Department of Electronic & Telecommunication Engineering

University of Moratuwa

EN 3023 – Electronic Design Realization

Automatic Lighting and Security System

Project Report

Group Number : 04

Group Members :

Name	***Index Number***
Jayalath M.W.K.S.	*180260U*
Nirhoshan S.	*180428T*
Pethangoda R.M.	*180472V*
Rathnayaka R.G.H.V.	*180529E*
Sewwandi B.L.P.N.	*180589K*
Thilakarathna G.D.O.L.	*180642T*
Udara A.W.T.	*180650P*
Udugamakorala G.D.	*180655K*
Vitharana N.	*180672J*
Watawana H.S.	*180677E*

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This Report is submitted as a partial fulfillment of the requirements for the module EN 3023 – Electronic Design Realization

Department of Electronic and Telecommunication Engineering,

University of Moratuwa.

Contents

1. Introduction on Product

The main purpose of this project is to make an affordable lighting system and a security system together. This product is configurable as a security system at once and automatic lighting system once with an IR remote controller. This product has 4 motion sensors along with four relays to control four lights. It's designed for outdoor lighting and security. When it switches to security mode, it will inform the owner with an alarm when someone passes by. When it switches to an automatic lighting system, the lights will turn on when someone passes by the motion sensor. There is more configurability with the product using IR remote like turning on just a single motion sensor to security mode while others are in lighting mode. Also, this device can identify day and night. The lights automatically turn on when it's nighttime.

2. Design Approach

Design approach of the product was based on User Centered Design (UCD) where analysis, conceptual design, detailed design, and design instructions play a major role. For this User Centered Design, Inclusive Design Toolkit was used as it is a step-by-step clear design approach where every design decision help to make the user experience better or worse. It is very essential to have an informed decision making at the conceptual design stage as it might be expensive if changes need to do later. Let's see the different phases in the inclusive design process one by one.

2.1. Phase 1 : Manage

- **Review progress and plan next steps**
  - **What have we got?**
    - A simple prototype of automatic light and security system which was implemented for the project in semester 02 under EN1070 – Electronic Product Design and Manufacture.
    - Enclosure with poor quality
    - Few conceptual designs
    - Resource personnel
    - Satisfactory product specifications
    - Components, tools, and equipment
  - **What are we missing?**
    - Additional Product functionalities
    - PCB with industrial touch
    - High quality enclosure
    - User need analysis
    - Sufficient Capital
    - Electronic components with high quality
  - **What resources are available?**
    - Experience received by team members through early semester projects
    - Improved theoretical knowledge of team members
    - Experience gained through earlier prototype design and testing it
    - Guidance received from lecturers
  - **What are deadlines?**
    - Initially project had to complete by Jan-2022. But with the start of Industrial training the deadlines were changed continuously. However, we could complete by May-2022.

- **What are the risks?**
  - Not being able to meet the initial deadline.
  - Not being able to improve the product within the targeted cost margins
  - Getting rejected by the customer
  - Unavailability of components with adequate quality
  - Availability of similar cheaper products in the market

- **What should we do next?**
  - Conducting a proper user centered survey
  - Analyzing the survey data properly
  - Adding new features according to customer's preferences
  - Redesigning PCBs according to new requirements and manufacturing
  - Redesigning a good quality enclose and manufacturing

➢ **Refine product goals**

- **What problem are we trying to solve?**
  - When someone comes near outside, lights automatically turn on at night.it informs that the light is on. So, consumers can notice someone there.
  - Consumers can change the setting of the controller to different types of modes. Therefore, the user can manually control the security, turn on lights using the remote control.
  - This can be implemented especially based on the availability of natural lights. This product can be mounted on the top of a gate or a door as per consumers' requirements.
  - Environmental signals are misled by the motion sensors. So, only human gestures are identified.
  - Waterproof enclosure with high rigidity.
  - Consumers can control the operating procedure according to their requirements.

- **What are the big issues?**
  - Protect household goods from thieves
  - Identifying the arrival of an individual from an entrance

- **What is the proposed solution and why is it different?**
  - Product is designed for outdoor light and security.
  - When it switches to security mode, it will inform the owner with an alarm when someone passes by.
  - When it switches to an automatic lighting system, the lights will turn on when someone passes by the motion sensor.

➢ **Build business case**

Business case was built with the aid of possible costs and benefits associated with an inclusive design project.

Below Excel spreadsheets provide a platform for performing cost-benefit calculations, together with a list of cost-benefit case studies for inclusive design.

Possible impact factors

Possible costs and benefits associated with an inclusive design project. Each section examines the factors associated with one stakeholder.

Is this significant for my project?	Impact Factor	Type of Cost / Benefit	How might inclusive design impact it?
		Stakeholder: Strategy	
X	Long-term development costs	Decreased cost	Inclusive design can reduce long-term development costs by reducing the need for architectural redesign to make future versions of the product easier to use.
☐	Revenue for other parts of the business	Increased revenue	Some designs can encourage sales of related products or the use of related services.
X	Meeting business objectives	Other benefit	Inclusive design can help to meet Corporate Social Responsibility (CSR) goals and other aspects of the business objectives.
		Stakeholder: Development	
☐	Cost of change (making changes to the design)	Decreased cost	Inclusive design can help to detect required changes early on (especially when these are due to usability and inclusivity problems). Changes are much easier and cheaper to make early in the development process.
☐	Cost of project slippage (delayed time to market)	Decreased cost	Inclusive design often reduces the risk of project slippage and reduces development timelines. This is because there is often less need for rework, as rework is often required due to incorrect design and miscommunication. In addition, the validity of designs can be confirmed at early stages of the project.
X	Documentation cost	Decreased cost	Inclusive products are often easier to explain and thus to document.
X	Development cost	Decreased or Increased cost	Inclusive design can reduce overall development costs by helping developers to identify and focus on the relevant functionality, by detecting required changes early and by reducing the need for rework. There are also development costs associated with conducting inclusive design (e.g. staff costs, cost of running usability studies) but these are often outweighed by the overall cost reduction. Both of these should be considered in the cost-benefit calculation.
X	Appropriate functionality	Other benefit	Inclusive design enables you to priorities the functionality that's important for customers rather than spending time developing undesired and unused features
☐	Risk management	Other benefit	Inclusive design can help to improve risk management by testing the validity of designs early in project development.
☐	Development effectiveness	Other benefit	Inclusive design can help to encourage good development practices, e.g., accessible websites need to be programmed in a clearer and more structured way.
☐	Other		
		Stakeholder: Manufacturing	
☐	BOM (Bill of Materials)	Decreased or Increased cost	Some designs require different materials to be used in manufacturing the product. If this is the case, then the change in the cost of the materials should be considered.
☐	Tooling costs	Decreased or Increased cost	Different designs require different tooling set-ups which may cost different amounts. In particular, making a change to an existing product may incur retooling costs.
X	Production costs	Decreased or Increased cost	The cost of producing each item (in addition to materials and tooling) may also be affected.
		Stakeholder: Sales	

