TO: Dr. Matthew Wettergreen
FROM: OwlCoin* (riceowlcoin@gmail.com)
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SUBJECT: Final Design Solution

Introduction and Motivation

Although cryptocurrencies have been around since 2009, utilization of this emerging category of currencies has been highly limited. Mainstream perspectives consider cryptocurrencies to be just another financial instrument, but the blockchain technology that underpins cryptocurrency operations can do much more than function as a currency - this emerging technology presents endless possibilities in the fields of cryptography, information security, and other data-based applications. However, the high level of knowledge required to understand and utilize cryptocurrencies remains the greatest barrier to entry to incumbent users. On this basis, our client, Erick Calderon, presented to us the challenge of designing a simple and intuitive device that could overcome this and other barriers to entry, and effectively introduce people to cryptocurrency mining. With this device, the spread of cryptocurrency could increase to people who would have never had the opportunity to learn about blockchain technology. OwlCoin has been successful in completing this challenge. In this memo, we will talk about the key aspects of our design solution, how they materialized in our final prototype, the results of our tests thus far, the strengths and weaknesses of the current design, and our plans for the future.

Overview of Design Solution

To accomplish our client's goal of increasing the use of cryptocurrency, we have created a device that is safe, easy to use, interest-generating, aesthetically appealing, and functional. We have created a device that requires little input from the user to operate.

Our design solution can be decomposed into three design blocks: the case, electrical components, and the software. For the case, to achieve the aesthetically appealing aspect of the design, we have designed a cylindrical coin-shaped case to house the components of the device (Figure 1). Secondly, in terms of electronics, our design solution will use a Raspberry Pi to mine the coins. It will also include an LCD display to display a balance and a physical button for the user to safely shutdown the device. Our final design block, centered on software development, is geared towards the creation of cryptocurrency mining scripts, bash (kernel) scripts to automate processes on the Raspberry Pi, and Python programs to interact with the hardware components of our device.

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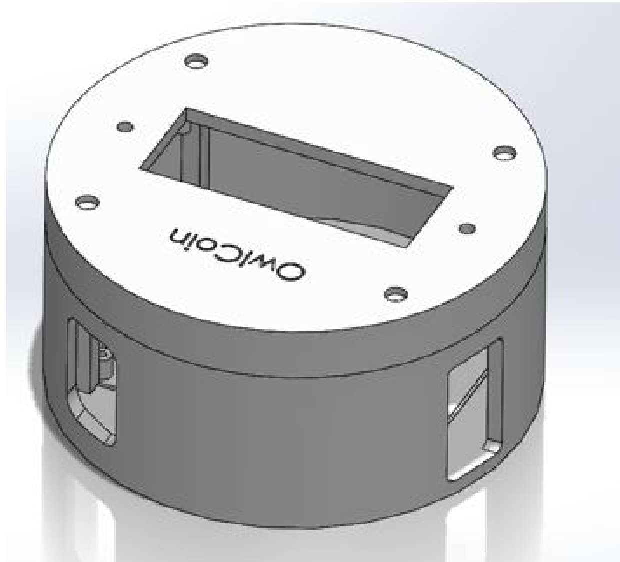


