UNIVERSITY OF MORATUWA, SRI LANKA

Faculty of Engineering

Department of Electronic and Telecommunication Engineering Semester 4 (Intake 2021)

Industrial End Effector

Prototype Design

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This report is submitted as a partial fulfillment for the module EN2160 - Electronic Design Realization, Department of Electronic and Telecommunication Engineering, University of Moratuwa.

1. User Requirements

An accurate and efficient end effector plays a critical role in reliably and efficiently completing precise tasks by acting as the interface between a robotic system and its operating environment. The end effector is the "hand" of the robot, used in space exploration, medical robotics, and industrial automation. It oversees handling things, carrying out delicate tasks, and carrying out difficult maneuvers. While its effectiveness ensures optimal performance, minimizes errors, and maximizes production, its accuracy guarantees activities are done with the necessary level of precision. An accurate and efficient end effector is critical to many aspects of robotics and automation, including manufacturing lines, supermarket logistics and surgery, as it directly affects the efficiency, speed, and safety of operations.

This industrial end effector project which was proposed by Professor Jayasinghe aims to create a game-changing device for automating tasks in places like supermarkets and factories. Unlike traditional vacuum-based methods, this new device can figure out how an object is oriented before a robot arm touches it. This means the robot arm can work more efficiently and safely. For example, in a supermarket, it could help sort products faster. In a factory, it could help assemble things more accurately. Overall, it makes automation smarter and more reliable, improving efficiency and reducing errors in various industries.

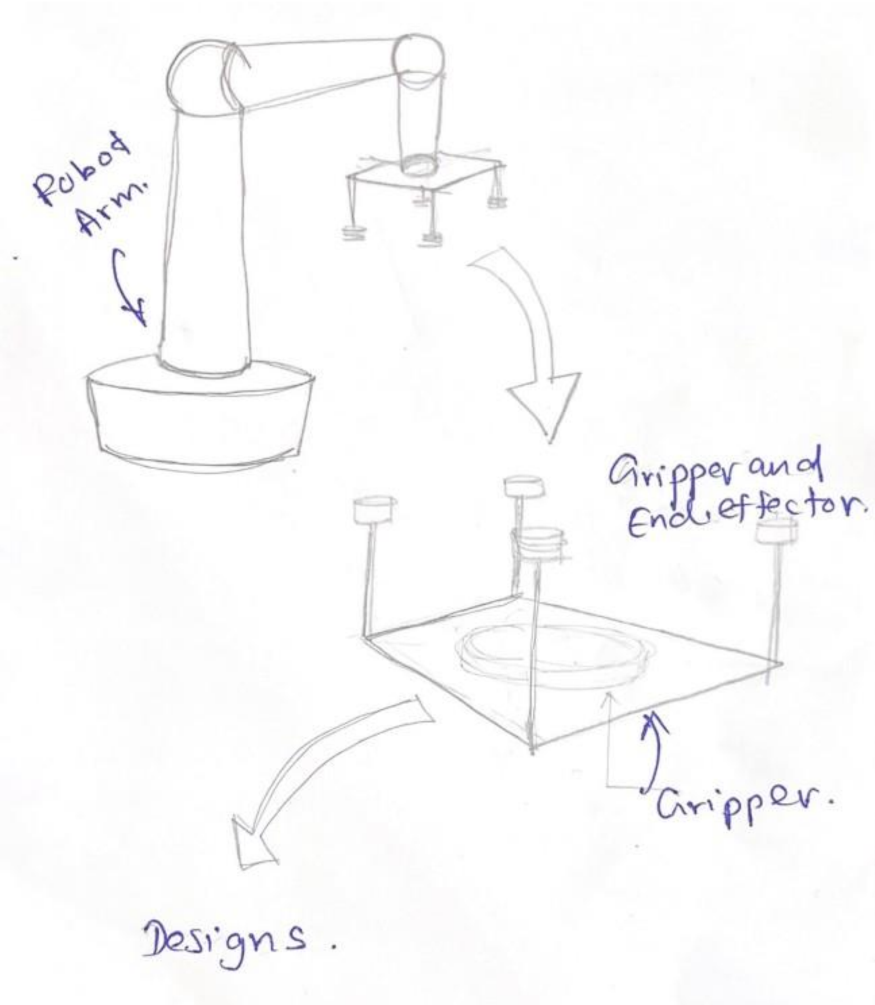
The following are some user requirements of an accurate end effector.

- Cost effectiveness: The end effector should be affordable to purchase and operate, minimizing the need for expensive maintenance or consumables.
- Time effectiveness: It should complete tasks quickly, without sacrificing accuracy, ensuring efficient operation within short timeframes.

• User-friendly interface: Operating the end effector should be simple and intuitive, requiring minimal training or technical expertise.
• Size and durability: It should be compact yet sturdy, capable of withstanding harsh conditions without compromising performance.
• Real-time data monitoring: Users should receive immediate feedback on its operations, enabling timely adjustments and monitoring of performance.

2. Conceptual Designs

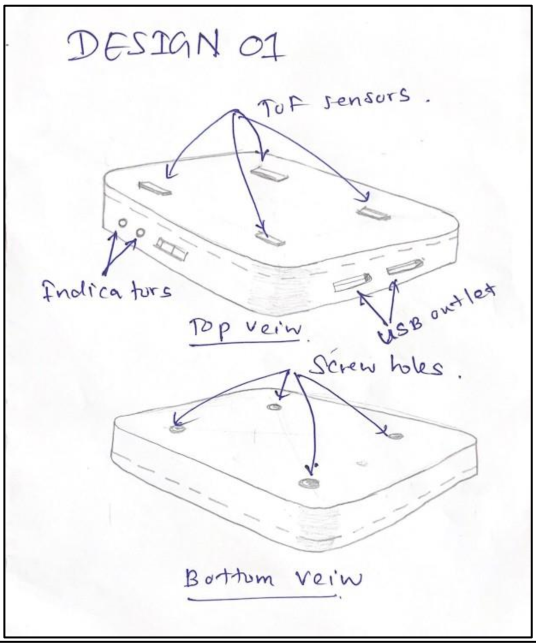
The following five conceptual designs were developed by the group members after having several brainstorming sessions and discussions within the group.

