commonplace robotics GmbH

User Guide

Embedded Control of the igus robolink-DCI Robot Arm

Operating Instructions for the Embedded Control System of the igus robolink DCi
Version 2019/10 V01.3-EN

Software Version TinyCtrl	V980-04-031
Software Version CPRog	V902-10
Firmware Version Supply	0x37 - 0x0302
Firmware Version Stepper	0x42 - 0x0210
Firmware Version DigitalIO	0x39-0x0309

Commonplace Robotics GmbH
Im Innovationsforum Bissendorf
Gewerbepark 9-11
49143 Bissendorf, Germany
+49-5402-968929-0
support@cpr-robots.com
www.cpr-roboter.de

Content

1. Safety instructions

- Always pay attention to safety of people while operating a robot arm or commissioning a robot cell! Make sure that nobody is within the operating range of the arm or other danger spots!

- CE marking: Robot arm and control system are just a part of one facility, which is assessed in its entirety for risks and must comply with currently applicable safety regulations. The commissioning engineer of the facility is responsible for this.

- The robot's control system has no protective devices. To ensure the essential safety of people, suitable components, such as safety relays and door switches, must be connected.

- Always disconnect the power supply before inserting or removing connectors, such as the display with joystick, emergency stop, digital I/Os or external relays.
  No hot plugging!

- Work on the robot's electronic system should only be carried out by qualified personnel. Observe the common ESD guidelines.

- Do not install or remove modules during operation, nor should you plug or unplug any connections during operation. For this, always turn off the system and unplug the mains connector.

- The robot arm must be set up on a stable surface and bolted or otherwise secured.

- Use and store the system only in a dry, clean environment.

- Use the system only at room temperature (15° to 32°C).

- The ventilation of the system must be able to operate without hindrance. There must be at least 10cm of space next to the robot's fan to ensure sufficient airflow to cool the motor modules.

2. Introduction

2.1 Robot components

Components of the robot: robot, emergency stop, control unit with joystick

Rear view of the robot

2.2 Specification

Type	igus robolink DCi
Number of axes	Depending on the type: 4 - 5
Payload	Depending on the type: 0.5kg
Power electronics	
Voltage supply	24V >= 5A
Communication	Internal CAN field bus 500kBaud External via Ethernet
Supply module	SlowStart function to prevent overload of the power supply. 1-channel emergency stop function without safety classification, connection option of an external safety relay.
Stepper module	For operation of a bipolar stepper motor Microstepping up to 1/256 RS422 quadrature encoders 24V reference switch input
Digital In/Out module	4 external and 3 internal digital inputs, 12 - 24V, based on optocouplers 4 external and 3 internal digital outputs, solid state relay, max. 500mA
Integrated control system	
Platform	Phytec Wega, ARM Cortex A8 (or comparable)
Operating system	Linux
Software	TinyCtrl Robot Control Software
Interfaces	Control of the drives and I/O modules via the CAN bus, connection to CPR via Ethernet, RS232 display connection

