ROBOTICS

Application manual

3D Printing

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Application manual

3D Printing

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Original instructions.

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Product documentation

Categories for user documentation from ABB Robotics

The user documentation from ABB Robotics is divided into a number of categories. This listing is based on the type of information in the documents, regardless of whether the products are standard or optional.

Tip

All documents can be found via myABB Business Portal, *www.abb.com/myABB*.

Product manuals

Manipulators, controllers, DressPack, and most other hardware is delivered with a **Product manual** that generally contains:

- Safety information.
- Installation and commissioning (descriptions of mechanical installation or electrical connections).
- Maintenance (descriptions of all required preventive maintenance procedures including intervals and expected life time of parts).
- Repair (descriptions of all recommended repair procedures including spare parts).
- Calibration.
- Troubleshooting.
- Decommissioning.
- Reference information (safety standards, unit conversions, screw joints, lists of tools).
- Spare parts list with corresponding figures (or references to separate spare parts lists).
- References to circuit diagrams.

Technical reference manuals

The technical reference manuals describe reference information for robotics products, for example lubrication, the RAPID language, and system parameters.

Application manuals

Specific applications (for example software or hardware options) are described in **Application manuals**. An application manual can describe one or several applications.

An application manual generally contains information about:

- The purpose of the application (what it does and when it is useful).
- What is included (for example cables, I/O boards, RAPID instructions, system parameters, software).
- How to install included or required hardware.
- How to use the application.

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- Examples of how to use the application.

Operating manuals

The operating manuals describe hands-on handling of the products. The manuals are aimed at those having first-hand operational contact with the product, that is production cell operators, programmers, and troubleshooters.

Safety

Safety of personnel

A robot is heavy and extremely powerful regardless of its speed. A pause or long stop in movement can be followed by a fast hazardous movement. Even if a pattern of movement is predicted, a change in operation can be triggered by an external signal resulting in an unexpected movement.

Therefore, it is important that all safety regulations are followed when entering safeguarded space.

WARNING

Program changes should always be validated and tested before entering production, to protect humans and property. Ensure it is possible to stop the robot with a protective stop device.

Safety regulations

Before beginning work with the robot, make sure you are familiar with the safety regulations described in the manual *Safety manual for robot - Manipulator and IRC5 or OmniCore controller*.

Network security

Network security

This product is designed to be connected to and to communicate information and data via a network interface. It is your sole responsibility to provide, and continuously ensure, a secure connection between the product and to your network or any other network (as the case may be).

You shall establish and maintain any appropriate measures (such as, but not limited to, the installation of firewalls, application of authentication measures, encryption of data, installation of anti-virus programs, etc) to protect the product, the network, its system and the interface against any kind of security breaches, unauthorized access, interference, intrusion, leakage and/or theft of data or information. ABB Ltd and its entities are not liable for damage and/or loss related to such security breaches, any unauthorized access, interference, intrusion, leakage and/or theft of data or information.

1 Overview of this manual

About this manual

The 3D Printing PowerPac is a RobotStudio add-in that extends RobotStudio with 3D printing functionality. This manual describes how to create, program and simulate robot cells and stations for 3D printing. This manual also explains the terms and concepts related to both offline and online programming.

Usage

This manual should be used when working with the offline or online functions of RobotStudio.

Who should read this manual?

This manual is intended for RobotStudio users, proposal engineers, mechanical designers, offline programmers, robot technicians, service technicians, PLC programmers, Robot programmers, and Robot System integrators.

Prerequisites

The reader should have basic knowledge of:

- Robot programming
- Generic Windows handling
- 3D CAD programs

References

Reference	Document ID
Operating manual - IRC5 with FlexPendant	*3HAC050941-001*
Technical reference manual - RAPID Overview	*3HAC050947-001*
Technical reference manual - System parameters	*3HAC050948-001*
Application manual - Functional safety and SafeMove2	*3HAC052610-001*
Application manual - Controller software IRC5	*3HAC050798-001*

Revisions

Revisions	Description
A	Released with the first version of 3D Printing PowerPac.
B	Released with RobotStudio 2020.1
C	Released with RobotStudio 2020.2
D	Released with RobotStudio 2020.4
E	Released with RobotStudio 2021.1
F	Released with RobotStudio 2021.2
G	Released with RobotStudio 2021.3
H	Released with RobotStudio 2021.4
J	Released with RobotStudio 2022.1

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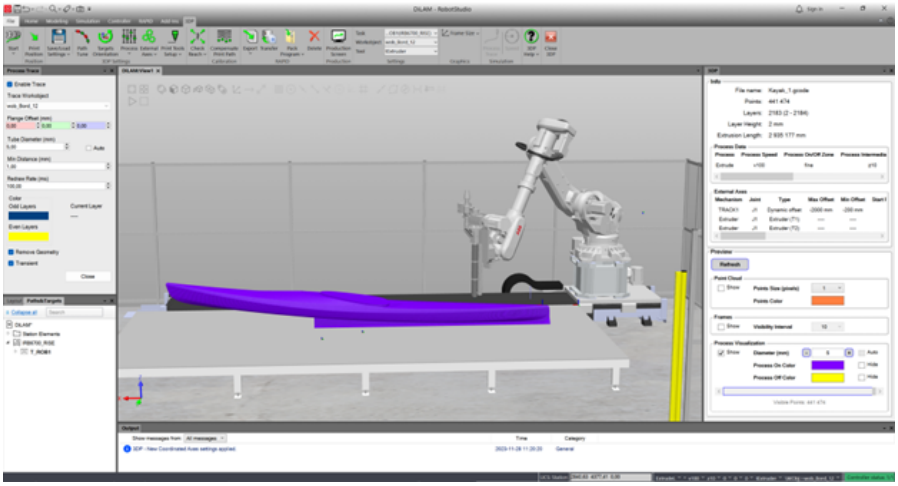
Revisions	Description
K	Released with RobotStudio 2022.2
L	Released with RobotStudio 2022.3
M	Released with RobotStudio 2022.3.1
N	Released with RobotStudio 2023.2
P	Released with RobotStudio 2023.3
Q	Released with RobotStudio 2024.1

2 Introduction

Overview

The 3D Printing PowerPac is a RobotStudio add-in that extends RobotStudio with 3D printing functionality. Use this add-in to perform offline programming and simulation of 3D printing of various CAD models. The input data to the 3D Printing PowerPac is a *G-code* file which is generated from CAD models in a third-party slicer software. The 3D Printing PowerPac converts the G-code to RAPID code with process support and external axes interpolation. The PowerPac can accept unlimited number of coordinate points.



