University of Hertfordshire UH

COURSEWORK

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Electronic Practical Portfolio

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555 Timer Circuit: Design, Implementation and Analysis

Circuit Description:

An LM555 timer integrated circuit (IC) in an astable mode is used in the circuit to generate a continuous oscillation. A current-limiting resistor (R3, 1 kΩ), an LED indication (LED1), one capacitor (C1, 100 µF), and two resistors (R1 and R2, each 4.7 kΩ) are all part of the circuit. The attached LED is essentially made to blink by this arrangement, which produces a simple oscillator whose output alternates between high (around supply voltage) and low (near 0 volts).

Simulation Results Analysis

(**Voltage Probe at 9V**): The timer's output pin is high when the voltage probe (PR1) reads 9 V. In this condition, current flows from the 555 timer through the resistor R3 and the LED, illuminates the LED, and the timer produces its maximum voltage, as evidenced by the voltage readout matching the provided voltage.

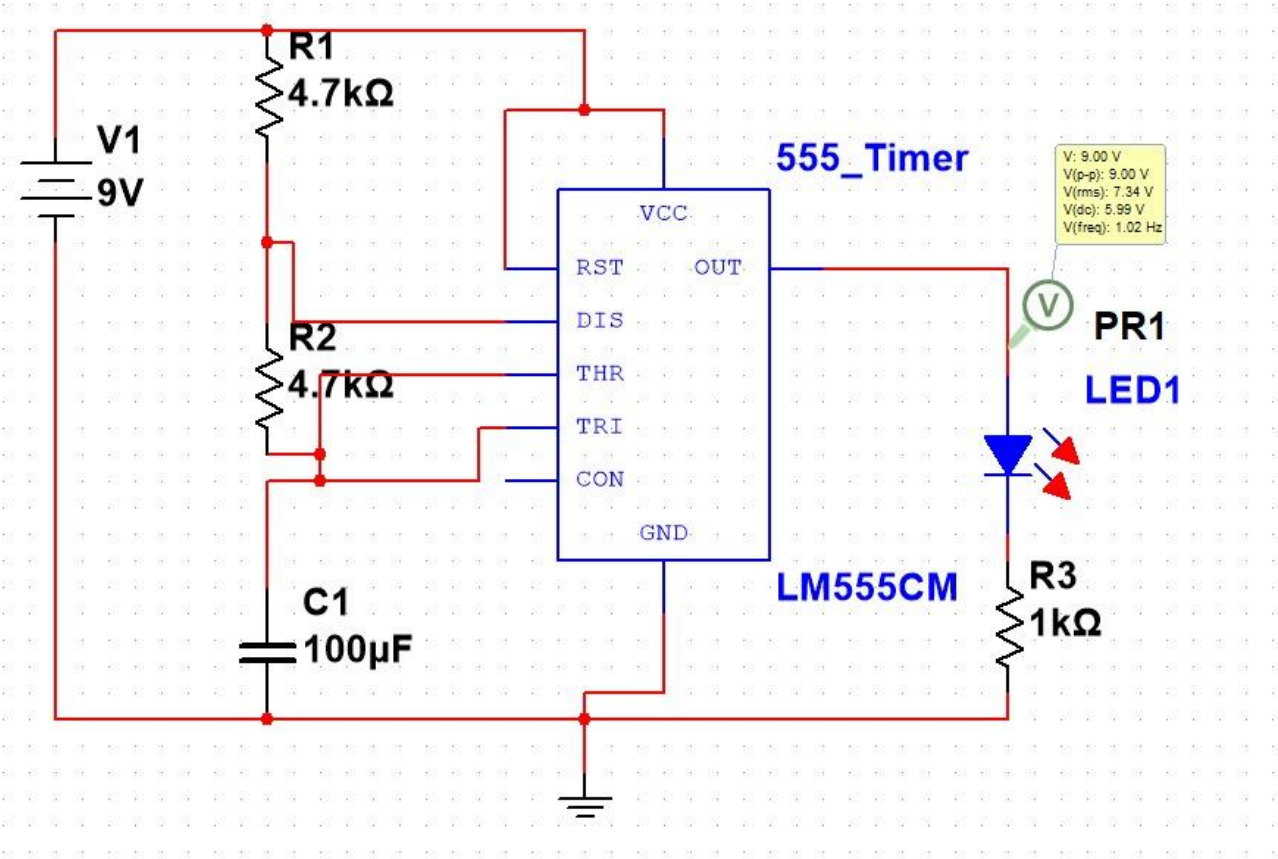


Figure 1: *Multisim simulation at 9V*

(**Voltage Probe 0V**): When the voltage probe (PR1) registers 0 V, the timer's output pin is LOW. There is insufficient voltage to forward-bias the LED, so it shuts out. As a result, the resistor R3 and LED do not receive any current.

