ECE445

Senior Design Lab
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Final Report

Chip dispenser

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Abstract

An automated chip dispenser for academic institutions that offer hardware courses is designed, implemented, and evaluated in this report. By automating the distribution of integrated circuit chips to students, the machine reduces staff's manual workload. Our design consists of a power system, a control system, an actuating system, and a sensor system. There is a 12V power supply for the actuation system and a 5V battery for the control and sensor system. A keypad is used for user input and two LCD screens are used to display chip inventory status and user commands. Chips are dispensed by solenoids, and chip drops are detected and counted by lasers. Through extensive testing, we verified the functionality and reliability of our design. Despite the system dispensing the correct number of chips with over 90% accuracy, chip counting accuracy was lower than desired due to factors such as chip orientation and sensor sensitivity. There is room for improvement in these areas. $10,970 was the total cost of the project, including labor and materials.

Content

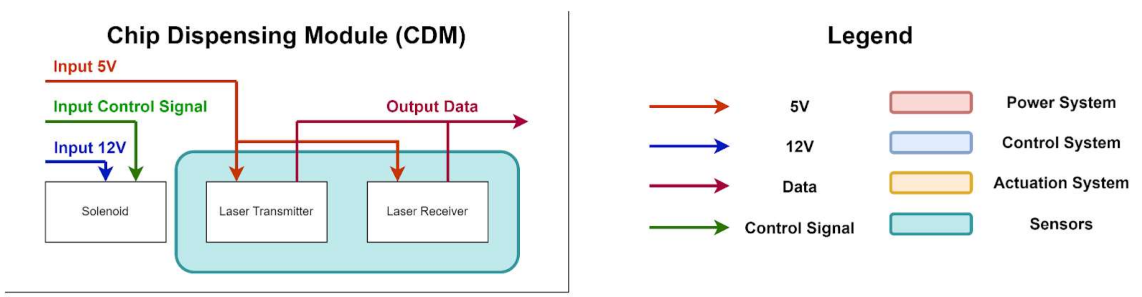
1. Introduction

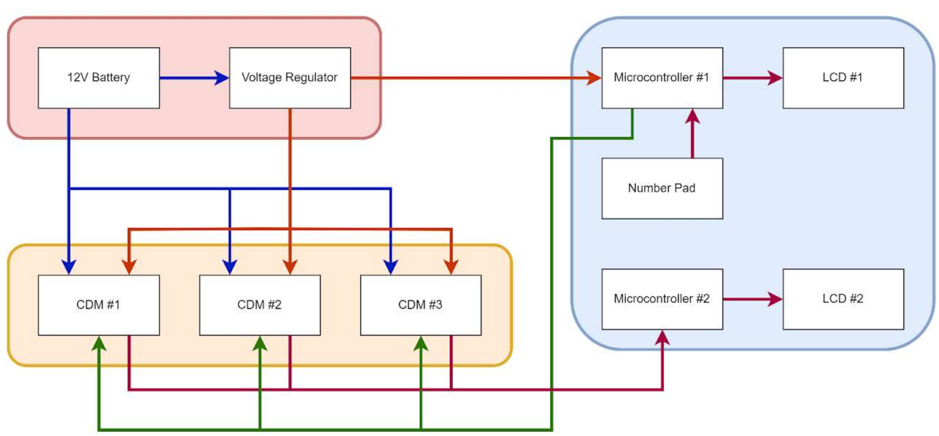
During our brainstorm stage, in the conversation with staff in University of Illinois at Urbana Champaign (UIUC in the following content) ,Electronic and Computer Engineering (ECE in the following content) department supply center, it was found that manual chip distribution existed. In courses like ECE 385 and ECE 210, students will receive a box of hardwares including integrated circuit chips (chips in the following content) with a certain number of each type. Considering all the courses in UIUC ECE department that required chips, chip distribution could become tedious work. Making a machine that could automate this work is our goal in the project design. Accordingly, universities or colleges with hardware courses that require chip distribution are our targeted customers.