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To handle 3D printing specific processes in the robot controller, the coordinate data is read dynamically without affecting the robot motion. The RobotStudio 3D printing PowerPac as such includes a RobotWare Add-In to support useful processes such as :

- DispenseWare
- Externally Controlled Extruder (for external control of extruder tool)
- ArcWare
- ExtrudeWare (for granules extruder controlled as an integrated external robot axis)

The 3D Printing PowerPac supports the following *External Axes*:

- Interpolation of coordinated robot track.
- Interpolation of coordinated rotational axis (can be combined with coordinated robot track).
- Interpolation of coordinated linear axis (fixed robot, workobject moved by linear axis).
- Interpolation of XYZ gantry with robot (Standalone Controller XYZ with no TCP).
- Granules extruder that is controlled as an integrated rotational axis. The 3D Printing PowerPac calculates the extruder rotation based on a set of selected process parameters.

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- Nozzle controlled as an integrated rotational axis that is aligned along the *path* (in the direction of path).

3 Installation

System requirements

Hardware requirements

High-performance desktop or laptop workstation, with the following requirements:

Part	Requirement
CPU	2.0GHz or faster processor, multiple cores recommended.
Memory	8 GB minimum. 16 GB or more if working with heavy CAD models.
Disk	10+ GB free space, solid state drive (SSD) recommended.
Graphics card	High-performance, DirectX 11 compatible, gaming graphics card from any of the leading vendors. For the Advanced lightning mode Direct3D feature level 10_1 or higher is required.
Display settings	1920 x 1080 pixels or higher resolution is recommended.
dots per inch (dpi)	Only Normal size supported for Integrated Vision.
Mouse	Three-button mouse.
3D Mouse [optional]	Any 3D mouse from 3DConnexion. See http://www.3dconnexion.com.

Software requirements

- RobotStudio latest version
- RobotWare 6.07 and later
- RobotWare 7.3.x and later
- 3D Printing PowerPac with a valid license
- 3D Printing RobotWare Add-In

3D Printing RobotWare Add-In is installed together with the 3DP Printing PowerPac.

Installing the PowerPac

Use the following procedure to install the 3D Printing add-in.

1. Download the 3D Printing PowerPac from *http://new.abb.com/products/robotics/robotstudio/downloads*.
2. On the **Add-Ins** tab, in the **RobotWare** group, click **Install Package** and select the downloaded *.rspak* file.
3. In the **Add-Ins** browser, verify that the 3DP PowerPac is visible under **Installed Packages**.
4. Follow the procedure for installing a license as in RobotStudio.

Installing RobotWare Add-In for RobotWare 6

With the 3D Printing RobotWare option added to the system, a new selection for *Additive Manufacturing* will be available in the Installation Manager 6 **Applications** tab. Depending on the process which will be used for printing, one or more 3D Printing options must be selected.

- **3D printing Arc**

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For welding. The RAPID instructions *ArcLStart, ArcL* and *ArcLEnd* are used for printing. For more information see, the application manual - Arc.

- **3D printing Dispense**

  For dispensing. The instruction *DispL* is used. For more information see the application manual – Dispense.

- **3D printing Externally Controlled Extruder**

  For dispensing. The instruction *PrintL* is used. *Externally Controlled Extrusion* is similar to *Dispense Ware* but is developed specially for 3D printing when the extrusion equipment is controlled externally. The use of *DispL* instructions can create too high CPU load on the robot controller, which can result in a condition where the robot randomly enters fine points and stands still for approximately 200 ms. To avoid these issues, *Externally Controlled Extrusion* can be used instead of *Dispense Ware*.

- **3D printing Integrated Extruder**

  For dispensing. The instruction *ExtrudeL* will be used. This is used together with an extruder that has a screw controlled as an integrated robot axis. The screw angle will be calculated for each coordinate point.

Depending on the process that is used for printing, the following RobotWare options must be selected together with the 3D Printing RobotWare Add-In:

Printing process	RobotWare options
3D printing Arc	623-1 Multitasking 633-4 Arc or 633-4 Arc with MultiProcess 687-1 Advanced Robot Motion
3D printing Dispense	623-1 Multitasking 637-1 Production Screen 641-1 Dispense or 641-1 Dispense with MultiProcess 687-1 Advanced Robot Motion
3D printing Externally Controlled Extrusion	623-1 Multitasking 637-1 Production Screen 687-1 Advanced Robot Motion
3D printing Integrated Extruder	610-1 Independent Axis 623-1 Multitasking 637-1 Production Screen 687-1 Advanced Robot Motion

Installing RobotWare Add-In for RobotWare 7

With the 3D Printing RobotWare option added to the system, a new selection for *Additive Manufacturing* will be available in the Installation tab. Depending on the process which will be used for printing, one or more 3D Printing options must be selected. 3D Printing RobotWare options are available in the **Options** folder.

- The **3D printing Externally Controlled Extruder** option is provided to be used for dispensing operations. The instruction *PrintL* is used. *Externally Controlled Extrusion* is similar to *Dispense Ware* but is developed specially for 3D printing when the extrusion equipment is controlled externally. The use of *DispL* instructions can create too high CPU load on the robot controller,

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which can result in a condition where the robot randomly enters fine points and stands still for approximately 200 ms. To avoid these issues, *Externally Controlled Extrusion* can be used instead of *Dispense Ware*.

- **3D printing Integrated Extruder**

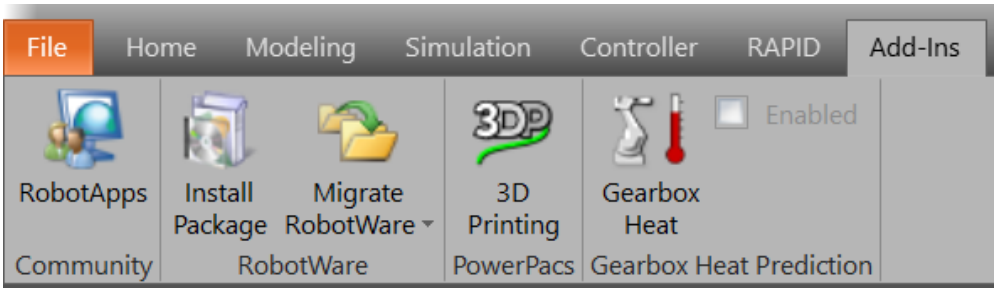
  For dispensing. The instruction *ExtrudeL* will be used. This is used together with an extruder that has a screw controlled as an integrated robot axis. The screw angle will be calculated for each coordinate point.

