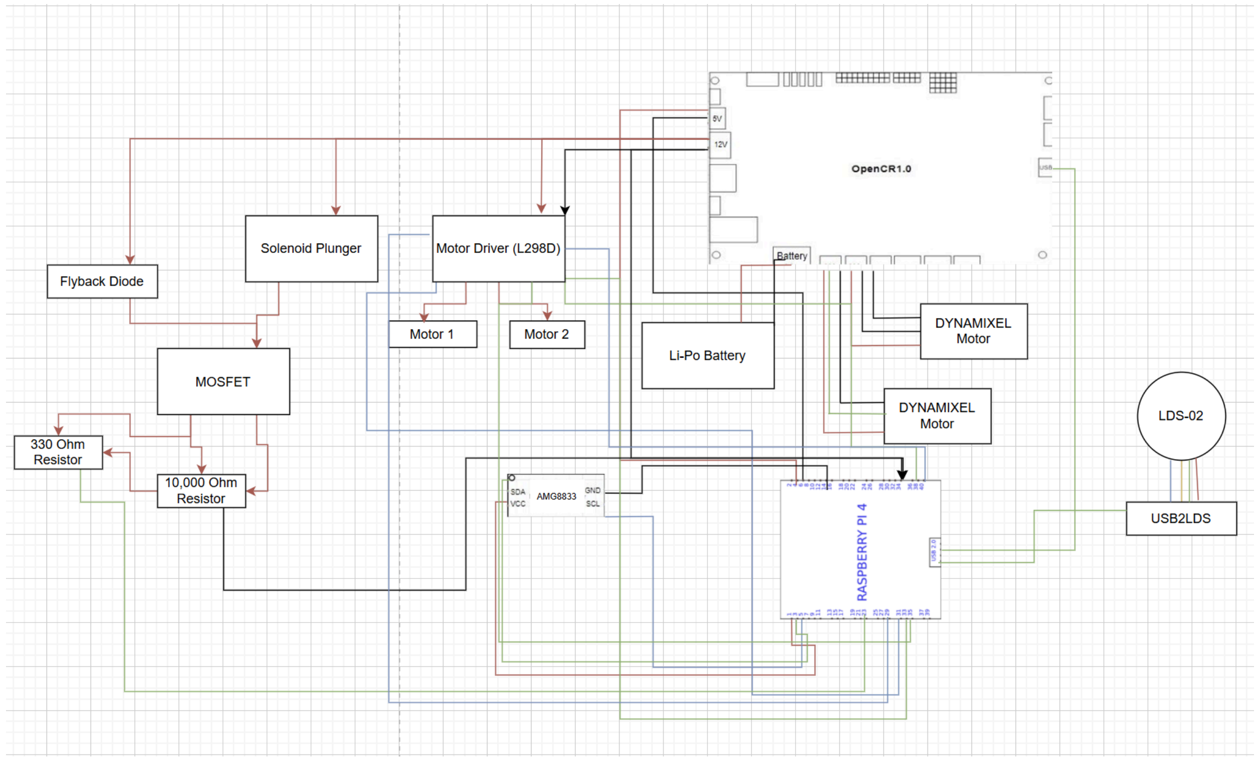
Electrical Subsystem



Overview of the Circuit:

This electrical setup integrates several subsystems including power, control, actuation (launching mechanism), sensory input, and robot navigation.

Main Components:

- Raspberry Pi 4
- OpenCR 1.0 Controller
- Li-Po Battery
- Solenoid Plunger Circuit
- L298N Motor Driver (Flywheel Motors)

- DYNAMIXEL Motors (Robot locomotion)
- AMG8833 Thermal Sensor
- LDS-02 LIDAR (connected via USB2LDS)

Detailed Functionality and Current Flow:

1. Power Supply and Distribution:

- Li-Po Battery supplies power to the entire robot.
- Battery output powers both the OpenCR controller and the motor driver circuit (L298N).
- OpenCR distributes regulated power to DYNAMIXEL motors and provides 5V/12V outputs, as required by components like sensors or Raspberry Pi.
- The Raspberry Pi is powered through regulated voltage provided by the OpenCR or via a DC-DC regulator ensuring stable voltage.

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2. Control System: Raspberry Pi and OpenCR

- Raspberry Pi 4 acts as the main computing device, running ROS 2 for sensor data processing, motor control signals, and solenoid activation commands.
- OpenCR is used as an intermediary for controlling DYNAMIXEL motors (navigation), managing battery status, and possibly distributing regulated power to peripherals.
- Communication between Raspberry Pi and OpenCR occurs through a USB or UART interface, allowing commands and sensor data transfer.

