughout the breadboard and PCB prototyping phases, with plans to switch to an SMD package for production.

8.1.2 Internal Power Regulation

The internal power engineers were responsible for regulating the 12V input to provide power to any components which required specific voltages, most notably the on-board microcontroller. Following the selection of the PIC16F18324 which has a wide operating voltage of 1.8V - 5.5V, a voltage regulator had to be selected which could handle the fluctuations in power and provide enough current to operate and electronics further down the line.

The two most common types of voltage regulators are linear and switching regulators. Linear regulators will only output a lower voltage than passed in, whereas the switching regulators can output a voltage that is higher, or of opposite polarity. Given the low operating voltage required and their high availability, linear voltage regulators were selected.

Linear voltage regulators are known to generate excess heat due to their relatively high thermal resistance during operation, making this a critical factor when selecting specific components. According to IPC2221B guidelines on PCB design, components should not exceed 20°C above their ambient temperature under normal operating conditions to prevent damage [30]. To generate this constraint, a maximum value for thermal resistance must be calculated:

With the default 4MHz internal clock on the PIC16F18324 operating at 5V and a provided current consumption of approximately 37μA/MHz [29], the ambient current draw of the microcontroller is calculated to be roughly 0.74mA (Equation 1).

$$I_{\text{MCU}} = 5V \times (37\mu A/MHz \times 4MHz \times 10^{-6}) = 0.74mA \tag{1}$$

When this value is combined with the measured 80mA current draw from an SRD 05VDC relay coil, and doubled for a factor of safety (and to add room for other peripheral components), the estimated minimum total current draw downstream from the regulator is 161.48mA. Given this value, the downstream power draw can be calculated as:

$$P = V \times I = 5V \times 161.48mA = 807.4mW \quad (2)$$

and with the maximum allowable temperature rise of 20°C, the maximum thermal resistance can then be determined using the equation:

$$R_{th} = \frac{\Delta T}{P} = \frac{20°C}{0.8074W} \approx 24.77\frac{°C}{W} \quad (3)$$

During the development phase, the voltage regulator choice should be based not only on the immediate requirements but also on the potential for circuit expansion. Prioritising a regulator with a higher peak output current provides the flexibility to incorporate additional components in the future. Thus, a regulator that is versatile in terms of form factor, supporting both breadboard prototyping and surface-mount configurations for advanced PCB designs, is highly advantageous.

In light of these criteria, the L7805ABD2T-TR 5V [31] regulator stands out as the optimal choice. This particular model supports an easy transition from the initial prototyping stage to the development of a more sophisticated PCB prototype. Table 9 below encapsulates the alignment of the L7805ABD2T-TR 5V regulator with the pertinent design considerations.

Input Range (V)	**DC Output (V)**	**Thermal Resistance (°C/W)**	**Peak Output Current @ 25°C (A)**
5-18	5	3	2.25

Table 9: L7805ABD2T-TR 5V (D^2PAK package) design specifications

8.1.3 Software Development

For the software development tasks in the project, the internal DCU team utilised a GitHub repository to manage and share the MCU source code. MPLAB X IDE was chosen as the primary development environment. To facilitate concurrent programming and hardware development, an MPLAB Xpress PIC16F18345 evaluation board shown in Figure 8 was purchased to help the programmers get used to the specialised software development processes. The programming language of choice was C, preferred over assembly due to its higher level of abstraction and native support with the MPLAB XC8 compiler. This choice not only leveraged the existing expertise within the internal DCU team but also significantly accelerated the development process.

Figure 8: MPLAB Xpress PIC16F18345 evaluation board [3]

8.2 PCB Development

8.2.1 Manufacturer Selection

After consultation with the team's thesis supervisor, JLCPCB [32] was chosen as the manufacturer for the prototype PCBs. Based in China, this foundry is known for reliability and affordability which was desirable. Additionally, they offer part sourcing and placement services which are highly complex undertakings if performed manually, benefitting the project's time constraints.

However, choosing JLCPCB came with some drawbacks. The manufacturer's location in China meant higher shipping expense and time. Local manufacturers were considered, but they did not provide equivalent component placement and sourcing services which was crucial for the project's needs.

Additionally, JLCPCB imposes a minimum order of five units per design, which increased costs. However, this requirement meant the team had extra units available for experimentation and backup, which was advantageous for thorough testing and validation.

8.2.2 Development Tools

The initial schematic and PCB designing was done using the Fusion360 platform in order to utilise the sharing capability and maintain both CAD models and electrical designs in one accessible location for the whole team. After beginning work it was found that locating existing part schematics and CAD models which were stocked by JLCPCB added unwanted complexity and time, as many of the required resources were unavailable outside of the JLCPCB integrated software platforms. Given this, the switch was made to the EasyEDA PCB designer, which offered seamless integration with existing component designs, prices and stock quantities as well as a one-click ordering service which automatically prepared and uploaded manufacturing files to the foundry.

8.3 Latch Integration

8.3.1 Junction Box

After much deliberation, the team decided that creating a separate Junction Box as a node in the vehicle's latch control system offered more benefits than disadvantages over a direct latch connection strategy to the central DCU. Initial designs connected latch plugs from the vehicle service body at the rear directly into the DCU in the cabin. This direct approach created a conflict between the number of supported latches and the small footprint size due to the required plug space in the housing. It also increased the overall length of the cables and installation complexity by requiring each latch to be individually routed through to the cabin. After consultation with the client, it became apparent that service body vehicle owners often require the flexibility to operate latches either individually or in pairs, allowing them the more granular control over their access points, which could not be easily achieved with a direct connection approach.

Further research revealed that Southco's latch control accessories typically incorporate a design pattern that separates the control systems from the latch connections, as evidenced by the existing Southco Junction Box product, pictured in Figure 9.

Emulating this established design pattern, the team decided to introduce a new custom Junction Box variant into the design. This extra device would act as a centralised node where multiple distinct pairs or single latches could be powered and monitored as a group by the

Figure 9: Existing Southco Junction Box accessory

DCU but operated as individual channels by the end user.

On the other hand, this introduced risks, as the additional hardware is another potential point of failure and would require more design and documentation work, as well as extra installation time and cost for the customer. This Junction Box would also be most likely installed in the service body, which would experience harsher environmental factors than the DCU in the cabin. Despite these concerns, the decision was approved unanimously, as the modular approach and simple integration were too enticing, with the added benefit of simpler maintenance, being easily replaceable independently of the DCU.

8.3.2 Daisy Chaining Junction Box Expansion

Following the decision to introduce a Junction Box, it was soon realised that the modular benefits could be expanded by allowing daisy chaining. This permits product users to upgrade the maximum number of supported latches in their vehicles with ease by simply replicating the same incoming DCU connection as an outgoing available plug on the Junction Box. The client expressed a keen interest in this idea as offering expansion packs added a new potential revenue stream.

8.4 Vehicle Integration

8.4.1 Central Locking Integration

In developing the interface with the central locking systems without the availability of actual vehicles for testing, the team faced significant challenges. After deliberation, it was determined that any lock signal from the vehicles would need to be conditioned into a universal signal which was compatible with the MCU prior to interfacing with the DCU. This conversion aimed to ensure that the locking status could be processed to general purpose IO ports on the MCU through a dedicated input 2-pin input header on the DCU.

Ultimately this decision is a significant compromise which defers the signal processing to external devices. Our research indicated, despite the lack of experimental results, that at least 3 types of signal conditioning devices would be needed to accommodate the large variety of automotive locking systems in modern vehicles. Consumers could purchase these products to ensure compatibility with their specific vehicle make and model. Despite this, a simulation was conducted and is described in the execution section of this report where a real motor vehicle linear locking actuator was used to validate the system to a certain extent. Although this could be considered a mild success, it highlights the need for further development.

8.4.2 Installation Location

Research on existing automotive accessories, such as the MCL3000 remote keyless entry kit [33], indicates that the optimal installation location for auxiliary devices integrating with locking systems is inside the driver's door panel. The DCU device is designed to be installed in the same area, with provisions for a rail mounting system which can accommodate multiple devices and/or position adjustments.

8.4.3 Power Source

Following the decision on the installation location, the optimal method to power the device is by splicing into the power lines found inside the driver's door panel. This method will use commonly available automotive splices, specifically 16-14 AWG varieties, which are robust enough to handle the necessary amperage and harsh engine conditions, making them suitable for cabin environments.

9 Execution

9.1 Simulation

It was recommended by the thesis supervisor to find a way to simulate the DCU PCB design electronically, so that it could be validated whilst the physical device was being manufactured, so that any issues could be detected early and potentially repaired.

9.1.1 Method

The final PCB schematic was transferred into LTSpice, seen in Figure 10, a powerful simulation tool provided for free to UNSW students. This simulation utilised transient analysis, denoted as .tran in the software, which evaluates time-varying changes in voltage and current within the circuit in response to an input signal. This type of analysis is essential for observing how the circuit behaves over time once the signal is applied.

It should be noted that certain components, such as the microcontroller could not be simulated directly and have been replaced with equivalent generic components.

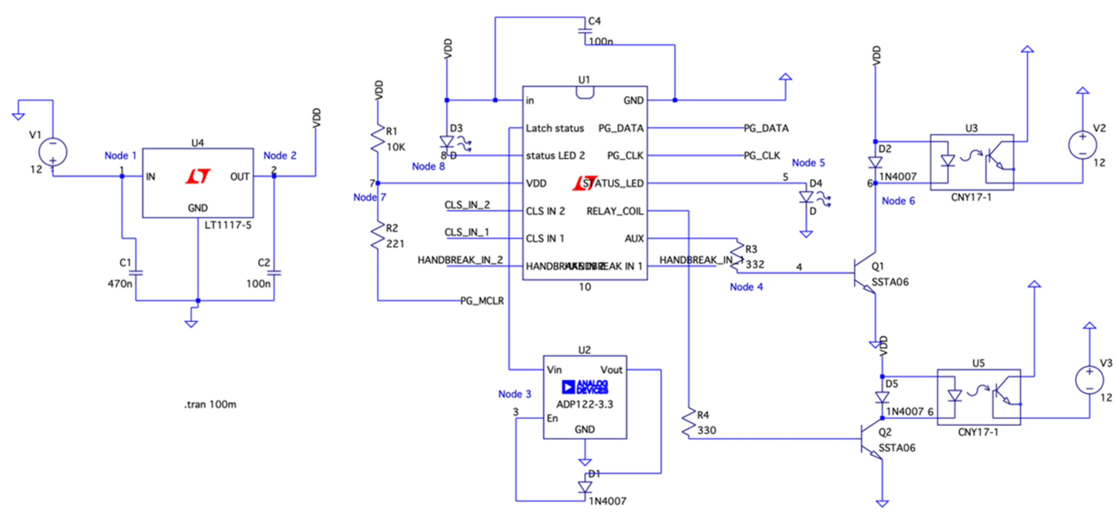


Figure 10: LTSpice DCU simulation schematic

9.1.2 Results

Node	Calculated (V)	Simulated (V)
1	12	12.0000
2	5	5.0040
3	≥ 0	0.009998
4	≥ 0	0.00171
5	0	0.0000
6	5	4.9800
7	5	5.0040
8	5	5.0040

Table 10: Simulated voltage results

```
Pseudo Transient succeeded in finding the operating point at 25.2133 s.
Ignoring empty pin current: Ix(u2:2)
Ignoring empty pin current: Ix(u2:5)
Ignoring empty pin current: Ix(u2:2)
Ignoring empty pin current: Ix(u2:5)
Total elapsed time: 0.333 seconds.
```

Figure 11: Simulation log

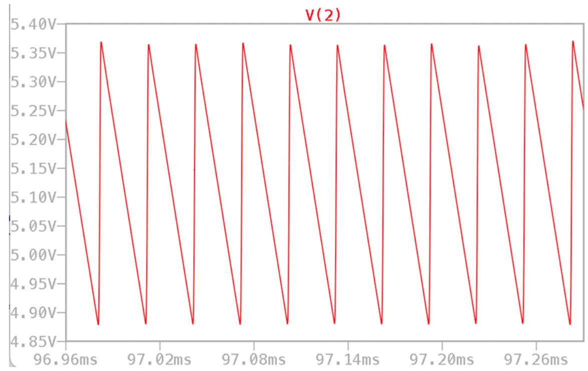


Figure 12: Simulated voltage graph (end peturbation)

9.1.3 Analysis

As demonstrated by the results above it was confirmed that the PCB operated as expected with inconsequential voltage discrepancies between the calculated and simulated ones.