Depending on the process that is used for printing, the following RobotWare options must be selected together with the 3D Printing RobotWare Add-In:

Printing process	RobotWare options
3D printing Arc	3416-x Arc 7 3100-1 Advanced Robot Motion 3114-1 Multitasking
3D printing Externally Controlled Extrusion	3100-1 Advanced Robot Motion 3114-1 Multitasking 3113-1 Path Recovery
3D printing Integrated Extruder	3100-1 Advanced Robot Motion 3114-1 Multitasking, 3111-1 Independent Axis 3113-1 Path Re-covery

Starting the 3D Printing PowerPac

In the **Add-Ins** tab, click the 3D Printing icon to start the 3D Printing PowerPac.



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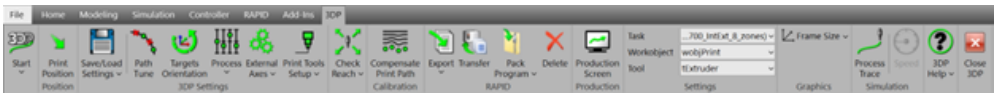
4 Navigating the User Interface

Introduction

Some of the commands, when clicked, extend its features further with browsers docked to the left or right side of the Graphics window. These browsers group feature-specific commands that are optimized for efficient access, the following sections focus on these browsers and their descriptions.

> **Note**
>
> Basic description for all 3D Printing commands are available in the respective ScreenTips, hover the mouse over these commands to avail information.



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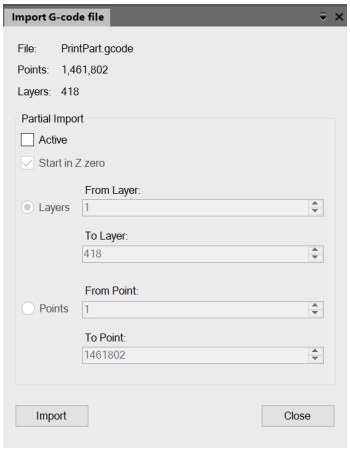
Open

	Options	Description
 xx2000001780	**File**	Name of the G-code file
	Points	Number of coordinate points in the G-code file
	Layers	Number of layers in the G-code file
	Partial Import	Provide controls for partial selection of G-code files. Select the Active check-box for enabling this option: • **Start in Z zero**: The print starts at 0 mm in Z-axis even if the print doesn't start at the first layer or the first point. • **Layers**: Select the layer to start import and last layer to stop the import. • **Points**:Select the coordinate point to start import and the last coordinate point to stop.

Simulation using a large *G-code* file is computationally intensive and increases the load on the CPU. This also needs higher consumption of CPU resources which can reduce the performance of the PC. By adopting partial import during trial simulations, file size can be reduced to facilitate optimum use of CPU resources. This helps in maintaining a healthy load on the CPU and optimizes PC performance.

A G-code file that is converted to RAPID creates many RAPID modules. At the first program execution after export, each of these modules are converted to a 3DP file format. This conversion consumes a specific amount of time. Hence, if the G-code file is large, the time taken for conversion also will be high. This delay will further

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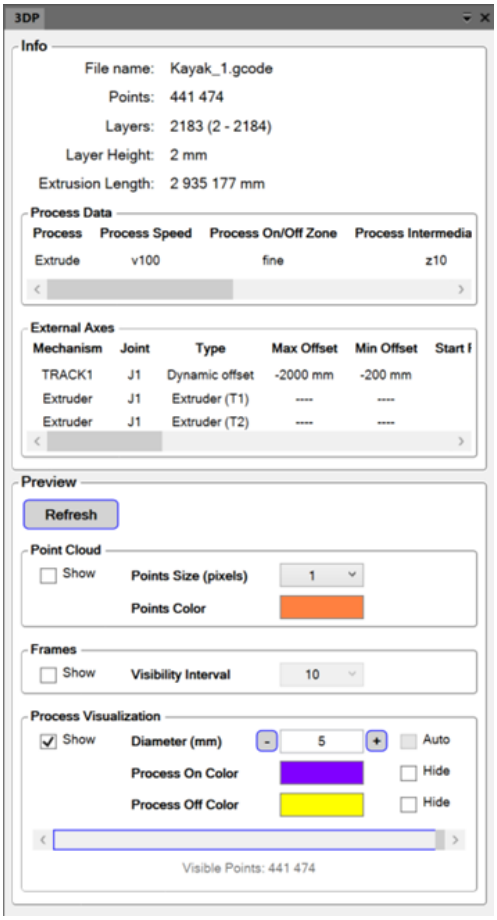
affect all subsequent steps of simulation. By adopting to partial import during trial simulations, this delay can be controlled, and simulation time can be optimized.

3DP window

The 3DP window gets displayed after a G-code file is imported, the 3DP window will be docked to the right side in the **Graphics** window of RobotStudio. The 3DP window displays the following details of the G-code files.

	Options	Description
 xx1900001718	**Points**	Number of coordinate points that will be exported.
	Layers	Number of layers that will be exported.
	Layer height	The height of each layer.
	Extrusion Length	The length of the print path where the process is *ON*.
	Process Data	Process settings as defined in the **Process** window.
	External Axes	External axes settings as defined in the *External Axis* windows.
	Preview: Point Cloud	Select the **Show** check-box to enable preview. Displays a point cloud with one point for each coordinate, the color and size of the points can be selected here.
	Preview: Frames	Select the **Show** check-box to enable preview. Displays frames for each coordinate point. For better view and to avoid performance issues, a visibility interval of the frames can be set here.
	Preview: Process Visualization	Select the **Show** check-box to enable preview. Displays the material used for printing as a round tube. When the process is *Off* a curve will be displayed instead of a tube: • **Diameter**: The diameter of the tube. If **Auto** is selected, the diameter will be read from the G-code file (if that information exists in the G-code). • **Process On Color**: The color of the tube gets displayed where the process is *ON*. Select the **Hide** check-box to hide tube. This can be useful to see the curves where the process is *Off*. • **Process Off Color**: The color of the curves where the process is *Off*. Select the **Hide** check-box to hide the curves. • **Scroll bar for Preview**: Displays partial preview. For performance reasons, this partial preview will only be updated when the scroll bar mouse click is released.

