UNIVERSAL ROBOTS

User Manual

August 1, 2013

Robot:
UR10

SN UR10: ______________________________

SN CB2: ______________________________

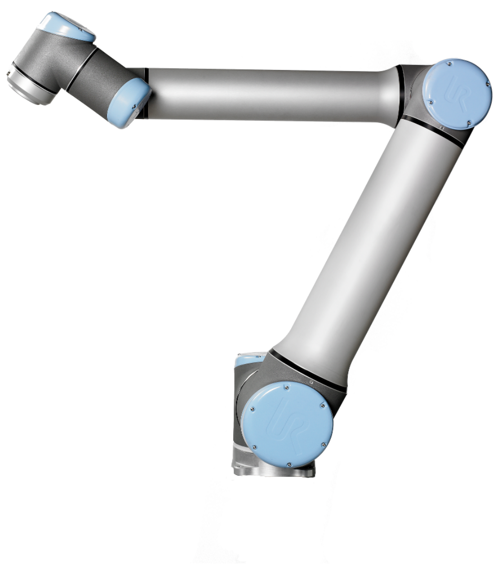
Contents

Chapter 1

Getting started

1.1 Introduction

Congratulations on the purchase of your new Universal Robot, UR10.

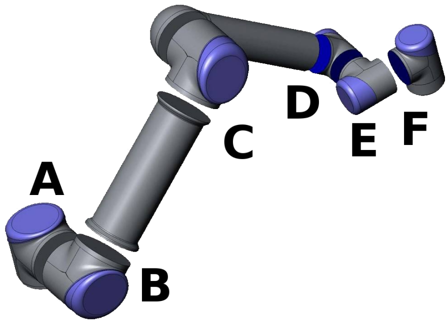


The robot is a machine that can be programmed to move a tool, and communicate with other machines using electrical signals. Using our patented programming interface, PolyScope, it is easy to program the robot to move the tool along a desired trajectory. PolyScope is described in the PolyScope Manual.

The reader of this manual is expected to be technically minded, to be familiar with the basic general concepts of programming, be able to connect a wire to a screw terminal, and be able to drill holes in a metal plate. No special knowledge about robots in general or Universal Robots in particular is required.

The rest of this chapter is an appetizer for getting started with the robot.

1.1.1 The Robot



The robot itself is an arm composed of extruded aluminum tubes and joints. The joints are named A:*Base*, B:*Shoulder*, C:*Elbow* and D,E,F:*Wrist 1,2,3*. The Base is where the robot is mounted, and at the other end (*Wrist 3*) the tool of the robot is attached. By coordinating the motion of each of the joints, the robot can move its tool around freely, with the exception of the area directly above and directly below the robot, and of course limited by the reach of the robot ($1300mm$ from the center of the base).

1.1.2 Programs

A program is a list of commands telling the robot what to do. The user interface *PolyScope*, described in the PolyScope manual, allows people with only little programming experience to program the robot. For most tasks, programming is done entirely using the touch panel without typing in any cryptic commands.

Since tool motion is such an important part of a robot program, a way of teaching the robot how to move is essential. In PolyScope, the motions of the tool are given using a series of *waypoints*. Each waypoint is a point in the robot's workspace.

Waypoints

A waypoint is a point in the workspace of the robot. A waypoint can be given by moving the robot to a certain position, or can be calculated by software. The robot performs a task by moving through a sequence of waypoints. Various options regarding how the robot moves between the waypoints can be given in the program.

Defining Waypoints, Moving the Robot. The easiest way to define a waypoint is to move the robot to the desired position. This can be done in two ways: 1) By simply pulling the robot, while pressing the 'Teach' button on the screen (see the PolyScope manual). 2) By using the touch screen to drive the tool linearly or to drive each joint individually.

Blends. Per default the robot stops at each waypoint. By giving the robot freedom to decide how to move near the waypoint, it is possible to drive through the desired path faster without stopping. This freedom is given by setting a *blend radius* for the waypoint, which means that once the robot comes within a certain distance of the waypoint, the robot can decide to deviate from the path. A blend radius of 5-10 cm usually gives good results.

Features

Besides moving through waypoints, the program can send I/O signals to other machines at certain points in the robot's path, and perform commands like `if..then` and `loop`, based on variables and I/O signals.

1.1.3 Safety Evaluation

The robot is a machine and as such a safety evaluation is required for each installation of the robot. Chapter 3.1 describes how to perform a safety evaluation.

1.2 Turning On and Off

How to turn the different parts of the robot system on and off is described in the following subsections.

1.2.1 Turning on the Controller Box

The controller box is turned on by pressing the power button, at the front side of the teach pendant. When the controller box is turned on, a lot of text will appear on the screen. After about 20 seconds, the Universal Robot's Logo will appear, with the text 'Loading'. After around 40 seconds, a few buttons appear on the screen and a popup will force the user to go to the initialization screen.

1.2.2 Turning on the Robot

The robot can be turned on if the controller box is turned on, and if all emergency stop buttons are not activated. Turning the robot on is done at the initialization screen, by touching the 'ON' button at the screen, and then pressing 'Start'. When a robot is started, a noise can be heard as the brakes unlock. After the robot has powereded up, it needs to be initialized before it can begin to perform work.

1.2.3 Initializing the Robot

After the robot is powered up, each of the robot's joints needs to find its exact position, in order to do so the joints need to move. The amount of motion needed depends on the joint position and type. Small joints need to move between 22.5° and 45°, large joints need to move half as much, the direction of rotation is unimportant. The Initialization screen, shown in figure 1.1, gives access to manual and semi-automatic driving of the robot's joints. The robot cannot automatically avoid collision with itself or the surrounds during this process. Therefore, caution should be exercised.

The *Auto* button near the top of the screen drives all joints until they are ready. When released and pressed again, all joints change drive direction. The *Manual* buttons permit manual driving of each joint.

A more detailed description of the initialization screen is found in the PolyScope manual.

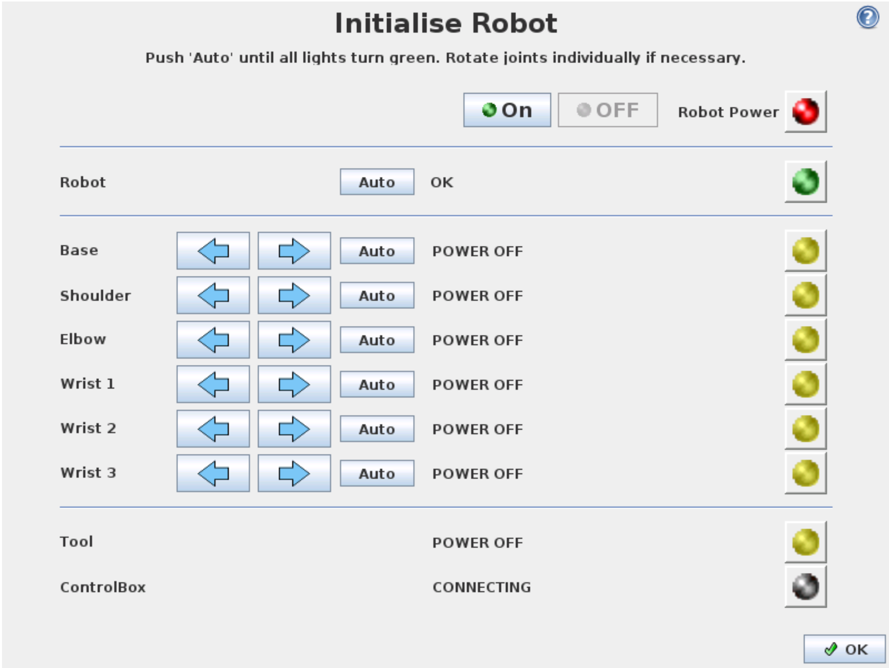


Figure 1.1: The initialization screen

1.2.4 Shutting Down the Robot

The power to the robot can be turned off by touching the 'OFF' button at the initialization screen. Most users do not need to use this feature since the robot is automatically turned off when the controller box is shutting down.

1.2.5 Shutting Down the Controller Box

Shut down the system by pressing the green power button on the screen, or by using the 'Shut Down' button on the welcome screen.

Shutting down by pulling the power cord out of the wall socket may cause corruption of the robot's file system, which may result in robot malfunction.

1.3 Quick start, Step by Step

To quickly set up the robot, perform the following steps:

1. Unpack the robot and the controller box.
2. Mount the robot on a sturdy surface.
3. Place the controller box on its foot.
4. Plug the robot cable into the connector at the bottom of the controller box.
5. Plug in the mains plug of the controller box.
6. Press the Emergency Stop button on the front side of the teach pendant.
7. Press the power button on the teach pendant.

