Arduino PCB Documentation

Scope: This document captures the rationale, constraints, and implementation notes for the Arduino-based PCB used in the rover electronics stack.

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1) Overview

This PCB is designed around **off-the-shelf modules and through-hole parts** to make first-time assembly reliable and repairable. It distributes power (including high-current 5 V rails), breaks out signals via headers, and supports multiple actuators and sensors.

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2) Design goals and constraints

Goals

- **Easy assembly** with basic soldering equipment (no reflow oven required).
- **Robust power delivery** for multiple servo motors and a Raspberry Pi 5 V rail.

- **Low-noise reference/return paths** for sensors and logic via continuous ground planes.
- **Modular connectivity** through pin headers for expansion and quick swaps.

Constraints

- **All components are THT** for easier assembly after ordering the PCB. If SMD were used, a heater/oven would be needed to melt solder paste (but the design can be more compact).
- Since **off-the-shelf electronic parts** are used, the board cannot be very small. If designed from scratch (custom regulators, custom MCU subsystem, etc.), it could be smaller but would be harder.

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3) System architecture

What this PCB supports

- **2× Arduino boards** (reason: servo motors require many pins; most pins are already used on the first Arduino).
- **4× servo motors**
  - 2× for the broom holding structure
  - 1× for raising a flag of the team's logo
  - 1× for a potential "sabotage" mechanism
- **LiDAR and sensors** (logic-level / lower current domain)
- **Raspberry Pi 5 V rail** (high current domain)

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4) Component choices

Through-hole vs. SMD (design decision)

- THT chosen for **easy hand assembly**, **rework**, and **repairability**.
- Tradeoff: increased board size vs. SMD.

Servo motor selection

- Servo motor: **MG996R** for high torque

    - Stall torque: **9.4 kg·cm at 4.8 V**

Buck converters

There are **3× 5 A buck converters**:

1. 5 A buck for **four servos**
2. 5 A buck for **LiDAR power and the 2nd Arduino power**
3. 5 A buck for **Raspberry Pi power**

Note: “5 A” is the regulator rating; real usable current depends on input voltage, thermal design, airflow, and PCB copper area.

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5) Power architecture

Bulk and local energy storage

- **2200 μF bulk capacitor** placed near the power source to filter low-frequency ripple and large voltage fluctuations.
- **Two decoupling capacitors** on the power rails:
    - **220 μF** (helps with lower-frequency ripple and load transients)
    - **0.1 μF** (helps with high-frequency noise)

Why this matters (especially with servos)

Servo motors create fast current spikes that can:

- Pull rails down (brownout resets on microcontrollers / Pi)
- Inject noise into sensor rails
- Increase EMI and ground bounce

Recommended layout intent:

- Place **bulk caps close to where current steps happen** (servo rail, Pi rail).
- Keep **sensor/logic decoupling close to the consuming device/module**.

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6) PCB stack-up and grounding strategy

4-layer plan

- **F.Cu** — Signal (0.035 mm)
- **In1.Cu** — Continuous ground plane (0.017 mm)
- **In2.Cu** — Continuous ground plane (0.017 mm)
- **B.Cu** — Power (0.035 mm)

Copper weights (as implemented):

- First and fourth layers: **1 oz copper**
- Second and third layers: **0.5 oz copper** (chosen due to cost of thicker internal copper)

Ground planes

Continuous ground planes:

- Provide a **very close return path** and allow **low-impedance returns**.
- Reduce loop area (good for EMI/noise).

Practical notes:

- Avoid splitting the ground plane unless you have a strong reason and clear current return analysis.
- Keep **high-current motor return currents** away from sensitive analog/sensor returns when possible (routing and placement strategy matters here).

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7) Routing rules (tracks, vias, current intent)

This board uses **two track widths** and **two via sizes**:

Track widths used

- **Signal / low-current: 1.000 mm** (≈ **39.37 mils**)
- **Power / higher-current: 2.000 mm** (≈ **78.74 mils**)

Via sizes used (pad / drill)

- **Smaller via (signal): 1.200 / 0.600 mm** (≈ **47.24 / 23.62 mils**)
- **Larger via (power): 1.600 / 0.800 mm** (≈ **62.99 / 31.50 mils**)

How these are applied

- **Signals** and normal logic connections are routed with **1.0 mm tracks** and **1.2/0.6 mm vias**.
- **Power distribution** is routed with **2.0 mm tracks** and **1.6/0.8 mm vias**.
- For rails with large transients (servo power) or higher total current (e.g., Pi rail), the layout relies on:
    - **shorter runs** (reduce voltage drop)
    - **wider copper where possible** (pours/planes when available)
    - **multiple vias in parallel** when transitioning layers

Via usage notes

- Lots of vias are used to provide more **return paths** and **heat dissipation**.
- When moving higher current between layers, prefer **via arrays (multiple vias)** rather than a single via.

