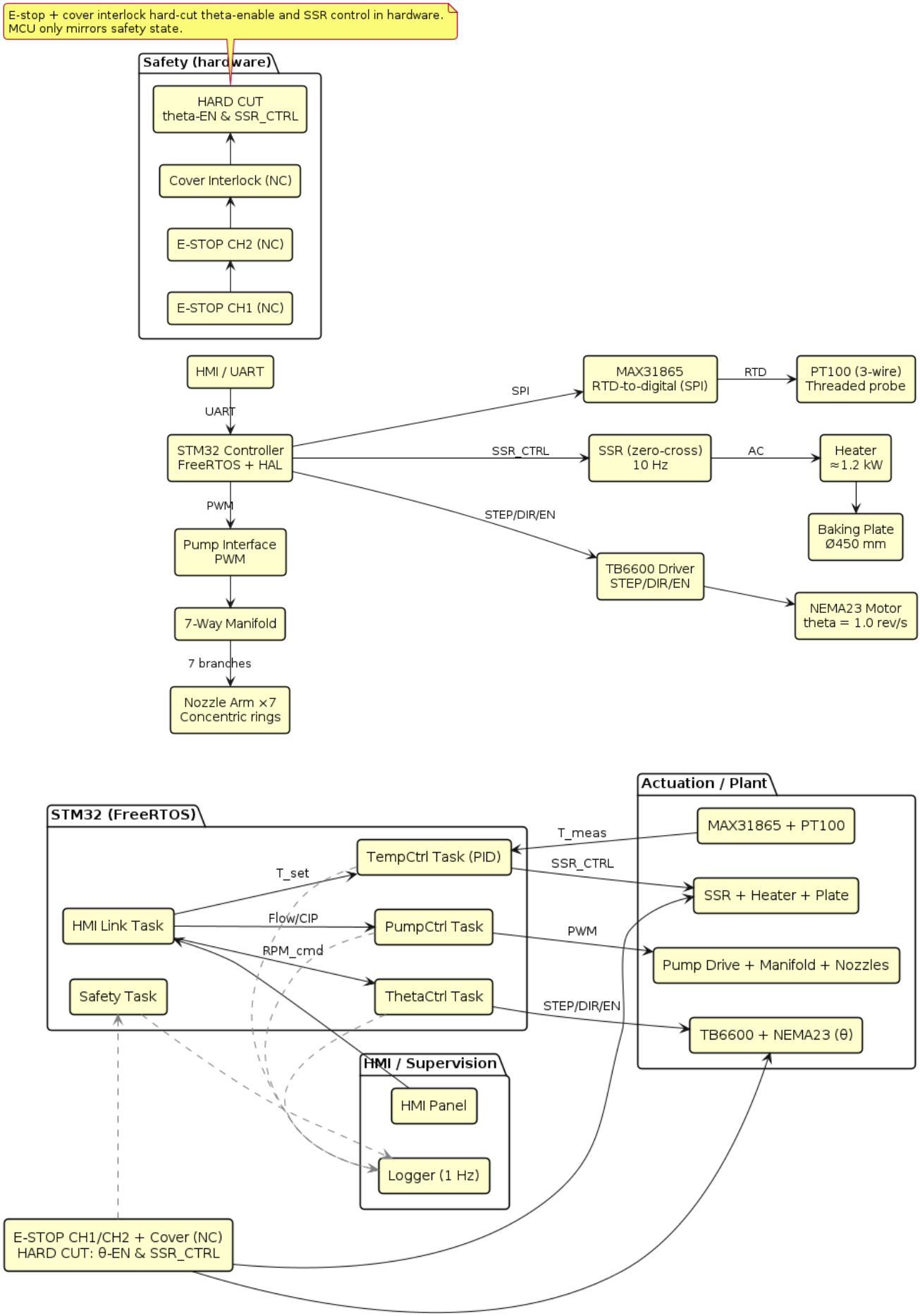
System Architecture

1) Overview

The STM32 controller supervises three subsystems—thermal, motion, and dispense—while a hardware safety chain can de-energize heat and motion independent of firmware.