8. Wait a minute while the system is starting up, displaying text on the touch screen.
9. When the system is ready, a popup will be shown on the touch screen, stating that the emergency stop button is pressed.
10. Touch the `OK` button at the popup.
11. Unlock the emergency stop buttons. The robot state then changes from 'Emergency Stopped' to 'Robot Power Off'.
12. Touch the `On` button on the touch screen. Wait a few seconds.
13. Touch the `Start` button on the touch screen. The robot now makes a noise and moves a little while unlocking the breaks.
14. Touch the blue arrows and move the joints around until every "light" at the right side of the screen turns green. Be careful not to drive the robot into itself or anything else.
15. All joints are now `OK`. Touch the OK button, bringing you the `Welcome` screen.
16. Touch the `PROGRAM Robot` button and select `Empty Program`.
17. Touch the `Next` button (bottom right) so that the `<empty>` line is selected in the tree structure on the left side of the screen.
18. Go to the `Structure` tab.
19. Touch the `Move` button.
20. Go to the `Command` tab.
21. Press the `Next` button, to go to the `Waypoint` settings.
22. Press the `Set this waypoint` button next to the `"?"` picture.
23. On the `Move` screen, move the robot by pressing the various blue arrows, or move the robot by holding the `Teach` button, placed on the backside of the teach pendant, while pulling the robot arm.
24. Press `OK`.
25. Press `Add waypoint before`.
26. Press the `Set this waypoint` button next to the `"?"` picture.
27. On the `Move` screen, move the robot by pressing the various blue arrows, or move the robot by holding the `Teach` button while pulling the robot arm.
28. Press `OK`.
29. Your program is ready. The robot will move between the two points when you press the 'Play' symbol. Stand clear, hold on to the emergency stop button and press 'Play'.
30. Congratulations! You have now produced your first robot program that moves the robot between the two given positions. Remember that you have to carry out a risk assessment and improve the overall safety condition before you really make the robot do some work.

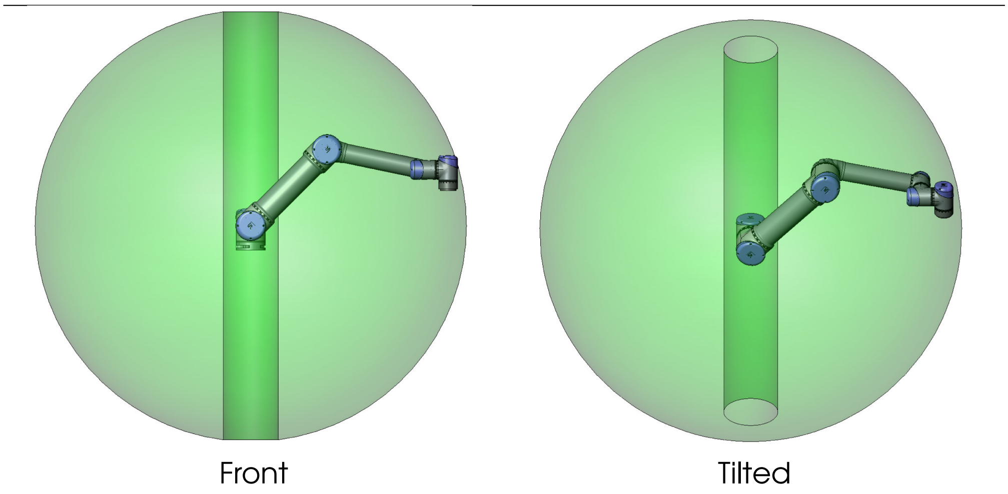


Figure 1.2: The workspace of the robot. The robot can work in an approximate sphere (Ø260cm) around the base, except for a cylindrical volume directly above and directly below the robot base.

1.4 Mounting Instructions

The robot consists essentially of six robot joints and two aluminum tubes, connecting the robot's *base* with the robot's *tool*. The robot is built so that the tool can be translated and rotated within the robot's workspace. The next subsections describes the basic things to know when mounting the different parts of the robot system.

1.4.1 The Workspace of the Robot

The workspace of the UR10 robot extends to 1300 mm from the base joint. The workspace of the robot is shown in figure 1.2. It is important to consider the cylindrical volume directly above and directly below the robot base when a mounting place for the robot is chosen. Moving the tool close to the cylindrical volume should be avoided if possible, because it causes the robot joints to move fast even though the tool is moving slowly.

1.4.2 Mounting the Robot

The robot is mounted using 4 M8 bolts, using the four $8.5mm$ holes on the robot's base. It is recommended to tighten these bolts with 20 Nm torque. If very accurate repositioning of the robot is desired, two Ø8 holes are provided for use with a pin. Also an accurate base counterpart can be purchased as accessory. Figure 1.3 shows where to drill holes and mount the screws.

1.4.3 Mounting the Tool

The robot tool flange has four holes for attaching a tool to the robot. A drawing of the tool flange is shown in figure 1.4.

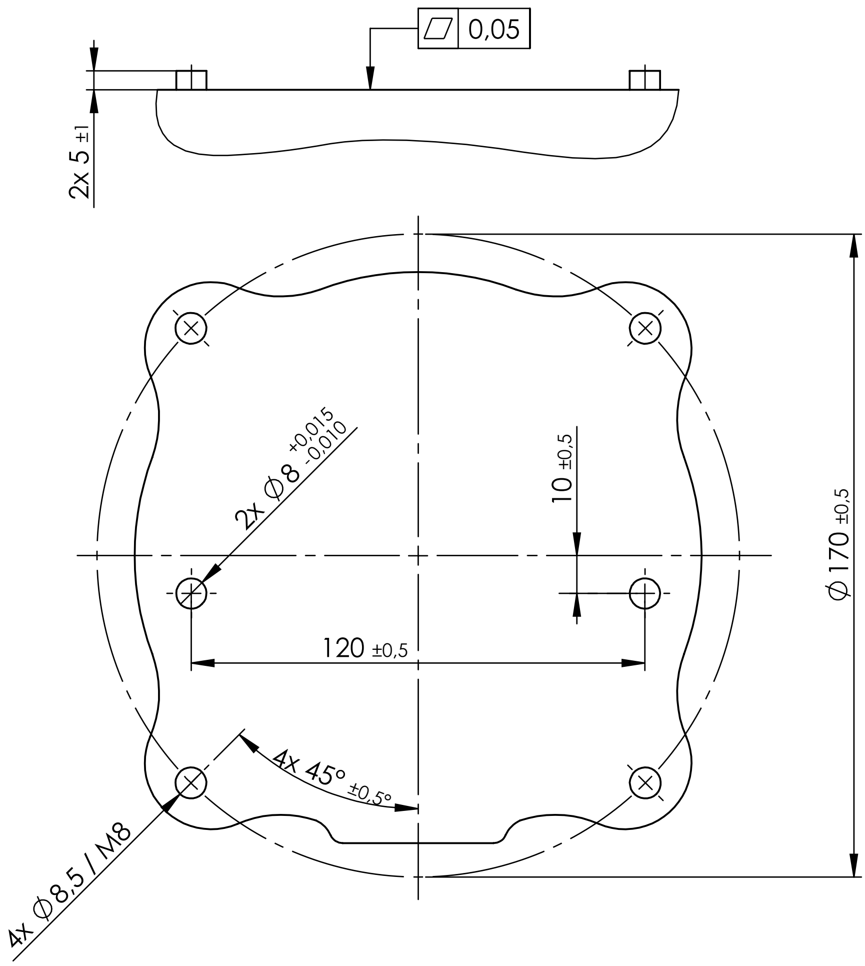


Figure 1.3: Holes for mounting the robot, scale 1:2. Use 4 M8 bolts. All measurements are in mm.

