CHAPTER 3 – RESEARCH METHODS

3.1 Design Justification

3.1.1 Mechanical Design Improvement

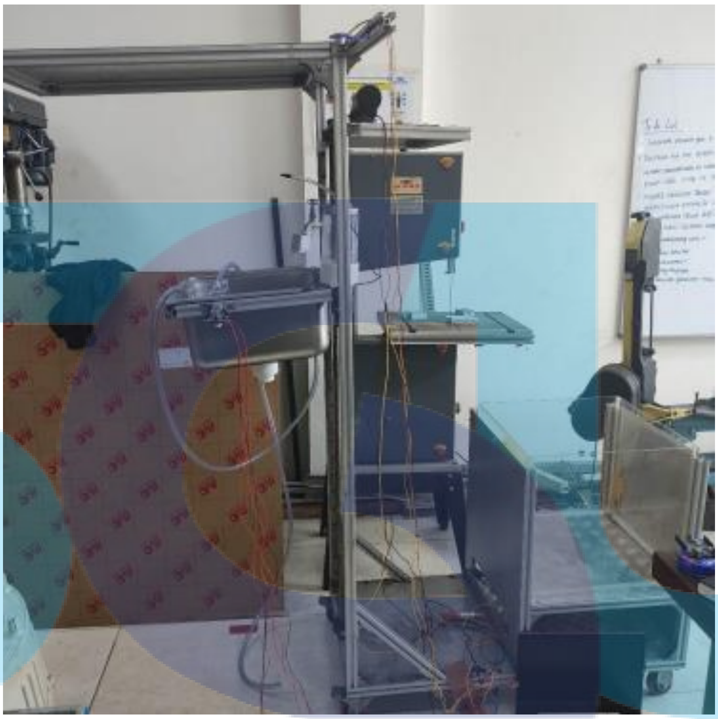

Figure 5. Previous Design

Figure 5 above shows the previous model of an automatic hand washer sink design by Benediktus Marshall Cristoval Wijaya. As seen in the figure, the sink holder cannot withstand the load force of the sink, causing it to bend downward and increasing the risk of falling. The sensors are also dangerously placed on the top with an aluminum profile, leaving them dangling without proper attachment. Additionally, the motors are attached on the top of the model with no cover on the bottom, making it unsafe for children to use. Moreover, the electrical parts and cables are left exposed with no water cover.

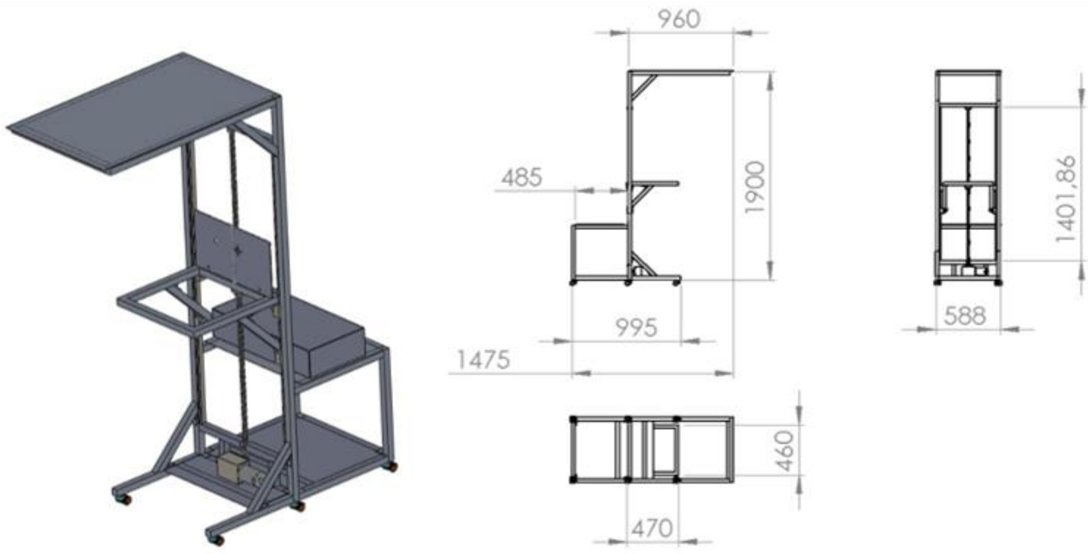

Figure 6. Design Improvement of the Automatic Height Sink Washer

On the newly mechanical design improvement, the dimensions of the model are approximately 59 cm wide, 148 cm long, and 190 cm tall. The rear part of the model is shorter to reduce the housing space. An additional framework is implemented to enhance the stability and rigidity of the model, addressing the issue of the previous iteration model's tendency to fall down due to its unstable design. The water container is placed on the bottom rear part, while electrical components are placed on top of it with a cover made from acrylic to prevent water damage or splash into the components. The DC Motor is placed on the bottom of the frame near the water container.

Figure 7. Added Framework on the Sink Holder

From the previous iteration, the sink holder frame was easily bent, primarily due to its lack of capacity to withstand the forces from the sink and other contributing factors. This resulted in a compromised structural integrity of the frame. Therefore, an additional frame is added and supported by linear bearing blocks to improve its strength while maintaining the stability of the movement of the sink.

Figure 8. 1st Ultrasonic Sensor for User Height Measurement

There are two ultrasonic sensors used in this model design for height measurement usage. The first ultrasonic sensor located on the bottom of the roof to measure the user's height. When the user stands in front of the sink, the sensor directly measures their height and calculates the required sink height based on the calculations made in the system program.

