Component Analysis

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Member 1: David Fall **Email:** dfall@purdue.edu
Member 2: Andrew Cali **Email:** acali@purdue.edu
Member 3: Jennifer Ferguson **Email:** fergu157@purdue.edu
Member 4: Maddie Flanagan **Email:** flanag24@purdue.edu

Assignment Evaluation: See Rubric on Brightspace Assignment

1.0 Component Analysis:

This report details the selection and specifications of the major components utilized in Team 1's Electronic Skee Ball Machine. The sections and their respective components analyzed are as follows:

Section 1.1: Microcontroller to serve as the central and only computer
Section 1.2: Servo motor to granularly control the direction of ball launching
Section 1.3: Electronic display to provide user instructions and feedback
Section 1.4: DC motor used for ball launching with user-controlled power
Section 1.5: Power supply for all electronic components of the machine

1.1 Analysis of Component 1: Microcontroller

Choosing the optimal microcontroller for our project was a complex decision that required careful analysis. We began by analyzing the STM32F091, a microcontroller that all of our team is familiar with from ECE 362. For programming the STM32F091, we use C, which requires more detailed coding compared to other languages. Next, we assessed the Adafruit HUZZAH32 – ESP32 Feather Board, which ¾ of our team had previously worked with in ECE 40862. Also, when writing to the ESP32, one would use micropython, which in comparison to C, is much less complex and easier to implement. We compared both microcontrollers based on important key features like maximum clock speed, memory available, PWM channels, and GPIO availability. The STM32F091 offers 6 PWM channels and 38 GPIO pins, providing options for interfacing with peripherals. It also supports 2 SPI channels and 2 I2S channels, which would allow us to handle audio and support the OLED screen. However, the ESP32 has 16 PWM channels and a few less GPIO pins available with only 28 pins. It also features 3 SPI channels and 2 I2S channels.

Feature	STM32F091	ESP32 Feather Board
References	[3]	[1] [2]
Maximum Clock Speed	48 MHz	240 MHz
Flash Memory	128 - 256 KB	4 MB

SRAM	32 KB	520 KB
Timers	12	4
GPIO pins	38	28
I2S Channels	2	2
PWM Channels	6	16
SPI Channels	2	3
UART	8	3

In conclusion, after comparing the features of both the STM32F091 and the ESP32 Feather board, we ended up choosing the ESP32 Feather board for our project. Not only does it offer more PWM and SPI channels, but it also provides more memory (4 MB of flash compared to 128-256 on the STM32F091). Also, the ESP32's higher maximum clock speed of 240 MHz (compared to 48 MHz on the STM32F091) will provide faster processing compared to the other microcontroller option. In addition, the ease of programming the ESP32 with MicroPython simplifies the process in comparison to programming in C.

1.2 Analysis of Component 2: Servo Motor

A motor is needed for gradually rotating a turntable that holds the launching system of our skee-ball machine. The most significant constraints when selecting a motor include the diameter of the turntable (8 inches) and the weight the launching system will bear on it. These factors predominantly influence the torque required from the motor. However, it's difficult to calculate an exact torque requirement because the components of the launch system (DC motor, 2-inch wooden ball, and motor shaft attachments) will not have their weights evenly distributed across the turntable, which also makes the average distance from the axis of rotation hard to approximate. Given these uncertainties and the potential for variable load distributions that increase mechanical demands, opting for a motor with higher torque capacity is important. This approach ensures that the motor will not be overstrained, providing a buffer to accommodate any unforeseen stresses and promoting longevity in operational performance. Although the motor only needs to rotate the turntable gradually, the ease of programming specific angular positions is also an important requirement.

Our first candidate was the SG90, a small 9 gram servo motor easily controlled by a PWM signal. While very light, compact, and offering decent speed, its torque (1.8 kg·cm) might not be sufficient for rotating the additional weight on top of the 8 inch turntable. However, it is feasible to mitigate potential torque deficiencies by compacting the launching system closer to the axis of rotation. This adjustment would reduce the torque required to rotate the turntable by minimizing the radial load, potentially making the SG90 a viable option.

The second candidate considered is the Hiwonder HPS-2018. This servo motor provides sufficient torque and precision control within 180 degrees, crucial for the accurate, incremental control needed for angling the launch. Its compact size and waterproof rating enhance its suitability for arcade environments, which often involve exposure to varying conditions that could impact electronic components. Similar to the SG90, it is easily controlled by a PWM signal, but offers significantly higher torque of 20 kg·cm, ensuring robust handling of the turntable's load without compromising on precision.

The third candidate considered was a standard DC motor, a QBL4208-61-04-013. Significantly heavier and providing constant rotation at high speeds (4000 RPM) without inherent positional control, this motor is less ideal for applications requiring precise movement control. The motor's torque, converted to approximately 3.87 kg·cm, and its higher RPM suggest it could supply the enough torque and speed for rotating a turntable with additional weight. However, lacking built-in positional control, this motor would require an external controller for accurate position management, adding complexity and potential failure points to the system.

