EEDURO Delta - User Manual

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Document Revisions

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1. Getting started

1.1. Initial Operations

1.1.1. Unpacking

Please check for completeness of parts while unpacking. Also check for any mechanical damage of loose parts, due to transportation. In case of transport damage inform the supplier immediately and do not operate the robot.

1.1.2. Safety instructions

TODO

1.1.3. Prepare for the first use

The EEDURO is controlled by a *BeagleBone Black* which has to be bought separately due to the resell restrictions of this board. You can get a BeagleBone Black from electronic distributors like Digi-Key or Farnell[1].

The EEDURO Delta education robot is available with the control electronic in the robot base or remotely in a separate casing. Locate the electronic housing of your robot and follow the appropriate instructions below.

Mounting the BeagleBone in the base case

1. Ensure that all cables are unplugged!
2. Turn the robot upside down.
3. Loose the four rubber bumpers and remove the plexiglas cover.
4. Plug the BeagleBone on the headers in the middle of the main board as shown in figure XXX.
5. Fix the BeagleBone with four screws M3x10 (use polyamide washers).

[1] A list with all distributors is available at beagleboard.org

6. Plug the USB cable into the USB host connector (P3) on the BeagleBone.
7. Plug the USB mini extension cable into the USB client connector (P4) on the BeagleBone.
8. Insert the SD-Card shipped with the robot.
9. Remount the plexiglas cover.
10. Fix the cover with the four rubber bumpers.

TODO

Figure 1.1.: Base case with BeagleBone Black mounted

Mounting the BeagleBone in the remote case

1. Ensure that all cables are unplugged!
2. Loose the four screws at the front of the case (see figure 1.2).
3. Remove the front cover and the black plastic frame. Mind the cables for the buttons and the power switch when removing the cover!
4. Draw out the closure head.
5. Plug the BeagleBone on the headers in the middle of the main board as shown in figure 1.3.
6. Fix the BeagleBone with four screws M3x10 (use polyamide washers).
7. Plug the USB cable into the USB host connector (P3) on the BeagleBone.
8. Insert the SD-Card shipped with the robot.
9. Remount the closure head plate.
10. Clip back the plastic frame and close the front cover.
11. Fix the front cover with the four screws.

Figure 1.2.: Remote case front view

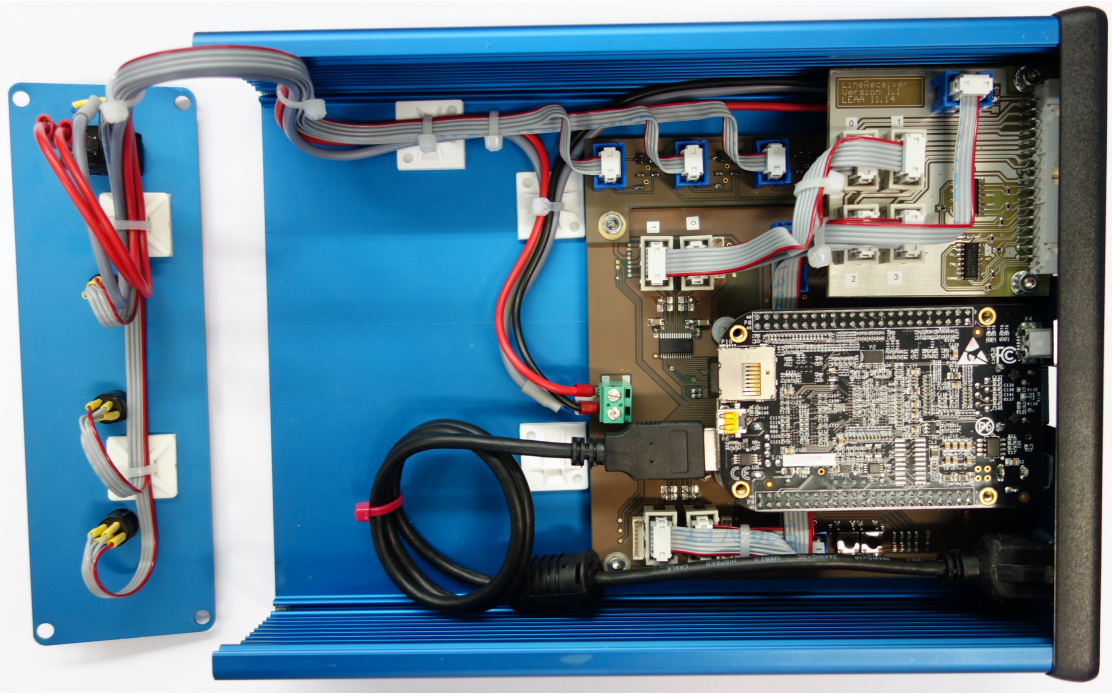


Figure 1.3.: Remote case top view with BeagleBone Black mounted

1.1.4. First start

1. Connect the power supply to the power connector X5 on the rear side. Use a power supply with 12 VDC output and at least 1.5 A. The coaxial power connector is a Type A according to IEC60130-10 with negative barrel.
2. Connect a PC mouse and/or a Microsoft XBox remote controller to the USB Port X1.
3. Switch on the robot using the power switch at the front.
4. Wait until the green button at the front starts lighting.
5. Ensure the working room of the robot is clear and press the green button. Caution: the robot now moves for initialization!
6. After initialization is done, there are three demo applications available. The default application allows to control the TCP with the mouse. With the second application the TCP can be controlled by the XBox Controller. The third demo application moves the TCP to some predefined positions. You can choose an application by pressing the blue button.

1.2. Setup a development environment

To develop software for the EEDURO platform, you will need a Linux based operating system. Any modern Linux distribution can be used.