Figure 9. 2nd Ultrasonic Sensor for Sink Height

The figure above shows the second ultrasonic sensor located on the bottom of the sink to measure the sink's height. When the first sensor measures the user's height, the sink sensor measures the current sink's height. If the required sink height is lower or higher from the current sink's height, the motor will start to rotate to move the sink upward or downward based on the location of the previous sink height. During the movement, if the sink height meets with the required height, the motor will stop immediately.

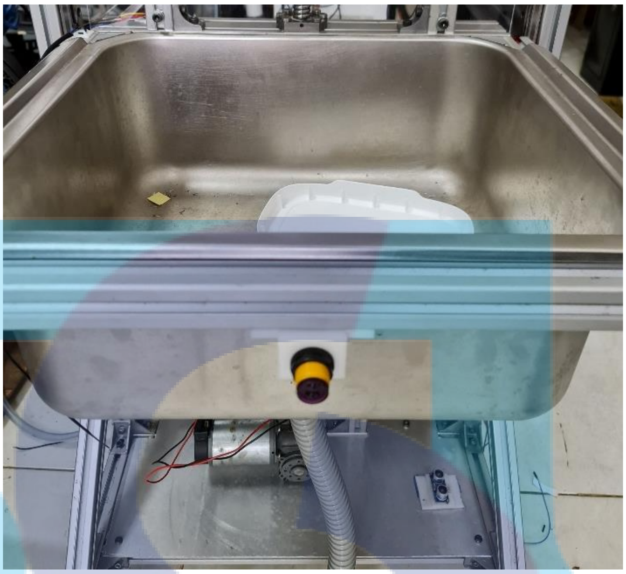

Figure 10. 1st Infrared Sensor for User Presence Detection

For safety system usage of the automatic sink, two infrared sensors are applied into the system. The first infrared sensor is used as user presence detection and located in the front of the sink. When no user is detected, the sink cannot move upward and downward to prevent unnecessary movement or an error glitch from the ultrasonic sensors. When the sensor is activated, the motor then can move the sink.

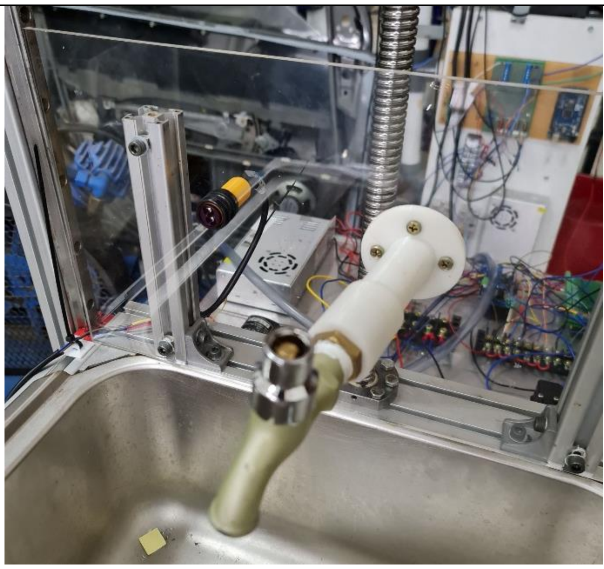

Figure 11. 2nd Infrared Sensor for Automatic Hand Wash Cycle Switch

For the second infrared sensor, it is located near the faucet on the sink to activate the automatic hand wash cycle. The location is set there to make it easier for the users to activate the automatic cycle. Another unique feature set that if no user is present, meaning the first IR sensor does not activate, the automatic cycle cannot be turned on even though the second IR sensor is activated.