3. Dimensions

3.1 Lateral view

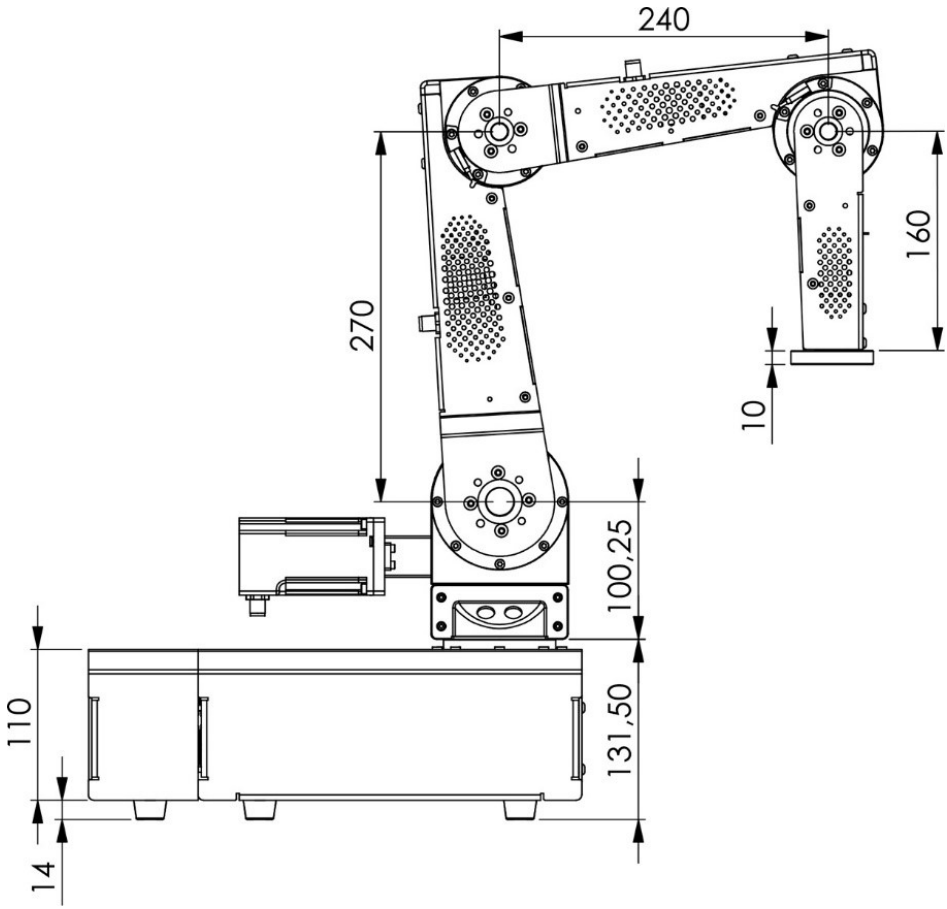


Diagram 1: Side view of the DCi robot. The robot axes (motors) are basically counted from the robot base. So axis 1 is the vertical axis in the robot base. An effector (e.g., gripper) can be attached to axis 4/5 (4 or 5-axis version).
A 4-axis robot has a mounting plate instead of the last axis.

3.2 Hole pattern flange (axis 5) and bottom

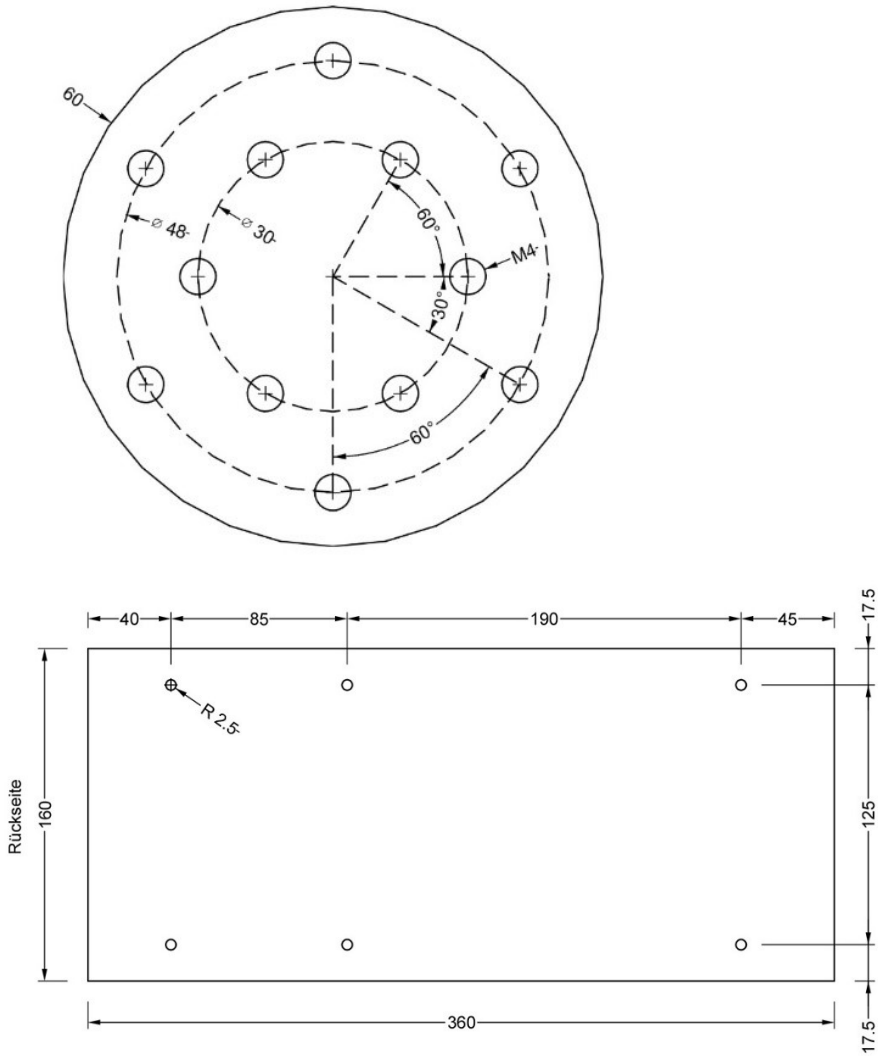


Diagram 2: Top: Hole pattern flange of the axis 5; Bottom: Hole pattern of the robot base.