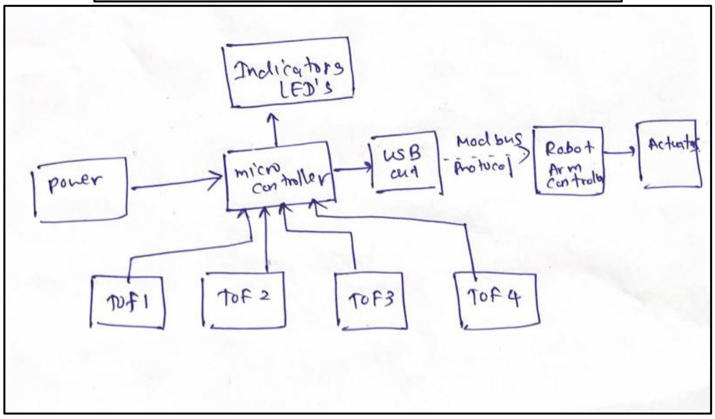


This will be the main structure of the robot arm that we are going to use for the end effector. The following designs will be mounted to this arm. The data that is received by the end effector will be fed to the robot arm. Then the arm controller will be able to take decisions according to the data fed to it.

2.1 Design 1

Enclosure

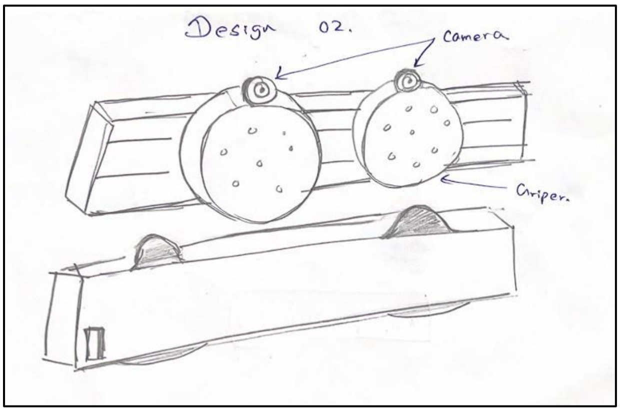




Functional Block Diagram

In this design we use the Time-of-Flight concept. We use 4 vl53l0x sensors here to measure distances. Modbus protocol is used to communicate with the robot arm controller though USB.

2.2 Design 2



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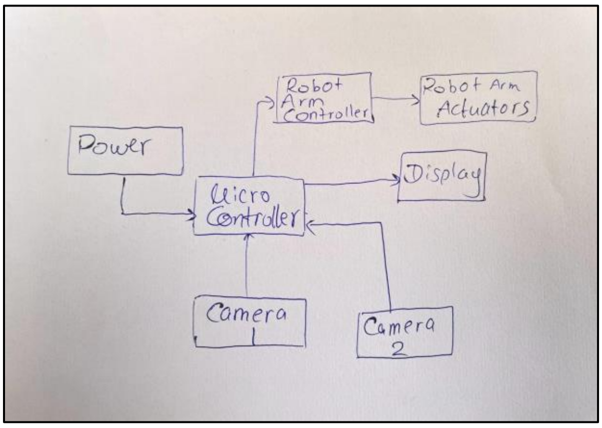
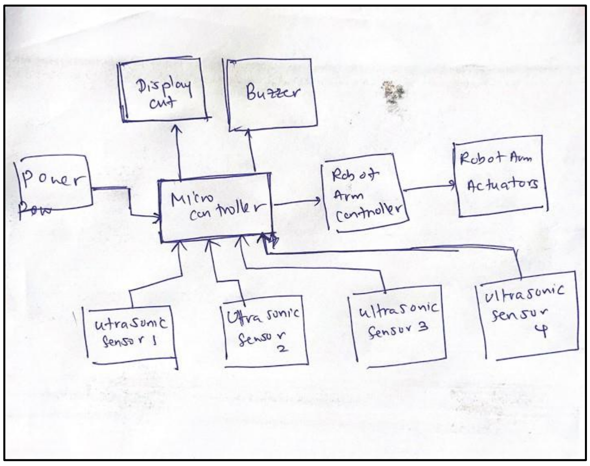


Functional Block Diagram

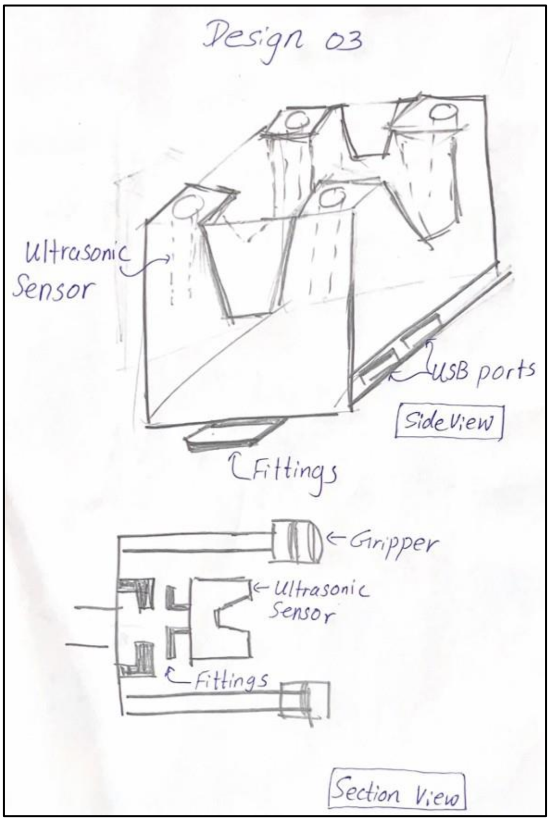
Here we use depth cameras to identify the distance to the object and its orientation. The 2 cameras are mounted at the top of the gripper. A display is used to show the outputs to the user.