E-stop + cover interlock hard-cut theta-enable and SSR control in hardware.
MCU only mirrors safety state.
Safety (hardware)
HARD CUT
theta-EN & SSR_CTRL
Cover Interlock (NC)
E-STOP CH2 (NC)
E-STOP CH1 (NC)
HMI / UART
UART
STM32 Controller
FreeRTOS + HAL
PWM
Pump Interface
PWM
7-Way Manifold
7 branches
Nozzle Arm ×7
Concentric rings
SPI
MAX31865
RTD-to-digital (SPI)
RTD
PT100 (3-wire)
Threaded probe
SSR_CTRL
SSR (zero-cross)
10 Hz
AC
Heater
≈1.2 kW
Baking Plate
Ø450 mm
STEP/DIR/EN
TB6600 Driver
STEP/DIR/EN
NEMA23 Motor
theta = 1.0 rev/s
STM32 (FreeRTOS)
TempCtrl Task (PID)
HMI Link Task
PumpCtrl Task
Safety Task
ThetaCtrl Task
T_set
Flow/CIP
RPM_cmd
HMI / Supervision
HMI Panel
Logger (1 Hz)
Actuation / Plant
MAX31865 + PT100
SSR + Heater + Plate
Pump Drive + Manifold + Nozzles
TB6600 + NEMA23 (θ)
T_meas
SSR_CTRL
PWM
STEP/DIR/EN
E-STOP CH1/CH2 + Cover (NC)
HARD CUT: θ-EN & SSR_CTRL

2) Power & Safety

- 230 VAC → EMI filter → MCB → RCD.
- Branches: (a) 24 VDC controls; (b) AC heater via SSR → thermal cutoff → heater.
- Hardware safety chain (E-STOP CH1/CH2 + cover NC) hard-cuts theta-EN & SSR.

Welcome to PlantUML!

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(details by typing `license` keyword)

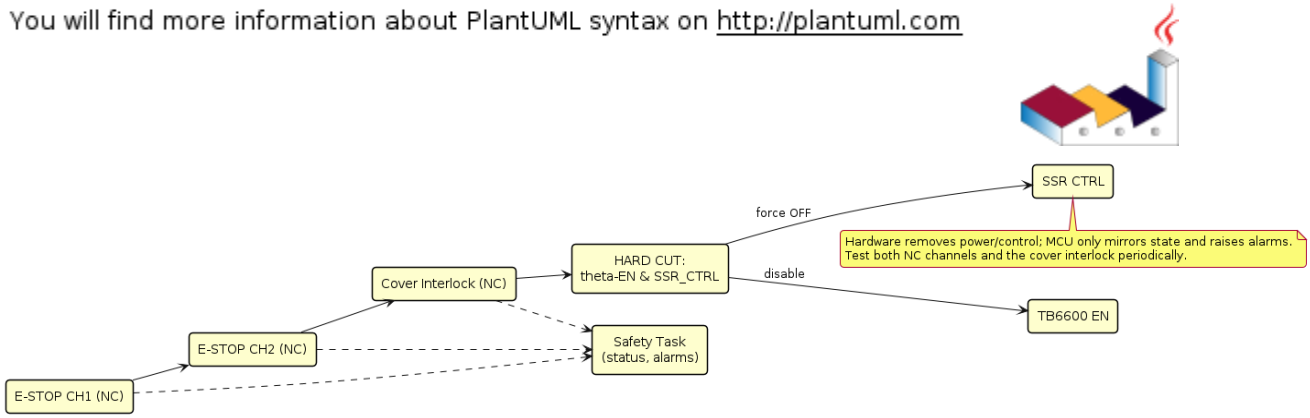
You can start with a simple UML Diagram like:

```
Bob->Alice: Hello
```