4. Connections and LEDs

4.1 Connections

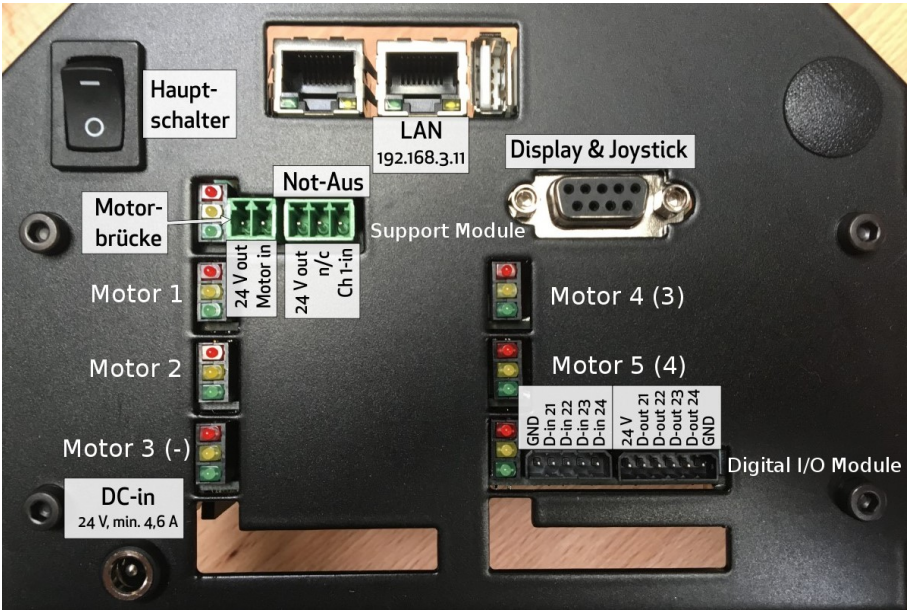
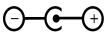
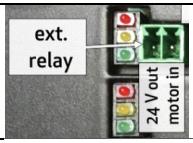
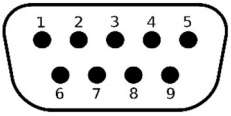


Diagram 3: Rear view of the robot base, here in the 5-axis version. In the 4-axis version the values in parentheses apply to the motor modules.

4.1.1 Pin assignment of support module and power supply

DC24V In		0V Outer 24V Inner
Ethernet		RJ45 Standard Ethernet socket. Use the ethernet connector on the right, which is set to IP 192.168.3.11
Ext. Relay / Motor bridge		Motor bridge for motors. Power supply to the motors can be interrupted here. Pin 1: 24V output Pin 2: 24V Input for motors
Connection display	 View of the plug contacts	Pin 1: 24V Pin 2: not connected Pin 3: TX Pin 4: CAN-L Pin 5: GND Pin 6: GND Pin 7: RX Pin 8: CAN-H Pin 9: GND Caution! The connection is proprietary. It is not suitable for a null modem cable or the like.
Emergency Stop		Pin 1: 24V Output Pin 2: not connected Pin 3: Emergency-Stop signal input (active low)

4.2 Digital Inputs/Outputs

4.2.1 Digital I/Os and the back wall

From the Digital Input/Output (DIO) board, 4 digital outputs and 4 digital inputs are routed to the outside. If further inputs and outputs are required, 3 more each can be achieved on the same module in the housing of the robot. Plug-in connectors are included.

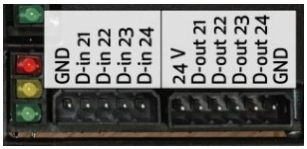
The outputs are not galvanically isolated in delivery condition; 24V and GND of the robot control system are used. If galvanic isolation is required, this can be done as described in section 10.1 "Galvanic isolation".

For testing, an LED with series resistor (e.g., 2K) can be connected between e.g. DOut1 (switched + 24V) and GND of the right 6-pin plug-in connector. This can be switched later in the software.

If an external signal from an external device has to be processed by the robot control system, this can be given to one of the **digital inputs** (DInX).

The digital inputs are always galvanically isolated from the robot control system by means of an optocoupler with 12K current limiting resistor, so as to connect both signal and 0V to the external device. The positive signal is fed to DIn1-4 of the 5-pin plug-in connector, flows via the 12K resistor through the optocoupler diode to the GND of the 5-pin connector.

