

# MAD76 Installation

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# 1 Installation Overview

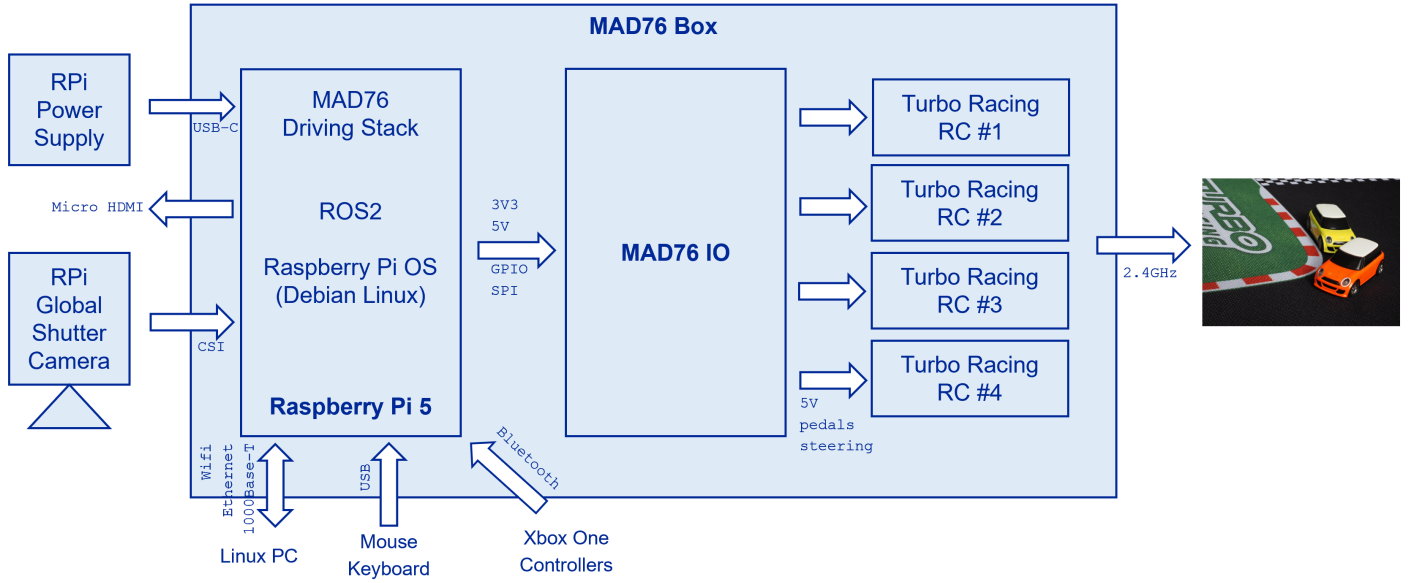


Figure 1: MAD76 System Architecture

The installation steps are:

- Build the MAD76 Box including the MAD76 IO PCB (see Section 2)
- Install Raspberry Pi OS, drivers, and ROS2 (see Section 3)
- Optionally install ROS2 on optional Linux-PC for distributed computing and software-in-the-loop (SiL) simulation (see Section 4)
- Install MAD76 Driving Stack (see Section 5)
- Optionally install MATLAB/Simulink for model-based software engineering (see Section 6)

## 2 MAD76 Box

The MAD76 Box is a self-built housing for the MAD76 electronics containing

- Raspberry Pi (RPi)
- MAD76 IO: self-built PCB electronics for coupling RPi to remote controllers (RC) for the Turbo Racing cars
- Up to 4 RC cars are supported

This section first lists the bill of materials (BOM) for the MAD76 Box. Then the MAD76 IO is described in more detail.

### 2.1 Bill of Materials (BOM)

#### 2.1.1 Raspberry Pi and Camera

	Description	Part Id	Order Link
1	Raspberry Pi 5 B 8GB Black Bundle	RPI5 BBDL 8GB	<a href="https://www.reichelt.de/das-raspberry-pi-5-b-8gb-black-bundle-rpi5-bddl-8gb-p362348.html">https://www.reichelt.de/das-raspberry-pi-5-b-8gb-black-bundle-rpi5-bddl-8gb-p362348.html</a>
1	microSD-Card 128 GB		<a href="https://www.rasppishop.de/Sandisk-microSDHC-UHS-I-128GB-Class10-mit-Raspberry-Pi-OS">https://www.rasppishop.de/Sandisk-microSDHC-UHS-I-128GB-Class10-mit-Raspberry-Pi-OS</a>
1	Raspberry Pi Active Cooler	RASP ACTIVE COOL	<a href="https://www.reichelt.de/raspberry-pi-luefter-fuer-raspberry-pi-5-rasp-active-cool-p360116.html">https://www.reichelt.de/raspberry-pi-luefter-fuer-raspberry-pi-5-rasp-active-cool-p360116.html</a>
1	Raspberry Pi Global Shutter Camera, 1.6MP, C/CS mount	RASP CAM GS CS	<a href="https://www.reichelt.de/raspberry-pi-kamera-1-6mp-shutter-c-cs-fassung-rasp-cam-gs-cs-p345205.html">https://www.reichelt.de/raspberry-pi-kamera-1-6mp-shutter-c-cs-fassung-rasp-cam-gs-cs-p345205.html</a>
1	Raspberry Pi Lens, CS mount, 6mm wideangle	RPIZ CAM 6MM WW	<a href="https://www.reichelt.de/raspberry-pi-objektiv-fuer-cs-fassung-6mm-weitwinkel-rpiz-cam-6mm-ww-p276922.html">https://www.reichelt.de/raspberry-pi-objektiv-fuer-cs-fassung-6mm-weitwinkel-rpiz-cam-6mm-ww-p276922.html</a>
1	AZDelivery Flex Cable 50cm, compatible to Raspberry Pi Zero Camera		<a href="https://www.amazon.de/AZDelivery-Flexkabel-Raspberry-Zero-Display/dp/B07SQ3HKNF">https://www.amazon.de/AZDelivery-Flexkabel-Raspberry-Zero-Display/dp/B07SQ3HKNF</a>
1	Joby GorillaPod 3K Kit Tripod		<a href="https://www.foto-erhardt.de/stative/joby-gorillapod/joby-gorillapod-3k-kit-black-charcoal.html">https://www.foto-erhardt.de/stative/joby-gorillapod/joby-gorillapod-3k-kit-black-charcoal.html</a>