Or

```
class Example
```

You will find more information about PlantUML syntax on http://plantuml.com



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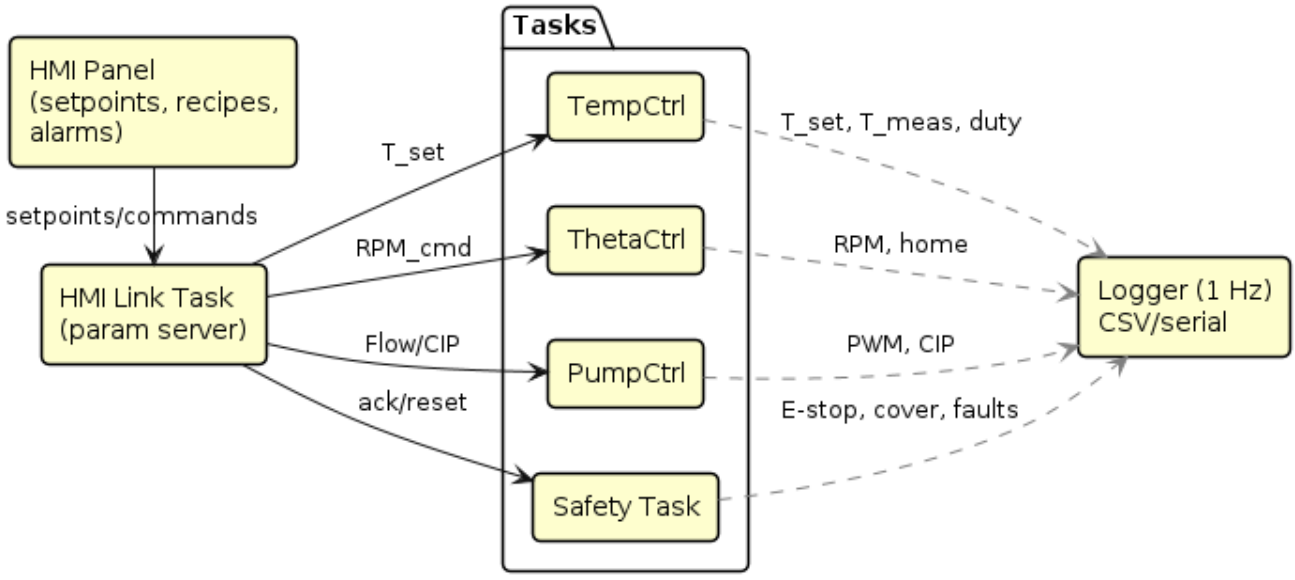
3) Control Electronics (24 V domain)

STM32 (FreeRTOS), MAX31865 + PT100, SSR at 10 Hz, TB6600 + NEMA23 (θ), pump PWM, HMI/Logger.



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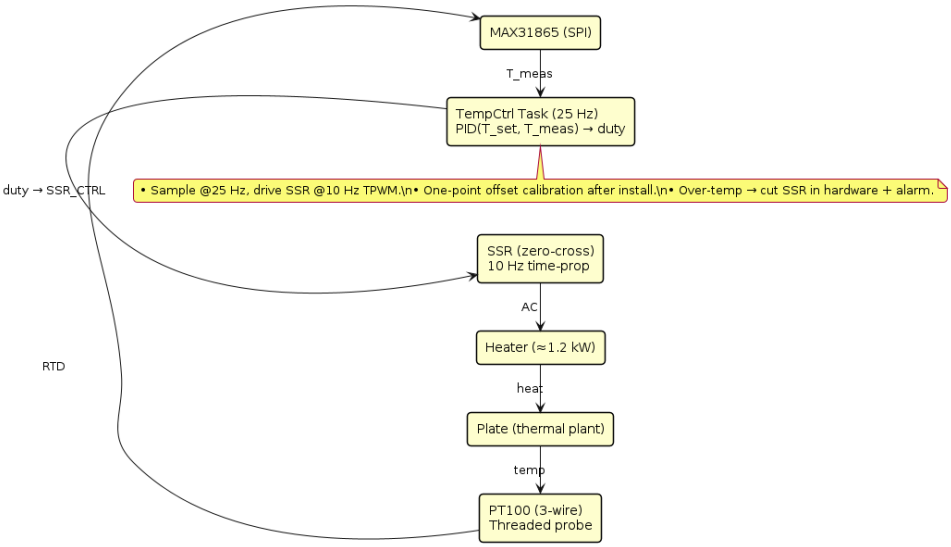
4) Subsystems