Digital I/O module



0V: External Ground (-)
DIn<X>: Digital input (+)

GND: 0V of the robot control system*
PWR: 24V of the robot control system**
DOut<X>: Digital output (24V of the robot controller) e.g. for controlling a gripper.

*See 10.1 Galvanic isolation

4.2.2 Internal digital I/Os

If further inputs and outputs are required, 3 additional ones are available internally in the housing of the robot on the rear side of the DIO module. To reach them, the robot must be placed on its side. Here DOut 25,26,27 and DIn 25, 26, 27 are available.

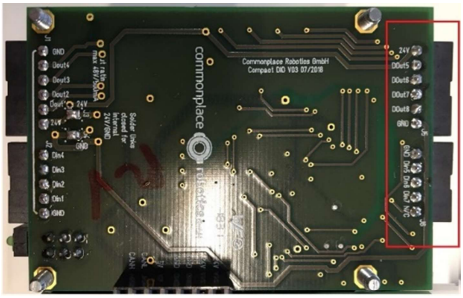


Diagram 4: Additional internal digital I/Os.

4.2.3 Use of digital I/Os in robot programmes

The use of the inputs and outputs takes place in CPRog with the number 21 upwards:

I/O Module	Physical input/output	Name in CPRog and in the robot programme
DIO 1 (standard)	Din21 to Din24 on rear wall Din25 to Din27 on inner side DOut21 to DOut24 on rear wall DOut25 to DOut27 on inner side	Inputs: DIn21 to DIn27 Outputs: DOut21 to DOut27
DIO 2 (optional)	Din31 to Din34 on rear wall Din35 to Din37 on inner side DOut31 to DOut34 on rear wall DOut35 to DOut37 on inner side	Inputs: DIn31 to DIn37 Outputs: DOut31 to DOut37
DIO 3 (optional)	Din41 to Din44 on rear wall Din45 to Din47 on inner side DOut41 to DOut44 on rear wall DOut45 to DOut47 on inner side	Inputs: DIn41 to DIn47 Outputs: DOut41 to DOut47

4.3 LEDs

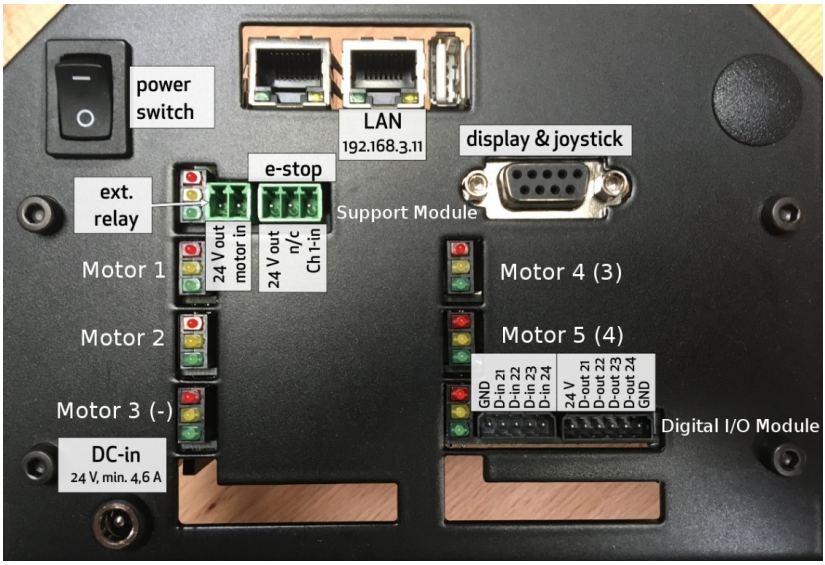


Diagram 5: Organisation of the robot control and LED signal lights of the individual modules.

After the power supply is established, the **green LEDs** of all modules **light up**. Approximately 20-30s later, the green LEDs of the motor and IO modules start **flashing**, which means that the control computer has established communication with the modules. The control system is now ready to receive commands.

Since the motors are not yet activated, the **red** LEDs of the motor modules light up.

The **yellow** LED on the motor modules lights up when the axis' reference switch is triggered.

As soon as the emergency stop is activated (pulled out), the red LED on the support module goes out.

After "Reset" followed by "Enable" have been pressed using display control, the red LEDs on the motor modules also go out.

