Self-check Mailbox

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1 Introduction

1.1 Objective

The prototype of the mailbox was patented in 1858 by Albert Potts; it was only a letterbox that collects letters.[1] In 2020, the use of mailboxes is still prevalent in the world. Nowadays mailboxes can collect flyers, bills or small packages. Even though our delivery service has been greatly expanded and developed over the past 150 years, the mailbox is still the same compared with the ones in the old days: they are just a box with a lock. Users don't know when their mailbox would have new mail; they cannot tell what is in their mailbox without opening it. Most mailing services and online shopping websites only guarantee 2-8 days delivery and thus it is common to have delayed mails or delivery.[2] As a result, people have to open the mailbox regularly to check if there's anything new, especially while waiting for something important to be delivered.

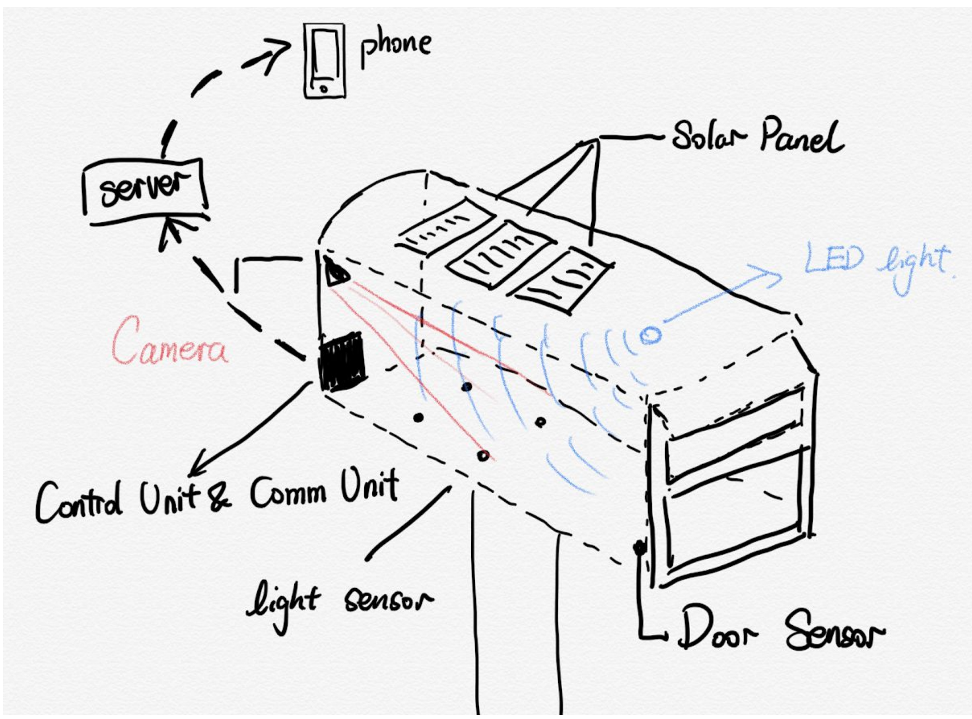
Our team thinks that this job is completely repetitive and can be replaced by a system with self-checking ability. Our system's goal is to detect new mails, take a picture of the mailbox's contents and notify users with the information collected by the system. The notification system will push to the user's phone or email address within 2 minutes of a new delivery. It will also attach a photo of the mailbox's inside to let users know what has been delivered. In addition, our design is incorporated with solar powering so this system can have self-sustained green energy for outdoor use.

1.2 Background

There's no product on the market now that has the exact same functionalities as our system does, but there are several similar ideas. The most similar one is the Amazon Locker, which could be found at the bookstore on the UofI campus. People could pick up their packages using QR code and get notified from Amazon App. However, the Amazon Lockers are not perfect; this hub is under the commercial operation of Amazon.com Inc; it's for Amazon users only. Also, people still have to go to the pickup location to pick their packages up. Another similar idea could be the smart doorbell, where there are plenty of choices on the market already. A smart doorbell usually includes a notification system and camera system; the main difference between our project and smart doorbell, however, is that we will automatically detect new delivery rather than let someone ring the bell for you. Also, we will use solar energy so that people don't have to replace the battery occasionally.

