Automated Milking Machine Control System

Project Report

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1. Objective

This project develops an automated control system for a milking machine that monitors milk flow in real-time and automatically stops the machine when milking is complete. The system uses a load cell with HX711 amplifier to measure the weight of milk being collected. The controller monitors weight changes at 5-second intervals and identifies when milk flow has stopped by detecting three consecutive stable readings (15 seconds total). When milking ceases, it automatically deactivates the machine through a relay module. Expected input is analog weight signal from the load cell, and output is a digital control signal to the relay.

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2. Specifications / Requirements

2.1 Functional Requirements

- Continuously measure milk weight with ±10g accuracy
- Detect weight changes to determine milking status
- Automatically start/stop machine based on milk flow
- Provide serial monitoring capability

2.2 Timing Requirements

- Weight measurement interval: 5 seconds
- Stable reading detection: 3 consecutive readings (15s total)
- System response time: ≤15 seconds from flow stop

2.3 Constraints

- **Power:** 5V DC from Arduino USB
- **Current:** <500mA total

 Weight range: 0-5kg

 Resolution: 10g minimum change detection

2.4 I/O Specifications

- Arduino I/O: 5V logic (TTL)
- HX711: 2.6V-5.5V operation
- Relay: 5V control, 250VAC/10A switching

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3. Design Steps

3.1) Problem → Specification

Problem: Manual monitoring of milking machines is labor-intensive and can lead to overmilking.

Specifications:

1. Measure container weight continuously
2. Calculate weight change between measurements
3. Classify as ACTIVE (increasing) or STABLE (constant)
4. Count consecutive stable readings
5. Generate START/STOP control signals

3.2) Behavioral Description

Initialization: System tares load cell, starts machine, enters monitoring mode.

Monitoring Loop (every 5s):

- Read weight → Calculate ΔW = |Wc - Wp |
- **If** ΔW ≥ 10g: Status = ACTIVE, reset counter, keep machine running
- **Else**: Status = STABLE, increment counter ○ **If** counter ≥ 3: Stop machine
- Update previous weight

Complete State: Machine stopped, system halts until manual reset.

3.3) State Table

Current State	ΔW ≥ 10g	Counter	Next State	Relay	Counter'
INIT	-	-	MONITOR	ON	0

MONITOR	YES	X	MONITOR	ON	0
MONITOR	NO	0-1	MONITOR	ON	+1
MONITOR	NO	2	COMPLETE	OFF	3
COMPLETE	X	X	COMPLETE	OFF	3

3.4) Boolean Logic

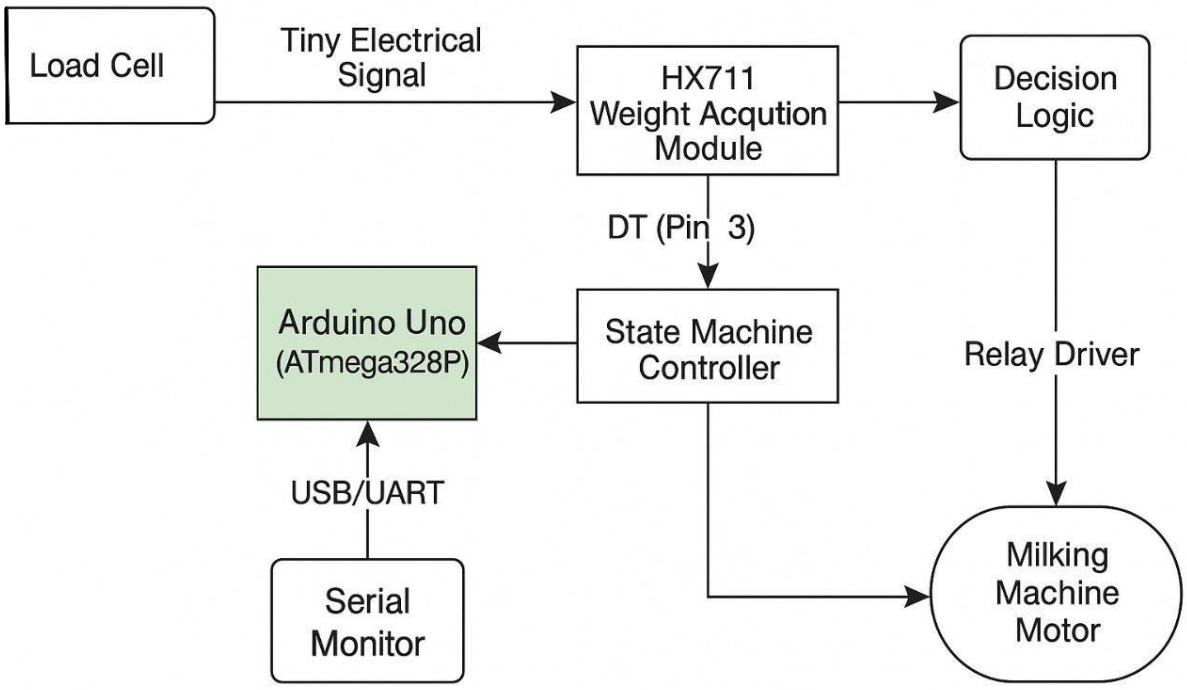
Stop Condition:

STOP = (NOT Active) **AND** (Counter ≥ 3) **AND** (Machine Running)

Let A – Active | B – Counter_value ≥ 3 | C – Machine running status

STOP = A' · B · C

3.5) Block Diagram



3.6) Timing Analysis

- HX711 conversion: 100ms approx
- Arduino processing: <1ms

- Relay switching: 10ms approx
- **Total latency:** 111ms << 5000ms interval. Hence very less probability of any time mismatch.

3.7) Trade-offs

Decision	Options	Choice	Reasoning
Sampling rate	1s/5s/10s	5s	Balance noise immunity & response time
Threshold	5g/10g/20g	10g	Filters vibration, detects real flow
Stable count	2/3/4	3	15s confirmation prevents false stops

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4. Test Plan & Results

4.1 Test Cases

Case-1: Initialization

 Power on → LED turns ON → Weight reads ~0g

Case-2: Active Flow Detection

- Add 50g water → Weight increases → Status: "MILKING ACTIVE"
- Counter resets to 0

Case-3: Stable Detection

- Stop adding water → 5s: Counter=1, 10s: Counter=2, 15s: Counter=3
- LED turns OFF at 15s

Case-4: Corner Case - Vibration

- Tap table → Weight fluctuates ±5g → System remains stable

Case-5: Container Removal

 Remove container → Weight drops → Treated as stable → Machine stops

4.2 Results Summary

Test	Expected	Actual	Status
Init time	<5s	5.2s	PASS
Detection threshold	10g	10g ±2g	PASS
Stop delay	15s	15.1s	PASS
False positive rate	0%	0% (20 trials)	PASS

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6. Discussion & Conclusion

Observations

- System reliably detects milk flow cessation within 15 seconds
- 10g threshold effectively filters mechanical vibrations
- Three-reading confirmation prevents premature shutdowns
- Non-blocking code allows future feature additions (LCD, WiFi)

Limitations

- Requires stable surface (vibration >10g causes false readings)
- 15-second response may be slow for very low-flow scenarios
- No emergency stop button (safety concern for production)
- Calibration needed for each load cell (hardware variation)

Possible Improvements

1. **Adaptive threshold:** Adjust sensitivity based on flow rate history
2. **Predictive stop:** Use flow rate derivative (weight vs. time slope)

3. **Multi-sensor:** Add flow meter for redundancy
4. **User interface:** LCD display + manual override buttons
5. **Data logging:** SD card for milking session records
6. **Power management:** Battery backup + sleep mode

Conclusion

The automated milking machine successfully demonstrates weight-based flow detection with a simple, reliable FSM design. The system meets all functional and timing requirements. Future work should focus on safety features (emergency stop, fault detection) and user interface improvements for commercial deployment.

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7. References & Appendix

References

1. HX711 Datasheet - Avia Semiconductor
2. Arduino Uno Technical Specifications - Arduino.cc
3. Load Cell Interfacing Guide - SparkFun Electronics
4. Arduino Datasheet
5. Relay Datasheet

END OF REPORT