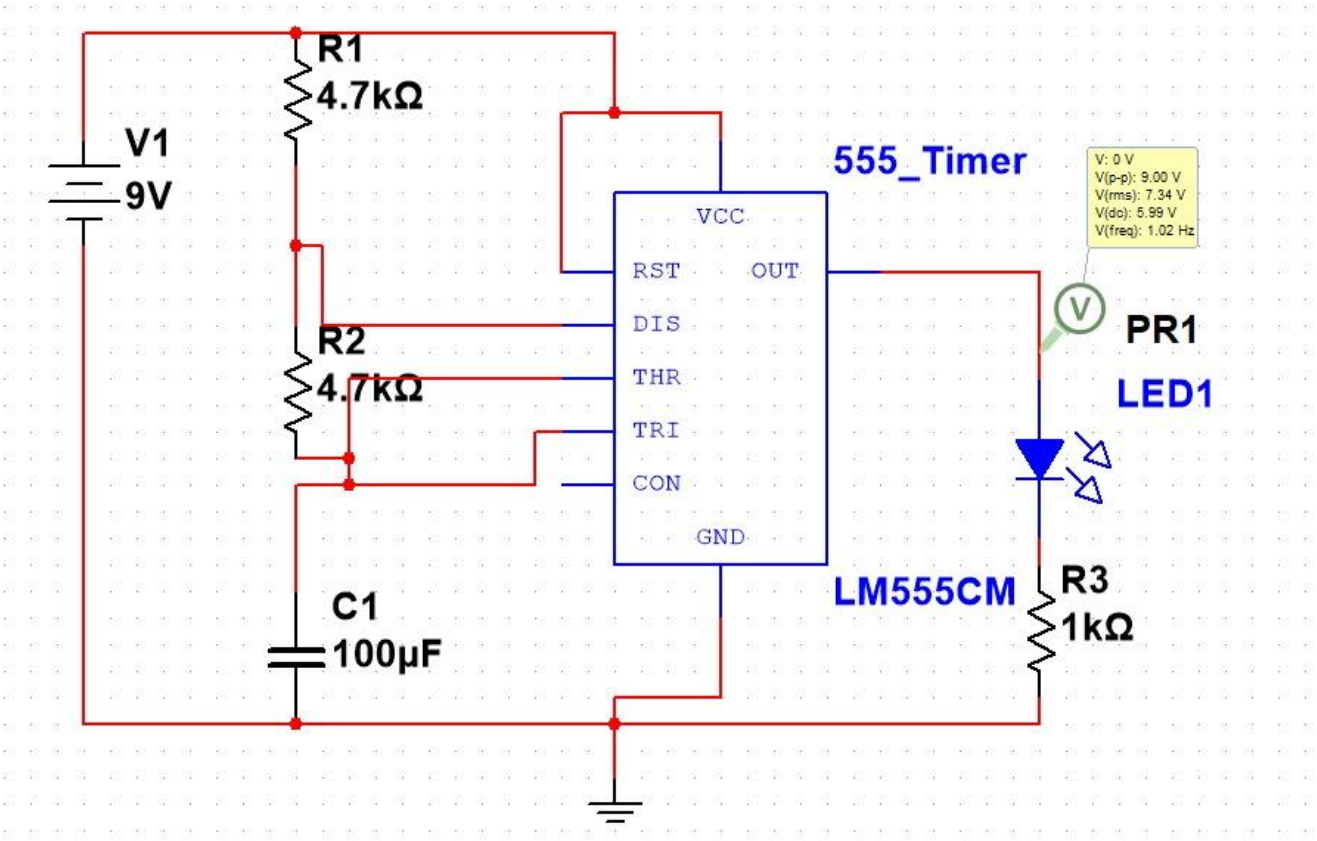


Figure 2: *Multisim Simulation at 0V*

The simulation phase was essential before committing to physical implementation. It verified the circuit design and enabled necessary component value adjustments to meet the target operating frequency.

Physical Implementation

The breadboard implementation allowed quick assembly and testing, while the Veroboard version represented a more permanent and robust prototype.

Assembly Process

1. **Component Preparation**: Before assembly started, all components were checked with a multimeter to ensure their values matched the design specifications.
2. **Circuit Layout Planning**: The physical layout for both implementations was planned. A central "spine" was found on the breadboard for power distribution, and I included the breadboard's architecture onto the Veroboard.
3. **IC Placement and Orientation**: To avoid harm from incorrect connections, the 555 timer IC was carefully positioned, making sure pin 1 was accurately recognised. The IC was also positioned to reduce the requirement for jumper wires on the Veroboard and to straddle the middle channel on the breadboard.
4. **Passive Component Installation**: Next, resistors and capacitors were added, adhering to the schematic model but considering the platform's physical limitations. To keep the

component leads in place when soldering, they were bent at 90-degree angles on the Veroboard before being inserted**.**

5. **Wiring and Connections**: The circuit connections were completed with jumper wires. Pre-cut jumper wires of different colours were utilised to differentiate between the breadboard's power, ground, and signal connections. The insulated wire was stripped, tinned, and soldered onto the Veroboard to build bridges between non-adjacent spots.
6. **LED Installation**: The last part was the LED, which was carefully positioned so the shorter lead could be connected to the current-limiting resistor R3 and then to the ground.

Breadboard Assembly

The breadboard implementation closely adhered to the schematic design. Components were placed to reduce wire lengths and preserve signal integrity. Support components were rationally grouped around the 555 timer IC, placed in the breadboard's middle.

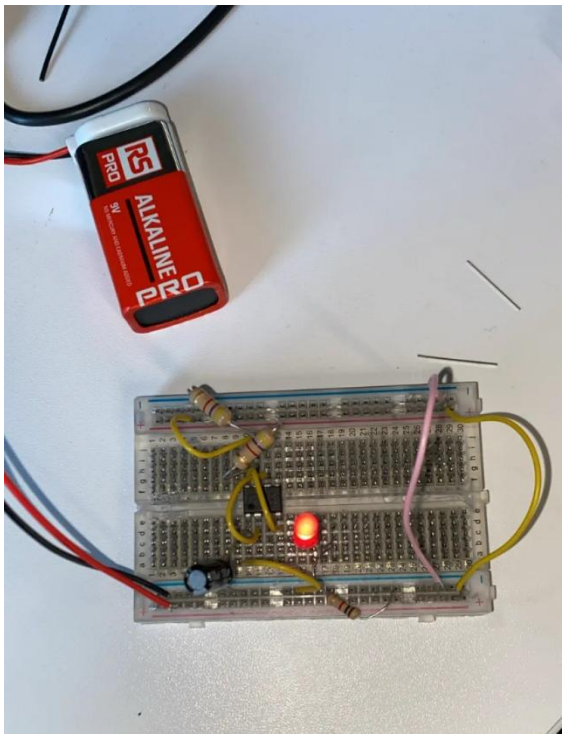


Figure 3: *555 Timer Circuit on a breadboard with an active LED powered by a 9V battery*.

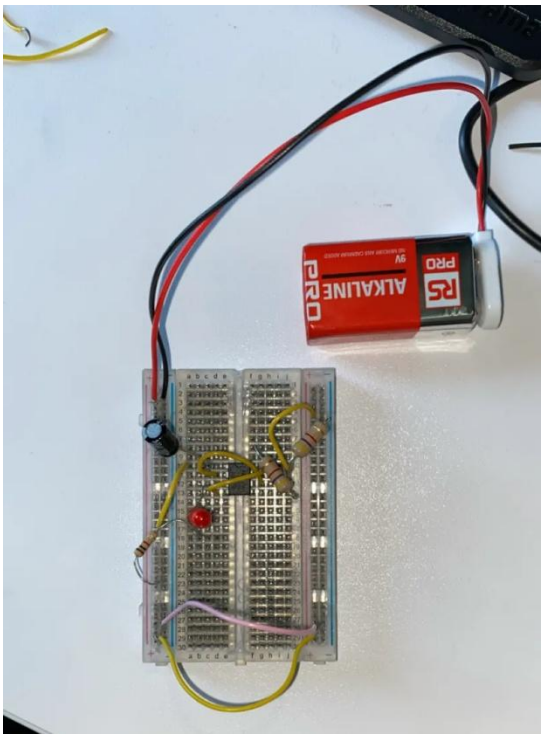


Figure 4: *555 Timer Circuit on breadboard showing LED in 'off' state during the oscillation cycle.*

As predicted by the modelling, the breadboard prototype showed dependable operation, with the LED blinking at intervals of about one second. The breadboard's modular design made testing and modifying various component values simple.

