Open Dynamic Robot Initiative (ODRI) Quadruped Robot

Documentation

Shivam Verma (Intern: July - August 2023)

Intention:

1) Study the Open Dynamic Robot Initiative (ODRI) Quadruped Robot
2) How to build and operate the 12 DOF version
3) Make the bill of materials

Introduction

It is an open-source torque-controlled legged robot system, with a low-cost and low-complexity actuator module at its core. It consists of a high-torque brushless DC motor and a low-gear-ratio transmission suitable for impedance and force control. It also contains a novel foot contact sensor suitable for legged locomotion with hard impacts.

There are two versions of this quadruped robot:

1) 8 DOF
2) 12 DOF

Open Dynamic Robot Initiative (ODRI) have their own :

Website - Open Dynamic Robot Initiative (open-dynamic-robot-initiative.github.io)

GitHub Page - Open Dynamic Robot Initiative (github.com)

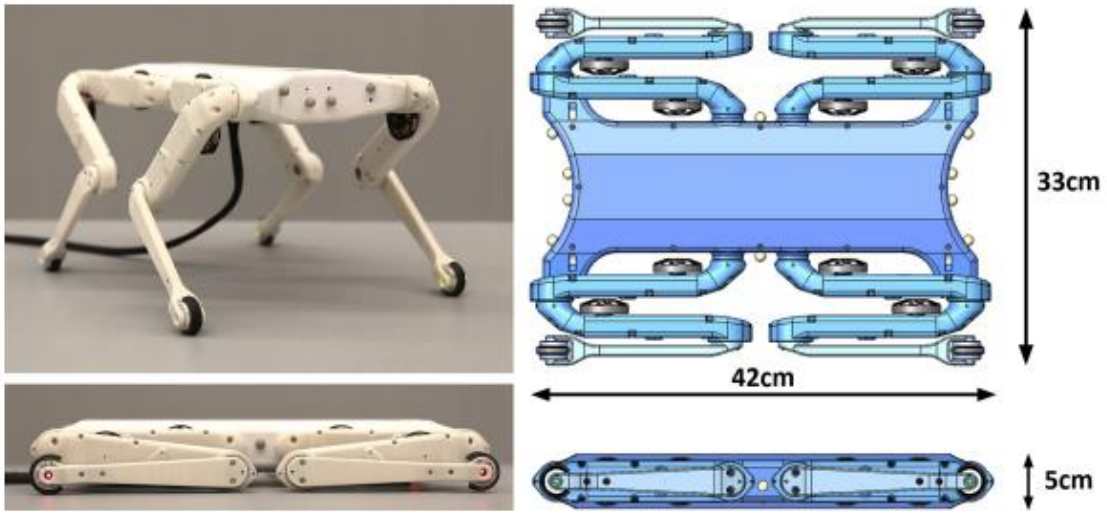
Discourse Forum - Categories - Open Dynamic Robot Initiative Forum (odri.discourse.group)

YouTube Channel - (126) Open Dynamic Robot Initiative - YouTube

All parts with their links and approximate prices can be found in :

Bill of Materials (BOM): Bill Of Materials (12dof quadruped robot) - Google Sheets

8 DOF Quadruped Robot



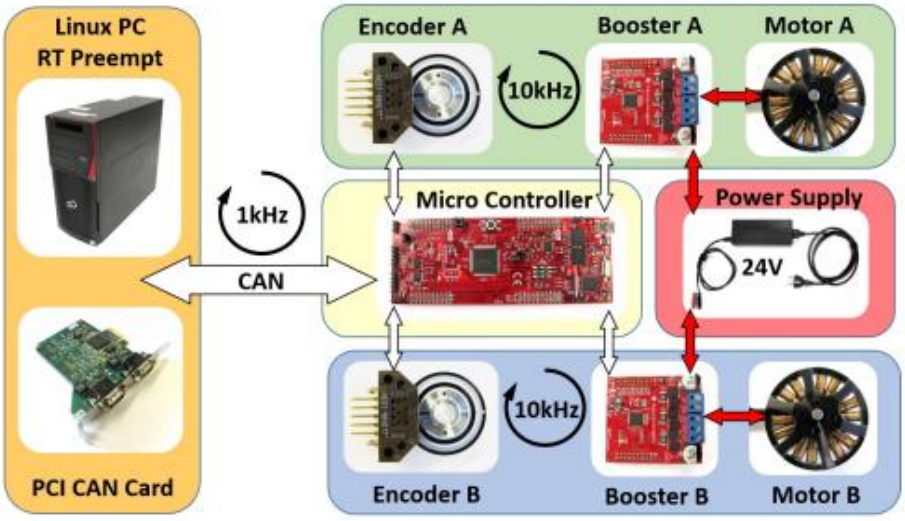
8 DOF means it has 8 degrees of freedom which is achieved by using 8 actuator modules