Where node 1 was simply the 12V supply, node 2 measured the output of the regulator, experiencing ripples of up to 0.35V on the upside, which indicates potentially insufficient capacitance, or capacitor ESR. All nodes from 3 to 8 are expected to then operate at 5V or below as they are downstream from the regulator, as shown by nodes 6, 7 and 8. Node 5 was placed around the status LED which had been correctly grounded. The generic relays in the simulation were programmed to be activated using transistors, and the 9mV measurement is expected due to leakage current.

Although the simulated data resembled the theoretical data, there were some discrepancies. For example, during our transient analysis with a simulation duration of 100ms, small fluctuations in voltage tails was observed. These frequent, small amplitude perturbations seen in Figure 12 could be attributed to the simulation time intervals. When the simulation time to 300ms, these disturbances at the tail end were no longer present.

Ultimately, this simulation proved to be a good demonstration of the feasibility of the design and met initial expectations.

9.2 Solution

9.2.1 Core Components

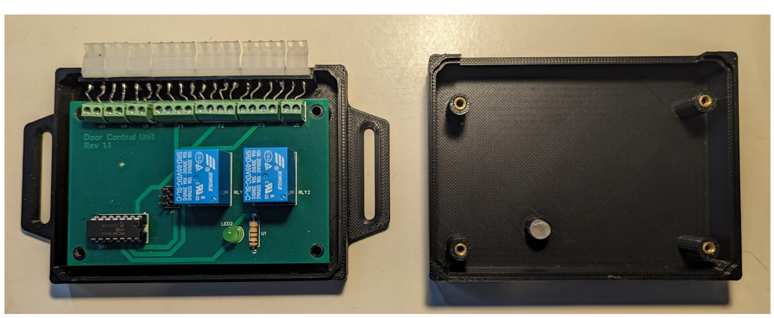


Figure 13: Door Control Unit disassembly

The solution is comprised of two main devices: the Door Control Unit (DCU) (Figure 13)

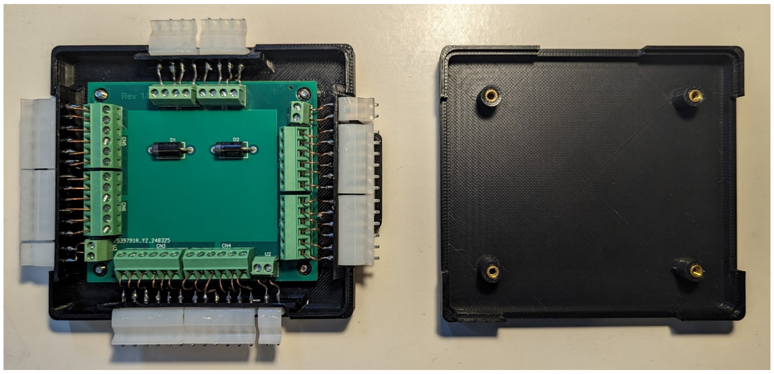


Figure 14: Junction Box disassembly

and Junction Box (Figure 14), each featuring printed circuit boards and corresponding 3D printed enclosures. Also included are essential supporting cables including the power input (with inline fuse), central locking signal input and 4-wire DCU to Junction Box connector. All cables are of shorter length than what would be actually required in a vehicle installation and are meant for demonstration purposes. Each cable uses a generic friction lock connector, to ensure secure connections in the high-vibration vehicle environments.

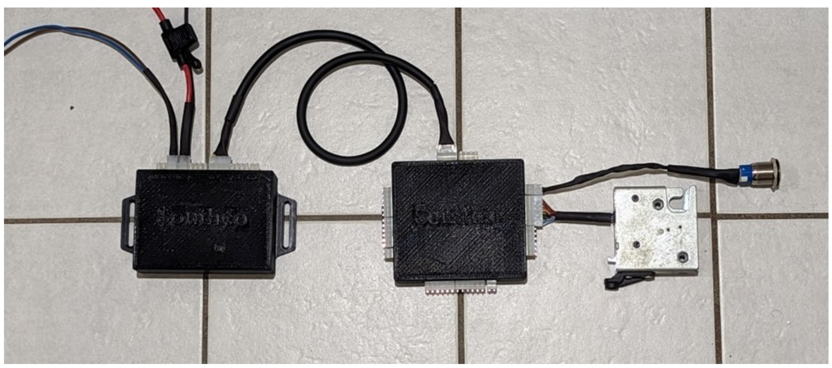


Figure 15: Solution installation example: Door Control Unit (left), Junction Box (right)

As shown above in Figure 15, these are the most basic components needed to achieve the core functionality of the solution, which solves the initial problem directly, as explained in the following functional logic section. It should be noted that the pushbutton and latch pictured will ultimately be supplied by the end-user and can be exchanged or modified to meet their specific requirements.

The full bill of materials can be found in Appendix C, and the material cost of the core components excluding the PCB itself amounted to $44.55. This number could be easily reduced in future iterations as many components were purchased through consumer electronics suppliers, where the price would be drastically reduced when purchased from wholesalers who supply manufacturers.

9.2.2 Functional Logic

The solution presented in this report operates on the principle that if the vehicle is detected to be in an unlocked state, power is supplied to all connected Junction Boxes whether they are daisy chained or connected directly to the DCU, allowing the end user to operate up to two latches at a time using a push button or other similar 2 wire mechanisms which complete a circuit that generates an opening signal.

The core value of this solution is that when the host vehicle is detected as locked, power is no longer supplied, reducing overall energy consumption and preventing unauthorised access to service body compartments via the Southco latches. This directly addresses the problem's core components of theft reduction and operator effort. A secondary function of this solution is that their open/closed status is being continually monitored by the DCU regardless of power. This allows the system to utilise software to activate the secondary relay when the vehicle's cabin doors are locked but a service body latch is open. The secondary relay outputs to an auxiliary port which is presumed to be some sort of alarm mechanism which can alert the vehicle operator, directly solving the stated problems of operator error, unauthorized access and tool loss for vehicle's where the cabin doors automatically lock once the vehicle is moving. Table 11 formalizes this logic, which is implemented via the microcontroller.

Input Conditions		**DCU Action Output**		
CLS locked?	**All latches closed?**	**Latch power supply relay enable (operable)**	**Auxiliary relay enable (operator alerting)**	**Status LED pattern**
Y	Y	N	N	Slow blink
N	Y	Y	N	Solid
Y	N	N	Y	Fast blink (alerting)
N	N	Y	N	Solid

Table 11: Solution logic table

9.2.3 Door Control Unit Printed Circuit Board

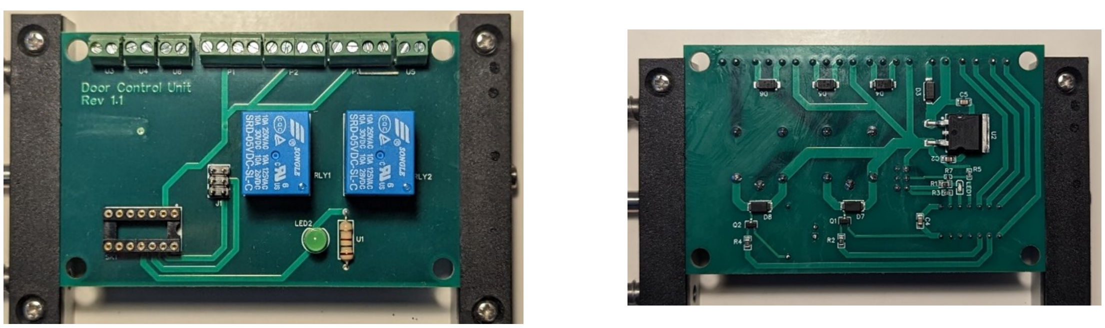


Figure 16: Door Control Unit PCB top (left) and bottom (right) view

Role Building upon the initial schematic design (Appendix D) the DCU PCB stands as the central functional element of this solution. It hosts the main relay responsible for controlling power to the Junction Boxes and thus, the latches. Controlling this latch relay via an intermediate transistor, seen in Figure 17, is the PIC16F18324 microcontroller which implements the overarching logic defined in Table 11 by integrating signals from both the latches and the central locking system to make decisions and generate the desired outputs.

Design Principles The components and layout were purposefully based on existing designs, where the plug headers, microcontroller family and relay orientation were all directly inspired by the design of the Southco EA-R02 [26] a product which uses a wireless keyfob to control Southco latches in a similar manner. This principle of copying was used because these existing design patterns approaches were already validated by Southco products on the market and would likely streamline manufacturing processes if identical parts were being used.