1. All required source code is hosted in a git repository at github.com. So the first step is to install the git client and all necessary build tools: git, g++ (version 4.7 or newer), CMake (version 2.8 or newer) and GNU Make. On a Debian based distribution you can install this by typing:

   ```
   $ sudo apt-get install git g++ cmake make
   ```

2. There are a handful of bash scripts available, which helps you setting up the develop environment. Clone the `eeduro-scripts` repository:

   ```
   $ git clone git://github.com/eeros-project/eeduro-scripts.git eeduro-project
   ```

3. Change into the `eeduro-project` folder and execute the `setup.sh` shell script.

   ```
   $ cd eeduro-project
   $ ./setup.sh
   ```

   The setup script checks if all packages are installed, clones the `eeros-framework` repository, clones the `eeduro-platform repository`, downloads the Linaro toolchain and creates folders for local and cross builds.

4. Now you can enter the `build-armhf` directory and build the software:

   ```
   $ cd build-armhf
   $ make
   ```

5. The copy2robot.sh shell script copies all the generated binaries to the robot. The script is configured to use the robot connected by USB. If you've connected the robot by ethernet, you have to adjust the script by setting the correct ip address of the robot.

1.3. Start programming

TODO Martin

2. Technical details

2.1. Overview

TODO Martin

2.2. Connectors

2.2.1. X1: USB

USB Type A receptacle, BeagleBone Black USB host connector, can be used for peripherals like a mouse

2.2.2. X2: Ethernet

RJ45 (8P8C) receptacle, BeagleBone Black Ethernet connector

2.2.3. X3: Host

USB Type Mini-A receptacle, BeagleBone Black USB client connector, can be used to connect a developer PC to the robot

2.2.4. X4: Robot

2x17 pin header with 2.54 mm spacing, Pin assignment see table 2.1

2.2.5. X5: Power

Coaxial power connector type A (IEC60130-10), Power connector, power supply with 12 V and min. 1.5 A necessary

1	Axis 1, V-	18	GND
2	Axis 1, V-	19	Axis 1, Encoder A+
3	Axis 1, V+	20	Axis 1, Encoder A-
4	Axis 1, V+	21	Axis 1, Encoder B+
5	Axis 2, V-	22	Axis 1, Encoder B-
6	Axis 2, V-	23	Axis 2, Encoder A+
7	Axis 2, V+	24	Axis 2, Encoder A-
8	Axis 2, V+	25	Axis 2, Encoder B+
9	Axis 3, V-	26	Axis 2, Encoder B-
10	Axis 3, V-	27	Axis 3, Encoder A+
11	Axis 3, V+	28	Axis 3, Encoder A-
12	Axis 3, V+	29	Axis 3, Encoder B+
13	Axis 4, V-	30	Axis 3, Encoder B-
14	Axis 4, V+	31	Axis 4, Encoder A+
15	+12 V	32	Axis 4, Encoder A-
16	Magnet -	33	Axis 4, Encoder B+
17	+5 V	34	Axis 4, Encoder B-

Table 2.1.: Pin assignment connector X4

2.3. Kinematic

TODO Martin (Doku Silvan)

2.4. FPGA design

TODO Adam

2.5. Communication between BeagleBone and FPGA

TODO Adam/Martin

2.6. Provided software

TODO Martin

2.6.1. Structure

TODO Martin

2.6.2. Control System

TODO Martin

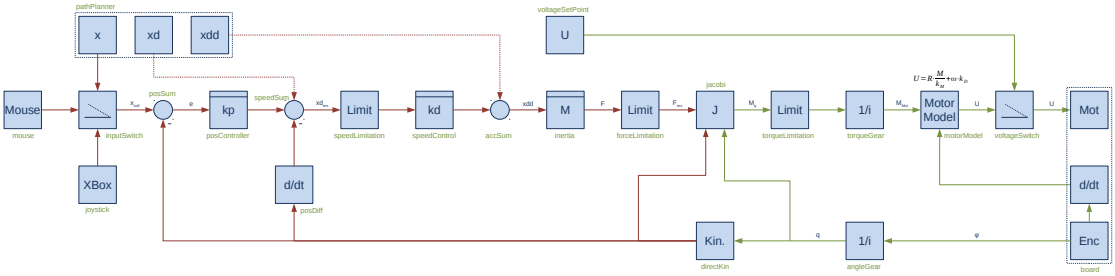


Figure 2.1.: Control loop

2.6.3. Safety System

TODO Martin

2.6.4. Sequencer

TODO Adam

2.7. Development environment

TODO Martin

3. Build a robot from scratch

3.1. Introduction

TODO Stefan/Martin

3.2. Getting all necessary parts

3.2.1. Manufactering the mechanical parts

TODO Stefan

3.2.2. Ordering the commercial parts

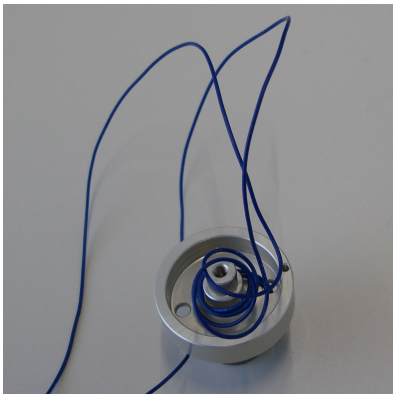
TODO Stefan/Martin

3.3. Mechanical assembly

3.3.1. EEDURO Delta robot

Step 1: Mount the electro magnet

- Remove the shrink tubing from the cable of the electromagnets.
- Screw the rotating tool carrier (11) and the electromagnet (B) with the grub screw M2x8 (A) together and fix them with Loctite.
- Wind the cable of the electromagnet at least three or four times around the thicker flange of the tool carrier.



