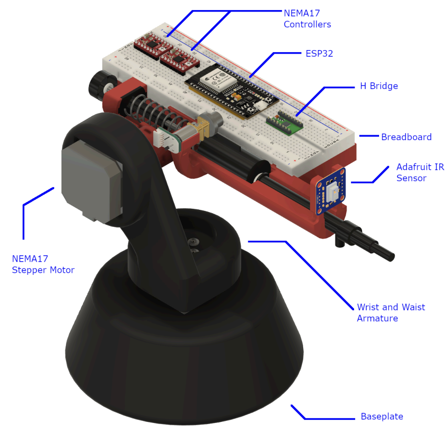
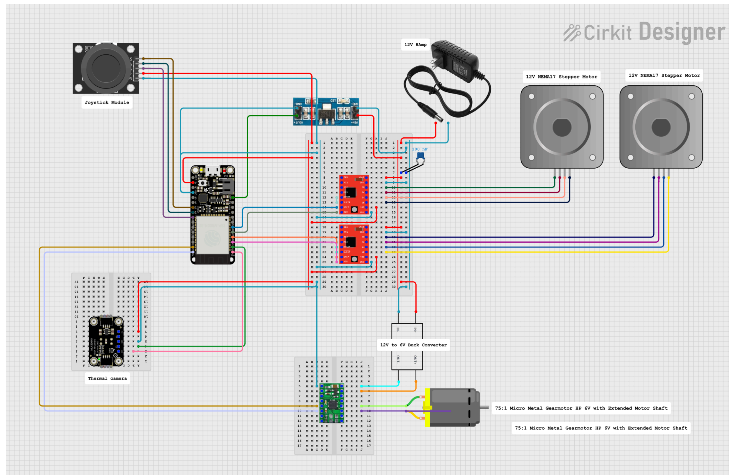
Menooa Avrand Project Portfolio

(Current Project) πRo-Bot: Autonomous Fire Suppression Robot





Objective: Designed and developed πRo-Bot, a compact, automated fire suppression system to detect, extinguish, and prevent brush fires. The system enhances real-time fire mitigation through infrared detection, remote accessibility, and preemptive deterrence in high-risk areas.

Methodology: πRo-Bot is an advanced, automated fire suppression system featuring a multi-modal control architecture for enhanced adaptability in wildfire-prone environments. It operates in three distinct modes:

- Automatic Mode: Utilizes a high-resolution infrared (IR) sensor array for real-time thermal imaging, detecting fire sources based on temperature thresholds. A closed-loop feedback system continuously adjusts the water jet trajectory for accurate suppression.
- Manual Mode: Implements a low-latency wireless control interface, allowing direct operator intervention via an off-the-shelf analog joystick controller. This mode ensures precise targeting in complex fire conditions.
- Preventive Mode: Integrates remote command protocols to autonomously spray fire retardant or water within a predefined area. The system features geofencing capabilities, enabling targeted preemptive fire prevention in high-risk zones

Impact:
Addresses growing wildfire threats by providing a scalable, automated solution for fire suppression and prevention. Enhances firefighter safety by enabling **remote fire mitigation** in hazardous conditions. Offers a **cost-effective alternative** to traditional suppression methods, reducing response times and environmental damage.

Skills Demonstrated:

- Embedded systems & automation for real-time fire detection and suppression.
- Infrared sensing & computer vision for precise heat-source targeting.
- Wireless control system design using game controllers for manual operation.
- Mechanical & electrical integration for a compact, mountable fire mitigation device.

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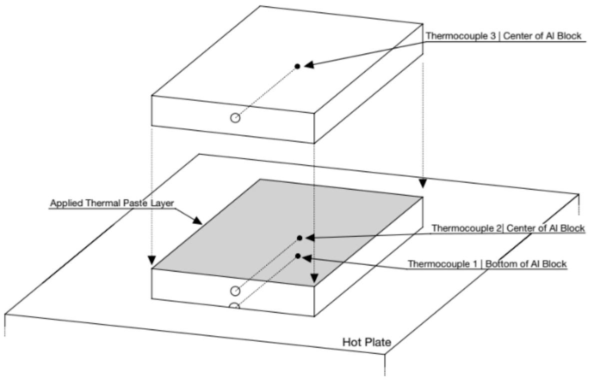
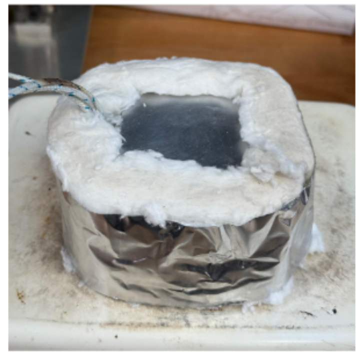
Thermal Paste Performance Evaluation for Heat Dissipation Optimization

Full Report Available Here





Objective: Investigated the thermal performance of different thermal pastes to enhance CPU/GPU cooling efficiency, ensuring optimal heat dissipation for high-performance computing applications.