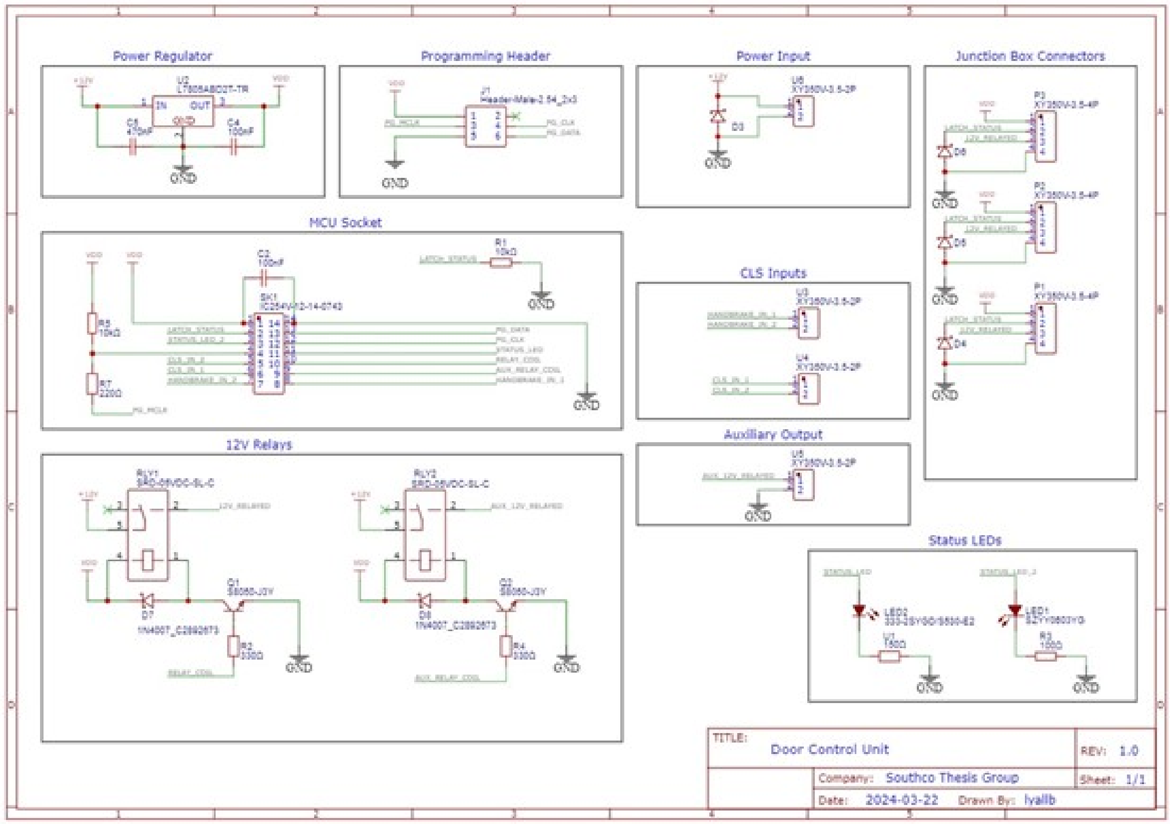


Figure 17: DCU PCB final prototype schematic

Three other generic wireless locking upgrade key fob kits were purchased via Ebay for study of their designs, but provided little relevant insight.

Cable Interface and Debugging As witnessed in Figure 13, an array of generic friction lock plugs interface with the PCB via stub wires. This decision was made to facilitate initial debugging efforts upon receipt of the physical PCB from China, based on the expectation that some components would not work and having the plug headers soldered directy into the board would add time and complexity to debugging. This complexity was assumed to be because custom cables would have to be made up for each pin to make individual connections, and that if the team ran out of the corresponding female plug, it would have to be ordered from China as it would not be available locally.

Unfortunately, this approach was later recognised as sub-optimal as the terminals were friction lock terminals found to be easily sourced and even available in Sydney at Jaycar. The time saved using these screw terminals for debugging was minimal and became a hassle when converting the prototype to a pluggable equivalent for demonstration. On the other hand, a similar cautious approach was taken with the microcontroller, at the recommendation of the team's thesis supervisor, where instead of soldering an SMD microcontroller onto the PCB where it would be hard to remove, a DIP socket was used allowing easy removal for debugging or replacement. This proved advantageous when 12V was accidentally applied to a GPIO input - far exceeding its 5V tolerance - causing the microcontroller to pop and smoke.

Plug configuration The screw terminals, seen in Figure 13 served a variety of purposes, as Table 12 explains there purpose from left to right (reading downwards).

Purpose	Input/Output	Note	No. Positions
Handbrake Signal	Input	To be implemented in future iterations.	2
CLS Signal	Input	Requires signal pre-conditioned to <5V.	2
Power Supply Input	Input	12V, inline fuse on cable.	2
Junction Box Channels 1,2 & 3	Mixed	Power supply and latch status.	4
Auxiliary Output	Output	Currently used with LED alarm to demonstrate operator alerting if vehicle locked but latch open.	2

Table 12: DCU PCB input and output plug descriptions

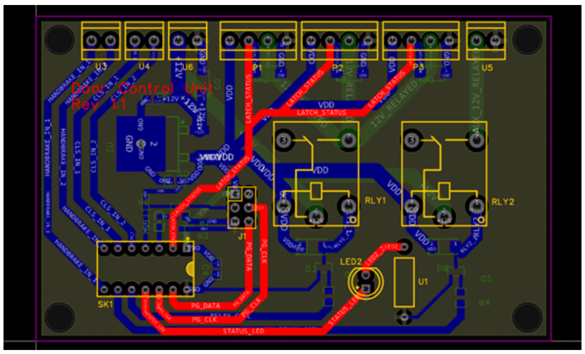


Figure 18: Door Control Unit PCB design

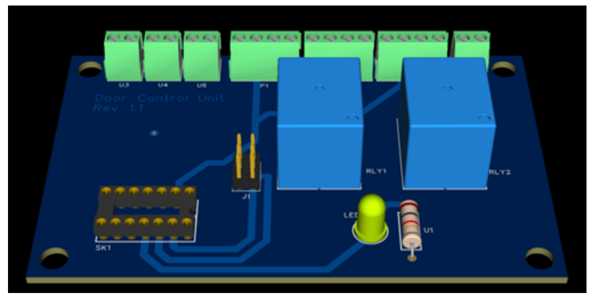


Figure 19: Door Control Unit PCB 3D model

PCB Specifications and Layout The board itself occupies a footprint of 95mm by 60mm and has a thickness of 1.6mm, featuring four conductive layers outlined in Table 13.

Copper Layer	Role	Figure X Trace Colour
Top	5V power distribution traces, throughole components	Red
Inner 1	Ground plane	Brown
Inner 2	12V power distribution traces	Green
Bottom	5V I/O signals, surface mount components	Blue

Table 13: PCB copper layer descriptions

Traces were manually routed for more intuitive design understanding, with trace widths set based on expected current loads, with 12V lines taking the maximum available width. Separation of traces was mantained where feasible to minimze interference, with vias used as a last resort. Ultimately this approach resulted in considerable unused space leaving ample room for footprint reduction improvements in future designs.

Protection Measures The final schematic (Figure 17) shows the effective use of NPN transistors to control a larger current whilst reducing the microcontroller load, which was an effective design choice. Apart from that, protective circuits on this PCB were implemented at the bare minimum standard, with six TVS diodes placed in appropriate areas to clamp voltage spikes caused by EMI from unplugging and inrush from load switching, these were rudimentary at best. Future revisions should include reverse polarity protection on the cable inputs as well given the high probability of human error as well as GPIO isolation from high voltage signals components such as optocouplers.

Summary In conclusion, whilst the design passed every functional test, there remains considerable scope for improvement in general circuit protection, footprint reduction, and connector terminal choice. Furthermore, chosen components were not scrutinised for price, standards adherence or reputation but rather electrical characteristics and more research could be performed to find components more suited for mass produced consumer products as well.

9.2.4 Door Control Unit Enclosure

Figure 20: DCU enclosure angled, top and front perspectives

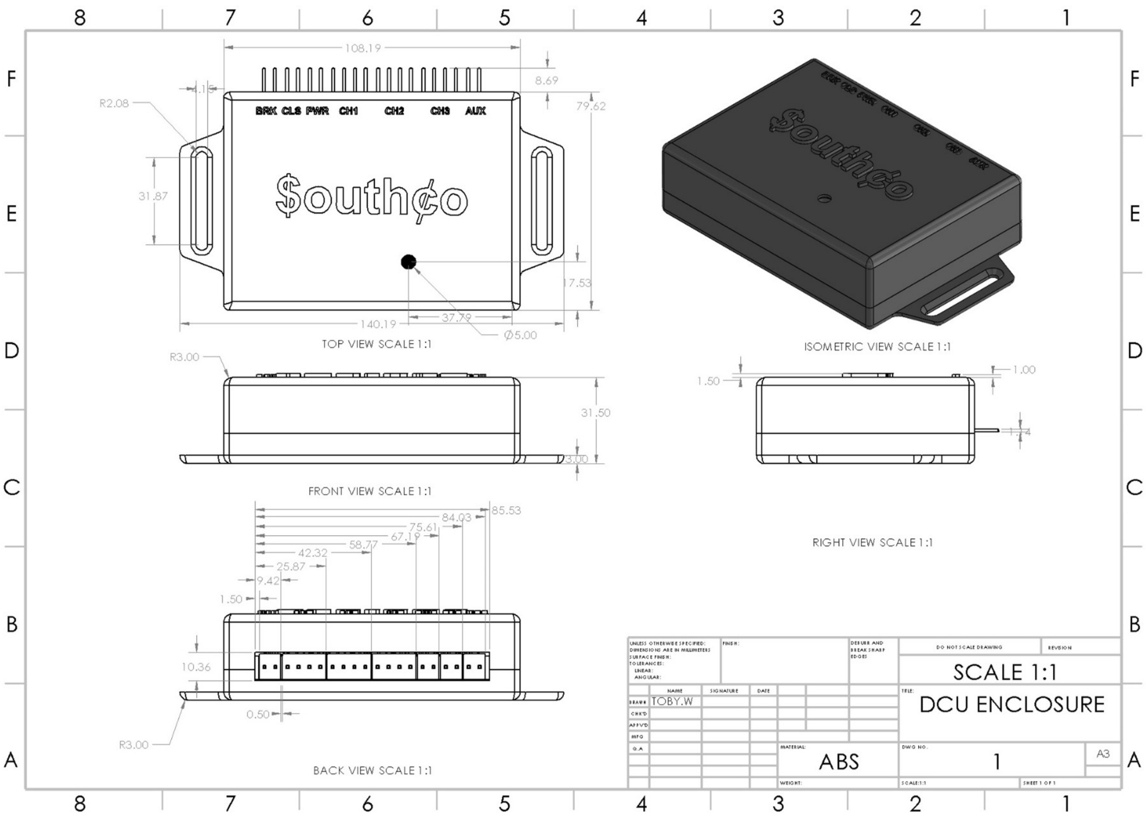


Figure 21: DCU enclosure engineering drawing

Design Overview The DCU enclosure design is heavily influenced by the existing EA-R02 product [26], seen in Figure 22, with the similarities especially evident in the exploded view in Appendix E. Some of the major features which were directly inspired by existing Southco design patterns were:

- A two-part enclosure, fastened with four countersunk M3 screws.
- Adjustable rail mounting tabs inside the door panel for versatile installation.

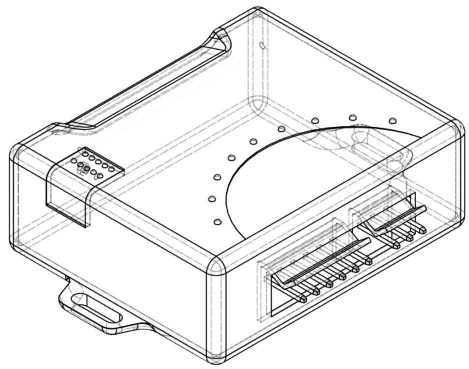


Figure 22: Southco EA-R02 Wireframe Isometric View

- Inbuilt PCB mounting standoffs, enhancing thermal management and vibration resistance by ensuring component clearance and air circulation.
- A press-fit tolerance on the base standoffs, securing the PCB firmly against vibrations.
- A 50-50 split design between the enclosure lid and base, with a guiding flange ensuring a neat assembly of the two halves.