Table 1: BOM of Raspberry Pi and camera

#### 2.1.2 MAD76 IO

	Description	Part Id	Order Link
1	Platine, Epoxyd, doppel-seitig, 300x200mm	EP2CU 300X200	<a href="https://www.reichelt.de/de/de/shop/produkt/platine_epoxyd_doppelseitig_300_x_200_mm-7404">https://www.reichelt.de/de/de/shop/produkt/platine_epoxyd_doppelseitig_300_x_200_mm-7404</a>
4	MCP42010 10kOhm DIL-14	MCP 42010-I/P	<a href="https://www.reichelt.de/digitalpoti-2-kanal-256-schritte-10-kohm-dil-14-mcp-42010-i-p-p90112.html">https://www.reichelt.de/digitalpoti-2-kanal-256-schritte-10-kohm-dil-14-mcp-42010-i-p-p90112.html</a>
1	L293B 1A DIP-16	L 293 B	<a href="https://www.reichelt.de/push-pull-4-kanal-treiber-1a-dip-16-l-293-b-p9660.html">https://www.reichelt.de/push-pull-4-kanal-treiber-1a-dip-16-l-293-b-p9660.html</a>
4	14-poliger DIL-Socket	GS 14P	<a href="https://www.reichelt.de/ic-socket-14-polig-superflach-gedreht-vergold-gs-14p-p8207.html">https://www.reichelt.de/ic-socket-14-polig-superflach-gedreht-vergold-gs-14p-p8207.html</a>
1	16-poliger DIL-Socket	GS 16P	<a href="https://www.reichelt.de/ic-socket-16-polig-superflach-gedreht-vergold-gs-16p-p8209.html">https://www.reichelt.de/ic-socket-16-polig-superflach-gedreht-vergold-gs-16p-p8209.html</a>
4	Wannenstecker, 10-polig, gerade	WSL 10G	<a href="https://www.reichelt.de/wannenstecker-10-polig-gerade-wsl-10g-p22816.html">https://www.reichelt.de/wannenstecker-10-polig-gerade-wsl-10g-p22816.html</a>
1	Wannenstecker, 40-polig, gewinkelt	WSL 40W	<a href="https://www.reichelt.de/wannenstecker-40-polig-gewinkelt-wsl-40w-p22836.html">https://www.reichelt.de/wannenstecker-40-polig-gewinkelt-wsl-40w-p22836.html</a>
6	SMD-Kondensator 100nF	KEM X7R0805 100N or X7R-G0805 100N or WAL 0805B104K500	<a href="https://www.reichelt.de/de/de/shop/produkt/vielschicht-kerko_100nf_50v_125_c-207073">https://www.reichelt.de/de/de/shop/produkt/vielschicht-kerko_100nf_50v_125_c-207073</a>
4	SMD-Kondensator 10uF	X5R-G0805 10/16 or KEM 0805 10U-2	<a href="https://www.reichelt.de/de/de/shop/produkt/smd-vielschichtkondensator_g0805_-_10_f_16v-89734">https://www.reichelt.de/de/de/shop/produkt/smd-vielschichtkondensator_g0805_-_10_f_16v-89734</a>

Table 2: BOM of MAD76 IO PCB

### 2.1.3 Housing

	Description	Part Id	Order Link
1	Industriegehäuse, 250x160x90mm, IP65, lichtgrau	5U340000	<a href="https://www.reichelt.de/industriengehaeuse-250-x-160-x-90-mm-ip65-lichtgrau-5u340000-p324394.html">https://www.reichelt.de/industriengehaeuse-250-x-160-x-90-mm-ip65-lichtgrau-5u340000-p324394.html</a>
1	40-poliges Flachbandkabel 30cm	RPI GPIO40 300	<a href="https://www.reichelt.de/raspberry-pi-gpio-kabel-40-pin-30cm-grau-rpi-gpio40-300-p293579.html">https://www.reichelt.de/raspberry-pi-gpio-kabel-40-pin-30cm-grau-rpi-gpio40-300-p293579.html</a>
4	Pfostenverbinder 2,54mm 2x5 (Flachbandkabel)	BKL 10120668	<a href="https://www.reichelt.de/de/shop/produkt/pfostenverbinder_2_54mm_2x5-262790">https://www.reichelt.de/de/shop/produkt/pfostenverbinder_2_54mm_2x5-262790</a>
1	sourcing map 20Stk. M2,5x8mm+5mm Stecker Buchse Messing PCB Motherboard Abstandhalter Ständer		<a href="https://www.amazon.de/gp/product/B08G1TP68G">https://www.amazon.de/gp/product/B08G1TP68G</a>
1	300 Stück M2.5 Schrauben Set M2.5 Hex Flach-Knopf Schraube Set, A2 Edelstahl Innensechskantschrauben Schraubensortiment		<a href="https://www.amazon.de/gp/product/B08B648WWQ">https://www.amazon.de/gp/product/B08B648WWQ</a>
8	JST-Buchsengehäuse, 1x3-polig	JST PH3P BU or 571-440129-3	<a href="https://www.reichelt.de/jst-buchsengehause-1x3-polig-ph-jst-ph3p-bu-p185042.html">https://www.reichelt.de/jst-buchsengehause-1x3-polig-ph-jst-ph3p-bu-p185042.html</a>
24	JST-Crimpkontakt, Buchse or 2.0mm, Crimp Contact Cut Strip of 100	JST PH CKS or 571-1735801-1-CT	<a href="https://www.mouser.de/ProductDetail/571-440129-3">https://www.mouser.de/ProductDetail/571-440129-3</a> <a href="https://www.reichelt.de/de/shop/produkt/jst-_crimpkontakt_buchse-_ph-185072">https://www.reichelt.de/de/shop/produkt/jst-_crimpkontakt_buchse-_ph-185072</a> <a href="https://www.mouser.de/ProductDetail/TE-Connectivity-AMP/1735801-1-Cut-Strip?qs=0XydCMRm13w8Ga1UL0Rh6A%3D%3D">https://www.mouser.de/ProductDetail/TE-Connectivity-AMP/1735801-1-Cut-Strip?qs=0XydCMRm13w8Ga1UL0Rh6A%3D%3D</a>

