Ribbon Drive

High-Speed Ribbon Drive Control and Ribbon Saver System for Thermal Transfer Printing

ELECOMP Capstone Design Project 2026-2027

Sponsoring Company:

Zebra Technologies Corporation

1301 Atwood Avenue

Suite 106N

Johnston, RI 02909

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:

Morgan Malone
Manager, Engineering
MMalone@zebra.com

Project Motivation:

Thermal transfer printing at extreme speeds (40+ inches per second) presents significant mechanical and electrical control challenges, particularly in managing the thermal transfer ribbon. Precise tension and speed control of the ribbon supply and take-up spindles are critical to prevent ribbon wrinkling, snapping, or print smudging. Furthermore, thermal ribbon is a major recurring expense for customers. A "ribbon saver" mode, which halts the ribbon during non-print areas while the media continues to advance, can drastically reduce waste and cost. However, executing the rapid acceleration and deceleration required for a ribbon saver mode at 40 ips without losing tension or registration requires highly advanced motor selection and closed-loop control systems.

Anticipated Best Outcome:

The anticipated best outcome is a fully functional prototype of a high-speed ribbon drive system capable of supporting 40 ips thermal transfer printing with an active, reliable ribbon saver mode. The team will successfully source the optimal motor drive type (e.g., BLDC, stepper, or servo), design the driving electronics, and develop the closed-loop firmware algorithms required to synchronize the ribbon supply and take-up spindles with the main media platen, maintaining perfect tension during extreme acceleration and deceleration profiles.

Project Details:

This project requires a deep dive into motor control theory, power electronics, and real-time embedded firmware to overcome the inertia and tension challenges of high-speed ribbon handling. Mechanical design support, including structural mounting and gearing if necessary, will be provided by Zebra Technologies engineering staff to support the student team.

Hardware/Electrical Tasks:

- **Drive Type Sourcing & Evaluation:** Research, evaluate, and select the optimal motor technology (e.g., Brushless DC, closed-loop steppers, direct drive vs. geared) capable of meeting the aggressive torque, inertia, and speed requirements of a 40 ips ribbon saver mode.
- **Motor Control Electronics Design:** Design and validate a custom printed circuit board assembly (PCBA) to drive the selected motors. This includes selecting the appropriate motor driver ICs, power regulation, and integrating feedback sensors (e.g., rotary encoders, tension sensors).
- **Closed-Loop Tension Control:** Develop the control theory (PID or advanced predictive control) to maintain consistent ribbon tension between the supply and take-up spindles dynamically as the roll diameters change over time.
- **System Profiling & Tuning:** Create test profiles to measure ribbon tension transients, stopping distances, and acceleration curves, tuning the system to prevent ribbon breakage or wrinkling under stress.

Firmware/Software/Computer Tasks:

- **High-Speed Ribbon Saver Firmware:** Develop embedded C/C++ firmware to synchronize the ribbon drive with the main printer controller. The firmware must execute the ribbon saver logic, stopping the ribbon precisely during blank label areas and accelerating it back to 40 ips perfectly synced with the media before the next print area begins.

Composition of Team:

2 Electrical Engineers & 1 Computer Engineer

Skills Required:

Electrical Engineering Skills Required:

- **Motor Control Theory:** Deep understanding of different motor topologies (BLDC, Stepper) and their respective driving methods, torque curves, and inertia management.
- **Power Electronics & PCB Design:** Ability to design high-current motor drive circuitry, manage thermal dissipation on the PCBA, and handle sensor signal conditioning.
- **Control Systems Engineering:** Strong background in closed-loop feedback systems, PID tuning, and dynamic system modeling.

Computer Engineering Skills Required:

- **Embedded Firmware Development:** Proficiency in C/C++ for microcontrollers, handling real-time interrupts, hardware timers, and high-speed motor commutation.

AI Usage:

The AI Use Policy for this project is defined in Appendix A at the end of this proposal. Technical Directors: complete 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

Mastering 40 ips thermal transfer printing with an effective ribbon saver mode will establish Zebra's industrial printers as the undisputed performance leaders in the market. The ribbon saver functionality significantly reduces the Total Cost of Ownership (TCO) for high-volume customers by minimizing consumable waste. This dual advantage of extreme throughput and lower operating costs will directly drive market share growth in logistics, manufacturing, and e-commerce fulfillment sectors.

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

- **Sustainability & Waste Reduction:** A highly effective ribbon saver mode at industrial speeds translates to miles of thermal ribbon saved annually per printer, significantly reducing plastic and chemical waste across the global supply chain.
- **Throughput Benchmarks:** Achieving reliable 40 ips thermal transfer printing pushes the boundaries of current logistics speeds, allowing warehouses and distribution centers to process packages faster than ever before.
- **Advanced Mechatronics Integration:** The control strategies developed here will serve as a foundational technology that can be adapted to other high-speed web-handling and media control challenges across the printing and packaging industries.

Appendix A: AI Use Policy – High-Speed Ribbon Drive Control and Ribbon Saver System for Thermal Transfer 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.