Electronic Drawer Organization System

ECE 445: Design Document

Group # 11

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1 Introduction

1.1 Problem Statement

One of the most important factors in productivity is the level of organization a person has in their workspace. The quickness and ease with which someone can find the tools or paperwork they need to do a job has a meaningful impact on the time the actual job takes. Currently, this is an area of the workplace that needs improvement, as 28% of office workers say they would save an hour every day if their workspace was more organized [1].

Perhaps the most common method of office organization involves drawers or cabinets of some kind. The issue with this method occurs when people forget which drawer they put a certain item in. Then, when they need to find it again, the best case scenario is that they have to open multiple drawers to find the one item they are looking for. The worst case scenario is that they don't find the item at all. This could very easily occur in someone's dresser or nightstand, but it becomes even more of an issue when in an environment with many tools or files stored in a large number of drawers, such as a restaurant kitchen or a big file cabinet.

1.2 Proposed Solution

The proposed solution allows a user to automatically 'open' the drawer containing the item they wish to find. This is done by using a smartphone app as a user interface where the desired item can be selected. Once the user chooses an item on the app, the smartphone communicates this choice with a micro-controller via Bluetooth. This micro-controller stores each drawer item with its corresponding drawer pair, and once it receives the item selection, it will optionally flash an LED on, open, or unlock the desired drawer. In this way, the user is always able to find the drawer containing their item with minimal rummaging and searching.

Some more specifics for the functionality of the drawer system might help make the system a little more clear. The drawer will be opened by controlling a linear motor that will push the drawer open. The locking mechanism for the drawer will be a solenoid that will drive a metal pin into a slot in the drawer to lock, and retract to unlock. The LED will be mounted on the front of the drawer system for maximum visibility.