Motor	**Weight (g)**	**Volume (in³)**	**Torque (kg·cm)**	**Speed**	**Additional Notes**
SG90 [4]	9	0.539	1.8	.1 sec/60°	PWM control
Hiwonder HPS-2018 [5]	68	1.577	20	.2 sec/60°	Waterproof, PWM control
QBL4208-61-04-013 [6]	450	2.37	3.87	4000 RPM	High RPM, H-bridge needed

The Hiwonder HPS-2018 is the best choice for its torque and precise control, which are essential for the angular control of the skee ball machine's launching system. Its capacity to handle the launch system load and maintain positioning without the need for complex external control systems (like an H-bridge for a DC motor) makes it ideal for this application.

1.3 Analysis of Component 3: Electronic Display

The main considerations for the choice of display were the programmability, cost, microcontroller pin requirements, and physical size. The team was concerned with programmability as an easily configurable interface with the display would allow for quick implementation and more time to dedicate to other critical tasks. Likewise, the cost consideration was raised by the team's limited budget of $425, so the display could not consume too much of the budget. Furthermore, the usage of the ESP32 Feather as the chosen microcontroller (see Section 1.1) limited the number of external pins available, so the number of pins occupied by the display became an additional consideration. Finally, as mentioned in the functional description detailed in the Function Specification, the display was meant to provide visible feedback and instructions to the user in an aesthetically pleasing and easily readable manner. Thus, the team determined that the display should be as large as possible while still fitting in its intended position on the backboard of the machine (maximum width and height of 14 inches and 6 inches, respectively).

The team first considered the usage of the SOC1602A character OLED display. This device was strong in both the cost and ease of usage categories. Regarding cost, each member of the team already had access to at least one SOC1602A, meaning none of the budget would need to be spent on acquisition. Likewise, the SOC1602A provides a well-documented serial interface, allowing for the usage of quickly configurable protocols like SPI or I2C [7]. The support for serial interfaces also allows the device to consume only three external pins on the microcontroller: one for serial data input, one for serial clock, and one for chip selection. The downside of the SOC1602A is its size: at only 3.14 inches wide and 1.41 inches tall, the SOC1602A can only display two lines with a maximum length of sixteen characters each. This allows minimal information to be displayed at one time, and the contents of the display may be difficult to read when placed on the back of the machine, approximately four feet away from the user. Ultimately, this display was not chosen as its physical size was too small to achieve the desired user experience.

Another option that the team considered was the MSP2202 TFT display. This option was cost-effective, but it suffered from difficulty of usage and suboptimal size. Similar to the SOC1602A, each team member had access to one of these displays already, so it could be used without spending any of the budget. The display also had the benefit of providing a fully configurable 320 by 240 set of RGB pixels, allowing for an enhanced user experience [8]. However, this RGB system also meant that configuring the display would be significantly more challenging, as entire arrays of carefully arranged pixels would have to be written to the display whereas the other two options (SOC1602A and NHD-0440AZ-FL-YBW) allowed for easily writable predefined characters. Moreover, the team planned to only use characters on the display regardless, so the more configurable set of pixels did not truly provide any benefit when compared to a simple character display. The display did provide a similar serial interface to the SOC1602A, using only a serial data line, serial clock, and chip select signal, meaning it would occupy only three microcontroller pins. Finally, the MSP2202 also lacked in physical size at only 1.57 inches tall and 2.64 inches wide. The team finally elected not to use this display due to the added complexity of usage and minimal size.

The final option considered was the NHD-0440AZ-FL-YBW character display. This display was more expensive than the previous two considerations and was somewhat difficult to configure, but it had the benefit of being much larger than the previous two displays. Since no members of the team had prior access to one of these displays, the device had to be purchased, costing a total of $35.58 including shipping [9]. Regarding ease of usage, the device supported only parallel interfaces with a ten-bit input size [10]. Due to the limited number of GPIO pins on the ESP32 Feather, configuring a direct ten-bit parallel interface between the microcontroller and the display was not possible. This raised the need for an external shift register to aid in the configuration of a parallel interface, and the shift register is controlled via SPI. This added complexity to the usage while also forcing the device to occupy four GPIO pins (two for serial communication, one for a strobe signal for the top two lines, and one for a strobe for the bottom two lines) as opposed to the three pins required by the other options. Despite these shortcomings, the display was far superior in size at 7.48 inches wide and 2.13 inches tall. The team ultimately decided to use this display because while the other options outperformed it in cost and ease of usage, the far better user experience outweighed its shortcomings.

