Switch Wizard

Senior Design Laboratory - Project Proposal

Team #4
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1. Introduction

1.1 Problem Statement

Pinball machines are complex, multifaceted devices, needing electrical and mechanical skills to troubleshoot, but we want to simplify the process. These machines primarily operate through switches that tell the machine what to show on the screen, solenoids to fire, etc. The issue is, troubleshooting these switches can be extremely challenging, because these machines typically have about 60-100 switches that all need to function properly. Pinball machines made in 1977 and later have rudimentary switch diagnostic features, but those produced before 1977 are designated as electromechanical, meaning they rely solely on physical relays and switches, without any software. This makes electromechanical pinball machines particularly difficult to troubleshoot.

1.2 Solution

Our solution to this problem is the Switch Wizard, a device capable of simultaneously monitoring multiple switches and transmitting data over Wifi to a nearby device. The device will be able to determine if a switch contact has been made and send a timestamp to the user's laptop. This product will be able to test switches while the game is in full operation, with live 6 VAC being used to power the pinball machine's logic. The score motors, which are cammed switched driven by a motor, are extremely difficult to diagnose and this product would provide a much simpler solution. We simply cannot overstate how much easier troubleshooting would become with this tool. If the product proves successful, we could genuinely see it having a valuable place in the industry. Gavin of Gavin's Game Service, a master technician in the Chicagoland area, has already shown interest in the product.

1.3 Visual Aid

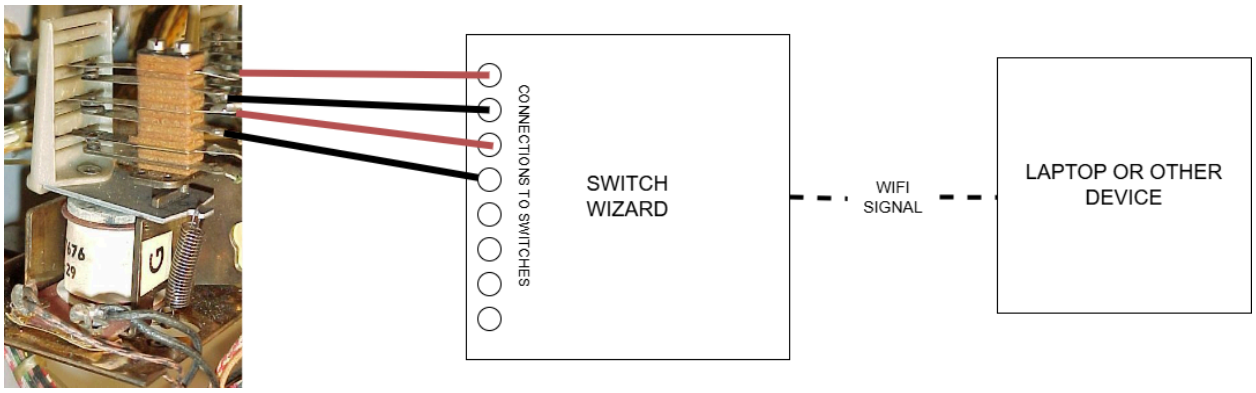

Figure 1: Visual Representation of the Switch Wizard

1.4 High Level Requirements

For this project to be considered successful, we have set some high-level criteria that the Switch Wizard needs to meet. These are:

1. The Switch Wizard must detect switch closures longer than 3ms, which is the estimated time for a successful switch closure.
2. The device will transmit the switch closure data over wifi in less than 10 seconds.
3. Multiple switches must be able to be connected and a closure of one switch can be detected without affecting other switches that are also connected.
   Voltage regulator needs to be rated for >240mA (500 expected) due to ESP32 needing 240mA at peak operation.