It Contains:

- 4 Legs
- 4 Foot sensors
- 8 Actuator Modules (2 in each leg)
- 4 Slave Controllers (Motor Drivers)
- 1 Master Controller
- 3D printed body structure

- 8 DOF robot can go forward, reverse, jump
- A single, 2-DOF leg is composed of two identical brushless actuator modules

Electronics Working (Hierarchy):



- Refer: 1910.00093.pdf (arxiv.org) (Research paper from ODRI)

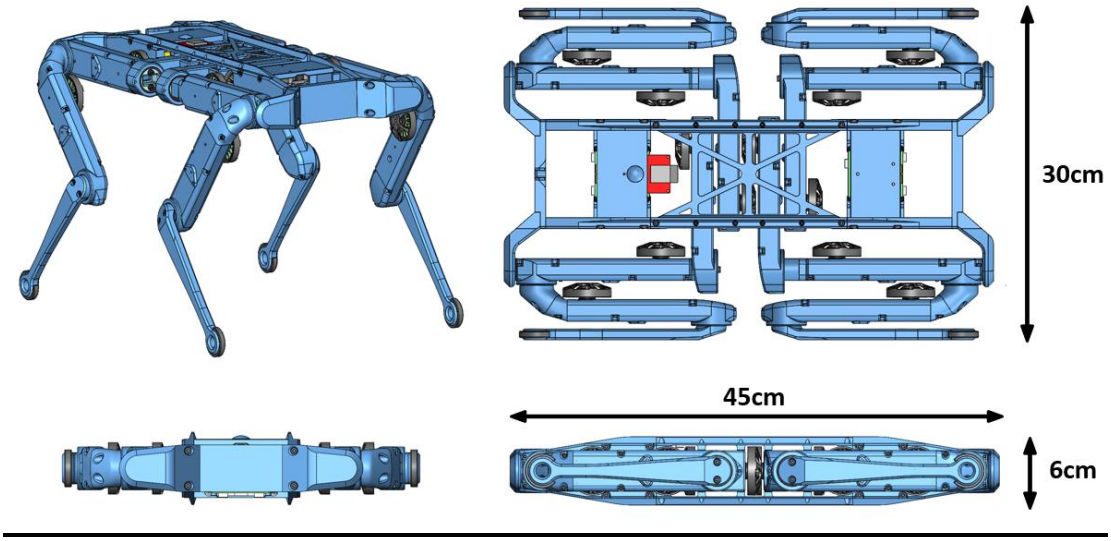
- Refer this repository for detailed info of electronics and mechanics :

open-dynamic-robot-initiative/open_robot_actuator_hardware (github.com)

(See 8 DOF solo robot and 2 DOF leg)

We are focusing on 12 DOF robot (which is a bigger version of 8 DOF with more features but same actuators, control boards and communication) hence detailed explanation can be found in that section.