The above comparisons and considerations are summarized in this table:

Name	Ease of Usage (Scale of 10, Unitless)	Cost (USD)	Microcontroller Pins Occupied	Size (Area, in^2)	Selected (Y/N)
SOC1602A	10	0	3	4.42	N
MPS2202	3	0	3	4.15	N
NHD-0440AZ-FL-YBW	4	35.58	4	15.93	Y

1.4 Analysis of Component 4: DC Motor

A motor is needed to launch the ball in our game system. The primary design constraints include the force required to propel the ball, the ability to control speed via PWM, and compatibility with our microcontroller-based control system. Selecting the appropriate motor involves considering torque, speed, voltage, and current draw to ensure it meets performance requirements without exceeding system limitations. The motor must operate within the available power supply range (~6V-12V) and should not exceed the current supply limits of our system. Additionally, it must generate enough torque to launch the ball with sufficient velocity while supporting PWM-based speed control. Cost and availability were also considered to ensure the motor is both practical and accessible for our design. Three candidate motors were evaluated: the 775 DC motor [11] RS550 DC motor [12], and the 28BYJ-48 stepper motor [13]. These options were compared based on voltage requirements, current draw, speed, torque, and control methods.

Motor Model	Weight (g)	Voltage Range	Current Draw	Speed (RPM)	Torque (kg*cm)	Control Method
775 DC Motor	350	6V- 18V	~3A	5000-10000	0.5-2.5	PWM
RS550	200	6V - 12V	~2.5A	3000-6000	0.3-1.5	PWM
28BYJ-48 Stepper Motor	40	5V	<500mA	15-200	<0.2	Stepper Control

The 775 DC motor [11] was selected as the optimal choice for our ball launching system due to its balance of speed, torque, and ease of integration with our control system. This motor provides a high-speed range of 5000-10000 RPM while delivering sufficient torque (0.5 - 2.5 kg·cm) to

propel the ball effectively. Its PWM compatibility allows precise speed control, enabling dynamic adjustments based on user input. Additionally, the 775 DC motor operates within the available voltage range and can be powered efficiently using our existing power supply setup. While slightly more expensive than the RS550 [12], it offers superior performance and durability, making it a reliable choice for our application. Another key factor in selecting this motor was its availability in our senior design shop's parts inventory, allowing for easier procurement and replacement if necessary. These combined factors ensure that the 775 DC motor meets the functional requirements and design constraints of our project.

1.5 Analysis of Component 5: Power Supply

A reliable power supply is essential to power all components of the skee ball machine system, including the servo motor, DC motor (via the Talon motor driver), sensors, speaker, and the ESP32 Feather V2. The primary design constraints for the power supply include providing sufficient voltage and current for the entire system, ensuring stability and safety under varying loads, and fitting within the available physical space. The system operates at 24V, with the motors requiring significant power (up to 10A for peak performance), while the rest of the components (sensors, display, etc.) have relatively lower power demands. The power supply must also be efficient and capable of providing the necessary protections (overvoltage, overcurrent, and overtemperature) to avoid damage to sensitive components. Additionally, the power supply needs to be cost-effective and available for procurement. Three candidate power supplies were considered: the ALT-2410T 24V 10A [14], LRS-350-24 24V 14.6A [15], and ECL-60US24 24V 2.5A [16].

Power Supply Model Comparison

Power Supply Model	Output Voltage	Output Current	Power Rating	Efficiency
ALT-2410T 24V 10A	24V	10A	240W	85-90%
LRS-350-24 24V 14.6A	24V	14.6A	350W	90%
ECL-60US24 24V 2.5A	24V	2.5A	60W	85-90%

The ALT-2410T 24V 10A power supply was selected as the optimal choice for our skee ball machine's power needs. This component meets the necessary voltage (24V) and provides adequate current (10A) to power the motor systems, sensors, and other components without exceeding system limits. The 240W power rating ensures that there is sufficient headroom to account for transient loads during motor startup and operation. The ALT-2410T also provides essential protection features, including overvoltage (OVP), overcurrent (OCP), and overtemperature protection (OTP), which help safeguard the components and ensure reliable performance under variable operating conditions.

While the LRS-350-24 24V 14.6A power supply offers a higher current output (14.6A), it provides more power than is necessary for our application, making it over-engineered for the needs of the system. This over-provisioning would not offer any significant advantage, and the larger size and increased cost make it less desirable than the ALT-2410T. The ECL-60US24 24V 2.5A offers insufficient power (60W) to drive the motor and other components effectively, making it unsuitable for the application.

Additionally, the ALT-2410T offers a good balance between cost and performance, ensuring that the system will operate efficiently without significant heat generation or excessive energy loss. It also fits the physical space requirements of the system and is available at a reasonable price point compared to the other candidates.

These factors ensure that the ALT-2410T 24V 10A power supply is the most suitable component for the skee ball machine's power needs, fulfilling both the functional requirements and design constraints effectively.

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