Methodology: Designed a controlled experiment using custom-milled aluminum blocks, K-type **thermocouples**, an **ESP32** microcontroller, and an insulating fiber blanket to measure heat transfer. Conducted **calibration** procedures with ice and boiling water for thermocouple accuracy. Tested Noctua NT-H2, Arctic MX-6, and Thermal Grizzly Kryonaut using a temperature-controlled hot plate to simulate real-world CPU heat generation.

Key Findings: Thermal Grizzly Kryonaut exhibited the best thermal conductivity, minimizing the temperature gradient and improving heat dissipation. Results aligned with third-party data, reinforcing the importance of thermal interface materials (TIMs) in cooling.

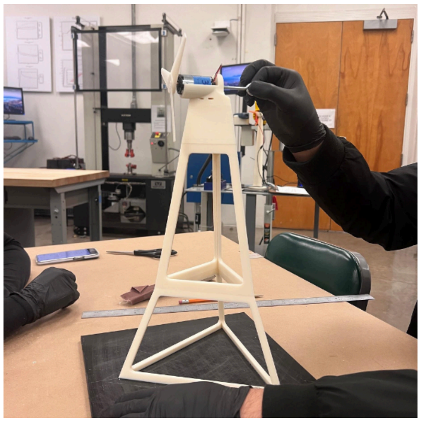
Impact: Provides engineers, PC builders, and overclocking enthusiasts with data-driven insights into selecting effective thermal pastes. Findings contribute to better heat management in consumer electronics and industrial applications, ensuring longevity and performance stability.

Skills Demonstrated:

- Thermal system evaluation and experimental design
- Data acquisition and signal processing using thermocouples and microcontrollers
- MATLAB-based data analysis for trend validation and result interpretation
- Mechanical design and fabrication of precision-milled components
- Troubleshooting and optimization to improve measurement reliability

3D Printed Wind Turbine Design and Testing

Full Report Available Here



Objective: Designed, 3D-printed, and tested a **miniature wind turbine** with the goal of **generating electricity** while ensuring structural stiffness and material efficiency.

Methodology: The wind turbine blade was designed using the NACA 4418 airfoil profile, with an optimized angle of attack (7.5°) and twist (15.3°) to enhance energy conversion efficiency. A three-blade configuration was selected to balance aerodynamic performance and structural stability. The tower structure was designed with a triangular support configuration, maximizing stiffness while minimizing material usage. The design adhered to weight and height constraints to ensure compatibility with testing conditions.
To assess the tower's structural integrity, a Finite Element Analysis (FEA) was conducted, simulating stress distribution, deflection, and the safety factor under operational loads. This analysis allowed for refinements in geometry to enhance mechanical stability. The wind turbine's performance was evaluated through controlled experimental testing, measuring power output, deflection under applied loads, and wind speed. The setup provided real-world validation of the design, ensuring the turbine's effectiveness in generating electricity.

Key Findings: The turbine **produced a peak power output of 1.823 W**, slightly under the **2 W target** but demonstrated high efficiency (98.75%). The tower **achieved a stiffness of 14.2 N/mm**, exceeding the 8 N/mm requirement, with a **maximum deflection of 3.17 mm under a 5 kg load**. The wind speed test confirmed 24.5 mph airflow, allowing optimal blade rotation and power generation.

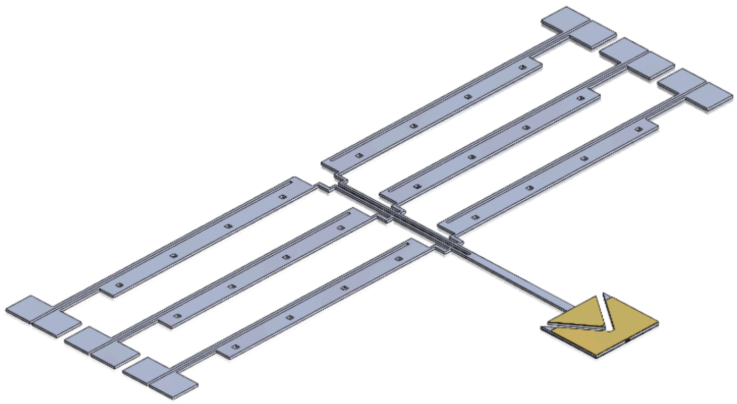
Impact: Provides insights into efficient wind turbine design for small-scale energy applications. Demonstrates 3D printing as a viable method for rapid prototyping and optimization in renewable energy projects. Offers a scalable approach for low-cost, custom-built wind energy solutions.

Skills Demonstrated:

- Computational fluid dynamics (CFD) and FEA for aerodynamics and structural analysis.
- 3D modeling and manufacturing using SolidWorks and 3D printing.
- Experimental data collection and validation for performance metrics.
- Optimization of mechanical structures for efficiency and material constraint

Microfluidic Exhaust Valve

Full Report Available Here



Objective: Designed and analyzed a **microfluidic exhaust valve** utilizing **thermal actuator arrays** and **electrostatic latching** to enhance fluid control and minimize leakage in MEMS devices.