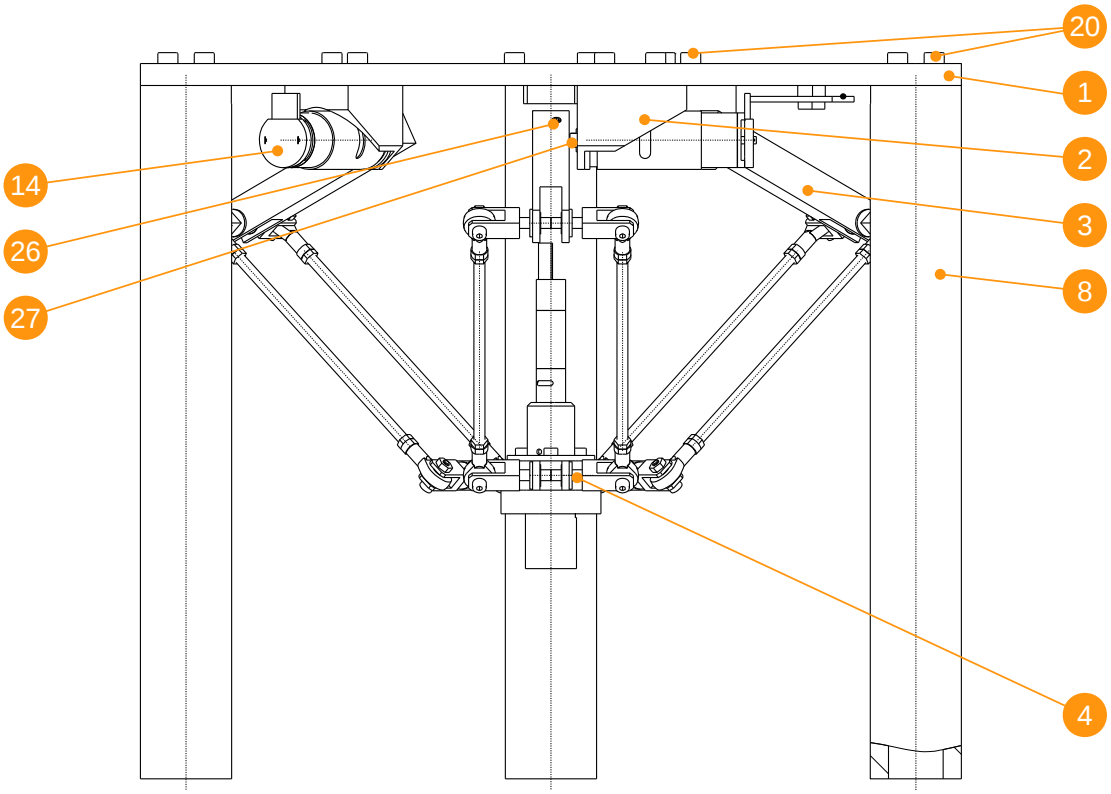


Figure 3.1.: EEDURO delta

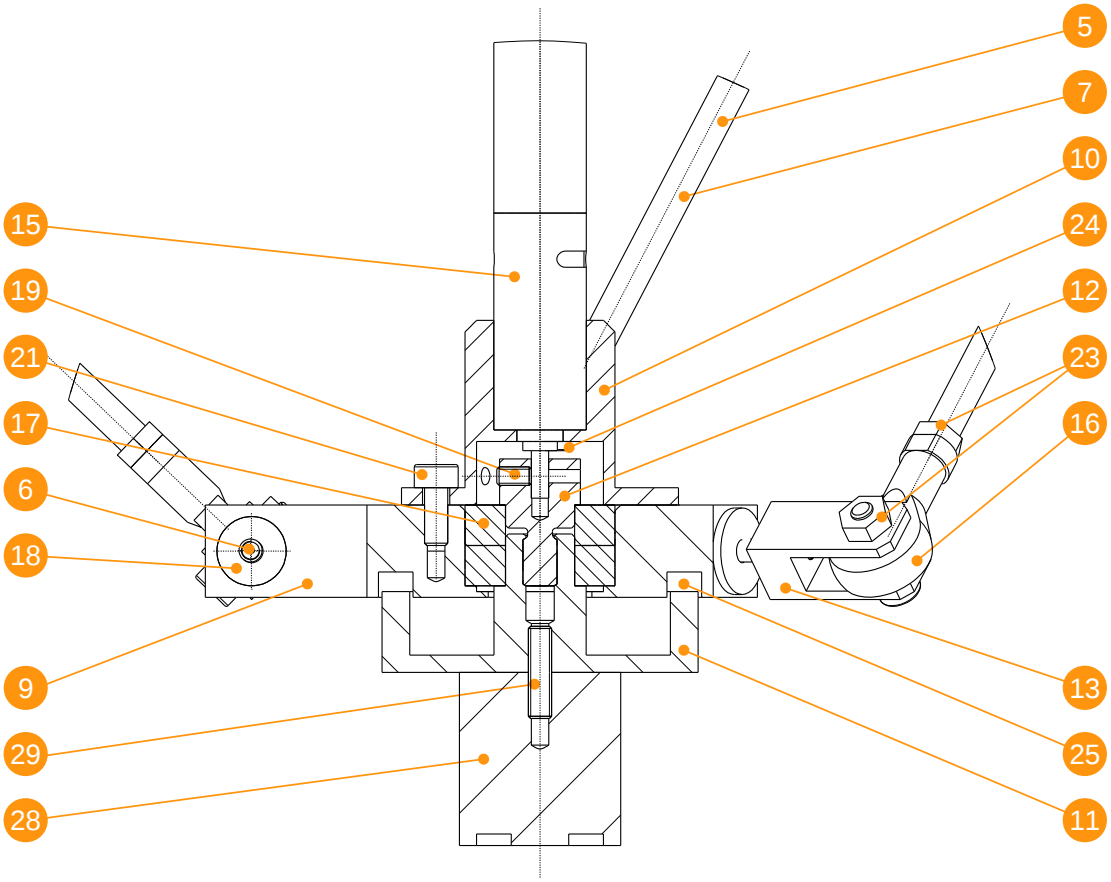
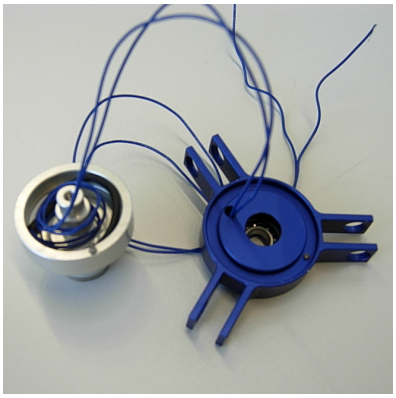


Figure 3.2.: EEDURO delta TCP detail view (with mounted electro magnet)

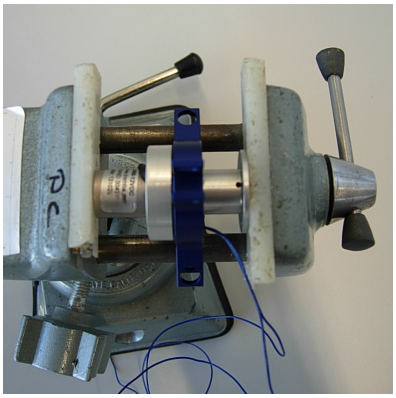
Step 2

- Put a cylinder bolt (25) in the TCP link (9) and in the rotating tool carrier.
- Lead the cable of magnet in the hole of the TCP link.
- Put a groove ball bearing (17) in the TCP link.