2. Design

2.1 Block Diagram

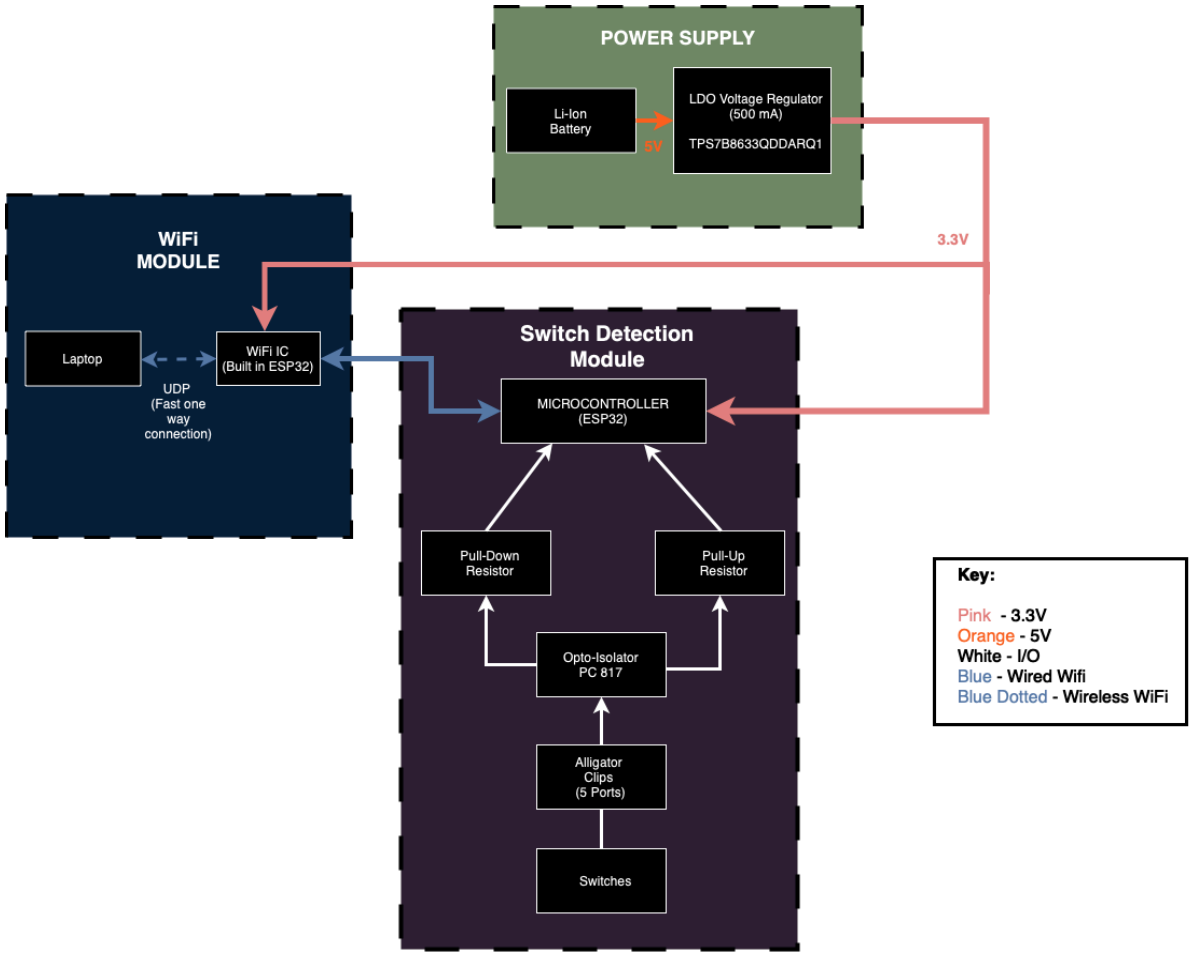

Figure 2: Block Diagram of the Switch Wizard's Subsystems

2.2 Subsystem Overview

2.2.1 Power Supply Subsystem

The Power Supply Subsystem is responsible for providing stable power to the circuit board. We are using a lithium-ion battery as the primary power source which offers us portability with our device. Additionally, a lithium-ion battery provides an average voltage range around 3.7V which is compatible with an ESP32 (3.3V). A linear voltage regulator steps down the battery voltage to a safe operating level for the ESP32. This subsystem ensures that the voltage supplied remains consistent (3.3V) regardless of the battery's charge state, safeguarding the functionality of these components. The power supply connects to the WiFi Module and Switch Detection Module by powering the microcontroller, which ensures viable switch detection and WiFi transmission.

2.2.2 Switch Detection Module

The Switch Detection Module monitors the state of the pinball machine’s switches. We use an optoisolator to isolate the switch from the high voltage pinball machine and the low voltage ESP32. When the switch is closed, the current flows through the optoisolator’s LED. The optoisolator enables us to use pull-up and pull-down resistors to detect the state of the switch. When the switch is closed, current flows through the LED and the pull down resistor pulls the GPIO pin of the ESP32 to low (0V). When the switch is open, the pull-up resistor pulls the GPIO pin to high (3.3V). The signals are sent via WiFi UDP to the laptop. From here, we program the ESP32 with Switch states (Open=1 and Closed=0) to read the inputs and display the corresponding state.

2.2.3 WiFi Module

The WiFi Module is built into the functionality of the ESP32 allowing us to communicate with outside devices such as a laptop using User Datagram Protocol. After the switch state has been detected by the Switch Detection Module, the WiFi module is responsible for transmitting the data. UDP is the most efficient way to transfer the signal data because it sends UDP packets containing the switch states (open or closed) to a predefined IP address, allowing for immediate response times. This is especially advantageous for real-time systems.