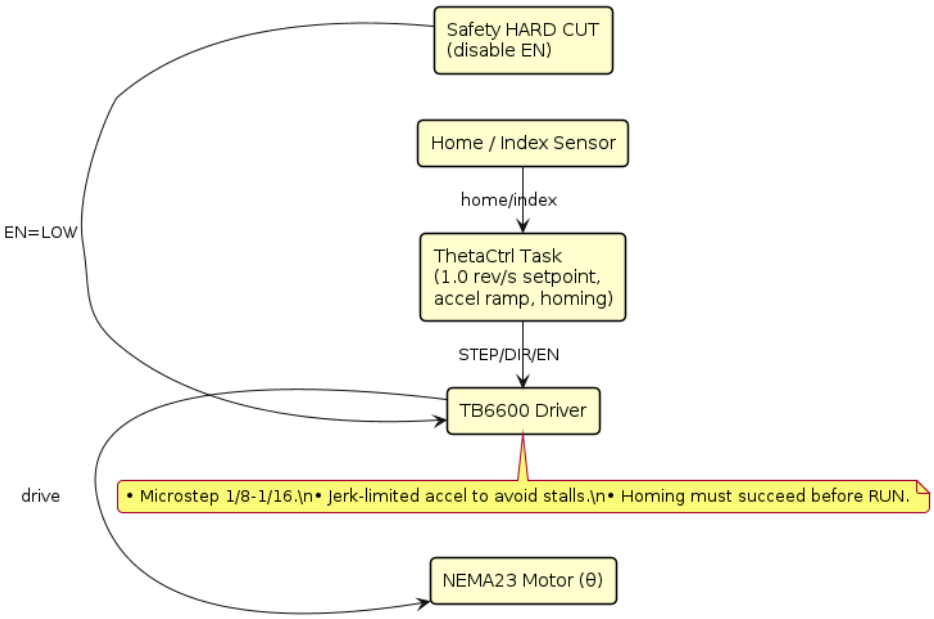
4.1 Thermal (bake plate)

PT100 → MAX31865 → Temp PID → SSR → heater → plate. Target: 210–230 °C, ±3 °C under cycling.



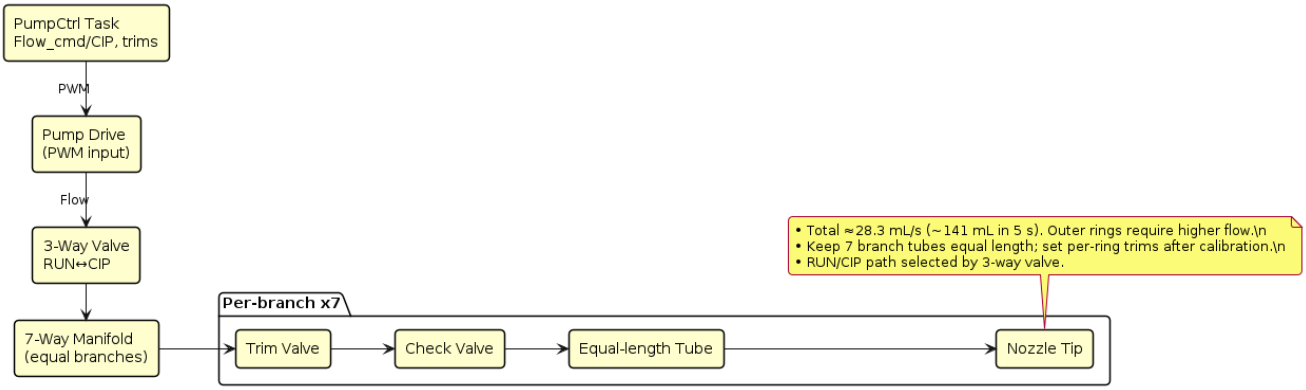
4.2 Motion (θ-axis)

1.0 rev/s with homing + jerk-limited ramps; STEP/DIR/EN → TB6600 → NEMA23; hardware EN cut.