Compromises While the design borrows heavily from proven products, it also introduces compromises and areas for future improvement:

- The plug terminals, offset from the PCB, required a secure fit achieved through a combination of press-fit, superglue and through-holes to secure, although this will not be an issue in the next iterations where these plugs will almost certainly be soldered directly onto the PCB.
- The lid's height is constrained by the size of the latch relays, with suggests that a conversation should be had with the PCB design team about smaller relay variants in future iterations.
- The enclosure material differs significantly from the EA-R02's injection-molded construction. The prototype's 3D printed PLA structure, whilst allowing rapid iterative development and customization, such as embossed labels for port identification and a branding logo on the lid, lacked the structural integrity for commercial deployment.

Enhancements The enclosure in this prototype offered several enhancements over existing products:

- Rapid development of minor iterations helped refine features like the flange fit tolerances.
- An embossed branding and functional embossing for port identification were integrated, where they do not exist on the current EA-R02, which enhanced usability and aesthetics but requires more improvement regarding legibility.
- A novel opening above the status LED (see Figure 21) with a clear glue stick being used as a diffuser demonstrated a way to aid users in visual diagnostics without having to completely disassemble the product. This opening could easily be secured against environmental ingress with silicone sealant or some other potting method

Summary Whilst not a primary concern, the DCU enclosure effectively met its primary objective in this phase of development by securing internal components and facilitating user interaction via the cables. Despite a larger than necessary footprint dictated by the internal PCB and visible layer lines from 3D printing, the design demonstrated significant potential for future enhancements. Future iterations could focus on reducing the physical footprint, enhancing structural integrity, or even improving environmental protection to better suit consumer-grade requirements.

9.2.5 Junction Box Printed Circuit Board

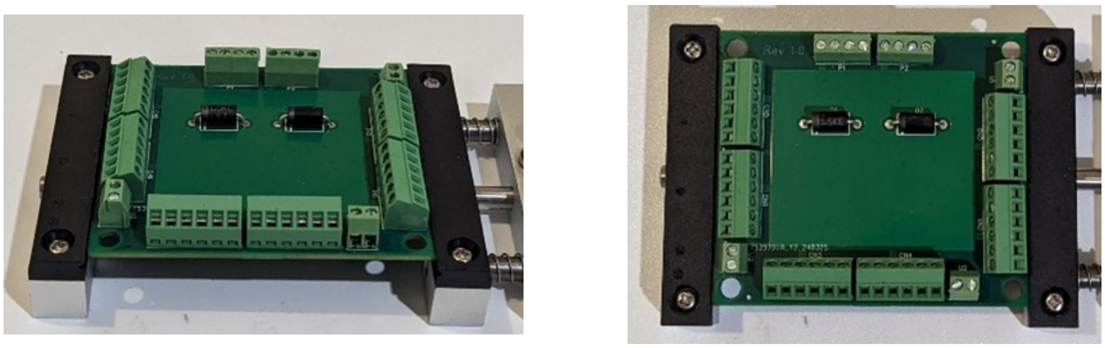


Figure 23: Junction Box printed circuit board

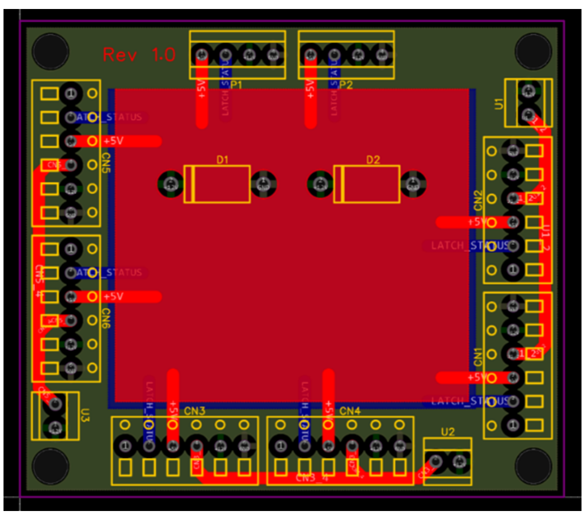


Figure 24: Junction Box PCB design

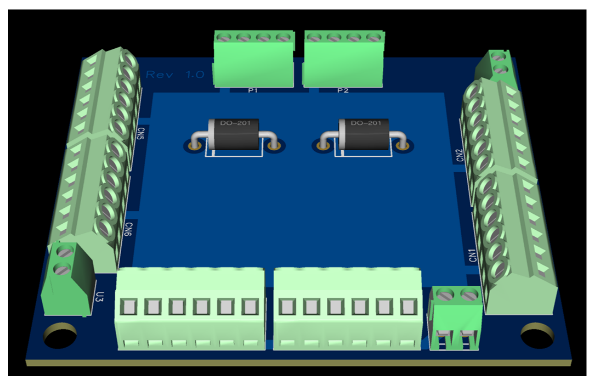


Figure 25: Junction Box PCB 3D model

Components and Functionality There are two channels in each Junction Box, with each having capacity for up to two latches being controlled in parallel, but a 2 wire button mechanism which is in an adjacent port to the right of each channel (Figure 27). This button simply short circuits the latch's power supply to the activation input on the R4 EM to open both latches simultaneously.

Of the four incoming signals from the DCU, two are 12V latch power supplies and are controlled by the DCU's logic which can prohibit their operation when the vehicle is locked. The other two wires are continuously operating and are chained in parallel via the normally disconnected red and blue copper planes in Figure 24 which form a connection if any of the latches are opened, due to the internal microswitch, which simply passes that 5V closed circuit signal straight back to the DCU where it can respond with an alarm or otherwise.

Electrical Design and Safety Features Daisy chaining the Junction Boxes is made possible by simply passing the input traces directly to an output. TVS diodes have been implemented on the main DCU connection input and daisy chaining output to establish some rudimentary protection against transient spikes but this does little for reverse polarity protection, which is especially necessary when plugs are used in consumer applications.

The PCB traces responsible for transmitting the 12V power in the Junction Box are set to a default width of 1.8mm, allowing a maximum current of approximately 2.9A, which is an undesirable value for daisy chaining applications and should be reconsidered in future applications. Whilst the heavy use of copper pours is a good idea for these applications it does not negate that bottleneck.

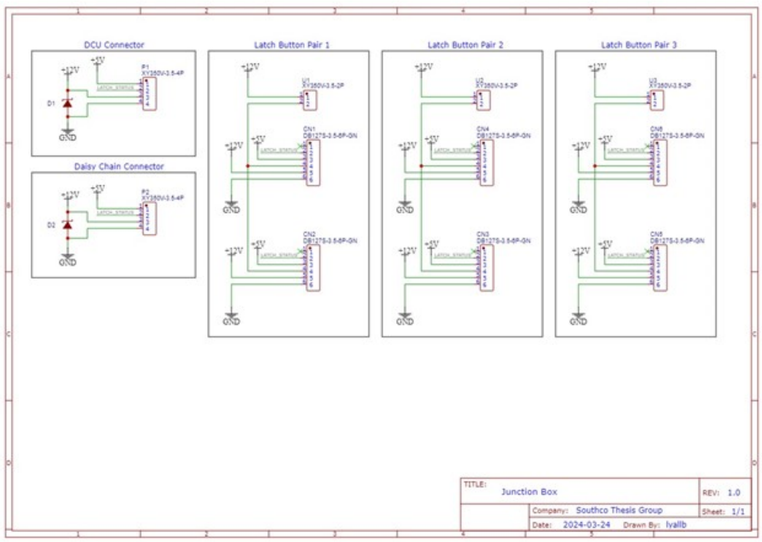


Figure 26: Junction Box PCB final prototype schematic

9.2.6 Junction Box Enclosure

Figure 27: Junction Box enclosure angled and frontal perspectives

As shown by Figure 28, the design of the Junction Box follow the exact same principles as the DCU enclosure and thus it is only necessary to identify the slight differentiations caused by the difference in the internally housed PCB:

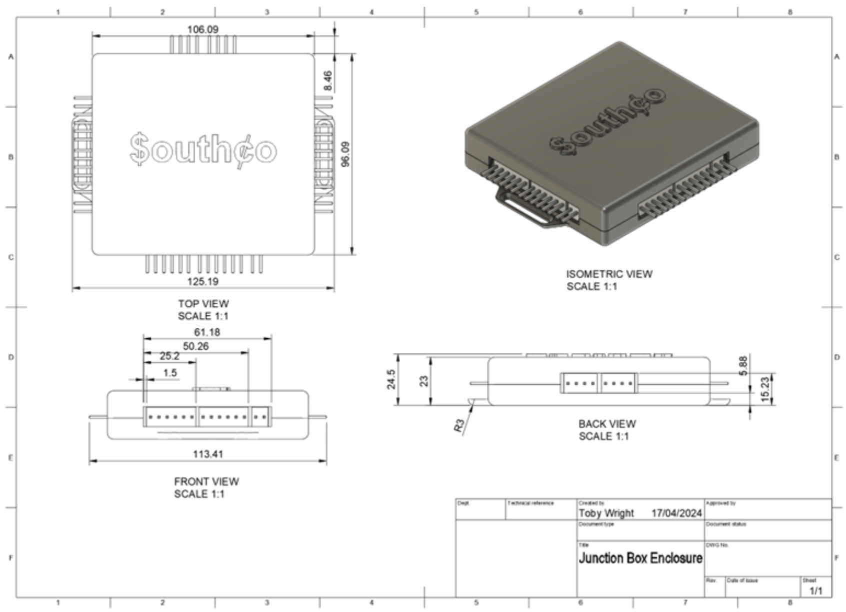


Figure 28: Junction Box engineering drawing

- The tabs which allow the Junction Box to be secured are covered by a connector which is inconvenient and should be revisited in future iterations (the tab itself is also comically small, and likely does not have the internal strength to support the compression from a fastener).
- The plug ports are on 4 sides to allow easier distinctions between the latch channels, but creates a slightly larger footprint than the DCU, which again, can be fixed in the same way the the DCU enclosure will be fixed.
- The design itself is vertically a lot smaller due to the low rise of the Junction Box PCB.

Upon reflection, the copy paste nature of this design seems a short sighted and whilst it has achieved the functional goals required of it at this stage of the project, it will be operating in a different location within the vehicle (in the service body) and will be subject to potentially different and harsher environmental conditions. These issues should be immediately addressed in the following iterations.

9.3 Testing and Validation

9.3.1 Enclosure Testing

When testing the final enclosure designs, there were no component fit discrepancies and all press fit components were secured soundly as planned. There was slight give between the lids and the bases of both the DCU and Junction Box due to printer error but this could easily be fixed in future using slower, refined settings or a better printer altogether. Furthermore, the final print used a 60% infill to increase structural integrity and was informally tested by applying a small bending force by hand to check for warping, snapping or delamination, of which none was observed.