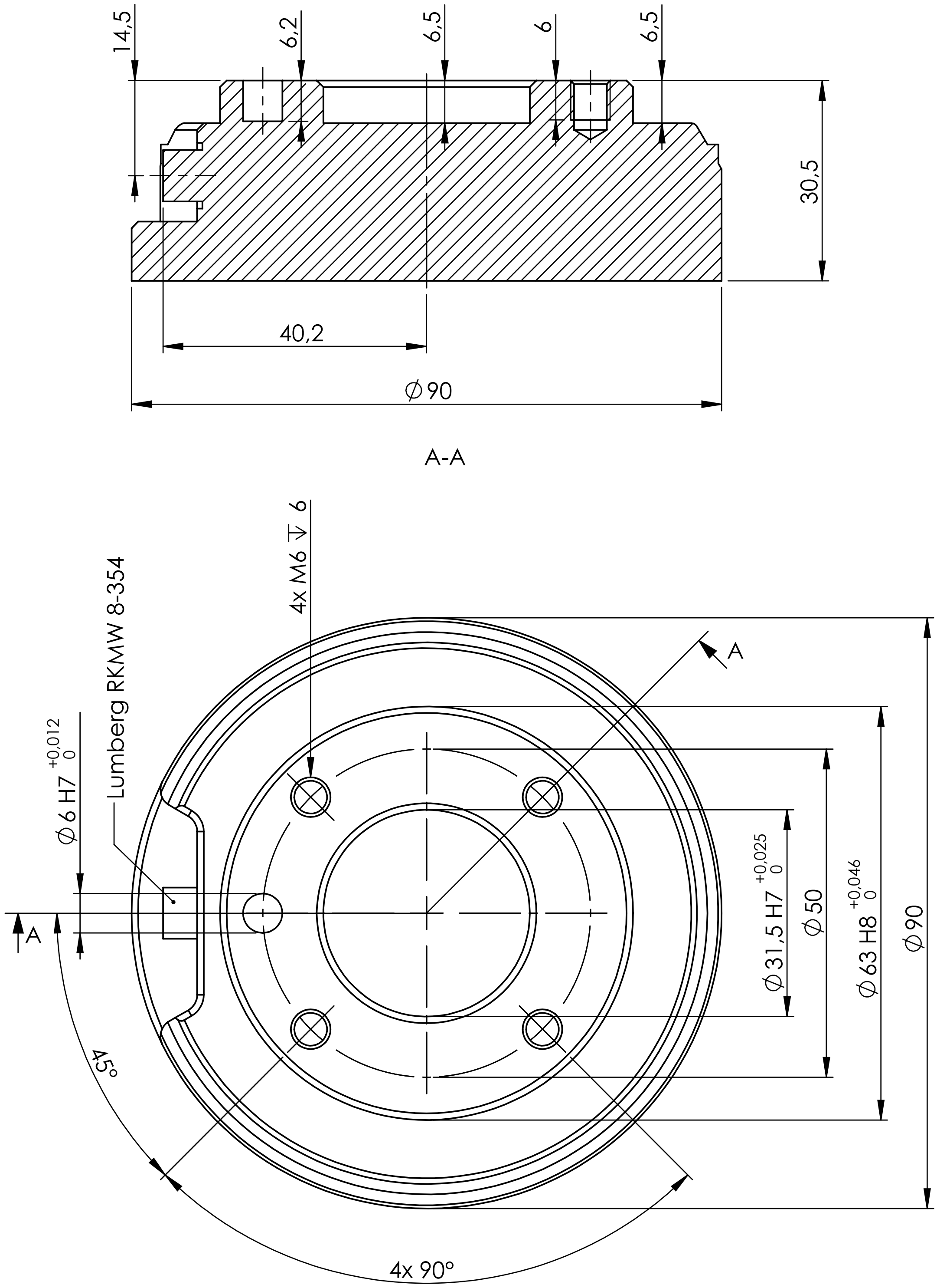


Figure 1.4: The tool output flange, ISO 9409-1-50-4-M6. This is where the tool is mounted at the tip of the robot. All measures are in mm.

1.4.4 Mounting the Controller Box

The controller box can be hung on a wall, or it can be placed on the ground. A clearance of 50mm on each side allows for sufficient airflow.

1.4.5 Mounting the Teach Pendant

The teach pendant can be hung on a wall or on the controller box. Extra fittings can be bought.

1.4.6 Connecting the Robot Cable

The cable from the robot must be plugged in to the connector at the button of the controller box. Ensure that the connector is properly locked. Connecting and disconnecting the robot cable may only be done when the robot power is turned off.

1.4.7 Connecting the Mains Cable

The mains cable from the controller box has a standard IEC plug in the end. Connect a country specific mains plug or cable to the IEC plug.

If the current rating of the specific plug is insufficient or if a more permanent solution is prefered then wire the controller box directly. The mains supply shall be equiped with the following as a minimum:

1. Main fuse.
2. Residual current device.
3. Connection to earth.

Mains input specification is shown below.

Parameter	Min	Typ	Max	Unit
Input voltage	100	-	240	VAC
External mains fuse (@ 100-200V)	15	-	16	A
External mains fuse (@ 200-240V)	8	-	16	A
Input frequency	47	-	63	Hz
Stand-by power	-	-	0.5	W
Nominal operating power	90	250	500	W

Use the screw connection marked with earth symbol inside the controller box when potential equalization with other machinery is required.

Chapter 2

Electrical Interface

2.1 Introduction

The robot is a machine that can be programmed to move a tool around in the robots workspace. Often, it is desired to coordinate robot motion with nearby machines or equipment on the tool. The most straightforward way to achieve this is often by using the electrical interface.

There are electrical input and output signals (I/Os) inside the control box and at the robot tool flange. This chapter explains how to connect equipment to the I/Os. Some of the I/Os inside the control box are dedicated to the robot safety functionality, and some are general purpose I/Os for connecting with other machines and equipment. The general purpose I/Os can be manipulated directly on the I/O tab in the user interface, see the PolyScope Manual, or by the robot programs.

For additional I/O, Modbus units can be added via the extra Ethernet connector in the control box.

2.2 Important notices

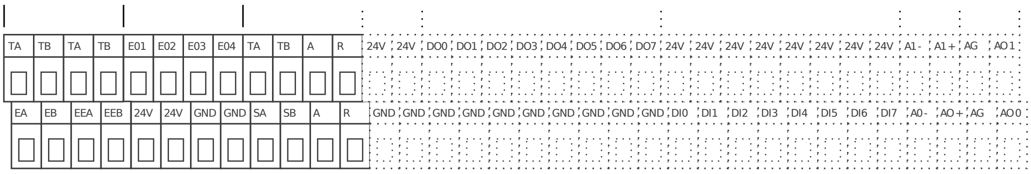
Note that according to the IEC 61000 and EN 61000 standards cables going from the control box to other machinery and factory equipment may not be longer than 30m, unless extended tests are performed.

Note that every minus connection (0V) is referred to as GND, and is connected to the shield of the robot and the control box. However, all mentioned GND connections are only for powering and signaling. For PE (Protective Earth) use one of the two M6 sized screw connections inside the control box. If FE (Functional Earth) is needed use one of the M3 screws close to the screw terminals.

Note that in this chapter, all unspecified voltage and current data are in DC.

It is generally important to keep safety interface signals seperated from the normal I/O interface signals. Also, the safety interface should never be connected to a PLC which is not a safety PLC with the correct safety level. If this rule is not followed, it is not possible to get a high safety level, since one failure in a normal I/O can prevent a safety stop signal from resulting in a stop.

2.3 The Safety Interface



Inside the control box there is a panel of screw terminals. The leftmost part, in black above, is the safety interface. The safety interface can be used to connect the robot to other machinery or protective equipment, to make sure the robots stops in certain situations.

The safety interface is comprised of two parts; the emergency stop interface and the safeguard stop interface, further described in the following sections. The table below summarizes their differences:

	Emergency Stop	Safeguard Stop
Robot stops moving	Yes	Yes
Initiations	Manual	Manual or automatic
Program execution	Stops	Pauses
Brakes	Active	Not active
Motor power	Off	Limited
Reset	Manual	Automatic or manual
Use frequency	Infrequent	Every cycle to infrequent
Requires re-initialization	Brake release only	No
EN/IEC 60204 and NFPA 79	Stop category 1	Stop category 2
Performance level	ISO 13849-1 PLd	ISO 13849-1 PLd

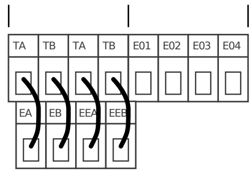
2.3.1 The Emergency Stop Interface

[TA]	Test Output A
[TB]	Test Output B
[EO1]	Emergency Stop Output Connection 1
[EO2]	Emergency Stop Output Connection 2
[EO3]	Emergency Stop Output Connection 3
[EO4]	Emergency Stop Output Connection 4
[EA]	Robot Emergency Stop Input A (Positive)
[EB]	Robot Emergency Stop Input B (Negative)
[EEA]	External Emergency Stop Input A (Positive)
[EEB]	External Emergency Stop B (Negative)
[24V]	+24V supply connection for safety devices
[GND]	0V supply connection for safety devices

The Emergency Stop interface has two inputs, the Robot Emergency Stop input and the External Emergency Stop input. Each input is doubled for redundancy due to the safety performance level **d**.

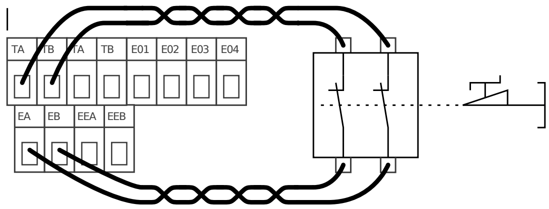
The Robot Emergency Stop interface will stop the robot, and will set the Emergency Stop output, intended for use by safety equipment near the robot. The External Emergency Stop will also stop the robot, but will not affect the Emergency Stop output, and is only intended for connecting to other machines.

The Simplest Emergency Stop Configuration



The simplest configuration is to use the internal emergency stop button as the only component to generate an emergency stop. This is done with the configuration shown above. This configuration is the default when the robot leaves the factory, and thereby the robot is ready to operate. However, the emergency configuration should be changed if required by the risk assessment.