4.3 Dispense (pump + manifold)

Single pump → 3-way RUN/CIP → 7-way manifold → trim/check/tube → 7 nozzles; equal-length branches; outer rings get higher mL/s.



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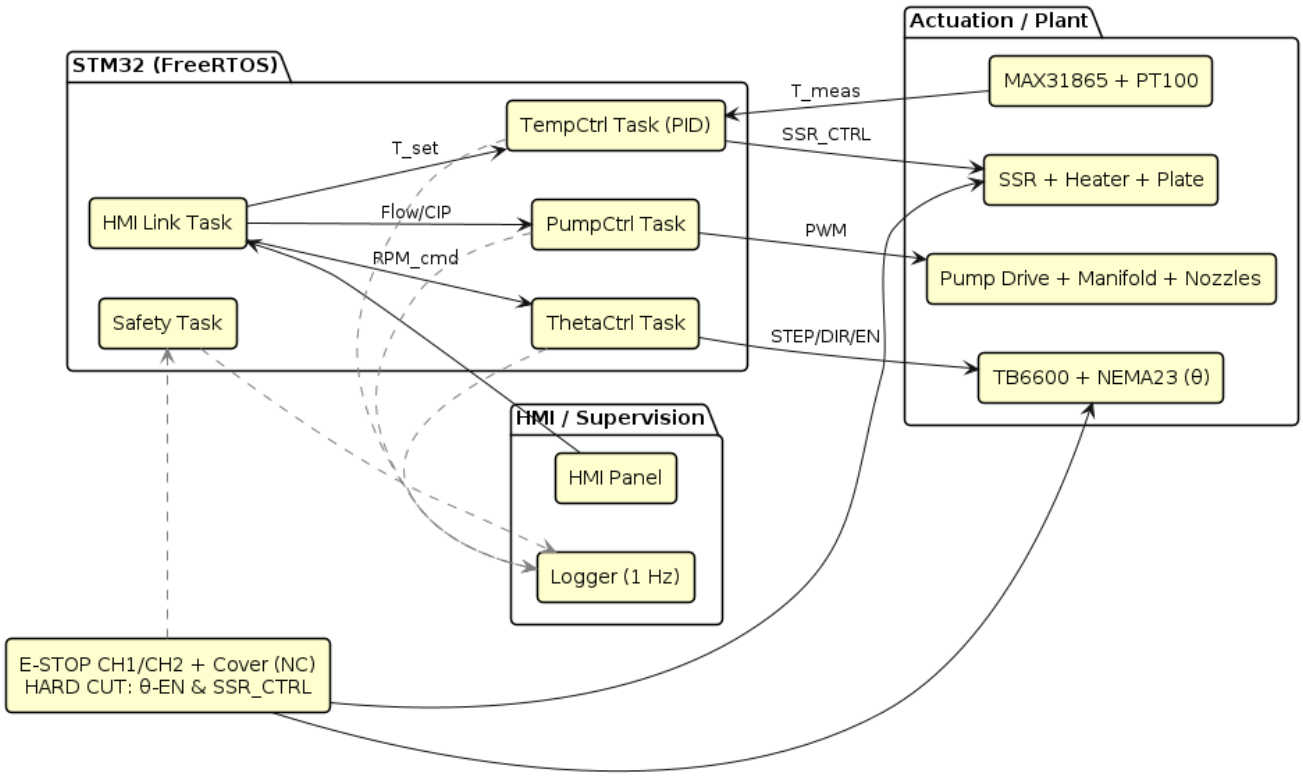
5) Software (FreeRTOS tasks)

Safety (1 kHz), TempCtrl (25 Hz; SSR 10 Hz), ThetaCtrl (timer-driven), PumpCtrl (10 Hz), HMI (2 Hz), Logger (1 Hz).