☐	Advertising costs	Decreased cost	Inclusive design can improve marketability and thus reduce advertising costs. A positive press response and user response to an inclusive product can also reduce the need for advertising.
☐	Retail costs	Decreased cost	Some projects may affect retail costs, e.g., making the stock management systems easier to use may improve staff efficiency and reduce retail costs.
X	Sales	Increased revenue	Inclusive design can result in increased sales for a variety of reasons. It increases the customer base and the likelihood of repeat customers. In addition, designs that are easy to use and meet the users' needs often "demo better and sell better". In the sector of e-commerce, websites that are designed to be usable and inclusive enjoy an increased visitor count and conversion rate.
☐	Customer base	Other benefit	Inclusive design increases the customer base by enabling more people to use the product or service. This includes both people with reduced abilities and those who are limited by their environment (e.g., by noise, cold or limited bandwidth).
☐	Repeat customers	Other benefit	Usable and inclusive designs are more likely to result in satisfied customers who will return and use the service again or buy another product from the company.
☐	Brand	Other benefit	Inclusive design can improve the brand image and market perceptions of a company.
☐	Differentiation	Other benefit	Inclusive design can help a product to stand out, particularly in a saturated market.
☐	Longevity	Other benefit	Inclusive designs may last longer in the market (reducing long-term development costs and increasing the revenue from each version of the product)
X	Word-of-mouth recommendation/ condemnation	Other benefit	Inclusive design often leads to more customer satisfaction and thus to more word-of-mouth recommendation. It also avoids the word-of-mouth condemnation that often arises from poor usability.
☐	Press response	Other benefit	Usable and inclusive designs can generate a positive press response (e.g. positive reviews), and avoid the negative publicity that can come from usability problems.
☐	Ease of finding the desired products (specific to ecommerce sites)	Other benefit	An inclusively designed e-commerce website is easier to navigate and thus it is easier to find the desired products. This leads to an increase in sales.
Stakeholder: Operations			
X	Back-office costs	Decreased cost	Some projects may affect back-office costs, e.g., making distribution systems easier to use may improve staff efficiency.
X	Cost of returns	Decreased cost	Inclusive design can reduce the rate of returns, as some products are returned because the customers find them too difficult to use.
X	Support costs	Decreased cost	Inclusive products cause less usability problems and hence generate less support calls. However, note that introducing any change to a system can initially increase the number of support calls before they settle down to the new daily rate.
☐	Training costs (internal)	Decreased cost	Fewer training materials and less training time are needed for more usable systems.
☐	Maintenance costs	Decreased cost	Inclusive systems are often better structured and thus easier to maintain.

☐	System costs (servers, databases, etc to keep the product running)	Decreased cost	The system costs vary a lot depending on the nature of the product but need to be considered. An inclusive design example is that an inclusive website with clear and consistent navigation reduces unwanted page downloading and thus reduces bandwidth and server load.
☐	Legal costs	Decreased cost	Inclusive products reduce the risk of legal action (and negative publicity) associated with inaccessibility.
X	User/employee satisfaction and productivity	Other benefit	More inclusive and usable systems can be used more efficiently by staff. In addition, less time is wasted by experienced staff helping when new users encounter difficulties. Inclusive systems are also often more pleasant to use, increasing user and staff satisfaction.

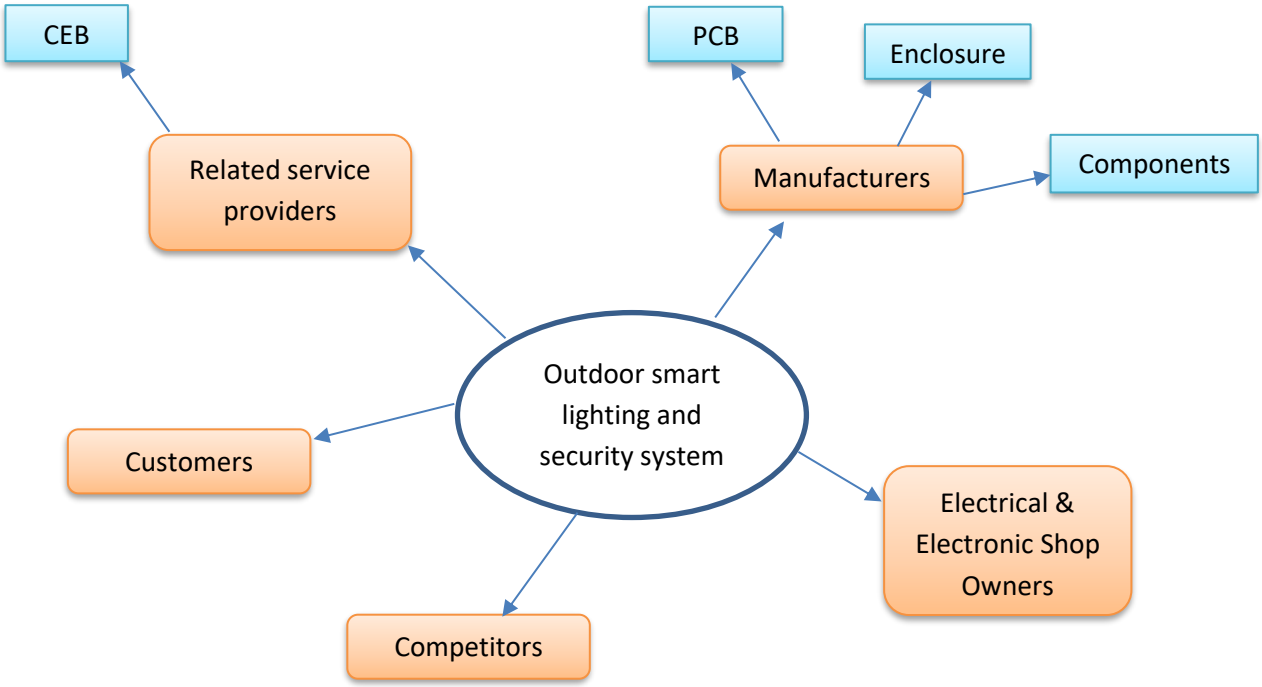
Initial impact assessment

Project Name: Outdoor Smart Lighting and Security System			Date: 08-Feb-2022	
Impact Factor Descriptions				Size of Impact (Choose from drop-down list)
Stakeholder	Impact Factor	Type of Cost / Benefit (Choose from dropdown list)	Rationale	
Strategy < Possible factors: Long-term development costs, Revenue for other parts of the business, Business objectives, Other >	Long-term development costs	Decreased cost	Concerning more on the user needs would help for better product where no need of development for a long time.	High
Strategy < Possible factors: Long-term development costs, Revenue for other parts of the business, Business objectives, Other >	Meeting business objectives	Other benefit	Can increase the sales count by improving customer satisfaction and functioning for both lighting and security purpose help the reduce the need of two devices	High
Development < Possible factors: Cost of change, Time to market, Documentation, Development costs, Other >	Documentation cost	Decreased cost	Easy to explain and do documentations due to inclusive design process.	High
Development < Possible factors: Cost of change, Time to market, Documentation, Development costs, Other >	Development cost	Decreased cost	Ability of addressing the relevant functionality and there by reworking cost may reduce.	High
Development < Possible factors: Cost of change, Time to market, Documentation, Development costs, Other >	Appropriate functionality	Increased revenue	Identify the user expecting functionalities through the product.	High
Manufacturing < Possible factors: Bill of Materials, Tooling, Production, Other >	Production costs	Decreased cost	Production cost can be reduced through having a clear emphasize on product and its manufacturing process.	High
Sales <Possible factors: Advertising, Retail, Sales, Brand, Press response, Longevity, Other >	Sales	Increased revenue	High customer demand is received for a product which meets user needs.	High
Sales <Possible factors: Advertising, Retail, Sales, Brand, Press response, Longevity, Other >	Word-of-mouth recommendation / condemnation	Increased revenue	Increase of customer base and mouth to mouth recommendation can be achieved through customer satisfaction.	Medium
Operations < Possible factors: Back office, Returns, Support, Training, Maintenance, System costs, Legal issues, User/Employee productivity, Other >	Back-office costs	Decreased cost	Distribution cost can be reduced by designing the product with minimum size.	Medium
Operations < Possible factors: Back office, Returns, Support, Training, Maintenance, System costs, Legal issues, User/Employee productivity, Other >	Cost of returns	Decreased cost	User satisfaction regarding the product will reduce the return of the products.	High
Operations < Possible factors: Back office, Returns, Support, Training, Maintenance, System costs, Legal issues, User/Employee productivity, Other >	Support costs	Decreased cost	Support requirements in handling the product can be reduces when product designed for easy manipulation	High