Connecting an External Emergency Stop Button

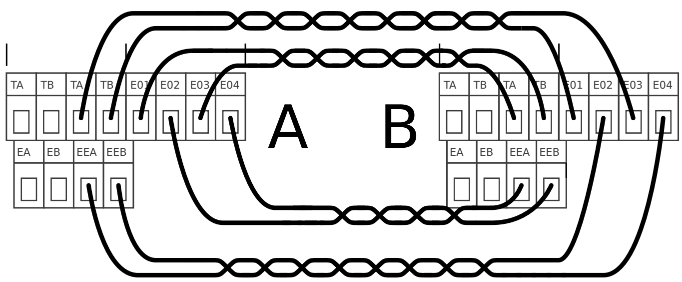


In almost every robot application it is required to connect one or more external emergency stop buttons. Doing so is simple and easy. An example of how to connect one extra button is shown above.

Connecting Emergency Stop to Other Machinery

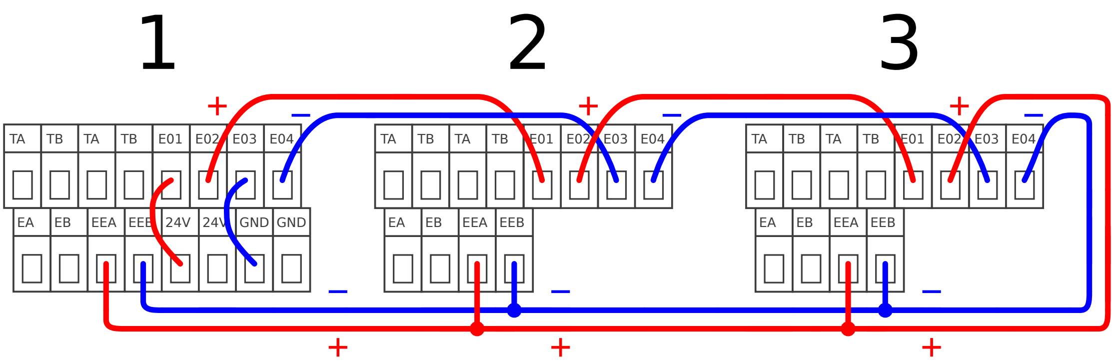
When the robot is used together with other electro-mechanical machinery, it is often required to set up a common emergency stop circuit. This ensures that if a dangerous situation arises, the operator does not need to think about which buttons to use. It is also often preferable for every part of a sub-function in a product line to be synchronized, since a stop in only one part of the product line can lead to a dangerous situation.

An example with two UR robots emergency stopping each other is shown below.



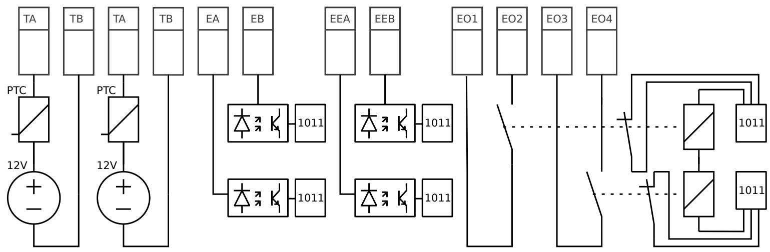
An example where multiple UR robots share their emergency stop function is shown below. Connect more robots as robot number 2 is connected.

This example uses 24V which works with many other machines. Make sure to comply with all electrical specifications when UR robots share emergency stop with other machinery.



Electric Specifications

A simplified internal schematic of circuitry is shown below. It is important to notice that any short circuit or lost connection will lead to a safe stop, as long as only one error appears at a time. Failure and abnormal behavior of relays and power supplies results in an error message in the robot log and prevents the robot from powering up.



Below: Specifications of the Emergency Stop Interface.

Parameter	Min	Typ	Max	Unit
[TA-TB] Voltage	10.5	12	12.5	V
[TA-TB] Current (Each output)	-	-	120	mA
[TA-TB] Current protection	-	400	-	mA
[EA-EB] [EEA-EEB] Input voltage	-30	-	30	V
[EA-EB] [EEA-EEB] Guaranteed OFF if	-30	-	7	V
[EA-EB] [EEA-EEB] Guaranteed ON if	10	-	30	V
[EA-EB] [EEA-EEB] Guaranteed OFF if	0	-	3	mA
[EA-EB] [EEA-EEB] ON Current (10-30V)	7	-	14	mA
[EO1-EO2] [EO3-EO4] Contact Current AC/DC	0.01	-	6	A
[EO1-EO2] [EO3-EO4] Contact Voltage DC	5	-	50	V
[EO1-EO2] [EO3-EO4] Contact Voltage AC	5	-	250	V

Note the number of safety components that should be used and how they must work depend on the risk assessment, which is explained in section 3.1.

Note that it is important to make regular checks of the safety stop functionality to ensure that all safety stop devices are functioning correctly.

The two emergency stop inputs EA-EB and EEA-EEB are potential free inputs conforming to IEC 60664-1 and EN 60664-1, pollution degree 2, overvoltage category II.

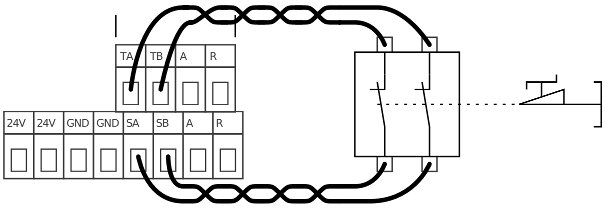
The emergency stop outputs EO1-EO2-EO3-EO4 are relay contacts conforming to IEC 60664-1 and EN 60664-1, pollution degree 2, over-voltage category III.

2.3.2 The Safeguard Interface

[TA] [TB]	Test Output A Test Output B
[SA] [SB]	Safeguard Stop Input A (Positive) Safeguard Stop Input B (Negative)
[A] [R]	Automatic continue after safeguard stop Reset safeguard stop
[24V] [GND]	+24V supply connection for safety devices 0V supply connection for safety devices

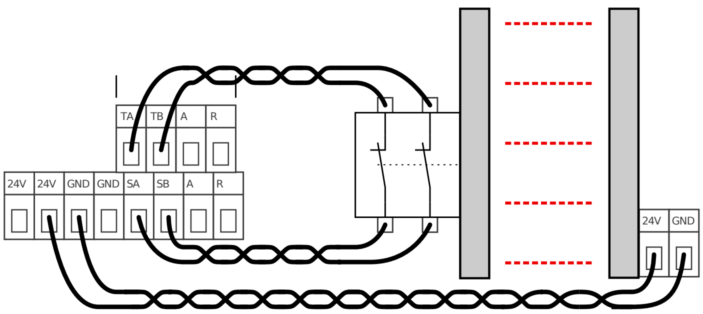
The Safeguard Interface is used to pause the robot movement in a safe way. The Safeguard Interface can be used for light guards, door switches, safety PLCs etc. Resuming from a safeguard stop can be automatic or can be controlled by a pushbutton, depending on the safeguard configuration. If the Safeguard Interface is not used then enable automatic reset functionality as described in section 2.3.3.

Connecting a door switch



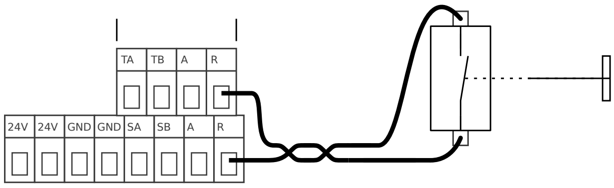
Connecting a door switch or something comparable is done as shown above. Remember to use a reset button configuration if the robot should not start automatically when the door is closed again.

Connecting a light guard



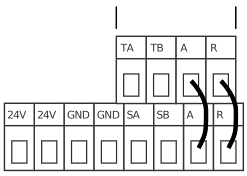
How to connect a light guard is shown above. It is also possible to use a category 1 (ISO 13849-1 and EN 954-1) light guard if the risk assessment allows it. When connecting a category 1 light guard use TA and SA and then connect TB and SB with a wire. Remember to use a reset button configuration so that the safeguard stop is latched.

Connecting a reset button



How to connect a reset button is shown above. It is not allowed to have a permanently pushed reset button. If the reset button is stuck a safeguard stop is generated and an error message will appear on the log screen.

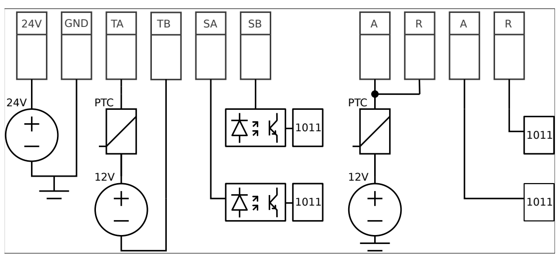
2.3.3 Automatic continue after safeguard stop



The safeguard interface can reset itself when a safeguard stop event is gone. How to enable automatic reset functionality is shown above. This is also the recommended configuration if the safeguard interface is not used. However, it is not recommended to use automatic reset if a reset button configuration is possible. Automatic reset is intended for special installations and installations with other machinery.

Electric Specifications

To understand the safeguard functionality, a simplified internal schematics of the circuitry is shown below. Any failure in the safety system will lead to a safe stop of the robot and an error message on the log screen.