Hence, our goal is to build a personal and affordable system for home mailbox, which allows all deliveries to be easily checked, and users can have real-time notification from their mailbox within minutes.

1.3 Physical Design

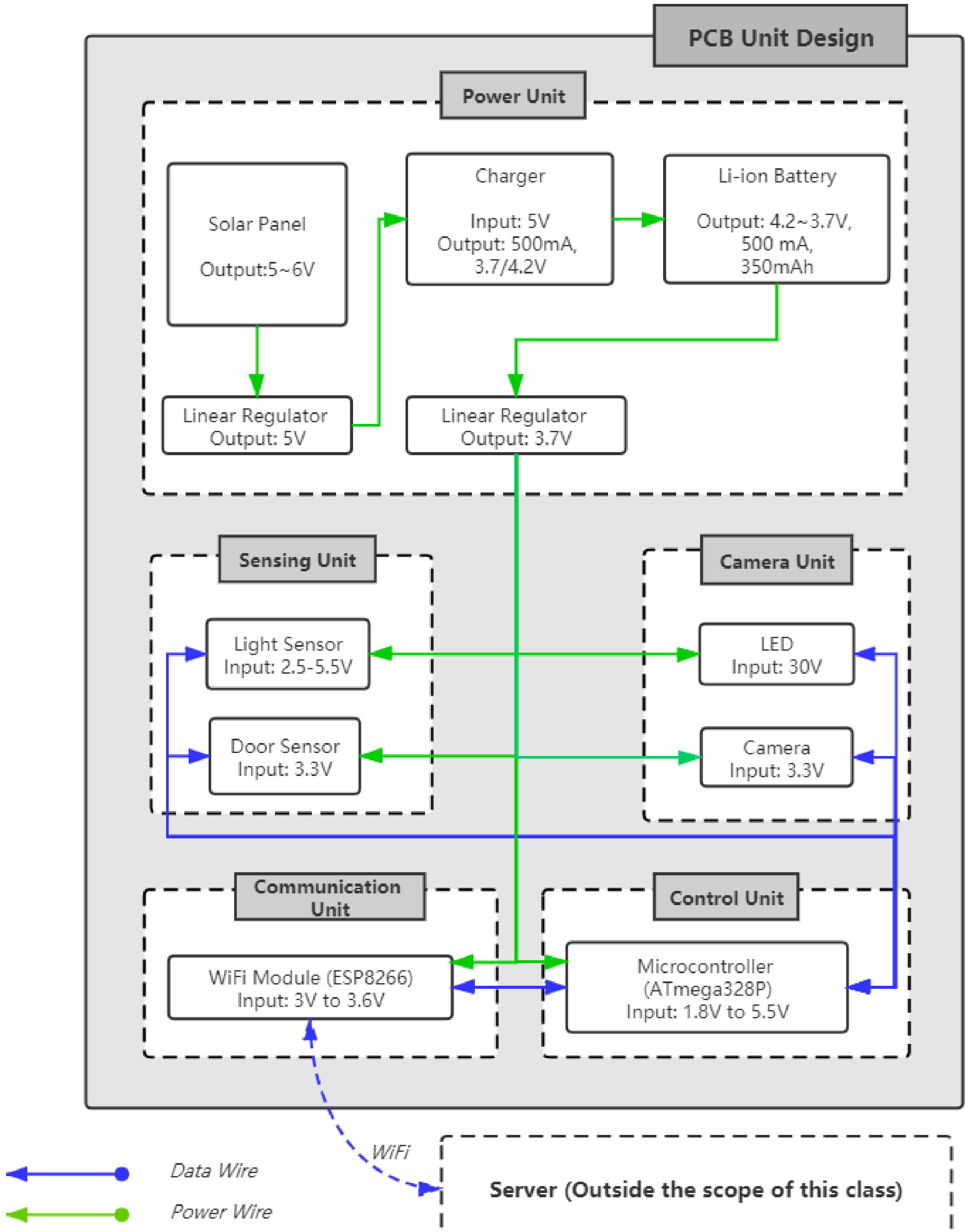


1.4 High-level Requirements

- The sensing system is real-time sensing, which can immediately respond, take pictures and send messages to users once new mail has been delivered within 2 minutes.
- This system's cost must be lower than most of the smart home devices, which are around $150. Our goal is to reduce its cost to at most $100.
- The battery unit can support the system to operate for at least 20 hours without solar panel charging.