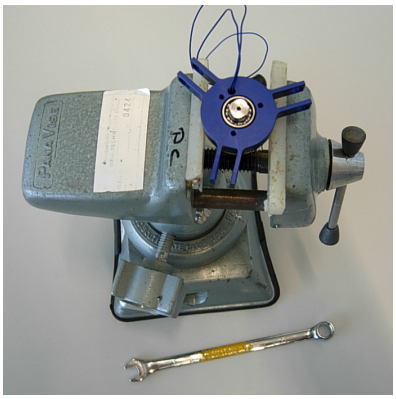
Step 3

- Link the rotating tool carrier with the TCP link on the groove ball bearing.
- If the connection is severe, use a vise to use the TCP motor carrier (10) as a mounting aid.



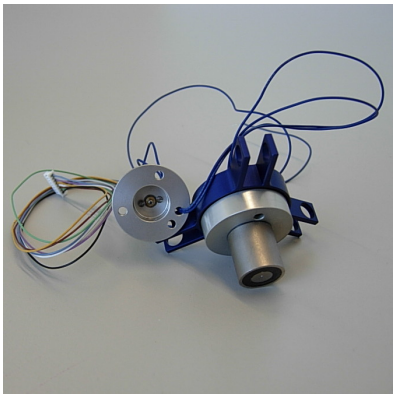
Step 4

- Put a second groove ball bearing (17) in the TCP link.
- Screw the tool carrier motor adapter (12) in.
- Screw two grub screws (19) in the tool carrier motor adapter, but not too deep.



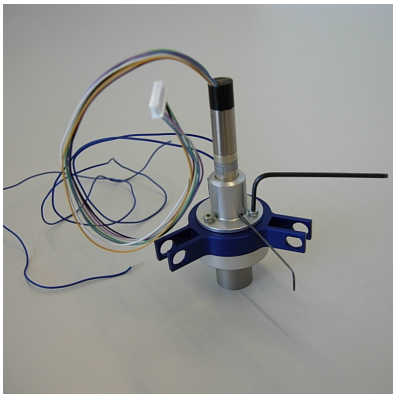
Step 5

- Mount the motor (15) with the cylinder head screws M1.2x3 (24) on the motor carrier (10).
- Lead the cable of magnet through the hole in the motor carrier.



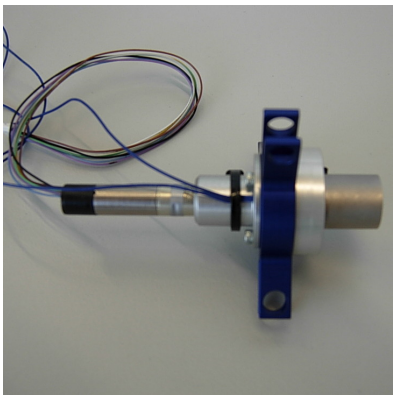
Step 6

- Mount the motor carrier (10) with the cylinder head screw M2x5 (21) on the TCP link (9).
- Attach the motor shaft of the motor (15) to the tool carrier motor adapter (12).



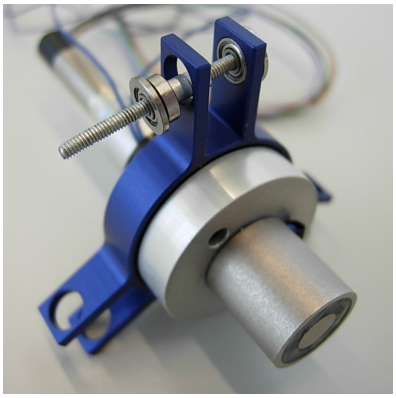
Step 7

- Fix the cable of the magnet with a cable tie.



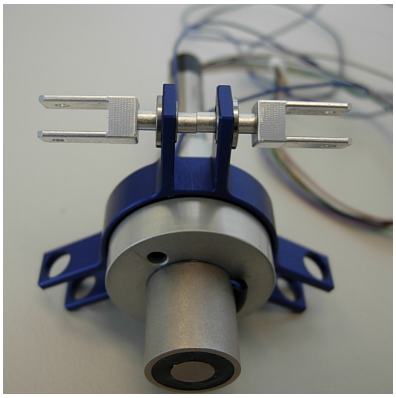
Step 8

- Mount one thread rod (6) with four distance sleeve (4) and two ball bearing (18) together.



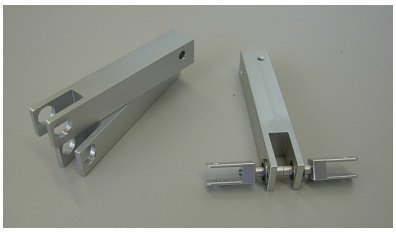
Step 9

- Screw on both ends of the threaded rod a quicklink (13).
- Repeat this step twice.



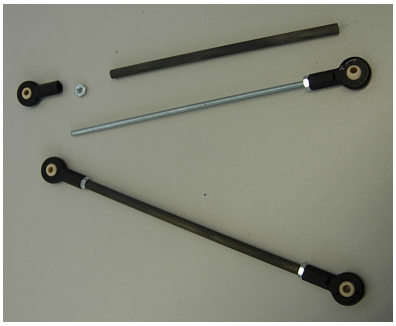
Step 10

- The same as the quicklinks (13) on the Delta upper arms (3) are fixed.
- Screw two grub screws M3x3 (xxx) in the Delta upper arms (3), but not too deep.