9.3.2 Visual PCB Inspection

As soon as the boards arrived from China a thorough visual inspection of each PCB was conducted to identify any visible defects, such as misaligned components, soldering errors, or discrepancies in component placement and polarity. Of all 10 boards inspected there were no faults found bar some slight misalignment of screw terminals, and everything was presented as expected when compared against the PCB design.

9.3.3 Continuity Testing

Subsequently, electrical testing was performed to ensure the correct connections were made within the PCBs. Using the schematics as reference, continuity testing verified the absence of open or short circuits, while each pin on the connectors, particularly those critical for power delivery and signal integrity, was rigorously tested to confirm their proper electrical characteristics. This step was crucial in guaranteeing the reliable operation of the PCBs.

9.3.4 Basic Functionality Testing

The following tests aimed to validate the fundamental operations of the solution in isolation and under controlled conditions.

Functionality Tested	Method/Equipment	Result
DCU capable of handling 12V operating voltage and the inline fuse allows proper current flow.	12V power supply, multimeter, watching, smelling and listening for failure indications.	No indication of fault.
On-board voltage regulator produces stable 5V.	Oscilloscope.	Slight ripple observed less than 0.2mV which is expected with linear regulators but could be dampened with better supporting capacitance.
The microcontroller is fully accessible via the programming header.	SNAP Programmer used to load blank program.	Passed.
Status LED's are controllable via MCU.	LED blink program.	Both the SMD and radial status LEDs lit up and turned off as was programmed.
Both the relays could be activated via the MCU which energized an intermediate transistor.	Basic relay activation program, listening for audible clicking, multimeter used to check changes in continuity at relay output.	Auxiliary and latch control relays operated as expected.
Cables were correctly wired between the Junction Box and DCU.	Multimeter applied to Junction Box test points.	Voltage levels and polarities as expected.
A connected pushbutton could activate a pair of latches.	Pushbutton, Southco latch.	Passed.
A connected pushbutton could not activate other latches in other Junction Box channels.	Pushbutton, Southco latch.	Passed.
MCU could read latch status.	Basic program to switch LED on if any latch detected as open.	LED switched on as expected
Latch status circuit behaves in a logical AND manner.	Same program used as previous test with multiple latches.	Passed.
Daisy chaining.	Second junction box PCB wired to daisy chain output with repeats of previous junction box tests.	Unavailable due to time constraints, likely to pass.

Table 14: Basic function progressive testing

9.3.5 Power Consumption

This test suite was completed by using a benchtop power supply which displayed both the current and power readings on the digital display. The power supply was set to provide an upper limit of 5A. All the following tests in Table 15 are progressive and conditions should assumed to remain the same unless explicitly modified.

Functionality Tested	**Method/Equipment**	**Result**
Conditions	Maximum Current (A)	Maximum Power (W)
Microcontroller programs erased, no peripheral cables connected, LEDs low, relays unactivated.	0.000	0.000
Top status (radial) LED activated, bottom status (SMD) LED not activated.	0.010	0.120
Top status (radial) LED not activated, bottom status (SMD) LED activated.	0.016	0.192
Both status LEDs activated.	0.032	0.384
No status LEDs activated, latch relay coil activated.	0.077	0.912
Latch and auxiliary relay coils activated simultaneously.	0.157	1.872
All LEDs and relay coils activated.	0.185	2.254
Junction box connected without latches or buttons attached.	0.185	2.254
One latch attached to junction box with no activating button attached.	0.188	2.256
Activator button connected, not pressed.	0.188	2.256
Button pressed (during latch opening motion).	0.251	3.012
Button held down (after latch opening motion completed).	0.197	2.364
Button released, latch remains open.	0.185	2.220
Button pressed again (during latch opening motion when latch is already open)	0.248	2.976
Second latch connected to same pair, both latches closed, button unpressed.	0.187	2.244
Button pressed (during latch opening motion).	0.376	4.512
Button held down (after latch opening motion completed).	0.210	2.520
Latches connected to different channels, both closed, control buttons unpressed.	0.185	2.220

Table 15: Power consumption test results

9.3.6 System Integration Testing

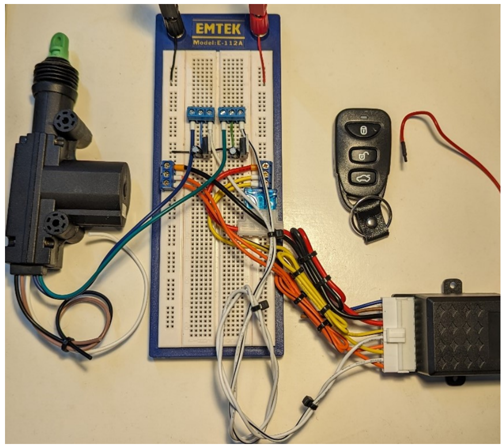


Figure 29: Integration testing bench layout

A simple test bed, depicted in Figure 30, was set up to simulate the behavior of a vehicle's central locking system. This setup allowed for comprehensive tests and validation of the high-level functional logic. The components used in this test rig are:

- A Master Car Lock Linear Actuator (Left): This actuator is also sold as a consumer vehicle accessory. It is designed to be installed and powered within the driver's side door panel, where this solution is intended to be placed, enhancing the realism as much as possible.
- Shared Power Supply with the DCU PCB (Top): This power supply is used in conjunction with the DCU PCB.
- Two Voltage Regulators (Center): These regulators condition the locking and unlocking signals, which have been spliced from the linear actuator down to 3V. This adjustment allows the signals to be reliably interpreted by the MCU.
- Keyless Entry Integration Kit with a Key Fob (Right): Connected to the linear actuator, this kit extends or retracts the locking state command based on inputs from the key fob.

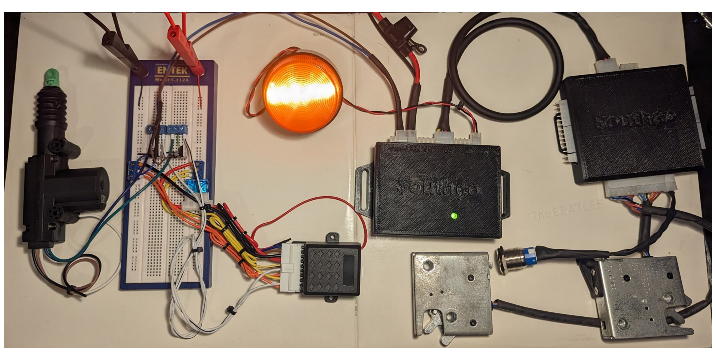


Figure 30: Integration testing bench layout

As shown in Figure 30, where the solution is fully integrated with the simulated Central Locking System (CLS), the desired behavior of the system was effectively validated. This is evidenced by the scenario depicted in the image, where the linear actuator is extended (CLS: locked) while the latches connected to the junction box are open. This scenario implies that the operator of the simulated vehicle has inadvertently left the service body compartments open, exposing them to potential theft. The DCU responds by alerting the operator through the flashing of the LED alarm and the illumination of the green status LED.

10 Conclusion

This thesis presents the design of a DCU unit capable of incorporating logic controls and supplying power under appropriate conditions. A prototype has been created and assembled; the solution has been tested and achieves what is expected by the client. Currently, the proposed device is located in the driver's side door. With its compact structure, the device will not obstruct the user and will maintain the vehicle's aesthetics. It is also conveniently situated in the door to access pre-existing power rails running through the car door and signals required for standard operation. Further wiring from the DCU can be run along the internal frame of the vehicle and traced to the latches via the cabin bed or the door frames, consistent with current electronic accessory installation methods. The latches should be attached at the rear of the service body door frames in the appropriate area. The installation of the device is assumed to be performed by a mechanic familiar with the vehicle model, given the large variety of vehicles and the unique complexities associated with each.

The prototype takes input signals from the handbrake and central locking system, logically processing these signals. In the case where the handbrake is engaged and the central locking system is disengaged, the DCU will enable power to the latches. This power is drawn from the car battery with an assumed 12V input, from splicing into a power rail within the vehicle's driver side door. The DCU is powered from the same rail but is regulated to an operational voltage of 5V via voltage regulators for proper functioning of the DCU. When all conditions are met, the 12V input will be directed into the Junction Box, functioning as a simple circuit. The Junction Box distributes power among each output channel to an associated latch when the requisite conditions are satisfied.

An intermediary button accessible to the driver is situated between the latch and the Junction Box, ensuring controlled opening of each latch. When the button is pressed, only the latch connected to the button will receive the required power to unlock. This is done to ensure that only the desired door is opened at any time, while providing full control to the operator in terms of which doors open.

This design effectively balances functionality and user-friendliness, ensuring a seamless integration into the vehicle's existing framework. Overall, the DCU system offers a robust and efficient solution for enhancing vehicle security and operational convenience.

10.1 Recommendations

The current state of the project makes several assumptions regarding the functionality and universality of the developed systems. To further enhance the solution and ensure its wide-scale applicability, the following recommendations are proposed:

Before production, it is recommended to conduct a comprehensive investigation into the integration of the DCU with locking systems of various vehicle types. This investigation should assess compatibility and identify any necessary modifications or adaptations required for seamless integration across different vehicle models. The DCU should be designed to interface with various central locking system architectures, including those that use negative or positive triggers, variable voltage levels, and different communication protocols. With thorough testing and analysis, the DCU can be easily modified to accommodate variations in vehicle systems. Suggested developments include modular interface components, programmable firmware, and adaptive circuitry capable of detecting and responding to different locking system configurations.

System performance and durability testing are also recommended. To properly understand the capabilities and functionalities of the prototype, rigorous real-world testing should be conducted. By integrating the DCU ecosystem into currently utilized service body vehicles such as the Mitsubishi Canter or Isuzu NPR, performance data can be obtained. This data can be further analyzed to identify potential issues or areas for improvement.

A potential development that can improve the design is the inclusion of a resettable fuse. This fuse should be integrated directly onto the DCU PCB to create a more compact product with reduced wiring complexity and fewer points of failure. By having the fuse situated on the DCU PCB, maintenance can be completed much faster, thereby streamlining the system and improving aesthetics.

Another suggested safety feature is the inclusion of manual override buttons on the exterior of the Junction Box, as demonstrated in Southco's box in Appendix 9 located on the right-hand side. These buttons allow authorized personnel to manually control the latch mechanism in case of malfunctions or emergencies. The buttons should be clearly labeled and protected from accidental activation. They should also be easily accessible for maintenance and troubleshooting purposes.

Currently, the prototype has the estimated capability of supplying power to 6 latches with further expansions also possible. The proposed design allows for daisy chaining multiple latches, with an estimation of supporting up to 20 latches. It should be noted that expansions of more than 6 latches, although possible, require PCBs designed to withstand more than 3A of current. The proposed PCB design can still be replicated for daisy chaining; however, the PCB copper traces must have a larger width and/or thickness. Consequently, the PCB and casing will need to increase in size. More appropriately rated copper wires to connect the DCU to the Junction Box may also be required in this case.