Veroboard Implementation

The Veroboard implementation represented a more permanent form of the circuit. To avoid accidental connections, this necessitated meticulous component positioning and track-cutting design. To ensure safe electrical connections, components were soldered straight to the Veroboard.

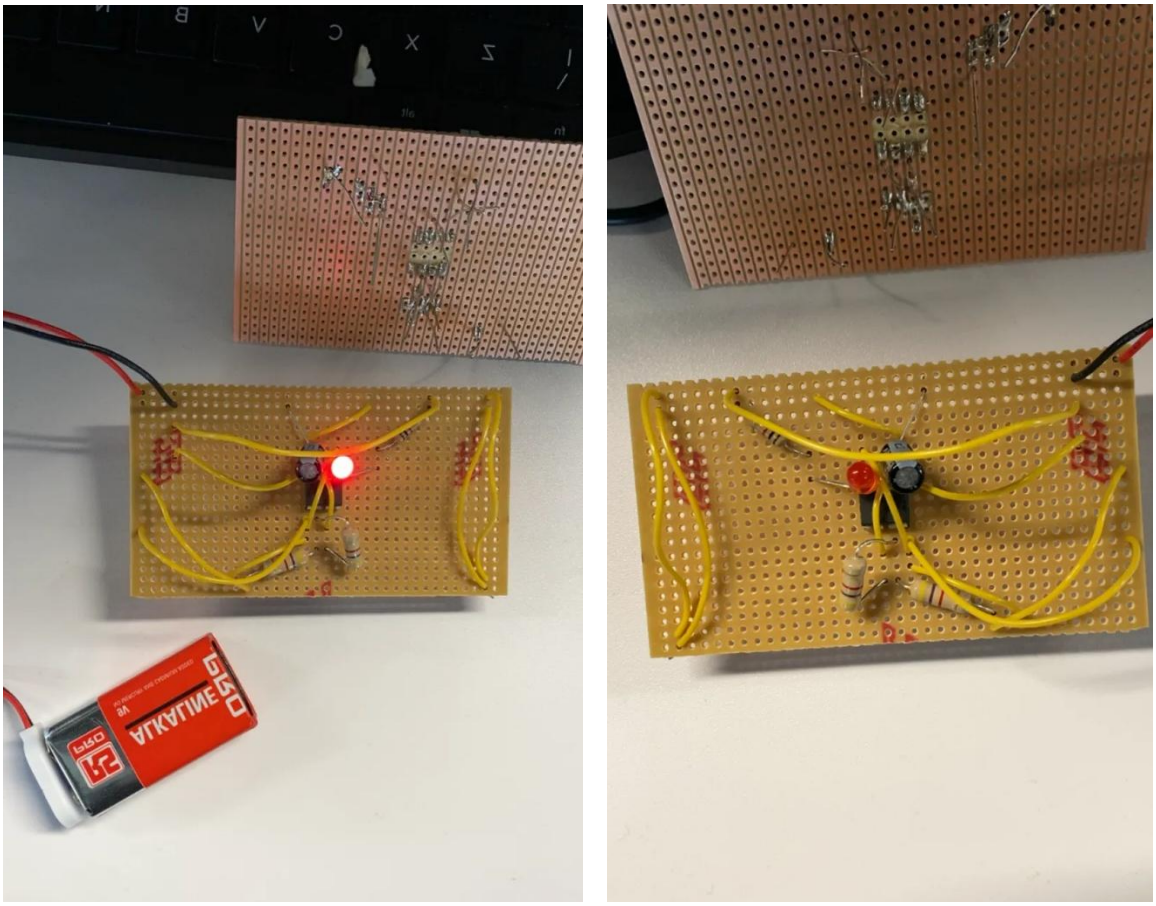


Figure 5: *Veroboard Adaptation of 555 Timer (ON) and (OFF) State.*

The LED blinked at the intended frequency in the Veroboard implementation, which likewise performed as anticipated. This circuit's structure was more robust and compact, making it appropriate for long-term usage or incorporation into bigger systems.

LED Output Behaviour and Circuit Configuration

A closer look at the circuit allows us to see how modifications to different parts directly impact the LED's blinking pattern.

1. **Resistance Values**: Determining the frequency and duty cycle of the LED blinking depends critically on the values of R1 and R2:
    - Increasing R1 primarily extends the LED's ON time
    - Increasing R2 lengthens the total period by influencing both ON and OFF times.
    - If R1 is substantially less than R2, the LED will stay ON much longer than it remains OFF.
    - R1 will keep the LED off longer if it is significantly greater than R2.
2. **Capacitance Value**: The capacitor C1 works in conjunction with both resistors:

- If the value of C1 were increased, the LED would flash more slowly, reducing the blinking frequency.
- If C1's value were decreased, the frequency would rise, and the LED would blink faster.

3. **Current-Limiting Resistor**: Resistor R3 determines the LED brightness:
    - The LED becomes dimmer when the current through it is reduced by larger values (e.g., 2.2kΩ instead of 1kΩ).
    - Lower values (470Ω, for example) increase current, which brightens the LED but may shorten its lifespan.
    - Removing R3 entirely damages the LED due to excessive current.

Challenges Faced

1. In early attempts, short circuits were caused by accidental solder bridges between adjacent tracks. This was fixed by deploying a solder sucker, desoldering braid, providing the proper quantities of flux, and using a solder with a smaller diameter.
2. After everything was assembled, it was challenging to find mistakes. This difficulty was resolved using incremental testing, which involves verifying individual circuit components before moving on to the next phase. Connections and voltage levels were checked with a multimeter throughout the assembly process.

Christmas Tree Circuit Assembly and Testing

Soldering and Assembly Process

The Christmas tree circuit must be carefully assembled in a particular order to guarantee correct operation. Working with various electronic components, two distinct astable multivibrators are produced to control the patterns of LED flash.

Component Preparation

Start by assembling the necessary parts: 16 LEDs, 8 resistors (100Ω), 4 capacitors (2× 22μF and 2× 10μF), 4 BC548 transistors, a switch, and a 9V battery connection.

Assembly Sequence

Following the recommended soldering order ensures successful assembly:

1. **LEDs**: These must be oriented correctly with the anode (longer leg) in the favourable position. The flat side of the LED indicates the cathode (negative) connection.
2. **Resistors (R1-R8)**: Proper soldering and bending of the resistors are necessary
3. **Capacitors (C1-C4)**: These electrolytic capacitors must be inserted with the proper polarity. The negative leg has a shorter stripe on the casing.
4. **Transistors (TR1-TR4)**: The three connections on each BC548 transistor (collector, base, and emitter) must align with the board marks. According to the guidelines, they should not be forced too far.

