Research Article

An Innovative Lift Control Board Design and Prototype Production Using CANbus Communication System and STM32 Microcontroller

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Abstract

In this study, Önder Group Inc. Design Center, with an innovative approach, designed controllers for the first time, and prototypes were produced for a wide range of goods lifts according to different needs. With the innovative board design, goods lift users can choose parameters such as the number of floors, door types, and lock types from a user-friendly menu to suit their needs. Within the scope of the study, all functions that may be needed were identified, and the hardware structure of the system was determined. By simply changing the defined parameters, the desired goods lift controller can be made ready in a very short time. Time savings were achieved by simply expanding the hardware structure with the design of the CANbus communication system according to the number of floors and stops of the elevators. Thus, a wide range of lifts can be used by simply increasing the number of floor announcer boards and selecting the menu. Additionally, thanks to the designed Wi-Fi plug-in software, operators will be able to monitor the malfunction and operating status of the lift. With this plug-in, technical service teams can intervene immediately in case of malfunction.

Keywords: *Goods Lift, CANbus, Control Board, STM32, Wi-Fi Plug-in*

1. Introduction

Goods lifts are essential machines used to raise heavy products to a certain level in warehouses, parking lots, small and medium-sized businesses, hangars, etc. Although the first use of goods lifts was in the 1850s, their functionality has gradually increased in recent years with the development of PLC (Programmable Logic Controller) and automatic control systems [1]. Controllers, which enable the automatic system to operate without human intervention, are an element of the closed-loop system that processes information to perform decision-making [2-5].

PLCs play a vital role in the rapid development of industrial automation systems. However, a single circuit and PLC program type cannot be used for elevators with different floor numbers, doors, and lock types. Control types are very diverse according to usage needs; separate hardware and software are required for each type of machine controlled by traditional automatic control or PLC management systems. This form of control is more expensive than embedded system controls, and labor costs are high.

PCB (Printed Circuit Board) technology offers an alternative, low-cost approach for producing various electrical-electronic devices [6-8]. For this reason, PCB board design has been carried out, and control of the goods lift has begun to be provided with embedded systems. In these goods lifts, communication between floors is provided by CANbus (Controller Area Network) communication protocol. The fact that all units connected to the line can obtain information through a single transmission line has made CANbus compatible with Industry 4.0, increasing its use in the industry [9-11]. Many industrial manufacturers in Turkey and worldwide prefer embedded systems controllers for freight elevators.

In this study, as a result of the innovative engineering activities within the Önder Group Inc. Design Center, a new generation controller that can be used in a wide range of goods lifts has been developed and designed, and a prototype has been produced. Thus, it aims to eliminate the deficiencies in using these controllers in the industry.

2. Materials and Methods

In the study, the embedded system controller designed for various freight elevators consists of four different PCB cards connected to each other via the CANbus communication system. The connection between the cards is given in Figure 1.