By implementing these recommendations, the DCU solution can be further refined, optimized, and validated, ensuring its suitability for a wide range of vehicles and market demands. Continuous improvement and iteration based on these recommendations will contribute to the development of a robust, reliable, and user-friendly door control unit system.

References

[1] Infineon Technologies AG. (2022) Power distribution box in automotive applications. Accessed: 2023-11-18. [Online]. Available: https://www.infineon.com/cms/en/applications/automotive/body-electronics-and-lighting/power-distribution-box/#interactivegraphic-9836578b-09a7-11ed-8606-005056945905/overview

[2] *R4-EM Electronic Rotary Latch*, Southco, accessed: 2023-03-15. [Online]. Available: https://files.southco.com/static/Literature/r4-em-all2.en.pdf

[3] "Mplab® xpress pic16f18345 evaluation board," https://www.microchip.com/en-us/development-tool/dm164141, Accessed 2024, accessed: 2024-04-10.

[4] "Car battery types," accessed: 2023-03-15. [Online]. Available: https://www.repairsmith.com/blog/car-battery-types/

[5] "How many amps is a car battery," accessed: 2023-03-15. [Online]. Available: https://www.batteryequivalents.com/how-many-amps-is-a-car-battery-car-battery-amps.html

[6] "Car battery amps," accessed: 2023-03-15. [Online]. Available: https://www.electronicshub.org/car-battery-amps/

[7] "Century hi-performance 4wd battery n70zzl mf," accessed: 2023-03-15. [Online]. Available: https://www.supercheapauto.com.au/p/century-century-hi-performance-4wd-battery-n70zzl-mf/602498.html

[8] "Decentralized vs centralized automotive architectures - rewire demo," https://www.rewire-he.eu/decentralized-vs-centralized-automotive-architectures-rewire-demo, 2023, accessed: 2023-11-18.

[9] "Choosing between centralized and distributed control system designs," https://www.controleng.com/articles/choosing-between-centralized-and-distributed-control-system-designs, 2023, accessed: 2023-11-18.

[10] "Distributed vs centralized controls for mobile vehicles," https://www.crossco.com/resources/articles/distributed-vs-centralized-controls-for-mobile-vehicles/, 2023, accessed: 2023-11-18.

[11] Automotive Training Centre. (2023) Thinking of automotive school? here's how power door locks work. Accessed: Nov. 18, 2023. [Online]. Available: https://www.autotrainingcentre.com/blog/thinking-automotive-school-heres-power-door-locks-work/

[12] The12Volt, "Relay diagrams," https://www.the12volt.com/relays/relaydiagrams.html, 2023, accessed: Nov. 18, 2023.

[13] A. Attridge, D. Walton, and G. Kalsi, "Developments in car door latching systems," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 216, no. 10, pp. 819–830, 2002.

[14] T. Glocker, T. Mantere, and M. Elmusrati, "A protocol for a secure remote keyless entry system applicable in vehicles using symmetric-key cryptography," in *2017 8th International Conference on Information and Communication Systems (ICICS)*. Irbid, Jordan: IEEE, 2017, pp. 310–315.

[15] "Hall effect sensors guide," https://au.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/hall-effect-sensors-guide, Accessed 2023, accessed: 2023-11-18.

[16] "Kl550 installation instructions," https://static.summitracing.com/global/images/

instructions/hfm-kl550.pdf, Accessed 2023, accessed: 2023-11-18.

[17] "Aec-q100 qualified products," https://www.renesas.com/us/en/products/automotive-products/aec-q100, accessed: 2023-11-18.

[18] "Arduino Nano," https://store.arduino.cc/products/arduino-nano, accessed: 2023-11-18.

[19] Microchip Technology Inc., *PIC32MX Datasheet*, 2023. [Online]. Available: https://ww1.microchip.com/downloads/en/DeviceDoc/PIC32MX_Datasheet_v2_61143B.pdf

[20] STMicroelectronics, *STM32F411CE Datasheet*, 2023. [Online]. Available: https://www.st.com/resource/en/datasheet/stm32f411ce.pdf

[21] Espressif Systems, *ESP32 Datasheet*, 2023. [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf

[22] Microchip Technology, "Pic16f630-i/sl datasheet," 2023, accessed: Nov. 18, 2023. [Online]. Available: https://au.element14.com/microchip/pic16f630-i-sl/mcu-8bit-pic16-20mhz-soic-14/dp/9760466

[23] Concept Latch, "R4-em electronic latches," 2018, accessed: Nov. 18, 2023. [Online]. Available: https://www.conceptlatch.com.au/cl-site-content/uploads/2018/10/R4-EM-Electronic-Latches-1.pdf

[24] Australian Automotive Aftermarket Association, "The truth about vehicle modifications," 2018, accessed: Nov. 18, 2023. [Online]. Available: https://www.aaaa.com.au/wp-content/uploads/2018/11/The-Truth-About-Vehicle-Modifications-Web-Version-Updated.pdf

[25] Australian Competition and Consumer Commission, "Motor vehicle sales and repairs: An industry guide to the australian consumer law," 2022, accessed: Nov. 18, 2023. [Online]. Available: https://www.accc.gov.au/system/files/1449_ACL%20Motor%20vehicle%20sales%20and%20repairs_FA_WEB.pdf

[26] "Ea-r02: Wireless keyfob kit," https://southco.com/en_au_int/ea-r02, Accessed 2024, accessed: 2024-04-10.

[27] Microchip Technology Inc., *PICkit 3 Programmer/Debugger User's Guide*, 2010, document Number: 51795B. [Online]. Available: https://ww1.microchip.com/downloads/en/DeviceDoc/51795B.pdf

[28] "Mplab snap in-circuit debugger," https://www.microchip.com/en-us/development-tool/pg164100, Accessed 2024, accessed: 2024-04-10.

[29] "Pic16f18324 microcontroller," https://www.microchip.com/en-us/product/pic16f18324, Accessed 2024, accessed: 2024-04-10.

[30] *IPC-2221B: Generic Standard on Printed Board Design*, Revision b ed., Association Connecting Electronics Industries, 2012, provides guidelines for the design of printed boards and their manufacturing and assembly processes. [Online]. Available: https://www.ipc.org/TOC/IPC-2221.pdf

[31] STMicroelectronics, "Datasheet - l78 - positive voltage regulator ics," https://au.mouser.com/datasheet/2/389/l78-1849632.pdf, 09 2018, accessed: 2024-02-27.

[32] "Jlc pcb," https://jlcpcb.com/, Accessed 2024, accessed: 2024-04-10.

[33] Mongoose Australia, "Mcl3000 remote keyless entry kit," https://www.mongoose.com.au/mcl3000-remote-keyless-entry-kit, n.d., accessed: April 17, 2024.

A Secondary Team Roles

Role	Responsibilities	Assignee
External DCU Team All engineering related to functionality outside of the core DCU device		
Team Manager	- Manage team progress - Liaise with the Internal DCU Team Manager to ensure alignment and resolve any conflicts or overlaps in project responsibilities	Toby Wright
CAD & Documentation Engineer	- Create and maintain CAD model(s) of the external components within the scope of the external DCU team - Collate electrical schematics from other engineers components - Review other team members submitted designs (button housing, status LEDs) for aesthetics	Martin Deng
Manufacturing Engineer	- In charge of sourcing components, creating prototype designs of all sub-assemblies being designed by the external DCU team - Reviewing designs for manufacturability	Yiqun (Peter) Li
Validation Engineers (2)	- Design and perform an extensive test suite to ensure that the prototypes meet the requirements set out in the document for power consumption, OBD integration and central locking state detection. - Gather data on performance and review with relevant designer where marked improvement could be made	Udish Davda, Aryan Jain
Internal DCU Team Development of the core DCU device, housing and internal electronics		
Team Manager	- Manage team progress - Liaise with the External DCU Team Manager to ensure alignment and resolve any conflicts or overlaps in project responsibilities	Lyall Beveridge
CAD & Documentation Engineer	- Create and maintain a singular CAD model of the core DCU housing, integrating other team members component designs - Collate and review electrical schematics - Maintain the BOM for the core DCU device	Jiahuan (Harvey) Zhang
Embedded Systems Engineer	- Manage the creation, integration of embedded systems software where necessary - Ensure that any proposed electrical signals being passed to or received from the designed components of team members meet the requirements of the microcontroller (i.e. signal voltage, TX/RX protocols)	Haoran (Charlie) Wen
Manufacturing Engineer	- In charge of sourcing components, creating prototypes of the core DCU product being designed by the internal DCU team - Review designs for manufacturability	Haoze (Jose) Zhang
Validation Engineer	- Design and perform an extensive test suite to ensure the scope goals of security and reliability are met - Design an experimental setup which can allow the simulation of incoming signals to test the logic of the embedded systems/circuits - Gather data on performance and review with relevant designer where marked improvement could be made	Ethan Athos