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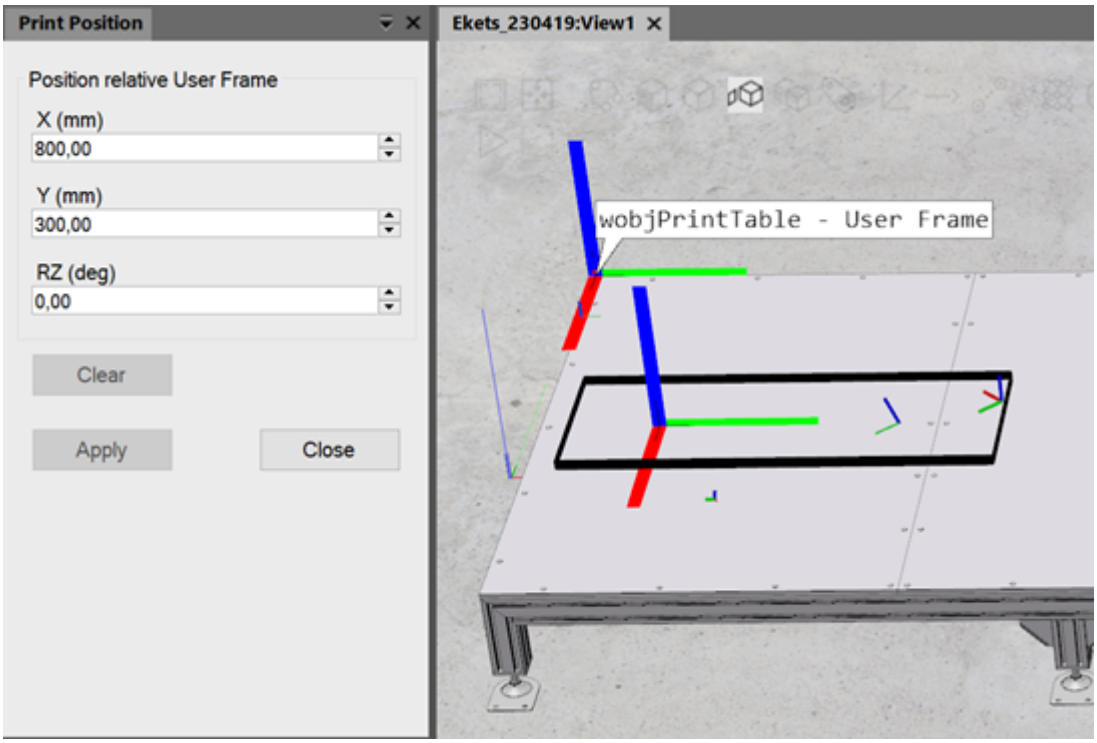
Print Position

Print Position is used to change the print position in the XY plane, and the orientation around the Z-axis. The position and orientation are relative to the active Workobject User Frame.



xx2300000960

If the **Use 3DP Print Position** check-box is selected during export, the **Print Position** values (X, Y and RZ) will be used during the print instead of the Workobject Object Frame values in the robot controller. Observe that the Object Frame Z-value will not be changed in the robot controller.

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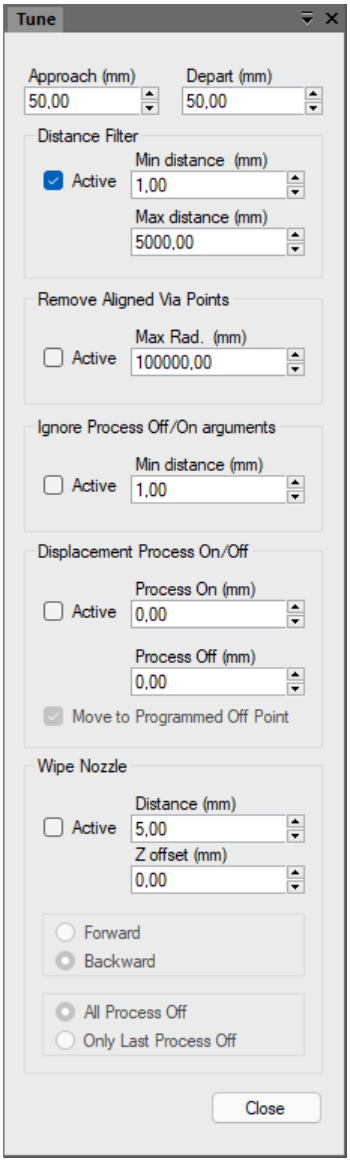
Path Tune

Path tune feature optimizes points on the trace and reduces the number of points along the path of the robot.



xx2000001782

Options	Descriptions
Approach	Set an offset from the print start point.
Depart	Set an offset from the last print point.
Distance Filter	Select the **Active** check-box to enable the option. • **Min distance**: Remove points that are closer than the specified value. • **Max distance**: Add point(s) if the distance to the next point is larger than the specified value. This option retains points when the process is turned **ON** or **Off** even if these points are closer than the specified **Min Distance**.
Remove Via Points	Select the **Active** check-box to enable the option. Remove points that are closer than the specified **Min Distance** value. **Note** This option retains points when the process is turned *ON* or *Off* even if these points are closer than the specified **Min Distance**
Remove Aligned Via Points	Select the **Active** check-box to enable the option, removes all linear via points. **Note** A *via point* is defined as linear if the via point, the previous point and the next point forms a path with radius larger than the specified **Max Radius**.
Ignore Process Off/On arguments	Select the **Active** check-box to enable the option. If the distance between a **Process Off** point to the next **Process On** point is less than the specified **Min distance** value, the Off and ON arguments will be ignored, and the process will stay on.
Displacement Process On/Off	• **Active** : When selected, it displaces the process points backwards for certain distance along the print path. • **Move to Programmed Off Point** :Select this option to continue the printing process along the programmed path even after the **Process Off** point, that is, even after the process has been turned off. If this option is not selected, then the printing process stops at the **Process Off** point and then resumes only at the next **Process On** point. The extruder will not dispense any material along the programmed path after the**Process Off** point.