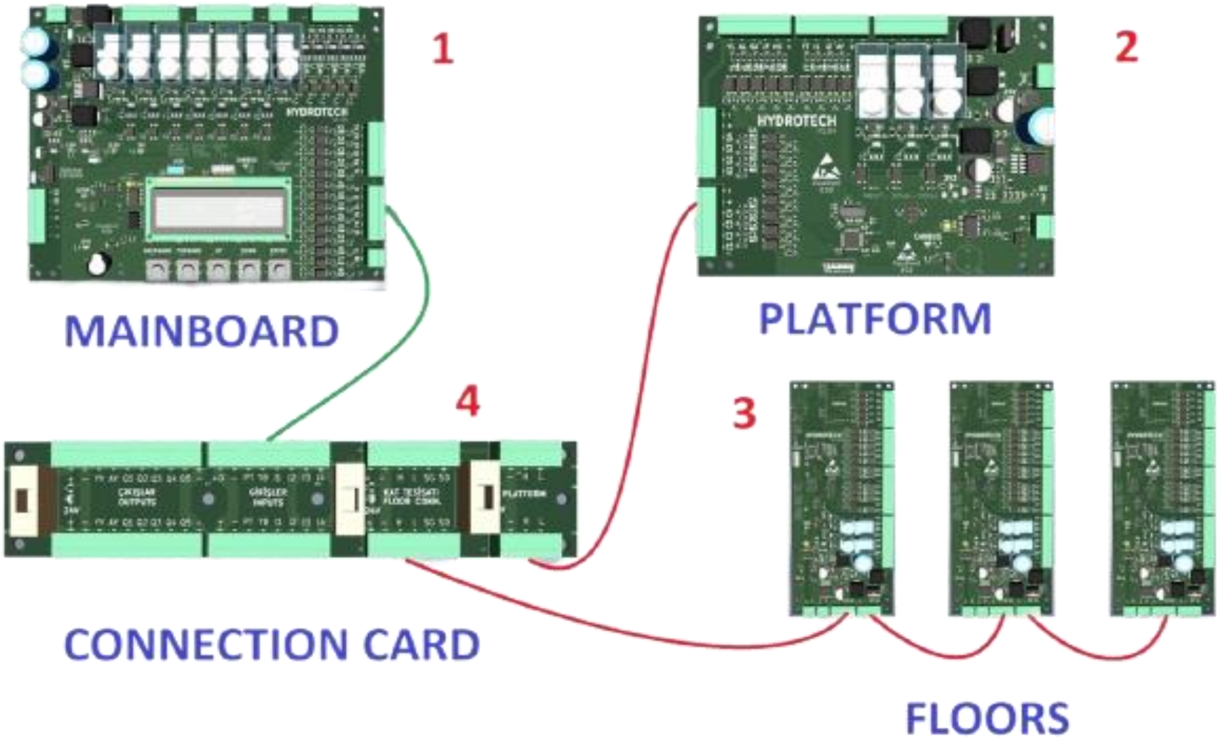

Figure 1: Connection Diagram Between PCB Boards

2.1. Boards That Make Up the System

2.1.1. Mainboard

The mainboard acts as the decision-maker for the entire system and processes the information from the boards by communicating with other boards via the CANbus communication protocol. It also determines the system's operation according to the parameter setting made by the operator from the menu. This parameter setting is made on the LCD consisting of 2 lines and 16 columns (2x16) on the mainboard. Five buttons have been added to enable this setting selection. The menu can be navigated with the left and right buttons, set parameter values with the up and down buttons, and record data with the enter button. The visual of the designed and produced mainboard is given in Figure 2, and the details of the STM32F103RCT6 microprocessor used in the mainboard and the board technical specifications are given in Table 1.

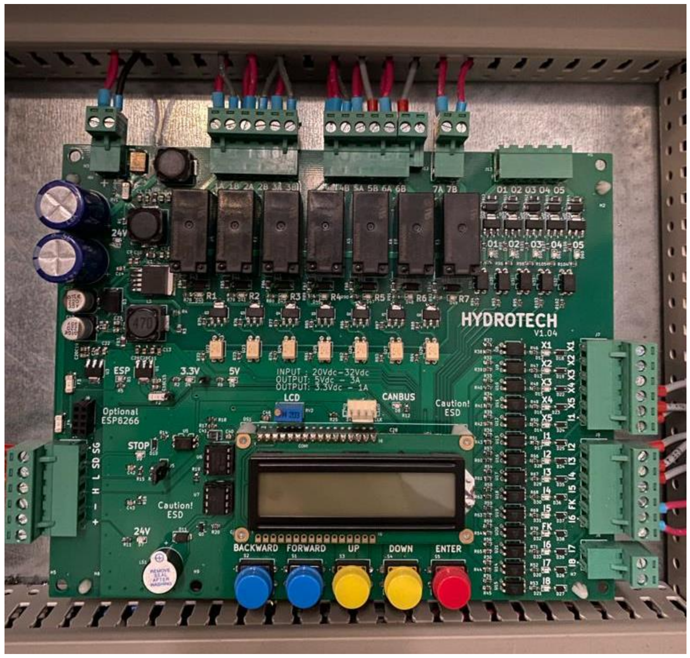

Figure 2: Mainboard Designed within the Scope of Study

Table 1: Technical Data of Embedded System Controller Mainboard

Board Feeding	24 VDC
Frequency	72 MHz
Processor Category	STM Microcontroller
Processor	32 Bit Microprocessor
Communication	500.000 Kbps CANbus / Wi-Fi
LCD Display	2x16 LCD
Memory/Additional Memory	Flash Memory/EEPROM
Program Memory Amount	256 kB - 512 kB Flash Memory
Parameter Type	Adjustable Parameter Values
Power Consumption	50 mA when LCD off