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3. Launching Mechanism: Flywheel Motors and L298N

- L298N Motor Driver receives commands directly from Raspberry Pi's GPIO pins or PWM outputs to control two flywheel motors.
- Flywheel motors spin rapidly to launch ping pong balls. Speed and power of these motors can be modulated by adjusting PWM signals from Raspberry Pi to L298N motor driver.
- The motors receive direct power from the OpenCR via the L298N motor driver, which provides sufficient current and voltage.

Current Flow in Flywheel motors:

Li-Po Battery → OpenCR→ L298N Driver → Flywheel Motors → Return via L298N → Common Ground

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4. Solenoid Loading System (MOSFET & Solenoid Plunger)

- A solenoid plunger loads ping pong balls into the flywheel system. It is controlled via a MOSFET-based switching circuit, driven by Raspberry Pi GPIO pins.
- GPIO pin triggers the MOSFET gate through a 330Ω resistor. The 10kΩ resistor ensures MOSFET gate discharge when GPIO is LOW.
- When activated, MOSFET completes the circuit and energizes the solenoid, retracting or extending its plunger, thus loading the ball.
- Flyback diode protects against voltage spikes generated by the solenoid coil upon switching off, ensuring protection of MOSFET and Raspberry Pi.

Current Flow in Solenoid Circuit:

- Activation (GPIO HIGH):

Li-Po Battery (12V) → Solenoid coil → MOSFET Drain → MOSFET Source → Ground

- Deactivation (GPIO LOW):

Inductive coil voltage spike → Flyback Diode → Solenoid coil → dissipated safely

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5. Robot Locomotion (DYNAMIXEL Motors)

- DYNAMIXEL Motors are directly controlled by OpenCR, providing robust positional and velocity control. These motors maneuver the robot around the operational area.
- They communicate digitally with OpenCR
- Power is supplied from OpenCR controller ports designed for these motors.

Current Flow in DYNAMIXEL motors:

Li-Po Battery → OpenCR regulated output → DYNAMIXEL Motors → Return via OpenCR → Battery Ground

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6. Sensors and Inputs

- AMG8833 Thermal Sensor is connected via I^{2}C communication (SDA/SCL) to Raspberry Pi, providing thermal data to detect heat sources (targets).
- The thermal sensor is powered by regulated voltage (usually 3.3V or 5V) provided by Raspberry Pi.
- LDS-02 LIDAR connects via USB2LDS converter, allowing Raspberry Pi to perform mapping (SLAM) and obstacle detection/navigation.

Current Flow in Sensor Circuit:

Raspberry Pi regulated power → AMG8833/LDS-02 → Return via Raspberry Pi Ground

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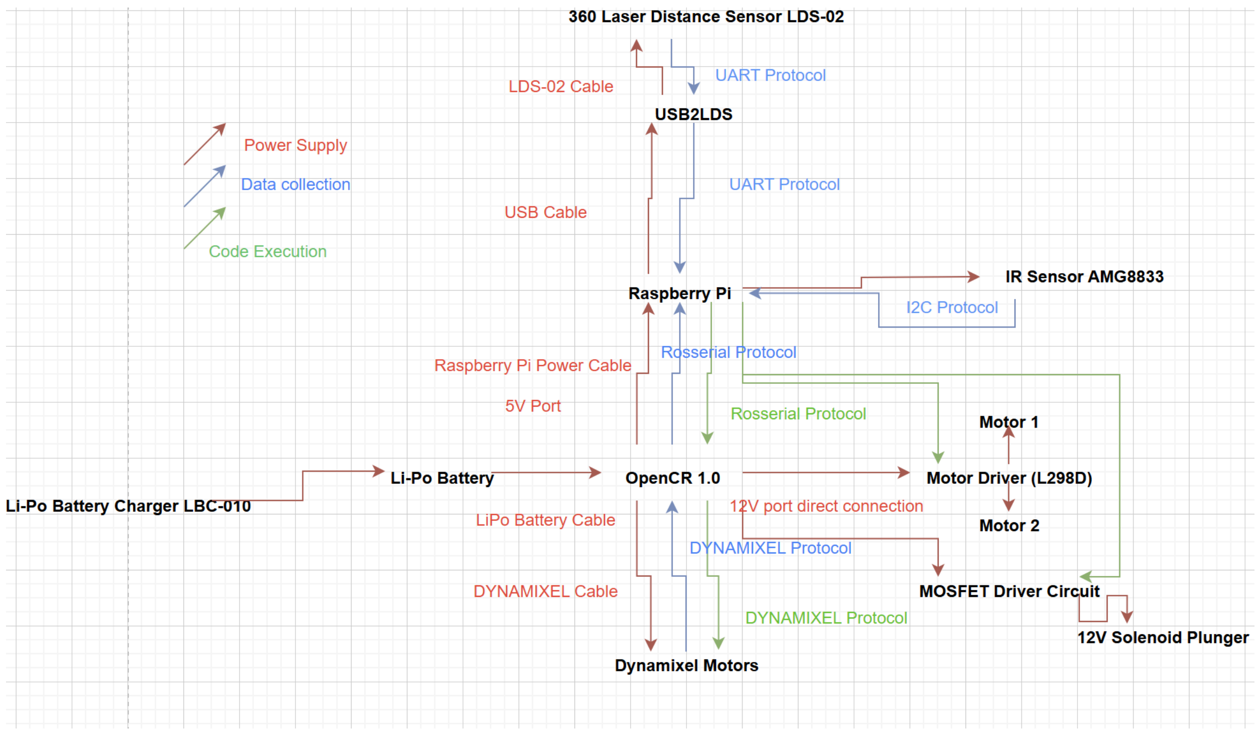
Overall Circuit Operation:

- The Li-Po Battery provides power to all systems.
- Raspberry Pi executes main logic via ROS2, manages flywheel launching motors (via L298N), and actuates the solenoid via GPIO and MOSFET circuit.
- OpenCR manages robot locomotion via DYNAMIXEL motors, provides regulated power distribution, and interfaces with Raspberry Pi.
- Sensors (AMG8833 thermal sensor, LDS-02 LIDAR) provide environmental feedback, enabling robot autonomy (heat detection, obstacle avoidance).
- MOSFET circuit with flyback diode ensures safe, reliable control of the solenoid loading mechanism, preventing circuit damage.



Power Budgeting

	Voltage (in V)	Current (in A)	Power (when running) in W	Power (when launching) in W
TurtleBot			8.72	8.72
Solenoid Plunger	12	1.5	12*0.4=4.8	12*1.5=18

AMG8833	3.3	4.5	3.3*0.8*10^-3=2.64*10^-3	3.3*4.5*10^-3=14.85*10^-3
Motors × 2 via L298N	11.1	0.21	2.3	16.9
Total			15.82	43.634

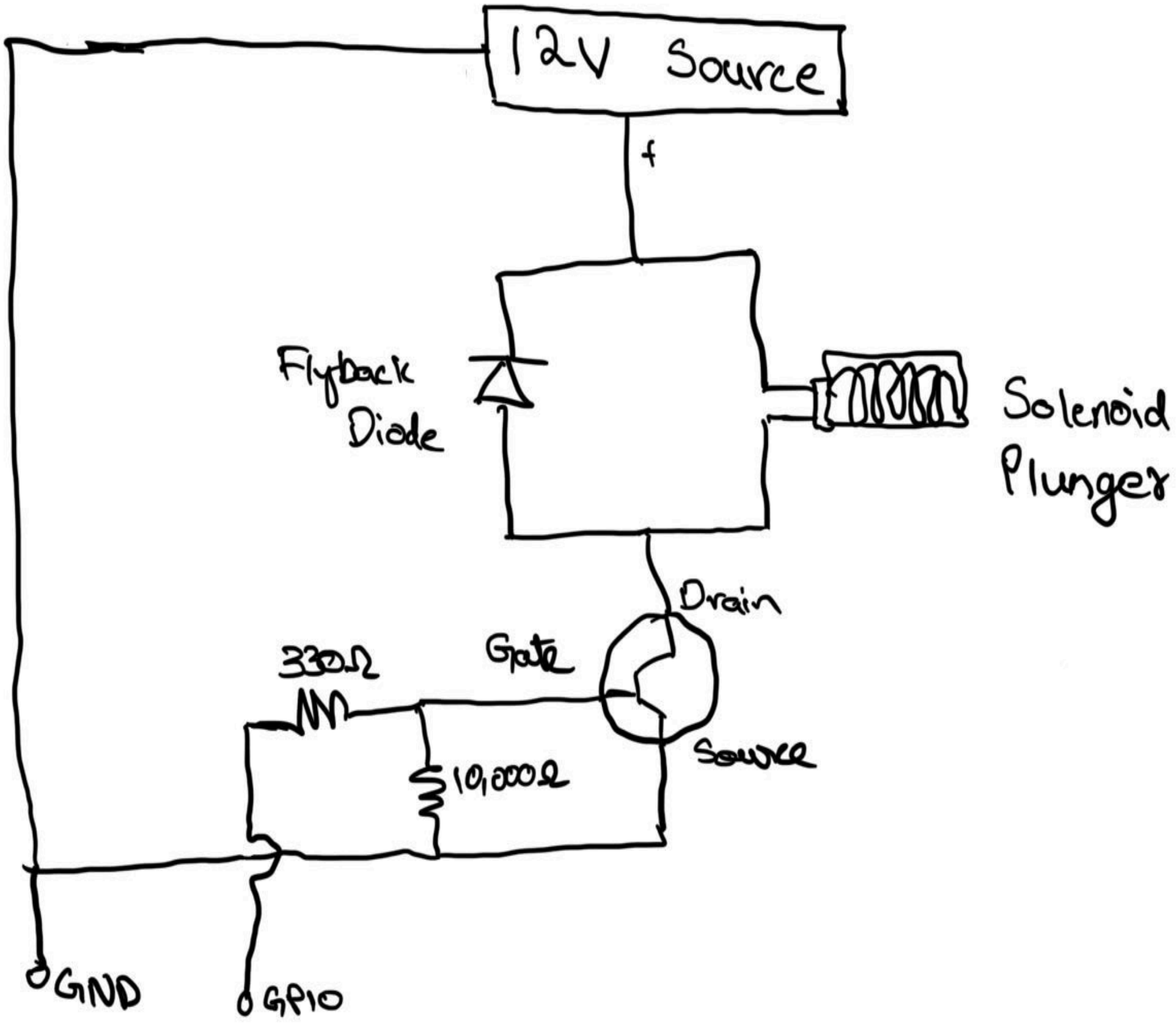
Power while running = 13.52
Power when launching = 43.634