Table 3: BOM of MAD76 Box housing

### 2.1.4 Turbo Racing Cars

	Description	Part Id	Order Link
1 to 4	Turbo Racing 1:76 Mini Cooper with RC <a href="https://www.turboracing.net/">https://www.turboracing.net/</a>		<a href="https://www.rcfox.de/TB-TR01-Turbo-Racing-1/76-Micro-Mini-Cooper">https://www.rcfox.de/TB-TR01-Turbo-Racing-1/76-Micro-Mini-Cooper</a> <a href="https://de.aliexpress.com/item/1005001936818767.html">https://de.aliexpress.com/item/1005001936818767.html</a>
1	Turbo Racing Mat Track 50x95cm		<a href="https://www.rcfox.de/TB-760101-Turbo-Racing-Race-Strecke-fuer-Micro-Rally-50x95-cm">https://www.rcfox.de/TB-760101-Turbo-Racing-Race-Strecke-fuer-Micro-Rally-50x95-cm</a> <a href="https://de.aliexpress.com/item/1005006267808509.html">https://de.aliexpress.com/item/1005006267808509.html</a>

Table 4: BOM of Turbo Racing cars

## 2.2 MAD76 IO

- MAD76 IO is the bridge from RPi to the Turbo Racing RCs.
- MAD76 IO controls up to 4 cars.
- MAD76 IO substitutes and emulates the two potentiometers for throttle/braking and steering by digital potis (MCP42010) for each car.
- MAD76 further provides the power supply of 5V for the RCs.
- The power supply is controlled individually for each RC by an L293B.
- The RPi controls the digital potis via SPI.
- The RPi controls the L293B via GPIO.
- The MAD76 IO is connected to the RPi via a standard RPi 40-pin GPIO cable.
- The MAD76 IO is connected to the RCs via 8-pin flat ribbon cables.

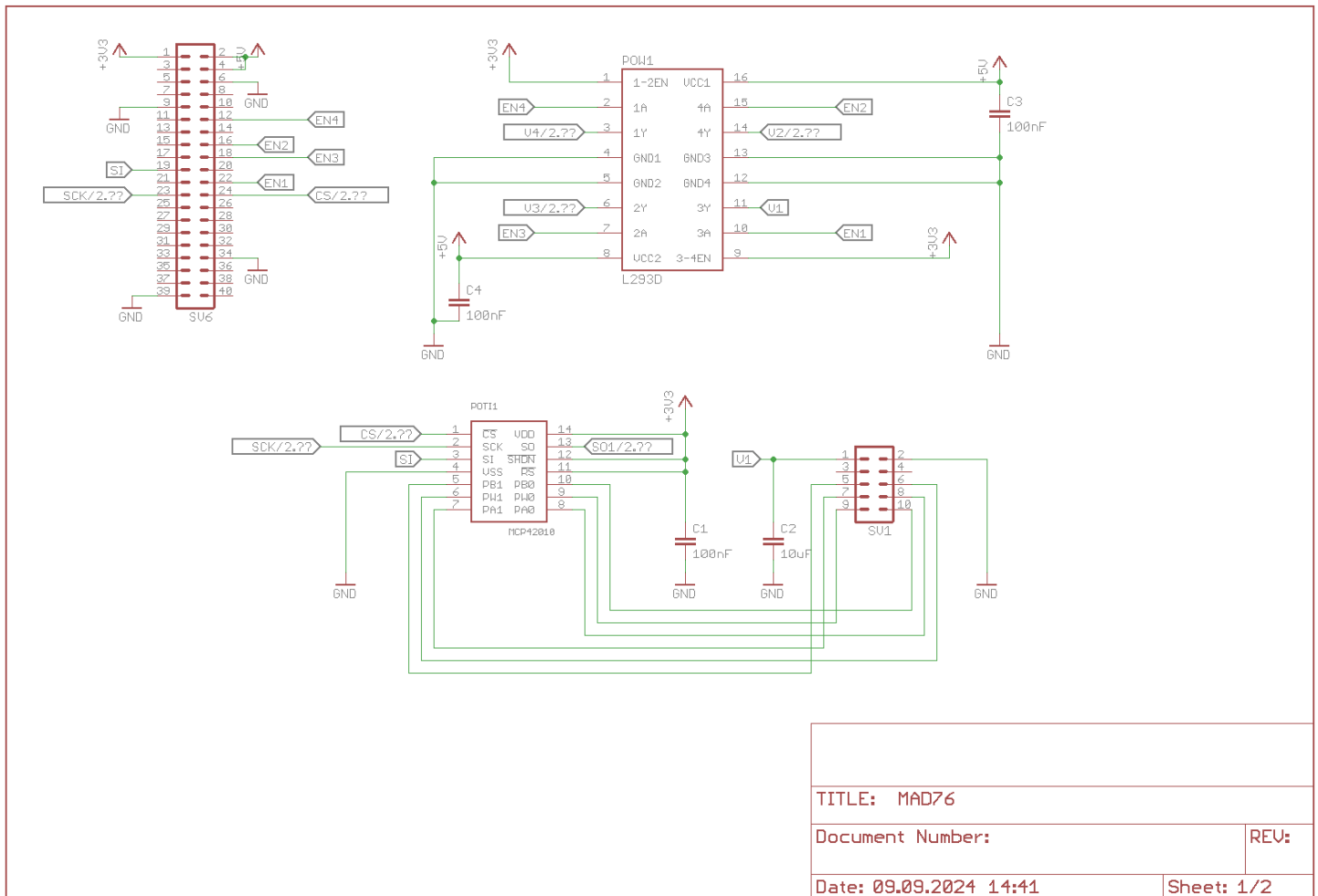


Figure 2: MAD76 IO Schematics Page 1 (Eagle schematics ../..pcb/MAD76.sch)