Methodology: Developed a **yoke-configured thermal actuator array**, adapted from Comtois and Bright (1997), to generate precise force for sealing microfluidic channels. Implemented an **electrostatic latching mechanism**, inspired by the Scratch Drive Actuator concept, using a gold-chromium metal layer to enhance sealing via voltage-controlled attraction. Ensured the device can be fabricated using the **MUMPS process**, ensuring compliance with MEMS design constraints.

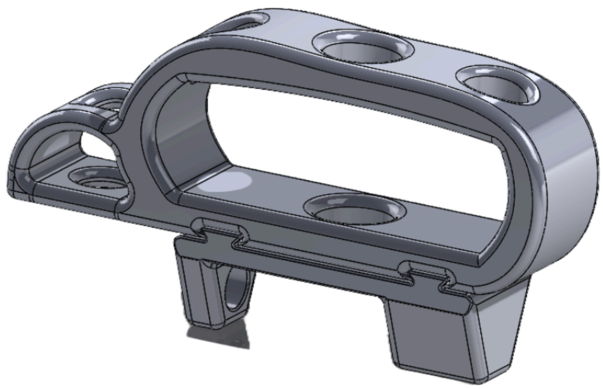
Key Findings: The **thermal actuator array generated 93 μN** of force at 8 μm deflection, effectively sealing the channel. Electrostatic latching demonstrated potential for **further enhancing the seal**, with force scalability based on applied voltage. Identified **design challenges**, including wiring integration for thermal actuation and electrostatic control.

Impact: Provides a novel approach to **reducing leakage in microfluidic MEMS systems**, improving precision in applications like biomedical diagnostics and micro-robotics. Demonstrates the feasibility of combining thermal and electrostatic actuation for robust, electronically controlled fluidic devices.

Skills Demonstrated:

- MEMS device design and microfabrication principles.
- Electrothermal actuation and electrostatics in fluidic control.
- Computational modeling and analysis for force estimation and sealing effectiveness.
- Microfluidic system integration and performance evaluation.

Assistive Utensil Device




Objective: Developed an ergonomic utensil assistive device designed to **enhance independence** for individuals with **limited finger mobility** due to musculoskeletal disorders, arthritis, or amputations.

Methodology: Designed a **flexible, palm-fitting band** to maximize **comfort, stability, and ease of use**. Created **interchangeable utensil adapters** using a **dovetail mechanism**, ensuring compatibility with different utensil types. Focused on **affordability** by utilizing **durable plastics and polymers** instead of metals.

Key Features: Designed to accommodate various hand sizes, ensuring a secure and ergonomic grip for maximum comfort and ease of use. By reducing strain on the fingers and joints, it effectively eliminates discomfort associated with traditional utensil use for individuals with limited finger mobility. The device is highly customizable and amputee-friendly, allowing users to adapt it to their specific needs for greater usability and independence. Additionally, it is printed with TPU (SLA)which is durable yet cost-effective, ensuring long-term daily use without the need for expensive components.

Impact: Restores independence in dining for individuals with limited mobility. Reduces pain and the need for painkillers, improving overall quality of life. Potential health benefits, including lower stress and blood pressure, which may contribute to increased life expectancy.

Skills Demonstrated:
- Human-centered design for accessibility solutions.
- Ergonomic product development with adaptive mechanics.
- Rapid prototyping and material selection for cost-effective manufacturing.
- Problem-solving for mobility impairments through iterative testing and user feedback

SolarSync: Automated Window Blinds

Objective: Developed an **automated window blind system** that adjusts based on external sunlight levels to improve **sleep-wake cycles** and energy efficiency.

Methodology: Integrated a photoresistor sensor to detect ambient light levels. Utilized an **ESP32 microcontroller** for real-time data processing and control. Implemented a **DC motor** with an **H-Bridge driver** for smooth actuation of the blinds. Enabled **wireless data transmission** using ESP-NOW, ensuring efficient and responsive operation.

Key Features: The photoresistor sensor was carefully tuned to accurately detect natural light variations, minimizing false positives and ensuring reliable performance. A software-based tracking system was implemented to monitor open and closed states, allowing the blinds to adjust automatically without manual intervention. To achieve precise and smooth movement, motor tuning techniques were tested and optimized, preventing excessive power consumption and mechanical strain. The system operates on a 3.7V Li-ion cell, utilizing a deep sleep state to enhance energy efficiency and ensure sustainable, low-power operation.

Impact: Enhances circadian rhythm regulation, leading to better sleep quality by aligning light exposure with natural sleep cycles. Provides cost-effective automation, offering a more affordable alternative to existing smart blind systems.Reduces energy consumption by optimizing natural light usage, potentially lowering electricity costs.

Skills Demonstrated:

- Embedded systems development using ESP32 and ESP-NOW.
- Sensor integration for ambient light detection and motorized actuation.
- Software design for state tracking and automation logic.
- Hardware prototyping and motor control optimization.