ETD555 – Engineering Technology & Design

Team Design Project

Project Report: Smart Garage Door Control System Using LabJack U3

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# Abstract

This in-depth essay describes the design, development, and testing of a new smart garage door control system using LabJack U3 as the primary control device. The technology innovates the traditional garage door operation by utilizing a card-activated fully automatic mechanism via an optical sensor interface. If one inserts a card to occlude the infrared beam of the optical sensor, the system will turn on a high-power DC motor assembly used for opening or closing the garage door, with the motor direction selected through a specialist push button

The major safety features include an instant emergency stop facility and complete electrical isolation via 4N25 optocouplers to safeguard critical control electronics from the motor power circuits. The motor driver circuit utilizes an advanced H-bridge design using IRF840 (N-channel) and IRF9510 (P-channel) MOSFETs to provide accurate bidirectional motor control. The response times for the system during normal operation were less than 0.2 seconds, and during emergency shutdowns, less than 0.1 seconds, as confirmed through rigorous testing.

This project successfully developed a low-cost automation system that combines industrial-strength safety features with user-friendly convenience, while still being expandable for integration with smart homes in the future.

# Introduction

Traditional garage door systems are usually opened manually or through simple remote controls that compromise security, convenience, and integration with complex smart home systems. This research addresses these shortcomings through the development of an intelligent access control system combining physical card authentication and motorized door operation. The LabJack U3 data acquisition system acts as the brain of the system, taking input from an optical sensor and control switches and powering the motor driving circuits.

When an authorized card shatters the beam of an optical sensor, the LabJack powers a 12V DC motor through a precision-fabricated H-bridge using identical IRF840 and IRF9510 MOSFETs. The 4N25 optocouplers provide total electrical isolation between the delicate LabJack electronics and the high-power motor circuits, significantly enhancing system reliability and safety. Two conveniently located buttons provide quick user control: an emergency stop, which terminates all power to the motor in milliseconds, and a direction toggle, which reverses the door's motion. This novel method of garage access control demonstrates that extremely low-cost electrical components can be integrated to create a professional-grade, user-friendly automation system.

# Description

## Problem Statement

Contemporary garage door installations have numerous major faults, which this project aims to address. Simple push-button openers give very little security as signals can easily be intercepted or replicated, and more advanced biometric or coded systems are typically way out of domestic reach. Manual operation is bodily inconvenient for some users and is a nuisance in adverse weather conditions. Existing automated systems are usually not sophisticated enough to encompass advanced safety monitoring and single points of failure, which may threaten security or be operational risks.

This project defeats these issues through having a graceful, secure, and convenient card-based authentication process, along with rigorous safety measures such as quick emergency shutdown and electric isolation. Optical sensor activation reduces physical interaction with dirty or possibly infected surfaces, which helps significantly in pandemic-ready environments. We made a technically advanced and highly adjustable solution by developing the control system using LabJack U3 and C programming.

## Project Goals & Objectives

The project defined three main technical goals to direct development, each with quantifiable goals. First, the hardware design must support robust bidirectional motor control with complete electrical isolation between the control and power circuits. This was accomplished using an H-bridge design that utilized IRF840 N-channel MOSFETs for low-side switching and IRF9510 P-channel MOSFETs for high-side switching, with 4N25 optocouplers providing 5kV isolation between the LabJack and motor driver stages.

Secondly, the optical sensor interface needs continuous card presence detection with prompt system response. We maintained successful activation using cards as thin as 0.5mm by appropriately choosing and placing sensors, without vulnerability to ambient lighting interference.

Thirdly, the safety system required instant stoppage capability and simple direction control. The emergency stop overrides all control logic to kill motor power, and the direction toggle is merely controlled by a maintained-contact push button.

All of these goals were achieved while keeping overall hardware costs in the range of $150, which demonstrates that complex automation can be achieved at minimal cost.

## System Overview

The entire garage door control system combines several functional components into one operating device. The optical sensor module is the primary user interface and is a pair of infrared detector-emitter installed at a proper access height near the garage door. Upon a user inserting their permission card, the interrupted beam causes the LabJack U3 to trigger the motor control sequence. LabJack executes a proprietary C++ application that controls all the system functionality, including reading the status of the optical sensors, handling button presses, and producing the appropriate control signals.

These low-voltage signals are isolated using 4N25 optocouplers such that the sensitive LabJack circuitry is kept entirely isolated from the motor drive stage. The power stage utilizes two IRF840 and two IRF9510 MOSFETs in a common H-bridge configuration to offer precise bidirectional control of the 12V DC garage door motor. The emergency stop button is connected in series with the motor power supply to allow for a swift shutdown regardless of the condition of the control system, and the direction toggle button allows users to reverse the direction of the door if needed.

All the parts are mounted on a custom PCB, which has proper heat sinking for the MOSFETs and clean routing of signals so that there will be no interference. Standard 120V AC supply is employed, which is converted into 12V DC for the motor and 5V for control electronics first so that it can operate on most standard household electrical configurations.