Table 16: Secondary role descriptions

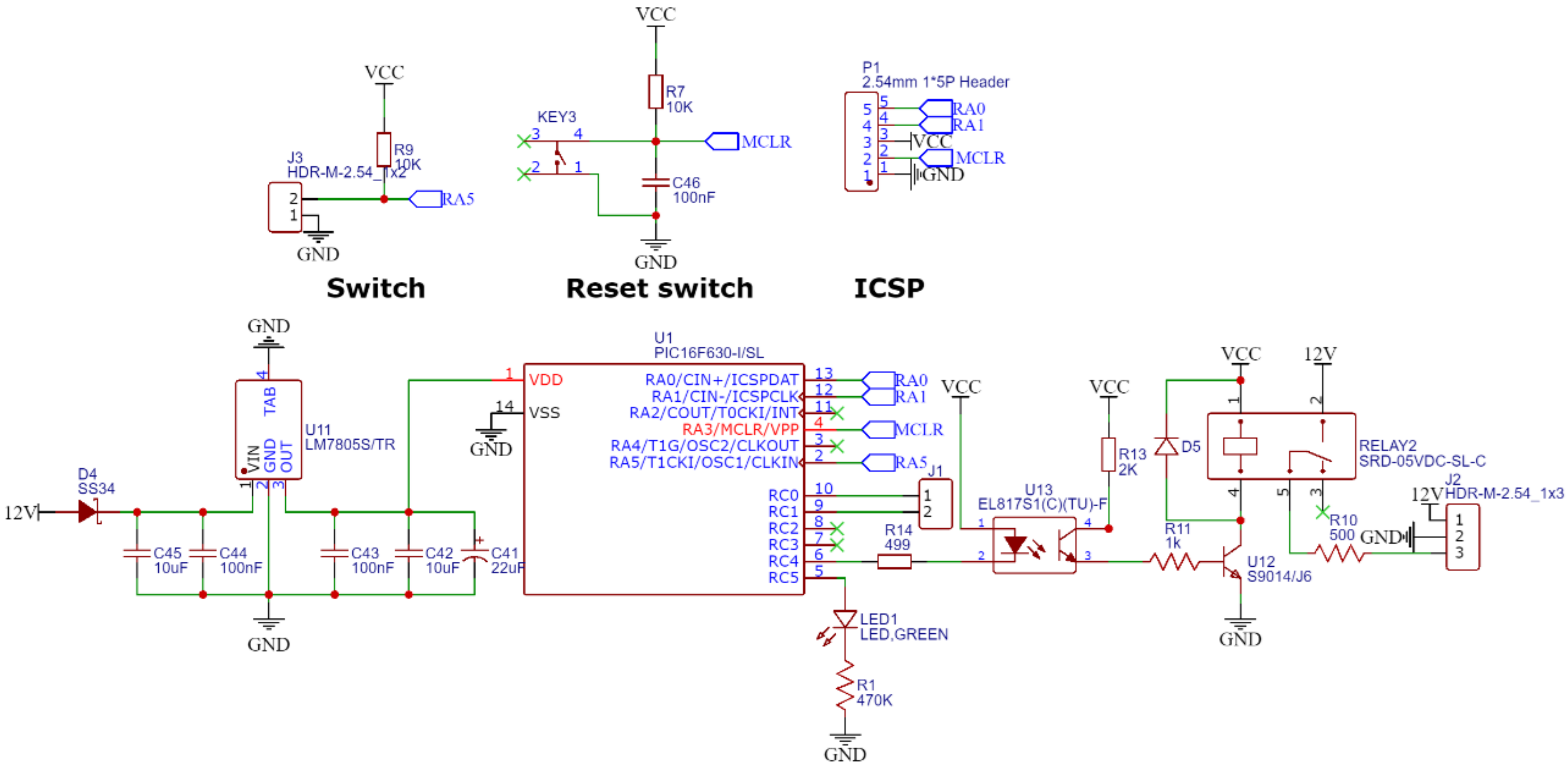
B Budget

UNSW Southco Thesis Project Budget								
Resource	**Description**	**Category/Phase**	**Manufacturer**	**Mfg. P/N**	**Actual Unit Cost**	**Qty**	**Actual Total Cost**	**Supplier**
Economical Diode Pack	Diodes	Breadboard Development	-	ZR1005	$ 10.95	1	$ 10.95	Jaycar
5V relay breakout board	5V relay breakout board	Breadboard Development	-	XC4440	$ 14.95	1	$ 14.95	Jaycar
CABLE HU RND H/D 7.5A TINNED 10M RL RED	Hookup wire 18AWG	Breadboard Development	-	WH3045	$ 6.50	1	$ 6.50	Jaycar
2.1mm DC Socket with Screw Terminals	Power jack connector	Breadboard Development	-	PA3713	$ 7.95	1	$ 7.95	Jaycar
Solderless Breadboard with Power and I/O Breakout Bo:	Breadboard and 12V regulator	Breadboard Development	-	PB8819	$ 29.95	1	$ 29.95	Jaycar
MAINS ADPT SMPS 3-12V 18W 7PLG+USB	12V power supply	Breadboard Development	-	MP3314	$ 39.95	1	$ 39.95	Jaycar
MODULE LED PUSHBUTTON ARDUINO GRN	12V LED pushbutton	Breadboard Development	-	XC3722	$ 9.95	1	$ 9.95	Jaycar
Red Quick Splice Connector 22-18AWG Pack of 6	Automotive Crimp	Breadboard Development	-	PT4537	$ 3.25	1	$ 3.25	Jaycar
BOARD DEV ESP32 WIFI B/T ARDUINO COMP	Development board	Breadboard Development	-	XC3800	$ 49.95	1	$ 49.95	Jaycar
MPLAB Snap Debugger	Programmer	Microchip Components	Microchip	PG164100-ND	$ 65.28	1	$ 65.28	Digikey
PIC16F630	Microcontroller	Microchip Components	Microchip	PIC16F630-E/P	$ 3.33	3	$ 9.99	Digikey
PIC16F18324	Microcontroller	Microchip Components	Microchip	PIC16F18324-I/P	$ 2.37	3	$ 7.11	Digikey
IC REG LINEAR 5V 400MA TO220-3	5V regulator	Microchip Components	Microchip	MIC2920A-5.0WT	$ 6.04	2	$ 12.08	Digikey
MPLAB XPRESS PIC16F18345 EVAL BD	Development board	Microchip Components	Microchip	DM164141	$ 31.56	1	$ 31.56	Digikey
4N25/4N28 Phototransistor Optocoupler	Optocoupler	Experimental Components	QT Optoelectronics	4N25/4N28	$ 2.45	1	$ 2.45	Jaycar
6N138 Opto Coupler IC	Optocoupler	Experimental Components	Isocom	6N138	$ 3.95	2	$ 7.90	Jaycar
RELAY GEN PURPOSE SPST 20A 5V	Relay	Experimental Components	CIT Relay and Switch	L114FL1AS5VDC.60D	$ 6.34	1	$ 6.34	Digikey
RELAY GEN PURPOSE SPDT 16A 3V	Relay	Experimental Components	Omron	G5RLU-1-E DC3	$ 7.33	1	$ 7.33	Digikey
SSR RELAY SPST-NO 9A 0-60V	Solid State Relay	Experimental Components	IXYS	CPC1709J	$ 12.64	1	$ 12.64	Digikey
Southco DCU PCB	PCB	Prototype Development	-	SMT02403241662526	$ 39.09	5	$ 195.45	JLCPCB
Southco Junction Box PCB	PCB	Prototype Development	-	SMT02403241662816	$ 16.00	5	$ 80.00	JLCPCB
JLCPCB Shipping Fee	Shipping	Prototype Development	-		$ 78.42	1	$ 78.42	JLCPCB
FILAMENT HYPER-PLA BLK 1.75MM 1KG RL	PLA 3D printing filament	Prototype Development	Creality	TL4791	$ 39.95	1	$ 39.95	Jaycar
FUSE HOLDER BLADE 125V 15A PCB	Blade fuse holder	Prototype Development	Littelfuse Inc	04820001ZXB	$ 4.67	1	$ 4.67	Digikey
5A Orange Mini Blade Fuse	Blade Fuse	Prototype Development	-	SZ2043	$ 1.90	3	$ 5.70	Jaycar
30A 32VDC Water Resistant Inline Mini Blade Fuse	Inline Blade Fuse Holder	Prototype Development	-	SF5072	$ 0.50	1	$ 0.50	Jaycar
6 Pin 0.156in Straight Locking Header	6 Pin Cable Lock	Prototype Development	-	HM3446	$ 0.95	15	$ 14.25	Jaycar
4 Pin 0.156in Straight Locking Header	4 Pin Cable Lock	Prototype Development	-	HM3444	$ 0.80	15	$ 12.00	Jaycar
2 Pin 0.156in Straight Locking Header	2 Pin Cable Lock	Prototype Development	-	HM3442	$ 0.55	15	$ 8.25	Jaycar
4 Pin 0.156in Header with crimp pins - 3.96mm	4 Pin Plug	Prototype Development	-	HM3434	$ 0.80	4	$ 3.20	Jaycar
2 Pin 0.156in Header with crimp pins - 3.96mm	2 Pin Plug	Prototype Development	-	HM3432	$ 0.55	7	$ 3.85	Jaycar
6 Pin 0.156in Header with crimp pins - 3.96mm	6 Pin Plug	Demonstration	-	HM3436	$ 1.75	4	$ 7.00	Jaycar
Linear locking actuator	Linear locking actuator	Demonstration	Response	LR8815	$ 22.95	1	$ 22.95	Jaycar
Car Remote Keyless Entry System	Keyless Entry Kit	Demonstration	-	401/T102 #G	$ 20.59	1	$ 20.59	Ebay
Total Budgeted Cost							**$ 810.56**	