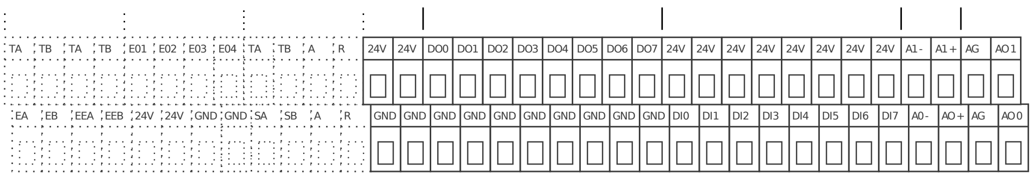


Parameter	Min	Typ	Max	Unit
24V Voltage tolerance	-15%	-	+20%	-
Current available from 24V supply	-	-	1.2*	A
Overload protection	-	1.4	-	A
[TA-TB] [A↑] [R↑] Voltage	10.5	12	12.5	V
[TA-TB] [A↑] [R↑] Current	-	-	120	mA
[TA-TB] [A↑] [R↑] Current protection	-	400	-	mA
[SA-SB] Input voltage	-30	-	30	V
[SA-SB] Guaranteed OFF if	-30	-	7	V
[SA-SB] Guaranteed ON if	10	-	30	V
[SA-SB] Guaranteed OFF if	0	-	3	mA
[SA-SB] ON Current (10-30V)	7	-	14	mA
[A↓] [R↓] Input voltage	-30	-	30	V
[A↓] [R↓] Input guaranteed OFF if	-30	-	7	V
[A↓] [R↓] Input guaranteed ON if	10	-	30	V
[A↓] [R↓] Guaranteed OFF if	0	-	5	mA
[A↓] [R↓] ON Current (10-30V)	6	-	10	mA

The safeguard stop input SA-SB is a potential free input conforming to IEC 60664-1 and EN 60664-1, pollution degree 2, over-voltage category II.

Note that the yellow 24V connections is sourced by the same internal 24V power supply as the 24V connections of the normal I/O, and that the maximum of 1.2 A is for both power sources together.

2.4 Controller I/O



Inside the control box there is a panel of screw terminals with various I/O parts, as shown above. The rightmost part of this panel is general purpose I/O.

[24V]	+24V supply connection
[GND]	0V supply connection
[DOx]	Digital output number x
[DIx]	Digital input number x
[AOx]	Analog output number x plus
[AG]	Analog output GND
[Ax+]	Analog input number x plus
[Ax-]	Analog input number x minus

The I/O panel in the control box has 8 digital and 2 analog inputs, 8 digital and 2 analog outputs, and a built in 24V power supply. Digital inputs and outputs are **pnp** technology and constructed in compliance with IEC 61131-2 and EN 61131-2. 24V and GND can be used as input for the I/O module or output as a 24V power supply. When the control box is booting it checks if voltage is applied to the 24V connection from an external power supply, and if not, it automatically connects the internal 24V power supply.

Electrical specifications of the internal power supply

Parameter	Min	Typ	Max	Unit
Internal 24V voltage tolerance	-15%	-	+20%	-
Current from internal 24V supply	-	-	1.2*	A
Overload protection	-	1.4	-	A
External power supply voltage	10	-	30	V

Note that the safeguard (yellow) 24V connections are sourced by the same internal 24V power supply as the 24V connections of the normal I/O, and that the maximum of 1.2 A is for both power sources together.

If the current load of the internal 24V power supply is exceeded, an error message is printed on the log screen. The power supply will automatically try to recover after a few seconds.

2.4.1 Digital Outputs

Parameter	Min	Typ	Max	Unit
Source current per output	0	-	2	A
Source current all outputs together	0	-	4	A
Voltage drop when ON	0	-	0.2	V
Leakage current when OFF 0	0	-	0.1	mA

The outputs can be used to drive equipment directly e.g. pneumatic relays or they can be used for communication with other PLC systems. The outputs are constructed in compliance with all three types of digital inputs defined in IEC 61131-2 and EN 61131-2, and with all requirements for digital outputs of the same standards.

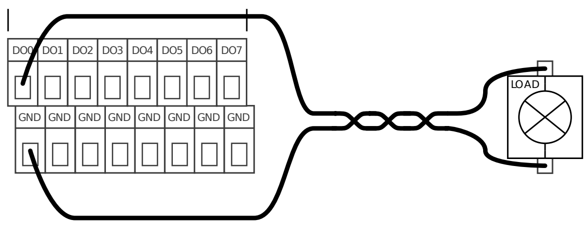
All digital outputs can be disabled automatically when a program is stopped, by using the check box "Always low at program stop" on the I/O Name screen (see the PolyScope manual). In this mode, the output is always low when a program is not running.

The digital outputs are not current limited and overriding the specified data can cause permanent damage. However, it is not possible to damage the outputs if the internal 24V power supply is used due to its current protection.

Note that the control box and the metal shields are connected to GND. Never send I/O current through the shields or earth connections.

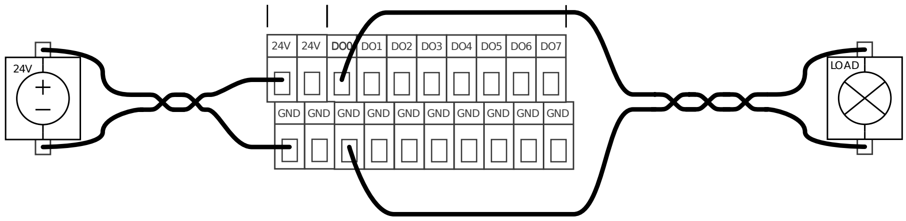
The next subsections show some simple examples of how the digital outputs could be used.

Load Controlled by Digital Output



This example illustrates how to turn on a load.

Load Controlled by Digital Output, External Power



If the available current from the internal power supply is not enough, simply use an external power supply, as shown above.

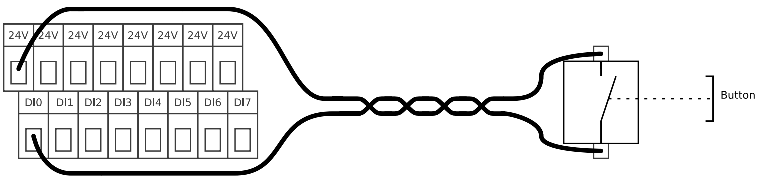
2.4.2 Digital Inputs

Parameter	Min	Typ	Max	Unit
Input voltage	-30	-	30	V
Input guaranteed OFF if	-30	-	7	V
Input guaranteed ON if	10	-	30	V
Guaranteed OFF if	0	-	5	mA
ON Current (10-30V)	6	-	10	mA

The digital inputs are implemented as **pnp** which means that they are active when voltage is applied to them. The inputs can be used to read buttons, sensors or for communication with other PLC systems. The inputs are compliant with all three types of digital inputs defined in IEC 61131-2 and EN 61131-2, which means that they will work together with all types of digital outputs defined in the same standards.

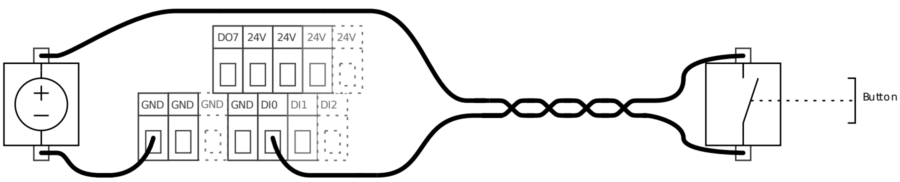
Technical specifications of the digital inputs are shown below.

Digital Input, Simple Button



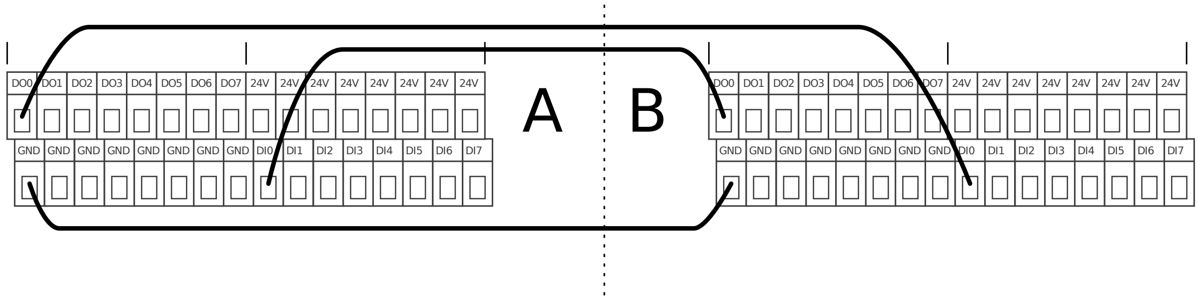
The above example shows how to connect a simple button or switch.

Digital Input, Simple Button, External Power



The above illustration shows how to connect a button using an external power source.

Signal Communication with other Machinery or PLCs



If communication with other machinery or PLCs is needed they must use **pnp** technology. Remember to create a common GND connection between the different interfaces. An example where two UR robots (A and B) are communicating with each other is illustrated above.