2.1.2. Platform Board

In goods lifts, the part that moves between floors and carries load is called the platform. Depending on the type of goods lift, the platform has different doors, sensors, and locks. Using the designed embedded system controller, elevators with different parameters can be controlled more efficiently with a single type of controller. Also thanks to the CANbus communication protocol, complete operation of the system can be ensured by providing the necessary outputs according to the parameter information from the mainboard.

2.1.3. Floor Announcer Board

In goods lifts, floor announcer boards are used as many as the number of stops. Floor announcer boards also communicate between the CANbus communication system and the mainboard. The button board receives the information to which floor the user wants to send the lift and transmits this information to the mainboard. The number of floor announcer boards can be easily increased with the CANbus input and output terminals included in the board design. Excess cables are prevented by connecting multiple floor announcer boards in parallel to the CANbus line, thus providing a regular control structure.

2.1.4. Connection Card

The connection card allows the boards to be connected via the communication system by reducing the cable connection to the mainboard. Using the CANbus communication system ensures that only two cables are sufficient to exchange data with the communication system. While in conventional systems, it is necessary to transfer the amount of data to be received through the platform via cable, the use of cables has been reduced to a minimum with the new generation design.

2.2. Hardware

The board design is based on ergonomics and low power consumption. In addition, thanks to the designed hardware, it will be possible to control a wide variety of freight elevators with a single type of panel. The design of PCB boards was carried out using the KiCAD program. Within the framework of the control scope of the board, the input/output names and quantities were determined for the design, and the STM32F103RCT6 microprocessor with ARM architecture, which has a sufficient number of legs, is popular in the market and continues to renew itself, was selected. In this design, a list of necessary components and integrated circuits was determined, a library was prepared, and layer designs were started [12].

2.2.1. Supply Circuit

24VDc voltage was preferred in the supply circuit design, and the system's highest current value is 5A. Therefore, amperage and voltage values were considered in all integrated selections to ensure a healthy operation. In addition, thanks to the EMI (Electromagnetic Interference) filter added to the supply circuit, electromagnetic noise and interference are reduced, ensuring the product's smoother and more stable operation.

Reverse Polarity Protection and High Voltage Protection circuits were designed considering customer connection errors. This circuit schematic drawing is shown in Figure 3. Since the microprocessor is 3.3 V, 24 volts were first reduced to 5 and then to 3.3 volts with the integrated selections.