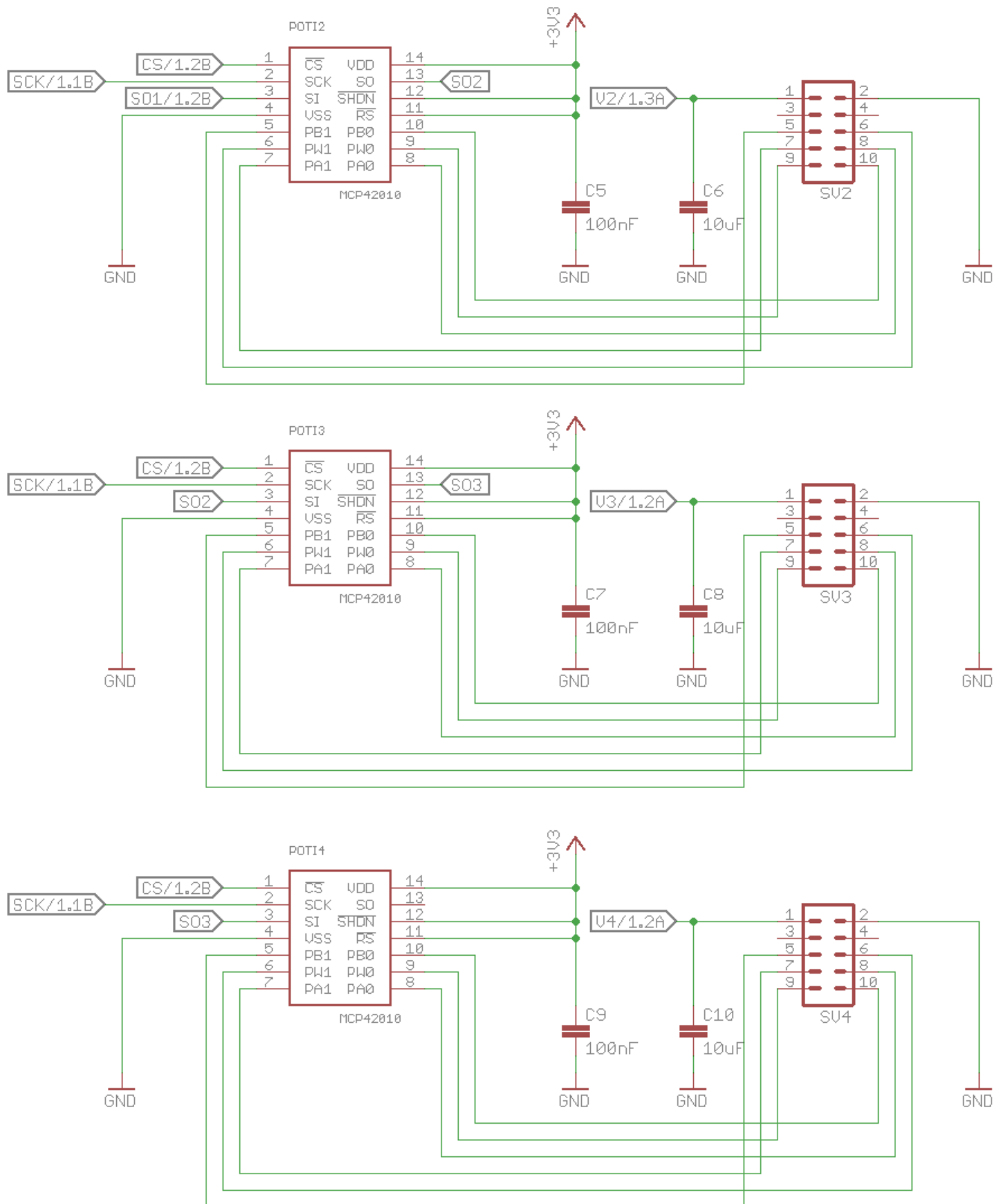


Figure 3: MAD76 IO Schematics Page 2 (Eagle schematics ../../pcb/MAD76.sch)