3.1.2 Electrical Design

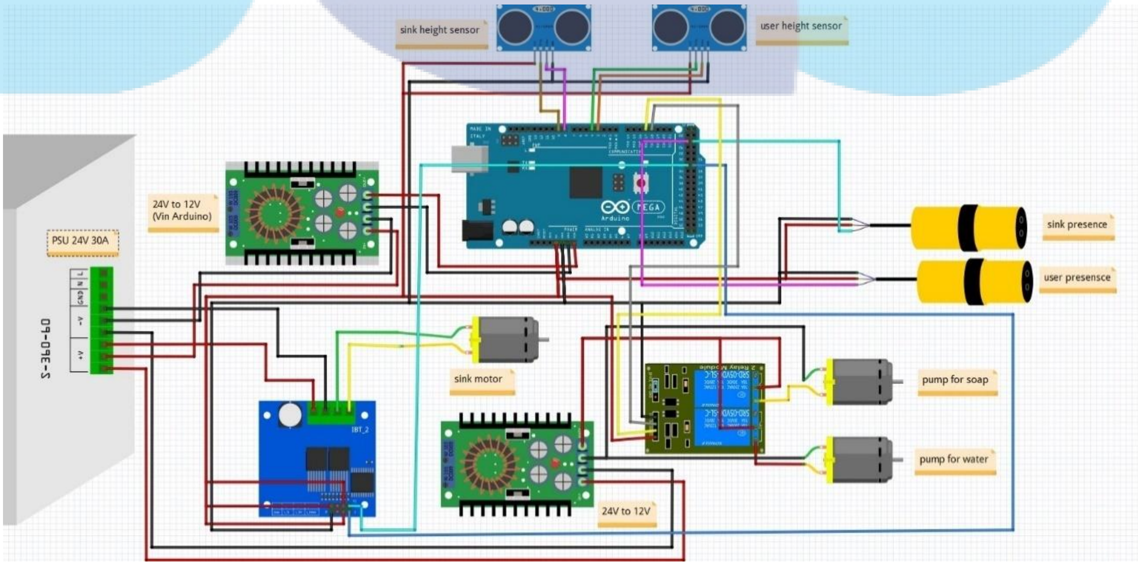

Figure 12. Fritzing Design of the Full System

The design shown in Figure **12** is the complete electrical design of the automatic height sink washer made from fritzing application. The power supply connected into 3 places, which are DC Motor, Arduino, and the pumps. This separation is due to the difference of voltage and ampere applied into the components and cannot be connected in serial connection. For the motor, the power supply and the motor are connected directly into IBT-2 as a controller. To decrease the voltage from 24 V into 12 V as the rest of the component's inputs are 12 V input, step-down voltage regulator modules are used for the Arduino board and the pumps. As for the relay and sensors, their power input can be taken from Arduino 5 V and ground pin. To control the pump flow timing, a relay double channel module is used.

3.2 Components Model

3.2.1 Mechanical Components

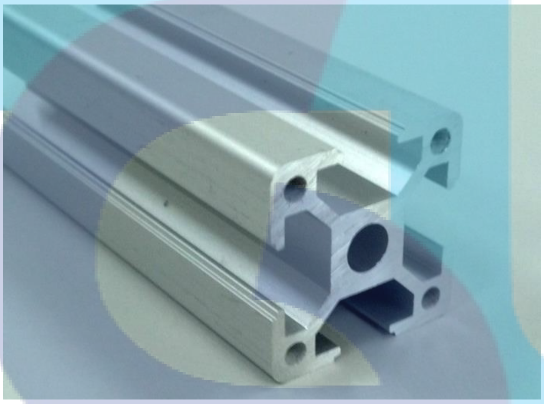

Figure 13. 30x30 Aluminum Profile

The framework for this thesis model uses 30 mm x 30 mm Aluminium profiles for its non-corrosion properties, low cost, and tough in light weight. For the sink holder, an aluminum profile 60 mm x 30 mm is utilized to support the frame.

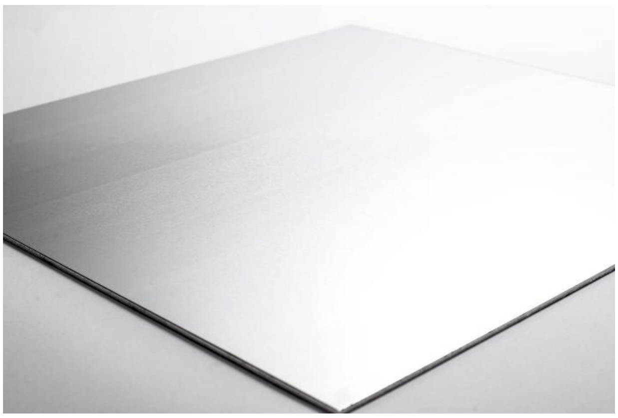

Figure 14. Aluminum Plate

The aluminum plates are used as cover for the roof of the model and surface parts for the electrical components and the motor. A 2mm thickness plate is used due to its strength in supporting the motor and other components.

Figure 15. Bevel Gear

The bevel gear is used as a connector between the lead screw shaft with the motor shaft in which their axles lie at 90 angles to each other. The model is using 30 tooth gear for both sides, with the inner diameter having different sizes. For the shaft motor, the inner diameter is 10 mm, while the lead screw shaft is 12 mm.

Figure 16. Ball Screw with Nut SFU2005

This ball screw is used to convert the rotary motion of the motor into linear motion as movement upward and downward, while also can transfer a high load force. The bottom and upper part of the ball screw is attached into a pillow block to prevent it moving around and staying in position. The diameter and pitch value can be seen from the parts name, which 20mm is the diameter and 5mm is the pitch.

Figure 17. HGH20CA Linear Bearing Guide

This linear guide is used as a guide for the sink to move up and down smoothly in a fixed rail that is attached on the left and right side. The support of the sink frame is also attached into linear block bearing to improve the strength of the frame while maintaining the rigidity and speed of the movement.

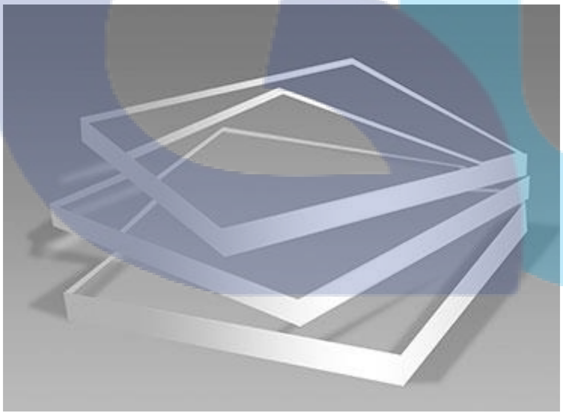

Figure 18. Acrylic Sheet

The acrylic sheet is used due to its lightweight, stronger than glass, and easy to fabricate. The cover for the electrical components and water container are used from this acrylic sheet with thickness between 3-5 mm.