Operations < Possible factors: Back office, Returns, Support, Training, Maintenance, System costs, Legal issues, User/Employee productivity, Other >	User/employee satisfaction and productivity	Intangible	High customer satisfaction gained due to the design process followed.	High

2.2. Phase 2 : Explore

➢ **Create stakeholder map**



➢ **Observe users**

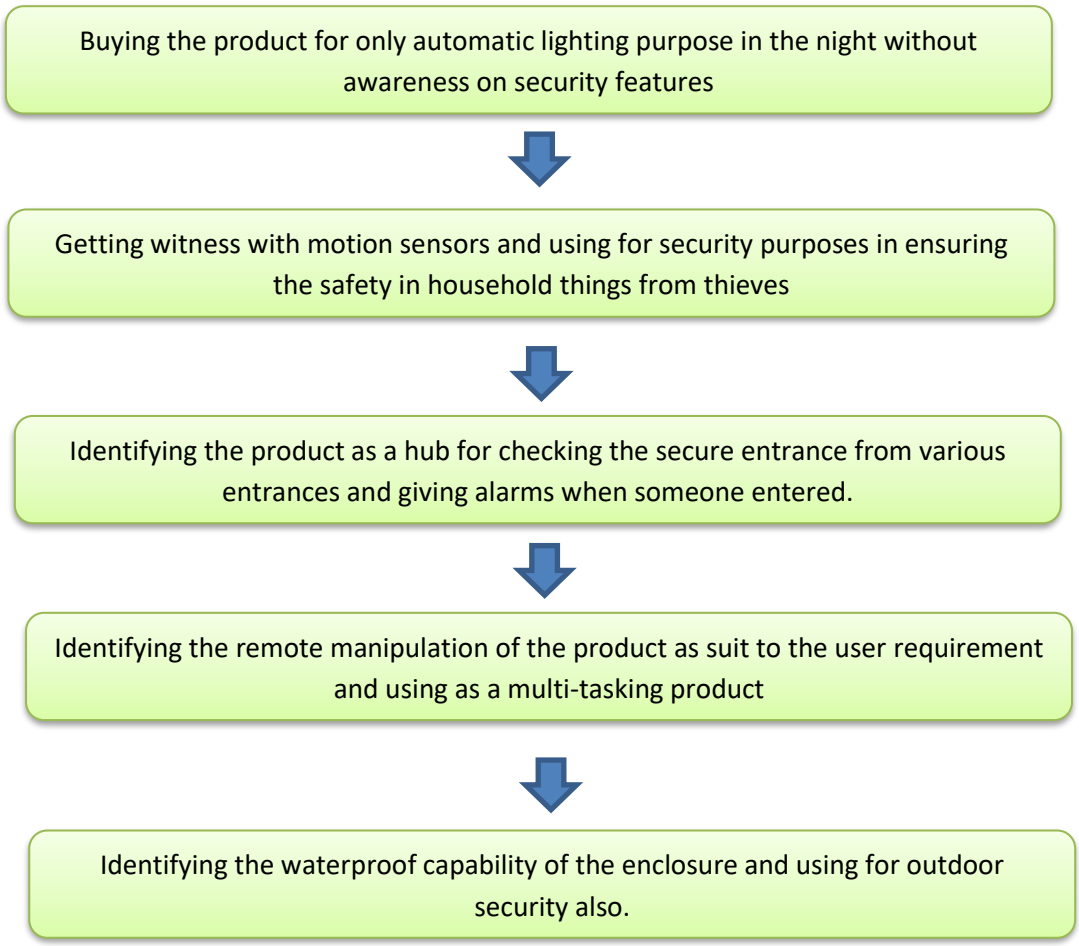
- **Customers**
  - Financial and emotional interest on product: positive feedback for low-cost affordable product
  - Motivation : Cost, functionality, and reliability
  - Required information : How the product works, how much the product costs and what are the installation requirements
  - Current opinion : Positive impression due to preliminary discussions regarding the product functionality.
  - Opinion Influencers : Electrical and Electronic shop owners

- **Electrical & Electronic shop owners**
  - Financial and emotional interest on product: positive feedback in earning profit by selling the product
  - Motivation : Cost, functionality, and marketability of the product
  - Required information : How the product works and how much the product costs.
  - Current opinion : Positive impression due to preliminary discussions regarding the product functionality.
  - Opinion Influencers : Their customers, other product manufacturers

- **Competitors**
  - Financial and emotional interest on product: Negative feedback as they don't want a competition to their market
  - Motivation : Competition in marketability of the product
  - Required information : How quality is the product and method of attracting the market
  - Current opinion : Competition can be lowered through small low budget product
  - Opinion Influencers : Their customers

➢ Describe user journeys

Currently there is no identical products with all the features similar to our product. But there is number of items with similar capabilities found on the market. households are concerned about energy-efficient and handy products. Our product is a 2 in 1 option which contains both lighting and a security system. User journey can be depicted as below.



- **Capture need list**

Stakeholder	Stakeholder's Expectation	Aim
Electrical & Electronic Shop Owners	Product should be sold with non-return.	Ensure the confidence of selling the product and earning the expected profit from sale.
	Product should attract the customer at first impression.	Ensuring the demand from the customer through multi-tasking functionality.
	Market demand should be high.	Can invest on the product with more confidence
Customers	Making the day-to-day purposes easy.	No need to concern on switching on and off lights when entering to a premise.
	Ensure the safety of the household things from theft attack.	Security alarm generation make to identify any entrance from the door access.
	Consuming less power due to performing the functions of two independent devices.	Save the power which is considered as a vital necessity in nowadays in Sri Lanka due to unnecessary lighting.
	Product should be at an affordable price.	Need only a single unit for a large house as it can manipulate 4 entrances.
	To have a reliable and durable product at a reasonable price	Can use the product for a longer period without malfunctions.