2.3 Design 3



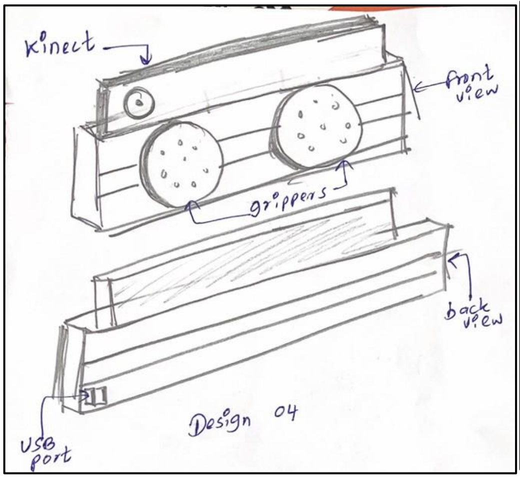
Functional Block Diagram

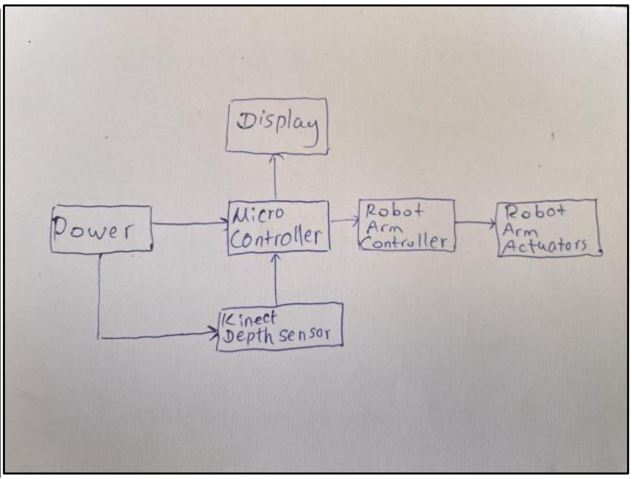
Enclosure



Here we use an ultrasonic sensor to map the distances to the object. From the distances measured we thought of identifying the orientations of the object. This design also has a display, and it has a buzzer.

2.4 Design 4





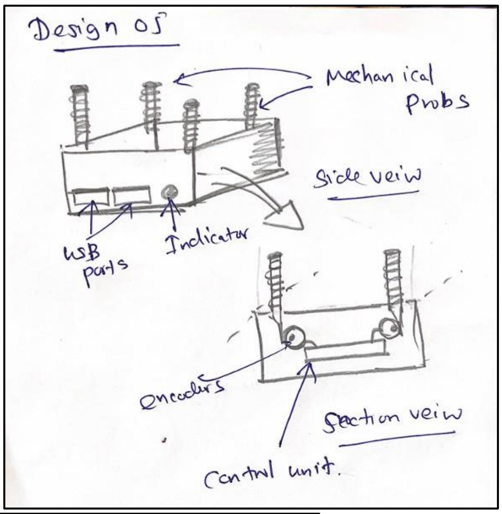
Enclosure

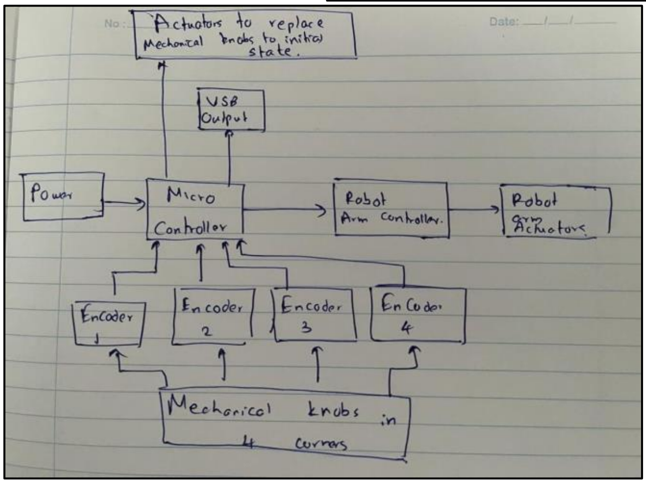
Functional Block Diagram

We use the Kinect here to measure the distances and to map the orientation of the object. Like the depth cameras design, the Kinect is also mounted above the gripper. A major drawback of this design is the cost of the Kinect sensor.

2.5 Design 5

Enclosure





Functional Block Diagram

In this design we thought of using a mechanical approach to measure the distances. We use 4 mechanical probes with encoders attached to them. The output of the encoders is fed to the micro controller and then the processed data to the robot arm actuators.

3. Evaluation of the Designs

	Design 1	Design 2	Design 3	Design 4	Design 5
Newly added features	Indicator LEDs USB Outputs RS 485 Module RS485 USB Converter	Display output. 2 Cameras	Display Output Buzzer output Ultrasonic Sensors	Kinect Sensor Display Output	Mechanical Probes Encoders USB Output
Removed features	Buzzer Output Display Output	LED Indicators Modbus Protocol	USB Outputs	USB Outputs Buzzer	Display Output

		Design 1	**Design 2**	**Design 3**	**Design 4**	**Design 5**
Enclosure design criteria comparison	Functionality	9	9	8	8	7
	Aesthetics	7	8	7	8	6
	Heat dissipation	7	9	7	8	9
	Assembly and serviceability	8	7	8	6	8
	Ergonomics	8	8	7	8	7
	Simplicity	9	7	9	7	8
	Durability	9	7	8	8	7
Functional block design criteria comparison	Functionality	9	9	8	9	6
	User experience	8	9	7	9	6
	Manufacturing feasibility	9	7	9	7	8
	Cost	8	6	9	4	8
	Performance	9	8	7	9	6
	Future prolongs	8	9	7	9	6
	Power	8	7	8	7	7
Total		118	108	117	117	107

3.1 Enclosure design criteria

- Functionality: How well-supported are the primary functionalities by the design?
- Aesthetics: To what extent is the user visually appealing overall?
- Heat dissipation: How much heat is produced and how effectively is it controlled?
- Assembly and serviceability: To what extent is it easy to assemble and disassemble?
- Ergonomics: How easily can the user engage with the design and how well does it fit in their hand?
- Simplicity.

3.2 Functional block diagram criteria

- Functionality: To what extent do functional needs get met by the circuit design?
- User experience: To what extent is the interaction intuitive and user-friendly?
- Manufacturing feasibility: Determine whether the design can be manufactured.
- Cost: Analyze the total cost-effectiveness of the capability offered.
- Performance: Assess the bandwidth range, resolution, and signal quality.
- Future proofing: How easily can individual components be upgraded or replaced in the design?
- Power Efficiency: To what extent is the device’s power usage managed effectively.