2 Design

Block Diagram



2.1 Power Unit

Green energy will be used to power the functionality of the PCB board. We will charge a Li-Po battery using a solar panel and employ some voltage regulators to ensure stability and safety. This power unit will provide enough power to drive our system to run at least 20 hours without solar panel charging.

2.1.1 Solar Panel

As the most abundant energy resource outside, sunlight will be collected through a solar panel to charge the Li-ion battery, providing a voltage output to the voltage regulator and then get through the battery charger.

Requirement*: 0.5W minimum is required and we want to output around 6V, 330mA. Must be able to rewire with a mini-B USB driven connector to the battery charger.*

2.1.2 Voltage Regulator

Two linear voltage regulators will be used. One will regulate the voltage coming from the solar panel since the generated voltage will be fluctuating based on the sunlight intensity. As a result, we need to make sure that it won't exceed a certain maximum voltage. Another regulator will be deployed between the Li-ion battery and other units for stable voltage safeguards.

Requirement*: The regulator of the solar panel will regulate the voltage to 3.7V which is the input of the Li-Po battery. The regulator of the battery will regulate the voltage 5V which is compatible with all the electronic components.*

2.1.3 Li-Po battery

Our design of inbox energy consumption is small and Li-Po battery is generally safer than Li-ion. On the other hand, although Li-Po has a shorter lifespan, the solar panel will consistently provide sufficient energy while Li-ion batteries will suffer from aging problems, which we don't want users to change the battery very often.[3] Hence, we will use a rechargeable Li-Po battery to power our circuit.

Requirement*: The battery will provide around 300mAh and power the circuit without charging up to 20 hrs. 3.7~4.2V and 500mA at least are required for charging or discharging.*

2.1.4 Li-Po battery charger

The charger is specifically designed for Li batteries. We want to use a USB-driven charger to charge the Li-Po battery. We will redesign the configuration between the charger and our solar panel and put Voltage regulators in between to adjust the input and output. Based on our PCB's power consumption, around 0.7 hour will be enough to charge the battery.

Requirement*: 5V input via mini-B USB connector. It will be able to charge a 3.7/4.2V Li-Po battery, which will provide 500mA charging current.*

2.2 Sensing Unit

2.2.1 Light Sensor

This is the major sensor we will use for sensing new things in the mailbox. It must be able to receive light from LED in the Camera Unit, detecting the light condition inside the mailbox. If the condition has been changed, it means that a new delivery has arrived and should send a signal to the microcontroller.

Requirement:
The light sensor must be able to detect the light with the luminance of 162lm from the LED.

2.2.2 Door sensor

This sensor is used to detect whether the door for the mailman is closed or opened. It will send a signal to the microcontroller, activating the camera to be used shortly after. By using a door sensor, we can reduce the usage of camera, only activating it while necessary (when there's new action on the mailbox).

Requirement: *It should be sensible enough to send the signal as soon as the door is closed by the mailman.*

2.3 Camera Unit

2.3.1 LED

LED is implemented at the top inside the mailbox. It will be turned on for 5 seconds after the door(for mailman) is closed for both the light sensors to know if there's new mail delivered and for cameras to have enough illumination for capturing pictures.

Requirement: *The luminance of the light should be strong enough to be sensed by the light sensor. Luminance: 162 lm/W, Voltage input 30V.*

2.3.2 Camera

The camera is implemented at the top inside the mailbox. It will take the picture of the mail when received the signal of the light sensor.

