Efficient Card Shuffler with Cut Card Insert

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ECE 445 Spring 2026

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1. Introduction

1.1 Problem

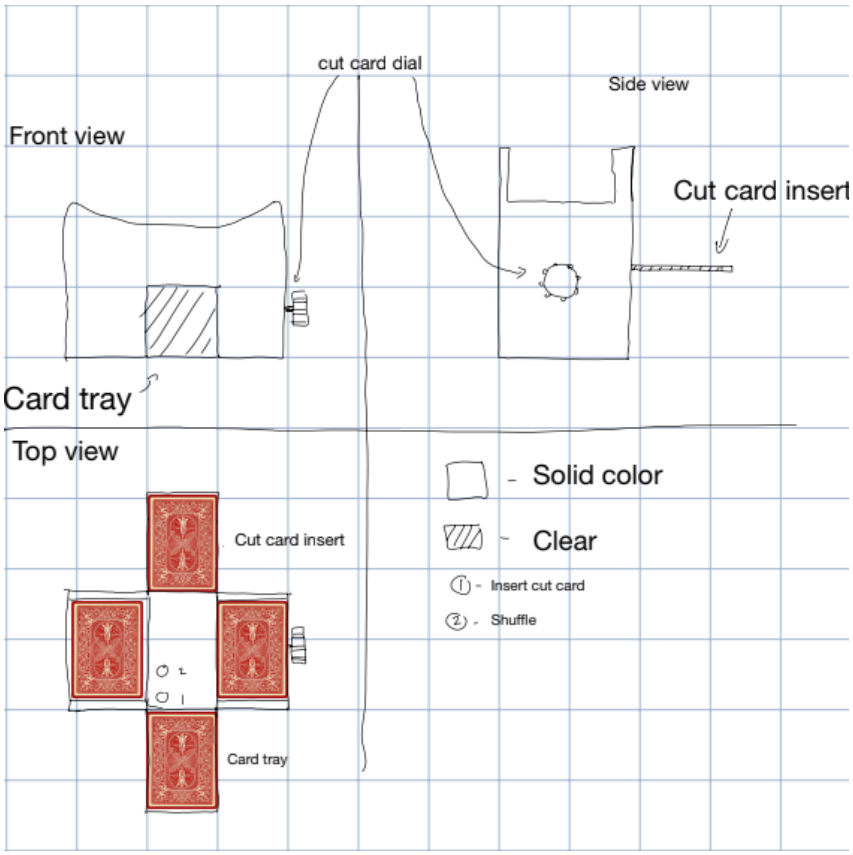
Many card games played by people today require continuous shuffling between rounds of play. Over time this becomes very disruptive, resulting in decreased playing time for players and an increased strain on dealers. While card shufflers do exist, most have a limited deck capacity, tend to be error-prone, are limited in features, and overall difficult to use. Specifically, games such as blackjack typically require use of more than 2 decks and an insertion of a cut card at a varying level of deck penetration before playing starts. There currently do not exist any card shuffler machines with a cut card insertion feature. Lower quality shuffle machines often require the constant push of a button to operate. This can result in overuse of motors and wasted energy. Another issue to be addressed is the manual retrieval of the shuffled deck, which can be cumbersome when reshuffling the same decks multiple times. Finally, if a certain deck penetration level is desired, it can be difficult to replicate similar levels in back-to-back games. These are the fundamentals issues we aim to address in our project.

1.2 Solution

Our solution is to design and build a card shuffling machine with added features of increased deck shuffle capacity, optical detection of shuffle completion, a retractable motorized shuffled deck tray, and a cut card insertion feature with electrical deck penetration customization. These features lead to six subsystems namely card deck(s) detection, deck shuffling mechanism, cut card insertion, completed deck tray extension, power supply, and the control module. The prevailing goal is to make the card shuffler as efficient as possible. There will only be three inputs available to the user. A shuffle button, a dial to set the cut card penetration, and a cut card insertion button. The entire shuffle function is fully automated with the push of a button. Once the user is ready for the cut card insertion, they will

set the dial and press the cut card insert button which will electrically align the cut card insertion window and create a delay to give the user time to insert the cut card.