4. Design Selection

According to the evaluation criteria, the first design has been chosen to develop.

4.1 Features of the Design

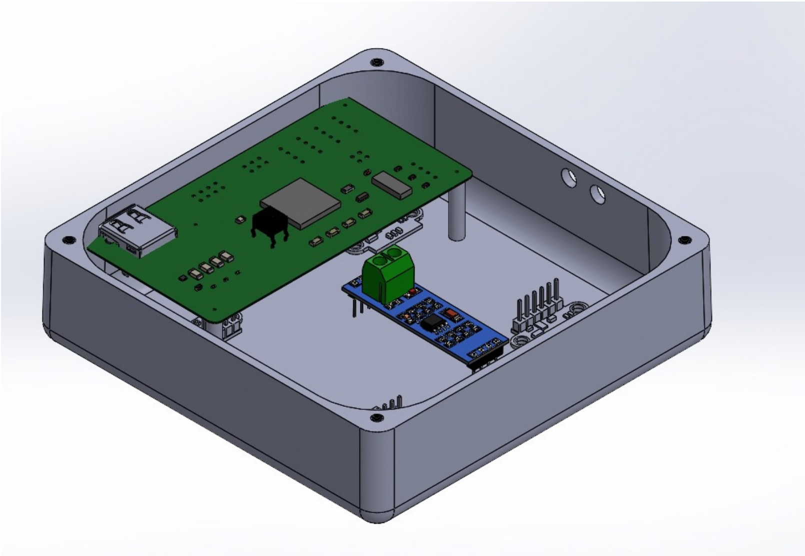
The choice of Conceptual Design 01 was a strategic decision, primarily due to its combination of compact size and durable construction. This compact and easily mountable design ensures seamless integration into the robot arm with vacuum gripper, optimizing space utilization.

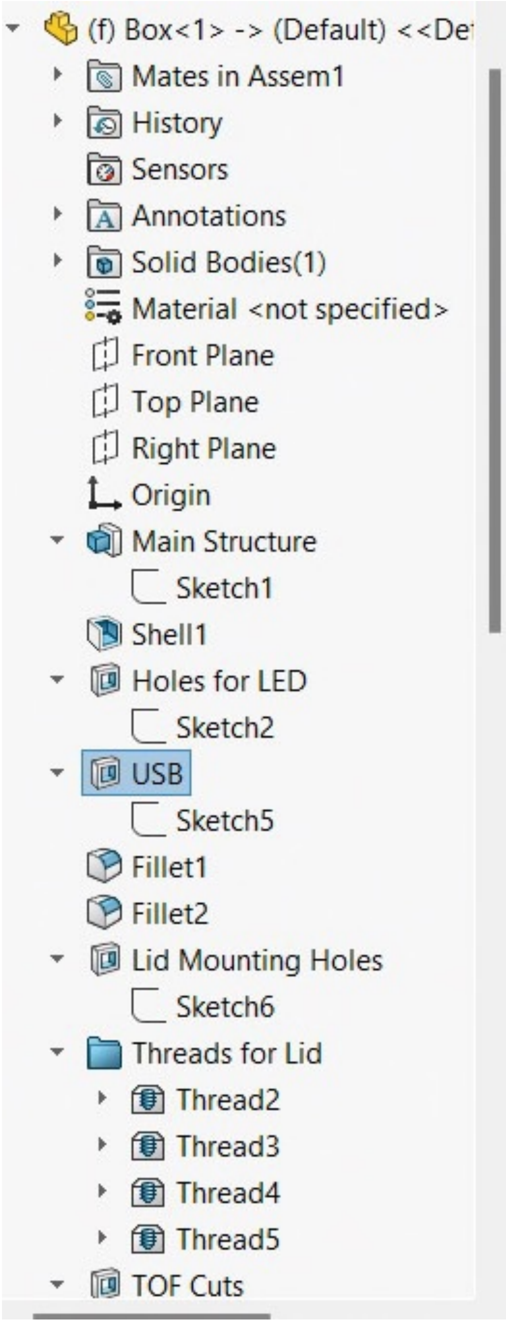
Furthermore, the integration of Time-of-Flight (ToF) sensors within Conceptual Design 01 offers a significant advantage by providing more accurate and reliable measurements. Maintaining a sufficient distance between ToF sensors ensures that the percentage error remains below 1%, guaranteeing precise results and enhancing the overall accuracy of our system.

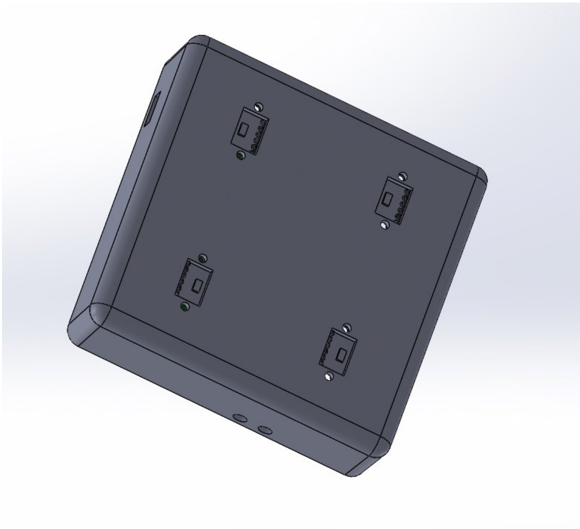
The inclusion of a USB port facilitates both power input to the circuit and communication with the robot, streamlining the setup process and enhancing connectivity.

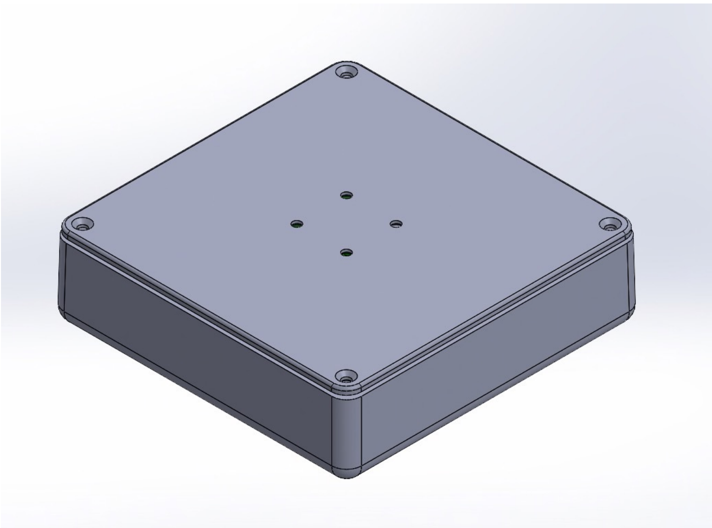
In addition, the deliberate choice to utilize only essential indicator LEDs while removing buzzers and displays enhances the industry suitability of Conceptual Design 01. By prioritizing simplicity and functionality, we ensure that our solution meets industry standards and requirements without unnecessary distractions or complexities.