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	Options	Descriptions
	Wipe Nozzle	Select the **Active** check-box to enable the option. After completing a print segment, the robot follows the trajectory forward or backward for certain distance with the process turned off. An offset in the **+Z** direction can be added to the wipe points. For wipe forward, the process off point must coincide with the previous process on point. Without meeting this condition, wipe movement will not be added. The **Wipe** option can be used on all process off points, or only at the end of the print. The wipe speed and an eventual wait time before the wipe movement can be defined in the **Process Settings** window. This function ensures a smooth ending to each print segment and avoids materials from getting dragged with the nozzle after the print.

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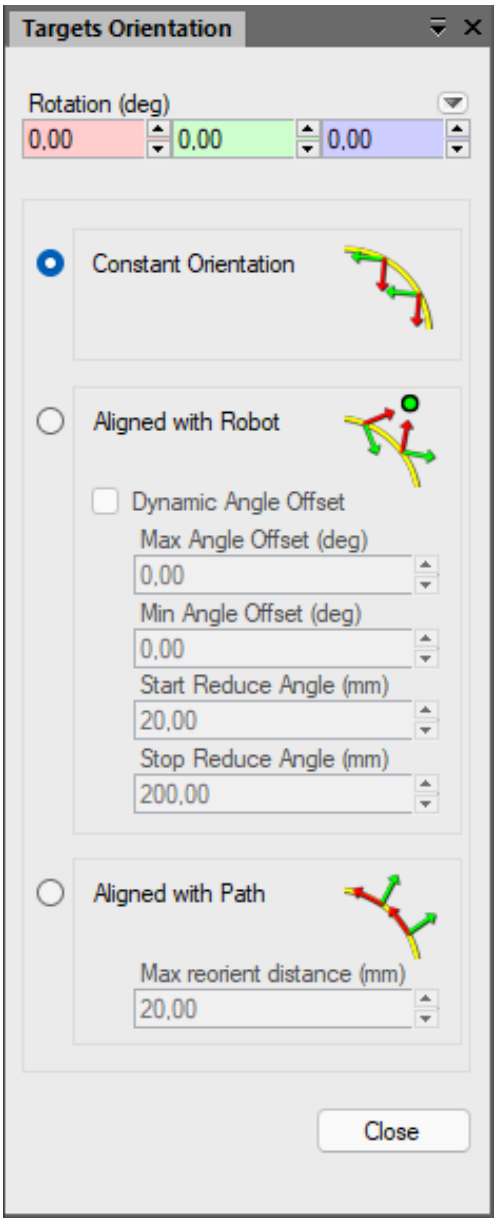
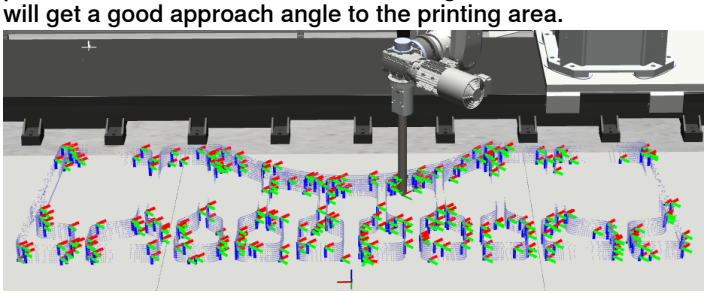
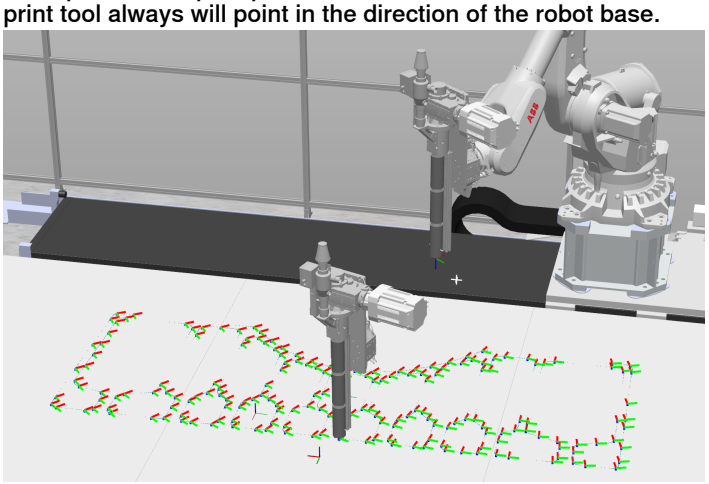
Targets Orientation

The G-code file may or may not include the *orientation* data. For G-code files with orientation data, the 3D Printing PowerPack will fetch the required orientation values. For G-code files that does not contain orientation data, these values must be defined in the 3D Printing PowerPac. This command provides three options, **Constant Orientation**, **Aligned with Robot** and **Aligned with Path**.

	Options	and descriptions
 xx2000002173	**Rotation(deg):**	The targets rotation is defined as RPY angles (Euler ZYX) or quaternions.
	Constant Orientation:	Constant orientation values are assigned to all points along the path. The orientation values must be assigned such that the robot will get a good approach angle to the printing area.  xx1900001732 **Note** If the orientation values are not defined carefully, the manipulator can get into *singularity*.
	Aligned with Robot:	Each point in the path possess individual orientations, so the print tool always will point in the direction of the robot base.  xx2000002183 While printing larger objects, the manipulator arm holding the tool can get into *singularity*. To avoid singularity during the print, a rotation value can be selected so that the print tool will not be pointing exactly towards the robot base, instead deviate by a number of degrees relative to the robot base.