Reminder: actual allowable current depends on copper thickness, trace length, temperature rise, and whether the trace is on an external vs. internal layer.

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8) Decoupling, bulk capacitance, and noise control

Placement guidelines

- 0.1 μF capacitors should be placed **as close as possible** to the power pins of the consuming device/module.
- Bulk capacitors (220 μF, 2200 μF) should be placed **near the rail entry point** and/or near **large transient loads**.

Servo noise containment (recommended)

- Route servo power as a **separate high-current path** with short loops.
- Keep the servo current return path tight and avoid routing it under sensitive sensor signal routes if possible.
- Consider adding footprints for:
    - extra bulk caps on the servo rail (optional)
    - ferrite bead or LC filtering for the sensor rail (optional)

9) Protection and safety

Fuse

- A **fuse** is used to cut the power when components malfunction and cause an overcurrent.

Reverse polarity protection (optional)

- Reverse polarity protection was checked with a TI instrument PDF.
- Although present in the schematic, it is **not in the PCB editor** because an **XT30 connector** is used:
  - Low chance of accidentally connecting power the wrong way
  - Uncertainty of malfunctioning also contributed to deletion
- Reverse polarity protection introduces a **small voltage drop**, but the benefits may outweigh downsides in many designs.

Recommendation: even if not assembled by default, consider keeping an **optional footprint/jumper** for reverse-polarity protection so you can add it later without a board respin.

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10) Connectors, headers, and expandability

- **Pin headers** are used for easy connection of other parts (servo motors, LiDAR, etc.).
- When possible, label headers with:
  - Signal name
  - Voltage rail
  - Ground pins
  - Pin-1 orientation marking

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11) Assembly and bring-up checklist

Before soldering

- Run ERC/DRC with the chosen fab's minimum rules.
- Confirm all connectors (XT30, headers) match the **mechanical footprint** and **pin orientation**.

Power-up sequence (recommended)

1. Power the board with a bench supply (current-limited).
2. Verify each buck output rail with no load.
3. Add loads gradually (Arduino → sensors → servos → Pi rail).
4. Observe voltage droop and ripple during servo movement.

Quick checks

- Confirm fuse rating matches expected peak currents.
- Confirm no unexpected heating on:
    - buck regulators
    - high-current pours/traces
    - connectors

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12) Known issues and documentation notes

Schematic net labels are incorrect

- The labels on the schematics are **INCORRECT** because they use the same label for all digital pins (**DIGI**).
- Correct approach: **DIGI1, DIGI2, ...** similar to the labels used for the connection between the motor and the motor driver.

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13) Future improvements

PMOS selection (placeholder → to be completed)

This section is currently a placeholder. When selecting a PMOS (for ideal-diode/reverse protection or power switching), define:

- **VDS rating** (must exceed worst-case battery voltage + spikes)

- **ID / power dissipation** under worst-case load
- **RDS(on)** at the available gate drive voltage (impacts voltage drop + heating)
- **Package/thermal** (THT vs SMD, heatsinking, copper area)
- **Gate protection** (TVS/zener and proper gate resistor if needed)

Additional "nice to have" footprints

- Test points for each rail (GND, 5 V servo, 5 V Pi, logic rail)
- Optional reverse-polarity protection footprint (even if normally bypassed)
- Current sense shunt footprint for debugging servo/Pi current draw

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Appendix: Design rationale summary (one paragraph)

The PCB is intentionally built with THT components and off-the-shelf modules to maximize assembly success and reworkability. A 4-layer stack with continuous ground planes reduces return-path impedance and noise. Routing uses **1.0 mm tracks + 1.2/0.6 mm vias for signals** and **2.0 mm tracks + 1.6/0.8 mm vias for power**, with wider copper, shorter runs, and parallel vias where higher current is expected. Bulk and decoupling capacitance supports transient-heavy loads (servos) and improves supply stability; a fuse provides basic overcurrent safety. Known documentation issues (non-unique digital net labels) are flagged for correction.

Post-manufacture testing:

Rev A:

PCB Correction: Capacitor Polarity and +18 V Rail Short

During PCB review and continuity testing, a short was identified between the +18 V rail and GND. Investigation revealed that several polarized capacitors had incorrect orientation, caused by rotating the components after routing without updating the associated traces. As a result, the positive capacitor pads were connected to GND and the negative pads to the power rail, creating an unintended short.

Corrective actions taken:

- Affected capacitors were rotated 180° to restore correct electrical connectivity.

- The footprints of the incorrectly oriented capacitors were updated so that pad numbering and polarity markings (+/–) correctly matched the schematic and connected nets.
- Routing was verified to ensure that power nets connect to positive capacitor pads and GND connects to negative pads.
- Silkscreen polarity markings were checked and corrected to prevent assembly errors.

After these changes, the +18 V rail and GND are no longer shorted, and both electrical connectivity and visual polarity markings are consistent with the schematic.