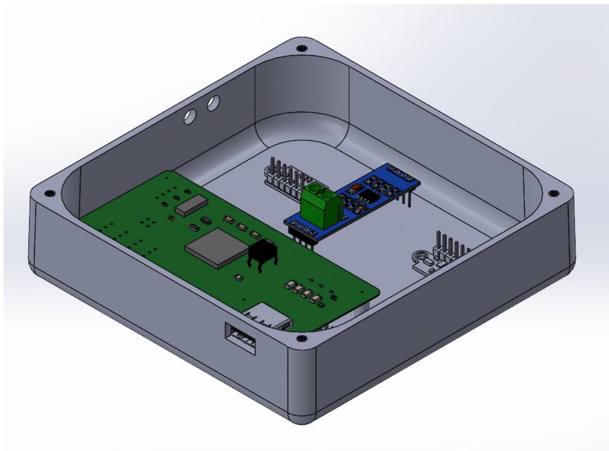
5. SolidWorks design



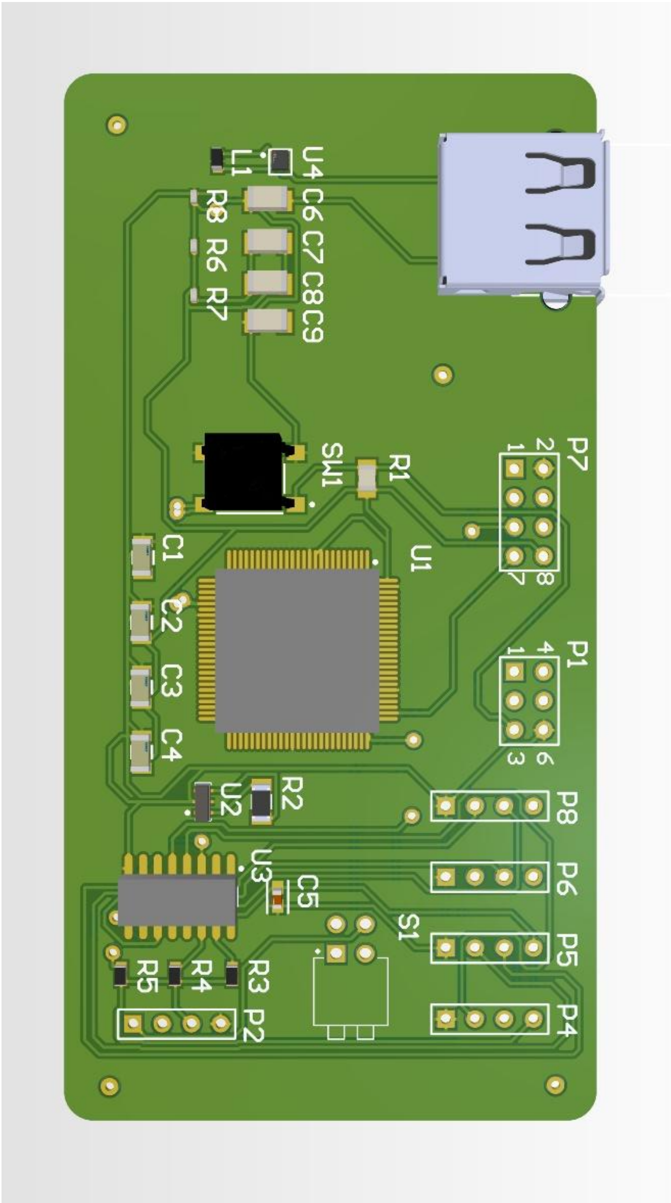


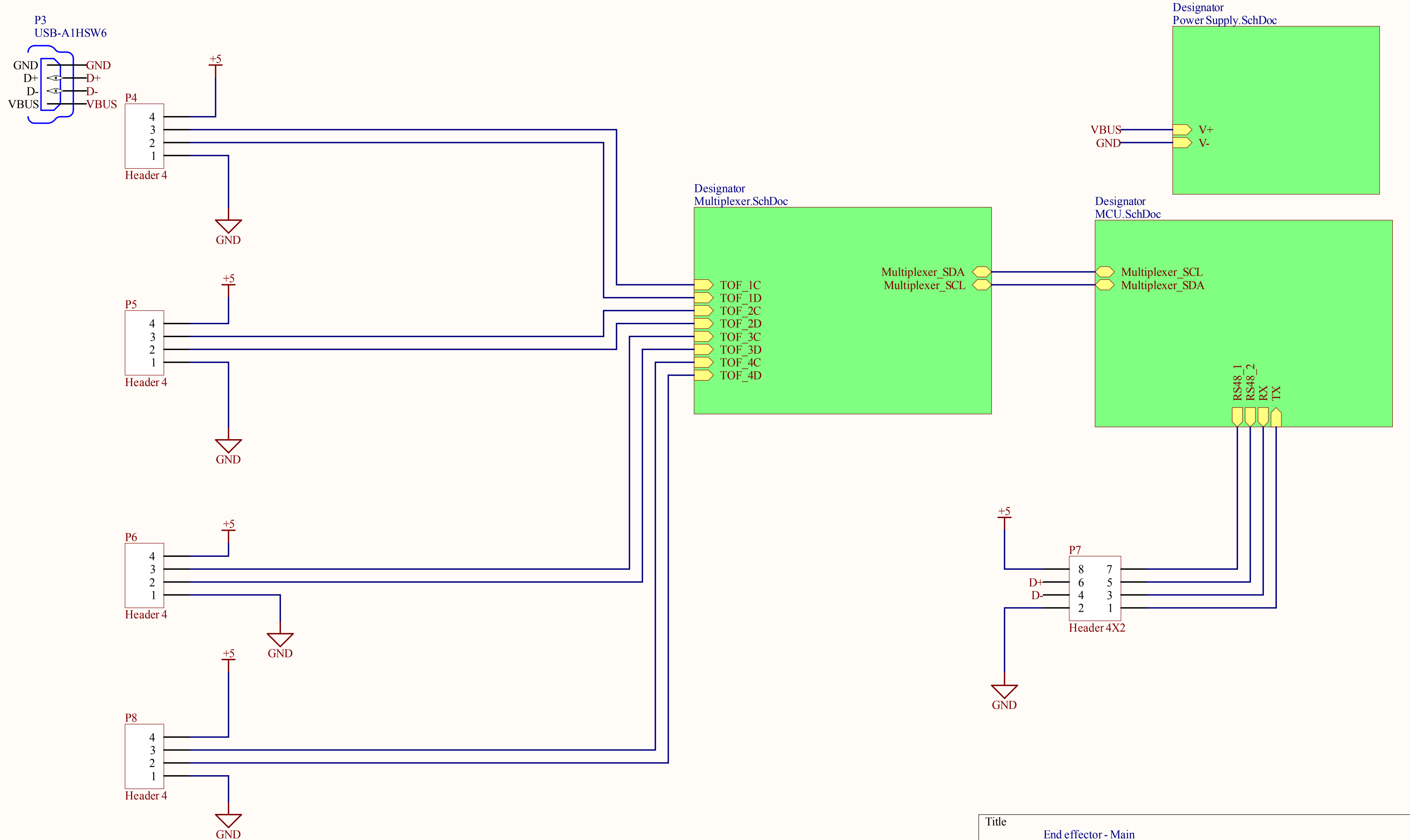