1.3 Visual Aid

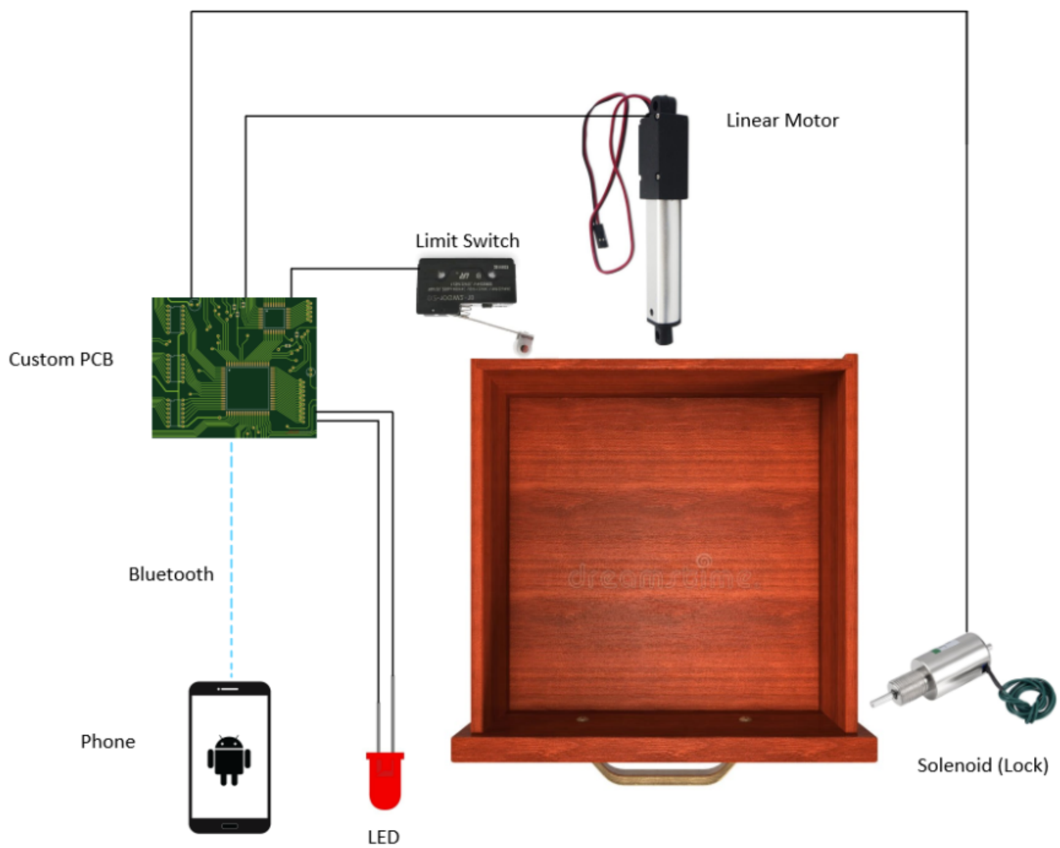

Figure 1: High Level Block Diagram

1.4 High Level Requirements

- The interaction between the micro-controller and the physical mechanisms on the drawer should produce the correct binary result. In other words, the LED lights, the motor moves forward and backward, and the solenoid extends and retracts when the MCU tells it to.
- The micro-controller must be able to interact with a smartphone app via Bluetooth. This means that all requests sent to the micro-controller must come from a smartphone.
- The Bluetooth connection between the smartphone and the micro-controller must have a range at least the size of an average room. The size of an average room is 14x16 feet, thus the Bluetooth connection must be established for at least 21.26 feet [2].

2 Design

2.1 Block Diagram

Figure 2 shows the Block diagram.

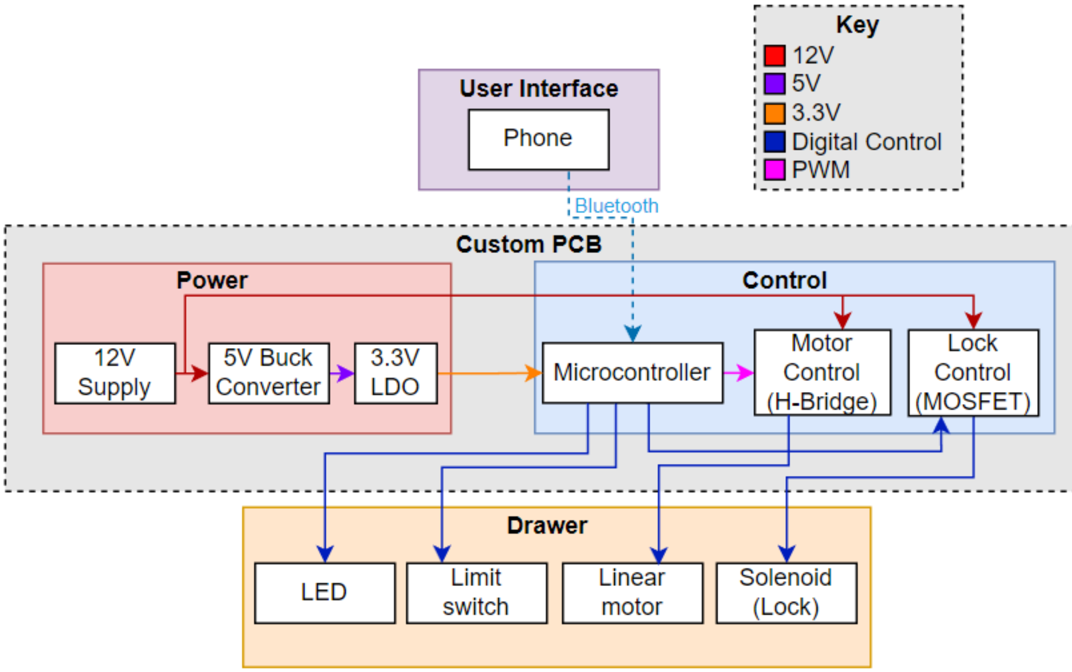

Figure 2: High Level Block Diagram

2.2 Physical Design

The physical size of the drawers will be slightly less than the size of a piece of paper, enough to contain things like a phone a sheet of notes, knives, calculator etc. More specifically the drawers will be around 8x5x4 inches and there will be three drawers stacked atop one another with some bottom space below each drawer for the motor placement, as well as around 2in of space in the back of the drawer to store the electronics and for easy access during the debugging phase of the project.