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6) Timing & Key Parameters

- θ speed: **0.2 rev/s**
- Dispense: **5 s**, **~28.3 mL/s** total (~141 mL)
- Temp sample: **25 Hz** (PID), **10 Hz** SSR drive
- Safety scan: **1 kHz** • Logging: **1 Hz**

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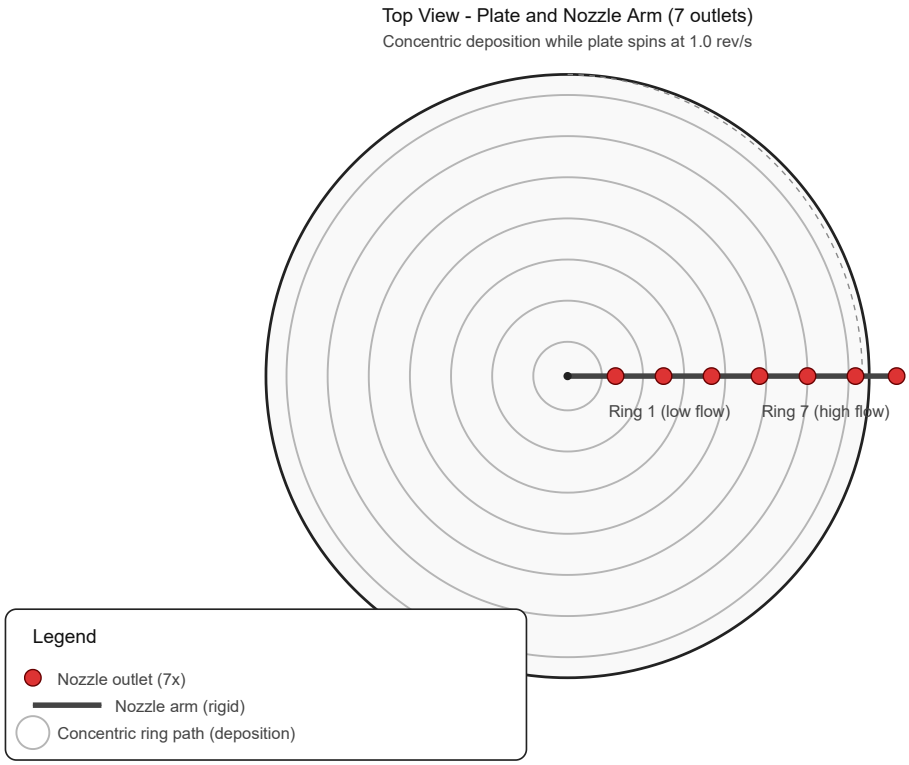
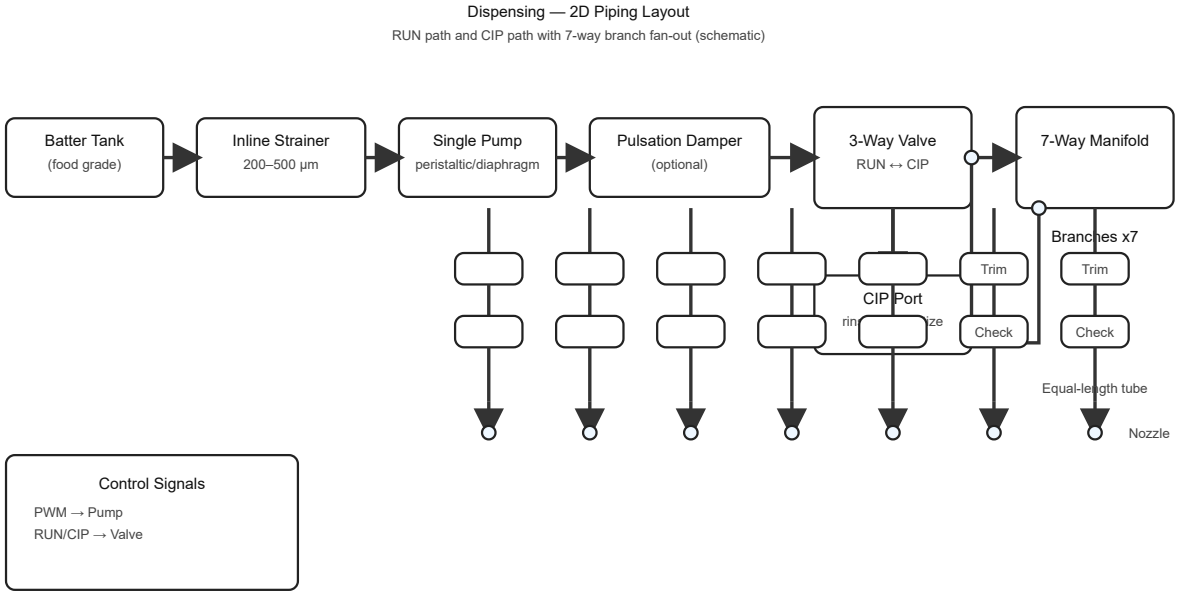
7) Dispensing — 2D Drawings (SVG)