Figure 1. CAD of OwlCoin Case

The Final Prototype

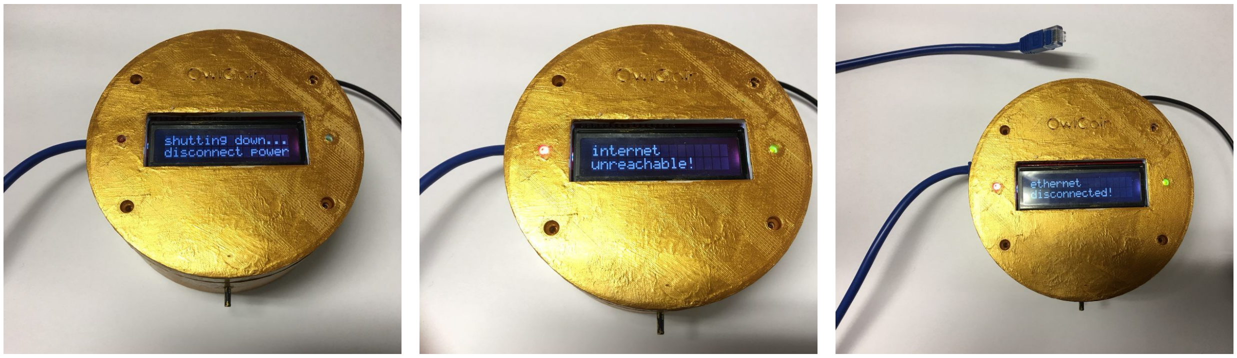
Thus far, we have created several prototypes to bring our design solution into fruition. We started with a low-fidelity prototype that focused on the case design block of our design solution, using low-cost materials like cardboard, popsicles, and tape. We then moved to a medium-fidelity prototype that lightly touched on each design block. With this prototype we wrote some basic scripts for the device, 3D printed a test case, drew out circuits, and wired the screen and LEDs to the Raspberry Pi. With our high-fidelity prototype, we focused on integrating all three design blocks. Now, we are at a final high-fidelity prototype that captures every aspect of our design solution (Figure 2). Our final prototype component is composed of a Raspberry Pi 3, 2x16 LCD display, Red LED light to indicate errors, Green LED light to indicate functionality, safe shutdown push button, 8GB micro SD card, Ethernet cable, DC power cable, housed in a 3D Printed Case.

Figure 2. Final Prototype: Screen with LED indicating lights (Left), Shutdown Push Button (Middle), and Ports for Power and Internet (Right)

Our final prototype was 3D printed with PLA filament. The coin shape is represented by a cylindrical design, and the case mainly comprises a top and bottom half. 3D printed pillars extend from the bottom half to the top half, which have screw holes for screws to fasten the top to the bottom half. On the inside surface of the bottom half, 3D printed standoffs secure the Raspberry Pi while elevating it to protect against blunt impact. On the side of the bottom half, there are openings for the power button, DC power cable, and ethernet cable. On the top plate, there are openings for the two LED indicating lights, the screen, and the screws that hold the overall assembly together.

Inside this case are the electrical components that allow the user to interact with the device. The hardware components include a push button that activates a shutdown script to safely shut down the device, a red LED light to display whether the device is experiencing an error, and a green LED light to display whether the Raspberry Operating System is running correctly. Other hardware components include the LCD screen which displays messages and a coin balance to the user, and the Raspberry Pi microcontroller that controls all the hardware components.

Running on the Raspberry Pi are the scripts that make mining possible, hardware scripts, and the wallet software. Currently, there are six main scripts: adafruitdisplay.py, update_display_asynch.sh, asynchleds.py, listen-for-shutdown.sh, listen-for-shutdown.py, and ledhandler.py. Adafruitdisplay.py handles writing data to the screen, update_display_asynch.sh figures out what data should be written and sends it to the adafruitdisplay.py script, asynchleds.py is a listener that receives inter-process signals and converts them into one of three LED states: blinking, off, and solid, ledhandler.py is used to send these inter-process signals to asynchleds.py, and listen-for-shutdown.py and listen-for-shutdown.sh start the update_display_asynch.sh script and shut down the device once the safe shutdown button is pressed (Figure 3A). The current state of the scripts is markedly different from our medium-fidelity prototype: now, only one script will ever interact with the LED, making certain that there are no issues of one script overriding another. Also, the screen now updates roughly once per second, meaning it will very rapidly catch errors and display relevant messages to the screen (Figure 3B and Figure 3C). This decision was implemented because it was previously necessary to wait up to 60 seconds before an error was detected and then another 60 seconds before the screen and LED were updated after the error was corrected. A visual cue of a moving asterisk (*) was also added to the display so the user would be certain the device was still functioning and not idly sitting there. Lastly, update_display_asynch.sh now uses owlcoind getbalance instead of comradecoind getbalance, as our client has launched our final cryptocurrency.



