Pocket Pal

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1 Introduction

1.1 Objective

Have you ever waited in line at a coffee shop during rush hour, only to have your coins disappear and scatter in your wallet when it's finally your turn to pay? When this happens to me, I frantically search my wallet for the perfect amount of coins while the caffeine-deprived mob waiting in line behind me casts angry glares. Even if this hasn't happened to you, you've most likely been one of those people in the back of the line, agonizing over how long you must wait until you can finally get your coffee fix.

With Pocket Pal, this will be a problem of the past. Instead of frantically fishing around for the perfect amount of coins that may or may not be your wallet, all you need to do is input the coin amount of your purchase into the device and Pocket Pal will dispense it for you. This compact, high-tech wallet keeps track of how many coins it has at any given time, and it will automatically update these values whenever the user inserts more coins into the device. Pocket Pal will be able to calculate and dispense the correct combination of coins needed for a purchase, overall making cash purchases quicker.

1.2 Background

Even though credit and debit usage is a solution for some people, cash purchases are still prevalent both in the U.S. and overseas. The 2019 Diary of Consumer Payment Choice found that cash purchases in the U.S. are common for small payments; cash is used for about half of all purchases under $10 and 42% of all payments under $25 [1]. Additionally, the German Association of Money and Bond Services found that 75% of Germany's purchases in 2020 were made through cash, even with the rise in card payments attributed to the pandemic [2].

Pocket Pal is a solution for those who prefer to use cash for small payments like coffee or fast food. Scrambling for the right coins at a cash register can oftentimes be awkward and time-consuming, but users will be able to hasten this process with Pocket Pal. Our innovative wallet will be capable of determining the exact combination of coins to match the amount input by the user. Pocket Pal will then dispense the coins, sparing the user from having to frantically look through their wallet for change. To reload the device, coins can be inserted into the coin loader, where they will be automatically sorted by coin type and placed in their respective coin compartment slot. The coin compartment will keep track of all the coins in the wallet using IR sensors, as they will detect whenever a coin is inserted into the device. The microcontroller will compute the correct combination of coins to distribute based on the user's input amount, and keep track of the counts of each coin type whenever loading or dispensing processes occur. For this project, we are primarily focusing on tracking and dispensing coins, as this is the most time consuming aspect of cash transactions when compared to bills.

1.3 High-level Requirements

- The coin loader must sort pennies, nickels, dimes, and quarters into their proper compartments with 95% accuracy.
- The coin dispenser must dispense the correct coin amount in a maximum of 15 seconds.
- The overall design of Pocket Pal must be compact, with a maximum size of 6"x4"x1.5".

2 Design

2.1 Block Diagram

Figure 2.1 shows the Pocket Pal's Block Diagram. The design will consist of 3 distinct subsystems: a power supply, a control unit, and a coin module. The power supply for Pocket Pal is a portable 5-volt battery. It will power the microcontroller, user input, IR sensors, coin dispenser, and solenoids. The control unit handles the user's input whenever they want to make a purchase and sends this information to the microcontroller. The microcontroller uses this data to calculate the correct combination of coins that must be dispensed, decrements all relevant coin counts, and signals to the coin dispenser to power the conveyor belts corresponding to the necessary coin types. When the user inserts coins into the coin loader, the IR sensors detect this change, and the microcontroller increments the coin counts accordingly.