2. Outline of the Chip Dispenser

2.1 Introduction

The project is mainly divided into four parts: Power system, Control system, Sensor system, and Actuation system. The power system consists of a 12V power supply and a 5V battery. The 12V power supply is connected to the actuation system to drive the solenoids to dispense the chips, while the 5V battery powers the control system, including the LCDs and the sensor system. Originally, we planned to use a voltage regulator to provide the 5V, but in practice, we simply used the output voltage of the Arduino board. For the control system, we have a num pad, two microcontrollers, and two LCD screens. The num pad is used to let the user input the bundle of chips they want from the dispenser. One LCD displays the bundle of chips input by the user, and the other LCD shows the chips remaining in each tube. The two microcontrollers connect one LCD to the num pad for user input, and the other to the sensor system to monitor chips remaining in the tube, respectively. For the actuation system, we have solenoids, which push the right amount of chips into the container after receiving the signals from the control. Finally, for the sensor system, lasers and their receivers are placed in such a way that they can detect chip drops and send signals back to the control system for the LCD to display the remaining number of chips.





Some key changes have been made to the project since the proposal. The lasers were originally designed to be placed close to the bottom of the tubes to detect if there is any chip remaining in the tube. However, that might not provide enough information about the current state of the tubes to let the user know whether their need would be fulfilled. Therefore, we redesigned the lasers to be placed at the slots where the chips drop, and by detecting the movement of the chips through the slots, the sensor system gives feedback to the control system and displays the information of the current state of the tubes on the LCD. Also we have found it quite inconvenient to drive both the sensor system and the actuation system with one microcontroller because the combined operation of the two systems is not linear, we decided to add another microcontroller to the dispenser to make things run more smoothly and accurately.

High-level requirements for each block are listed below:

Power system: The capacity of the battery needs to sustain the dispensing process at least 20 times with every component of the system working correctly.
Control system: The system should hint to the user about the current state of the system with 98% accuracy (input mode, output mode, or halt).
Actuation system: The system needs to achieve at least 90% accuracy during 10 consecutive dispensing processes.
Sensor System: The system should be able to hint to the user about the number of remaining chips for all three types of chips with 90% accuracy.

2.2 Design

The most difficult aspect of the dispenser system is keeping the granules at the bottom of each tube. Standard IC circuits have U-shaped channels. The contacting surface of each crystal on the pedestal is not spherical. As a result, chips may collapse and become trapped beneath other chips. This could bring down the entire dispensing system. To prevent this from occurring, we must evaluate the chip-tube elevating height, platform surface texture, and solenoid pushing speed. Combining a rugged and smooth platform surface with a specific hoisting height is likely to yield the best results. Prior to achieving our ultimate objective, the chip that descends from the conduit must be as straight as feasible. Second, the solenoid must place one single chip on the holding wall. After the final ship has been eliminated, the second-to-last chip must land on the platform without rebounding. These three stages must be executed without hiccups.

Power consumption: The solenoid and number pad are the only components in our design with significant power consumption. Other components, such as the laser transmitter and receiver module, microcontroller, and pushbutton, have a mW power consumption.

The nominal capacity of a typical 12V alkaline battery is 720 milliwatt-hours. The actuation system will consume the most energy, as it will operate for less than three seconds per execution (dispense the intended combination of chips only once). The total power consumption of twenty iterations will be less than 8.5 watts times three seconds times twenty, or 141 milliwatt-hours. Thus, 1 standard 12V alkaline battery (720 mWh) should be sufficient to power 20 iterations.

Component	Approx. Power / W	Reference
Solenoid	2.5 * 3 = 7.5	[2]
Number Pad	0.5	[3]
Low Power Devices	< 0.5	Laser[4]
Total	< 8.5	

Table 1

The circuit design focuses mainly on the actuation system. Each of the solenoids is controlled by a MOSFET, whose G is connected to the microcontroller to receive the on/off signal. In practice, we found it was useful to add a capacitor of 100uf to each of the solenoids to boost their working power in order to better dispense the chips and stabilize the system, because the higher the working power, the faster the chips get pushed from the bottom, and chips remaining in the tube can fall down more stably. The coding part was all implemented on arduino. Two parts were most evident, one that controls the num pad to its corresponding LCD, and the other controls the laser receiver and its LCD. We have tried to put the two parts together, but the only way to do it was to use the interrupt function, which takes too much computation power of the arduino and sometimes leads to error in detecting the chip drops. As a result, we decided to use two separate microcontrollers each controlling one subsystem.