12 DOF Quadruped Robot



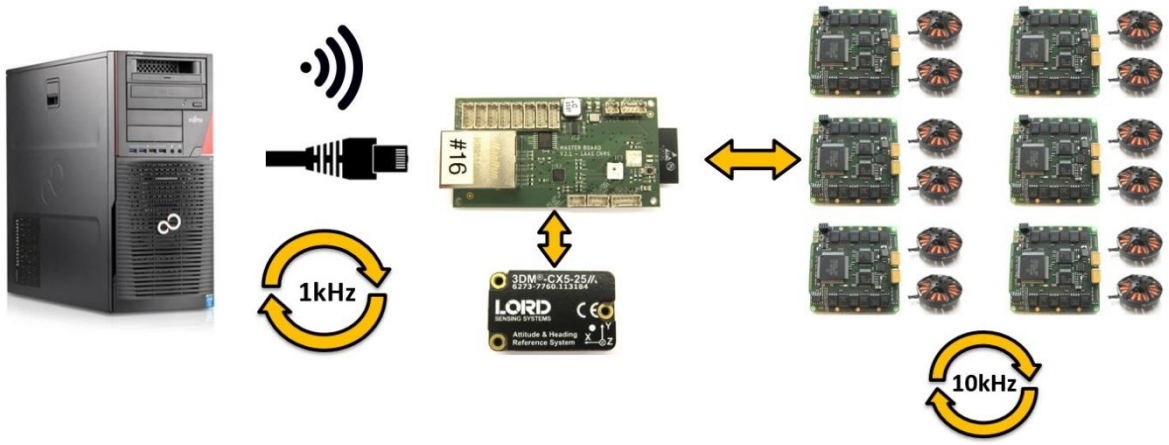
12 DOF means it has 12 degrees of freedom which is achieved by using 12 actuator modules

It Contains:

- 4 Legs
- 4 Foot sensors
- 12 Actuator Modules (3 in each leg)
  6 Slave Controllers (Motor Drivers)
- 1 Master Controller
- 3D printed body structure

12 DOF robot can go forward, reverse, side by side, jump

Working:



Actuators:

We use **Antigravity 4004 300kV from T-Motor**, **ODRI Encoder Kit** (Refer BOM for all parts) and

Prepare:

1) Rotor
2) Stator
3) Motor Shaft
4) Centre Pulley
5) Output Pulley
6) Encoder
7) Actuator Module

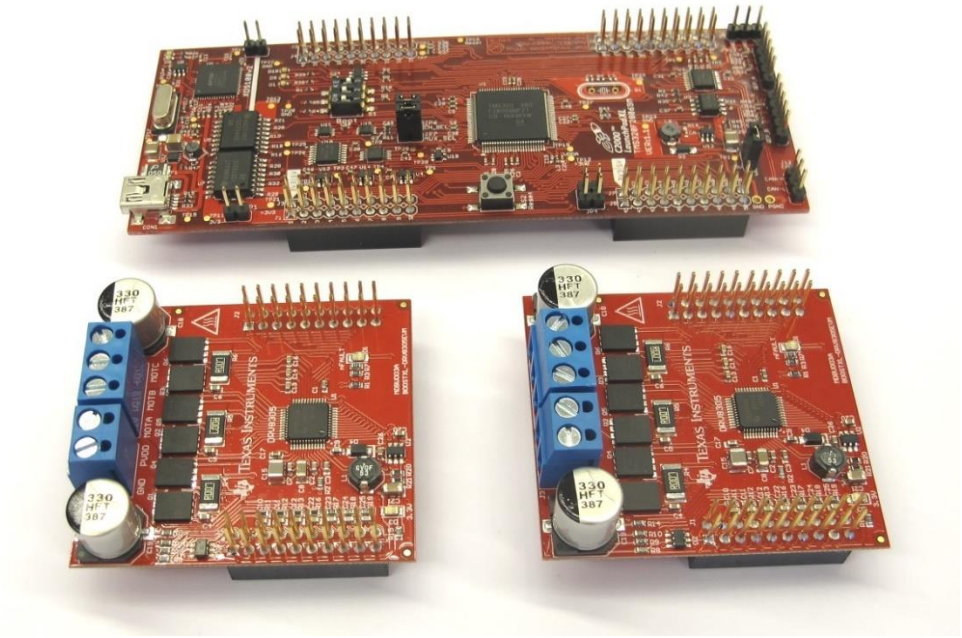
Using the instructions given in the motor preparation part of the repository [open_robot_actuator_hardware/mechanics/actuator_module_v1/details/details_motor_preparation.md at master · open-dynamic-robot-initiative/open_robot_actuator_hardware (github.com)]