2.3. Phase 3 & 4 : Explore & Evaluation

- **Simulate ideas – Conceptual Designs**

  - **Design No : 01**

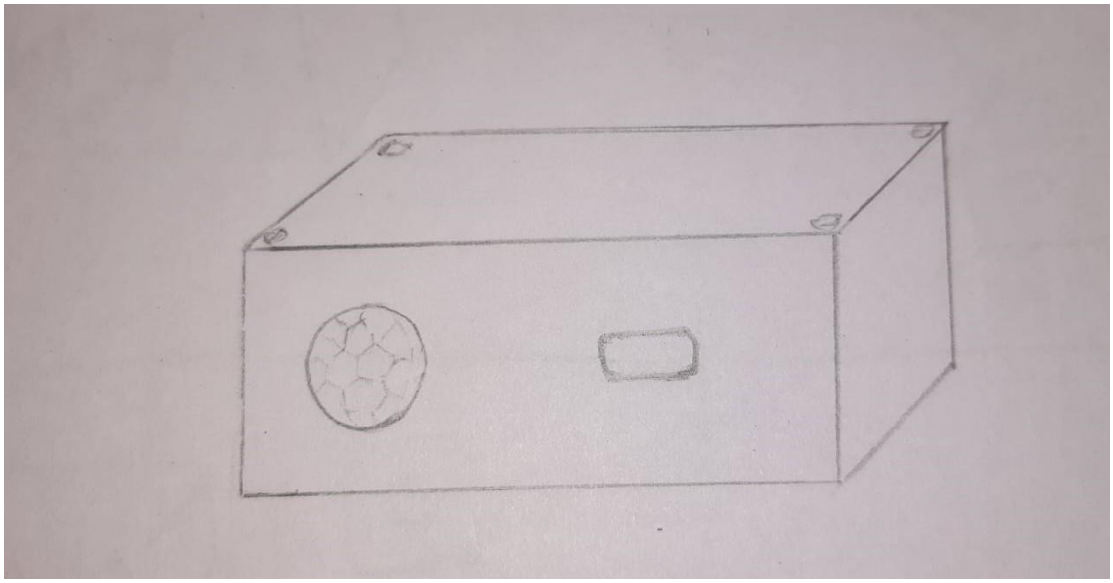


Figure 2.1 – Conceptual Design Sketch 01

- **Design No : 02**

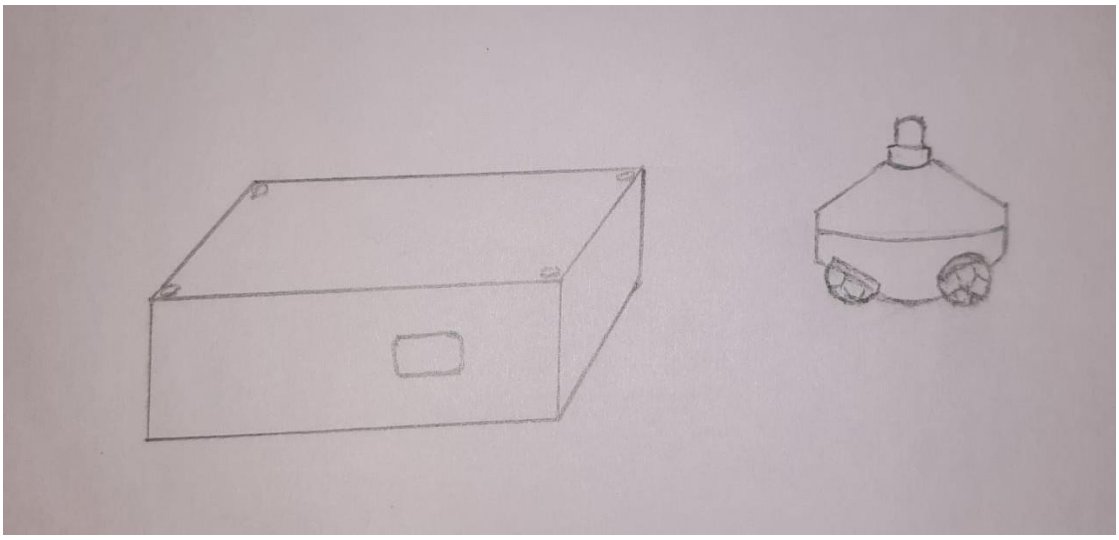


Figure 2.2 – Conceptual Design Sketch 02

- **Design No : 03**

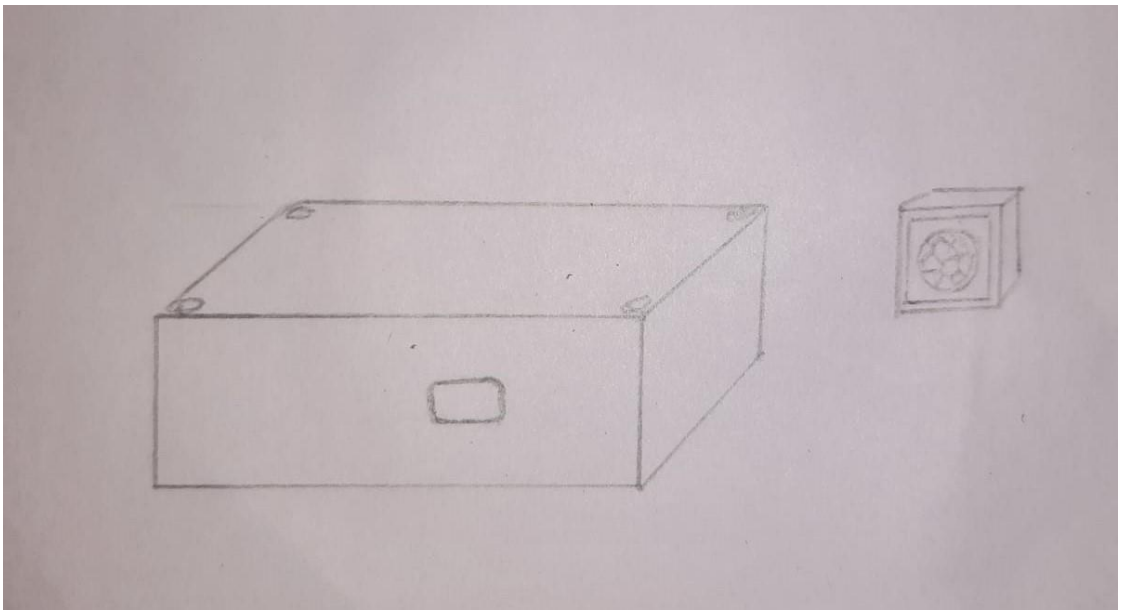


Figure 2.3 – Conceptual Design Sketch 03

➢ Develop Concepts – Conceptual Design Evaluation

Design Number	Pros	Cons
Design No : 01	No external wiring for sensor needed	Motions are happening in the range of control unit only can be detected
	Simple system design	A lot of blind spots are present in the system
Design No : 02	External sensor wiring is simple	External wiring is needed
	The most critical entry point can be covered completely	Blind spots are present in the system

Design No : 03	No blind spots are present in the system	Complicated wiring system
	Motions happening in each side of the premises can be identified separately	

In our project, the considered critical factor was covering complete area without blind spots. Therefore, we decided to implement Design No : 03.