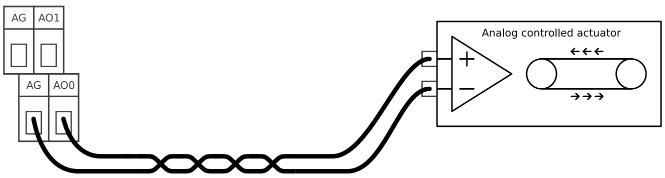
2.4.3 Analog Outputs

Parameter	Min	Typ	Max	Unit
Valid output voltage in current mode	0	-	10	V
Valid output current in voltage mode	-20	-	20	mA
Short-circuit current in voltage mode	-	40	-	mA
Output resistance in voltage mode	-	43	-	ohm

The analog outputs can be set for both current mode and voltage mode, in the range of 4-20mA and 0-10V respectively.

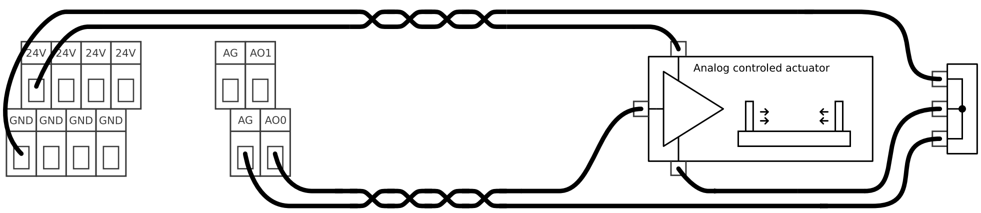
To illustrate clearly how easy it is to use analog outputs, some simple examples are shown.

Using the Analog Outputs



This is the normal and best way to use analog outputs. The illustration shows a setup where the robot controller controls an actuator like a conveyor belt. The best result is accomplished when using current mode, because it is more immune to disturbing signals.

Using the Analog Outputs, Non-Differential Signal



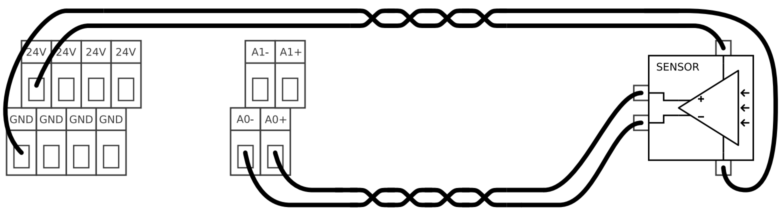
If the controlled equipment does not take a differential input, an alternative solution can be made as shown above. This solution is not very good in terms of noise, and can easily pick up disturbing signals from other machinery. Care must be taken when the wiring is done, and it must be kept in mind that disturbing signals induced into analog outputs may also be present on other analog I/O.

2.4.4 Analog Inputs

Parameter	Min	Typ	Max	Unit
Common mode input voltage	-33	-	33	V
Differential mode input voltage*	-33	-	33	V
Differential input resistance	-	220	-	kohm
Common mode input resistance	-	55	-	kohm
Common mode rejection ratio	75	-	-	dB

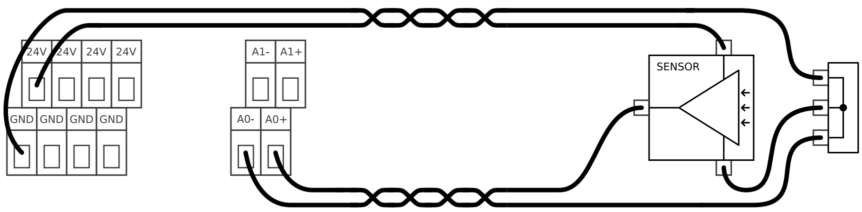
The analog inputs can be set to four different voltage ranges, which are implemented in different ways, and therefore can have different offset and gain errors. The specified differential mode input voltage is only valid with a common mode voltage of 0V. To make it clear how easy it is to use analog outputs, some simple examples are shown.

Using Analog Inputs, Differential Voltage Input



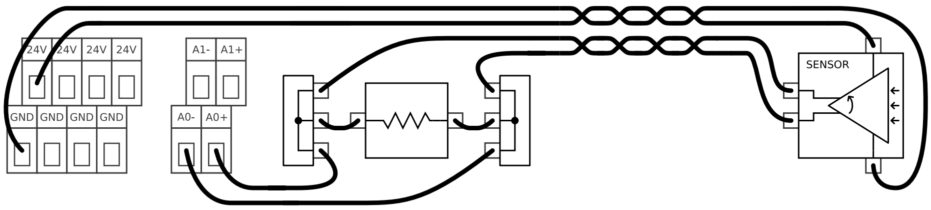
The simplest way to use analog inputs. The equipment shown, which could be a sensor, has a differential voltage output.

Using Analog Inputs, Non-differential Voltage Input



If it is not possible to achieve a differential signal from the equipment used, a solution could look something like the setup above. Unlike the non-differential analog output example in subsection 2.4.3, this solution would be almost as good as the differential solutions.

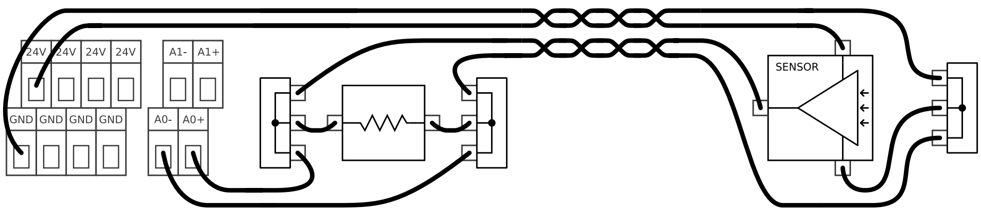
Using Analog Inputs, Differential Current Input



When longer cables are used, or if it is a very noisy environment, current based signals are preferred. Also, some equipment comes only with a current output. To use current as inputs, an external resistor is needed as shown above. The value of the resistor would normally be around 200 ohms, and the best result is accomplished when the resistor is close to the screw terminals of the control box.

Note that the tolerance of the resistor and the ohmic change due to temperature must be added to the error specifications of the analog inputs.

Using Analog Inputs, Non-differential Current Input



If the output of the equipment is a non-differential current signal, a resistor must be used as shown above. The resistor should be around 200 ohms and the relationship between the voltage at the controller input and the output of the sensor is given by:

Voltage = Current x Resistance

Note that the tolerance of the resistor and the ohmic change due to temperature must be added to the error specifications of the analog inputs.

2.5 Tool I/O

At the tool end of the robot there is a small connector with eight connections.

Color	Signal
Red	0V (GND)
Gray	0V/12V/24V (POWER)
Blue	Digital output 8 (DO8)
Pink	Digital output 9 (DO9)
Yellow	Digital input 8 (DI8)
Green	Digital input 9 (DI9)
White	Analog input 2 (AI2)
Brown	Analog input 3 (AI3)

This connector provides power and control signals for basic grippers and sensors, which may be present on a specific robot tool. This connector can be used to reduce wiring between the tool and the control box. The connector is a standard Lumberg RSMEDG8, which mates with a cable named RKMV 8-354.

Note that the tool flange is connected to GND (same as the red wire).

Internal Power Supply Specifications

Parameter	Min	Typ	Max	Unit
Supply voltage in 24V mode	TBD	24	TBD	V
Supply voltage in 12V mode	TBD	12	TBD	V
Supply current in both modes	-	-	600	mA
Short-circuit current protection	-	650	-	mA
Capacitive load	-	-	TBD	uF
Inductive load	-	-	TBD	uH

The available power supply can be set to either 0V, 12V or 24V at the I/O tab in the graphical user interface. Take care when using 12V, since an error made by the programmer can cause a voltage change to 24V, which might damage the equipment and even cause a fire.

The internal control system will generate an error to the robot log if the current exceeds its limit. The different I/Os at the tool is described in the following three subsections.

2.5.1 Digital Outputs

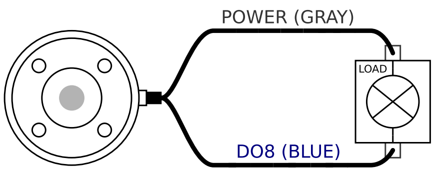
Parameter	Min	Typ	Max	Unit
Voltage when open	-0.5	-	26	V
Voltage when sinking 1A	-	0.05	0.20	V
Current when sinking	0	-	1	A
Current through GND	-	-	1	A
Switch time	-	1000	-	us
Capacitive load	-	-	TBD	uF
Inductive load	-	-	TBD	uH

The digital outputs are implemented so that they can only sink to GND (0V) and not source current. When a digital output is activated, the corresponding connection is driven to GND, and when it is deactivated, the corresponding connection is open (open-collector/open-drain). The primary difference between the digital outputs inside the control box and those in the tool is the reduced current due to the small connector.

Note that the digital outputs in the tool are not current limited and overriding the specified data can cause permanent damage.

To illustrate clearly how easy it is to use digital outputs, a simple example is shown.