2.3 Subsystem

2.3.1 Power Subsystem

The Electronic Drawer Organization System draws its power from a wall-outlet. In the USA, wall outlets typically provide 120V AC at 60Hz. This is obviously a lot more voltage than the components in the project can tolerate. To combat this, a 12V power supply rated for 10 Amps of current, the ALITOVE LJH128 model, will be connected to the outlet power. From the output of this 12V supply, the voltage will be regulated to create DC voltage levels needed by the various project components.

The recommended voltage required to power the ESP32 MCU is 3.3V, and the current required is at least 500mA. In order to change the output of the 12V power supply to meet these specifications, a buck converter must be used in addition to an LDO regulator. The buck converter is necessary to step down the voltage from 12V to 5V. This is because of the large amount of current that needs to be supplied to the MCU. A current of 500mA going through an LDO that needs to drop the voltage from 12V to 3.3V would have to dissipate a large amount of power.

$$P = I * (V_{out} - V_{in}) \tag{1}$$

From equation(1), it can be seen that the power needed to be dissipated over an LDO alone would need to be 4.35W. This is a large amount of power for a small LDO to dissipate, so to decrease that, the MP1584 Buck converter will be used to step down the voltage to 5V prior to regulating the voltage. The MP1584 buck converter has a maximum output current of 3A, which is why it was chosen [3]. Then, with a current of 1A as an input, a LM3940 LDO will be used to regulate the 5V input to an output value of 3.3V. The regulated 3.3V and up to 1A of current can be used to power the MCU [4]. This specific LDO was chosen due to its robust current output to input voltage fluctuation, as it should output its maximum current value (1A) for voltages in the range of 4.5-5.5V [5].

The solenoid that will be used for the locking mechanism will be the ROB-11015. This solenoid has an input voltage of 5V, and draws with a maximum power rating of 5.5W. This implies that the max current it will draw is 1.1A. The Buck converter previously mentioned will have an output of 3A, 1A of which is the maximum necessary to power the MCU. Thus, the 2A remaining from the maximum Buck Converter output current can be used to supply the 5V and 1.1A necessary to power the solenoid [6]

The three linear actuators used to physically open the drawers are of the OK03 model. These motors require 12V DC power. [7]. The motors are each controlled by an H-Bridge, model BD62130AEFJ-E2. This H-Bridge has an input voltage range of 8V-28V and a maximum output current of 3A [8]. Since the power supply gives an output of 12V and a current of 10A, there will be more than enough current supplied by to power source to route the H Bridge motor controller directly to the power supply so that all three motors can be run simultaneously.

Table 1: Power Subsystem Requirements and Verification Table

Requirement	**Verification Procedure**
• Supply 12V+/-10% and 1A+/-10% as output from power supply	• Plug in power supply to wall outlet. Using a digital multi-meter in the lab, measure the output voltage and current, making sure it is in the desired range.
• MP1584 buck converter supplies 5V+/-10%, 3A+/-10% at output, once it has been connected to 12V power supply.	• Using digital multi-meter in the lab, measure the output voltage of the buck converter after connecting it to the power supply. • Using digital multi-meter in the lab, measure the output current of the buck converter. after connecting it to the power supply
• LDO supplies Current of at least 500mA, Voltage of 3V+/-10% to the ESP32 microcontroller.	• Using digital multi-meter in the lab, measure the output voltage of the LDO. • Using digital multi-meter in the lab, measure the output current of the LDO

2.3.2 User Interface Subsystem

The User Interface is a smartphone application that will be connected via Bluetooth to the Control subsystem. This application will be on an Android phone, since app development in the Android environment is considerably easier than iOS, although extending app functionality to iOS is a possible direction the project could take after the completion of the semester. The application will allow the user to see all of the drawers in their user's currently connected drawer system, as well as all of the items currently stored in each drawer. Essentially, the app will act as a GUI for the user to interact with the micro-controller in specified ways. Through the app interface, the user will be able to add drawer-item pairs to the micro-controller, search and select an item currently stored in a drawer, and receive information back from the micro-controller via Bluetooth to check the status of a drawer.