C Bill of Materials

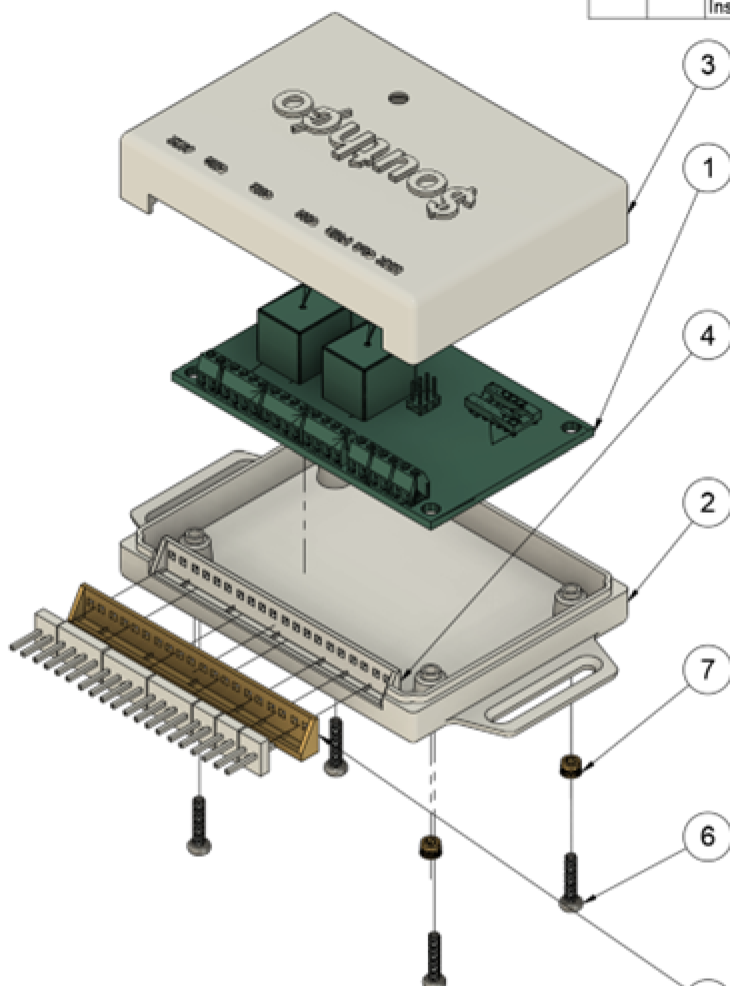
Part Name	Description/Purpose	Parent Component	Qty	Unit Price	Total Price	P/N	Manufacturer
DB127S-3.5-6P-GN	Screw Terminal	Junction Box PCB	6	$ 1.97	$ 11.84	DB127S-3.5-6P-GN	DIBO(地博电气)
1.5KE18A_C132974	Flyback Diode	Junction Box PCB	2	$ 1.11	$ 2.23	1.5KE18A	ST(意法半导体)
XY350V-3.5-4P	Screw Terminal	Junction Box PCB	2	$ 0.59	$ 1.19	XY350V-3.5-4P	XINLAIYA(新莱亚)
XY350V-3.5-2P	Screw Terminal	Junction Box PCB	3	$ 0.29	$ 0.87	XY350V-3.5-2P	XINLAIYA(新莱亚)
Header-Male-2.54_2x3	Programming Header	DCU PCB	1	$ 0.05	$ 0.05	2.54-2*3P针	BOOMELE(博穆精密)
333-2SYGD/S530-E2	Radial LED	DCU PCB	1	$ 0.05	$ 0.05	333-2SYGD/S530-E2	EVERLIGHT(亿光)
XY350V-3.5-4P	4 Pin Screw Terminal	DCU PCB	3	$ 0.38	$ 1.14	XY350V-3.5-4P	XINLAIYA(新莱亚)
SRD-05VDC-SL-C	Relay	DCU PCB	2	$ 0.52	$ 1.04	SRD-05VDC-SL-C	松乐
IC254V-12-14-0743	DIP Socket	DCU PCB	1	$ 0.46	$ 0.46	IC254V-12-14-0743	XFCN(兴飞)
150Ω	Resistor	DCU PCB	1	$ 0.01	$ 0.01	CR1/2W-150Ω±5%-XT52	VO(翔胜)
XY350V-3.5-2P	2 Pin Screw Terminal	DCU PCB	4	$ 0.19	$ 0.74	XY350V-3.5-2P	XINLAIYA(新莱亚)
SMAJ16A_C908770	TVS Diode	DCU PCB	1	$ 0.05	$ 0.05	SMAJ16A	GOODWORK(固得沃克)
SMAJ5.0A_C2925443	TVS Diode	DCU PCB	3	$ 0.04	$ 0.13	SMAJ5.0A	Liown(里阳半导体)
100nF	Capacitor	DCU PCB	2	$ 0.02	$ 0.03	TCC0805X7R104K101DT	CCTC(三环)
SZYY0603YG	SMD LED	DCU PCB	1	$ 0.02	$ 0.02	SZYY0603YG	yongyu(永裕光电)
10kΩ	Resistor	DCU PCB	2	$ 0.01	$ 0.02	ERJ3GEYJ103V	PANASONIC(松下)
100Ω	Resistor	DCU PCB	1	$ 0.12	$ 0.12	ERA6AEB101V	PANASONIC(松下)
220Ω	Resistor	DCU PCB	1	$ 0.01	$ 0.01	ERJ2GEJ221X	PANASONIC(松下)
470nF	Capacitor	DCU PCB	1	$ 0.01	$ 0.01	TCC0805X7R474M500DT	CCTC(三环)
S8050-J3Y	Transistor	DCU PCB	2	$ 0.01	$ 0.02	S8050-J3Y	MDD
330Ω	Resistor	DCU PCB	2	$ 0.13	$ 0.26	ERA6AEB331V	PANASONIC(松下)
L7805ABD2T-TR	Voltage Regulator	DCU PCB	1	$ 0.68	$ 0.68	L7805ABD2T-TR	ST(意法半导体)
1N4007_C2892673	Diode	DCU PCB	2	$ 0.01	$ 0.02	1N4007	YONGYUTAI(永裕泰)
25A Tinned DC Power Cable	Cabling	CLS Signal Cable	2	$ 0.93	$ 1.86	WH3087	Jaycar
2 Pin 0.156in Header with crimp pins - 3.96mm	2 Pin Plug	CLS Signal Cable	1	$ 0.55	$ 0.55	HM3442	Jaycar
30A 32VDC Water Resistant Inline Mini Blade Fuse	Inline Blade Fuse Holder	Power Supply Cable	1	$ 0.50	$ 0.50	SZ2043	Jaycar
5A Orange Mini Blade Fuse	Blade Fuse	Power Supply Cable	1	$ 1.90	$ 1.90	SF5072	Jaycar
25A Tinned DC Power Cable	Cabling	Power Supply Cable	1	$ 0.93	$ 0.93	WH3087	Jaycar
2 Pin 0.156in Header with crimp pins - 3.96mm	2 Pin Plug	Power Supply Cable	1	$ 0.55	$ 0.55	HM3442	Jaycar
CABLE SPKR 4CORE RND FLEX 100M RLGTH	4 Wire Alarm Cable	DCU-Junction Box Cable	1	$ 3.00	$ 3.00	WB1762	Jaycar
4 Pin 0.156in Header with crimp pins - 3.96mm	4 Pin Plug	DCU-Junction Box Cable	2	$ 1.45	$ 2.90	HM3434	Jaycar
100g 3D printed part	Enclosure Lid	DCU Enclosure	1	$ 4.50	$ 4.50	-	Creality
100g 3D printed part	Enclosure Base	DCU Enclosure	1	$ 4.50	$ 4.50	-	Creality
M3 x 10mm Steel Screw	M3 Screw	DCU Enclosure	4	$ 0.35	$ 1.40	HP0403	Jaycar
Brass Heat-Set Inserts for Plastic - M3 x 4mm	M3 Heat Set Insert	DCU Enclosure	4	$ 0.19	$ 0.74	4255	Adafruit
4 Pin 0.156in Straight Locking Header	4 Pin Cable Lock	DCU Enclosure	3	$ 0.80	$ 2.40	HM3444	Jaycar
2 Pin 0.156in Straight Locking Header	2 Pin Cable Lock	DCU Enclosure	4	$ 0.55	$ 2.20	HM3442	Jaycar
100g 3D printed part	Enclosure Lid	Junction Box Enclosure	1	$ 4.50	$ 4.50	-	Creality
100g 3D printed part	Enclosure Base	Junction Box Enclosure	1	$ 4.50	$ 4.50	-	Creality
M3 x 10mm Steel Screw	M3 Screw	Junction Box Enclosure	4	$ 0.35	$ 1.40	HP0403	Jaycar
Brass Heat-Set Inserts for Plastic - M3 x 4mm	M3 Heat Set Insert	Junction Box Enclosure	4	$ 0.19	$ 0.74	4255	Adafruit
6 Pin 0.156in Straight Locking Header	6 Pin Cable Lock	Junction Box Enclosure	6	$ 0.95	$ 5.70	HM3446	Jaycar
4 Pin 0.156in Straight Locking Header	4 Pin Cable Lock	Junction Box Enclosure	2	$ 0.80	$ 1.60	HM3444	Jaycar
2 Pin 0.156in Straight Locking Header	2 Pin Cable Lock	Junction Box Enclosure	3	$ 0.55	$ 1.65	HM3442	Jaycar
Total Budgeted Cost					**$ 44.55**		

D Initial DCU PCB Schematic



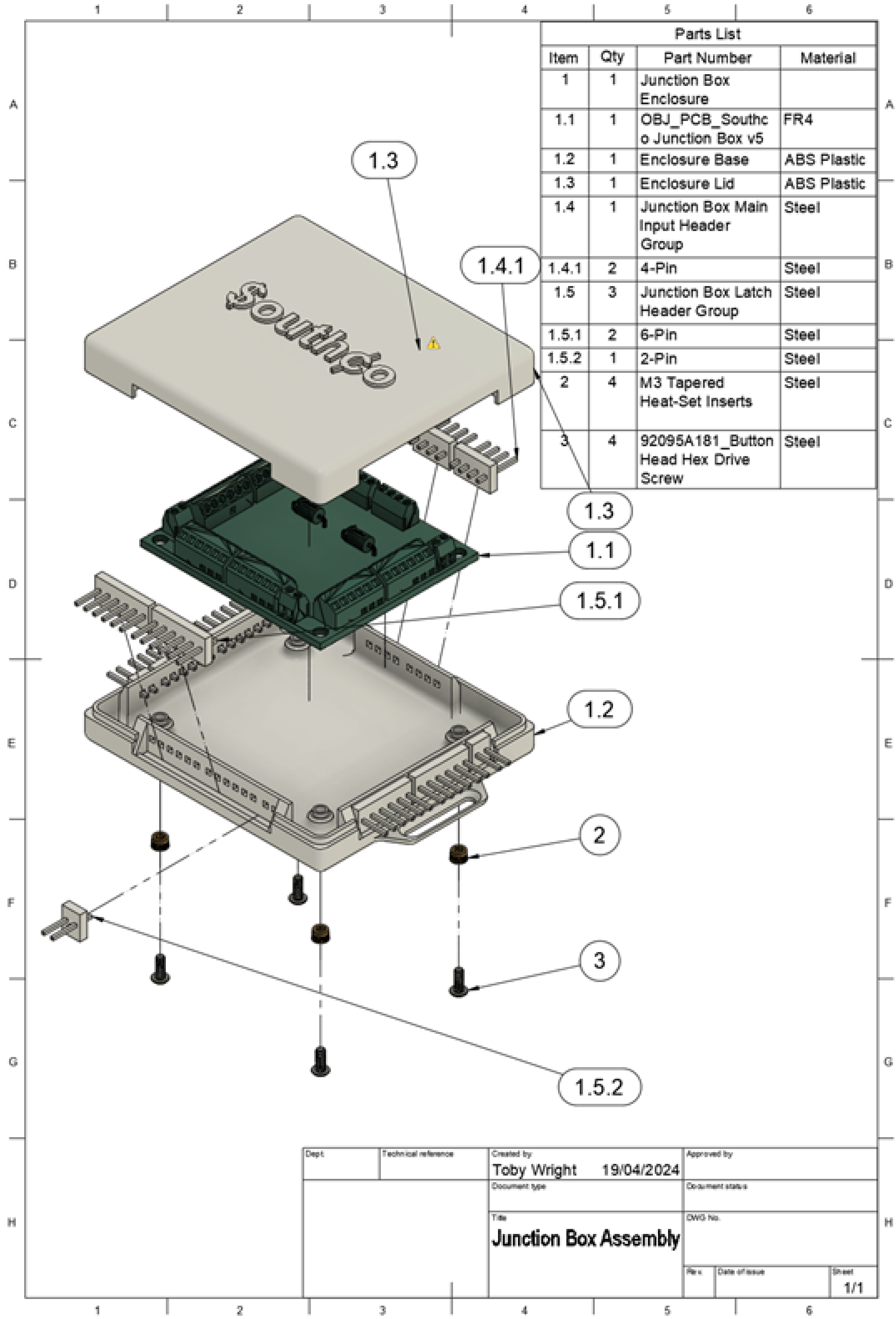
E DCU Enclosure Exploded View

Parts List			
Item	Qty	Part Number	Material
1	1	OBJ_Door Control Unit PCB	FR4
2	1	Enclosure Base	ABS Plastic
3	1	Enclosure Lid	ABS Plastic
4	1	DCU Header Test Fit	
5	1	DCU Header Test Fit v6	Brass
6	4	M3 Screw	Steel
7	4	Tapered Heat-Set Inserts	Brass



Dept.	Technical reference	Created by	Approved by
		Toby Wright 19/04/2024	
		Document type	Document status
		Title: DCU Enclosure	DWG No.
			Rev. / Date of issue / Sheet: 1/1

F Junction Box Enclosure Exploded View



Item	Qty	Part Number	Material
1	1	Junction Box Enclosure	
1.1	1	OBJ_PCB_Southco Junction Box v5	FR4
1.2	1	Enclosure Base	ABS Plastic
1.3	1	Enclosure Lid	ABS Plastic
1.4	1	Junction Box Main Input Header Group	Steel
1.4.1	2	4-Pin	Steel
1.5	3	Junction Box Latch Header Group	Steel
1.5.1	2	6-Pin	Steel
1.5.2	1	2-Pin	Steel
2	4	M3 Tapered Heat-Set Inserts	Steel
3	4	92095A181_Button Head Hex Drive Screw	Steel