A B C

Figure 3. Shutdown and Error Messages on the display

The simplicity of our device manifests in a simple, three-step user operation process. First, the user must plug in the device to the wall and connect it to a local-area network using an ethernet cable. Secondly, the user must wait a maximum of 2 minutes for the device to start up. And, lastly, the user can sit back, relax, and watch the OwlCoin device mine cryptocurrency automatically! **(To see a demonstration of this, refer to the OwlCoin demonstration video on YouTube: https://youtu.be/EflcxropQAA)**

Key Testing Results

Functionality: Pass

- Design Criteria: Completes all functions 100% of the time.
- Four distinct functions: power on & off, start mining, stop mining, and display balance.
- Total of 10 power cycles, all 4 functions successful 10 out of 10 times.

Cost: Fail*

- Design Criteria: Total Cost < $50
- Total Cost: $62.70
- Cost-Saving Measures:
    - Screen cost $16, but equivalent screens can range as low as $5 (would require slight changes in physical design and programming.)
    - Cables bought individually were $9 total, but when bought in bulk, price becomes ~$3.
    - Roughly $5 can be saved buying Raspberry Pi and SD card in bulk.

Full detail on part prices and possible price saves can be found in Table 1 in the Appendix.

Our current prototype does not pass the cost design criteria. However, multiple realistic price saving options, especially when buying in bulk, will put any finished device under the $50 goal. The first two cost-saving measures alone would put us comfortably below the $50 level.

Our client understands that during production, costs will sink considerably, so he is not overly worried about our cost being elevated.

Size: Pass

- Design Criteria: <60 cubic inches volume, no side >7 inches.
- Diameter (longest side): 4.792 inches
- Height: 1.766 inches
- Volume: 31.85 cubic inches

All averaged over 16 measurements by two team members listed in Table 2 in the Appendix to ensure there was no inaccuracy in the digital calipers.

Weight: Pass

- Design Criteria: <1.36 kilograms (3 pounds)
- Total Weight: 0.16335 kilograms

Averaged over three separate measurements with range 1.27 grams.

Safety: Pass

- Design Criteria: No safety issues caused.
- Safety Experts: Danny Blacker and Fernando Cruz
    - "No chance of shortages or safety issues"

Strengths and Limitations

With all the hardware and software in place in our final prototype, we have successfully created a fully functional OwlCoin mining device. Having passed the size and weight tests, this device can be easily transported in a student or teacher's bag. Physically, the prototype meets our initial vision of being a coin-shaped mining device. It was judged to be safe to use by two OEDK lab technicians, and as it simply rests on a table for extended periods of time, we are confident that no one will be injured in any way by our device. The device responds to errors immediately so the user can correct them as soon as possible, and immediately updates once the error has been corrected. The device contains a safe-shutdown button which makes certain that no crucial data is corrupted if used correctly. The major limitation in our final prototype is the wiring inside our device. To secure electrical connections, our prototype uses perfboards, which is more practical than a breadboard but still more clunky than a printed circuit board. Should our device be manufactured on a large scale, printed circuit boards would be more economical and hence a viable replacement to the perfboard. Another limitation is the durability of our device. Our case is 3D printed with plastic filament which, while lightweight and cheap, is not the most structurally stable. We observed that one of our previous 3D printed prototypes had several dents after being dropped only a few times from table height. Should this device be manufactured on a large scale, we would suggest that more durable plastics be used. Finally, our client informed us that OwlCoin will eventually exceed the storage capacity of the SD card, as millions of transactions must be stored on each mining device to construct the blockchain. Once this happens, the operating needs of OwlCoin will exceed the limits of our current solution and our device will be rendered useless. However, our client estimates that this will happen in no less than a year, which we find to be reasonable from the perspective of a non-profit, educational venture.