3.2.2 Electrical Components

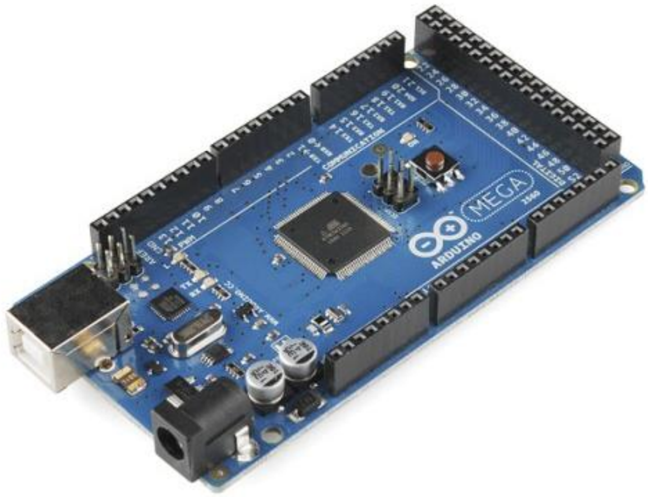

Figure 19. Arduino Mega 2560

In this thesis model, Arduino Mega 2560 is used as the microcontroller to control the flow of the automatic hand sink washer. Instead of using Arduino UNO R3, Arduino Mega is chosen for its capabilities and greater number of I/O pins than other Arduino boards. This Arduino controls the pump of the water and soap, motor, relay, and the sensors, both ultrasonic and infrared. Electrical designs are changed completely as the cycle of the hand washing is done automatically.

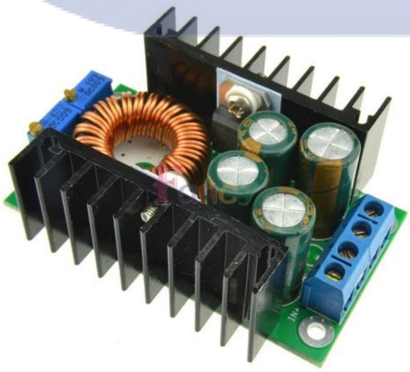

Figure 20. DC Step Down Buck Converter Module

As 24V/30A power supply is used in this model, a step-down buck converter is needed to decrease the voltage for pumps and the Arduino to prevent overload. In this buck converter, the output voltage can be adjusted from 1.2V to 35V with current flow of 9A.

Figure 21. Relay Module 5V Dual Channel

As the hand washing cycle is done automatically, relay is used as an automatic switch where the timer is set on the Arduino. The dual channel is needed since the water pump and soap pump have different timer sets and run independently. The input for this relay is 5 V where it can be powered from the Arduino.

Figure 22. HY-SRF05 Ultrasonic Sensor

HY-SRF05 Ultrasonic sensors are used on this model to measure the height of the users and height of the sink. When users' height is measured by the first sensor, it will be calculated on the Arduino to find the target height for the user's hand. The target value is then matched with the second sensor that is placed on the sink. If the value of the target is higher than the second sensor, the motor will be activated to move upward or vice versa. These sensors can detect up to 450 cm with error precision of 0.3 cm.

Figure 23. Dunkermotoren GR63X25 with SG80K Gearbox Attachment

The DC motor that is used in this thesis model is Dunkermotoren GR63X25. With input voltage of 24V, the nominal torque for this motor is 0.14Nm and rated speed of 3000 RPM. To increase the torque, a SG80K gearbox is applied, resulting in 2.1 Nm of torque, but the rated speed output has decreased into 200 RPM.

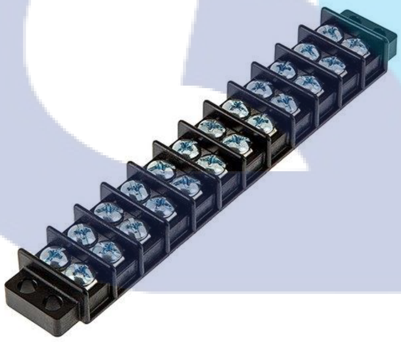

Figure 24. Terminal Block

The terminal block is used to connect other electrical components in a parallel connection from a single source. It also provides a bigger safety point for reliable connection for the wire, therefore increasing the safety factor onto the circuits. In this thesis work, terminal blocks 25 A and 60 A are used for the high and low electrical components current input.

Figure 25. Motor Driver IBT-2

The IBT-02 Driver is used to control the speed and direction of the motor to move the sink upward and downward. However, the motor maximum speed is needed to fasten the movement of the sink. Therefore, the driver only controls the direction.

Figure 26. Nagasaki Water Pump 12V

This water pump is used to pump the water and soap water from the container into the faucet on the sink. Two pumps are utilized to pump the water and soap water solely, where the timing flow is controlled by a relay module. Each pump has a flow rate of 5 litres per minute with 110 psi of pressure.