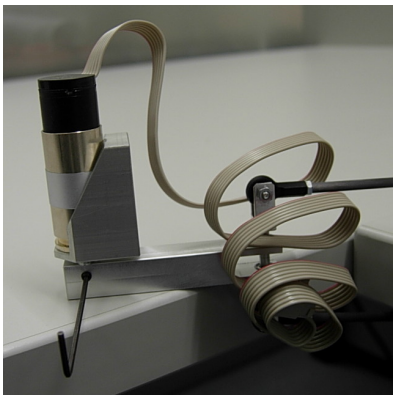
Step 11

- The arms consist of two nuts (23), a thread rod (7), a carbon tube (5) and two Igubal swivel head (16).
- Make six arms.



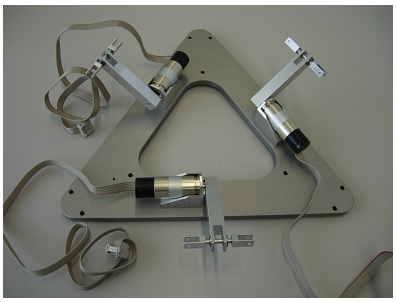
Step 12

- Attach the motor (14) on the delta motor carrier (2) with two screws M2x4 (xxx). Important is that the grub screw to press on the straight surface from motor shaft.



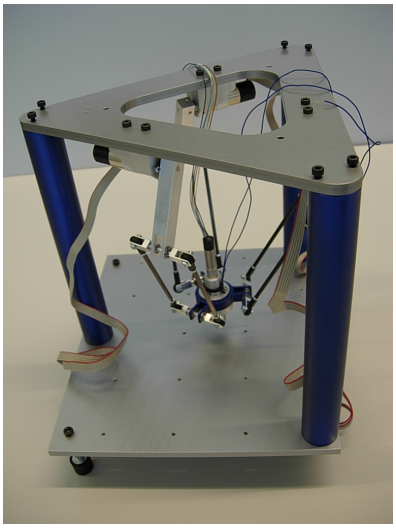
Step 13

- Mount the three delta motor carrier (2) on the delta top carrier (1), note that the orientation of the motors must be counter clockwise.



Step 14

- The TCP link (9) is connected to the delta upper arms (3) through the arms that were built in the 12th step. They are connected with the cylinder screws M2x8 (22) and nuts (23).
- The image gives an overview of the whole construction. Please ignore the orientation of the motors in this image, since it is not the same as for your robot.



TODO: replace Image

3.3.2. Base Case

TODO Stefan

3.3.3. Remote Case

TODO Stefan

3.3.4. Tile playing field

3.4. PCB assembly

3.4.1. Main board

3.4.2. HMI extension board

The HMI extension board connects three buttons with integrated LEDs to the FPGA on the main board. For connecting both boards, a 20 wire ribbon cable is used (see Appendix B.2 at page B.2 for detailed information about the cable). This cable connects P1 on the main board with P1 on the extension board.

The buttons are connected with 4 wire ribbon cables as described in appendix B.2. Use U1 to connect the blue button, U2 for the red and U3 for the green.

On the EEDURO main board Revision 3 or older, a reset circuit for the FPGA is missing. As a workaround this can be assembled instead of P2 on the extension board. There is also no support

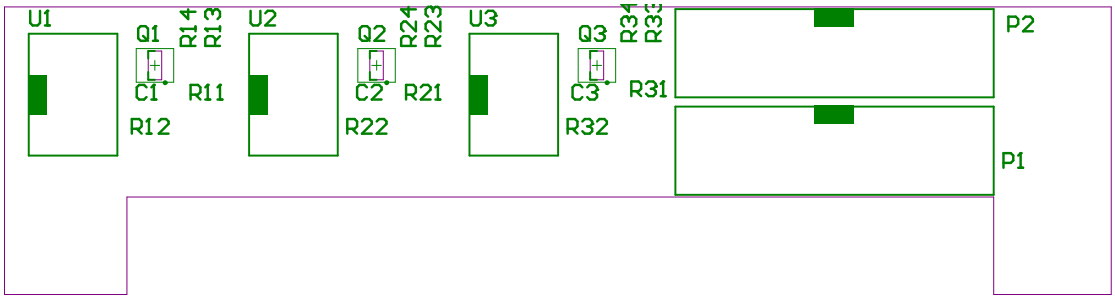


Figure 3.3.: EEDURO HMI extension board assembly drawing

voltage available on P1 of the main board. Therefore a two way Molex connector P6 is used. Figure 3.4 shows the necessary modification.

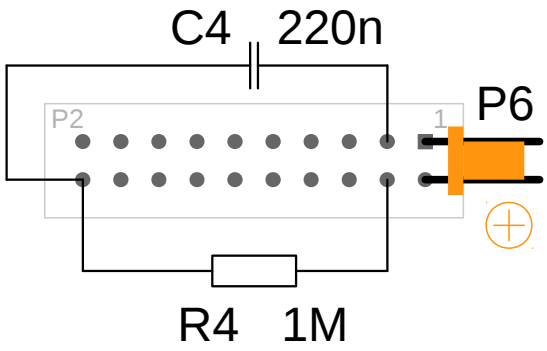


Figure 3.4.: EEDURO HMI extension board modifications

3.4.3. Line receiver board

3.4.4. Line transmitter board

3.5. Wiring

3.5.1. Delta robot with base case

TODO

3.5.2. Delta robot with remote case

Build instructions for the cables can be found in appendix B on page 29.

(1) USB extension cable with panel jack, see part list in appendix A.4 at page 24. Connect to *USB Host* (`P3`) on the BeagleBone Black.

(2) 20 wire ribbon cable, connects `P1` on the main board with `P1` on the HMI extension board.