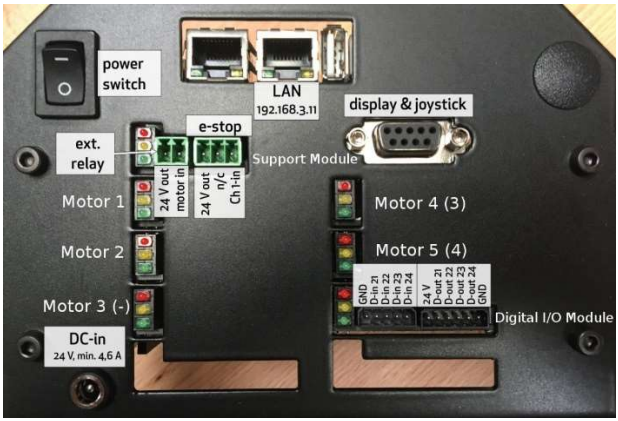
The yellow LEDs of the Digital In/Out modules light up briefly when the status of an input or output changes.

For the detailed meaning of the LEDs, see the table in the section 11.

5. Commissioning

Do not disconnect or connect any electrical connections to the robot while it is plugged into the mains.

1. Make all plug-in connections:
    a. Plug in the Emergency Stop Button at the e-stop connector.
    b. Fasten display/joystick (D-Sub connector)
    c. Check that the motor bridge is plugged in
    d. Plug in power connector
    e. Provide the power supply unit with power
    f. Turn on the main switch on the rear side of the robot.



2. The green LEDs on the rear side of the robot light up, and the internal computer starts up.
   The message "No Connection" is shown in red on the display until the internal PC has booted up and the control software has started.
3. When the control software (TinyCtrl) is started, the green LEDs of the motor modules start to flash, and the "No Connection" display disappears. The software version is briefly displayed, followed by "Motion not allowed / Not Ref'd"
4. Press the emergency stop button and release it again. You will now hear two relays release the motor current one after the other.

6. Operation

After all electrical connections to the robot have been established, the robot has been switched on and the emergency stop has been released, it must first be activated.

When moving the robot, always keep a hand on the emergency stop to prevent it from hitting an object unexpectedly, for example if it is about to collide with the table.

6.1 Reset errors/Enable robot

On the display, press the "Enable" button in the upper menu to get to the Enable menu.

Now press "Reset": The status changes to "MNE" (Motor Not Enabled)

Press "Enable": The status changes to "No Error". "Not ref'd!" means not referenced. We'll come back to that later.

6.2 Manual method of the robot

Once the robot is enabled, the axes of the robot can be moved.

1. To do this, press the "Jog" button at the top of the display

2. Press A1. Then move and turn the joystick. You can now move the axes 1, 2 and 3.

3. Press A4. Now, move axes 4 and 5 by moving and rotating the joystick.

Repeat steps 2 and 3 until the robot is roughly in a "gallows position" and the "IK" mark on the flange of axis 5 points towards the robot base.

6.3 Referencing the robot

To enable an automatic programme sequence, the robot electronics must be referenced.

1. To do this, press the "Enable" button at the top edge of the display.

2. The robot must be in "NoError" status. If it is in an error state, enable it with "Reset" and "Enable".

3. Now press the "Ref All" button to reference all axes. The robot now carries out search movements for each axis.

4. Referencing is complete when there is a 1 next to Ref A1-A5 respectively.
   For a 4-axis robot, Ref A5 will remain at 0.
   Ref E1 is intended for additional external axes.

5. After referencing, the axes are in the error state. This is necessary because the actual position has changed in the referencing process.

6. Now press the round "Reset" button, followed by the round "Enable" button. The robot is now referenced.

The type of referencing movement depends on the robot or encoder type.

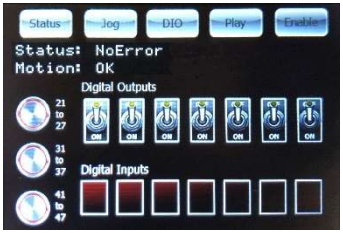
6.4 Starting and stopping a programme

After referencing, the robot is ready to replay a programme.

1. To do this, press the "Play" button at the top edge of the display and use the "prev" and "next" buttons to select the *Igus5DOF_TestMotion* programme.
2. Load the programme using the "Load" button
3. Let the programme replay once using "Single Play".
4. "Cont. Play" plays the loaded programme continuously.
5. „Stop“ stops the movement.
6. The slider "Override" can be moved to the right to increase the speed of the movement or to the left to decrease it.

6.5 Set the digital inputs/outputs

The digital outputs can be activated and deactivated by pressing the illustrated switches.



If e.g. a gripper is connected to the digital I/O module, this can be activated or deactivated by switching the illustrated switches.
If a signal is present at the digital input, it will be displayed in the digital inputs field at the bottom edge of the display.