An important feature that the app will have is search functionality. All of the items currently stored in the drawer system will be stored in a list. Manually looking through every item in this list could be extremely tedious, which is something this project is trying to improve on. Thus, the user will be able to use a search bar to search for a given item. The search bar will work in by comparing characters in the search bar to the items currently stored in the drawers, and then updating its list of items to present the user with a much smaller, more manageable list.

Table 2: User Interface Requirements and Verification Table

Requirement	**Verification Procedure**
• Send and receive data to and from the ESP32 micro-controller via Bluetooth	• Test data sending capability by using an LED connected to a GPIO pin on the micro-controller. Send a digital signal from phone telling MCU to light the LED. Verify LED lights up. • Test data receiving capability by sending a known string of Bluetooth data to the phone app. Have the app echo the received data and verify it matches the sent string.
• Micro-controller responds to user input within 1 second.	• Verify this capability using the same test procedure as above, with an LED and a GPIO pin on the ESP32. Using a stopwatch, time the response between LED turning on/off and the request for LED to turn on/off. • If a stopwatch is too slow to time accurately, then our latency must be low enough.
• User interface responds to micro-controller status within 1 second	• Test this capability using the same test procedure as above, sending a Bluetooth signal from the micro-controller telling the phone app that a certain drawer is closed or opened. Use a stopwatch to verify that the time between the data send and app update is less than 1 second. • If a stopwatch is too slow to time accurately, then our latency must be low enough.

When an item is searched for and selected in the User Interface application, the micro-controller will check the status of the corresponding drawer and, if possible, perform the desired action on it.

The micro-controller will send a signal back to the smartphone indicating which action has been taken, or send an error message if the action could not be performed. Then, on the app, the user will be able to see a text representation of the action/lack of action that has been done.

One final important feature that the app will need to have is a settings section, where preferences for drawer behavior can be set. This means that updating the settings in the app sends a signal via Bluetooth to the micro-controller, which will then update a flag or register value to determine whether a given drawer physically opens or lights the LED when an item is chosen, as well as whether a drawer will lock or unlock with the use of a digital pass code inputted through the app interface.

2.3.3 Control Subsystem

As shown by the high level block diagram in Figure 2 the Control module contains a micro-controller, an H Bridge motor controller, and a Power MOSFET for lock control.

The micro-controller that will be used for this system is the ESP32. The ESP32 was chosen mainly due to its on-chip Bluetooth capability [4] . The micro-controller will be able to control the LED through its output pins. Control FETS for the LED may be required to avoid shorts which could harm the micro-controller. The input pins will be used to interact with the limit switch as well. The micro-controller will therefore be able to process any IO necessary to control all auxiliaries in other parts of the control system. The ESP32 has 520KB of SRAM which is enough to store our program data [4]. Furthermore, assuming a maximum string length of 20 characters per item, e.g. 20 Bytes, and 20 items per drawer, storing all of the items for one drawer would take up 400 Bytes of memory. Therefore all three drawers only need 1200 Bytes of memory to store all the item locations. In other words, there would be plenty memory left for the program data, even if more characters/items are allowed.

An H-Bridge will be used to to control the motor, allowing easy reversal of direction of the motor as well as easy control of the motors. In particular, the micro-controller must be able to drive signals to the H-Bridge for motor control. The H-bridge, a BD62130AEFJ, can tolerate input logic signals less than 5.5V, which is possible from a micro-controller pin [8]. Furthermore, a supply voltage of 12V is more than enough for this chip. The H-Bridge is capable of supplying 2.4A, which is all that is needed to drive the motors.