Motor Drivers:

We have 2 options for this

First Option:

- **Texas Instruments Evaluation Board (*Launchpad F28069M with two DRV8305 Booster Packs*)**
  Refer(open_robot_actuator_hardware/electronics/ti_electronics/README.md at master · open-dynamic-robot-initiative/open_robot_actuator_hardware (github.com))



- It has inbuilt programmer and hence can be programmed
- the Launchpad F28069M is optimized for high performance dual brushless motor control
- Each Booster Pack drives one brushless motor with continuous current up to 15A (20A peak)
- max supply voltage 45V - we operate our robots at 24V
- Field Oriented Control (FOC) at 10kHz for each channel
- 1kHz control loop with Realtime pc (RTOS pc) and CAN card (to be added)
- CAN or USB communication

Or

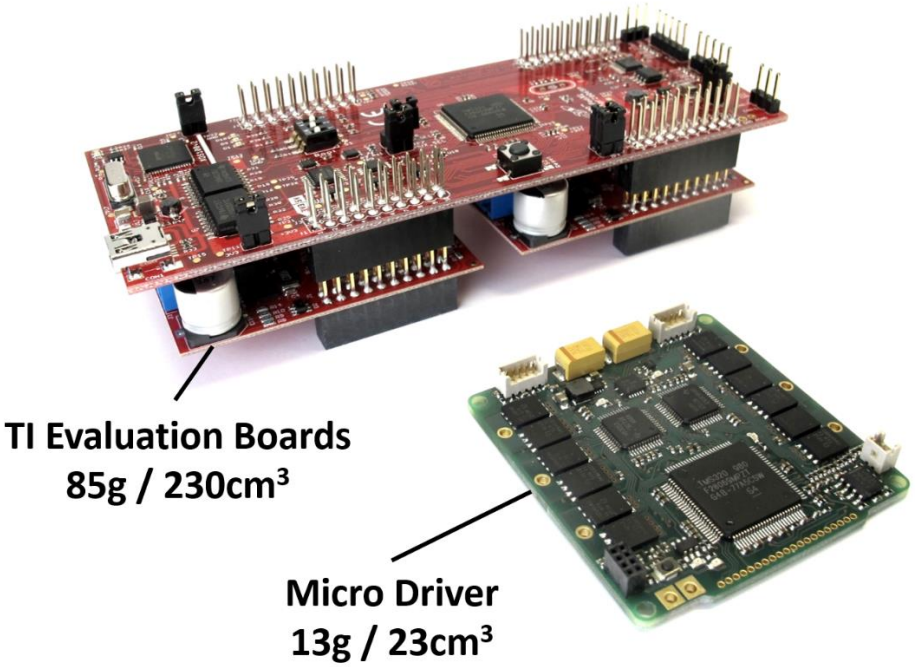
Second Option:

ODRI have designed a smaller version of the same board which is known as

Micro Driver in which the programmer is removed

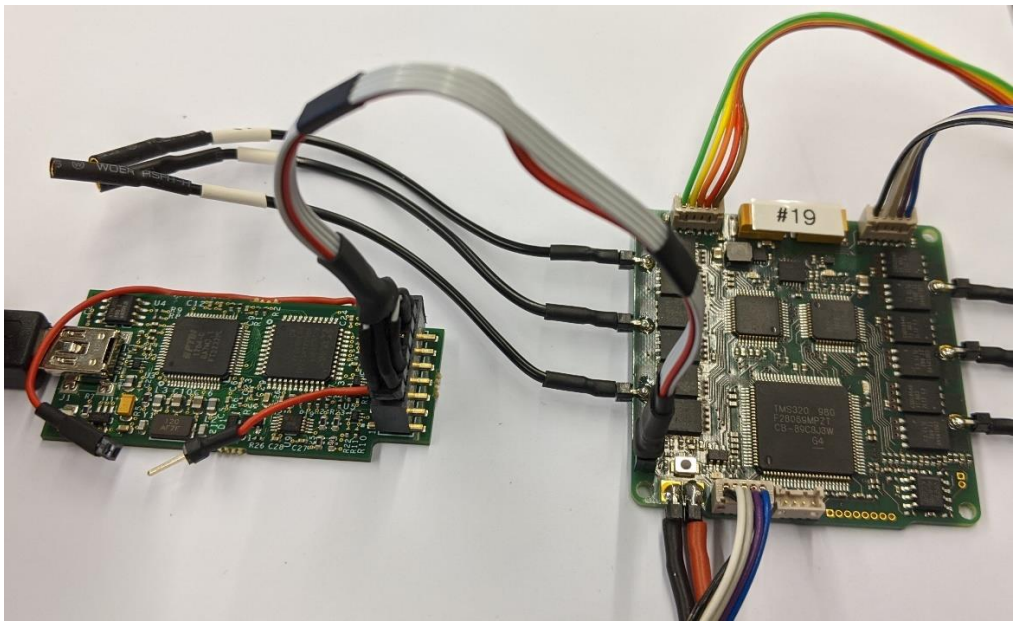
(Refer:open_robot_actuator_hardware/electronics/micro_driver_electronics/README.md at master · open-dynamic-robot-initiative/open_robot_actuator_hardware (github.com))

- **Micro Driver Electronics:**



- dual brushless motor driver electronics
- performs torque control at 10kHz for each motor
- miniaturized version of the Texas Instruments Evaluation Boards
- SPI communication with Master Board at 1kHz
- 6-layer board / FR4 / copper thickness 35µm
- Dimensions: 51mm x 50mm
- Weight: 13g
- input voltage: 5V - 32V (we operate our robots at 24V)

Every micro driver board is programmed using external **JTAG programmer (JTAG EMULATOR XDS100V2 USB).**



All the motor drivers (4 in 8DOF and 6 in 12DOF) are controlled by a master board.

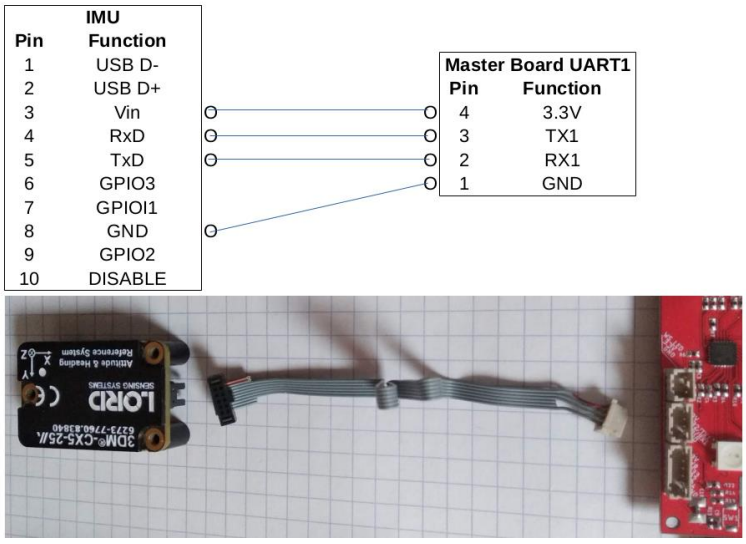
Master Board:

Refer - open-dynamic-robot-initiative/master-board: Hardware and Firmware of the Solo Quadruped Master Board (github.com)

- This board centralises all the sensor and actuator data and provides wired and wireless connection to a real-time computer.
- It handles communication between the IMU, Sensors, Motor Drivers and Realtime PC
- Connectivity:
- SPI: Address up to 8 SPI Slave: (max 80Mhz, DMA capable) compatible with BLMC µDriver SPI interface
- Wi-Fi: Wireless communication with a computer via raw ESP-NOW: round trip time of 1.2ms (including driver and OS latency) for a 127bytes message.
- Ethernet: Wired communication with a computer via raw frames: round trip time of 0.2ms (including driver and OS latency) for a 127bytes message.
- GPIO: 4GPIO free. Can be mapped to I2C, UART etc. Two of them are currently used for **IMU** (described later) **communication via UART**
- UART: Used to upgrade the ESP32 firmware, free on normal operation.
- The board is programmed via the ESP-IDF tool chain https://github.com/espressif/esp-idf