6. Schematic and PCB design





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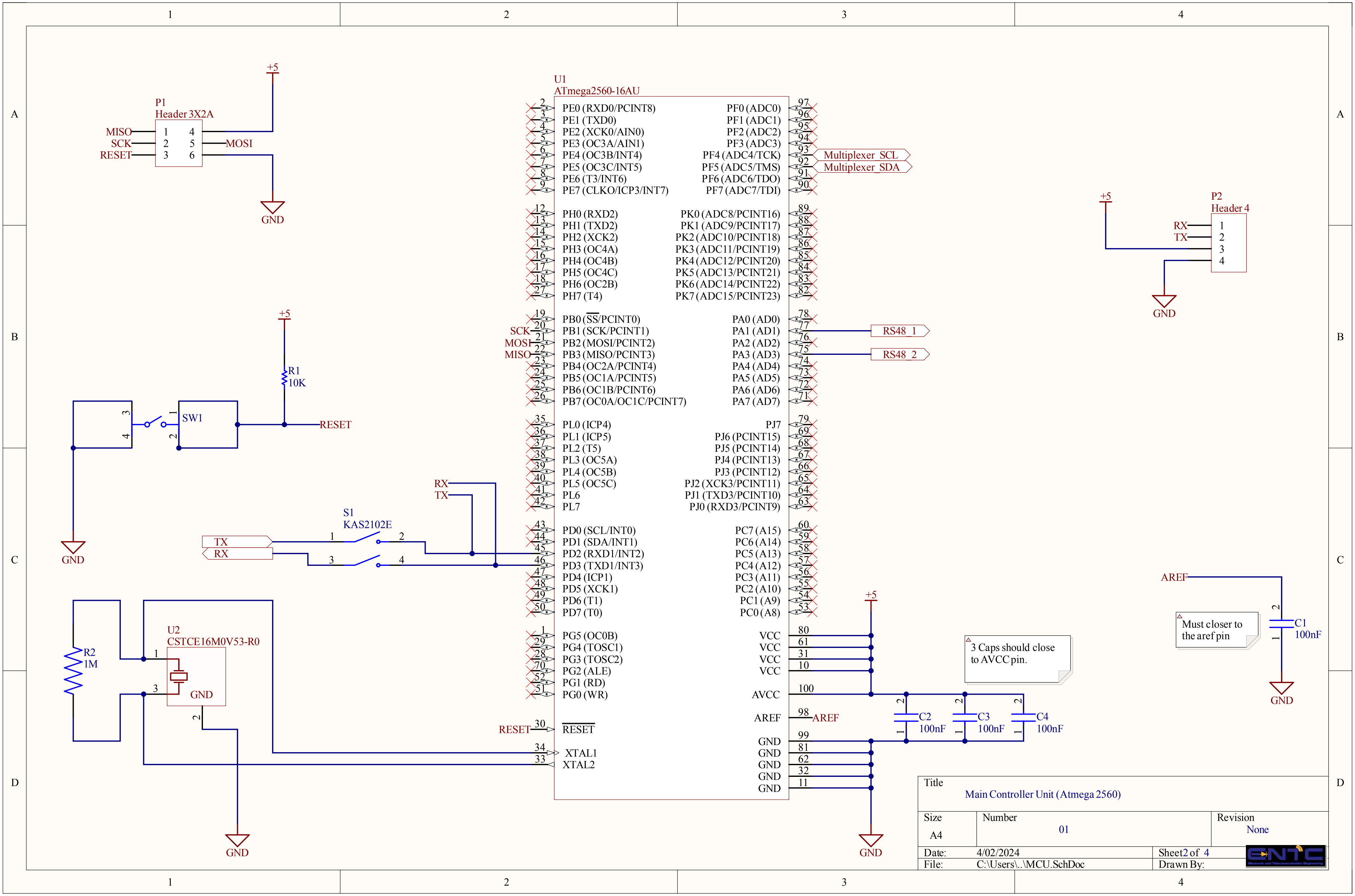

