3-Servo Synchronized Motion Control System

Architected & Built by
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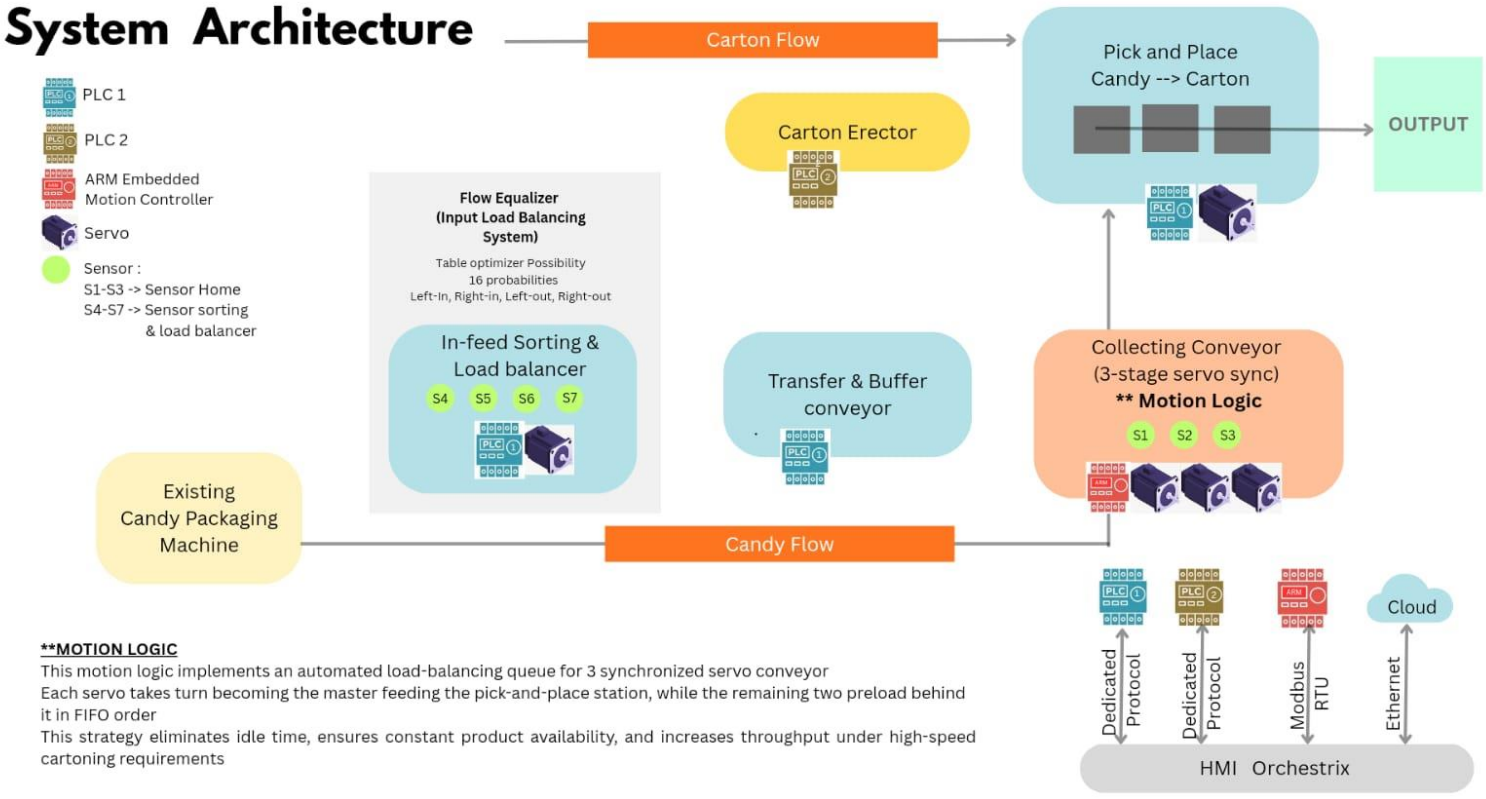


****MOTION LOGIC**
This motion logic implements an automated load-balancing queue for 3 synchronized servo conveyor
Each servo takes turn becoming the master feeding the pick-and-place station, while the remaining two preload behind it in FIFO order
This strategy eliminates idle time, ensures constant product availability, and increases throughput under high-speed cartoning requirements

Role : Designed, programmed, and delivered the full system end-to-end: architecture, PLCs, motion logic, servo control, safety, HMI, and commissioning.