IMU (Inertial Measurement Unit)

- ODRI robot uses Lord Microstrain 3DM-CX5-25
- It is an AHRS (Attitude and Heading Reference System)
- It communicates with the master board
- It is one of the most expensive parts and hence we may try to use a cheaper option which can be found in the BOM (link in introduction)

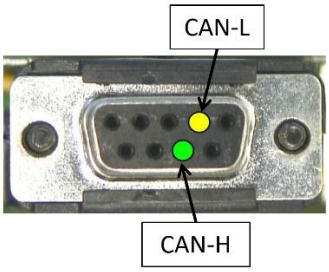


- The cheaper option costs around 150 USD and has some limitations .
- Cheaper option's gyroscope's resolution is lesser than the Lord Microstrain one
- (Details in link in BOM)

Communication Method

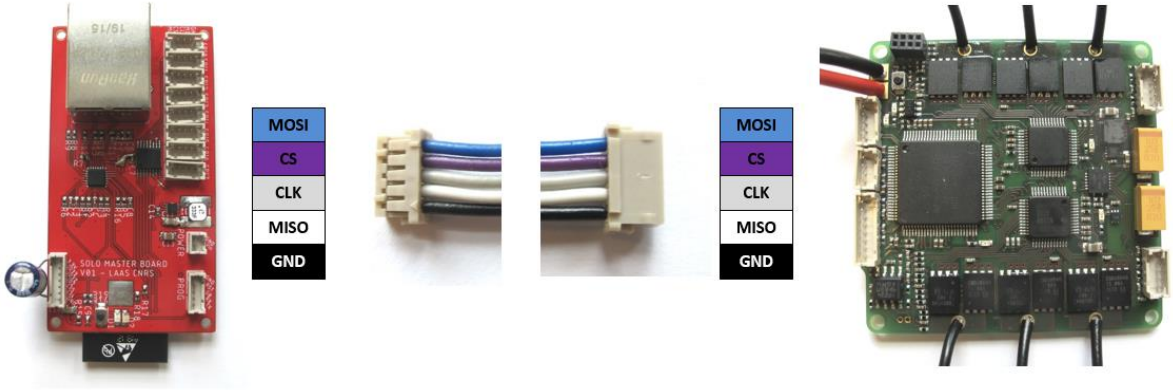
(Referring wiring : open_robot_actuator_hardware/electronics/details/details_wiring.md at master · open-dynamic-robot-initiative/open_robot_actuator_hardware (github.com))

- for communicating with the Texas Instruments Evaluation Boards we use a 2 pole wire with a 9 pin D-sub connector



- on the computer side we use a PEAK PCI Express CAN card

- for the SPI connections between the master board and the micro driver boards we use [0,14 mm² Kabeltronik wires] with two [5 pole Hirose DF13 connectors]



Control Interface:

What it is?

Common interface for controlling robots build with the odri master board.

Refer this repo - [open-dynamic-robot-initiative/odri_control_interface: Low level control interface. (github.com)] [open-dynamic-robot-initiative/odri_control_interface: Low level control interface. (github.com)]

Research more on this

Bill Of Materials:

Refer this link

Bill Of Materials (12dof quadruped robot) - Google Sheets

- This contains the required parts for making the 12DOF quadruped robot.
- Some of the things are to be purchased from local vendors and their approximate prices are provided in the sheet
- The most expensive parts are the
    - Motors
    - Encoders
    - AHRS (IMU)
- Motors are kept the same
- Encoder can be purchased separately or with the kit (else you have to make the kit by purchasing individual parts)
- IMU can be purchased as per given details in BOM
- For using different imu (that is cheaper) some modifications in the firmware and thorough testing is needed (option B is available in BOM but needs to be tested)

Offline Files:

The files for 3D printed parts can be found locally in ODRI folder

You can clone the GitHub repositories for local access of all the files