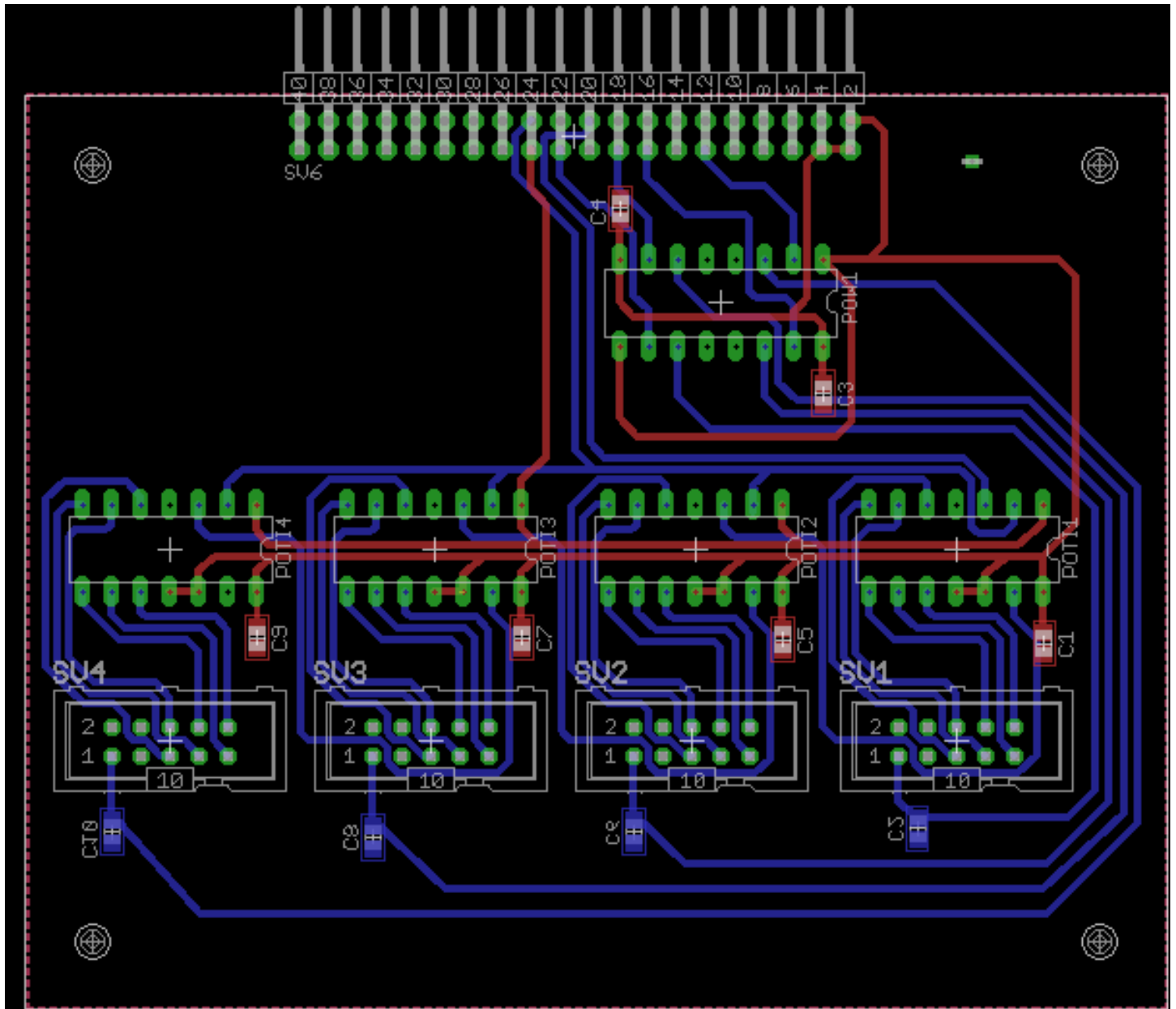


Figure 4: MAD76 IO Board Layout (Eagle layout ../../pcb/MAD76.brd)



## 3 Raspberry Pi Installation

### 3.1 Raspberry Pi OS

- Download and start installer [2]
  - Raspberry Pi OS with desktop (Debian 12 Bookworm 64-bit)
  - Configure <username>
  - Configure <hostname>
  - Configure WiFi
  - Enable SSH
- Login: `ssh <username>@<hostname>`
- Update Debian

```
sudo apt-get update
sudo apt-get dist-upgrade
# reboot in case of kernel/firmware updates
sudo shutdown -r 0
```

### 3.2 Raspberry Pi Configuration

- Enable SPI for MAD76 IO
  - `sudo raspi-config`
  - Goto menu 3 Interface Options
  - Select I4 SPI

### 3.3 VNC Server

VNC Server allows you to remotely connect to the Raspberry Pi from your development PC, either Linux, Windows or MacOS.

- Remove RealVNC

```
sudo apt-get purge realvnc-vnc-server
```

- Install VNC server

```
sudo apt-get install tigervnc-standalone-server
sudo apt-get install tigervnc-xorg-extension
```

- Start VNC server

```
vncserver -localhost no -geometry 2550x1350 -depth 24
```

- Connect to VNC server from your VNC client: `<hostname>:1`
- TightVNC on Windows or Remmina on Linux are popular VNC clients.

## 3.4 Python Coding

```
sudo apt-get purge python3-rpi.gpio # remove GPIO library for RPi4
sudo apt-get install python3-rpi-lgpio # install GPIO library for RPi5
sudo apt-get install python3-ipykernel # install Jupyter kernel
sudo apt-get install python3-sphinx # install Sphinx for code documentation
```

## 3.5 WiringPi

WiringPi is a GPIO library for C / C++ programming that is used to access the MAD76 IO board.

- Install WiringPi for MAD76 IO

```
cd
mkdir src
cd src
git clone https://github.com/WiringPi/WiringPi.git
cd WiringPi
./build
```

## 3.6 ROS2

ROS2 is the middleware for the MAD76 software stack.

- ROS2 Jazzy Jalisco is required. No other ROS2 distribution is supported because of compatibility to both Debian Bookworm and MATLAB/Simulink R2025a.
- Building ROS2 Jazzy Jalisco from source [3, 4]

```
mkdir -p ~/src/ros2_jazzy/src
cd ~/src/ros2_jazzy

locale # check for UTF-8

sudo apt-get install \
  build-essential \
  cmake \
  git \
  python3-colcon-bash \
  python3-pip \
  vcstool \
  wget

sudo apt-get install sqlite3
sudo apt-get install python3-lark python3-netifaces
sudo apt-get install python3-flake8-blind-except python3-flake8-builtins python3-flake8-
  class-newline python3-flake8-comprehensions python3-flake8-deprecated python3-flake8-
  import-order python3-flake8-quotes python3-pytest-repeat python3-pytest-rerunfailures
sudo apt-get install python3-rosdep2 python3-vcstools
sudo apt-get install python3-opencv python3-scipy python3-matplotlib
sudo apt-get install python3-flask python3-peewee
sudo apt-get install libbullet-dev libboost-dev
```

```

sudo apt-get install libasio-dev libtinyxml2-dev
sudo apt-get install qtbase5-dev qtbase5-dev-tools
sudo apt-get install libacl1-dev libcap-dev libssl-dev libxaw7-dev libogre-1.12-dev
libeigen3-dev
sudo apt-get install libopencv-dev
sudo apt-get install liblttng-ust-dev
sudo apt-get install libboost-python-dev libboost-system-dev libboost-log-dev libgtest-
dev libjsoncpp-dev
sudo apt-get install netcat-openbsd netcat-openbsd

wget https://raw.githubusercontent.com/ros2/ros2/jazzy/ros2.repos
vcs import src < ros2.repos

rosdep update
rosdep install --from-paths src --ignore-src --rosdistro jazzy -y --skip-keys "rti-
  connex-dds-6.0.1 python3-vcstool"

touch src/eclipse-cyclonedds/COLCON_IGNORE
touch src/eclipse-iceoryx/COLCON_IGNORE
touch src/gazebo-release/COLCON_IGNORE
touch src/ros2/rviz/COLCON_IGNORE
touch src/ros2/rmw_connextdds/COLCON_IGNORE
touch src/ros2/rmw_cyclonedds/COLCON_IGNORE

colcon build --symlink-install --cmake-args -DCMAKE_BUILD_TYPE=Release