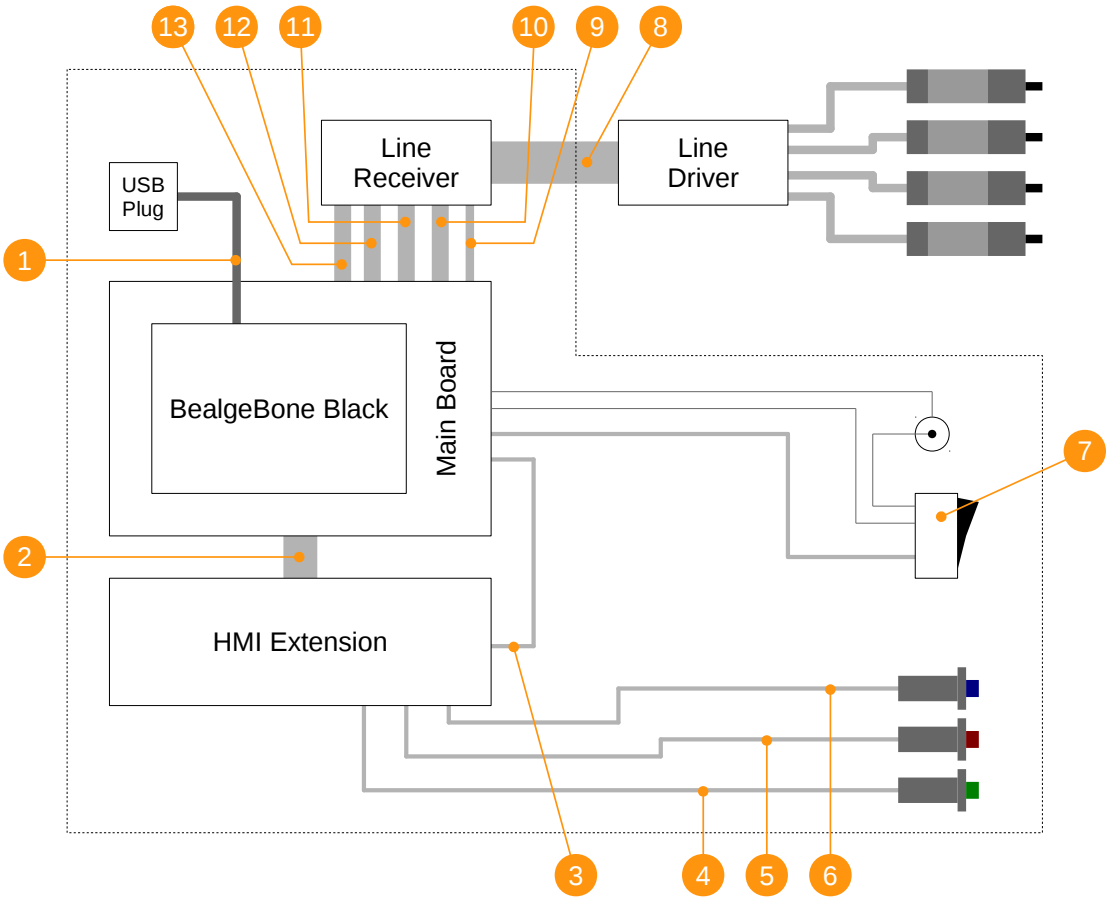


Figure 3.5.: Cabling overview for the EEDURO delta robot with a remote control case

(3) HMI extension board power cable. Connects P6 on the extension board to the power terminal P2 on the main board. Consider the polarity!

(4) Green button with integrated LED for user interaction. Connect to U3 on the HMI extension board.

(5) Red button with integrated LED for user interaction. Connect to U2 on the HMI extension board.

(6) Blue button with integrated LED for user interaction. Connect to U1 on the HMI extension board.

(7) Connect the black ground wire (coming from the power connector X5) and the red wire (coming from the power switch) to the terminal P2 on the main board. Also connect the two wire cable for the power LED to the P2 terminal.

(8) 34 way ribbon cable to the robot. Use X4 of the remote case.

(9) 4 way ribbon cable for the electro magnet (Position 28 in Figure 3.2 at page 11) and the supply voltage for the line receiver board. Connect P1 on the line receiver board with POUT on the mainboard.

(10) 6 way ribbon cable for axis 1 (Motor 0). Connect MOT1 on the line receiver board with MOTOR0 on the mainboard.

(11) 6 way ribbon cable for axis 2 (Motor 1). Connect MOT2 on the line receiver board with MOTOR1 on the mainboard.

(12) 6 way ribbon cable for axis 3 (Motor 2). Connect MOT3 on the line receiver board with MOTOR2 on the mainboard.

(13) 6 way ribbon cable for axis 4 (Motor 3). Connect MOT4 on the line receiver board with MOTOR3 on the mainboard.

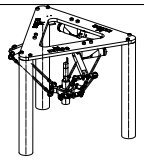
A full wired remote case is shown in figure 1.3 on page 5.

3.6. Testing

Appendix

A. Part list

A.1. Overview

EEDURO Delta Robot	sub parts see appendix A.2 at page 21	
EEDURO Base case	sub parts see appendix A.3 at page 23	
EEDURO Remote Case	sub parts see appendix A.4 at page 24	
EEDURO Tile Play Set	sub parts see appendix A.5 at page 25	
EEDURO Delta Pencil Tool	sub parts see appendix A.6 at page 25	

A.2. EEDURO Delta Robot

Qty	Description	Details		Reference
1	Delta top carrier	Drawing `EEDURO-D-001`		1
3	Delta motor carrier	Drawing `EEDURO-D-002`		2
3	Delta upper arm	Drawing `EEDURO-D-003`		3
24	Distance sleeve ($\varnothing 2/3 \times 2.8$)	Drawing `EEDURO-D-004`		4
6	Carbon tube ($\varnothing 2/3 \times 72$)	Drawing `EEDURO-D-005`		5
6	Thread rod ($M2 \times 25$)	Drawing `EEDURO-D-006`		6
6	Thread rod ($M2 \times 85$)	Drawing `EEDURO-D-007`		7
3	Pillar	Drawing `EEDURO-D-008`		8
1	TCP link	Drawing `EEDURO-D-009`		9
1	TCP motor carrier	Drawing `EEDURO-D-010`		10
1	Rotating tool carrier	Drawing `EEDURO-D-011`		11
1	Tool carrier motor adapter	Drawing `EEDURO-D-012`		12
12	Quicklink	Drawing `EEDURO-D-013`		13
3	Faulhaber DC-Motor with gear	1524E012SR + IEH2-4096 + 15/8-76:1		14
1	Faulhaber DC-Motor with gear	0816D012SR-K256 + HEM3-256-W + 08/3-120:1		15
12	Igubal swivel head	Igus KBRM-02		16
2	Groove ball bearing 16/6x3.5	Type 686		17
12	Ball bearing F692ZZ	Type F692ZZ		18