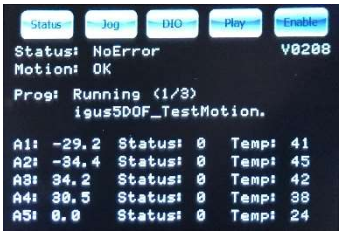
The three buttons on the left side allow you to switch between several DIO modules.

If a signal is present at the digital input, it will be displayed in the digital inputs field at the bottom edge of the display.

For details about the pin assignment of the inputs and outputs, see section 4.2.

6.6 Display of status information

Status information can be displayed by pressing the "Status" button at the top left corner of the display.



The name of a programme is displayed, for example while a programme is running.

The axis positions of axes 1-5 (or 1-4 for 4-axis robots) are displayed (A1-A5).

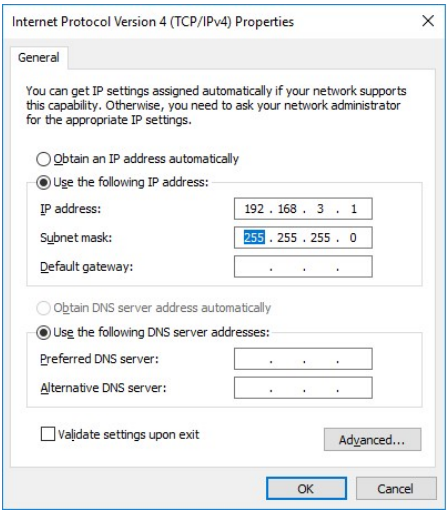
The temperature of the motor modules is also displayed. Due to the varying loads on the individual axes different holding currents are applied, which lead to different temperatures of the motor modules.

7. Programming

The robolink DCi is programmed on a Windows computer using the 3D robot control system CPRog. To do this, install the CPRog software as described in the CPRog operating instructions.

7.1 Establish connection

- Connect the right Ethernet port of the robot to a Windows PC using a standard LAN cable.
- Set the IP of the PC to 192.168.3.1. (The robot has IP 192.168.3.11)



- Start the robot and CPRog on the PC. Once the green LEDs on the motor modules on the rear side of the robot start flashing, the connection can be established (see the section 5)
- Press "Connect" (connector icon in the menu of CPRog.)

Now you will see the robot view on the CPRog interface. When you move the robot using the joystick of the operating device, the graphics will adjust.

Likewise, you can now use the functions of the CPRog software to move the robot downwards, for example, in the Z direction.

7.2 Creating a programme

The creation of the programme is carried out as described in the CPRog operating instructions.

7.3 Uploading a programme

Before a programme created in CPRog can be played back on the robot, it must be uploaded to the robot's internal computer. Afterwards it can be started as described in section 0 .

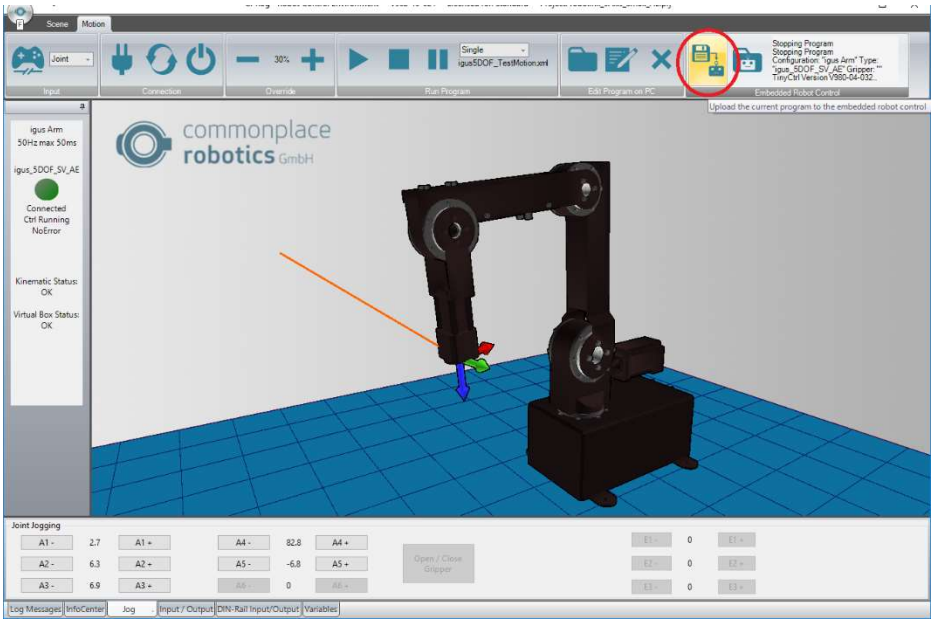


Diagram 6: CPRog Windows software with red marked upload button.