The last block in the control subsystem is the Lock Control MOSFET, an N channel Mosfet that can easily control the 5V Buck supply with a 3.3V control signal. Something like the DMN2300UFB4-7B would work very well as it can carry 1.3A needed to run through the solenoid [9]. In addition, the MOSFET will work well as a switch even when driven by the 3.3V of our micro-controller as th resistance of the MOSFET is $240m\Omega$ at a 2.5V V_{GS}, which is readily available from our micro-controller.

Table 3: Control Subsystem Requirements and Verification Table

Requirement	**Verification Procedure**
• Receive command from user interface via Bluetooth	• When command to light LED is sent from the phone, the microcontroller must turn on the LED.
• Micro-controller can determine using sensors if a drawer is open or closed and relay that information to the phone app.	• If drawer is closed, it appears as closed on the app, with some potential delay (1 second maximum). • If drawer is open it appears as opened on app with some potential delay (1 second maximum).
• Micro-controller can toggle its output pins	• Flash Micro-controller with simple program that drives pins and measure the voltage at those pins with a multi-meter. • Setup the pins output a PWM waveform and verify with an Oscilloscope that the output matches the desired PWM signal.

2.3.4 Drawer Mechanics Subsystem

The drawer mechanical subsystem is responsible for interfacing between the control system and the drawer hardware to open and lock the drawers, as well as to detect if the drawer is closed. The drawer hardware subsection is comprised of three linear actuators (Ok03 model), one solenoid (ROB-11015), three limit switches (MZ-7611), and three LEDs (WP7113ID5V). The linear actuators are controlled by the H-Bridge to enable both forward and reverse operation. The solenoids will be controlled by n-type MOSFETs connected to the micro-controller. The limit switches will provide input to the micro-controller to signal the open or closed status of the drawer. The LEDs will be controlled by n-type MOSFETs connected to the micro-controller to identify drawers if the user does not want to open the drawer at that time.

Table 4: Drawer Mechanics Subsystem Requirements and Verification Table

Requirement	Verification Procedure
• Linear actuators are driven by the H-Brige of the Control Subsystem	• Initially verify micro-controller GPIO output is functioning as expected by using an LED connected to a GPIO pin and control using the app • Remove LED and connect H-Bridge to GPIO. Use a multimeter to verify output of H-Bridge is as expected. • Connect linear actuator to output of H-Bridge. Verify actuator rotates as expected
• Solenoids are controlled by the micro-controller to lock the drawers	• Verify GPIO functionality using the above test procedure • Connect the gate of a n-type MOSFET to the GPIO pin of the micro-controller • connect the negative terminal of the solenoid to the drain of the MOSFET and +12V to the positive terminal of the solenoid.Verify the solenoid actuates as expected when toggling the output of the micro-controller
• Limit switches are able to detect when the drawer is open or closed	• Connect 3.3V to limit switch • Connect limit switch to input of micro-controller • Actuate the switch and monitor the input of the micro-controller to verify expected behavior

2.4 Tolerance Analysis

One of the most critical systems is the Physical Drawer Sensors and Mechanics subsystem. In particular, the motor mechanical force requires tolerance analysis to ensure that the drawer can open properly. The force that the motor needs to overcome is the force of static friction, and therefore we merely need to ensure that our linear motor can push with a force greater than that of the static friction of the drawer itself. In particular,

$$F_{motor} = \mu_s mg \tag{2}$$

Obviously the coefficient of static friction will be bigger than kinetic friction. However, since we can only estimate static friction, we may as well use it for our energy and power calculations. We can multiply our force by the speed at which we wish to open it to calculate the power needed for the motor to open the drawer. That is:

$$P_{motor} = \mu_s m g v_{drawer} \quad (3)$$

For example, apply this formula to a typical kitchen drawer‘s weight capacity of 50 lbs [10]. We can estimate our coefficient of friction as 0.4. That is, we need to push with 20lbs of force or about 89N, which is providable by the motor [7]. The rate of the motor is about 1cm/s, a fairly reasonable speed to safely open a drawer. This will require a motor power of 0.89W, which gives us an idea that our power supply should be able to give at least 5W exclusively to the motors at any given time to ensure mechanical operation. Note this is more than 3 times as much as needed to move one drawer in this manner, since there are three motors, plus a little extra power to account for any losses. Obviously this only approximates the power since our force will need to be somewhat greater than that of static friction, and will need to increase until kinetic friction matches it at the speed of our motor. However, this is a good approximation since we won‘t be moving our drawer very fast so the amount of force needed to apply will be nearly that of the force required to overcome static friction. Overall it is very feasible to supply this amount of power to the mechanical system and push a drawer with this much force, as even this estimated amount of force is fairly trivial for most linear motors to produce.

3 Cost & Schedule

3.1 Cost

The total cost for parts as seen below in Figure 18 before shipping is $136.76. 5% shipping cost adds another $6.84 and 10% sales tax adds $13.67. We can expect a salary of $40/hr*2.5hr*60 = $6000 per team member. We need to multiply this amount with the number of team members, $6000* 3 = $18,000 in labor cost. This comes out to be a total cost of $18,157.28.

Table 5: Cost Analysis Table of Components

Description	**Manufacturer**	**Quantity**	**Total Price**
MCU ESP-WROOM-32	EspressIf Systems	1	$4.20
H Bridge BD62130AEFJ-E2	ROHM Semiconductor	3	$5.61
Solenoid Lock ROB-11015	SparkFun Electronics	1	$5.50
Linear Actuator OK03	KIRANDY	3	$81.54
12V Power Supply LJH128	ALITOVE	1	$35.00
LDO LM3940	Texas Instruments	1	$0.59
LED WP7113ID5V	Kingbright	3	$0.20
Micro Limit Switch MZ-7811	Moujen	3	$3.82
–	–	–	**$136.76**

3.2 Schedule

Table 6: Schedule table

Week	Task	Team Member
Week 1 9/26 - 10/2	Design Check and Meet Machine Shop Again to Verify Component Selection	Everyone
	Verify Parts and Start Drafting Schematics/Layout and Order ESP32 Dev-kit	Michael S
	Get Android Phone for Group Use and Research Programming on Android	Michael G
	Research ESP32 Programming	Nathan
Week 2 10/3 - 10/9	Design Review and PCB Board Reviews	Everyone
	Continue Schematic, Order Components?, and Start First Layout	Michael S
	Begin Coding App and attempt to Interface with ESP32 Hardware	Michael G
	Begin Testing Code on ESP32 and Try to Interface With App	Nathan
Week 3 10/10 - 10/16	First PCB Way, Teamwork Evaluation and Last Machine Shop Check	Everyone
	Finish Layout and Assist Testing	Michael S
	Continue App and Start Performing Basic Tests With Microcontroller	Michael G
	Assist Michael G With App and Perform Tests	Nathan
Week 4 10/17 - 10/23	Test and Develop Software and Firmware	Everyone
Week 5 10/24 - 10/30	Start Assembling PCBS and Testing Hardware	Everyone
	Test Hardware and Modify PCB Schematic and Layout	Michael S
	Test App with Actual Hardware	Michael G
	Test ESP32 with Actual Hardware	Nathan
Week 6 10/31 - 11/6	Second PCB Way Order	Everyone
	Finish Layout Changes and Test	Michael S
	Debug Software Based on Tests	Michael G
	Debug Firmware Based on Tests	Nathan
Week 7 11/7 - 11/13	Everyone Develop Software and Firmware	Everyone
Week 8 11/14 - 11/20	Mock Demo and Final Debugging	Everyone
Week 9 11/28 - 12/4	Final Demo	Everyone
Week 10 12/5 - 12/8	Final Presentation and Paper Wrap up	Everyone

4 Ethics & Safety

In order to have a successful product at the end of the senior design process, creating the project in a safe and ethical manner will be paramount.