5. **Switch:** This should be positioned facing the base of the tree.
6. **Battery Connection**: The battery clip wires are inserted through the board from back to front to ensure proper polarity.

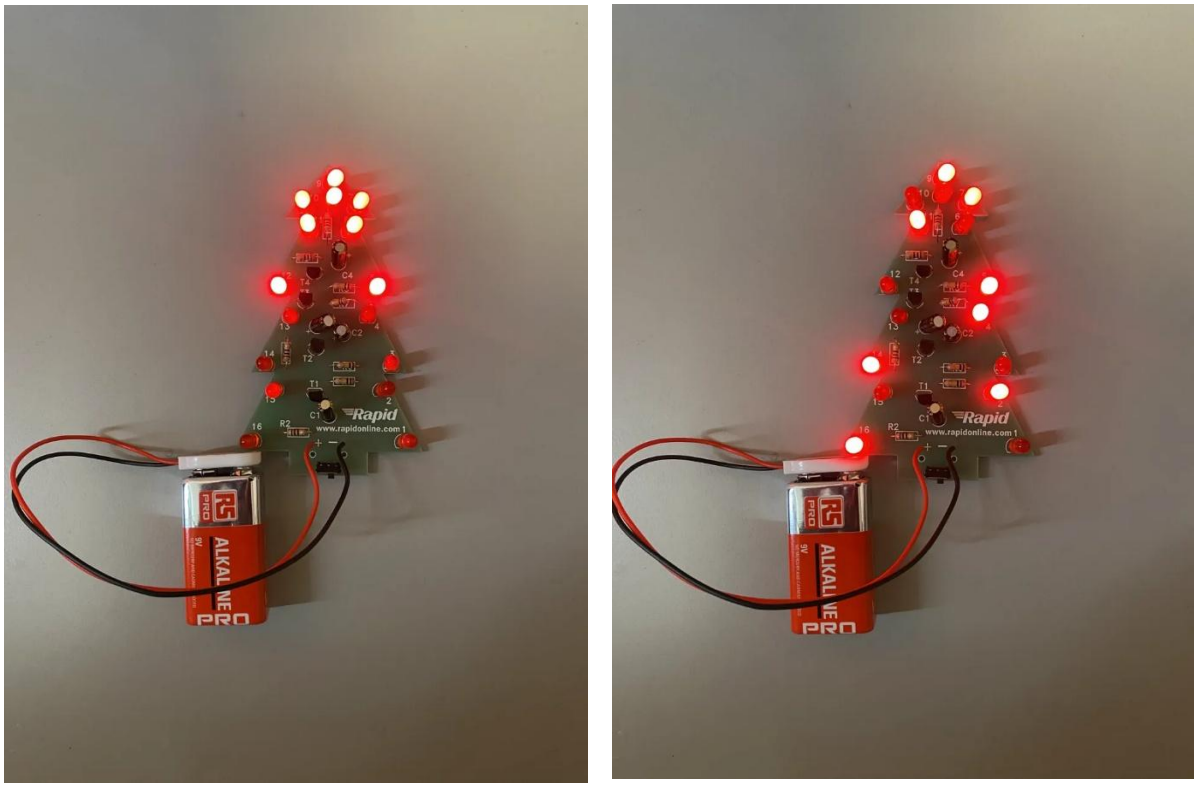


Figure 6: *Alternating pattern of the Christmas Tree Circuit*

Visual Inspection

After soldering each component, a careful visual inspection is needed to check for Proper component orientation (especially LEDs, capacitors, and transistors), good solder joints (shiny, not dull or "cold"), and no solder bridges between adjacent connections. All components are correctly seated.

The images display a successfully assembled circuit with all the parts in place, and the red LEDs turn on when power is applied.

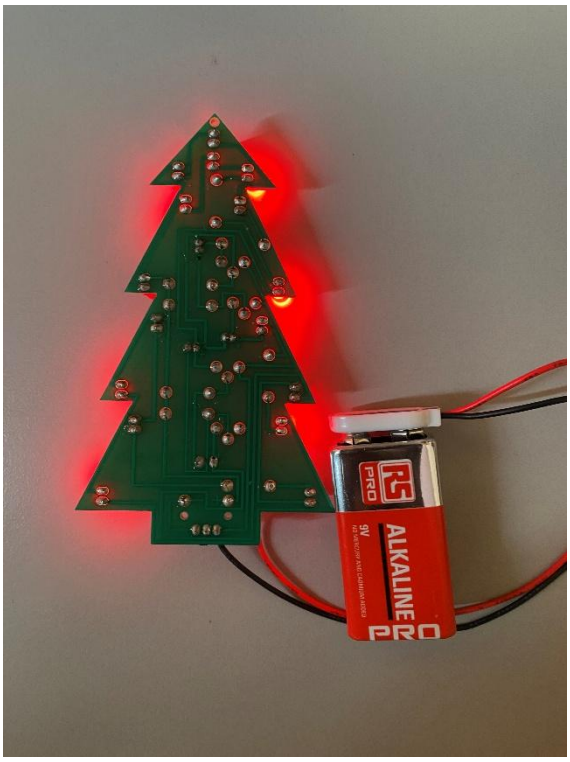


Figure 7: *Christmas tree circuit board showing solder connections on the component side with active LED pattern.*

Testing and Evaluation

After attaching the 9v battery to the clip, turn the switch to the "on" position. The dual-astable multivibrator circuit should cause the LEDs to flash alternately.

Multimeter Testing

Voltage Measurements:

- Battery input: When measured, it reads 8.83V.
- Across each LED, when lit, reads from the range 1.8-1.9V.
- Collector-emitter voltage on transistors: Alternate between 0V (when conducting) and 2.35V (when off). Transistors are driven between saturation and cutoff by timing pulses produced by the capacitors charging and discharging through the resistors. As a result of this switching motion, the LEDs flash in an alternating pattern.

Troubleshooting Common Issues

My circuit did not function correctly on the first attempt; it took 2 tries to get it working.

1. Some LEDs do not light:
    - Check LED polarity (may be installed backwards)
2. No LEDs light up:
    - Verify battery connection and voltage
    - Check switch functionality
    - Inspect soldering on power connections
3. No flashing occurs:
    - Inspect capacitor and transistor connections
    - Verify capacitors are correctly polarised
    - Check resistor values with a multimeter

Robot Control Board Assembly and Testing on Veroboard

A Raspberry Pi Pico serves as the system's main microcontroller. An LM35 temperature sensor and an HC-SR04 ultrasonic distance sensor were combined to provide sensing capabilities. An SG90 micro servo motor provides mechanical actuation. An L7805ACV voltage regulator provides steady 5V power from a 9V battery. Additional supporting components include jumper wires, connecting headers, and other passive parts to finish the circuitry.