Qty	Description	Details	Reference
2	Grub screw M1.6x3		19
12	Cylinder head screw M3x10	ISO 4762	20
3	Cylinder head screw M2x5	ISO 4762	21
12	Cylinder head screw M2x8	ISO 4762	22
24	Nut M2	ISO 4032	23
2	Cylinder head screw M1.2x3		24
2	Cylinder bolt $\varnothing 1.5 \times 5h6$		25
6	Grub screw M2.5x3		26
6	Cylinder head screw M2x4	ISO 4762	27
1	Electro magnet	Tremba GTO-14-0.5000	28
1	Grub screw M2x8		29

A.3. Base case

Qty	Description	Details		Reference
1	EEDURO base case	Drawing `EEDURO-001`		1
1	Base case cover (plexiglas)	Drawing `EEDURO-002`		2
1	EEDURO main board	sub parts see appendix A.8		3
1	HMI extension board	sub parts see appendix A.9		4
1	Power connector with switch	sub parts see appendix A.7		5
1	Power supply 12 V, 1.5 A	TBD		6
1	USB cable with panel jack	Ampire XUB060		7
1	USB mini extension cable	Length: ca. 200 mm		8
1	USB mini panel mount	Drawing `EEDURO-003`		9
4	Cylinderic rubber pad M3	Norelem 26106-00800855		10
6	Cylinder head screw M3x12	ISO 4762		11
2	Countersunk head screw, M3x12	ISO 10642		12
2	Washer M3			13
2	Nut M3	ISO 4032		14

A.4. Remote case

Qty	Description	Details		Reference
1	Remote case	Hammond 1455T2201BU, see Drawing TBD		1
1	Main board	sub parts see appendix A.8		2
1	HMI extension board	sub parts see appendix A.9		3
1	Line Receiver board	sub parts see appendix A.11		4
1	Power connector with switch	sub parts see appendix A.7		5
1	Power supply 12 V, 1.5 A	Nordic Power AM04151A-12V		6
1	USB cable with panal jack	Ampire XUB060		7
4	Spacer bolt M3x5 mm	Distrelec 340962		8
6	Countersunk head screw, M3x6	ISO 10642		9
4	Nut M3	ISO 4032		10
8	Polyamid washer $\varnothing 7/3.2 \times 0.5$	ISO 7089		11
2	Spacer block M3, 6x6x12	Ettinger 05.60.233, Farnell 1466866		12
1	Line Driver board	sub parts see appendix A.10		13
1	EEDURO robot base plate	Drawing EEDURO-004		14
6	Cylinder head screw M3x12	ISO 4762		15

A.5. EEDURO Tile Play Set

Qty	Description	Details		Reference
1	Tile 1	Drawing `EEDURO-A-001`		1
1	Tile 2	Drawing `EEDURO-A-002`		2
1	Tile 3	Drawing `EEDURO-A-003`		3
1	Tile playing field	Drawing `EEDURO-A-004`		4
4	Spacer bolt M3x15 mm	TBD		5
4	Cylinder head screw M3x12	ISO 4762		6
4	Washer M3			7

A.6. EEDURO Delta Pencil Tool

Qty	Description	Details	Reference
1	Lead mount	Drawing `EEDURO-D-014`	

A.7. Power connector with switch

Qty	Description	Details		Reference
1	Rocker switch 19.6 mm x 13 mm	Miyama DS-850-K-F1-LG Conrad 706032		
1	Coaxial power plug ∅5.8/2.5	Conrad 716916		
1	Litz wire, 1.0 mm^2, red	Length 450 mm		
1	Litz wire, 1.0 mm^2, red	Length 430 mm		
1	Litz wire, 1.0 mm^2, black	Length 210 mm		
1	Two-Wire cable, 2x0.22 mm^2	Length 430 mm		
1	Axial-lead resitor	$1k\Omega$		

A.8. Main board

Qty	Description	Reference
1	BeagleBone Black, BBB-CNCT-O	BBB
1	Buck Converter TPS5432, SO-PPAD-DDA-8	U5
1	Buck Converter TPS54531, SO-PPAD-DDA-8	U4
1	Capacitor 15pF, 0603	C2
1	Capacitor 2.2nF, 0603	C27
1	Capacitor 22pF, 0603	C30
1	Capacitor 6.8nF, 0603	C37
1	Capacitor 68pF, 0603	C38
17	Capacitor 100nF, 0603	C9, C11, C12, C14, C15, C16, C17, C18, C19, C21_H01, C21_H23, C22_H01, C22_H23, C23, C32, C34, C47
2	Capacitor 22uF, 1206	C35, C36
2	Capacitor 4.7uF, 1206	C24, C25
2	Capacitor 47uF, 1206	C28, C29
4	Capacitor 100uF, 1206	C45_H01, C45_H23, C46_H01, C46_H23
4	Capacitor 10uF, 1206	C10, C33, C40, C42
7	Capacitor 330nF, 0603	C1, C5, C7, C13, C41, C43, C44
9	Capacitor 10nF, 0603	C3, C4, C6, C8, C20_H01, C20_H23, C26, C31, C39
1	DC Input Plug, DCJACK	P3
2	DUAL H-BRIDGE DRIVER IC DRV8841PWPR, TI_HTSSOP(PWP)-(R-PDSO-G28)_R	U3_H01, U3_H23
1	Dual N-Channel MOSFET FDC6561AN, SuperSOT-6	Q1
1	Header 2x2, H100P2X2-F	POUT
1	Header 9X2, H100P2x9	P1
4	HEM3, Molex-51021-8	MOT0, MOT1, MOT2, MOT3
4	IE2, IE2	MOTOR0, MOTOR1, MOTOR2, MOTOR3
1	Inductor - Power 3.3uH, XAL4020	L2
1	Inductor - Power 4.7uH, XAL4020	L1
1	JTAG Connector JTAG, JTAG	JTAG
2	Jumper, H100P2x2	J1, J2
1	LDO Linear Regulator LP38852, DDPAK-7	U6
1	MOSFET Driver FAN3227, SOIC127P600X175-8M	U1
1	Oszillator 48MHz, KC5032A	X1
	ProASIC3 Flash Family FPGA, 71 User IOs, 125K System	