3.2.3 Fabricated Components

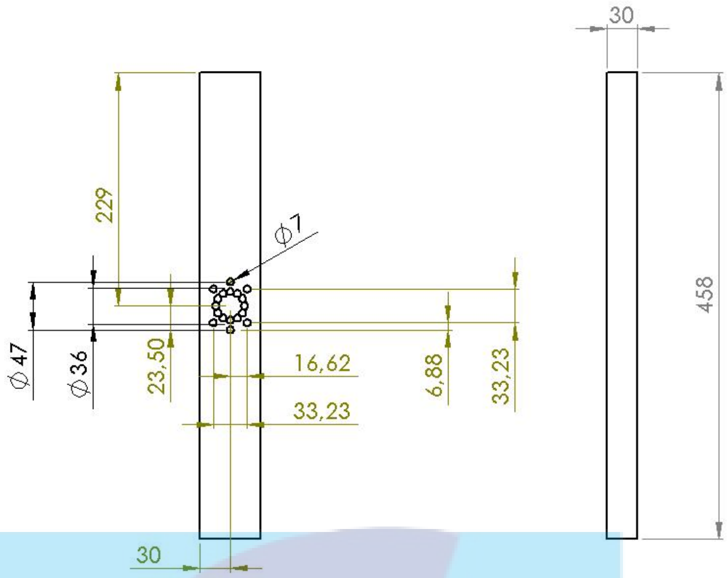

Figure 27. Aluminum Frame Bracket on Lead Screw

This aluminium bracket is used to connect the sink frame into the nut of the lead screw. The nut is inserted inside the middle hole then secured tightly with the nut housing, to ensure the nut does not rotate when the lead screw rotates. To ensure fixed linear motion, the left and right side of the aluminium bracket are attached into linear block bearings. The fabricated part was made from the milling process in the SGU workshop for 2 (two) days.

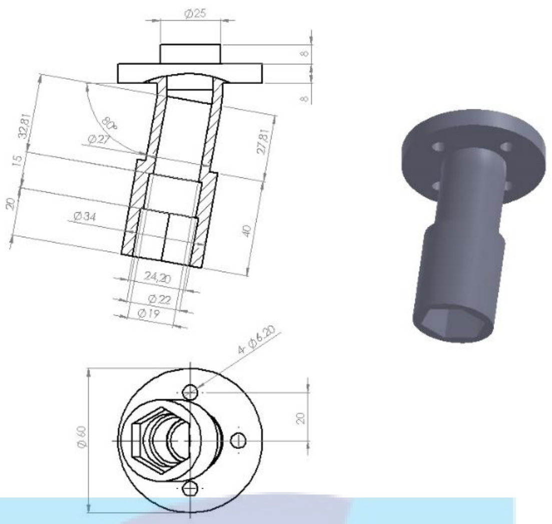

Figure 28. 3D Bracket for the Faucet

This bracket is designed to hold the faucet on the sink in the middle position. In previous studies, the faucet was welded and placed on the left side of the sink, requiring users to slightly turn to the left when washing their hands. With this bracket, the faucet is positioned in the middle of the sink, allowing users to wash their hands comfortably and preventing the back hose from entangling with the lead screw. The bracket is made from a 3D printing process.

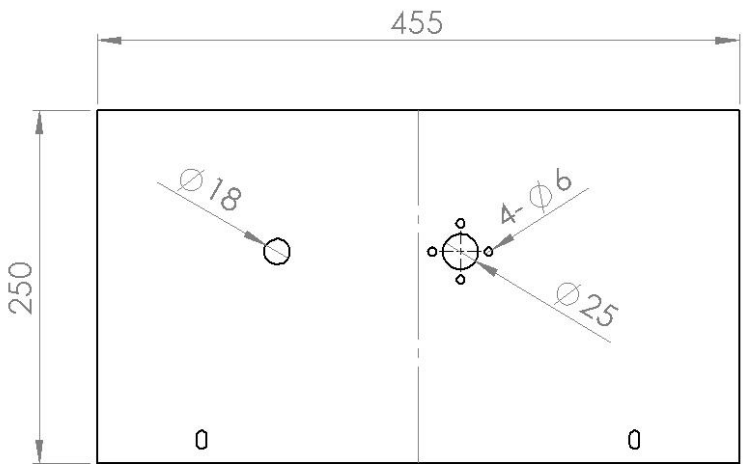

Figure 29. Acrylic Sink Holder

The acrylic sink holder is designed to hold the 3D faucet bracket and the infrared sensor to activate the automatic hand wash cycle, also to prevent water splash into the lead screw and electrical components at the back of the frame that could lead to short circuit. The acrylic is attached into the aluminum frame bracket by using corner brackets.

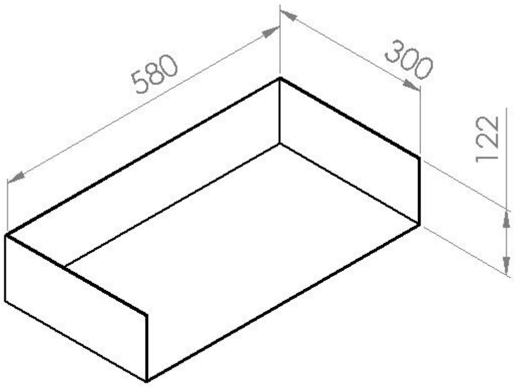

Figure 30. Electrical Wiring Cover

The cover is designed to cover the electrical components and wiring on the back of the model from water splash to prevent short circuit or broken components. The dimension of the cover is 300 mm in length, 580 mm in width, and 122 mm in height. A 2mm thick acrylic is used as the material for this model design.