Project period : 2023 – 2024

1. Executive Summary

- **End-to-End Motion Control System:** Designed and built a brand-agnostic, 3-servo synchronized automation for sorting, collecting, and cartoning, including PLC design, motion logic, and full integration.
- **High-Performance, Scalable Design:** 100% motion-driven (no cams), sub-1 ms servo sync, engineered for 240 PPM design and 120 PPM operational throughput, with fully scalable architecture—add servo modules without redesign.
- **Proven Reliability & Integration:** Running in production >1 year with low downtime; designed for ERP, AI-based reporting, and predictive maintenance.

2. System Architecture (Brand Agnostic Design)

1. Control Layer
The system uses a multi-controller architecture composed of:

- A primary PLC handling infeed logic, product detection, and load-balancer sequencing.
- A secondary PLC managing downstream machine operations and overall coordination.
  These controllers exchange signals to maintain synchronized product flow.

2. Motion Control Layer
A dedicated motion-control unit governs the three synchronized servo conveyors.
It manages position, speed, servo handover, and the reciprocal standby-to-active sequence required by the load-balancer function.

3. Servo Conveyor Group
The system employs three servo-driven conveyors operating in a rotating role pattern:

- One conveyor active
- One conveyor in standby
- One conveyor replacing the active unit
  This structure maintains continuous throughput and compensates for product variation.

4. Sensing and Feedback Layer
Sensors and encoder feedback provide real-time product presence, alignment, and machine status information to the controllers.
This ensures consistent motion timing and accurate handoff to downstream processes.

5. Pick & Place Interface
The motion logic and PLC coordination deliver timing signals to the pick-and-place mechanism, enabling reliable transfer to the next machine stage.

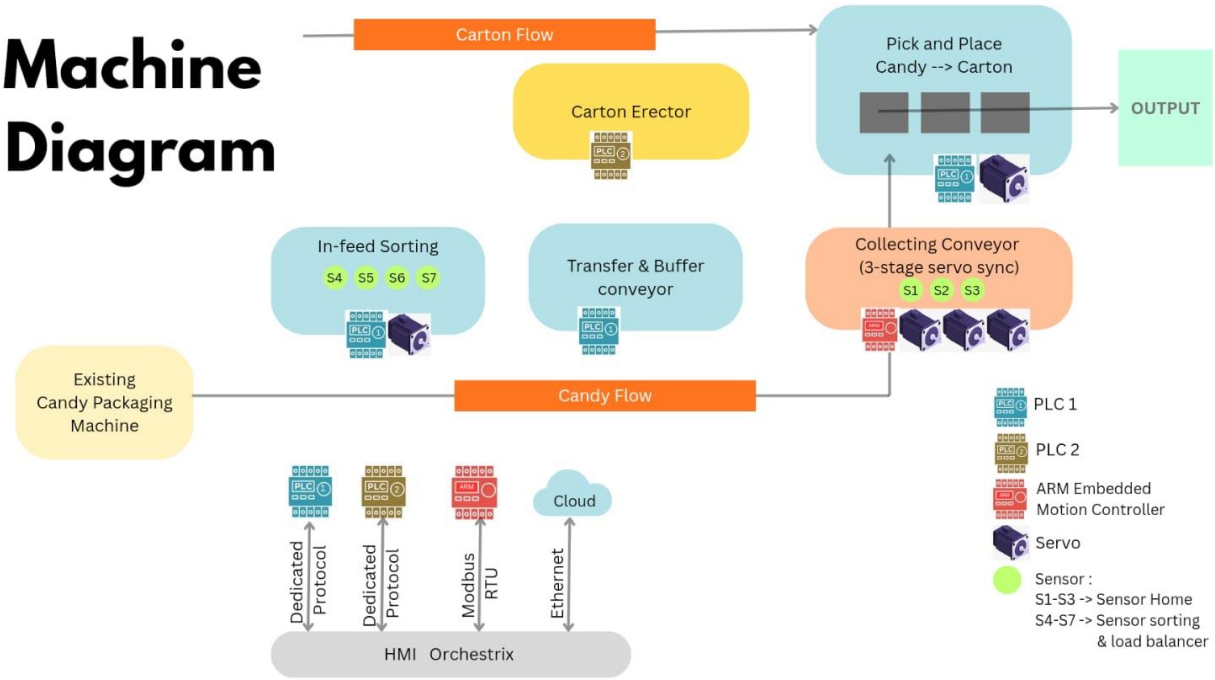
6. HMI and Operator Interface
An HMI provides visibility into production status, performance metrics, alarms, and basic controls.
Operators can adjust parameters and monitor system health.