3. Verification

3.1 Power system

From the design document, the requirements for power system are as follows:

Requirements	Verification
• Requirement #1: The voltage regulator must be able to supply the correct voltage to the control system, actuation system, and sensors during the dispensing process.	• Make sure there is no malfunction during full load and no load. The output of the voltage regulator should be 3.3V(+/-0.2V) measured by an oscilloscope. Also, test if each component can be sustained with stable power during the 10 consecutive tests.
• Requirement #2: The capacity of the battery needs to sustain the dispensing process for a normal chip dissipating job of faculty.	• The power system needs to sustain the dispensing process at least 20 times. The voltage that reaches the solenoids during and after the test should be in the range of 10V-12.5V.

Table 2

The test was done with 20 cycles. In each cycle, a solenoid pushed twice. The voltage reached the solenoid and from the voltage regulator were measured with an oscilloscope in the following chart.

Test number	1	2	3	4	5	6	7	8	9	10
Solenoid voltage (V)	12.1	12.1	12.0	12.1	12.1	12.0	12.1	12.1	12.1	12.1
Regulator voltage (V)	3.3	3.3	3.3	3.4	3.3	3.3	3.3	3.3	3.3	3.4

Table 3

Test number	11	12	13	14	15	16	17	18	19	20
Solenoid voltage (V)	12.1	12.1	12.0	12.1	12.0	12.1	12.1	12.1	12.1	12.1
Regulator voltage (V)	3.3	3.3	3.2	3.3	3.4	3.3	3.3	3.3	3.3	3.3

Table 4

Based on testing data, we can conclude that the power system did accomplish the design goal and maintained the desired voltages in certain ranges.

3.2 Actuating system

3.2.1 Solenoid

The requirements for storage subsystem and dispensing subsystem from the design document will be verified in this section. The requirements are as follows:

Requirements	Verification
• Requirement #1: The tube can be easily placed and secured in the intended position.	• The tube can be smoothly placed and secured in the intended position in less than 30 seconds.
• Requirement #2: The counter should display the correct number of remaining chips with at least 80% accuracy.	• During the test for requirement #1, keep a record of the remaining chips. Check if the system can correctly display the number of remaining chips with 80% accuracy.
• Requirement #3: The system must correctly dispense the intended amount of chips. It is important to dispense chips smoothly without getting stuck.	• Pressure tests the system using three complex combinations of chips. For instance, try (2,3,1), (3,3,4), and (1,2,4), where each number in the tuple represents the quantity of each chip. The system's reliability can be proved when the system can correctly dispense the three combinations of chips.
• Requirement #3: After falling out of the dispensing system, over 90% of all chips should remain undamaged.	• LED chips will be used for verification. The test requires 20 function chips to be outputted by the dispensing system consecutively. At least 18 chips should remain functional (could be lit up as designed).

Table 5

6 groups of tests of reloading 20 chips and checking for chip count after reloading were done to verify **requirement #1 and #2**. Note that chips were pre-arrange before reloading. Reset button needs to be pushed manually after reloading. The data is as follows:

Test number	1	2	3	4	5	6
Reloading time (s)	23	26	20	25	20	24
Chip count correctness	Correct	Correct	Correct	Correct	Correct	Correct

Table 6

Due to physical condition, we only made one complete chip dispensing module (CMD) as stated in the block diagram. The following tests were performed on this single CMD module and 2 resting solenoids (without physical setups).