P1
Header 3X2A
MISO
SCK
RESET
MOSI
+5
GND
U1
ATmega2560-16AU
PE0 (RXD0/PCINT8)
PE1 (TXD0)
PE2 (XCK0/AIN0)
PE3 (OC3A/AIN1)
PE4 (OC3B/INT4)
PE5 (OC3C/INT5)
PE6 (T3/INT6)
PE7 (CLKO/ICP3/INT7)
PH0 (RXD2)
PH1 (TXD2)
PH2 (XCK2)
PH3 (OC4A)
PH4 (OC4B)
PH5 (OC4C)
PH6 (OC2B)
PH7 (T4)
PB0 (SS/PCINT0)
PB1 (SCK/PCINT1)
PB2 (MOSI/PCINT2)
PB3 (MISO/PCINT3)
PB4 (OC2A/PCINT4)
PB5 (OC1A/PCINT5)
PB6 (OC1B/PCINT6)
PB7 (OC0A/OC1C/PCINT7)
PL0 (ICP4)
PL1 (ICP5)
PL2 (T5)
PL3 (OC5A)
PL4 (OC5B)
PL5 (OC5C)
PL6
PL7
PD0 (SCL/INT0)
PD1 (SDA/INT1)
PD2 (RXD1/INT2)
PD3 (TXD1/INT3)
PD4 (ICP1)
PD5 (XCK1)
PD6 (T1)
PD7 (T0)
PG5 (OC0B)
PG4 (TOSC1)
PG3 (TOSC2)
PG2 (ALE)
PG1 (RD)
PG0 (WR)
RESET
XTAL1
XTAL2
PF0 (ADC0)
PF1 (ADC1)
PF2 (ADC2)
PF3 (ADC3)
PF4 (ADC4/TCK)
PF5 (ADC5/TMS)
PF6 (ADC6/TDO)
PF7 (ADC7/TDI)
PK0 (ADC8/PCINT16)
PK1 (ADC9/PCINT17)
PK2 (ADC10/PCINT18)
PK3 (ADC11/PCINT19)
PK4 (ADC12/PCINT20)
PK5 (ADC13/PCINT21)
PK6 (ADC14/PCINT22)
PK7 (ADC15/PCINT23)
PA0 (AD0)
PA1 (AD1)
PA2 (AD2)
PA3 (AD3)
PA4 (AD4)
PA5 (AD5)
PA6 (AD6)
PA7 (AD7)
PJ7
PJ6 (PCINT15)
PJ5 (PCINT14)
PJ4 (PCINT13)
PJ3 (PCINT12)
PJ2 (XCK3/PCINT11)
PJ1 (TXD3/PCINT10)
PJ0 (RXD3/PCINT9)
PC7 (A15)
PC6 (A14)
PC5 (A13)
PC4 (A12)
PC3 (A11)
PC2 (A10)
PC1 (A9)
PC0 (A8)
VCC
VCC
VCC
VCC
AVCC
AREF
GND
GND
GND
GND
GND
Multiplexer_SCL
Multiplexer_SDA
RS48_1
RS48_2
P2
Header 4
RX
TX
R1
10K
SW1
S1
KAS2102E
TX
RX
U2
CSTCE16M0V53-R0
R2
1M
C2
100nF
C3
100nF
C4
100nF
C1
100nF
3 Caps should close to AVCC pin.
Must closer to the aref pin
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Number
01
Revision
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4/02/2024
Sheet2 of 4
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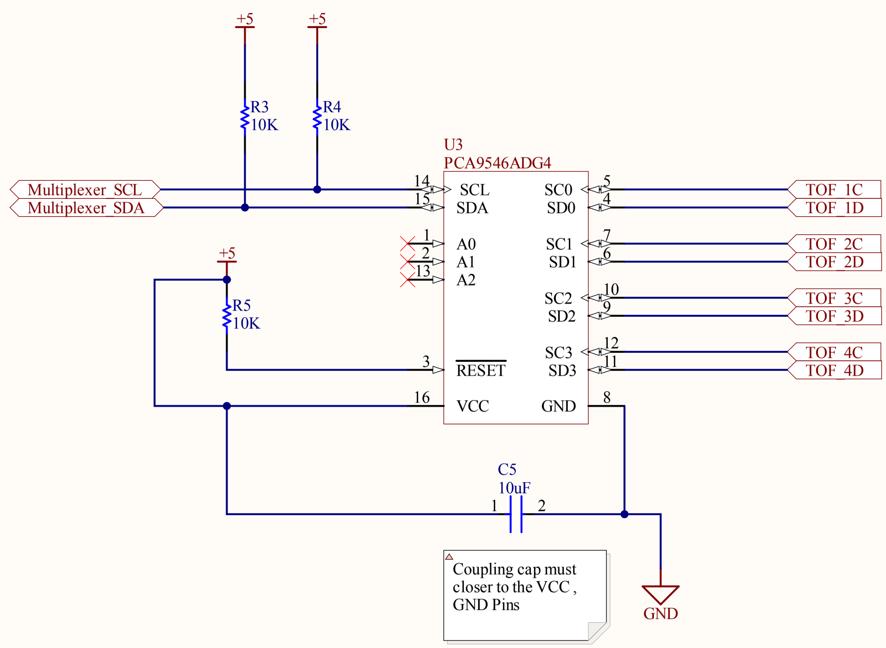