Battery: 1800mAh, 11.1V -> Capacity: 19.98Wh

Energy consumption: 0.33*13.52+6*43.634*0.000555556 = 4.4616+0.0267= 4.488Wh

Battery can run for: 19.98/4.488=4.39

Battery can run four 20 minute cycles until it dies. (This is with the assumption that the motors will run at full capacity.)



This is the primary circuit that we had used to integrate the Solenoid and the Motors mechanisms. We had to find a way to split the 12V supply, we had to power both the motor and the solenoid using the OpenCR. Which is why we used the MOSFET driver system to get the GPIO signal from the RPI and get the voltage from the OpenCR.

Components in the Circuit:

- 12V DC Source: Provides the required voltage to energize the solenoid coil.
- Solenoid Plunger (JF-0530B): An electromagnet-based mechanical actuator that moves (extends/retracts) when powered.
- N-channel MOSFET (IRL8803): Acts as an electronic switch controlled by a low-voltage GPIO pin (Raspberry Pi).
- Flyback Diode (1N4001): Protects the circuit from high-voltage spikes created when current through the solenoid coil suddenly stops.
- Gate resistors (330Ω and 10kΩ): Protect the MOSFET's gate and ensure proper switching (10kΩ resistor also ensures the gate discharges to ground when GPIO is off).

Working Principle:

1. Initial State (GPIO LOW):

- Initially, the GPIO pin from the microcontroller is at a LOW state (0V).
- The gate of the MOSFET is effectively grounded through the 10kΩ resistor, which ensures the MOSFET remains off (no conduction).
- With the MOSFET off, no current flows through the solenoid coil, keeping the solenoid plunger inactive.

2. Activating the Solenoid (GPIO HIGH):

- When the GPIO pin is set to HIGH , a voltage is applied through the 330Ω resistor to the MOSFET gate.
- This positive voltage at the gate turns the MOSFET on, creating a conduction channel from the drain to the source.
- With the MOSFET conducting, current flows from the 12V source → through the solenoid coil → into the MOSFET drain → out of the MOSFET source → to the ground (GND).
- As current flows, the solenoid energizes and the plunger moves (usually inward or outward depending on the type).

3. Deactivating the Solenoid (GPIO LOW):

- When the GPIO pin goes back to LOW (0V), the gate voltage is removed, causing the MOSFET to switch off.
- With the MOSFET off, the current flowing through the solenoid coil suddenly stops.
- Because solenoids (coils) are inductive loads, they generate a large voltage spike due to rapidly changing current.
- This spike can potentially damage components. Therefore, the flyback diode comes into action.

Role of Flyback Diode:

- The diode is reverse-biased during normal operation, thus not affecting the circuit.
- Upon MOSFET turn-off, the solenoid's inductive coil tries to maintain current flow (due to stored magnetic energy), generating a voltage spike in the opposite direction.
- The diode becomes forward-biased by this voltage spike, allowing current to circulate safely through the diode-coil loop, dissipating the energy as heat safely and protecting the MOSFET and the microcontroller from voltage spikes.

Current Flow:

- GPIO HIGH:
    - 12V Source → Solenoid → MOSFET Drain → MOSFET Source → Ground.
    - MOSFET is ON, Solenoid is activated.
- GPIO LOW:
    - MOSFET switches OFF, no direct current flow from 12V source.
    - Flyback diode safely dissipates the inductive voltage spike generated by the solenoid coil.

Thus, the MOSFET and diode arrangement provides a robust, safe, and efficient means of controlling a solenoid using a low-voltage microcontroller output.