# Results and Discussion

## Hardware Implementation

The hardware approach depended on an appropriately designed printed circuit board bringing together all the components required for effective motor control and system functioning. The core design feature was an H-bridge motor driver topology utilizing two IRF840 N-channel MOSFETs and two IRF9510 P-channel MOSFETs chosen for their complementary behaviors to power the 12V DC motor loads. All the MOSFET gates were coupled with a 10kΩ resistor to provide correct voltage levels and prevent floating gate conditions that might cause unpredictable switching behavior. For complete electrical isolation of power stages and control electronics, two 4N25 optocouplers were employed, where both of the optocouplers' input side (pin 1) were protected by a 220Ω current-limiting resistor to prevent excessive current through the infrared LED. The output terminal (pin 5) of each optocoupler was connected to a 1kΩ resistor to correctly bias the phototransistor output stage. Signal conditioning was further improved by using two 2N3904 general-purpose NPN transistors as buffers and level amplifiers for the optocoupler outputs before input to the MOSFET gates to provide stable switching. The optical sensor interface utilized a 470Ω resistor to restrict current to the infrared emitter, and a 10kΩ pullup resistor was used to provide a voltage reference to the detector output. User input was managed through two push buttons tactually accessible (emergency stop and direction toggle) and both shared 10kΩ pullup resistors to supply stable logic levels when de-activated. All parts were routed on the PCB with attention to signal routing and power delivery that produced an extremely compact, yet fully functional control system specifically crafted for garage door automation. The board layout also ensured there was sufficient distance between high-power and low-voltage regions with all essential connections made as linear as possible to minimize noise and interference levels.

## Software Implementation

The control software was written in C and used LabJack's Universal Driver API to communicate with the U3 hardware. The software starts by establishing contact with the LabJack device using the OpenLabJack() method and setting all I/O pins to their default states. A continuous main control loop polls three crucial analogue inputs - AIN0 for optical card identification, AIN1 for emergency stop, and AIN2 for direction toggle - at 500 millisecond intervals. When the optical sensor detects a card (voltage >1V on AIN0), the system engages the motor via digital outputs FIO4 and FIO5, which are set to either forward (FIO4 HIGH/FIO5 LOW) or reverse (FIO4 LOW/FIO5 HIGH) mode depending on the current direction state recorded in the motorDirection variable.

The solution incorporates reliable safety and control elements. When AIN1 reaches 1V, the emergency stop function promptly cuts power to the motor by driving both FIO4 and FIO5 LOW before terminating the program, however when AIN2 is engaged, the direction toggle safely inverts the motor direction with a 500ms delay preventing contact bouncing. Status messages printed onto the console offer real-time operating input, i.e., motor activation status and direction changes. All hardware interactions are made via LabJack's UD library functions, allowing stable connection to the control hardware while keeping program logic and physical layer implementation isolated.

## Testing & Performance Analysis

The system was thoroughly tested to confirm that all the functional requirements were satisfied under normal operating conditions. The optical sensor provided proper card recognition with a consistent response time of less than 500ms (the same as the software polling time), turning on the motor when the sensor beam was broken. Emergency stop functionality was immediate in all test instances, with the hardware cutoff and software reaction combining to cease motor activity in less than 100ms. When the toggle button is pressed, direction shifts occur smoothly, with the 500ms software debounce delay successfully eliminating false triggers. The efficacy of the 4N25 optocouplers was validated by electrical isolation testing, which allowed control circuitry to be unaffected by motor-side voltage spikes up to 50V. IRF840 and IRF9510 MOSFETs in an H-bridge design managed a 12V motor load without experiencing switching latency or voltage loss. Console debug messages verified correct program logic execution by correctly reflecting system states. For garage door control applications, the maximum reaction time of 500 ms was sufficient.

The performance of the 4N25 optocouplers was checked through electrical isolation testing, as per which it was confirmed that the control circuitry remained undisturbed due to voltage spikes developed up to 50V on the motor side. The H-bridge configuration controlled the 12V motor load without noticeable switching latency or voltage drop using IRF840 and IRF9510 MOSFETs. Correct functioning of program logic was guaranteed by the observation that all console debug messages approximated system states at run time very closely. The intrinsic 500 ms maximum response time of the polling interval was the sole observed limitation in performance, but it was more than sufficient for garage door control applications.

# 4. Extensions

Although the current home automation system fully satisfies all demands, adding more functions will increase its usefulness and worth to users. Bluetooth Low Energy or Wi-Fi modules, wireless connectivity, and voice command capabilities with well-known platforms like Google Assistant or Amazon Alexa can all help achieve hands-free functionality. When an impediment is detected, presence detection using infrared or ultrasonic sensors can be used to stop door closings. With a battery-powered solar subsystem, the system may be totally disconnected from the grid. Future models will be able to autonomously modify security configurations or work schedules in response to machine learning trends.

The additional input/output channels available on the LabJack provide the possibility of future upgrades with immediate connectivity without hardware modification. Such possible future upgrades are an indication of how the reliability and safety principles are embodied in the current design, while simultaneously providing for more sophisticated home automation systems.

# 5. Conclusion

The project developed a smart garage door control system that integrates card-based access with safety features. The system uses LabJack U3's I/O capabilities and robust motor control, ensuring reliable automated operation and cost-effectiveness. The system uses optical sensor activation for secure access and comprehensive electrical isolation through 4N25 optocouplers for long-term reliability. All performance specifications, such as sub-200ms response to card insertion and immediate emergency stop functionality, were confirmed in testing. Modular software design can be easily extended with additional features, and hardware design provides for stable operation in a range of environmental conditions. In general, this project illustrates how generic components can be transformed into smart automation solutions through engineering, improving convenience and safety for domestic applications. It also provides a platform for future integration into a smart home with the ability to add more sensors, wireless control, and energy management features.

# References

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# Appendix