To verify **requirement #3**, together with **high level requirements for power and actuating systems**, 3 testing sizes (20,30 and 40 chips) were used. In each size, a designated number of chips were loaded. Three dispensing configurations were used: dispensing 1, 2 and 3 chips at a time. 40 dispensing processes were done on each dispensing configuration together with each testing size. Overall, 360 dispensing processes were done. The result is as follows:

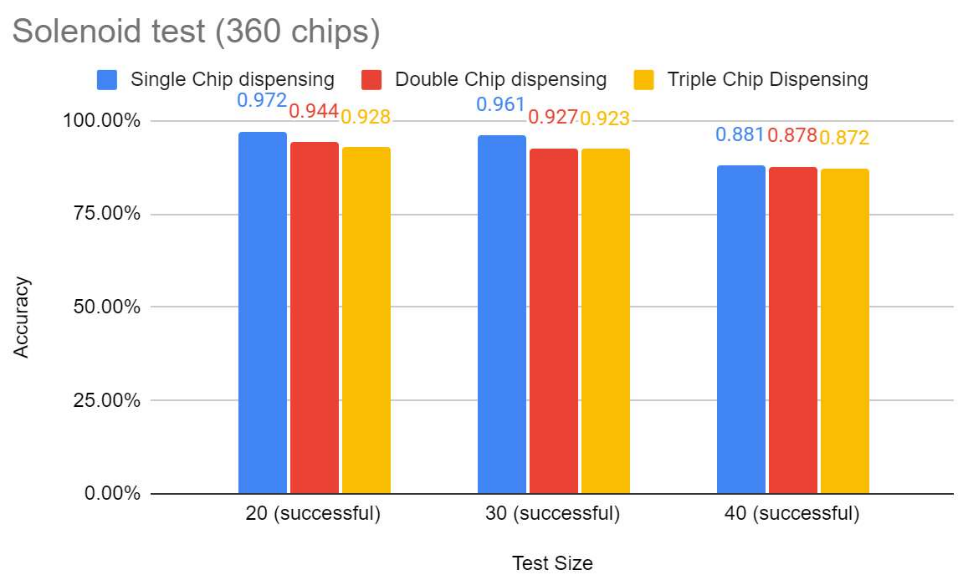


Chart 1

It can be seen from the graph that all dispensing configurations for 20 and 30 loading sizes achieved over 90% accuracy. Requirement #3 for the actuating system, high level requirements for power and actuating systems are accomplished.

To verify **requirement #4,** chips TL082 (op amp) were used. We used the following circuit to test if op amp chips were damaged.

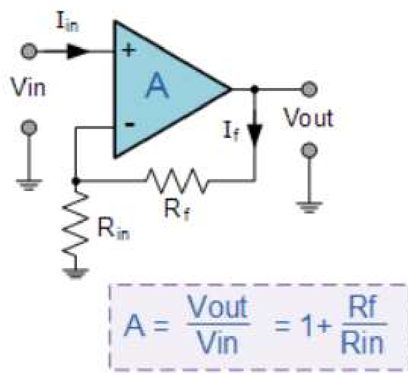


Chart 2

Rin and Rf were chosen to be 220 Ohms. Vin was set to be 1V. Vout was measured to calculate the op amp gain. If an op amp remains undamaged, the gain should be close to 2.
20 pre-tested op amps were pushed by solenoid. The gains for each chips calculated are as follows:

Chip number	1	2	3	4	5	6	7	8	9	10
Gain	1.9	1.9	2.0	2.0	2.0	1.9	2.1	2.0	2.2	1.9
Chip number	11	12	13	14	15	16	17	18	19	20
Gain	2.0	2.0	1.8	1.9	2.0	2.0	2.0	2.0	2.1	2.2

Table 7

Based on the table, we can conclude that 20 out of 20 chips remained undamaged after the dispensing process. The actuating system requirement #4 is fulfilled.