```

- Install ROS2 packages for camera, diagnostics, and Xbox controller

```

sudo apt-get install libcamera-dev
source ~/src/ros2_jazzy/install/setup.bash
mkdir -p /src/ros_ws/src
cd ~/src/ros_ws/src
git clone https://github.com/ros/diagnostics.git -b ros2-jazzy
git clone https://github.com/ros-perception/vision_opencv.git -b rolling
git clone https://github.com/christianrauch/camera_ros -b main
git clone https://github.com/ros-drivers/joystick_drivers -b ros2
touch joystick_drivers/ps3joy/COLCON_IGNORE
touch joystick_drivers/spacenav/COLCON_IGNORE
touch joystick_drivers/wiimote/COLCON_IGNORE
touch joystick_drivers/wiimote_msgs/COLCON_IGNORE
cd ..
colcon build --symlink-install --cmake-args -DCMAKE_BUILD_TYPE=Release

```

### 3.7 Update ROS2

If you want to update ROS2 later on, you can do the following.

- Update ROS2 distribution

```

cd ~/src/ros2_jazzy
vcs custom --args remote update
vcs import src < ros2.repos

```

```
vcs pull src
colcon build --symlink-install --cmake-args -DCMAKE_BUILD_TYPE=Release
```

- Update ROS2 packages for camera and diagnostics

```
cd ~/src/ros_ws/src
cd diagnostics
git pull
cd ../vision_opencv
git pull
cd ../camera_ros
git pull
cd ../joystick_drivers
git pull
cd ../../
source ~/src/ros2_jazzy/install/setup.bash
colcon build --symlink-install --cmake-args -DCMAKE_BUILD_TYPE=Release
```

### 3.8 Xbox One Controllers

Optionally, Xbox One controllers can be used to manually control the MAD76 cars in car racing mode.

- Enable Bluetooth Low Energy (BLE) privacy, so that Xbox One controllers can be paired to Raspberry Pi
  - Add line `Privacy=device` to the [General] section of `/etc/bluetooth/main.conf` according to [https://www.reddit.com/r/linux\\_gaming/comments/js0trh/comment/gddwyjk/](https://www.reddit.com/r/linux_gaming/comments/js0trh/comment/gddwyjk/)
- Follow the instructions on <https://pimylifeup.com/xbox-controllers-raspberry-pi/>

## 4 Linux-PC Installation

Next to the Raspberry Pi installation, MAD76 may be further installed optionally on a Linux PC. The Linux PC allows for more efficient MAD76 software development and debugging. Furthermore, MAD76 may be run in Software-in-the-Loop (SiL) simulation mode on the Linux PC. MATLAB/Simulink may be applied for model-based software engineering of MAD76. For controlling the real MAD76 system, The MAD76 software stack may be run on a distributed ROS2 environment including the Raspberry Pi and the Linux PC.

- Install an Ubuntu Desktop version that supports ROS2 Jazzy Jalisco, such as Ubuntu Noble Numbat 24.04 [1]. ROS2 Jazzy Jalisco (and no other ROS2 version) is required, otherwise distributed computing with PC and Raspberry Pi will not work.
- However, if you only want to run MAD76 in Software-in-the-Loop (SiL) simulation mode only, you may use other ROS2 and Linux distributions.
- Install ROS2 Jazzy Jalisco binary (deb) packages according to [5]. Make sure to install the following ROS2 packages:

```
sudo apt-get install ros-dev-tools ros-jazzy-desktop ros-jazzy-diagnostic-updater
```