- **Make prototypes – Preliminary Designs**

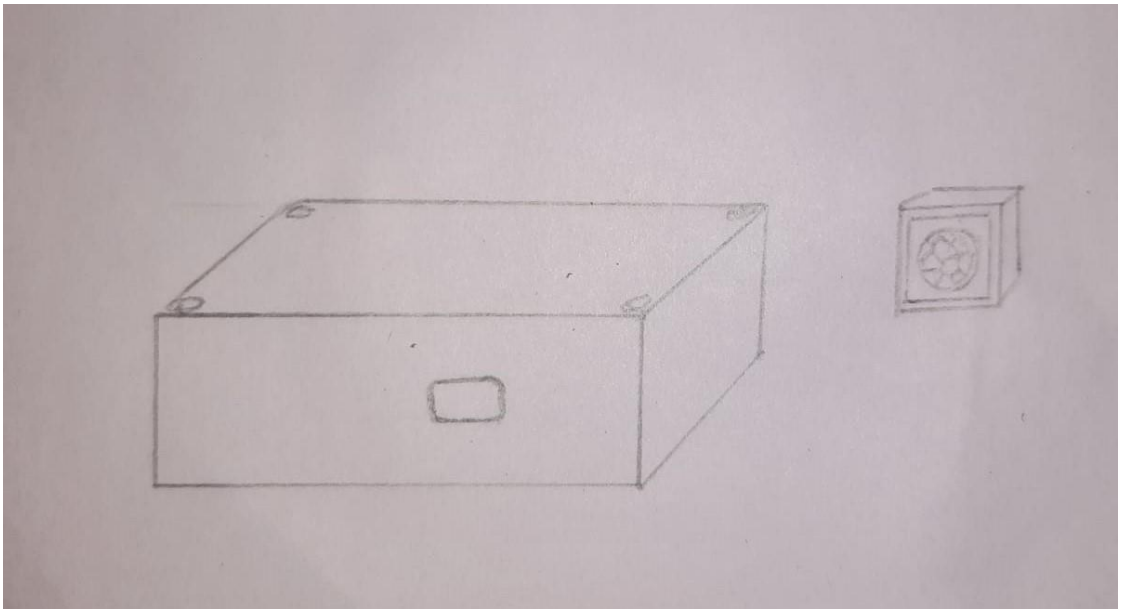


Figure 2.4 – Conceptual Design sketch used as Preliminary Design

As a 360-degree view can be monitored through 4 PIR sensors, there won't be any blind spots. So this will enhance the requirements of the stakeholders and also the multi functionality than our initial product.

3. Detailed Design

For the design purpose of the PCB prototype **Easy EDA** was used and for the design of enclosure **Solidworks** was used.