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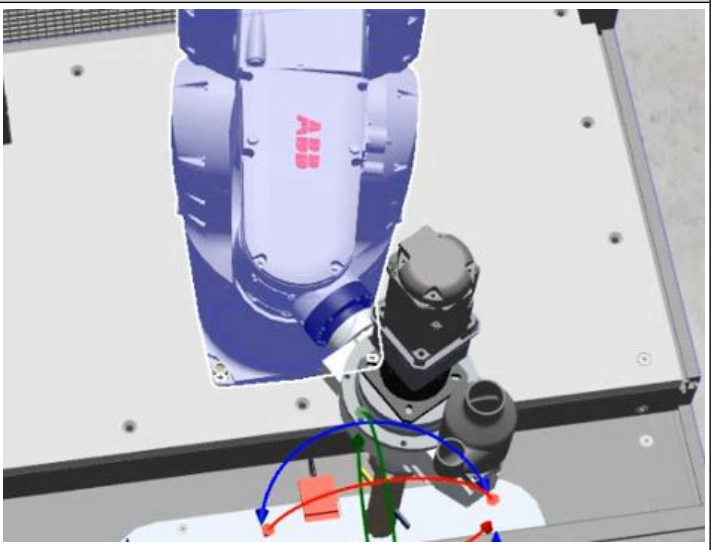
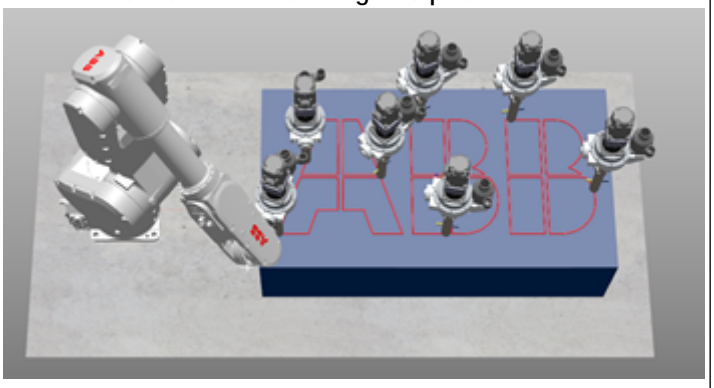
	Options	and descriptions
		 xx2000002182 **Dynamic Angle Offset**: With this option, the print area can be maximized by enabling the robot to print close to the robot base. The angle between the tool and the robot will be adjusted according to the distance from the tool to the robot base. • **Max Angle Offset**: The maximum angle between the tool and the robot base, used when printing close to the robot base. • **Min Angle Offset**:The minimum angle between the tool and the robot base, used when printing farther from the robot base. • **Start Reduce Angle**: The distance between the robot base and the tool where the angle must start decreasing. • **Stop Reduce Angle**: The distance between the robot base and the tool where the angle stops to decrease.  xx2200000604
	Aligned with Path:	In **Aligned with Path**, each point in the path posses individual orientations, so the selected **Travel Vector** will point in the direction of *path*.

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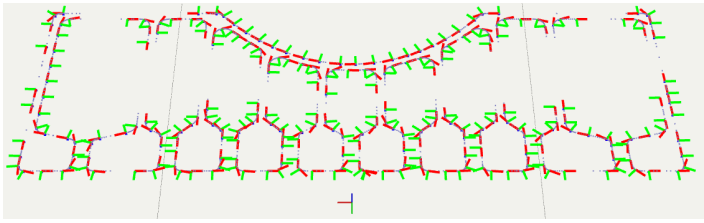
	Options	and descriptions
		 xx1900001728
	Max reorient distance:	Adds *via points* such that the reorient distance between two points will not exceed the specified **Max reorient distance**.

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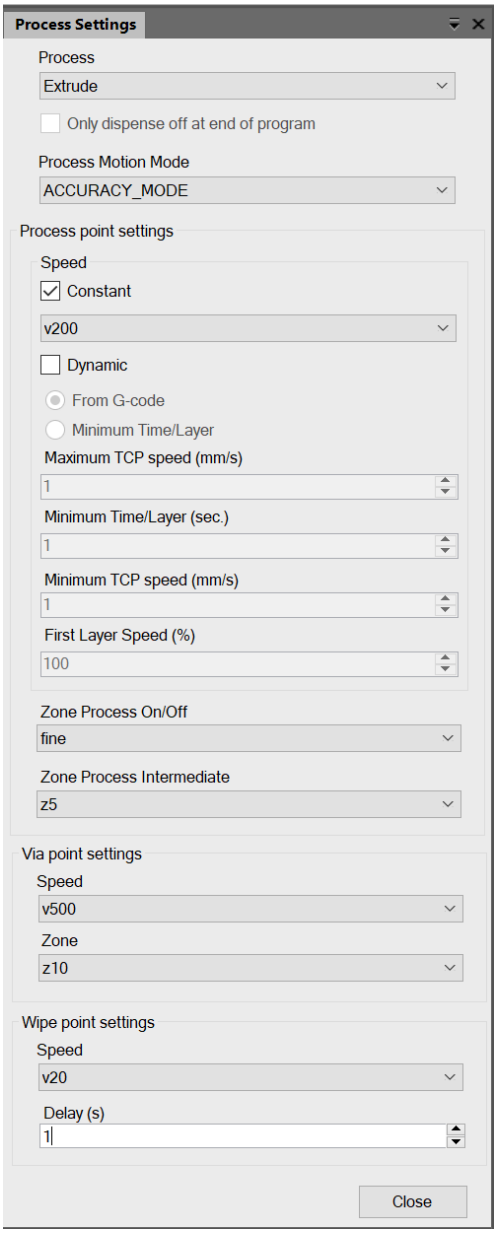
Process

Process settings defines the RAPID instructions and the corresponding arguments used in the printing process.