## 5 MAD76 Driving Stack

### 5.1 Software Architecture

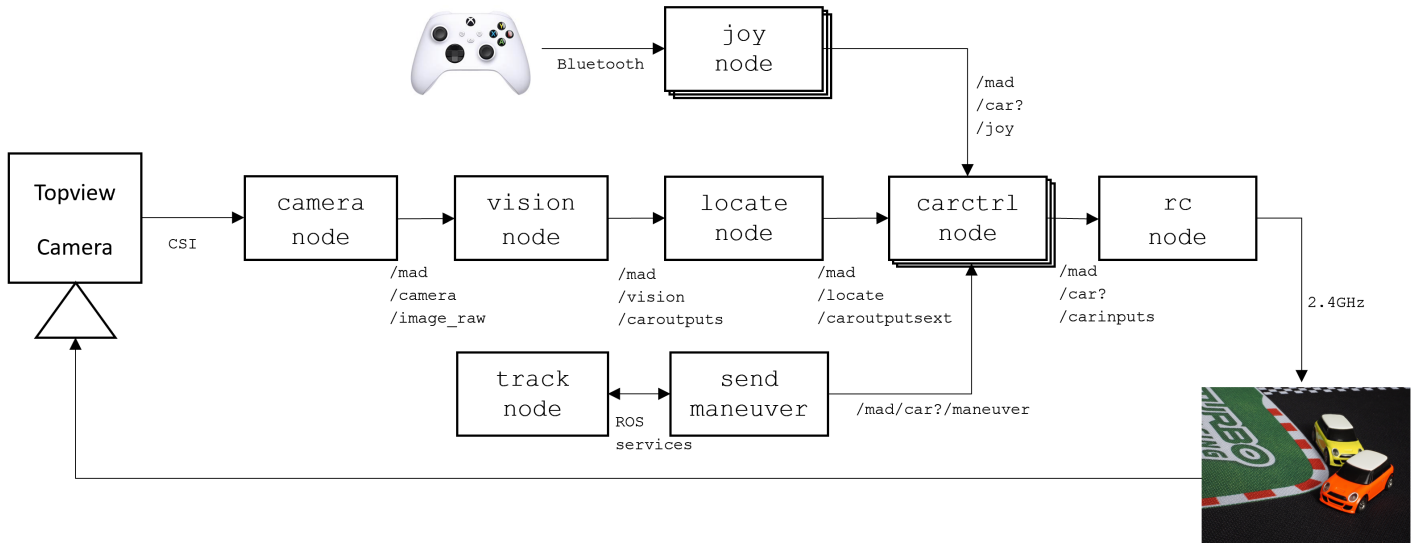


Figure 5: ROS2 nodes of MAD76 Driving Stack

ROS2 Node	Description
camera_node	Raspberry Pi camera driver
visionnode	computer vision
locatenode	multi-object tracking
carctrlnode	motion planning and control for each individual car
rcnode	remote control signals output to 2.4GHz channel via SPI
tracknode	track map
joy_node	optional node for manual control via joystick

Table 5: ROS2 nodes of MAD76 software

### 5.2 Build MAD76

- MAD76 can be built and run on Raspberry Pi and on Ubuntu Linux computers
- ROS2 nodes can run on distributed system with multiple computers
- ROS2 nodes `camera_node` and `rc_node` must run on the Raspberry Pi for interfacing with the camera and Turboracing remote controllers
- All other nodes can run on other computers
- ROS2 supports this distributed computing transparently when setting a common ROS domain ID
- For running MAD76 in Software-in-the-Loop (SiL) simulation mode (see Section 5.3), a build of MAD76 on an Ubuntu Linux-PC is sufficient because SiL mode does not do any input / output, except for optional joystick control
- Clone Git repository and build MAD76 workspace

ROS2 Topic	ROS2 Message Type	Description
/mad/camera/image_raw	sensor_msgs::msg::Image	camera frames with sampling time 25ms
/mad/camera/camera_info	sensor_msgs::msg::CameraInfo	camera calibration info
/mad/vision/caroutputs	mbmadmsgs::msg::CarOutputsList	list of car poses
/mad/locate/caroutputsext	mbmadmsgs::msg::CarOutputsExtList	list of car poses including velocities
/mad/car?/carinputs	mbmadmsgs::msg::CarInputs	control signals for each individual car
/mad/car?/maneuver	mbmadmsgs::msg::DriveManeuver	maneuvers for path following and parking
/mad/car?/joy	sensor_msgs::msg::Joy	standard ROS2 joystick messages

Table 6: ROS2 topics of MAD76 software

```

export RMW_IMPLEMENTATION=rmw_fastrtps_cpp
export ROS_DOMAIN_ID=221
source ~/src/ros_ws/install/setup.bash # on Raspberry Pi
#source /opt/ros/iron/install/setup.bash # on Ubuntu Linux-PC
cd ~/src
git clone https://github.com/modbas/mad76
cd mad76/mad_ws
colcon build --symlink-install --cmake-args -DCMAKE_BUILD_TYPE=Release

```

For building on Raspberry Pi, the `colcon build` command must be extended by `-parallel-workers 1` to avoid out-of-memory problems

```
colcon build --parallel-workers 1 --symlink-install --cmake-args -DCMAKE_BUILD_TYPE=Release
```

- Add security limits

```

sudo addgroup mad
sudo adduser <username> mad # where <username> is your username
sudo -i
echo "@mad - rtprrio 98" >> /etc/security/limits.conf
echo "@mad - memlock unlimited" >> /etc/security/limits.conf
shutdown -r 0 # reboot

```

- Add the following lines to the end of `~/ .bashrc` for automatic setup

```

export RMW_IMPLEMENTATION=rmw_fastrtps_cpp
export ROS_DOMAIN_ID=221
source ~/src/mad76/mad_ws/install/setup.bash

```

### 5.3 Software-in-the-Loop Simulation

- In order to test your MAD76 installation, you may run MAD76 in software-in-the-loop (SiL) simulation mode
  - The real cars, the camera, and the ROS2 nodes `camera_node`, `vision_node` and `rc_node` for computer vision and RC output are replaced by simulation models