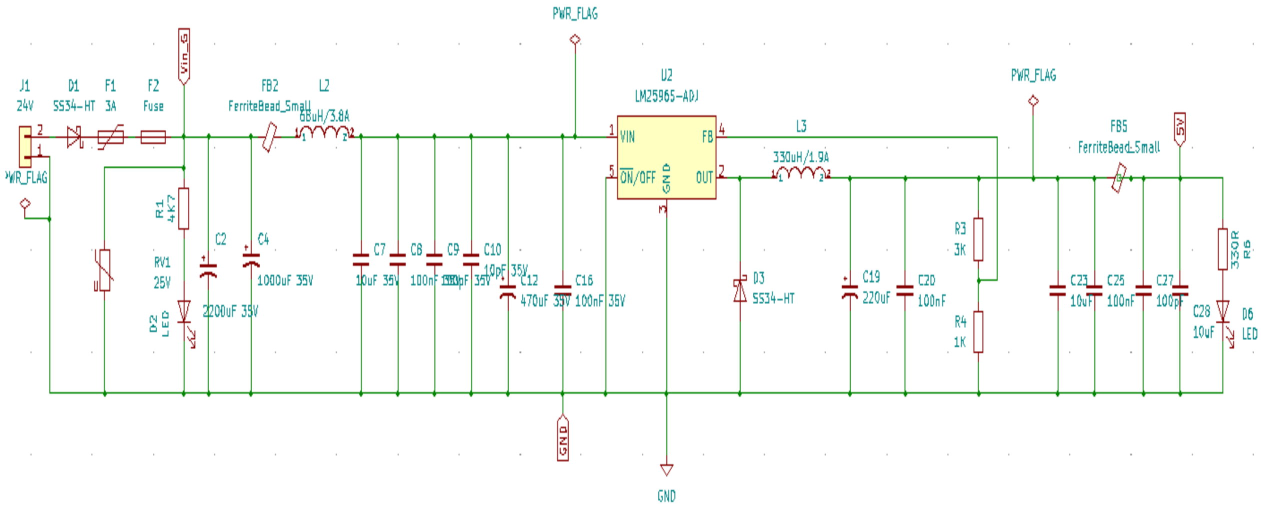

Figure 3: Supply Circuit Schematic Drawing

2.2.2. Input – Output Circuit Design

In the input circuit design, to transfer the 24 V signal detected from the input to the processor, the appropriate diode was selected among many zener diodes, and a limit voltage of 12 volts was achieved. Different voltage groups are controlled with the most suitable optocoupler, and a 3.3 V signal is received from the output of the optocoupler. This 3.3V signal received from the optocoupler output is transmitted to the microprocessor. In output circuits, this is the opposite. The 3.3V coming from the microprocessor was increased to 24 V with integrated circuits and additional components. 5A power can be controlled by relay control with the 24 V produced. The interference and high reverse voltages caused by the relay's reverse electromotive force are suppressed using diodes.

2.2.3. Processor Selection and Hardware Structure

The number of processor's legs was decided by considering input, output, EEPROM inter-module communications, and other necessary needs. Considering the high speed and data to be stored, 32-bit processors were chosen. There are a total of 3580 processors in the STM32 family. Among these processors, the STM32F103RCT6 processor, which will not cause any stock problems, was selected considering the number of legs, communication infrastructure, and necessary peripherals. The necessary electronic integrated circuit selections were made by examining the datasheet of the microprocessor and taking into account the voltage and current values. The crystal oscillator provides the operating frequency of the processor.

2.2.4. Communication Protocol

CANbus is a communication protocol designed for reliable high-speed data transmission. This protocol includes a set of standards and protocols to regulate the transmission of data packets, avoid collisions, and detect errors. The wireless connection feature allows CANbus circuits to provide fast and reliable communication between different floor announcer boards. It has a high transmission and communication speed of 500.000 kbps. This communication speed ensures fast data exchange between floor announcer boards. There are also versions of the CANbus protocol that can operate at various speeds, such as high-speed CAN (High-Speed CAN) and low-speed CAN (Low-Speed CAN).

In the CANbus system, termination resistors are used at the beginning and end of the communication line to ensure signal integrity and prevent distortions. These resistors match the impedance of the line by reducing signal reflections. While 120-ohm termination resistors are generally used at the end of the line for high-speed CAN (High-Speed CAN) communication, termination resistors may differ for low-speed (Low-Speed CAN) communication. However, resistors around 60 ohms are often used. The use of termination resistors may vary in specific applications and depending on the requirements of the device. Figure 4 shows the high-speed CAN (High-Speed CAN) communication line.