2.3 Subsystem Requirements

2.3.1 Power Supply Subsystem

Lithium-ion battery supplies 3.7V to the LDO Linear regulator which lowers the voltage to a steady 3.3V at 500 mA. ESP32 operates at 3.3V 500mA current rating, so the linear regulator is necessary for proper functionality. The Power Subsystem must be able to supply at least 500mA to the rest of the system continuously at 3.3V for WiFi and Switch Detection to work.

I/O:
Input: Lithium-ion battery (3.7V)
Output: Regulated 3.3V to ESP32 and other modules
Current Rating: Minimum of 500 mA

Requirements:
Voltage Supply: Stable output of 3.3V
Current Rating: Supply at least 500 mA continuously
Regulation: Maintain voltage stability regardless of battery charge state
Compatibility: Compatible with ESP32's operating voltage and current requirements.

2.3.2 Switch Detection Module

The alligator clip connects to Terminal 1 or input of the switch nodes. The terminal 1 node is then connected to the anode of the optoisolator. The pull down resistor is connected between the cathode of the optoisolator to the ground of the ESP32. The 10k pull-up resistor is connected between the collector of the optoisolator to the GPIO Pin of the ESP32. The emitter of the optoisolator is connected to the ground of the ESP32.

I/O:
Input: Switch voltage
Output: GPIO Pin reading of 0V or 5V on ESP32

Requirements:
Resistor values: Must use appropriate resistances for pull-up pull-down resistors
Frequency: The frequency of the optoisolator must be compatible to detect the switch state within a 5ms period

2.3.2 WiFi Module

The WiFi module is built into the ESP32 and transmits wireless UDP packets to the laptop's specific IP address.

I/O:
Input: Switch state (Open = 1 and Closed = 0)
Output: UDP Packets to IP address

Requirements:
Rate of transfer: transfers packets within a 100ms
Faulty transmission: handles dropped packets during data transfer
Network connection: able to connect to a network with SSID and password

2.4 Tolerance Analysis

In the design of a pinball machine using the PC817 optoisolator, a key risk is the timing precision of the switch closure, which takes approximately 5 ms with a potential tolerance of ±0.5 ms due to mechanical variability. The PC817 has a response time of around 5-10 μs, allowing it to detect switch closures well within the timing window.

Maximum:
Number of detections = 5ms / 5 μs = 1000

Minimum:
Number of detections = 5ms / 10μs = 500

This means the optoisolator can detect the switch closure up to 1000 times during the 5 ms period and up to 500 times during the 5 ms period.

3. Ethics and Safety

3.1 Ethics

There are some potential ethical considerations that may arise during the development and use of the Switch Wizard. One such concern during development is ensuring strong collaboration within our group. Poor communication, unfair workload distribution, and/or a lack of participation would negatively impact our project. We are committed to maintaining a professional and ethical working environment by ensuring each member in our group contributes fairly and meaningfully to the project. Another major ethical issue pertains to the possibility of referencing existing designs for any part of the Switch Wizard that are on the market. We will ensure that any such references are done with ethics in mind and make sure to properly cite such references.

We will uphold the IEEE Code of Ethics by adhering to all of their principles including but not limited to: upholding the highest standards of integrity, showcasing responsible behavior, treating all persons fairly and with respect, and avoiding injuring others or their property. We will avoid any potential ethical issues through many ways. To ensure strong and fair collaboration among the team, we will communicate regularly through a group chat. This will help us be reliable and allow us to hold each other accountable. Consistent communication will also ensure that all of the work we do is original and of high quality. If we have any questions or concerns about anything with regards to ethics or safety, we will make sure to contact our TA or any other members of the course staff. All of this will ensure that the IEEE Code of Ethics is always at the forefront of our minds as we progress through this project and course.

3.2 Safety

With regards to safety, we have made sure to identify several potential risks we may encounter. These are mostly related to the power supply and the integration of the pinball machine's live components. The Switch Wizard relies on a lithium-ion battery to power the ESP32, which presents typical risks associated with these types of batteries such as overheating and the potential for fire. To help mitigate these risks, we will make sure to read and thoroughly understand the safe battery usage document on the ECE 445 course website. The integration of the pinball machine's live components also poses a possible risk due to potential electrical hazards. We will always make sure to follow standard lab safety protocols from our lab safety training and ensure that all wiring and soldering are conducted with care. Throughout the development of the Switch Wizard, we will comply with all relevant safety regulations and standards.