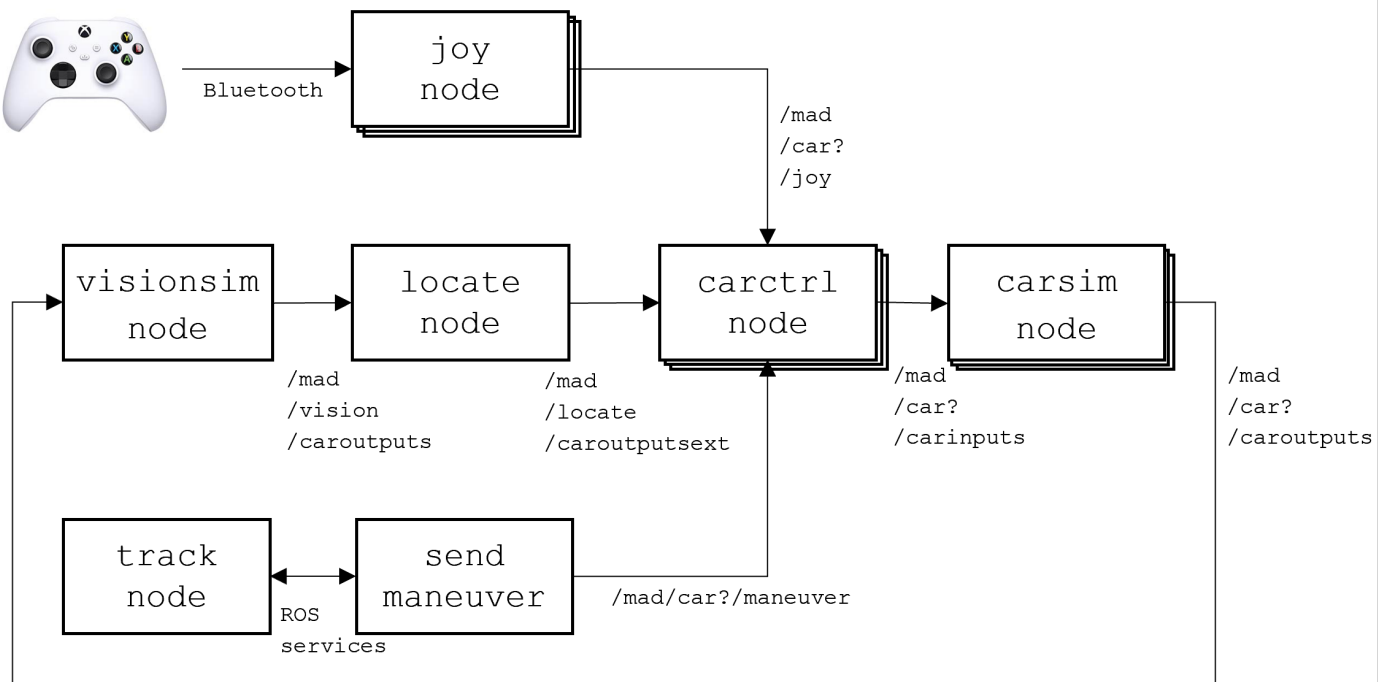


Figure 6: ROS2 nodes in SiL simulation mode

- The MAD76 Driving Stack runs in the loop with vehicle dynamics simulation models
- Full operation of the driving stack is supported in SiL simulation mode
- Open a new terminal and start MAD76 in SiL mode

```
ros2 launch mbmad madpisim.launch
```

- Open a further terminal and send a maneuver to car 0 (orange car)

```
ros2 run mbmadcar send_maneuver.py 0 0.3 0.25
```

- First argument is the car identifier (0 for orange car, 1 for yellow car)

0	orange car
1	yellow car
2	blue car
3	white car

- Second argument is the car reference speed in  $\frac{m}{s}$
- Third argument is the lateral reference position

0	right curb
0.25	right lane
0.5	center line
0.75	left lane
1	left curb

- Stop `send_maneuver.py` by hitting `Ctrl+c` and send maneuver to car 1 (yellow car)



```
ros2 run mbmadcar send_maneuver.py 1 0.2 0.25
```

- The maximum speed of each car is  $0.5 \frac{m}{s}$
- You may stop the individual car by sending a maneuver with reference speed  $0 \frac{m}{s}$
- Reverse driving is possible by setting a negative reference speed

## 6 MATLAB/Simulink Installation

- The following MATLAB release and toolboxes are required
  - MATLAB R2025a
  - Simulink
  - Stateflow
  - Control-System-Toolbox
  - Curve-Fitting-Toolbox
  - ROS-Toolbox
  - Simulink Coder
  - Embedded Coder
- For model-in-the-loop (MiL) simulation and control design, MATLAB can be installed on any supported platform
- For code generation and MAD76 programming, MATLAB needs to be installed on the MAD76 Linux PC

### 6.1 Python 3.10 Installation

- MATLAB ROS-Toolbox requires Python 3.10 which is not installed per default on Ubuntu Noble Numbat 24.04
- The default Python 3.12 installation does not work
- Install Python 3.10 on the MAD76 Linux PC from the PPA Deadsnakes

```
sudo add-apt-repository ppa:deadsnakes/ppa
sudo apt update
sudo apt install python3.10 python3.10-venv
```

- Activate Python 3.10 in MATLAB ROS-Toolbox
  1. Open MATLAB Settings ROS-Toolbox
  2. Browse for `/usr/bin/python3.10`
  3. Hit pushbutton `Recreate Python Environment`
  4. Select `rmw_fastrtps_cpp` as ROS Middleware

### 6.2 ROS Custom Messages

- Make custom ROS message types of MAD76 available in MATLAB/Simulink (only needed for code generation)
  1. ROS2 Jazzy Jalisco and MAD76 must be installed on the MAD76 Linux PC running Ubuntu Noble Numbat 24.04 (see <https://github.com/modbas/mad76/blob/main/doc/install/install.md#linux-pc-installation>)

2. At the MATLAB prompt, change to the ROS workspace directory

```
cd ~/src/mad76/mad_ws
```

3. Generate MATLAB/Simulink objects for the custom ROS message types

```
ros2genmsg src
```

4. Test if the message types are available in MATLAB/Simulink

```
ros2 msg list
```

This displayed list must contain message types `mbmadmsgs/*` and `mbsafemsgs/*`

### 6.3 Test Simulink MiL Simulation

- The Simulink model `s06_sig_template.slx` is the template model for vehicle dynamics modeling and controller design
- Test your new MATLAB/Simulink installation by simulating this model

```
cd ~/src/mad76/matlab/vertical  
s06_sig_template
```

- The model should run without errors and display initial positions of the vehicles in the MATLAB figure

### 6.4 Test Simulink for Code Generation

- The Simulink model `c71_car0_template.slx` is the template model for code generation
- Test your new MATLAB/Simulink installation by simulating this model which communicates with the ROS environment
- Run the ROS environment in manual simulation mode (without MAD76 driving stack)

```
ros2 launch mbmad madpisimman.launch
```

- Start the simulation of `c71_car0_template.slx`

```
cd ~/src/mad76/matlab/vertical  
c71_data  
c71_car0_template
```

- Send a maneuver message to the Simulink model, so that the main subsystem is enabled

```
ros2 run mbmadcar send_maneuver.py 0 0.2 0.5
```

- You can now manually control the orange car with id 0 by manipulating the sliders in subsystem Motion Control and `carinputs msg/Motion Control/Sliders` or `Joystick/Sliders`

## References

- [1] Canonical Ubuntu. *Alternative Downloads*. Accessed: 2025-02-25. 2025. URL: <https://ubuntu.com/download/alternative-downloads>.
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