8. Integration in safety circuit

The robot control system does not provide any safety-related functions. The integrated emergency stop functions are executed in a single channel. In order to operate the complete, customer-specific robot system, the commissioning engineer has to carry out, among other things, a risk assessment within the framework of the CE certification and, depending on the result, integrate further safety components. These are usually safety relays and door switches.

The integration of safety relays is made possible by the motor power jumper plug of the support module. The motor currents are led out and in again through this connector. If this connection is interrupted, no active movement of the motors is possible.

This enables the implementation of the safety functionality with the SIL level required by the application.

9. Interfaces

9.1 Digital inputs and outputs

The simplest connection, for example to a PLC, is possible via digital inputs and outputs. Each robolink control system comes with a DIO module. See section 4.2
If additional inputs and outputs are required, up to two additional DIO modules can be integrated.

9.2 PLC interface

The PLC interface enables the integration of the robolink arm into a production system controlled by a PLC. By means of digital inputs, the PLC can switch the robot ready for operation and start a programme. It can monitor the status of the robot via digital outputs. In this way, the robot can work without manual interaction. Further details are available on the Wiki wiki.cpr-roboter.de, section PLC interface.

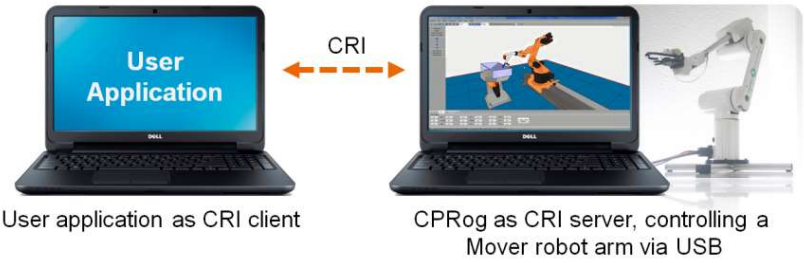
9.3 Plug-in interface

CPRog provides a plug-in interface. It makes it possible to connect, for example, image processing systems or PLC components. With various defined functions, the plug-ins represent a bridge between programme execution in CPRog and external systems.
Example: The IFM O2D SmartCamera can detect taught-in outlines and transfer the target position via Ethernet. The corresponding plug-in reads this position and transfers it to the CPRog programme sequence. The robot can then move to the appropriate position and grip the part.

The plug-ins can be provided by CPR, or they can be created on a project-specific basis. Further information and C# example code for a plug-in can be found on wiki.cpr-roboter.de.

9.4 CRI interface

The CRI interface allows the robot to be controlled via Ethernet. The robot can be moved, programmes can be uploaded and executed.



This interface makes it possible to combine the CPRog functions with application-specific algorithms, such as a teleoperation system or a database.

The CRI documentation and a C# sample project for a client have to be downloaded from the wiki.cpr-roboter.de, section "Interfacing".

10. Extensions / Adjustments

10.1 Galvanic isolation of digital outputs

If an external device with a different potential than the robot control system (for example a self-powered LED) has to be switched, the DOut pins must be disconnected from the robot's 24V supply voltage GND. This can be achieved by disconnecting solder links J3 and J4 of the DIO board. J3 and J4 are accessible from below the robot. They are marked red in the picture below.

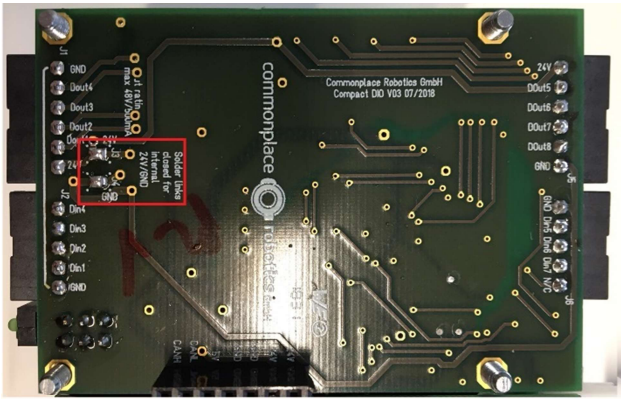


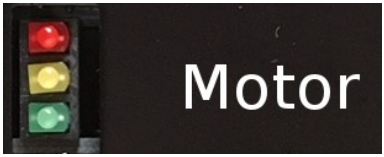
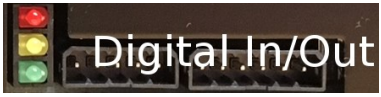
Diagram 7: Galvanic isolation of the digital outputs