1.3 Visual Aid



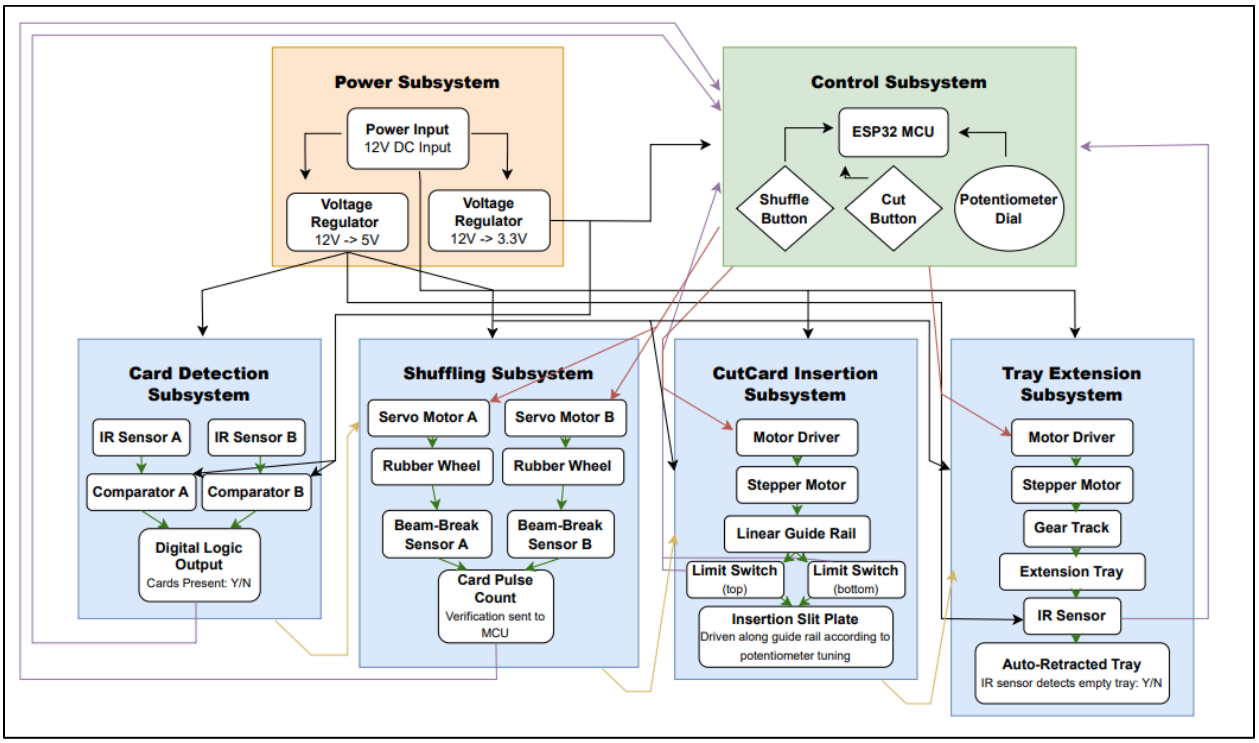
1.4 High – level requirements list

- With the press of the start button, the device successfully shuffles 4-6 standard sized decks without manual intervention. The shuffled product is extended out in the product tray after shuffle completion.
- Cut card insertion slot moves in accordance with the dial. The dial is measured as a percentage of deck penetration ranging from 0-100%, allowing for desired insertion at any deck penetration level.

- Successful operation of the IR sensors. This includes shuffling continues until all cards from the input trays are emptied and halts once there are no more cards left in the trays. Once the cards are received from the finished product tray, the tray retracts automatically.