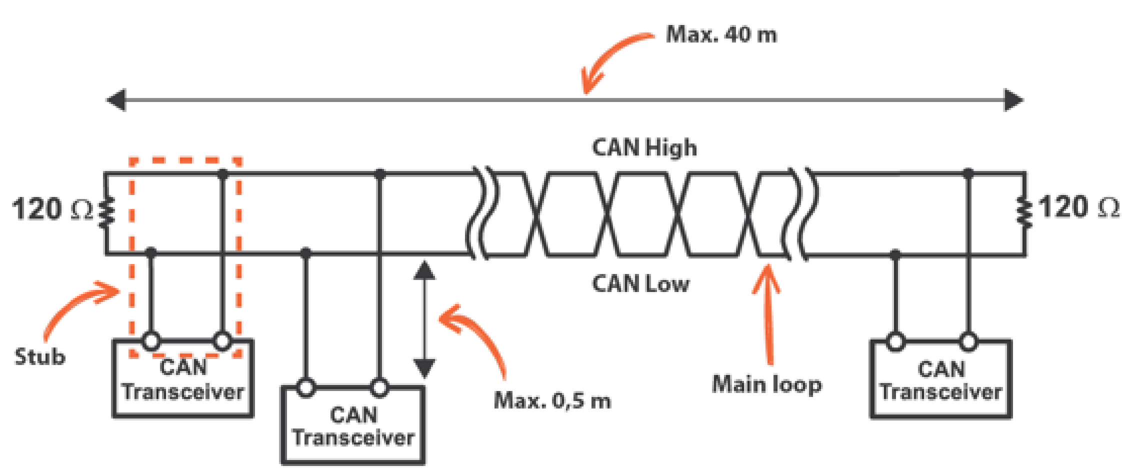

Figure 4. High-Speed CAN Communication Line [13]

The mainboard processes information received from environmental sensors via CANbus communication. Each regulated voltage information can be monitored with the LEDs on the board.

One of the most commonly used devices for Internet of Things applications is the ESP8266 Wi-Fi serial transceiver module, which works with the received signal strength indicator feature [14-17]. Internet access can be provided with the ESP8266 module added to the board, and information such as the device's current data, malfunctions, and operating status can be accessed via the Internet.

2.3. Software

In the hardware part, a microprocessor from the STM32 family was selected. The STM32 series has advantages such as high speed, low power consumption, and reliability [18-21]. In order to program this microprocessor, the STM32CubeIDE software development platform, which is suitable for multiple operating systems, was preferred. STM32CubdeIDE is an advanced C/ C++ development platform with code generation, compilation, and debugging features for STM32 microcontrollers and microprocessors. Thanks to the software developed through this IDE, the lift control board will realize its operating principles, and the user can select the menu via the 2x16 LCD. The interface of this platform is given in Figure 5, and the parameters that can be selected on the LCD screen are given in Table 2.

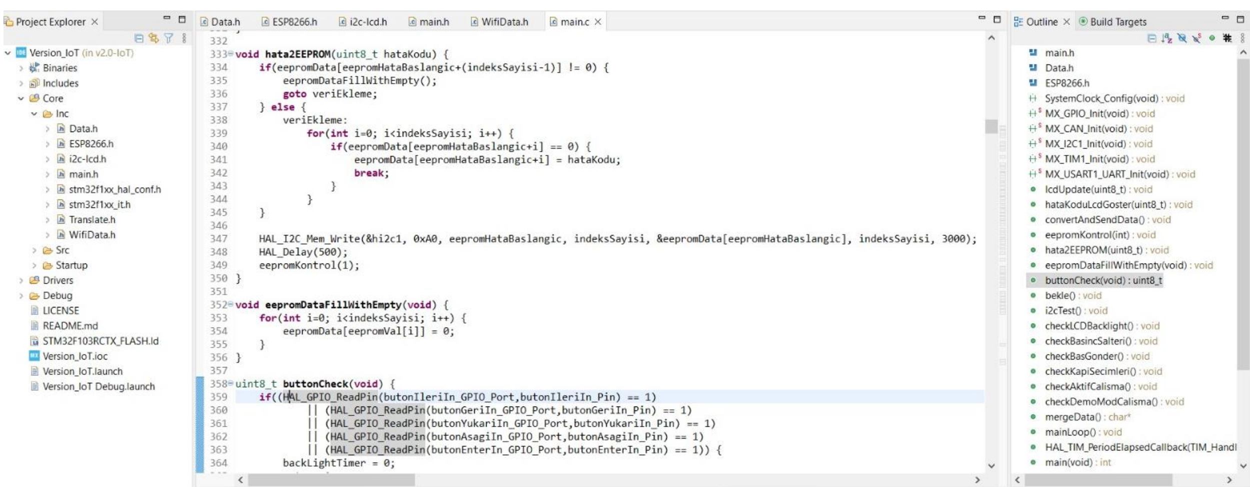

Figure 5: STM32CubeIDE Software Development Platform Interface

Table 2: Mainboard Parameter Types

Menu Counter	Parameter	Selection	Selection	Selection	Selection	Selection
1	Number of Stops	Value between 2 and 5				
2	How It Works	Single Acting	Double Effect	VVVF Drive		
3	Door Opening Time	Value between 2 and 99				
4	Door Closing Time	Value between 2 and 99				
5	Max. Cruising Time	Value between 2 and 99				
6	Docking Max. Duration	Value between 1 and 99				
7	Door Type	Locked Type	Unlocked Type	Automatic	Telescopic Automatic	
8	Tube Error Time	Value between 1 and 99				
9	High Speed Duration	Value between 1 and 99				
10	Docking Mode	Closed	Hydraulic Type-1	Solenoid Type-2	Solenoid Type-3	
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25	Relay-3 Selection	Open the Door	Close the Door	Docking	Lift Pump	Lighting
26	Photocell Signal	Door Only	Door+Stop			
27	Board Diagnostics	Test Mode				