xx1900001733

Options	Description
Process	The process that must be used for printing. All supported processes in the *virtual controller* with a defined **Instruction Template** gets displayed in the list. Supported processes are **Arc, Dispense, Print and Extrude**. The selected **Process Type** is linked to the active *Instruction Template*, so as to map the changes in the **Process Settings** with the **Instruction Template**, and vice versa.
Process Motion Mode	Sets the motion process mode. For more information, see the *RAPID technical reference manual: Instructions – MotionProcessModeSet*.
Process Speed	• **Constant**: Constant TCP speed that is selected from the list with declared speed data from the virtual controller. • **Dynamic From G-code** Dynamic speed will be read from the G-code file. • **Dynamic - Minimum Time/layer**: Speed will be calculated with **Maximum TCP speed** and **Minimum Time/Layer**. • **Maximum TCP speed**: Maximum TCP speed, used together with **Minimum Time/Layer**. • **Minimum Time/Layer**: The minimum robot motion time for a layer. If the motion time for a layer goes below the minimum time with the selected Maximum TCP speed, the TCP speed for that layer will be reduced till it reaches the minimum time. • **Minimum TCP speed**: Minimum allowed process TCP speed. Overrides Minimum Time/Layer. If the process speed for a layer goes below the Minimum TCP speed, then the process speed assumes the Minimum TCP speed for that layer and overrides the Minimum Time/Layer. • **First Layer Speed**: Reduction of the first layer speed in percentage. Minimum TCP speed will override this setting.
Zone Process On/Off	The zone data for instructions where the process is turned *On/Off*.
Zone Process Intermediate	The zone data for intermediate instructions where the process is turned *ON*.
Via Points Speed	The *TCP* speed where the process is turned *Off*.
Via Points Zone	The zone data for intermediate instructions where the process is turned *Off*.
Wipe point settings	

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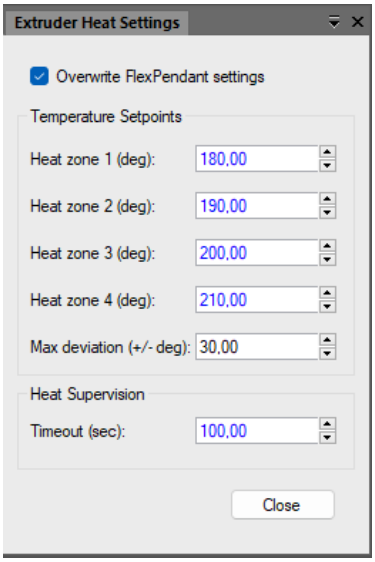
	Options	Description
		• **Speed**: The TCP speed for wipe movements. • **Delay**: Wait time before the wipe movement starts. Wipe is optional and is activated in the **Path Tune** window.

Extruder Heat Settings

Extruder Heat Settings is enabled only if the options **3D Printing Integrated Extruder** and the **addition Extruder Heat Control** are selected while configuring the system.

These settings are also available on the FlexPendant for the **Extruder Heat Control** option. During program execution, these settings will overwrite FlexPendant settings if the **Overwrite FlexPendant settings** check-box is selected.

	Options	Description
 xx2200001222	**Temperature Set-points**	This group displays the following fields: • To set the temperature of heat zones 1 to 8. • To set the maximum allowed temperature deviation (plus and minus).
	Heat Supervision: Timeout(sec)	The heat zones are turned off when the extruder screw stops its movement and remains immovable for a longer time span than the set timeout value. This is indicated by orange color on the FlexPendant. **Note** The Extruder heat zones option is enabled for externally controlled extruders, but without heat supervision of extruder rotation.

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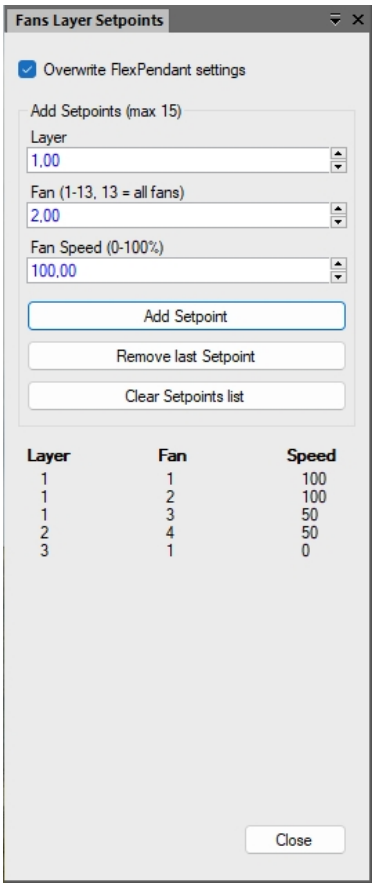
Fans Layer Setpoints

Fans Layer Setpoints is enabled only if the option **3D Printing Fan Control** is selected while configuring the system.

These settings are also available on the FlexPendant for the **Fans Layer Setpoints** option. During program execution, these settings will overwrite FlexPendant settings if the **Overwrite FlexPendant settings** check-box is selected.

	Options	Description
 xx2200001223	**Add Setpoints**	• **Layer:** The selected fan changes speed at the beginning of this layer. • **Fan:** Indicates the fan to be changed, fan 13 will affect all fans. • **Fan Speed:** Speed of the fan in percentage. • **Add Setpoints:** Setpoints are added to this list. • **Remove last setpoint:** Removes the last setpoint from the list. • **Clear Setpoints list:** Clears the list.
	Setpoints list	List containing the added setpoints, contains maximum 15 setpoints.

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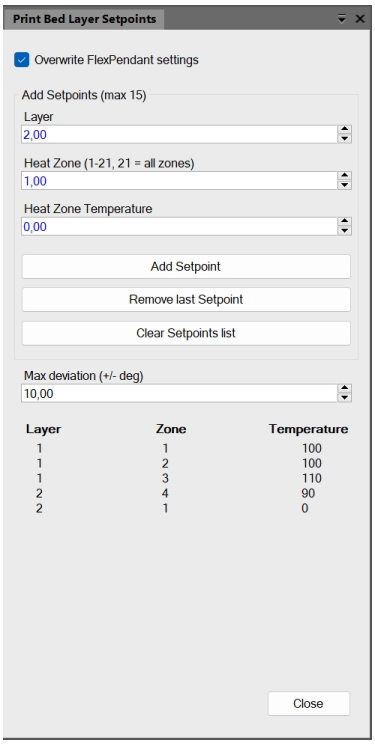
Print Bed Layer Setpoints

Print Bed Layer Setpoints is enabled when the option **3D Printing Print Bed Heat Control** is selected while configuring the system.

These settings are also available on the FlexPendant for **Print Bed Layer Setpoints** option. During program execution, these settings will overwrite FlexPendant settings if the **Overwrite FlexPendant settings** check-box is selected.