11. Troubleshooting and support

11.1 Error codes

The robot control system gives several status information:

- Status LEDs on the electronic modules
- CPRog status information, received via the CAN status bytes

 Support Module	Green LED On: Logic voltage available Green LED flashes: CAN communication active Orange LED On: Error Red LED On: Emergency stop pressed
	Green LED On: Logic voltage available Green LED flashes: CAN communication active Orange LED On: Reference switch triggers Red LED On: Motor not ready (emergency stop pressed or error)
	Green LED On: Logic voltage available Green LED flashes: CAN communication active Orange LED On: Status of an input or output is changing. Red LED On: Error

11.2 CAN-Bus and CPRog status information

Error	Bit in the error byte	Meaning	Measures
Bus dead		The CAN-Bus is not available. Reasons are missing power supply or missing plug connections.	Check the connections of the power supply and the CAN cable. Reboot the control computer.
Temp.	Bit 1	The motor module temperature is too high	Check if the ventilation is installed and working.
E-Stop/Supply	Bit 2	Emergency stop or too low voltage	Check if the emergency stop switch is released
MNE Motor not enabled	Bit 3	No error. The motors are not released yet.	Press the "Release Motor" button
COM Comm Watch Dog	Bit 4	The time period without CAN command from the controller was too long	The position commands via the CAN bus must be sent at short intervals. Turn off other programmes or update/virus scan functions.
LAG Position lag	Bit 5	Tracking error. The robot cannot comply with the target position.	Decrease the speed of movement.
ENC Encoder error	Bit 6	Error in motor or absolute encoder	Check the encoder cables
OC Over Current	Bit 7	Overcurrent in the motors	Reduce the motor current
DRV	Bit 8	Error in the motor driver or the motor algorithm	Drive-specific

After an "Error Reset", the normal status of the axes is 0x04 (motor not released).
After enabling the motors, the status is 0x00, now the axes are ready for operation.

11.3 Hardware

- The green LED on the modules is not on?
  Check the power supply and the safety fuse.
- Aren't the motors moving?
  Make sure the emergency stop button is pulled out. The red LED on the support module must not be on.
- The modules do not respond to software commands. The green LED does not flash.
  The software on the robot's internal control system is not running. Reboot the robot and wait 30s. If the green LEDs are still not flashing, contact us.
- The motor is locked ("motor stall"): It does not stop the movement and makes increasingly loud buzzing noises.
  This happens when the load on the motor is too high:
  - Check if there is a collision
  - If the problem occurs several times, the load must be reduced (reduce speed or acceleration).
  - Alternatively, the current rating can be increased; more information can be found on our wiki.cpr-roboter.de
- If CPRog cannot connect
  - Check if the green LEDs of the motor modules flash approx. 30s after a restart of the robot.
  - Make sure the connection between the robot and the PC is made as described in section 7.1.

11.4 Software

The software that runs on the robot's internal control system is called TinyCtrl. In case of problems upgrade the software to the current version found on the Wiki:

http://wiki.cpr-robots.com

11.5 Support contact

In case of problems we would be happy to help!

- Wiki page: wiki.cpr-roboter.de with a lot of instructions and articles
- Mail: support@cpr-robots.com
  Please describe the problem briefly and send the file "logMessages.log" from the folder c:\CPRog\.

12. EC Declaration of Conformity

Commonplace Robotics GmbH
Im Innovationsforum Bissendorf
Gewerbepark 9-11
49143 Bissendorf, Germany

We, the Commonplace Robotics GmbH, declare that the machine parts / components described in the following

- Embedded Control System for robolink DCi robots, consisting of embedded Linux board, support board, LC and HC stepper motor controller, digital IO module, operating panel

complies with all relevant requirements of the EC Machinery Directive 2006/42/EG.

The incomplete machine must not be put into operation until conformity of the complete machine with the EC Machinery Directive 2006/42/EG has been ensured. The commissioning engineer is responsible for this.

Applied harmonized standards:

- Safety of machinery: EN ISO 12100:2010
- EMC: Directive 2004/108/EC, EN61000, EN55022, EN55011
- RoHS: Directive 2002/95/EC

The technical documentation defined in Annex VII, Part B of the Machinery Directive has been created and can be consulted by public authorities.

Responsible for the documentation: Dr.-Ing. Christian Meyer

Bissendorf, December 2018 Dr.-Ing. Christian Meyer