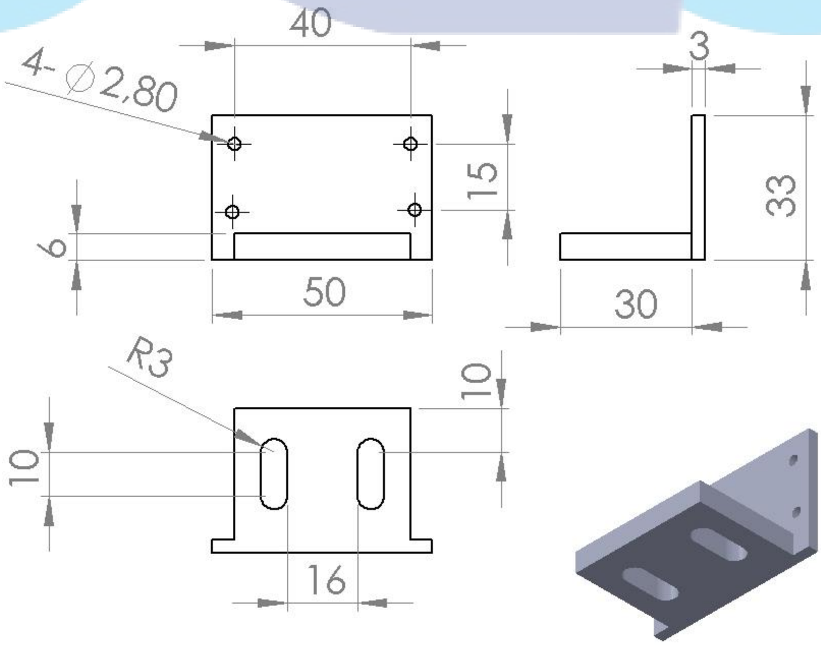

Figure 31. 3D Bracket for Height Ultrasonic Sensor

This 3D bracket is used as an ultrasonic sensor holder for the user's height measurement. It is placed on the roof of the model. Ultrasonic is attached into the bracket by using spacers.

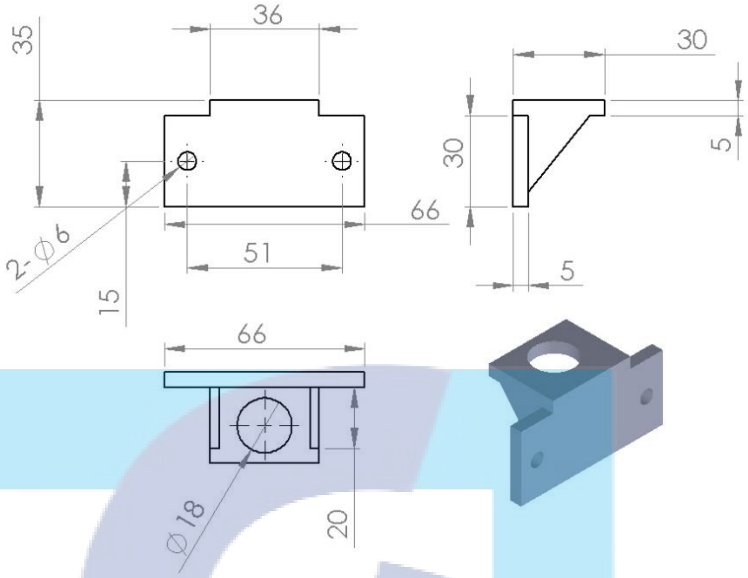

Figure 32. 3D Bracket for User Presence Sensor Detection

This 3D bracket is used as an IR sensor holder for user presence detection. The bracket is placed under the sink while facing to the front, to detect users and start the system. Infrared is attached into the bracket by using nuts that is already attached into the outer screw of the IR sensor.