➢ Schematic Design

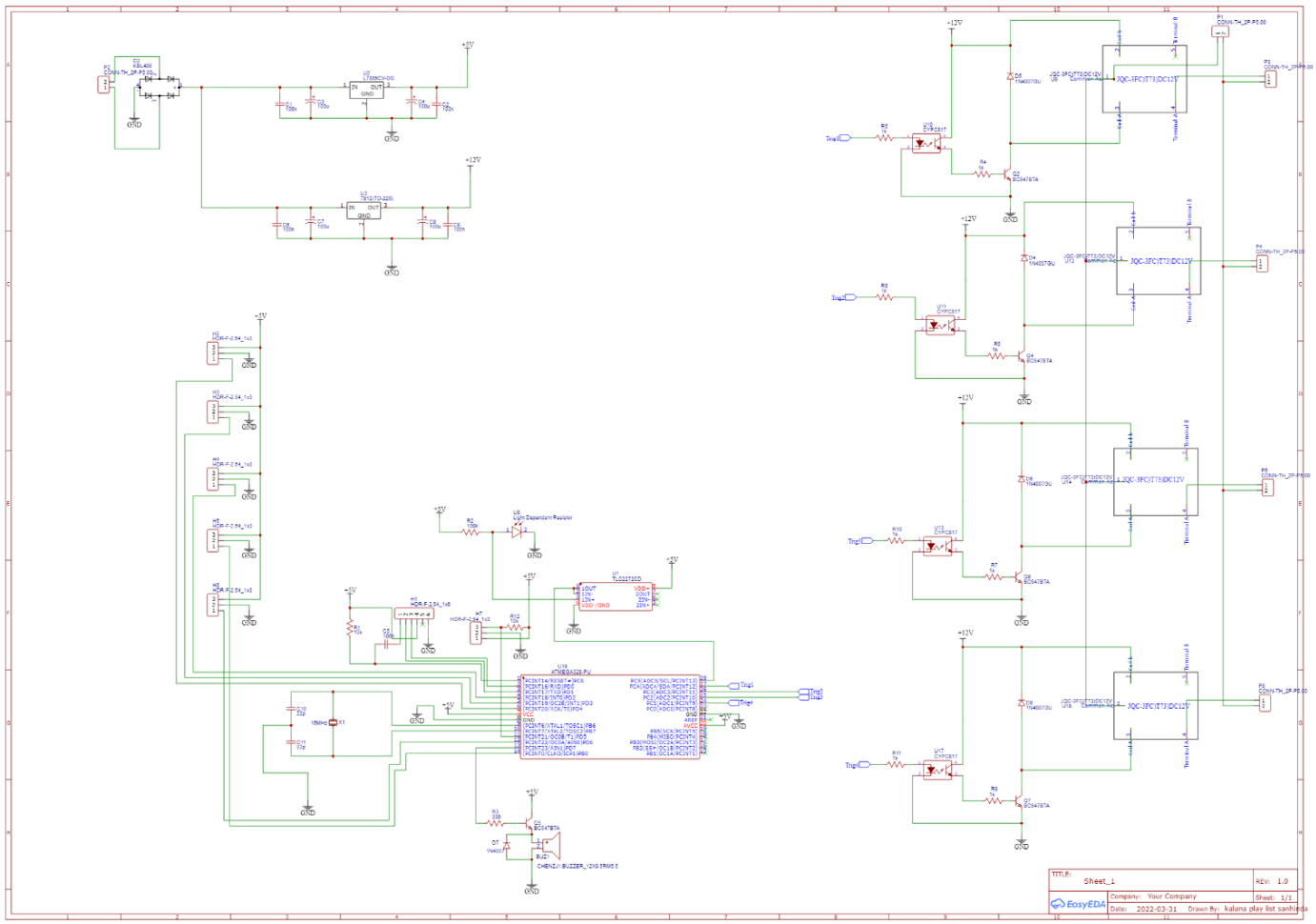


Figure 3.1 - Schematic Design for PCB

➢ PCB Design

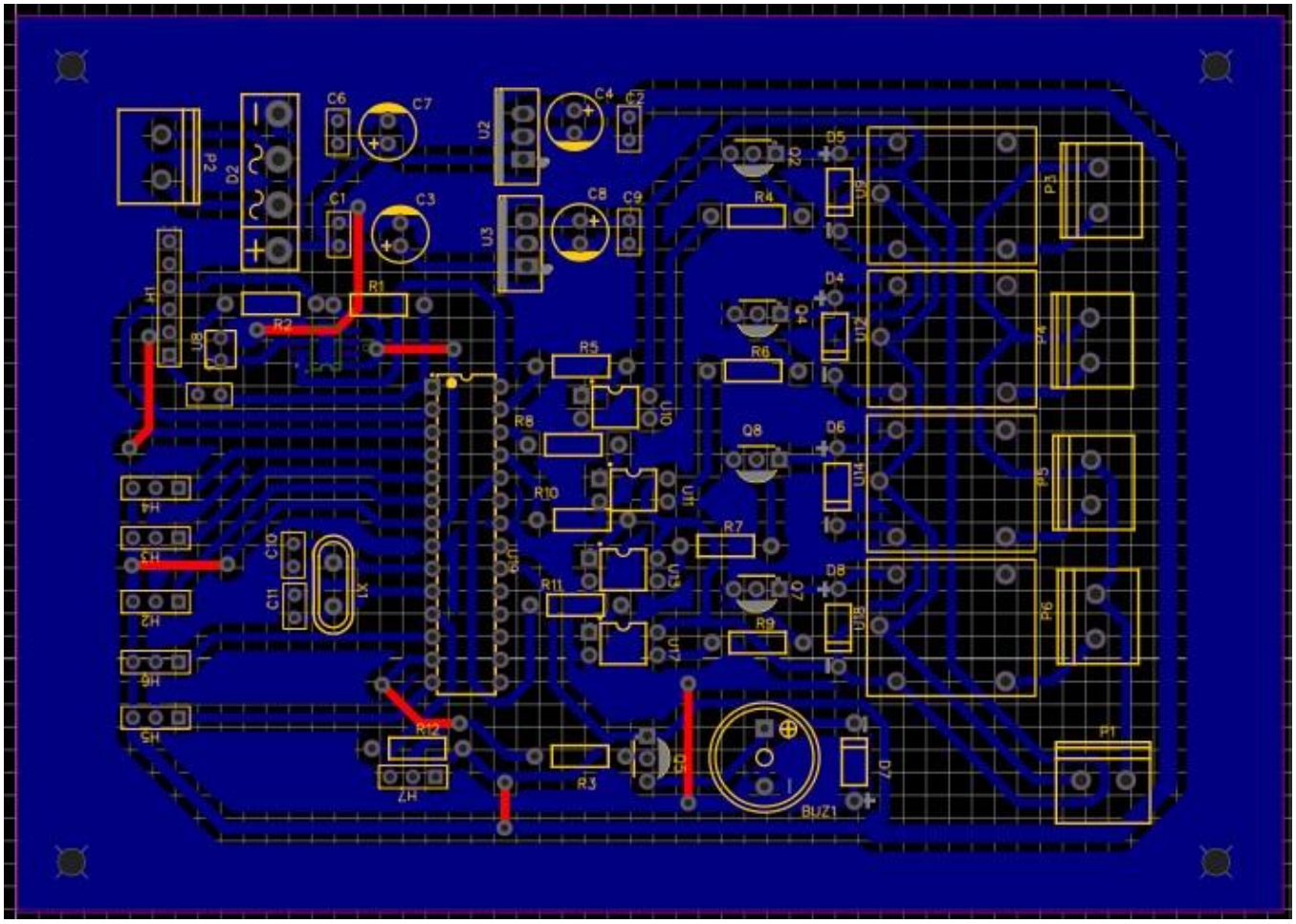


Figure 3.2 – PCB Design

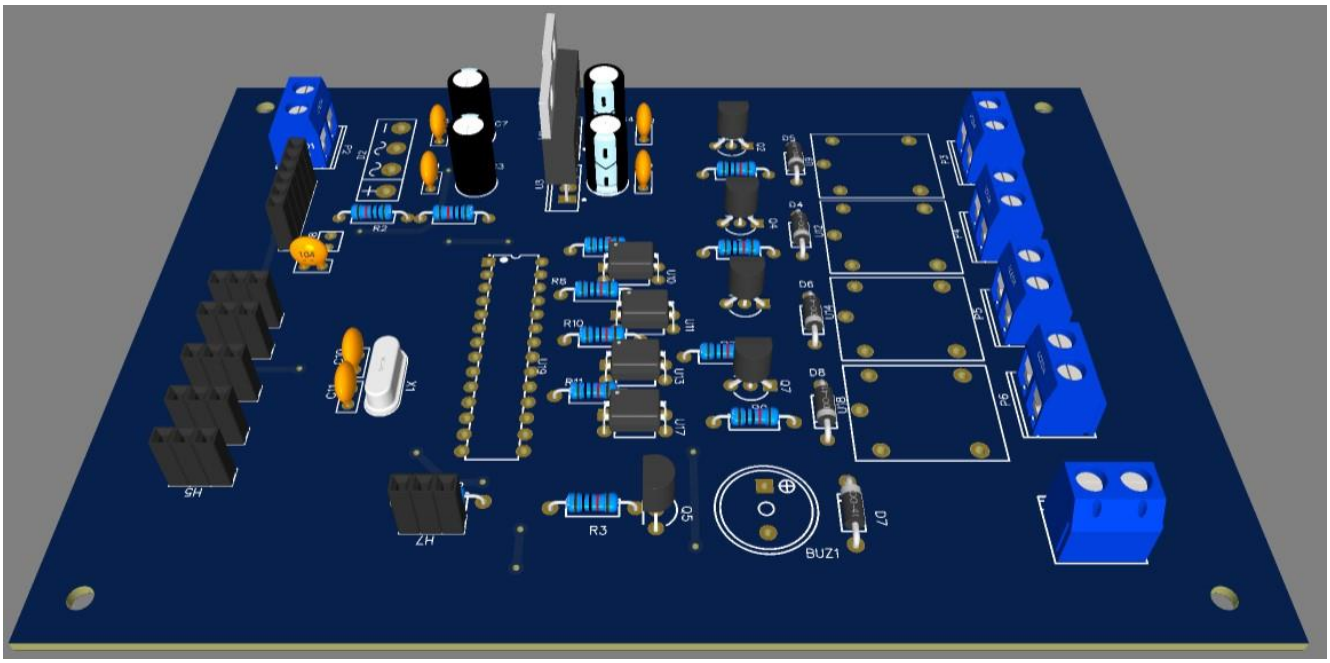


Figure 3.3 – PCB Design 3D View

- **Enclosure Design**
  - **Main enclosure**

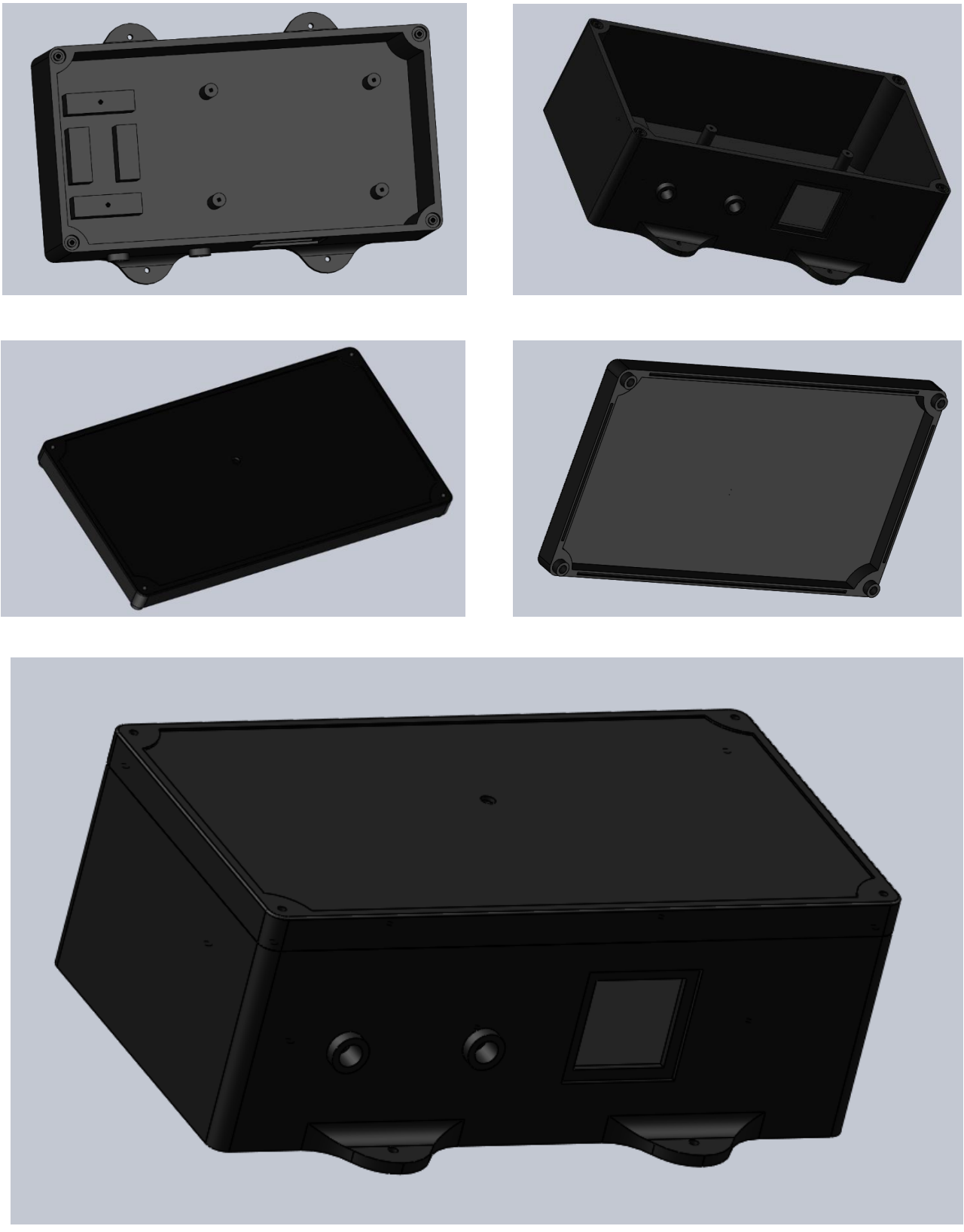


Figure 3.4 – Snaps of Main Enclosure Design

- **PIR Sensor enclosure**

Figure 3.4 – Snaps of PIR Sensor Enclosure Design

4. Production Process

In this section The PCB fabrication process, soldering process, enclosure manufacturing process are described. Few parts of the production process are outsourced due to low volume of manufacturing and insufficient locally available facilities.

➢ PCB Fabrication

The Schematic designed through **Easy EDA Software** was fabricated on a copper plate as shown in the below figure.

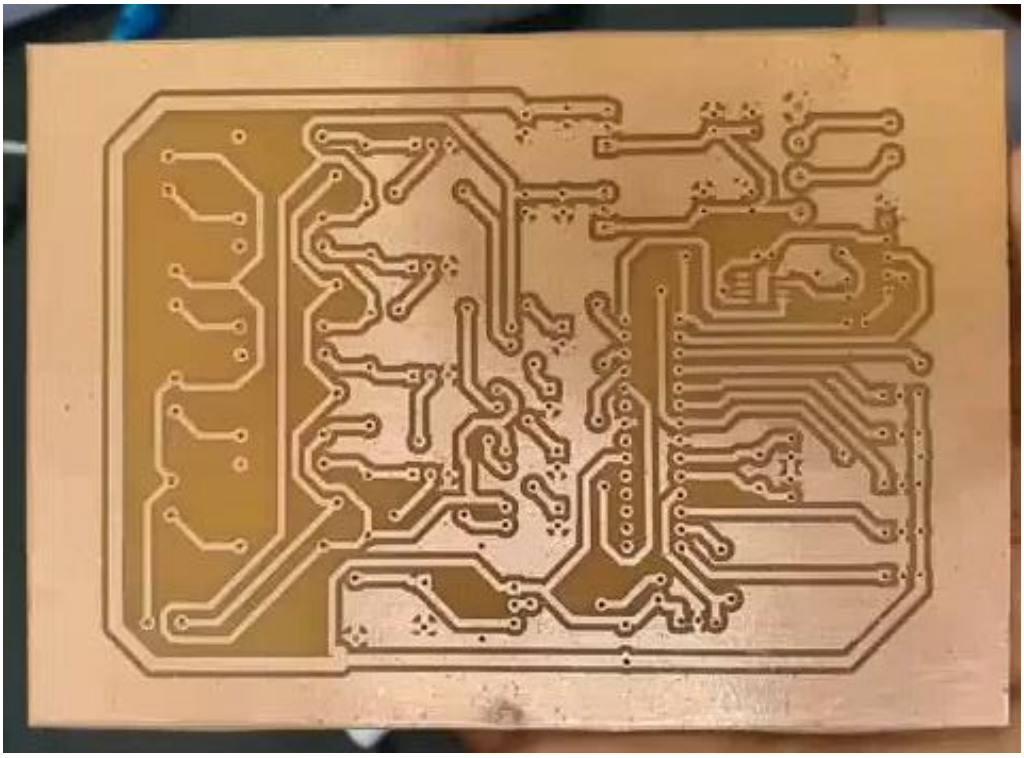


Figure 4.1 – Fabricated PCB for the product

➢ Soldering process