7. Communication Infrastructure
A network links the PLCs, motion controller, HMI, and I/O modules to ensure deterministic communication and coordinated high-speed operation

Key Specifications Table:

Parameter	Value
Conveyor throughput (design)	**240 ppm**
Conveyor throughput (actual)	**120 ppm**
Load Balancer	**120 ppm**
Servo latency	**< 1 ms**
Product size	**125 g pack**
Carton capacity	**24 packs**
Error Handling	**Collision stop**
Labor reduction	**From 6 operator → 2 per shift**
Deployment status	**Running in production for 1+ years**
Downtime	**Occasional, depends on upstream cutting**

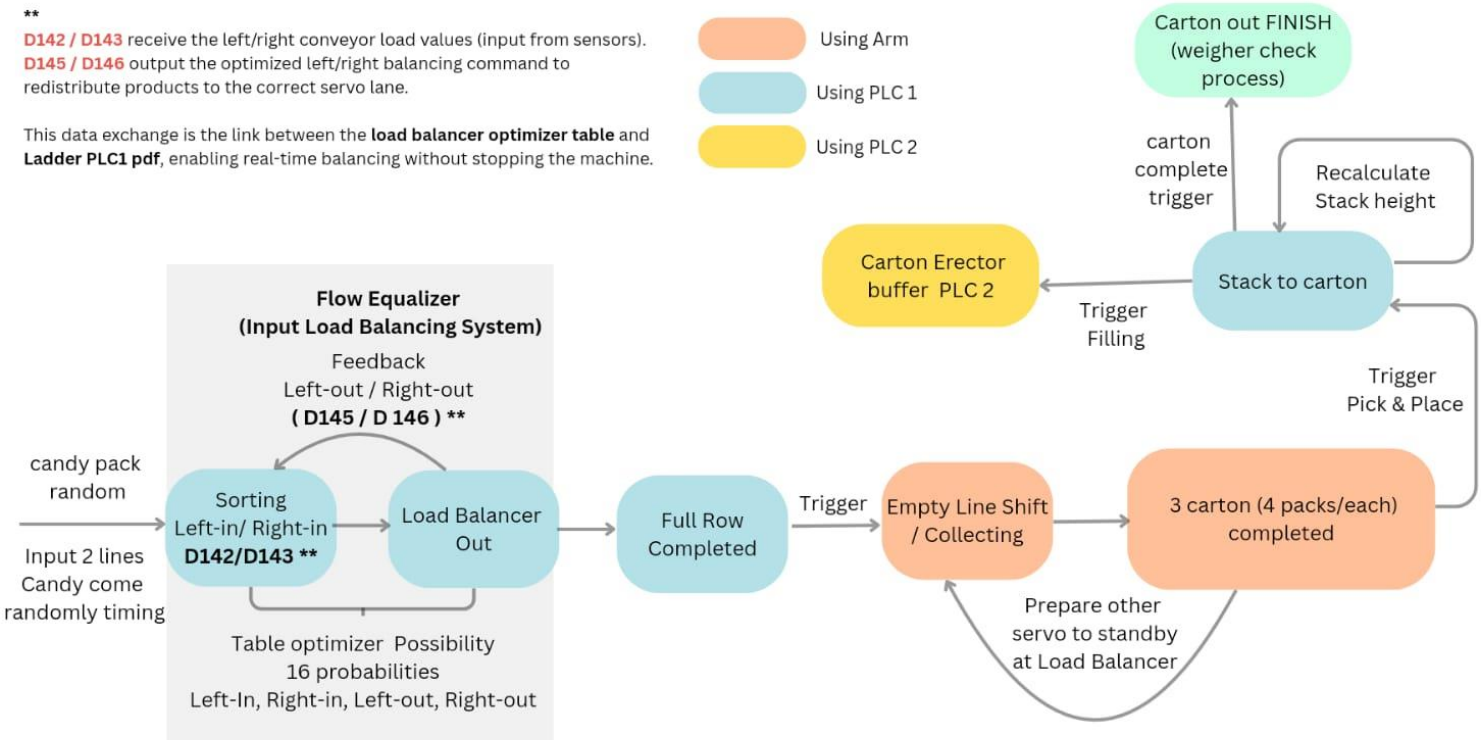
Machine Diagram



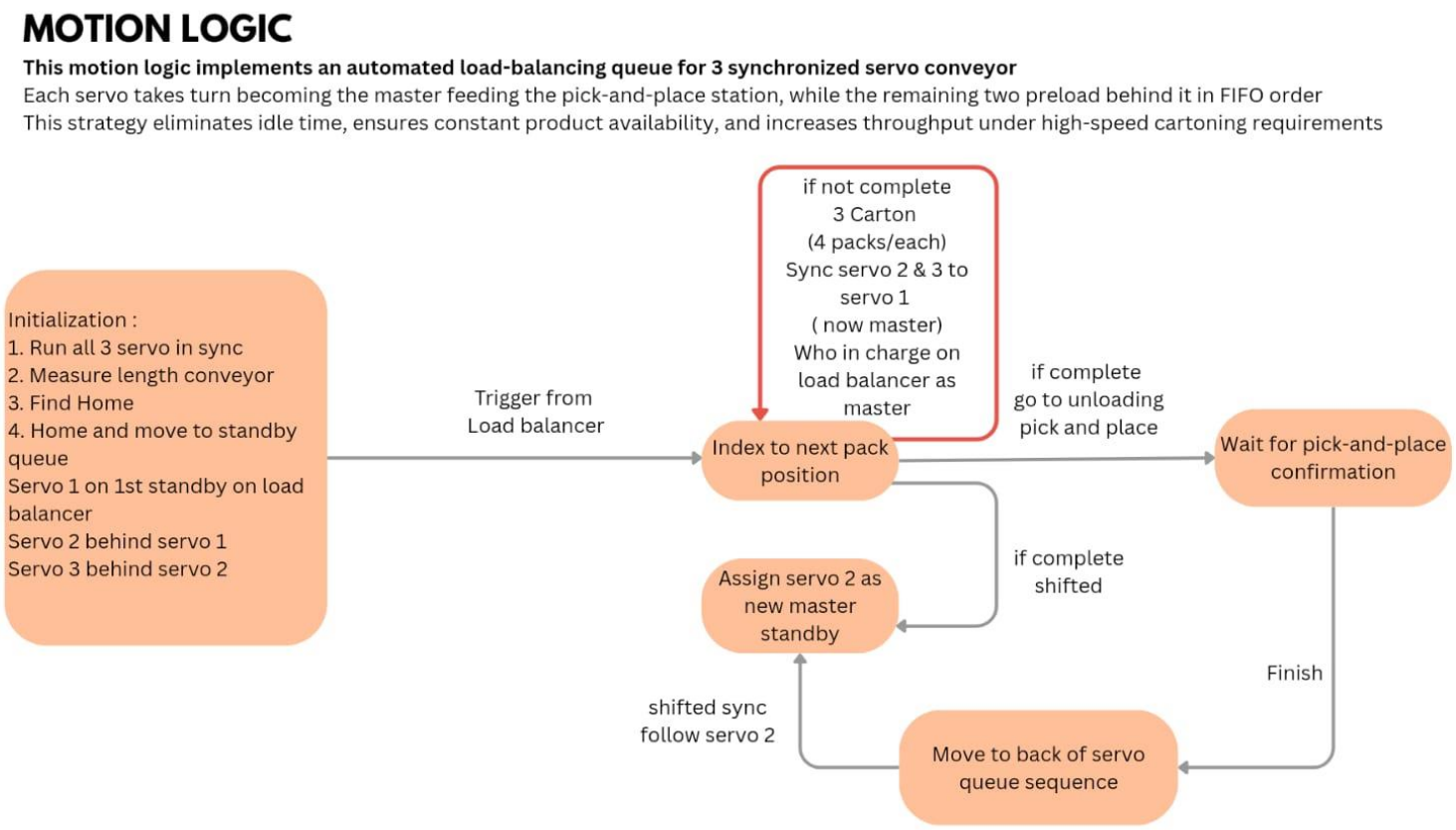
In-line cartoning diagram

**
D142 / D143 receive the left/right conveyor load values (input from sensors).
D145 / D146 output the optimized left/right balancing command to redistribute products to the correct servo lane.