3.3 Flowchart System

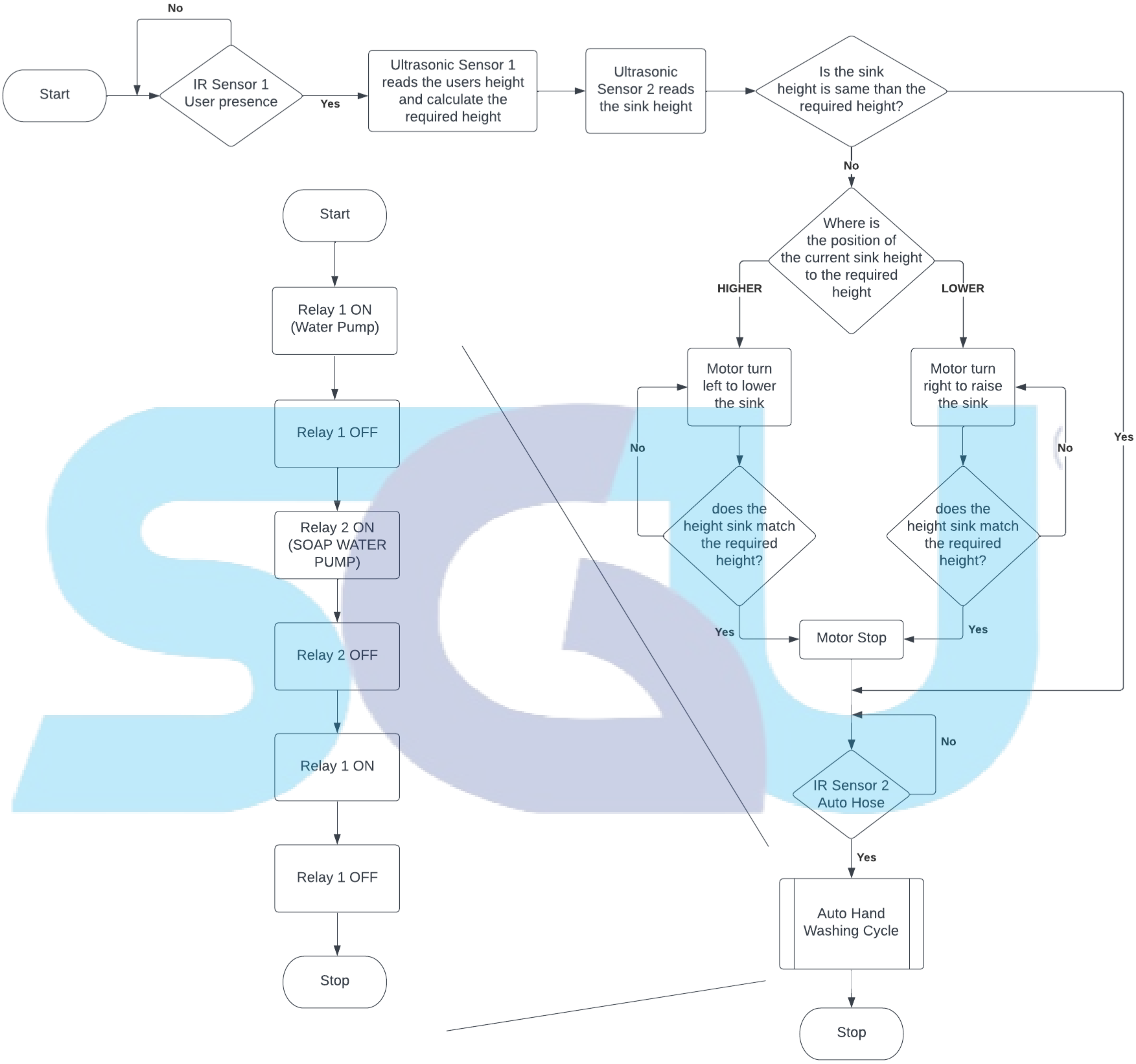

Figure 33. Flowchart Diagram

The figure above shows how the automatic height sink washer system works with the addition of an automatic hand washing cycle. The author handled the start of the system until the height adjustment motor program stops. Dana Abdul Karim handled the automatic hand washing cycle until the end of the system program.

3.4 Work Breakdown Structure

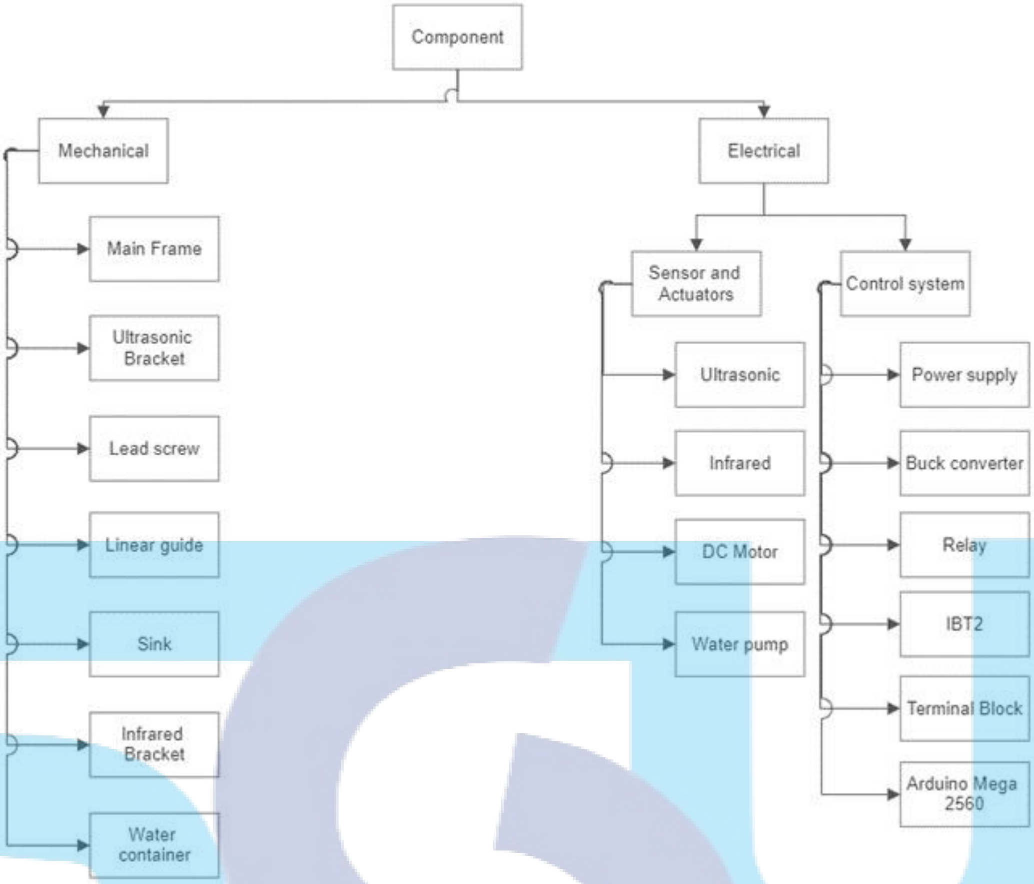

Figure 34. Work Breakdown Structure of the system

The overall system is broken down into two structures, which are mechanical side and electrical side. The design of the electrical structure and integration of the program model is handled by Dana Abdul Karim.

The mechanical components consist of the main frame, ultrasonic bracket, lead screw, linear guide, the sink, infrared bracket, and the water container. The main frames, mainly made from aluminum profiles, were assembled in the workshop. Some of the fabricated components are also from aluminum material and filament PLA. The lead screw and linear guide is used as the main movement and support for the sink adjustment motion.

The water container is made from acrylic from a laser cutting process. It was made from the previous iteration then modified into two separate rooms for water and soap water containers.