As there are only few numbers of components per PCB and there is one PCB for a product soldering process was done manually by hand which helps in reducing the cost too. As this is the initial stage of the product sale, whenever a growth in budget happen possibly can shift to automatic component soldering technique.

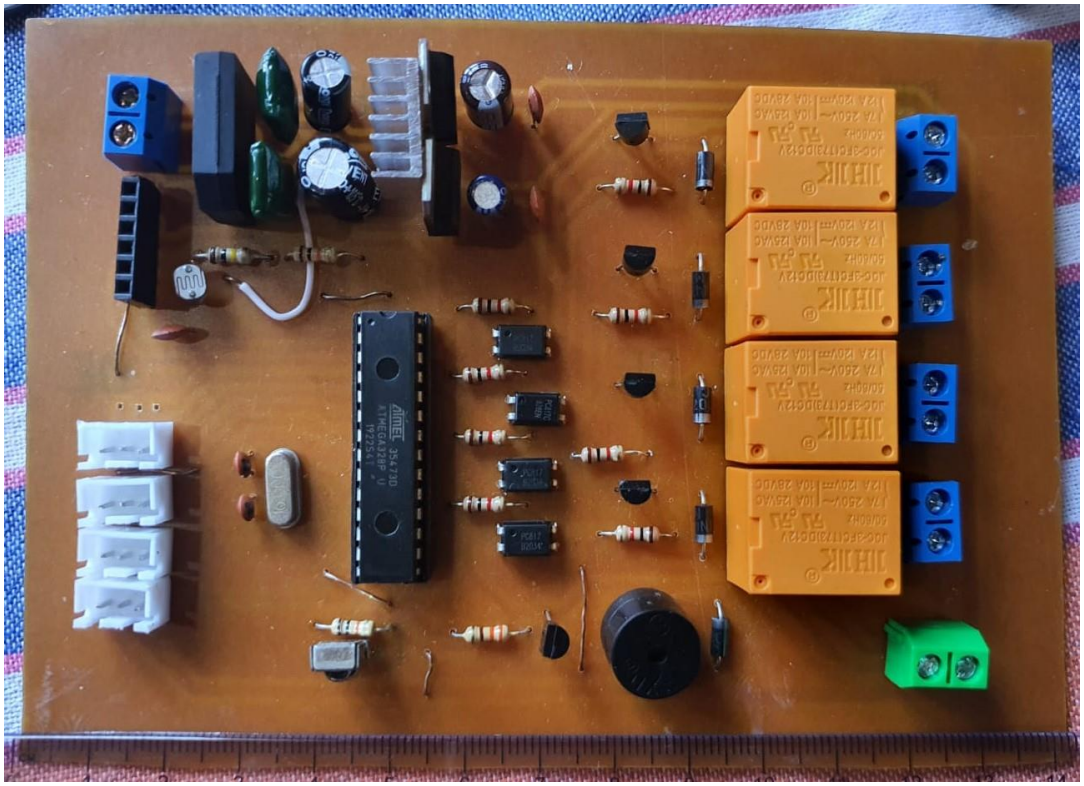


Figure 4.2 – PCB after Soldering Components

➢ Enclosure Manufacturing Process

Enclosure of the automatic light and security system is basically containing two enclosures for the main PCB unit and the PIR sensor unit. Both are basically box like structures. The entire enclosure design was modelled using **Solidworks** Software. 3D printing is used for this manufacturing process as it can be performed with an affordable cost than other mechanisms like injection molding. The enclosure was manufactured using plastic as raw material as it is the best material that can ensure the safety of the components. Images shown below are the snaps of the manufactured enclosure.