Instead of soldering components directly, pin headers were used to achieve a modular design approach. This approach avoids disassembly or resoldering the whole main board while maintaining flexibility for component replacement, testing, and system reconfiguration.

Component Assembly and Soldering Process

A working prototype was built on a breadboard before permanent assembly to verify the circuit design and component interactions. This interim stage enabled quick testing and debugging before committing to soldered connections.

Signal route optimisation to reduce interference, logical grouping of related components, adequate spacing for thermal concerns, and accessibility for testing and maintenance were all considered when planning the component location on the Veroboard.

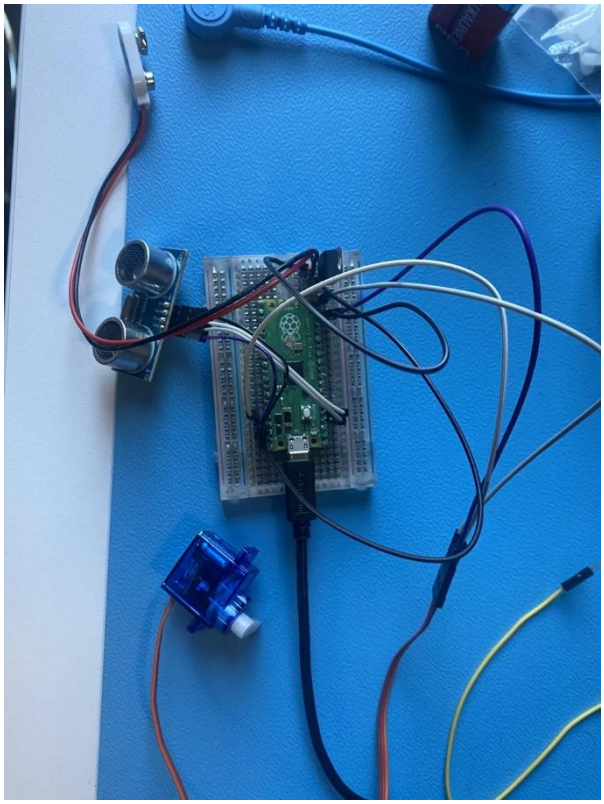


Figure 8: *Breadboard Adaptation of Robot Control Board*

Soldering Methodology

The Assembly process followed this process:

1. **Pin Header Installation**: Pin headers were soldered strategically to establish connection sites for all major components instead of directly soldering components.
2. **Power Distribution Network**: First, power rails and any necessary controlled voltage lines and tracks for the 9V battery supply were set up. The vertical conductive strips on the Veroboard were used to make power distribution buses.
3. **Microcontroller Integration**: When mounting the Raspberry Pi Pico in the centre, a secure mechanical attachment and correct pin alignment were carefully considered. Due to the mounting position, all GPIO pins needed for the different sensors and actuators were easily accessible.
4. **Sensor Connections**: The LM35 temperature sensor (analogue input) and the HC-SR04 ultrasonic sensor (trigger and echo pins) have added header pins. These connections were logically organised in the Veroboard arrangement to reduce wire crosses.
5. **Actuator Control Circuitry**: The SG90 servo motor's connections and any required driver parts were made. These connections were guaranteed to have the appropriate current capacity to meet the servo's power needs.

6. **Cable Management**: The wiring was arranged with the proper lengths and routing to reduce mechanical stress and electromagnetic interference. When necessary, small wire jumpers were used to bridge connections across the vertical conductive strips of the Veroboard.

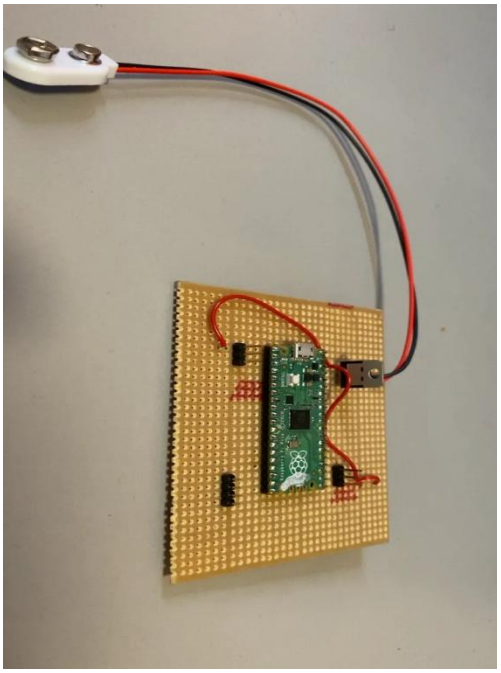


Figure 9: *Robot control board on Veroboard showing Raspberry Pi Pico with header pins for modular component connections.*

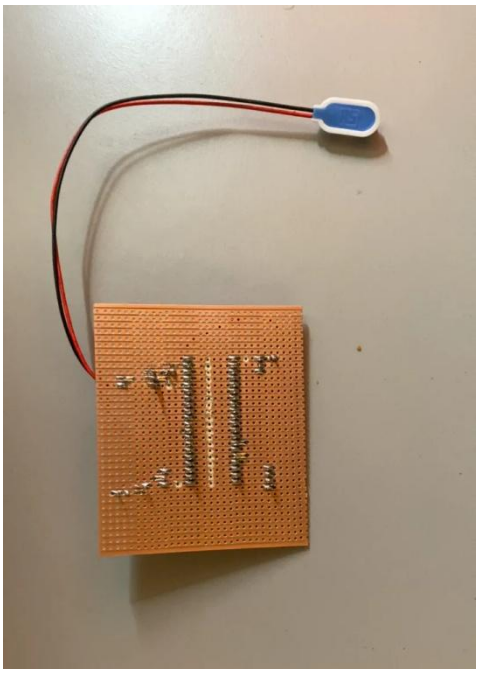


Figure 10: *The Veroboard underside shows soldered connections with strategic track breaks to isolate circuit sections.*

Testing and Evaluation

Power System Verification: The main goal of the initial testing was to validate the power distribution network. The battery voltage was verified to be 9V when there was no load, and voltage stability was assessed when there was a high load.