3.2.1 Laser sensor

The verification for sensor's high level requirement was done under the same configuration as for actuating system requirement #3 in section 3.2.1. 90 dispensing processes were done on three different loading sizes (20,30 and 40 chips). The results are as follows:

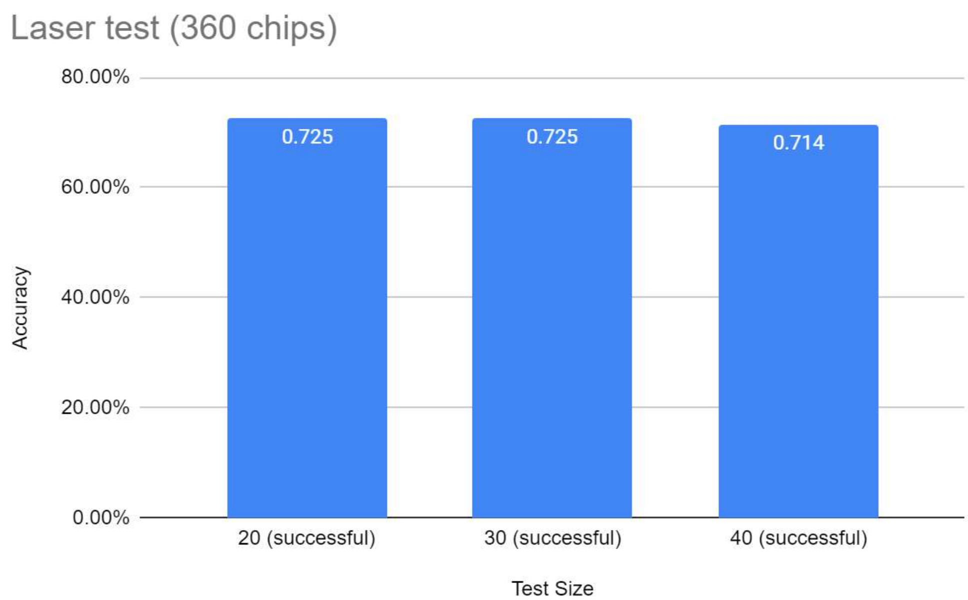


Chart 3

The highest accuracy (72.5%) we achieved for laser sensors was under 20 or 30 loading size. It is lower than 90% accuracy as listed in high level requirements. We consider chip orientation and sensor sensitivity to be mian factors for low accuracy. More detailed reasons and further improvement are demonstrated in section 5.2.

3.3 Control system

The criterias stated in the design document for control system or user terminal is as follow:

Requirements	Verification
• Requirement #1: The system must correctly handle the user input by dispensing the correct amount of chips with at least 95% accuracy.	• Verify using the simulation. For instance, input (2,3,1), and check the simulation of the microcontroller to determine whether the corresponding pulses are generated. Make sure the 98% accuracy with 10 consecutive tests.
• Requirement #2: The terminal should hint to the user about the current state of the system (input mode, output mode, or halt).	• During the test for dispensing the system, check if the LED is correctly showing the current state of the system. (See Sect. 2.2.2 Verification)

Table 8

For requirement, instead of simulation, we checked the number of times solenoid pushed in each dispensing process and compared that with the setup. Instead of using LEDs to notify the current state of the system, we used an LCD screen to show this information. The verification was done under same setup as for actuating system requirement #3 in section 3.2.1. The results are as follows:

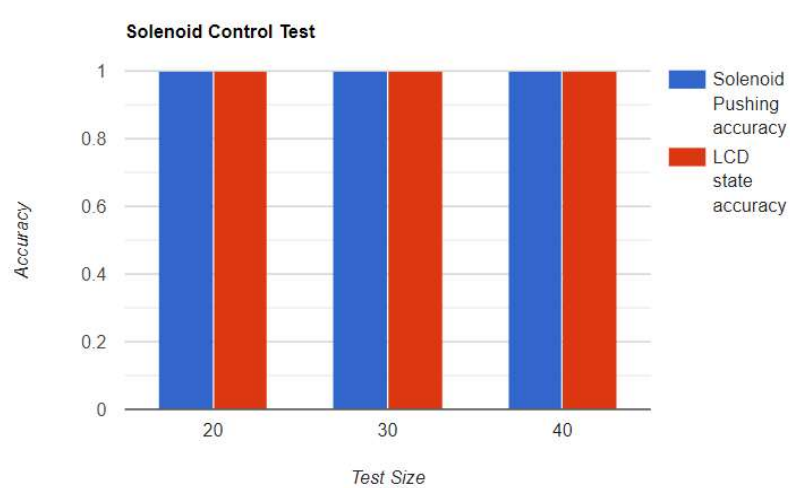


Chart 3

Under 360 tests, the solenoid pushing accuracy and LCD state accuracy were 100%. Our design goals for the control system were accomplished.