TODO: import CSV

A.9. HMI extension board

TODO: import CSV

A.10. Line driver board

TODO: import CSV

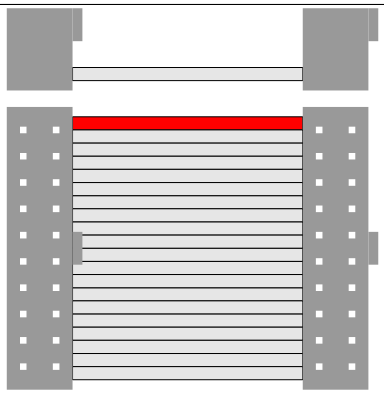
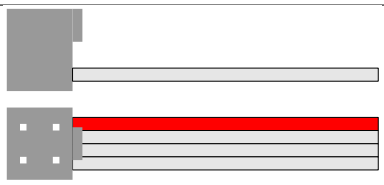
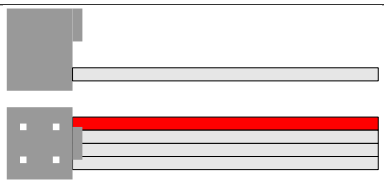
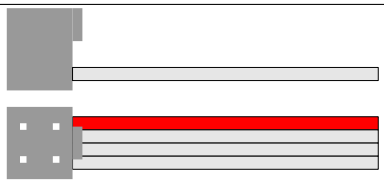
A.11. Line receiver board

TODO: import CSV

B. Cable build instructions

B.1. Power supply cables

B.2. HMI extension cables

Cable	Pins	Length	Connector alignment
xxxxx	20	2.0 cm	
xxxxx	4	45.5 cm	
xxxxx	4	42.5 cm	
xxxxx	4	41.5 cm	

The Buttons has to be soldered as shown in figure B.1. Cut the LED pins to the same length as the button pins before soldering. Use a heat shrink tube to isolate the soldering.

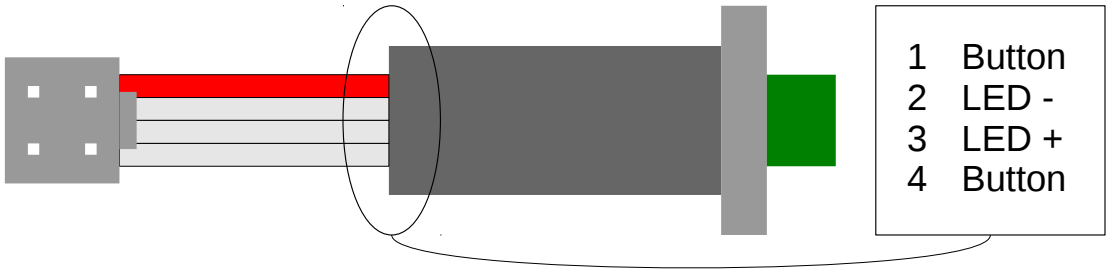
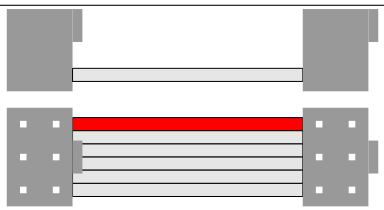
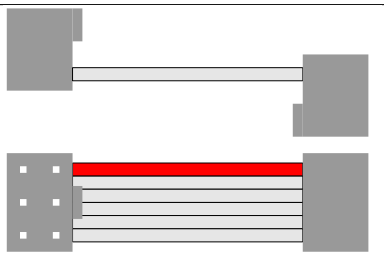
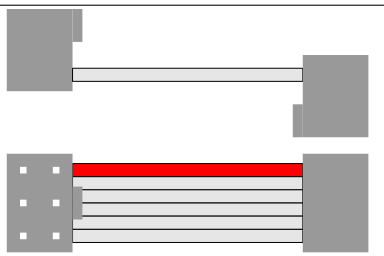
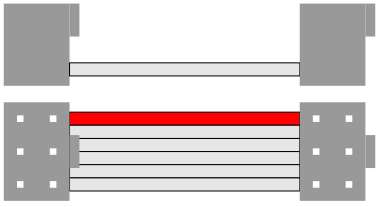
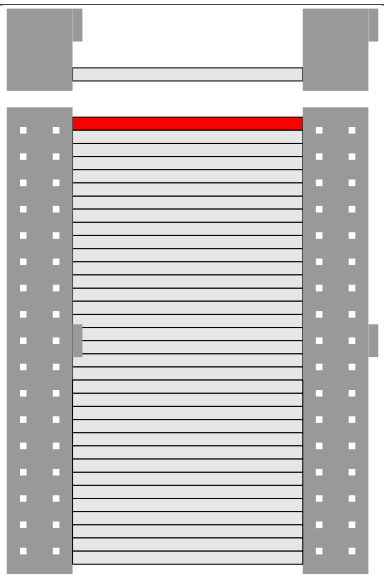


Figure B.1.: Pin assignment for the buttons

B.3. Line receiver and line driver cables

Cable	Pins	Length	Connector alignment
xxx.001	6	7.5 cm	
xxx.002	6	10.5 cm	
xxx.003	6	15.0 cm	
xxx.004	6	15.0 cm	
xxx.005	4	18.0 cm	
xxx.zzz	34	custom	

C. Prepare a SD card for the BeagleBone