Requirement 1: *Camera's image should provide enough details about the mailbox's content.*
Requirement 2: *It must be able to communicate in UART with the microcontroller(ATmega328P).*

2.4 Communication Unit

2.4.1 WiFi Module

The WiFi module should be capable of communicating with the server directly, taking the responsibility to send the photos taken to the server. To balance performance and cost in our design, we will use ESP8266 as our WiFi module for our microcontroller and communicate via 802.11b/g/n.

Requirement 1: *The WiFi IC should be able to set up WiFi hotspot mode over IEEE 802.11b/g/n and exchange data with the server.*
Requirement 2: *It must be able to communicate in UART with the microcontroller(ATmega328P).*

2.5 Control Unit

2.5.1 Microcontroller

The microcontroller should be powerful enough to process images from the camera and provide a real-time response within a 2 minutes period. To balance performance and cost in our design, we choose ATmega328P as our microcontroller. This is a

Requirement 1: *The microcontroller can communicate over UART with the camera and WiFi module.*
Requirement 2: *The microcontroller should finish image processing in less than 2 minutes.*

2.5.2 Server

We will use a Raspberry Pi as our server to push notifications and send photos to users. This Raspberry Pi is connected to the internet. We will write scripts on it to do everything automatically. How to setup this device is not in the scope of this class.

2.6 Risk Analysis

The solar power unit is a major risk for our system's completion. It is the most crucial part of our design, as it provides the only power source for our system. If this part fails, then our whole system will fail. There are a lot of real-world problems we have to take into consideration, including safe use and operating conditions.

Solar panel's charging ability is largely affected by uncertainties, so we have to design this part as robust as possible. Considering that light intensities change will vary the output of the solar panel, it's necessary to regulate the output voltage to be stable and strictly under 5V. Similarly, the regulation between the Li-Po battery and our PCB also has to be consistent. Otherwise, our PCB will be broken. Other problems like safety use are also important because batteries could be dangerous under wild use. We will put extra safeguards on our system such as linear regulators to ensure its safety.

3 Safety and Ethics

Our project's paramount goal is to provide users with a safe and reliable system. As a result, we will specifically focus on designing our system with many safety guarantees.

First, since the whole system is built for outdoor use, we have to consider some outdoor conditions including extreme weather, high moisture level, etc.. Scenarios like pouring rain and sultry weather are common these days that we have to deal with. These real-world factors could potentially interrupt our system's operation or reduce its lifetime reliability. To accomplish that, we will test that our system can work under harsh conditions varying from -15°C to 45°C and it can achieve at least IP66 water resistance level (resist to pouring rain).

Second, we will take special care with our battery. Scenarios like puncture, overcharge, overheating, etc. are everywhere. Li-ion batteries are generally more dangerous than Li-Po batteries in terms of accidents like leaking electrolytes and the most reported incidents occurred while the battery was charging. Hence our design of power supply will stay with Li-Po rechargeable battery.[4][5]

Safety is our paramount goal in our design, as the IEEE Code of Ethics says, "hold paramount the safety, health, and welfare of the public"[6]. Apart from safety, privacy is also our top concern. Our project involves collecting the privacy of users, including taking photos of the mailbox's content. In the IEEE Codes of Ethics, it says that "to avoid injuring others, their property, reputation, or employment by false or malicious action"[6], and we are strictly following that. The camera usage is also strictly limited to the content of the mailbox. Without infringing the delivery person's privacy, the camera should only keep record of the inside of the mailbox. In our design, we will not utilize these data for any other use; data will be kept locally, and only shared with the user himself/herself. Once a new record is sent to the user, our system will delete it permanently from the flash drive. However, even though we will try our best to keep the user's privacy safe, these data are still vulnerable if the server is being hacked or stolen. To avoid potential privacy issues, users shouldn't put the server in a risky environment.

This project will be developed under the BSD License 2.0[7]. As in the IEEE Code of Ethics, "to assist colleagues and co-workers in their professional development and to support them in following this code of ethics"[6], we will have minimal restrictions toward the usage of our design and code, and we encourage sharing and learning our project.

References

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