4. Costs:

4.1. Cost for components:

Component	**Quantity**	**Cost**
Solenoid[5]	**5(1 pack)**	**13.58**
battery[6]	**5**	**5.99**
Num pad[7]	**1**	**16.99**
Laser beam[8]	**3**	**32.97**
Laser receiver[9]	**5**	**10.99**
Microcontroller[10]	**1**	**28.5**
7-segment display[11]	**10**	**8.99**
Others	**Unknown**	**30.0**
	Total	**148.01**

Table 9

4.2. Cost of labor

Suppose the salary of a UIUC ECE graduate is $40/hr and one team member needs to devote about 15 hours to the project every week: $40/hr * 15 hr/week * 6 weeks * 3 (members) = $10,800.

4.3. Total cost

Suppose the shipping fee and sales tax combined with being 15%, the cost of components will be $148 * 1.15 = $170. Thus, the total cost of this project will be $170 + $10,800 (labor fee) = $10970.

5. Conclusion

5.1 Summary

Overall, it could be said that we accomplished most of our design requirements. After verification, users could enter and change the system configuration as wanted. Users could receive the wanted type of chips with over 90% accuracy. On the user terminal, notification for the number of chips remaining is not precise (72.5% under 20 chips load configuration). Since the project purpose is to distribute chips, though the chip counter could be useful for staff to reload, the correct number of chips sent out is our primary focus. Consequently, we consider the project fulfilled our motivation as described in the introduction section (section 1). With the help of our chip dispenser, staff in the supply center could free themselves from tedious ship selecting work.

5.2 Further Improvement

- Firstly, the power supply system could expand its output. 12V and 200mA is its current limit. Increasing the current output to 1A could enlarge the selection of solenoid types that fit for different chips. For example, LED chips weigh more than normal IC chips and require more powerful solenoid.
- Secondly, the actuating system could be improved in three ways.
  - Replacing the solenoid with a more powerful one could decrease the possibility of chip stucking at the bottom of each chip storage tube. Thus, the dispensing accuracy could get increased.
  - Changing the orientation of the chip storage tube could facilitate the laser detection process. In our current design, the lazer sender and receiver are placed to detect the thinnest side of chips. If the tube could change its orientation to detect the main top large surface of chips, the detection accuracy could be improved.
  - Replacing the sensor type could make the chip counting process more accurate. In our design, due to problems including chips flying too fast in air and chips not covering the whole laser beam, chip counting accuracy did not accomplish our design requirement. Replacing laser sensors with weight sensors could solve these problems.
- Thirdly, adding more slots together with a mechanical cover could make our design more practically useful. In the real scenario, more than 20 slots could be needed to cover all types of chips used in hardware courses. A mechanical cover could reduce the risk of flying chips and laser beams.

5.3 Ethics

The highest voltage used in the project is 12V. It is safe for humans to touch by hand without protection. The laser beam could cause possible blindness if it shines directly into the eye. The solenoid has a similar risk of pushing chips into the eye. With the protection of mechanical cover as described in further improvement (section 5.2), the risk of laser and solenoid could be ignored.

After verification, the power supply is reliable and can last for more than 360 solenoid push cycles. The dispensing system is reliable to use as it achieves our design accuracy. The chip counting process reflected on the user terminal could produce misleading information. Without further improvement, the user should pay attention to the actual number of chips in the storage tube and refill them when empty.

Reference

https://www.ti.com/lit/ds/symlink/tlc080.pdf (op amp)

https://www.electronics-tutorials.ws/opamp/opamp_8.html (op amp testing)