Using Digital Outputs



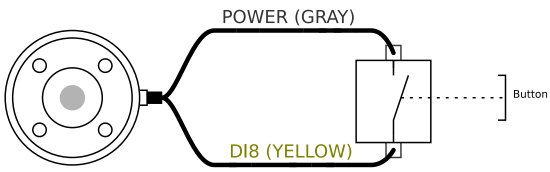
This example illustrates how to turn on a load, when using the internal 12V or 24V power supply. Remember that you have to define the output voltage at the I/O tab. Keep in mind that there is voltage between the POWER connection and the shield/ground, even when the load is turned off.

2.5.2 Digital Inputs

Parameter	Min	Typ	Max	Unit
Input voltage	-0.5	-	26	V
Logical low voltage	-	-	2.0	V
Logical high voltage	5.5	-	-	V
Input resistance	-	47k	-	Ω

The digital inputs are implemented with weak pull-down resistors. This means that a floating input will always read low. The digital inputs at the tool are implemented in the same way as the digital inputs inside the control box.

Using Digital Inputs



The above example shows how to connect a simple button or switch.

2.5.3 Analog Inputs

The analog inputs at the tool are very different from those inside the control box. The first thing to notice is that they are non-differential, which is a drawback compared to the analog inputs at the controller I/O. The second thing to notice is that the tool analog inputs have current mode functionality, which is an advantage compared with the controller I/O. The analog inputs can be set to different input ranges, which are implemented in different ways, and therefore can have different offset and gain errors.

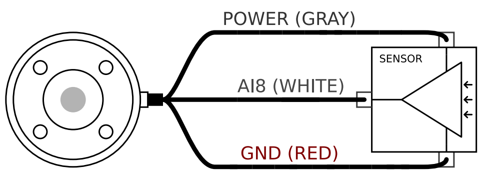
Parameter	Min	Typ	Max	Unit
Input voltage in voltage mode	-0.5	-	26	V
Input voltage in current mode	-0.5	-	5.0	V
Input current in current mode	-2.5	-	25	mA
Input resistance @ range 0V to 5V	-	29	-	kΩ
Input resistance @ range 0V to 10V	-	15	-	kΩ
Input resistance @ range 4mA to 20mA	-	200	-	Ω

An important thing to realize is that any current change in the common GND connection can result in a disturbing signal in the analog inputs, because there will be a voltage drop along the GND wires and inside connectors.

Note that a connection between the tool power supply and the analog inputs will permanently damage the I/O functionality, if the analog inputs are set in current mode.

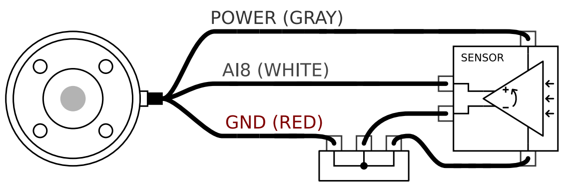
To make it clear how easy it is to use digital inputs, some simple examples are shown.

Using Analog Inputs, Non-differential



The simplest way to use analog inputs. The output of the sensor can be either current or voltage, as long as the input mode of that analog input is set to the same on the I/O tab. Remember to check that a sensor with voltage output can drive the internal resistance of the tool, or the measurement might be invalid.

Using Analog Inputs, Differential



Using sensors with differential outputs is also straightforward. Simply connect the negative output part to GND (0V) with a terminal strip and it will work in the same way as a non-differential sensor.

Chapter 3

Safety

3.1 Introduction

This chapter gives a short introduction to the statutory documentation and important information about the risk assessment, followed by a section concerning emergency situations. Regarding safety in general all assembly instructions from 1.4 and 2.1 shall be followed. Technical specifications of the electrical safety interface, including performance level and safety categories, are found in section 2.3.

3.2 Statutory documentation

A robot installation within the EU shall comply with the machinery directive to insure its safety. This includes the following points.

1. Make sure that the product comply with all essential requirements.
2. Make a risk assessment.
3. Specify instructions for the operator.
4. Make a declaration of conformity.
5. Collect all information in a technical file.
6. Put a CE mark on the robot installation.

In a given robot installation, the integrator is responsible for the compliance with all relevant directives. Universal Robots takes responsibility for the robot itself complying with the relevant EU directives (See section 5.1).

Universal Robots provides a safety guide, available at http://www.universal-robots.com, for integrators with little or no experience in making the necessary documentation.

If the robot is installed outside EU, the robot integration shall comply with the local directives and laws of the specific country. The integrator is responsible for this compliance. It is always necessary to perform a risk assessment to ensure that the complete robot installation is sufficiently safe.

3.3 Risk assessment

One of the most important things that an integrator needs to do is to make a risk assessment. Universal Robots has identified the potential significant hazards listed below as hazards which must be considered by the integrator. Note that other significant hazards might be present in a specific robot installation.

1. Entrapment of fingers between robot foot and base (joint 0).
2. Entrapment of fingers between the arm and wrist (joint 4).
3. Penetration of skin by sharp edges and sharp points on tool or tool connector.
4. Penetration of skin by sharp edges and sharp points on obstacles near the robot track.
5. Bruising due to stroke from the robot.
6. Sprain or bone fracture due to strokes between a heavy payload and a hard surface.
7. Consequences due to loose bolts that holds the robot arm or tool.
8. Items falling out of tool. E.g. due to a poor grip or power interruption.
9. Electrical shock or fire due to malfunction of power supplies if the mains connection is not protected by a main fuse, a residual current device and a proper connection to earth. See section 1.4.7.
10. Mistakes due to different emergency stop buttons for different machines. Use common emergency stop function as descriped in section 2.3.1.

However, the UR10 is a very safe robot due to the following reasons:

1. Control system conforms to ISO 13849-1 performance level **d**.
2. The control system of the robot is redundant so that all dangerous failures forces the robot to enter a safe condition.
3. High level software generates a protective stop if the robot hits something. This stop force limit is lower than 150N.
4. Furthermore, low level software limits the torque generated by the joints, permitting only a small deviation from the expected torque.
5. The software prevents program execution when the robot is mounted differently than specified in the setup.
6. The weight of the robot is less than 28kg.
7. The robot shape is smooth, to reduces pressure (N/m^2) per force (N).
8. It is possible to move the joints of an unpowered robot. See section 3.4

The fact that the robot is very safe opens the possibility of either saving the safety guards or using safety guards with a low performance level. As a help in convincing customers and local authorities the UR10 robot has been certified by the Danish Technological Institute which is a Notified Body under the machinery directive in Denmark. The certification concludes that the robot complies with article 5.10.5 of the EN ISO 10218-1:2006. This standard is harmonized under the machinery directive and it specifically states that a robot can operate as a collaborative robot (i.e. without safety guards between the robot and the operator) if it is in compliance with the article 5.10.5. The risk assessment still needs to conclude that the overall robot installation is safe enough of course. A copy of the certification report can be requested from Universal Robots.

The standard EN ISO 10218-1:2006 is valid untill the 1st of January 2013. In the meantime the newer version EN ISO 10218-1:2011 and the corrosponding EN ISO 10218-2:2011 addressed to the integrators are also valid. Where the EN ISO 10218-1:2006 specifically states that a maximum force of 150N combined with a supporting risk assesment is required for collaborative operation, the newer standards does not specify a specific maximum force but leaves this to the specific risk assesment. In general this means that regardless of the standard used a risk assesment shall confirm that the collaborative robot installation is sufficiently safe, and for most cases the combination of a well constructed robot installation and the maximum force of 150N is sufficient.

3.4 Emergency situations

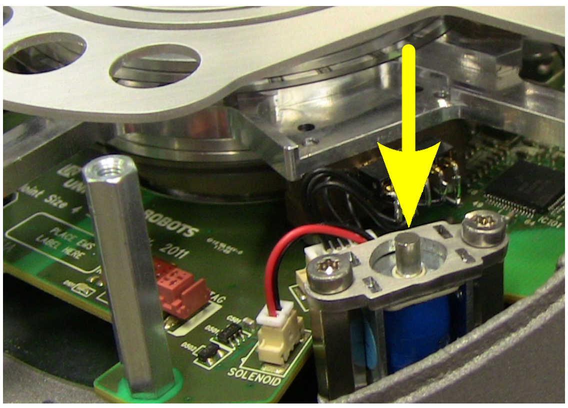
In the unlikely event of an emergency situation where one or more robot joints needs to be moved and robot power is either not possible or unwanted, there are three different ways to force movements of the robot joints without powering the motors of the joints:

1. Active backdriving: If possible, power on the robot by pushing the "ON" button on the initializing screen. Instead of pushing the "break release" button to power up the joint motors, push the teach button on the backside of the teach pendant. A special backdrive mode is entered and the robot will loosen its breacks automatically while the robot is hand guided. Releasing the teach button re-locks the breaks.

2. Manual break release: Remove the joint cover by removing the few M3 screws that fix it. Release the break by pushing the plunger on the small electro magnet as shown in the picture below.