3. Discussion and Conclusion

Today's needs have also increased with developing technologies. These needs are tried to be solved with maximum efficiency. Within the scope of this project, goods lifts used in many sectors are controlled by parameter selection from a single board. A variety of methods have been used to ensure that this board works most healthily and efficiently. In order to maintain the performance of the device at the highest level, an EMI filter has been added to the supply circuit. Thanks to this filtering, high-frequency noise is reduced and a low-pass filter function is provided, preventing the spread of this noise. Data transmission has been made more reliable and disruptions in data transmission have been reduced. In addition, by preventing the circuit from spreading its own electromagnetic noise to other devices, the device is provided with a more stable performance. By increasing compatibility between systems, undesirable effects are thus minimized. Figure 6 shows the status of the output signal created by passing the signal in the device through an EMI filter. Figure 7 shows the waveforms before and after more detailed filtering.

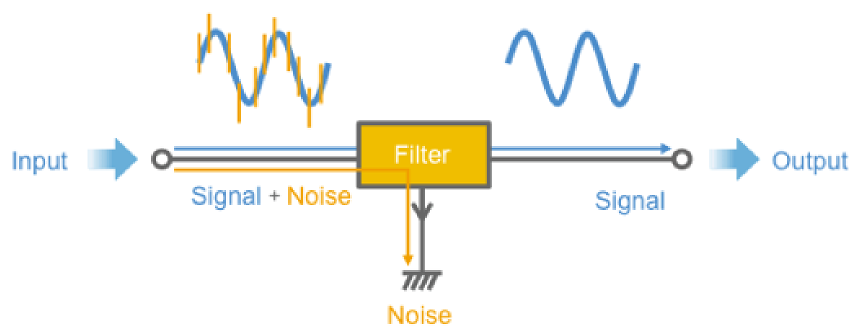

Figure 6: Input-Output Signal Status in EMI Filtered Circuit [22]

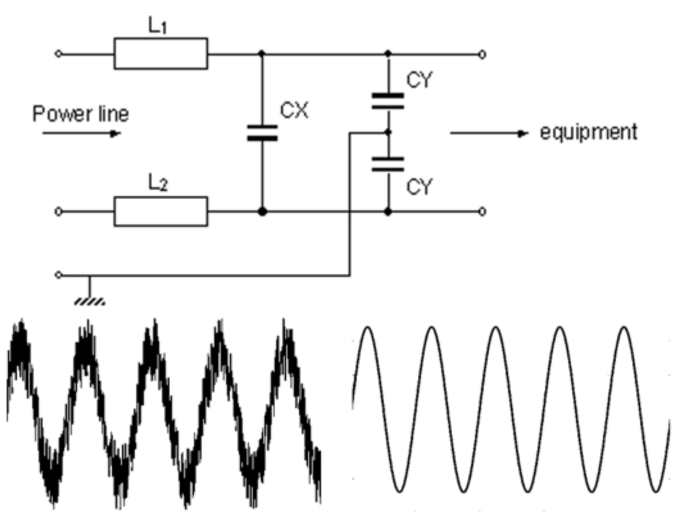

Figure 7: Waveforms Before and After Filtering with EMI Filter [23]

Since the control board can be used in various freight elevators, large production quantities will be possible, stock will be kept, and the cost will be minimized. Thus, a certain standard was achieved by not creating a separate controller software for each project. In addition, since the connections are standard, manufacturing can be done quickly and easily. A certain standard will be reached, and since the connections are standard, it will save time and labor, so an increase in production can also be observed. Thanks to the designed control board, the technical service team can proceed with preliminary information in case of malfunctions and provide faster solutions. Thus, customer satisfaction may increase. Table 3 compares the designed new generation control board with conventional PLC systems and gives the gains achieved.