Sensor Calibration:

HC-SR04 Ultrasonic Sensor: Distance measurements were compared to established reference distances to ensure accuracy. Repeated measurements at different ranges were used to evaluate response consistency. Timing settings for the trigger and echo signals were optimised for dependable operation over the sensor's useable range.

LM35 Temperature Sensor: A straightforward but efficient technique was used to test and confirm the LM35 temperature sensor's operation. The sensor was initially seen recording the room temperature. I generated heat by rubbing my hands and then brought them close to the sensor to confirm that it was responsive to temperature changes. The console output confirmed Proper sensor operation, which displayed a noticeable and instantaneous increase in the reported temperature compared to the ambient reading. When my hands were removed, the temperature readings returned to normal, exhibiting the proper thermal response characteristics.

Actuator Test

Positional accuracy was used to assess the servo motor's performance at different set points.

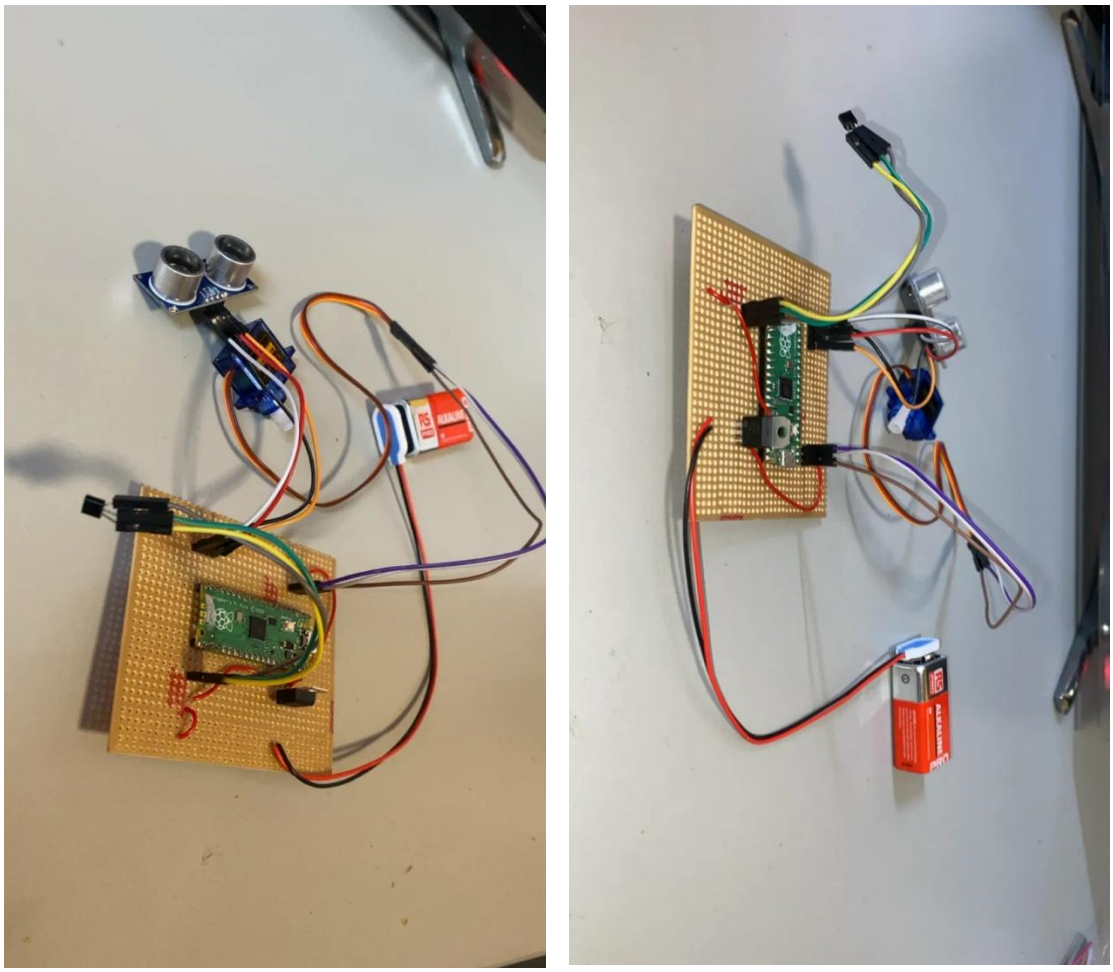


Figure 11: *The complete robot control board system shows Raspberry Pi Pico, an ultrasonic sensor, and a servo motor connected via header pins for modular testing.*

Test Results and Observation

Sensor Performance

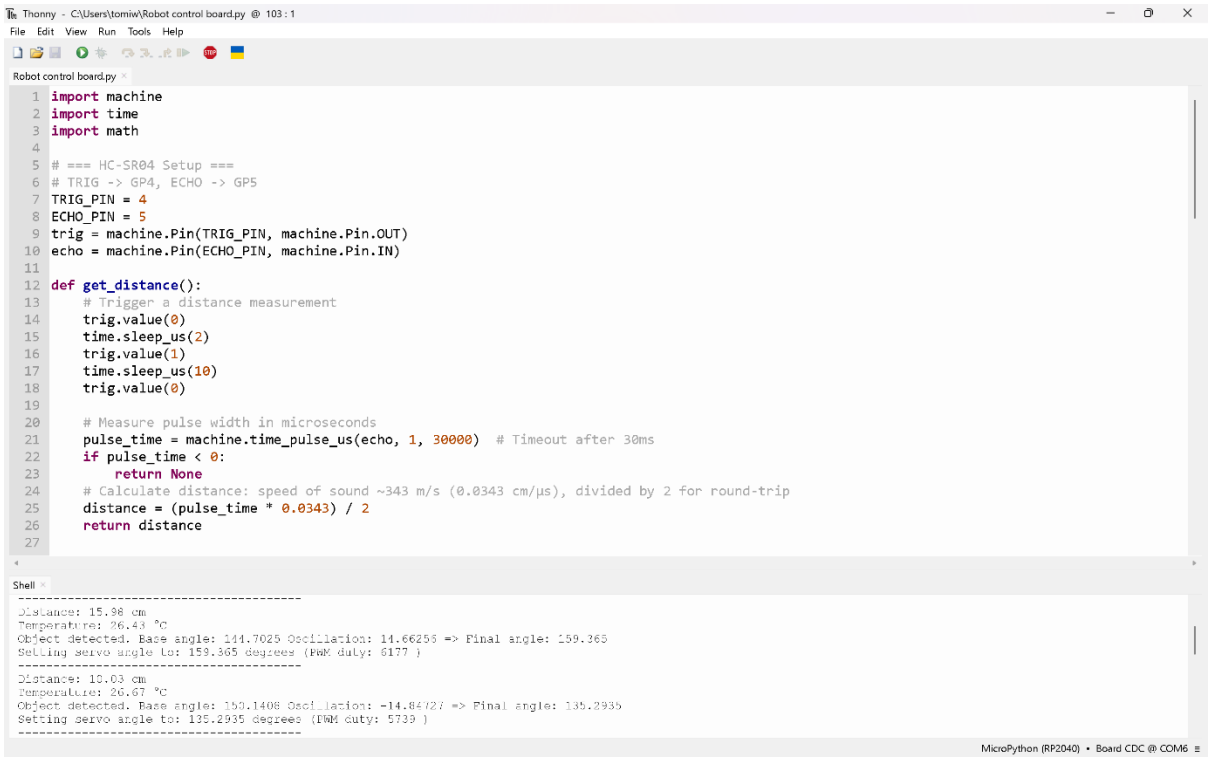
HC-SR04 Ultrasonic Sensor: During testing, the ultrasonic sensor showed measurement accuracy of about ±2 cm at distances ranging from 5 to 200 cm. Its performance declined at extreme ranges, but its reliable detection range was between 3 and 300 cm.