3. Forced backdriving: Force a joint to move by pulling hard in the robot arm. Each joint break has a friction clutch which enables movement during high forced torque. Forced backdriving is intended for urgent emergencies only and might damage the joint gears and other parts.

Do not turn any joints more than necessary and beware of gravity and heavy payloads.



Chapter 4

Warranties

4.1 Product Warranty

Without prejudice to any claim the user (customer) may have in relation to the dealer or retailer, the customer shall be granted a manufacturer's Warranty under the conditions set out below:

In the case of new devices and their components exhibiting defects resulting from manufacturing and/or material faults within 12 months of entry into service (maximum of 15 months from shipment), Universal Robots shall provide the necessary spare parts, while the user (customer) shall provide working hours to replace the spare parts, either replace the part with another part reflecting the current state of the art, or repair the said part. This Warranty shall be invalid if the device defect is attributable to improper treatment and/or failure to comply with information contained in the user guides. This Warranty shall not apply to or extend to services performed by the authorized dealer or the customer themselves (e.g. installation, configuration, software downloads). The purchase receipt, together with the date of purchase, shall be required as evidence for invoking the Warranty. Claims under the Warranty must be submitted within two months of the Warranty default becoming evident. Ownership of devices or components replaced by and returned to Universal Robots shall vest in Universal Robots. Any other claims resulting out of or in connection with the device shall be excluded from this Warranty. Nothing in this Warranty shall attempt to limit or exclude a Customer's Statutory Rights, nor the manufacturer's liability for death or personal injury resulting from its negligence. The duration of the Warranty shall not be extended by services rendered under the terms of the Warranty. Insofar as no Warranty default exists, Universal Robots reserves the right to charge the customer for replacement or repair. The above provisions do not imply a change in the burden of proof to the detriment of the customer.

In case of a device exhibiting defects, Universal Robots shall not cover any consequential damage or loss, such as loss of production or damage to other production equipment.

4.2 Disclaimer

Universal Robots continues to improve reliability and performance of its products, and therefore reserves the right to upgrade the right to upgrade the product without prior warning. Universal Robots takes every care that the contents of this manual are precise and correct, but takes no responsibility for any errors or missing information.

Chapter 5

Declaration of Incorporation

5.1 Introduction

According to the machinery directive 2006/42/EC, the robot is considered a partly completed machine. The following subsections corresponds to and are in accordance with annex II of this directive.

5.2 Product manufacturer

Name	Universal Robots A/S
Address	Sivlandvænget 1 5260 Odense S Denmark
Phone number	+45 8993 8989
E-mail address	sales@universal-robots.com
International VAT number	DK29138060

5.3 Person Authorised to Compile the Technical Documentation

Name	Lasse Kieffer
Address	Sivlandvænget 1 5260 Odense S Denmark
Phone number	+45 8993 8971
E-mail address	kieffer@universal-robots.com

5.4 Description and Identification of Product

The robot is intended for simple and safe handling tasks such as pick-and-place, machine loading/unloading, assembly and palletizing.

Generic denomination	UR10
Function	General purpose industrial robot
Model	UR10
Serial number of robot arm	
Serial number of control box	
Commercial name	UR10

5.5 Essential Requirements

The individual robot installations have different safety requirements and the integrator is therefore responsible for all hazards which are not covered by the general design of the robot. However, the general design of the robot, including its interfaces meets all essential requirements listed in annex I of 2006/42/EC.

The technical documentation of the robot is in accordance with annex VII part B of 2006/42/EC.

Applied directives	2006/42/EC Machinery Directive 2004/108/EC EMC Directive 2002/95/EC RoHS Directive 2002/96/EC WEEE Directive
Applied harmonized standards (Under applied directives)	ISO 13849-1:2006 ISO 13849-2:2003 ISO 10218-1:2006 (Partly) ISO 10218-1:2011 (Partly) ISO 10218-2:2011 (Partly) ISO 13850:2006 ISO 12100:2010 ISO 3745:2003 IEC 61000-6-2 ED 2.0:2005 IEC 61000-6-4 AMD1 ED 2.0:2010 IEC 61131-2 ED 3.0:2007 (Partly) EN ISO 13849-1:2008 EN ISO 13849-1/AC:2009 EN ISO 13849-2:2008 EN ISO 10218-1:2008 (Partly) EN ISO 10218-1:2011 (Partly) EN ISO 10218-2:2011 (Partly) EN ISO 13850:2008 EN ISO 12100:2010 EN ISO 3745:2009 EN 61000-6-2:2005 EN 61000-6-4/A1:2011 EN 61131-2:2007 (Partly) EN 1037:2010
Applied general standards (Not all standards are listed)	ISO 9409-1:2004 (Partly) ISO 9283:1999 (Partly) ISO 9787:2000 (Partly) ISO 9946:2000 (Partly) ISO 8373:1996 (Partly) ISO/TR 14121-2:2007 ISO 1101:2004 ISO 286-1:2010 ISO 286-2:2010 IEC 60664-1 ED 2.0:2007 IEC 60947-5-5:1997 IEC 60529:1989+A1:1999 IEC 60320-1 Ed 2.0:2001 IEC 60204-1 Ed 5.0:2005 (Partly) EN ISO 9409-1:2004 (Partly) EN ISO 9283:1999 (Partly) EN ISO 9787:2000 (Partly) EN ISO 9946:2000 (Partly) EN ISO 8373:1996 (Partly) EN ISO/TR 14121-2:2007 EN ISO 1101:2005 EN ISO 286-1:2010 EN ISO 286-2:2010 EN 60664-1:2007 EN 60947-5-5:1998 EN 60947-5-5/A1:2005 EN 50205:2003 EN 60529:1991+A1:2000 EN 60320:2003 EN 60204:2006 (Partly)

Note that the low voltage directive is not listed. The machinery directive

2006/42/EC and the low voltage directives are primary directives. A product can only be covered by one primary directive and because the main hazards of the robot are due to mechanical movement and not electrical shock, it is covered by the machinery directive. However, the robot design meets all relevant requirements to electrical construction described in the low voltage directive 2006/95/EC.

Also note that the WEEE directive 2002/96/EC is listed because of the crossed-out wheeled bin symbol on the robot and the control box. Universal Robots registers all robot sales within Denmark to the national WEEE register of Denmark. Every distributor outside Denmark and within the EU must make their own registration to the WEEE register of the country in which their company is based.

5.6 National Authority Contact Information

Authorised person	Lasse Kieffer +45 8993 8971 kieffer@universal-robots.com
CTO	Esben H. Østergaard +45 8993 8974 esben@universal-robots.com
CEO	Enrico Krog Iversen +45 8993 8973 eki@universal-robots.com

5.7 Important Notice

The robot may not be put into service until the machinery into which it is to be incorporated has been declared to be in conformity with the provisions of the Machinery Directive 2006/42/EC and with national implementing legislation.

5.8 Place and Date of the Declaration

Place	Universal Robots A/S Sivlandvænget 1 5260 Odense S Denmark
Date	1. December 2011

5.9 Identity and Signature of the Empowered Person

Name	Lasse Kieffer
Address	Sivlandvænget 1 5260 Odense S Denmark
Phone number	+45 8993 8971
E-mail address	kieffer@universal-robots.com
Signature	

Appendix A

Certifications

DANISH TECHNOLOGICAL INSTITUTE

Teknologiparken
Kongsvang Allé 29
DK-8000 Århus C
Tel. +45 72 20 10 00
Fax +45 72 20 10 19

Universal Robots ApS
Attn.: Lasse Kieffer
Svendborgvej 102
DK-5260 Odense S

16 March 2012
1302213-463858
TGR/BBJ

Test of UR10 Robot

Danish Technological Institute, Centre for Materials Testing has tested a UR10 robot for Universal Robots ApS, see report 1302213-463858.

The test is performed in accordance with the following standards:

- EN ISO 10218-1:2011 5.10, item 5.10.5
- EN ISO 10218-2:2011 5.11, item 5.11.5.5
- EN ISO 10218-1:2006 5.10, item 5.10.5
- ANSI/RIA/ISO 10218-1-2007 5.10, item 5.10.5

The robot is tested in a limited workspace and a force limit of 150N at the tool center point (TCP) of the robot is used during testing. The following results are found during testing:

Test	Max. force [N]	Reason for end of test	Stop code
0	53.3	Security stop	Joint 2 C43A0
1	56.5	Security stop	URcontroller C113A0
2	66.7	Security stop	URcontroller C113A0
3	86.7	Security stop	URcontroller C113A0
4	91.9	Security stop	URcontroller C113A0
5	62.9	Security stop	URcontroller C113A0
6	76.6	Security stop	URcontroller C113A0
7	73.2	Security stop	URcontroller C113A0
8	76.8	Security stop	URcontroller C113A0
9	86.0	Security stop	URcontroller C113A0
10	64.2	Security stop	URcontroller C113A0
11	52.6	Security stop	URcontroller C113A0
12	84.8	Security stop	URcontroller C113A0

The test has verified that the robot is in compliance with the former mentioned items of the standards. All the forces measured during testing are below the chosen force limit of 150N at the TCP.

Yours faithfully
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