First and foremost, safety concerns that might be potential issues with the project must be addressed (IEEE Code of Ethics I.1) [11]. Because the project in question is a drawer system, there are not many inherent safety risks, although some still are present. One concern that exists is a possibility of electrical shock or fire due to poor wiring of circuits or incorrect regulation of current and voltage. This can be remedied by making sure that the wires used in the project are in working order, and making sure to check that our currents and voltages don't surpass the maximum rating values for any of our components. Another safety concern is the possibility of injury if a motorized opening drawer is pushed open into a person. This cannot be completely mitigated in the design process, as the user of the product has some responsibility to not put themselves in harm's way. However, by having the linear motor operate at a relatively low speed, the risk of injury from such an event can be minimized.

Ethical concerns for the project must be addressed to ensure that the design process is completed in a manner compliant with IEEE standards. The main concern with ethics with regards to this specific project involves plagiarism (IEEE Code of Ethics II.5) [11]. It is extremely likely, if not certain, that this project will require its designers to perform research on different components and design methods. To make sure that credit is given to the correct people, it is imperative that every effort is put forth to make sure the proper sources are cited in the proper manner.

References

[1] S. Borsheim, "Organizing & time management statistics," *Simply Productive*, 23-Apr-2014. [Online]. Available: `https://www.simplyproductive.com/2012/03/time-management-statistics/`. [Accessed: 12-Sep-2022].

[2] L. Eiler, "The average bedroom size & what to consider when Remodeling yours," *CRD Design Build*, 28-Jul-2021. [Online]. Available: `https://www.crddesignbuild.com/blog/average-bedroom-size`. [Accessed: 12-Sep-2022].

[3] "MP1584EN-LF-Z: Digi-key electronics," *Digi.* [Online]. Available: https://www.digikey.com/en/products/detail/monolithic-power-systems-inc/MP1584EN-LF-Z/5291742. [Accessed: 25-Sep-2022].

[4] "ESP32 series - espressif." [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf. [Accessed: 24-Sep-2022].

[5] "LM3940 1-a low-dropout regulator for 5-V to 3.3-V conversion ... - ti.com." [Online]. Available: https://www.ti.com/lit/ds/symlink/lm3940.pdf. [Accessed: 25-Sep-2022].

[6] "Rob-11015: Digi-Key Electronics," *Digi.* [Online]. Available: https://www.digikey.com/en/products/detail/sparkfun-electronics/ROB-11015/6163694. [Accessed: 25-Sep-2022].

[7] "6V 12V micro linear actuator motor durable and compact 10/21/30/50/100mm stroke for remote controls robotics home automation - DC motor - aliexpress," *aliexpress.com.* [Online]. Available: https://www.aliexpress.us/item/3256801240894103.html?_randl_currency=USD&src=google&memo1=freelisting&aff_fcid=8a77596466ae46828b5cf8d5c31f4887-1664242276736-02629-UneMJZVf&aff_fsk=UneMJZVf&aff_platform=aaf&sk=UneMJZVf&aff_trace_key=8a77596466ae46828b5cf8d5c31f4887-1664242276736-02629-UneMJZVf&terminal_id=1fa33c848b824aecae5a17b81719a7ae&afSmartRedirect=y&gatewayAdapt=glo2usa&_randl_shipto=US. [Accessed: 26-Sep-2022].

[8] "BD62130AEFJ," ROHM. [Online]. Available: https://www.rohm.com/products/motor-actuator-drivers/dc-brush-motor/bd62130aefj-product. [Accessed: 24-Sep-2022].

[9] "DMN2300UFB4 - diodes incorporated." [Online]. Available: https://www.diodes.com/assets/Datasheets/DMN2300UFB4.pdf. [Accessed: 25-Sep-2022].

[10] T. Felder, "How much weight can kitchen drawers hold?," Kitchen Seer, 12-Aug-2021. [Online]. Available: https://kitchenseer.com/weight-kitchen-drawers-can-hold/. [Accessed: 12-Sep-2022].

[11] "IEEE code of Ethics," IEEE. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 12-Sep-2022].