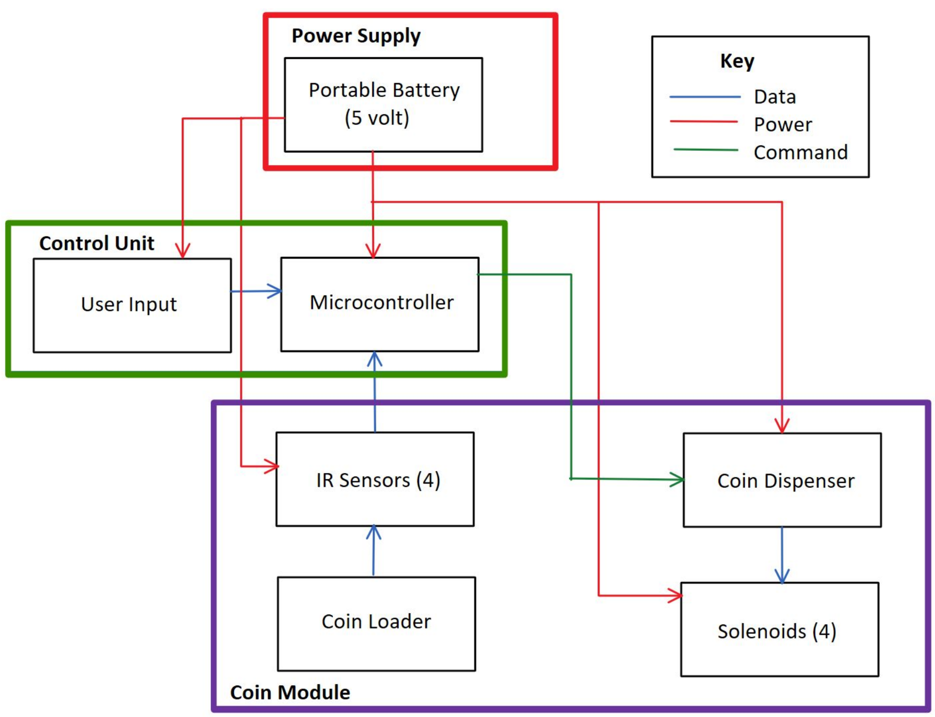

Figure 2.1. Block Diagram of Pocket Pal

2.2 Physical Diagram

Figure 2.2 depicts Pocket Pal's proposed physical design. Coins can be inserted individually through the coin loader slot. As each coin slides down the ramp, it will fall into its respective coin compartment. Notice that the opening to each coin compartment is sized according to the coin type (quarter, nickel, penny, dime), so that larger coins will be able to pass over a smaller coin's compartment. When a coin falls into its compartment, the IR sensor will trigger and the microcontroller will increment the coin counts accordingly.

The solenoids keep the coins from being dispensed unintentionally. To dispense a coin, we will quickly toggle the power to its corresponding solenoid so that the coin can fall into the collecting tray. We will repeat this process for every necessary coin. Once complete, the user can empty the device through its coin dispenser slot.