The Future of OwlCoin

At this point, our device can be considered functionally complete. While optimizations can be made on certain aspects, such as cost, the current iteration of our device is reproducible and distributable if desired. Thus, our plan from here is to pass our final prototype and CAD designs on to our client so that he can begin his own series of tests and implementations in real world scenarios. We plan to keep in touch so that if Mr. Calderon has any reasonable requests for further improvements to the device, we can help him achieve those. The only tests we have yet to conduct are the durability drop test and the overall user interaction test. Given the amount of time left in the semester and the exams our team has to deal with, we do not find it feasible to complete these tests on our own. Luckily, these tests are simulations of real world scenarios, so the data our tests collect can also be gathered by our client's distribution of the product to users in the real world. Thus, rather than having plans to conduct tests in the future, we plan to respond to Mr. Calderon's own tests by aiding him in improving the device as is necessary.

Video Demonstration: https://youtu.be/EflcxropQAA

Appendix

Table 1. Prices (unit and bulk) for each part used in final prototype.

Part	Raspberry Pi	SD Card	16x2 Char. Screen	Assorted Cables	3D Printer Filament
Price (Unit)	$30.00	$9.00	$16.00	$6	$1.70
Price (Bulk)	$27.00	~$7	$5-7	~$2	Unknown

Table 2.Measurements of dimensions.

Measurer	Diameter					Height		
Zachary	4.792	4.791	4.788	4.791	4.794	1.768	1.771	1.781
Corrin	4.795	4.797	4.792	4.790	4.793	1.765	1.766	1.779

Testing Procedures

Test 1: Safety

The potential safety risks of our device can be simplified into a few main components: exposed wiring that can cause electric hazards, sharp edges that can hurt the user, and the possibility of broken screen fragments detaching and cutting users' fingers.We want to have no major injuries caused as shown in Table 2, so we have mitigated the risk of exposed wiring by placing all wiring entirely inside the case. We created a cylindrical case to deal with the possibility of sharp edges, as there are no pointed edges on a cylinder. The screen could shatter if the device was dropped, and then the screen could become a safety hazard, electrically and because of sharp edges. We are attempting to design the case to minimize the possibility of shattering the screen. It is impossible to accurately measure the number of injuries this device will cause in the next year given we have only a month in which to work, so we as a surrogate measurement we will ask 2 experts to evaluate our device. We have tentatively selected Danny Blacker (or one of the lab techs) and our faculty mentor Dr. C. Sidney Burrus to evaluate our device, both in terms of the issues we listed and anything else that we might missed. These two are well-versed in the practical and theoretical aspects of electrical engineering, and so are some of the best people we have on hand to evaluate safety.

Test 2: Functionality

In order for our device to be used, it must be able to perform its basic functions consistently without fail. We have identified 4 core functions: it can be powered on and off, it can mine cryptocurrency, it can start and stop this mining, and it can display the cryptocurrency balance.

1. To test whether the device can be powered on and off, the device must be able to draw power and to boot the operating system on the Raspberry Pi. In order to test this, the device will be connected to a power supply. If the message "booting up…" appears on our LCD screen, that means the operating system has successfully loaded, and the test is successful.
2. To test whether the device can mine cryptocurrency, a computer must be connected to the Raspberry Pi using the ssh protocol. If the command "owlcoind setgenerate true -1" does not write anything to the standard error file, the test is successful.
3. To test if the device can start and stop mining, a computer must be connected to the Raspberry Pi using the ssh protocol. If the commands "owlcoind setgenerate false" followed by "owlcoind setgenerate true -1" both write nothing to the standard error file, the test is successful.
4. To test whether the device can display the cryptocurrency balance, the tester must boot the device, and then wait for 10 minutes. If a balance appears on the LCD screen at any point, the test is successful.

Each one of these functions will be tested 5 times by a member of our team. Since these are essential functions of the device, a single failure on any test means the device fails the entire test.