LM35 Temperature Sensor: According to datasheet specifications, the LM35 temperature sensor offered basic ambient temperature monitoring capabilities with a measurement resolution of 0.1°C. According to informal observations, it takes around five seconds for the system to stabilise following significant temperature changes in the surroundings.

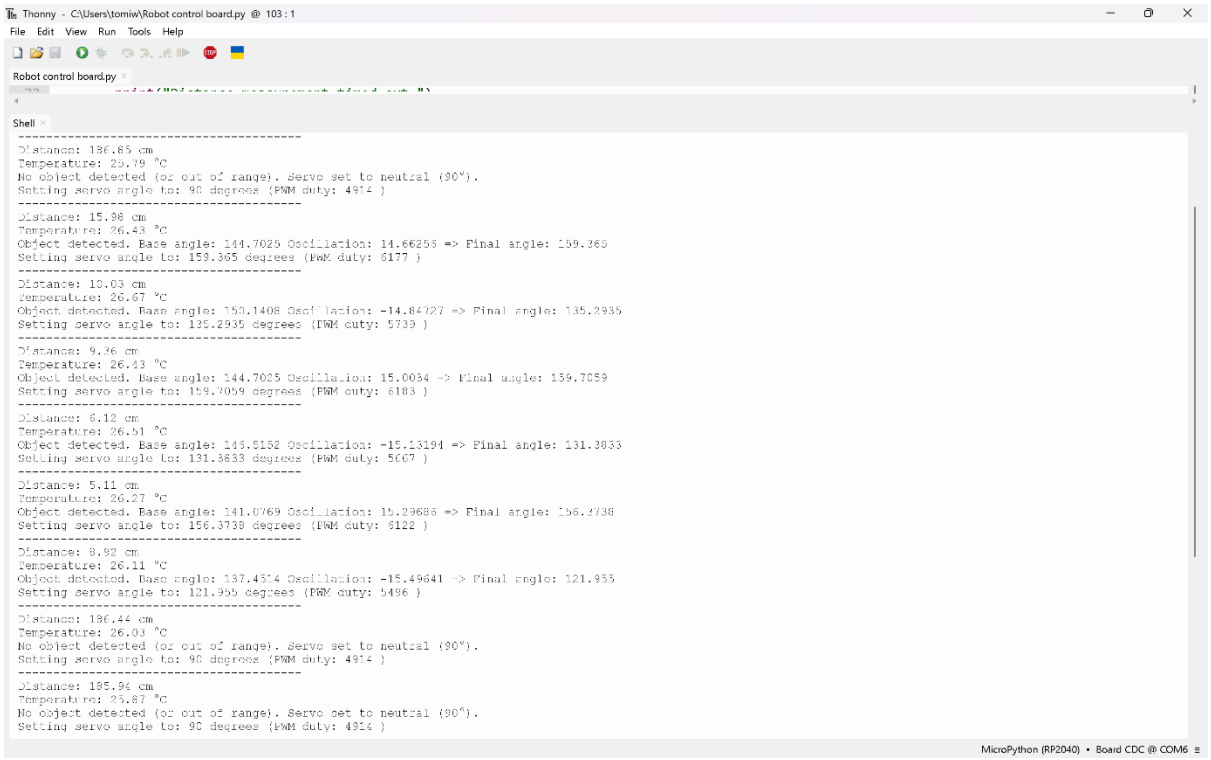
Actuator Evaluation: The performance parameters of the SG90 servo motor were suitable for the robotics application. The measured positioning accuracy was roughly 3° off the requested position, which aligns with the requirements for this particular class of micro servo.

System Integration Findings

The robot control board showed strong functionality when functional as a whole. Even when operating continuously, accurate sensor readings and servo control were possible due to the lack of noticeable component interference. The microcontroller avoided timing conflicts by handling simultaneous sensor reading and actuator control activities.



The console output consistently displays temperature values around 26°C and precise distance readings, offering empirical proof of the system's operation. The object detection and servo placement algorithm operated efficiently with the proper servo angle modifications based on recorded distances. Between 4914 and 6200, the system determined the proper servo angles and matched PWM duty cycles for objects roughly 5 to 15 cm away from the sensor. The system successfully reset the servo's neutral position (90 degrees) when objects exceeded the detection threshold (about 180 cm), exhibiting the desired fail-safe behaviour.



Circuit Improvement and Analysis

1. **Basic Power System Enhancement**: To increase reliability under various load circumstances, especially when the servo motor is turned on, additional supporting components are required for the current design's L7805ACV voltage regulator.
   Proposed Improvement: Adding three crucial parts to the current power regulating circuit would be a simple improvement. In order to prevent damage if the battery is inadvertently connected backwards, a 1N4001 diode would be installed at the battery input to offer reverse polarity protection. Second, the possibility of microcontroller resets during motor operation would be decreased by adding a 100µF electrolytic capacitor at the regulator output, significantly enhancing voltage stability when the servo pulls unexpected current. Third, the L7805ACV would operate consistently as the regulator manages power dissipation from the 9V input to the 5V output if a tiny aluminium heatsink were mounted to prevent overheating during prolonged operation. These straightforward upgrades would significantly increase power system reliability with little change, particularly during dynamic operation when the servo and sensors operate simultaneously.
2. **Signal Integrity Optimisation**: Sensor data showed some signal noise, especially from the analogue temperature sensor.
   Proposed Improvement: Install better circuits for signal conditioning, such as decoupling capacitors close to sensor power inputs. Apply hardware filtering (a basic RC low-pass filter) for analogue signals. Twisted-pair wiring is used for delicate signal connections, and power and signal lines are physically separated and shielded.
3. **Software Optimisation**: The existing software implementation provides basic functionality. However, it lacks some optimisations that would improve efficiency and dependability.