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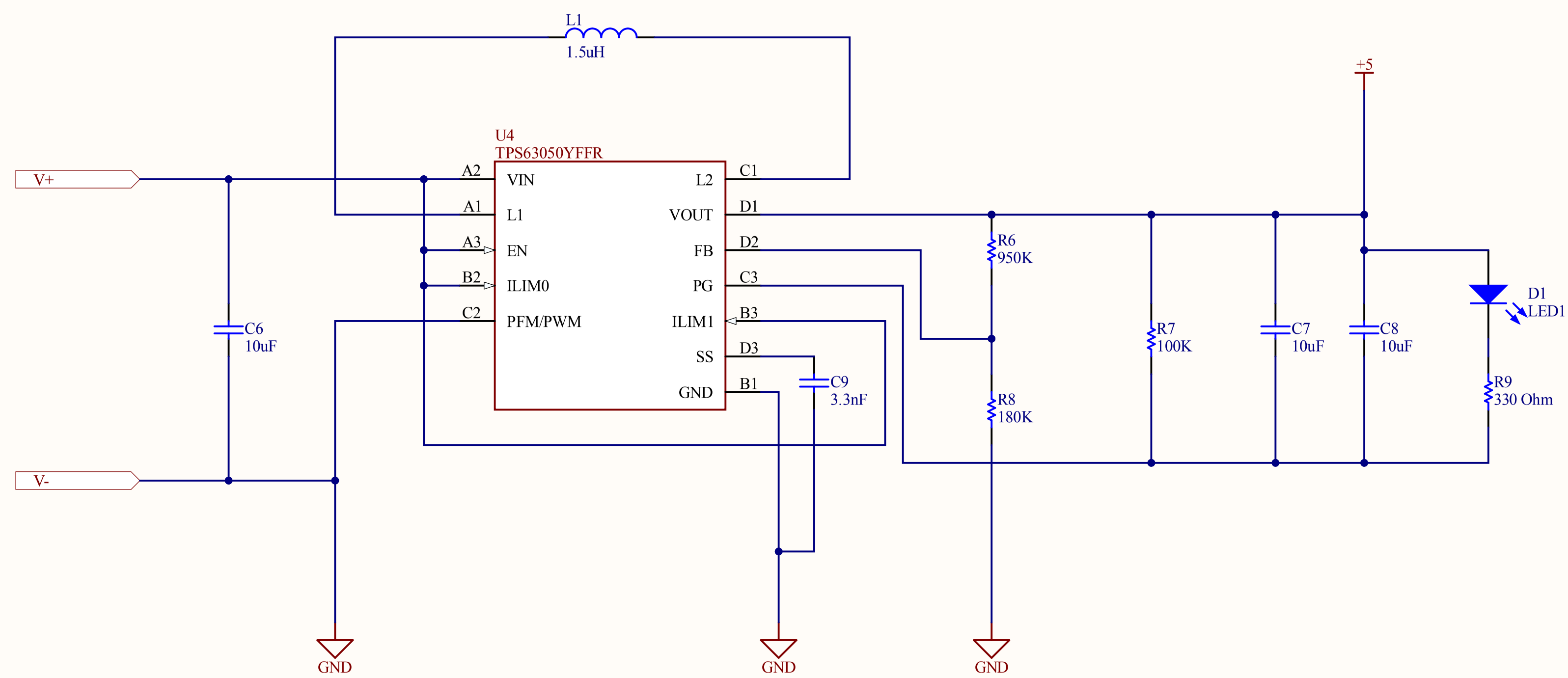

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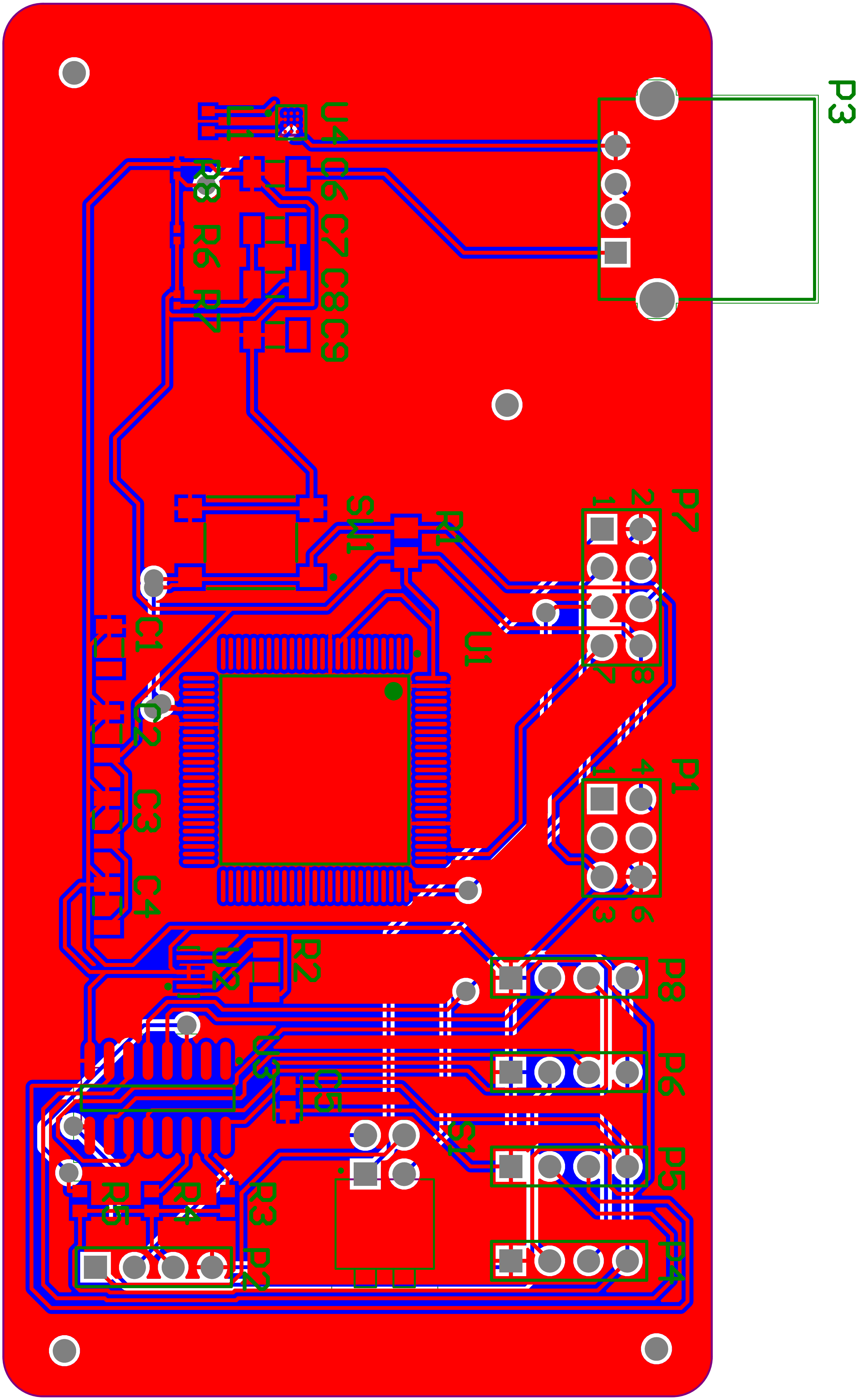
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U4
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C6
R8
C7
R6
C8
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C9
SW1
R1
P7
U1
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C3
C4
P1
R2
U2
P8
U3
C5
P6
S1
P5
R5
R4
R3
P2
P4