Table 3: Differences Between the Designed New Generation Control Board and Traditional PLC

New Generation Control Board	**Traditional PLC**	**Results**
Low Cost	Costly	Cost is minimized with the use of a control board.
Stock Available	Deadline is Long	With the control board, there is no disruption in production, and an increase is observed.
Control Many Scissor Lifts with Single Control Board	Separate Controller for Each Platform	A wide variety of scissor lifts can be controlled with a single control board containing all parameters. The steps required for each scissor lift are eliminated.
Connections and Control Panel are Standard	Additional Module Use is Realized, Control Panel and Connections Are Not Standard	The connection stages in the control board are standard, and the control panel part is much easier than PLCs, thus minimizing labor and increasing production. Additionally, stock-based work can be done on the control board.
Error Code Display Yes	Error Code Cannot Be Displayed When HMI (Human-Machine Interface) Panel Design Is Not Realized	Error codes displayed on the LCD screen with the control board will provide convenience to the technical team. A quick solution can be reached. Additionally, system data can be viewed instantly on the screen.
Number of Input and Output is High	Use of Additional Module is Needed	The control board has more input/output than the PLC, so there is no need to use additional PLC modules. In this respect, hardware is superior to PLC.

Table 3: Differences Between the Designed New Generation Control Board and Traditional PLC (Continues)

New Generation Control Board	Traditional PLC	Results
Memory Yes	Memory Yes	Data is recorded via EEPROM with the control board. Even if there is a power outage, the information saved in the EEPROM can be viewed in its last recorded form. Faults during operation are recorded in the EEPROM, and ten faults can be viewed retrospectively.
Improvement Can Be Made	Only Plugins Provided by the Manufacturer Can Be Used	The control board has the infrastructure to add high-value-added add-ons. Desired revisions can be made.

The control board designed within the scope of the study will be used in the goods lift shown in Figure 8a. The electrical panel prepared for this goods lift is shown in Figure 8b. Figure 9 shows that the labor of electrical panels will be reduced with the new generation control panel compared to the electrical panel of the goods lift using PLC.

Figure-8. a. Prototype Goods Lift Using New Generation Lift Control Board and b. Electric Panel

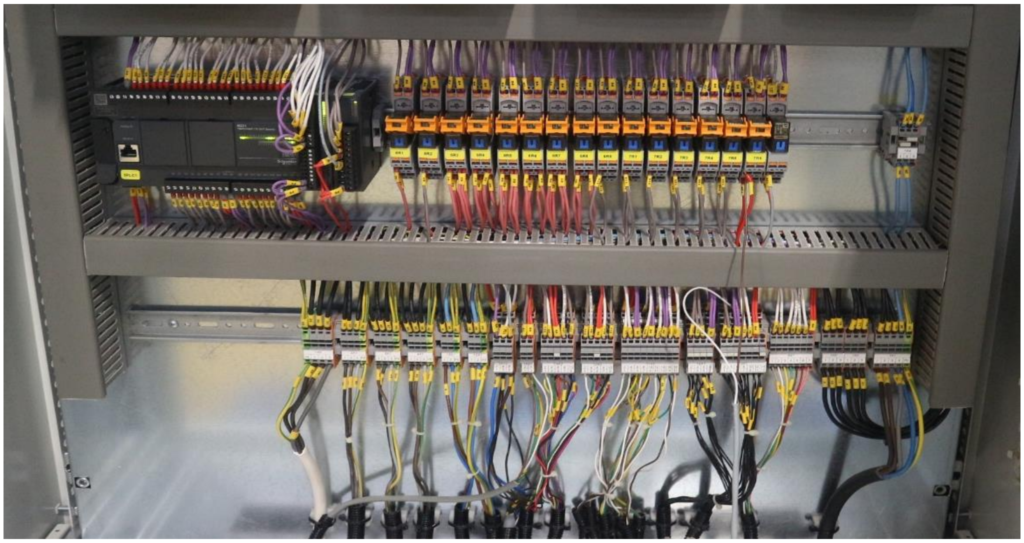

Figure 9: Traditional PLC Used Goods Lift Electrical Panel

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