These render natively on GitHub. Place the files under `docs/architecture/svg/`.

- Top View (plate + rotating arm + 7 nozzles):



- 2D Piping Layout (RUN/CIP + 7 branches):



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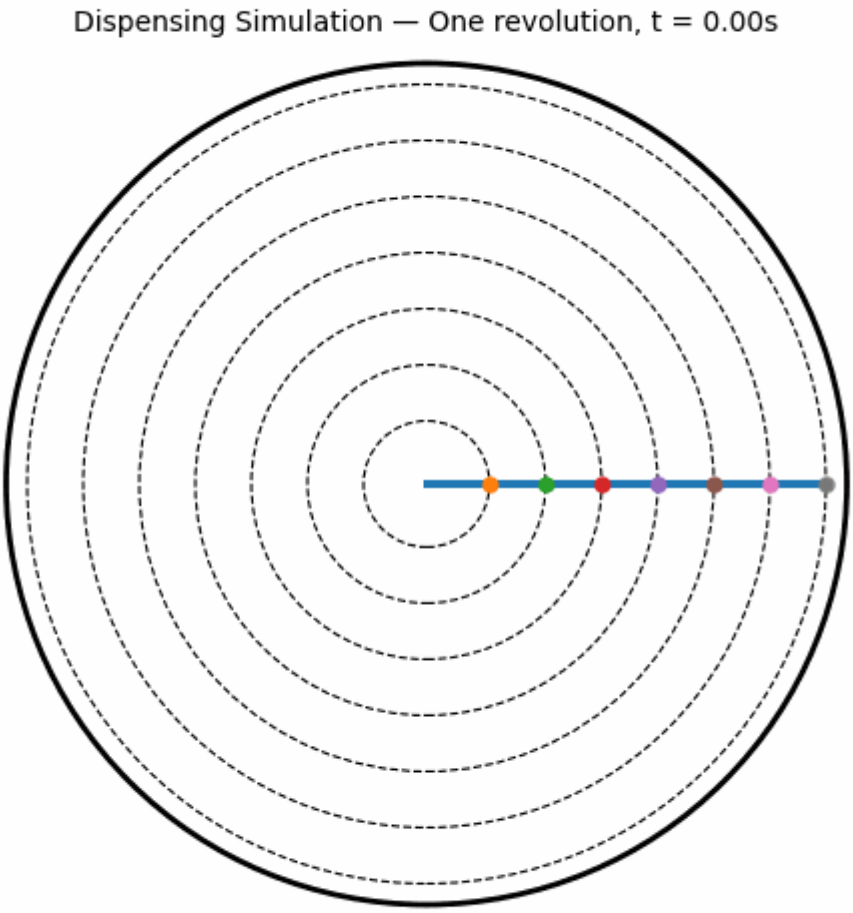
8) Video Simulation (One Revolution)

Animated visualization of a single **5 s** cycle where the arm completes **exactly one full revolution** while depositing seven concentric rings.
Place this file at `docs/architecture/media/dispense_simulation_one_rev.gif` and embed as below:



Dispense Simulation