PARCAE (High-Speed Ribbon Control)

High-Speed, Continuous-Duty Thermal Printing

ELECOMP Capstone Design Project 2026-2027

Sponsoring Company:

Zebra Technologies Corporation
1301 Atwood Avenue, Suite 106N
Johnston, RI 02919
http://www.zebra.com

Company Overview:

Zebra Technologies Corporation and its subsidiaries provide enterprise asset intelligence solutions in the automatic identification and data capture solutions industry worldwide. The company designs, manufactures, and sells printers, which produce labels, wristbands, tickets, receipts, and plastic cards; dye-sublimation thermal card printers for personal identification; RFID printers; and a wide range of accessories, software, and services. Zebra serves retail and e-commerce, manufacturing, transportation and logistics, healthcare, and public sector industries through direct sales and a network of channel partners. The company was founded in 1969 and is based in Lincolnshire, Illinois.

Technical Director(s):

Morgan Malone
Manager, Engineering
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Project Motivation:

This project aims to overcome the current thermal barriers that limit thermal printing speeds. By leveraging the achievements of two prior capstone projects, the Universal Printhead Fixture and the Peltier Cooler Control Loop, this initiative will focus on developing a system capable of achieving steady-state thermal printing at speeds of 40+ inches per second (ips) on a continuous-duty basis. The Universal Printhead Fixture provides a high-precision platform for controlling any printhead, while the Peltier project offers a proven method for active thermal management. Combining these technologies will enable the development of next-generation, high-performance printing solutions, addressing a significant market need for increased throughput in industrial and logistics applications.

Anticipated Best Outcome:

The best outcome is a fully realized and documented prototype fixture that successfully demonstrates steady-state thermal printing at speeds of 40+ ips under a continuous duty cycle. This system will integrate active cooling and advanced control algorithms to maintain optimal printhead temperature, ensuring consistent print quality and hardware reliability without thermal degradation.

Project Details:

Overall system concept:

The core of this project is the integration of the Peltier-based cooling system with the Universal Printhead Fixture to create a testbed for high-speed printing. The system must be capable of precise thermal regulation while operating at unprecedented speeds.

Key Tasks & Deliverables:

- System Integration: Mechanically and electronically integrate the Peltier cooling module (Peltier coils, heat sinks, fans) with the Universal Printhead Fixture.
- Develop a Unified Control System: Design and implement a closed-loop control system that synchronizes motor speed, print data transmission, and active thermal management. The controller must be able to adjust Peltier current in real-time based on temperature feedback from the printhead thermistor.

- High-Speed Data & Power Management: Develop the electronics and firmware necessary to manage the high data rates and increased power demands required to drive a printhead at over 40 ips.
- Thermal Performance Characterization: Develop and execute test plans to characterize the system's thermal performance across various speeds and duty cycles. This includes developing new thermal correction algorithms to compensate for latency at extreme speeds.
- Software Interface: Create a comprehensive software interface that allows an operator to control print speed, thermal setpoints, and image data, while providing real-time feedback on temperature and system status.

Composition of Team:

3 Electrical Engineers & 1 Computer Engineer

Skills Required:

Electrical Engineering Skills Required:

- Advanced Control Systems: Expertise in designing and implementing closed-loop feedback control systems that integrate multiple physical domains (thermal, mechanical, electrical).
- Power Electronics Design: Ability to design and manage high-current power delivery systems for both the printhead and the Peltier thermoelectric coolers.
- Thermal Management: Strong understanding of heat transfer, thermodynamics, and experience with active cooling systems.
- System Integration & Testing: Proven ability to integrate disparate hardware and software components into a cohesive system and develop robust test methodologies.

Computer Engineering Skills Required:

- Embedded Systems & Firmware: Advanced skills in microcontroller programming (C/C++) for real-time control, high-speed data handling, and algorithm implementation.
- Software Development: Experience in creating user interfaces (e.g., in Python or C#) for complex hardware control and data visualization.

AI Usage:

The AI Use Policy for this project is defined in Appendix A at the end of this proposal. Technical Directors have completed the checklist in Appendix A to indicate which AI uses are permitted on this project. Any item left unchecked is not allowed.

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

A successful project will provide Zebra with a critical technological advantage, enabling the development of a new class of high-speed industrial printers. This will directly translate to faster fulfillment operations for customers in logistics, e-commerce, and manufacturing, reducing bottlenecks and increasing efficiency. The ability to print at 40+ ips would significantly shorten time-to-market for new high-performance products, reduce R&D costs by leveraging a standardized test platform, and solidify Zebra's position as an industry innovator.

Broader Implications of the Best Outcome on the Company's Industry:

This project has the potential to redefine the performance standard for thermal printing across the industry.

- Setting a New Performance Benchmark: Achieving reliable 40+ ips printing would create a new benchmark that competitors would be forced to chase.
- Enabling New Applications: Such high speeds could unlock new applications for on-demand thermal printing where it was previously not viable.
- Driving Innovation: This work would spur further innovation in media, printhead technology, and thermal management solutions across the supply chain.

Previous Year Results:

This project builds on the results of two ELECOMP Capstone projects from the 2025-2026 academic year. Their posters and final presentation videos are available at the links below.

- **Universal Printhead Fixture:** Poster (page 25 of the 2026 Spring Summit posters) | Presentation Video
- **Peltier-Based Thermal Control System:** Poster (page 22 of the 2026 Spring Summit posters) | Presentation Video

Appendix A: AI Use Policy – High-Speed, Continuous-Duty Thermal Printing

Allowed

- Students may use AI tools for
  - ☒ brainstorming support
  - ☒ concept development
  - ☒ literature and publicly available documentation review
  - ☒ software development
  - ☒ debugging
  - ☒ data analysis
  - ☒ test development
  - ☒ non-proprietary paragraph editing
  - ☒ non-proprietary single-slide formatting
  - ☒ preparation of project deliverables
  - ☐ note taking or transcription of meetings
  - ☐ Others: _____

Not Allowed

- Using AI in violation of university policies, applicable laws, or course-specific rules identified by capstone instruction team and project-specific rules identified by the technical directors.
- Entering proprietary, confidential, personally identifiable, security-sensitive, or otherwise restricted information into an AI system without authorization.
- Submitting AI-assisted work without understanding, reviewing, verifying, and appropriately disclosing its use.
- Submitting entire documents or presentations to an AI system for editing or formatting.
- Any unchecked items from the allowed list above.

Requirements

- If any use is allowed, AI tools may only be used to enhance, but not replace, students' technical reasoning, engineering judgment, and understanding. Students must be able to explain, justify, and defend all submitted designs, code, analyses, test results, documentation, and conclusions.
- During the first two weeks of the project, the student team shall work with the Technical Directors to: identify any proprietary or confidential information that may be involved in the project; determine what information may or may not be shared with AI

systems; identify the AI tools, models, accounts, and configurations approved for project use; and document any project-specific restrictions or approval requirements.

- Students shall transparently document the uses of AI using the URI CYPHER AI Usage Marking guidelines (https://web.uri.edu/cypher/ai-marking/). A workshop is planned for September to familiarize students with these guidelines.
- Students retain full professional responsibility for all design decisions, analyses, implementations, testing, documentation, presentations, and final deliverables, regardless of whether AI tools contributed to the work.