<u>Test 3: Durability</u>

We want the device to remain fully functional with no repairs required for at least a year, as in Table 3. It is not possible to test this directly, so a surrogate method was devised. We decided that a drop test would be best, as the device is almost entirely passive, with the only potential for damage coming from user error. In the course of standard use, we estimate that the device will be dropped from table height, estimated as 3 feet, once a month; therefore, we decided that we should drop the device 12 times from three feet to simulate a full year of use. In each test, the device will be dropped from a random angle to simulate the many possibilities of how the device may fall. After each drop, we will run through all 4 of the functionality tests. In order for the device to pass, it must be fully functional after 12 drops.

<u>Test 4: Ease of Use, Interest Generation, Aesthetic Appeal</u>

Since all three of these design criteria are based on user-defined scales, we need an integrated test of potential users using the device to allow them to accurately respond to our questions. Our device needs a specialized environment that we have created in the Oshman Engineering Design Kitchen (OEDK) to connect to the secure Rice wired internet, so we will need to bring students to our group table to conduct these tests. We will survey each student using our three user-defined scales: Ease of Use, Interest Generation, and Aesthetic Appeal.

Rice students are ideal test subjects because the intended users of this device are high school and college students around the country. Rice students come from diverse backgrounds and cultures as well, so Rice students are an indicative sample of our end users.

First, we will poll the users to see if they find the device aesthetically appealing, using the user-defined scale for aesthetic appeal found in Table 6. One team member will show the user the user-defined scale, and will verbally ask the subject what level on the scale most accurately describes their experience. To pass, we need an average score of 3.5 or greater on the user-defined scale.

Next, we will provide the user with a manual of common problems and a disconnected device, as it would be coming out of shipping, and observe how long it takes to learn all functions. We will have a group member timing with a stopwatch, and the user will be told to stop once he or she gives up or is able to explain the number on the screen, how to properly power off the device, and how to connect the device to a power source. Scores for the device will be assigned based on our user-defined scale for Ease of Use (Table 4). To pass, we need an average score of 4 on the user-defined scale, indicating the average user masters all functions in about 10 minutes.

If at this point the device is not fully set up, one team member will complete the set up for them. Next, we will show each our user-defined scale for interest generation, and verbally ask them which level most accurately describes their experience. To pass, we need an average score of 3.5 or greater on our user-defined scale (see Table 5).

Altogether, each test will take roughly 10-30 minutes depending on the speed of user setup. Only one team member needs to facilitate at a time. Because this test encompasses both of our most important design criteria, we want to be very thorough in our testing. These measurements are surrogate and constructed, meaning there is a lot of variation likely among users. To minimize the effects of this, we need a sizable amount of test subjects, and we chose 30 because that is a well-established rule of thumb for surrogate, constructed measurements. However, it is very likely that time constraints will limit us to only 20 tests. Either way, we will have enough information to determine whether we have passed each of the three tests.

Test 5: Cost

The cost must be calculated based on the price of the components used. We have used the following:

- Raspberry Pi 3
- LED

- LCD screen
- 8 GB SD card with Raspbian installed
- 2 breadboards
- 15 jumper cables
- Push button switch
- 3D printed case
- Gold foil, sealant, and adhesive

Each part listed above has a retail value except for the printed case. For this, we can utilize the 3D printer's meter of how much filament is used to print any given project. Since we know the cost per meter of filament, we can then determine how much the case cost. To test whether our cost is less than $50, a cost should be obtained for every component. If the summation of these costs is less than or equal to $50 after two separate verifications, the test is successful.

Test 6: Size

Since the device is meant to remain on a table top while hooked up to a computer, we want to minimize its size. One of our team members will perform this calculation by measuring the inside diameter and the height of the device and calculating the total volume using the equation $V=\pi r^2 h$. One other team member will verify that the calculation is correct by independently measuring the diameter and height and performing the volume calculation. If both volume measurements are less than 60 cubic inches, and both diameter measurements are under 7 inches, the device has successfully met this design criteria.

Test 7: Weight

For weight, we decided that ideally, the device would weigh 60 grams or less. To find the weight, two of our team members will perform a calculation using two different analytical scales. If both measured weights are less than 60 grams, the test is successful. If only one test measures a weight less than 60 grams, the testing should be repeated until either both measurements are greater than 60 grams or less than 60 grams.