3.5 Program Algorithm

In this chapter, the algorithm of the system will be explained briefly. The program was written in a software application Arduino IDE.

```
float sinkheight() { //sink height pake signal p
  pdistance = pduration = sonar1.ping_median(iterationp);
  pdistance = (pduration * 0.034828 / 2) + 35;
  return pdistance;
  delay(500);
}
```

Figure 35. Coding Script 1

This code function is used to measure the distance between the sink and the ground. Since the sensor is placed above the ground slightly higher and it detects the bottom of the sink, the value is added by 35 to equalize the distance between the ground and the upper sink.

```
float heightsens() { //tinggi orang pake signal w
  wdistance = wduration = sonar2.ping_median(iterationp);
  wdistance = (wduration * 0.034828 / 2);
  tinggiorang = MAX_DISTANCE - wdistance;
  return tinggiorang;
  delay(500);
}
```

Figure 36. Coding Script 2

This code function is used to measure the user's height. To get the final result of the user's height, the actual value is subtracted by the height of the sensor from the ground, which is 194 cm.

```
float calculateTarget() {
  float heightSens = heightsens();
  target = (heightSens * 0.6);
  return target;
  delay(500);
}
```

Figure 37. Coding Script 3

This code function is used to calculate the required height of the sink, which is to level the user’s hand height. After measuring the actual body height and hand height of multiple participants, it has been found that the height of a person's hand is 60 percent of the height of the person's body. Therefore, the required height of the sink is the value of the user’s height multiplied to 0.6.

```
float height = heightsens();
float sink = sinkheight();
float currentTarget = calculateTarget();
if(A == LOW & B == HIGH){
Serial.println("USER DETECTED");

  if (var == 1){
    if (height >= 90 && height <= 185) {
      if (sinkheight() < currentTarget){
        Serial.println("naik");
        digitalWrite(LMOTOR,1); // naik
        digitalWrite(RMOTOR,0);
      } if (sinkheight() > currentTarget) {
        Serial.println("turun");
        digitalWrite(LMOTOR,0);
        digitalWrite(RMOTOR,1); // turun
      } if((sinkheight() > currentTarget - 5.00) && (sinkheight() < currentTarget + 5.00)){
        Serial.println("stop");
        digitalWrite(LMOTOR,0); // Stop
        digitalWrite(RMOTOR,0); // Stop
        var = 2;
      }
    }
  }
```

Figure 38. Coding Script 4

This code is to determine the user’s presence during the running of the system. The system will deny any users below 90 cm since the sink cannot move downward any further to prevent hitting the bottom frame. The motor will move depending on the current sink height to the required sink height. To find out the measurement input of the sensors and the running of the system, serial print commands are inserted between the code scripts.

3.6 Motor Design

3.6.1 Motor Calculation

In order for this automatic height sink washer to move properly, motor calculation is crucial to determine the motor selection that is required to move the system smoothly and safely.

As the weight of the sink is 7.5 kg and the force gravitational is 9.81 $\mathrm{m/s^2}$, the downward force of the sink is

(Equation 1) $$\boldsymbol{F_n = m \cdot g}$$

$$\mathrm{F_n} = 7.5 \cdot 9.81$$

$$\mathrm{F_n} = 73.58\ N$$

To find out the minimum torque require to run the model properly, the formula that is used is the torque that is used to raise the model, which is raising the torque

(Equation 2) $$Tr = \frac{Fn \cdot dm}{2}\left(\frac{l + (\pi \cdot f \cdot dm)}{(\pi \cdot dm) - (f \cdot l)}\right)$$

All variables can be taken from the ball screw, where the friction force *f* is 0.3 N, force of the sink *Fn* is 0.073 KN.

Variables *l* and *dm* can be taken from the formula below,

(Equation 3) $$dm = d - \frac{p}{2}$$

(Equation 4) $$l = n \cdot p$$

where *d* is the diameter of the lead screw and *p* is the pitch of the screw

$$dm = 20 - \frac{5}{2}$$

$$dm = 17.5\ mm$$

$$l = 4 \cdot 5$$

$$l = 20\ \mathrm{mm}$$

After all variable is taken, it is then inserted into Equation 2

$$Tr = \frac{0.073 \cdot 17.5}{2}\left(\frac{20 + (\pi \cdot 0.3 \cdot 17.5)}{(\pi \cdot 17.5) - (0.3 \cdot 20)}\right)$$

$$Tr = 0.476\ Nm$$

Applying into the safety factor of 1.5, therefore the result is 0.713 Nm

Assume the speed needed is 20 mm per second, and the lead screw pitch is 5 mm, therefore

20 mm/s → 1200 mm/minute

(Equation 5) $$\textit{\textbf{Rated speed}} = \textit{\textbf{speed/pitch}}$$

$$\text{Rated speed} = 1200/5$$

$$\text{Rated speed} = 240\ \text{RPM}$$

So, the final result for the rate speed and torque needed for the motor selection are 0.713 Nm and 240 RPM.

3.6.2 Motor Selection

The Dunkermotoren GR63X25 is suitable motor for this model, as based on the datasheet, the motor produces 2.1 Nm with a rated speed of 200 RPM. The problem is located within the speed on the motor itself and the requirement needed. The reason is because due to fact that if the movement of the sink is slow, the users can be impatient and reluctant to use, particularly where the user's target is for children. Therefore, changing the DC Motor into faster motor is recommended, since the current gearbox is already permanently place within the motor and the current motor model is now aged.