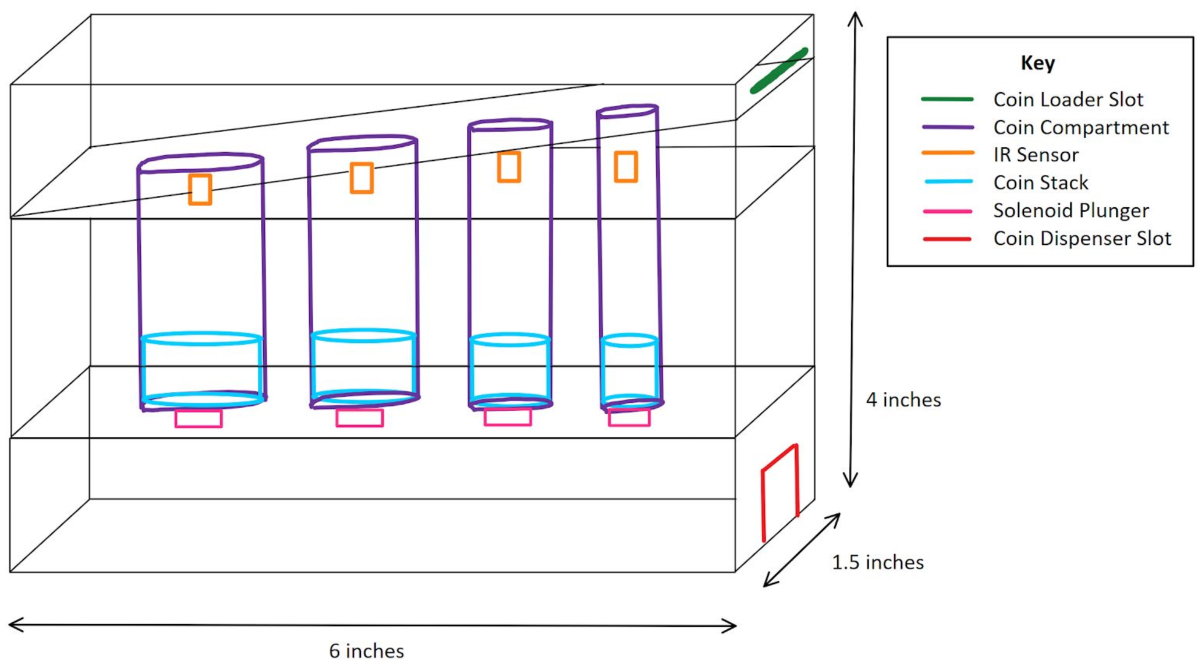

Figure 2.2. Proposed Pocket Pal Physical Design

2.3 Requirements and Verification Tables

2.3.1 IR Sensor

Requirement	Verification
IR receivers output 5.3 volts whenever a coin passes over the IR emitter, and will not output 5.3 volts unintentionally due to the push-pull mechanism of the solenoid moving coins up and down. Otherwise, it will output -0.3 volts. For the IR receiver datasheet, see [3]. The IR emitter is found at [4].	1. Measure the voltage of the IR emitter for each compartment, and ensure it is 5 volts and powered on. 2. Measure the voltage of the IR receiver and make sure it is -0.3 volts and powered on. 3. For one coin type, insert a single coin. 4. Measure the voltage output of the IR receiver for that coin type's compartment, and make sure the receiver outputs 5.3 volts when the coin passes over the IR emitter. 5. For the same coin compartment, supply maximum power to its solenoid at maximum voltage (5V). 6. Measure the voltage output of the IR receiver for the same coin compartment, and ensure the receiver never outputs 5.3 volts. 7. Repeat steps 1 through 4 for each coin type.

2.3.2 Coin Loader

Requirement	Verification
Loader sorts all four types of coins (quarter, nickel, dime, penny) with 95% accuracy.	1. Collect four coins of each coin type (16 total) and put them in a pile. 2. Grab a single coin at random, and insert it through the coin loader slot. 3. Repeat step 2 for the other 15 coins. 4. Count how many coins were successfully sorted into the correct coin compartment, and record the ratio of correct coins to total coins (e.g. 14 coins were sorted correctly, so the ratio is 14/16). 5. Remove all 16 coins from the device and put them in a pile. 6. Repeat steps 2 through 4 two more times. 7. Calculate the average percentage of all three runs, which is the value we will use to determine our coin loader's accuracy.

2.3.3 Battery

Requirement	Verification
Charging the battery at maximum current and voltage can be sustained below 85°C to ensure the user's safety	1. Power the battery at full capacity (5V) without limiting current 2. Measure the voltage across the battery and ensure it is running at 5 volts 3. Leave the battery running for 10 minutes. 4. Using an IR thermometer, check that the battery temperature is never greater than 85C.