This data exchange is the link between the **load balancer optimizer table** and **Ladder PLC1 pdf**, enabling real-time balancing without stopping the machine.



3. Motion & Control Logic



This system uses 3 synchronized servo conveyors operating in a rotational queue (1→2→3→1→..) to maintain continuous loading to the pick-and-place station

Stage	**Master on Load Balancer**	**Standby 1**	**Standby 2**
Initialization	Servo 1	Servo 2	Servo 3
After First pack complete	Servo 2	Servo 3	Servo 1
After second pack complete	Servo 3	Servo 1	Servo 2

- When a pack is completed, the master servo unloads the products to pick-and-place
- The next servo in queue becomes master instantly (no downtime).
- The previous master moves to the end of the queue and synchronizes behind Standby 2
- Cycle repeats until 3 cartons X 4 packs complete, then system waits for unloading sequence.

PURPOSE, to achieve :

- Zero idle time on pick-and-place
- Higher throuput under high-speed production
- Automatic load balancing without stopping the conveyor line

4. Technical Advantages

- **Deterministic Multi-Controller Coordination**
  Dual PLCs and a dedicated motion controller operate with predictable timing for high-speed flow.
- **High-Precision Servo Synchronization**
  Three servos maintain continuous alignment with <1 ms updates, enabling stable 240 ppm cycles.
- **Adaptive Load-Balancing Logic**
  Automatic servo handover (standby → active → replace) minimizes gaps and stabilizes throughput.
- **Modular and Brand-Agnostic Design**
  System architecture works across different hardware vendors and can scale or adapt easily.
- **Real-Time Feedback Integration**
  Sensor and encoder data provide immediate correction for product presence, alignment, and timing.
- **Built for Continuous Operation**
  Proven in a production environment for 1+ years with minimal intervention

5. Performance & Results

- **Design capability:** 240 ppm
- **Operating throughput:** 120 ppm (sufficient for current production needs)
- **Downtime:** Occasional, primarily due to upstream cutting issues
- **ROI:** Reduced operators per shift; faster packing for 125 g packs
- **Carton filling:** 24 packs per carton reliably

Overall, the system demonstrates high efficiency, safety, and scability, making it suitable for industries demanding high-speed automated handling

6. Safety & Error Handling Notes

- Collision detection stops conveyors and pick-and-place arm automatically
- Downtime due to upstream issues is safely handled
- Operator safety ensured with emergency stops and protected motion zones
- Errors are logged for maintenance follow-up

7. Future Scaling & Digital Integration

Scalable Conveyor Architecture:

- The inline conveyor system is **modular and continuous**, designed to support **more than three servo conveyors** in a single line.
- To achieve **higher throughput**, additional servo modules can be added seamlessly without redesigning the system.
- Load-balancing and pick-and-place logic scale automatically with new servos, maintaining smooth synchronization and product flow.

Digital Integration with Orchestrix or Similar Platforms:

- **ERP:** Integrate production data for scheduling, inventory tracking, and resource planning.
- **OEE Monitoring:** Track availability, performance, and quality in real time.
- **AI & Reporting:** Generate insights for efficiency, throughput optimization, and process improvements.
- **Predictive Maintenance:** Use sensor data and historical logs to prevent downtime and extend machine life.
- **Analytics Dashboard:** Visualize production KPIs, bottlenecks, and error events for data-driven decision making.

Key Advantage:

The system combines hardware scalability (add servos for higher throughput) with software-enabled digital integration**,** making it suitable for future-proof, high-speed production environments**.**

8. Appendix

Full PLC-1 ladder (non-proprietary sections) is available on GitHub

https://github.com/sinfu98android/3-Servo_Motion_Control_Automation

Video Link :

https://youtube.com/shorts/RkutWhYk8Z4?si=lX6ldTjML1j5Pb9A