2. Design

Block Diagram



- Black lines denote paths for power distribution to the various subsystems.
- Red lines dictate digital signals from the MCU (control system) to various subsystems to trigger action items
- Purple lines feed data from subsystems to the MCU
- Yellow lines follow physical card progression from subsystem 1 – 4

2.1 - Subsystem 1 – Card Deck(s) Detection

The purpose of this subsystem is to detect whether cards are present in the input trays for the shuffler. Detection will be determined by using reflective optical sensors and is critical for the prevention of overdriving motors and ensuring shuffling continues until completion. The reflective sensors on each tray will measure the light reflected off the bottom card of the stack to determine if the tray is empty or still full. The IR sensors will be flushed to the bottom of the tray's surface, and their outputs will be fed to a comparator to differentiate between the signals for when no cards are present

and for when there are cards present. The resulting digital signal is read by the MCU through GPIO inputs. When the sensors report no cards are present, the MCU concludes that the shuffling process is complete.

Subsystem Components

- Reflective infrared optical sensor (Vishay TCRT5000) (2x)
- Comparator IC (LM393) (2x)

Subsystem Requirements:

- Sensor response time must be less than 50ms to prevent delaying motor functionality
- Sensor should be able to identify varying card presence under dim lighting conditions
- Comparator output must produce digital logic levels such that the signals are compatible with 3.3V GPIO inputs on MCU

2.2 - Subsystem 2 – Deck Shuffling Mechanism

This subsystem is responsible for the physical shuffling of the cards. It will involve two motors, each positioned at the bottom of the pre-shuffle deck trays. Each motor will slide one card at a time from its respective card stack inwards into a common pile forming a shuffled card pile. The motors will be in contact with the cards by a wheel with a rubber edge. Once the shuffle button is pressed and the finished tray is fully retracted (from the previous operation), the motors will begin shuffling. To ensure that the cards are being shuffled reliably, a beam-break sensor will be positioned below the motor wheels, and as each card passes through the slot, the sensor will generate a pulse that is read by the MCU to confirm that no jam has occurred (or if there is no pulse, that there has been a jam, and to reset

the cards) and to keep count of the cards that have been passed through. Shuffling will continue until a signal is received by subsystem 1 that there are no more cards remaining to be shuffled.

Subsystem Components

- Servo Motor (HitecSKU: RB-Hit-27) (2x)
- Optical beam-break sensor (omron ee-sx1103) (2x)

Subsystem Requirements:

- Motor wheel must advance one card per motor actuation under nominal conditions to ensure acceptable shuffling
- Beam-break sensor must generate a pulse for at least 1ms duration so that it can be detected by MCU
- Servo motor torque must be able to overcome card friction without deteriorating cards

2.3 - Subsystem 3 - Cut Card Insertion

This section will include a user-controlled dial (0-100 scale) which will set the desired depth at which the cut card will be inserted into the shuffled deck (ex. Tuning the potentiometer halfway around would insert a cut card in the middle of the deck). The dial will be electronically coordinated with a slitted plate which will move upon the vertical axis along the card deck based on the dial's input. A rotary potentiometer will serve as the dial, and the voltage read from the potentiometer will be fed into an ADC on the MCU (ESP32 comes with an ADC). The output of the ADC will be scaled to a corresponding linear displacement for the slitted plate, and the slitted plate will be driven by a stepper motor connected to a linear guide rail which will guide the plate up and down the deck. This allows the user to insert the cut card practically anywhere within the card stack. Additionally, we would add limit

switches at the top and bottom of the rail to prevent any overtravel.

Subsystem Components

- Rotary potentiometer (Bourns 91A1A-B28-L15) (physical button will be interfaced with control subsystem)
- Stepper motor (NEMA 17)
- Motor driver (TMC2208)
- Linear Guide Rail (MGN9H Linear Guide Rail + Carriage Block)
- Limit Switches (Omron SS-3GLPT)

Subsystem Requirements

- Potentiometer input must be able to map entire deck depth, regardless of deck size, from 0 – 100%, with a margin of error of ~5%
- Positioning error of stepper motor must be > 2 mm along guide rail to ensure proper vertical movement
- Limit switches must reliably trigger before mechanical end-of-travel is reached to prevent device damage
- System must pause motion within 100ms of limit switch activation

2.4 - Subsystem 4 - Completed Deck Tray Extension

This subsystem will be responsible for extending the completed shuffled deck at the end of the shuffle operation. This will require the use of one motor and one optical sensor. The motor used will be a small gear motor attached to a gear track. These are optimal since they have high torque and require low voltage to operate. In addition, we will use an optical sensor to detect when the shuffled deck has

been retrieved from the extended tray. Once the shuffled deck is retrieved, the tray will retract automatically.