Reflection

Key Lessons Learned and Development of Practice Skills

My practical experience has been important throughout this subject and has dramatically improved my ability to practise electronics. Working on several projects, from the 555 timer circuit to the Christmas tree circuit and the robot control board, has given me a gradual learning path that has increased my technical proficiency and self-assurance.

1. The most significant lesson I learnt was the importance of a systematic approach in electronics design and implementation. Adhering to a straightforward, rational procedure might prevent many errors throughout the creation of the robot control board. For instance, after independently testing the L7805ACV voltage regulator circuit, I linked it to the Raspberry Pi Pico microcontroller. This methodical approach saved much debugging time and shielded vital components from power irregularities.
2. Working with delicate parts like the LM35 temperature sensor taught us another important lesson. I have direct experience with how circuit features and ambient conditions impact sensor data. I learned the practical features of sensor calibration and response that textbooks

alone could not supply by testing the LM35 by producing localised heat with my palms and seeing the instantaneous temperature increase in the console output. My approach to sensor implementation has completely altered due to this experience; instead of assuming optimal performance based on datasheet specs, I now prioritise real-world testing under various scenarios.

3. This module has also improved my comprehension of electronic circuit power management. The robot control board project showed how appropriate voltage regulation improves overall system stability while working with the Christmas tree circuit showed how transistor switching affects LED behaviour. I gained valuable knowledge about transistor operation by measuring collector-emitter voltages in the Christmas tree circuit that fluctuated between 2.35V (off) and close to 0V (conductive), impacting my switching circuit design approach.

Most significantly, the unavoidable difficulties that arise in each project have helped me improve my troubleshooting abilities. I have learnt to approach problems methodically, test hypotheses, and isolate factors from diagnosing difficulties, whether software timing issues with the ultrasonic sensor or solder bridges on the Veroboard. Just one talent has changed my potential as an electrical professional.

Managing Design Trade-offs

1. During the circuit design process, I encountered many scenarios that required a careful balance of conflicting objectives. One important trade-off was the arrangement of the robot control board's components on the Veroboard. I had to choose between a more roomy configuration that would make testing and customisation easier and a smaller layout that would reduce the board size.
2. After weighing the pros and cons of both strategies, I decided to increase the distance between parts, especially around the Raspberry Pi Pico microcontroller. This choice resulted in a larger overall footprint. However, it also offered important advantages, such as improved thermal dissipation for the L7805ACV voltage regulator, easier access for voltage measurements during testing, and a lower chance of solder bridges between neighbouring pins. This choice was influenced by the Christmas tree circuit's experience, where debugging was challenging due to tightly packed components. The large architecture proved beneficial when I wanted to verify pin connections and signal integrity throughout the testing phase.
3. The interaction between the microcontroller and sensors was the subject of another significant trade-off. I could have soldered these connections directly for a more durable and marginally dependable electrical connection. Instead, I constructed modular connection points using pin headers. Although there was a slight chance of irregular connections, this offered great flexibility for testing various sensor combinations and made troubleshooting easier by enabling component isolation. This choice was beneficial when I needed to confirm that the ultrasonic sensor was working apart from the rest of the circuit.

4. Another difficult trade-off was the power regulation system. The L7805ACV linear regulator was easier to install than a switching regulator, but it produced more heat and used less power. Signature purity and ease of implementation were more important for this application than power efficiency. During testing, I noticed steady sensor readings even when the servo motor was operating, which confirmed that the linear regulator supplied clean power despite its inefficiency. This confirmed my conclusion. However, I would reevaluate this trade-off in future designs for battery-critical applications and devote the extra design time to a switching regulator solution.
5. The software architecture for the robot control board also has to strike a balance between readability and maintainability of the code and processing efficiency. Even though this increased the program's size, I decided to put more emphasis on writing clean, well-structured code with informative variable names and comments. When I ran into problems with the ultrasonic sensor timing, this method simplified debugging and enabled me to locate and fix the problematic code sections swiftly.

Evolution of Understanding Design for Manufacturing and Assembly

My viewpoint on manufacturing and assembly design has changed significantly throughout this session. At first, I thought of PCB design as a logical exercise in component connections. It is a multidisciplinary problem that requires balancing assembly issues, manufacturing limitations, and electrical performance.

1. From hand soldering components onto the Veroboard for the entire project, I gained direct knowledge of assembly difficulties. I realised that board layout, lead spacing, and component orientation all directly affect manufacturing viability. For instance, I made sure there was enough room for the soldering iron tip and that all of the pins were accessible when I positioned the Raspberry Pi Pico on the Veroboard. My understanding of standardised component layouts and uniform spacing in PCB design has grown as a result of my first-hand experience with manual assembly.
2. Moving from prototype to production was evident when working with the robot control board and 555 timer circuit's Veroboard and breadboard implementations. The permanency of soldered connections on the Veroboard contrasted dramatically with the breadboard's ease of modification, highlighting the significance of careful design validation before final assembly. This experience has persuaded me to include more thorough design reviews and prototyping phases in subsequent projects.
3. This module has caused me to include several manufacturing-oriented strategies in my designs. Instead of soldering direct components, I used pin headers to create a modular robot control board. This would simplify assembly verification in a production setting and make testing and change easier during development. Before final integration, components could be tested separately, lowering the possibility of putting together a system that does not work.

4. Another manufacturing aspect was the meticulous routing of connections on the Veroboard, with special attention to minimising wire crosses and ensuring logical signal flow. Whenever feasible, I arranged power distribution to follow the vertical conductive strips of the Veroboard, which eliminated the need for jumper wires and made assembly easier. Clean traces lower manufacturing complexity and increase yield in formal PCB design, where this method of signal routing is immediately relevant.
5. Most importantly, I now understand how crucial paperwork is to production. My building process would have been more straightforward if there had been explicit assembly instructions and component placement diagrams, especially for the Christmas tree circuit with many LEDs. Realising that even the most exquisite circuit design is only partially functional if it cannot be reliably replicated, I now see such documentation as an essential component of the design process rather than an afterthought.

These hands-on experiences have given me a more comprehensive understanding of electronics design that considers the whole product lifespan, from conception to production to field service and possible modification. This all-encompassing viewpoint will improve my approach to future electronics projects since I will consider manufacturing and assembly concerns from the beginning of the design process rather than addressing them after the fact.