PAROL6 Legacy Hardware Mapping

This document captures the physical hardware reality of the PAROL6 robot based on an analysis of the original `PAROL6 control board main software` (the open-source, open-loop firmware baseline).

As we migrate to a closed-loop Teensy 4.1 architecture (Phase 4), this map serves as the definitive reference for how the physical endstops and limit sensors are electrically configured.

🛑 Limit Switch & Inductive Sensor Mapping

The original firmware defines six distinct endstop inputs (`LIMIT1` through `LIMIT6`). Analysis of how these pins are initialized and evaluated reveals that the robot uses **Active Inductive Proximity Sensors** for its joints, not passive mechanical micro-switches.

How do we know this?

1. **No Internal Pull-ups**: In `hw_init.cpp`, all six limit pins are initialized strictly as `pinMode(LIMITX, INPUT);`. If these were simple mechanical switches, reliable embedded design would mandate `INPUT_PULLUP` to prevent floating states. Active inductive sensors (which operate at 12V/24V and output a strong, driven logic signal—often via external optocouplers) require pure `INPUT`.
2. **Mixed Trigger Edges**: In `motor_init.cpp`, the `limit_switch_trigger` struct variables are explicitly assigned `1` (HIGH) or `0` (LOW) depending on the joint. Furthermore, the interrupt routines in `hw_init.cpp` are mapped to a mix of `RISING` and `FALLING` edges. This mixed-polarity design is highly characteristic of industrial inductive sensors (NPN normally-open vs. PNP normally-closed) being deployed across different axes.

The Explicit Joint Mapping

PAROL6 Joint	Assigned Limit Pin	Electrical Trigger Polarity	Expected Sensor Type
Joint 1 (Base)	`LIMIT6`	Active **LOW** / `FALLING` edge	Inductive Sensor (Likely NPN NO)
Joint 2 (Shoulder)	`LIMIT2`	Active **HIGH** / `RISING` edge	Inductive Sensor (Likely PNP NO)
Joint 3 (Elbow)	`LIMIT3`	Active **HIGH** / `RISING` edge	Inductive Sensor (Likely PNP NO)
Joint 4 (Wrist 1)	`LIMIT4`	Active **HIGH** / `RISING` edge	Inductive Sensor (Likely PNP NO)
Joint 5 (Wrist 2)	`LIMIT5`	Active **HIGH** / `RISING` edge	Inductive Sensor (Likely PNP NO)
Joint 6 (Wrist 3)	`LIMIT1`	Active **LOW** / `FALLING` edge	Inductive Sensor (Likely NPN NO)

⚠️ *Important Academic Note on Polarity: Sensor polarity must be verified on hardware before final wiring, as inductive sensor types (NPN vs PNP) and Normally Open / Normally Closed states vary wildly across production batches of the same mechanical robot.*

⚙️ Safety & Architecture Implications for Teensy 4.1

1. **Voltage Warning**: The active inductive sensors on the PAROL6 operate at industrial voltages (typically 12V or 24V). The new Teensy 4.1 MCU is strictly **3.3V tolerant**.
   - **Mandatory Requirement**: You must use opto-isolators or voltage dividers (level shifters) on the custom PCB between the inductive sensors and the Teensy GPIO pins (Zone 4) to avoid instantly destroying the i.MXRT processor.
2. **EMI Coupling Danger**: Because these sensors carry active voltage logic, their signal wires must be physically isolated from the high-speed FlexPWM STEP signals on the PCB and wire harness. Failing to do so will result in induced EMI causing false limit-trips and random robot halts.