Subsystem Components

- Reflective infrared optical sensor (Vishay TCRT5000)
- Stepper motor (NEMA 17)
- Motor driver (TMC2208)
- Gear Track (22460300)

Subsystem Requirements

- Optical sensor must detect deck removal with at least 95% reliability to allow for repeated shuffling processes
- Motor driver supplied current must be high enough to move loaded tray without stalling
- System must automatically retract tray once removal is detected

2.5 – Subsystem 5 - Power Supply

The power supply subsystem is responsible for supplying power to the device and its various components. There are three different voltage levels required by the device. The stepper motors require 12 volts, the IR sensors, motor drivers, and servos require 5 volts, and the MCU runs on 3.3v. To achieve these various voltage levels, we will be using a 12-volt power supply and several voltage regulators. These regulators will constitute the power subsystem and will require traces routed from this subsystem to the rest of the other subsystems.

Subsystem Components

- 12v Power Supply ECE Supply Center 620130252
- Voltage Regulator ECE Supply Center LM317T (2x)

Subsystem Requirements

- Voltage outputs are of correct magnitude and within a reasonable level of tolerance
- Traces routed from this subsystem are required to adhere to the correct minimum thickness to allow for proper power distribution
- Regulators must prevent overloaded voltage supplies and board damage

2.6 – Subsystem 6 - Control Module

The purpose of this subsystem is to serve as the brain of the card shuffler. It receives power from subsystem 5, data, and various inputs from several other subsystems to control the devices' motors and the timing of operation. The inputs to this subsystem are the shuffle command, cut card insertion, and cut card penetration level. The first two inputs mentioned will be administered using pushbuttons, the cut card penetration level will be set by a dial. This dial will be on a scale from 0-100%.

Subsystem Components

- ESP32 MCU
- Pushbuttons ECE Supply Center - MPB-43 (2x)
- Potentiometer ECE Supply Center – part 377

Subsystem Requirements

- Commands from input buttons and dials are correctly received and able to communicate across all subsystems

- Must be able to continuously operate throughout multiple shuffling cycles to ensure proper operation
- Read and store pulses from potentiometer reading to accurately correlate to cut card depth insertion

Tolerance Analysis

One aspect that poses a risk to our success is the accuracy of the card cut insertion feature. We expect there to be some degree of error between what the dial percentage is set to and the actual penetration of the cut card. Let's say we are shuffling 4 standard size decks. There are 4*52 = 208 total cards to be shuffled and cut. Our dial is on a scale from 0% to 100% deck level penetration. For simplicity, we'll say each percentage point is equivalent to roughly 2 cards (208/100 = 2.08). We would like our actual penetration level to be within +/- 5% of our desired dial setting. This means we will be within roughly 20 cards of our desired cut. Anything outside of this range will not reflect the desired setting by the user and should be considered a malfunction of the cut card insertion feature. Since our rotary encoder will take measurements in increments of 4%, we feel that a 5% margin is very appropriate.

3. Ethics and Safety

The largest safety concern when it comes to our product would likely be pinch points caused by people trying to handle cards when components are in operation. Most commonly, this can occur when people leave their fingers in the tray for too long when extracting the completed shuffled deck. To prevent this, we can add a delay on the IR sensor to ensure there is no human presence. Pinch points could also occur if someone was messing around with the empty machine and didn't clear their fingers of the motors before starting operation. This could possibly cause scrapes or cuts especially if the user is

not careful. A very large ethical issue for our project is to “uphold the highest standards of integrity” [1] as best we can. This could occur in our project relatively easily since errors with the shuffling could create unfair advantages for the dealer, which would likely discourage card players. We can mitigate this by making sure we test the randomness of the shuffle and document it often reducing the chance that the shuffle could be stacked or unfair. We can also run into issues with integrity when it comes to the improper use of our product causing the decks to be stacked in a bad way or the cut card system to be taken advantage of. To simplify this, we can have the systems for the product be very accessible to people who have not used the device before allowing anyone to help reduce chances for error.

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