2.5 Circuit Schematics

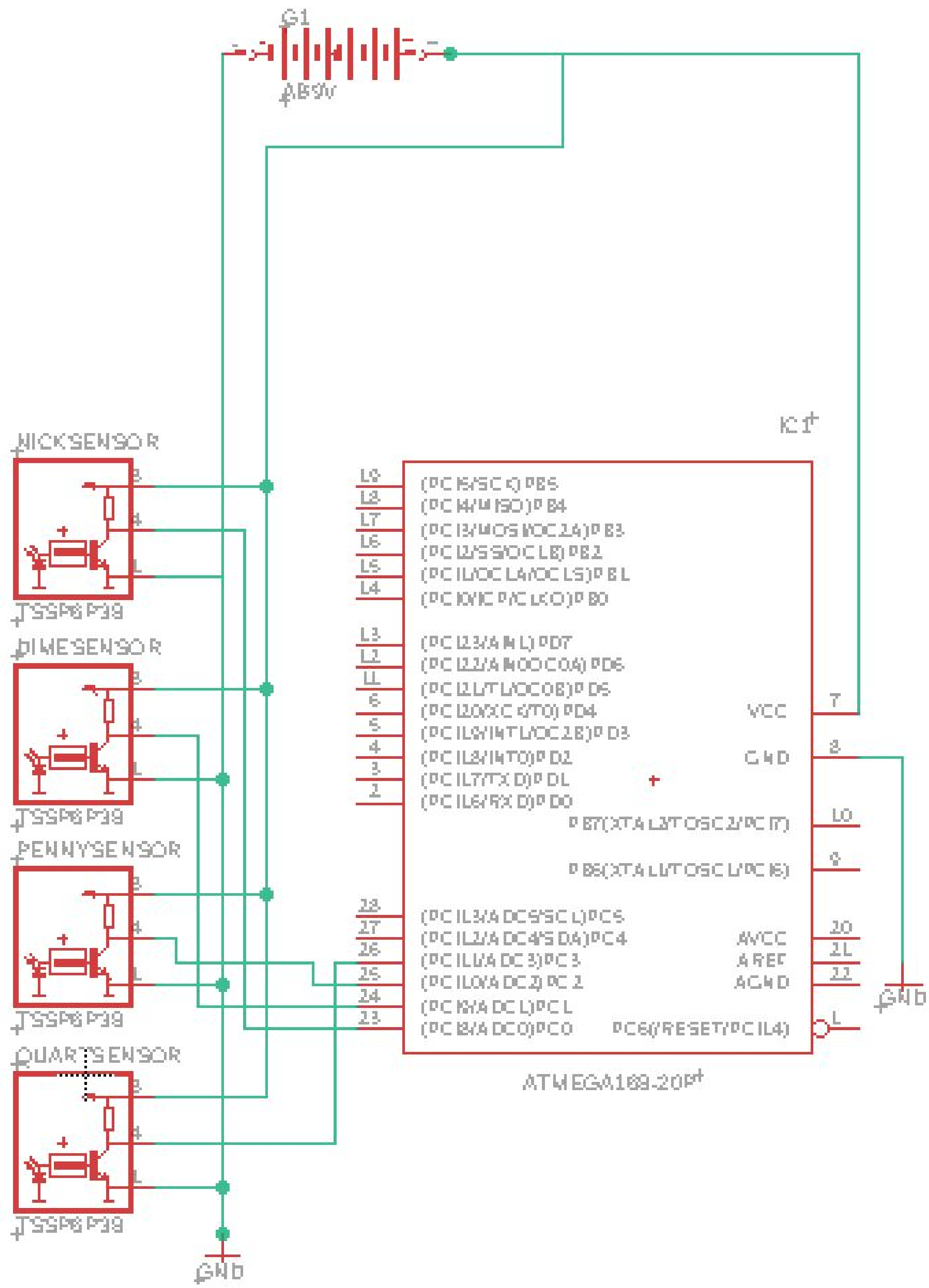

Fig 2.5. Circuit Loader Schematic Diagram

2.6 Tolerance Analysis

Our project primarily relies on accurate dispensing of coins through their respective coin compartments, i.e for an amount of $0.58 we would need 2 quarters, 1 nickel and 3 pennies. This accurate dispensing on coins is dependent on the force exerted by the solenoid on the coins. The throw (linear motion) of the solenoid has to be varied within the range **]0,35mm]** using current regulators to ensure only a single coin is dispensed through the coin compartment.

The following table shows the dimensions of coins and solenoids used in our project.

Solenoid Lead Length: 57 mm = 0.057 m   *Solenoid Stroke/Throw : 35mm = 0.035 m [6]*

Coins	Pennies	Nickels	Dimes	Quarters
Radius (m)	0.009525	0.010605	0.008955	0.01213
Width (m)	0.00152	0.00195	0.00135	0.00175
Surface Area (m^2)	0.00028502	0.0003533	0.0002519	0.0004622

Table 1 : Dimension of coins and solenoid [7]

The force exerted by a solenoid is directly proportional to second power of current flowing through it: $F \propto I^2$ as shown in Eq.1. As linear motion of the solenoid is inversely proportional to the force it exerts we need to regulate the current to hold/dispense coins of different width. The solenoids are connected to a microcontroller via a transistor and resistor, so we will be able to regulate the current according to the distance from tip of solenoid plunger (g), number of turns on the solenoid coil (N), and current flowing through it (I).

$$F = (N * I)^2 * \mu o * A/(2 * g^2) \qquad \text{-- Eq.1}$$

This design helps us achieve maximum accuracy (>95%) and efficiency (< 10 seconds) in accordance with our project requirements. However, a significant trade off with this design is the increased size of the device. Our initial design of Pocket Pal was 6” x 4” x 1.5”. However considering a solenoid - with a minimum stroke of 25mm (0.984 inches) - will be attached to the side of each compartment, our device will almost certainly be longer than 6” in length.

4 Safety and Ethics

There are a few safety concerns with our product. The first being comfortability. Wallets stay in the pocket for extended periods of time, so rough edges can hurt the user. The edges and corners will be filed. The material (cardboard) for the design will be soft and pose little harm when carried.

Second, there is a slight risk of the power supply malfunctioning and hot battery in pockets, especially during hot weather when the batteries will be exposed to more heat. To mitigate this risk, we are looking at efficient microcontrollers and other components that work accurately and operate with a low power consumption. This will also help reduce the risk of fire hazard caused by the battery. Lower power consumption and usage will reduce the risk of a hot battery in the pocket.

As stated in the IEEE code of ethics, we have a responsibility to "improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems." [5]. Through Pocket Pal, we will be able to showcase these capabilities by increasing the flexibility of coin usage for smaller payments.

Pocket pal will not distribute the collected information as per IEEE code of ethics 9, to avoid injuring others, their property and reputation [5]. We take privacy very seriously and will not disclose the amount of coins in the wallet.

5 Citations

[1] R. K. and S. O'Brien, "2019 Findings from the Diary of Consumer Payment Choice," Federal Reserve Bank of San Francisco, 26-Jun-2019. [Online]. Available: https://www.frbsf.org/cash/publications/fed-notes/2019/june/2019-findings-from-the-diary-of-consumer-payment-choice/. [Accessed: 19-Feb-2021].

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