Figure 4.3 – Snaps of Enclosure

- **Final Product**

Figure 4.4 – Snaps of final product

5. Operation Algorithm

This product: Automatic lighting and security system is acting two devices as of its name suggests. One is for lighting purpose and other is for security purpose. PIR sensor (Passive Infrared Sensor) facilitate the security purpose while four bulbs facilitate the automatic lighting purpose. This system can identify motion from four set of directions front, back, left and right as we set them. The four bulbs are set correspond to each of these directions. A buzzer is there for sound alarming purpose, and it is common for all four directions. It can use lighting system for security system function also. With the help of IR remote it is capable to give commands as of user preference. Remote keys are coded as of functioning different user set preferences. Chart shown below is the key configuration which has coded to the micro controller in the PCB to act according to the user preference.

Main Menu

Keys	Controls
1	Security in the 1st direction
2	Security in the 2nd direction
3	Security in the 3rd direction
4	Security in the 4th direction
5	Buzzer is switched on
6	Buzzer is switched off
7	Light is switched on
8	Light is switched off
9	Automatic Lighting for night (LDR)

If motion detected (default configuration)
1. Buzzer on
2. Light on

Sub Menu

Arrows	Control
Right	Buzzer on and light off
Left	Light on and Buzzer off
Up	Blinking and Buzzing in a preset frequency
Down	Buzzer and light off
*	Buzzing only in a preset frequency
#	Blinking only in a preset frequency

Keys 1-9 are used as main menu functions. Out of them keys 1-4 are used for direction controlling. For an example, If the user press the Key 1, PIR sensor will monitor any motion from the direction No : 01. In default configuration, when a motion is detected from the selected direction both buzzer and the light get on infinitely. There are some sub menu configurations also from arrow keys, star, and hash keys. Sub menu keys does not change the direction monitor set earlier. Keys 5-8 is used to manually On and Off the buzzer and the light respectively. Keys 6-7 can be used as regular light ON and Off keys. Key 9 is set for the automatic lighting purpose in the night when a LDR has employed for the concern. Here, light and the buzzer will turn On if the surrounding it detected to be dark.

- To switch off the automatic lighting (LDR) press Left arrow
- When Up arrow, * and # keys are pressed to return to the default configuration of the Security control – press Left Arrow
- To return to the main menu from the sub menu - press OK

There are some special key configurations as when we need to exit from the automatic lighting, we can press left arrow key. In order to return towards the default configuration after pressing up arrow, *, and # keys, we can press left arrow key. In order to return to the main menu from the sub menu OK key can be used.

6. Cost Estimation

Automatic and Lighting and Security System Cost Calculation for a Month		
Direct Materials:		
Electronic Components	200,000 LKR	
Enclosure Materials	125,000 LKR	**325,000 LKR**
Direct Labor:		
Fixing and Assembling	25,000 LKR	
Testing	25,000 LKR	
Packaging	15,000 LKR	**65,000 LKR**
Direct Other Expenses:		
PCB Printing and Soldering	150,000 LKR	**150,000 LKR**
Indirect Other Expenses:		
Electricity	10,000 LKR	
Shipping	5,000 LKR	
Transport and Courier	15,000 LKR	
Rent	15,000 LKR	**45,000 LKR**
Total cost for a month		**585,000 LKR**
Total number of units per month		**50 Units**
Total cost per unit		**11,700 LKR**
Profit		**2,299 LKR**
Selling Price of the Product		**13,999 LKR**

7. Appendix

➢ PCB Documentation

	A	B	C	D	E	F	G	H	I	J
1	ID	Name	Designator	Footprint	Quantity	Manufacturer Part	Manufacturer	Supplier	Supplier Part	Price
2	1	TLC2272CD	U1	SOIC-8_L4.9-W3.9-P1.27-LS6.0-BL-2	1	TLC2272CD	Texas Instruments	LCSC	C352994	1.972
3	2	CHENZJ1:BUZZER_12X9.5F	BUZ1	BUZ-TH_BD12.0-P6.50-D0.6_SEA-1285F	1	chenzj1:Buzzer_12x9.5RM6.5	null	LCSC	C9900008742	
4	3	100n	C1,C2,C5,C6,C9	RAD-0.1	5					
5	4	22p	C10,C11	RAD-0.1	2					
6	5	100u	C3,C4,C7,C8	CAP-D6.3×F2.5	4					
7	6	KBL406	D2	KBL_4P-L19.0-W6.3-P5.10	1	KBL406	Yangzhou Yangjie Elec Tec	LCSC	C698552	0.268
8	7	1N4007GU	D4,D5,D6,D8	DO-41_BD2.4-L4.7-P8.70-D0.9-RD	4	1N4007GU	DIYI Elec Tech	LCSC	C189226	0.017
9	8	1N4007	D7	DO-41_BD2.4-L4.7-P8.70-D0.9-RD	1	1N4007	SEMTECH	LCSC	C106903	0.02
10	9	HDR-F-2.54_1x6	H1	HDR-F-2.54_1X6	1			LCSC	C40877	0.069
11	10	HDR-F-2.54_1x3	H2,H3,H4,H5,H6,H7	HDR-F-2.54_1X3	6			LCSC	C146690	0.093
12	11	CONN-TH_2P-P5.00	P2,P1,P3,P4,P5,P6	CONN-TH_2P-P5.00	6			LCSC		
13	12	BC547BTA	Q2,Q4,Q5,Q7,Q8	TO-92-3_L4.8-W3.7-P2.54-L	5	BC547BTA	ON Semicon	LCSC	C258144	0.101
14	13	1k	R1,R4,R5,R6,R7,R8,R9,R10,R11	R_AXIAL-0.4	9					
15	14	100k	R2	R_AXIAL-0.4	1					
16	15	330k	R3	R_AXIAL-0.4	1					
17	16	10k	R12	R_AXIAL-0.4	1					
18	17	L7805CV-DG	U2	TO-220-3_L10.0-W4.5-P2.54-L	1	L7805CV-DG	STMicroelectronics	LCSC	C3795	0.179
19	18	7812(TO-220)	U3	TO-220-3_L10.0-W4.5-P2.54-L	1	MC7812BTG	ON	LCSC	C45387	0.579
20	19	Light Dependant Resistor	U8	DIO410X340X250	1	NSL 19M51.	Advanced Photonix	Element14	3168335	
21	20	JQC-3FC)T73)DC12V	U9,U12,U14,U18	JQC-3FC-12VDC RELAY	4	JQC-3FC)T73)DC12V	HKE	HKE	JQC-3FC)T73)DC12V	
22	21	CYPC817	U10,U11,U13,U17	DIP-4_L6.4-W4.6-P2.54-LS7.6-BL	4	CYPC817	OCIC	LCSC	C385061	0.034
23	22	ATMEGA328-PU	U19	DIP-28_L35.0-W6.5-P2.54-LS7.6-BL	1	ATMEGA328-PU	MICROCHIP(美国微芯)	LCSC	C613508	5.218
24	23	16MHz	X1	HC-49S_L11.0-W4.4-P4.88	1	49S12.28M20PF20PPMROHS	LCSC	LCSC	C52065	0.068

Figure 7.1 – Documentation on Components in PCB