	Options	Description
 xx2200001224	**Add Setpoints**	• **Layer:** The heat zone changes status at the beginning of this layer. • **Zone:** Indicates the zone to be changed, zone 21 will affect all heat zones. • **Zone Temperature:** The print bed heat zone setpoint temperature value. • **Add Setpoint:** Setpoints are added to this list. • **Remove Last Setpoint:** Removes the last setpoint from the list. • **Clear Setpoints list:** Clears the list.
	Max Deviation	The maximum deviation between the setpoint value (group output) and the actual value (group input).

External Axes

- **Coordinated Axes** - For interpolating coordinated external axes. Linear and/or rotational.
- **Extruder Axis** - For calculating extruder screw angle for granules extruder.
- **Aligned Nozzle Axis** – For accurately aligning nozzle to path. This is used in tools where the nozzle is controlled as an external axis.
- **From G-code** - Reads external axes values from G-code.

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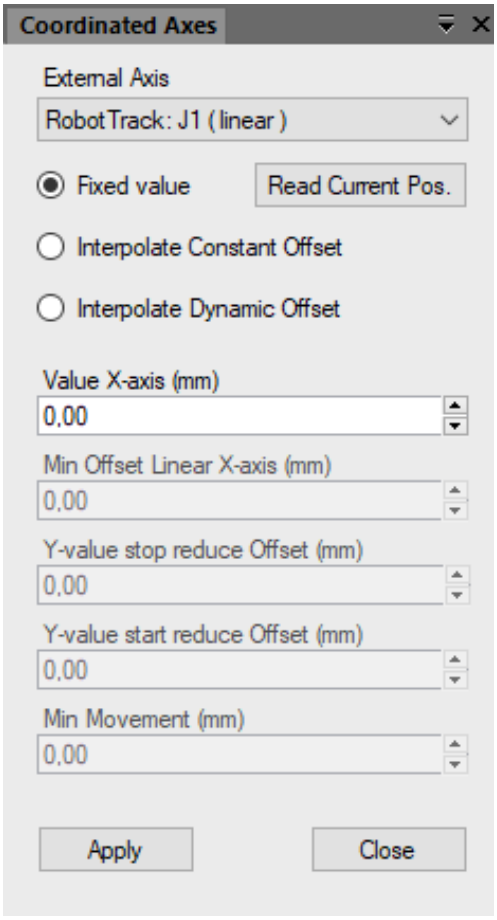
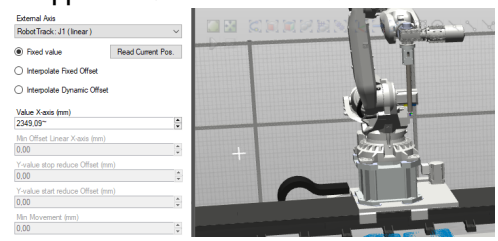
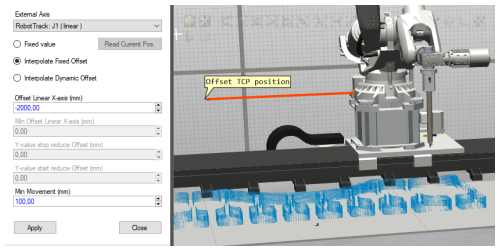
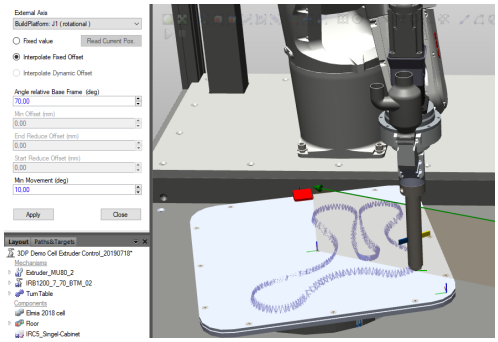
Coordinated Axes

	Options	Description
 xx1900001738	**External Axis**	Lists all coordinated axes in the system. All external axes where the *base frame* has been moved are considered as coordinated, options are available for interpolating one external axis (either linear or rotational) and two external axis based on the selected external axis such as a turn table or a robot track. IRBPA positioner : Select this option to calculate the interpolation of an IRBPA positioner (two external axes) where the TCP orientation is set to a constant value. A G-code file that includes orientation data (nX, nY, nZ) where the target orientations follow the shape of the object to print must be used for this option.
	Fixed Value	Sets the same external axis value to all *targets*. For linear axes, the current position can be applied with **Read Current Pos**.  xx1900001741
	Interpolate Constant Offset - linear axis	The track carrier (center of robot axis 1) will keep the same Offset to the *TCP*, defined with Offset Linear.  xx1900001742
	Interpolate Constant Offset - rotational axis	The rotational axis will be interpolated such that the robot tool (TCP) will work in the same area on the turntable. The area is defined with **Angle relative Base Frame** as an Offset angle relative to the *Base Frame* of the turntable.  xx1900001743

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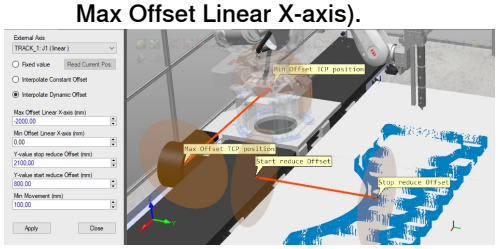
	Options	Description
	Interpolate Dynamic Offset (only coordinated robot track)	When large objects are printed where the robot has to spread out more to reach all coordinate points of the workobject at the side of the track, a dynamic Offset is required. The Offset between the track carrier and the TCP will change depending of the *side distance* between the track and the TCP. • **Max Offset Linear X-axis**: The maximum Offset between the track carrier and the TCP. This Offset will be used as long as the *side distance* is lower than the **Y-value start reduce Offset**. • **Min Offset Linear X-axis**: The minimum Offset between the track carrier and the TCP. This Offset will be used when the *side distance* is equal to or larger than **Y-value stop reduce Offset**. • **Y-value stop reduce Offset**: The *side distance* where the offset between the track carrier and the TCP will reach **Min Offset Linear X-axis** (see **Min Offset Linear X-axis**). • **Y-value start reduce Offset**: The *side distance* where the offset starts to reduce from **MaxOffset Linear X-axis** to **Min Offset Linear X-axis** (see Max Offset Linear X-axis).  xx2100000049
	Min Movement	The minimum distance the track or turntable will move in one direction. This is used to avoid short backward and forward movements of the external axis, to enable smooth movements of the axis.

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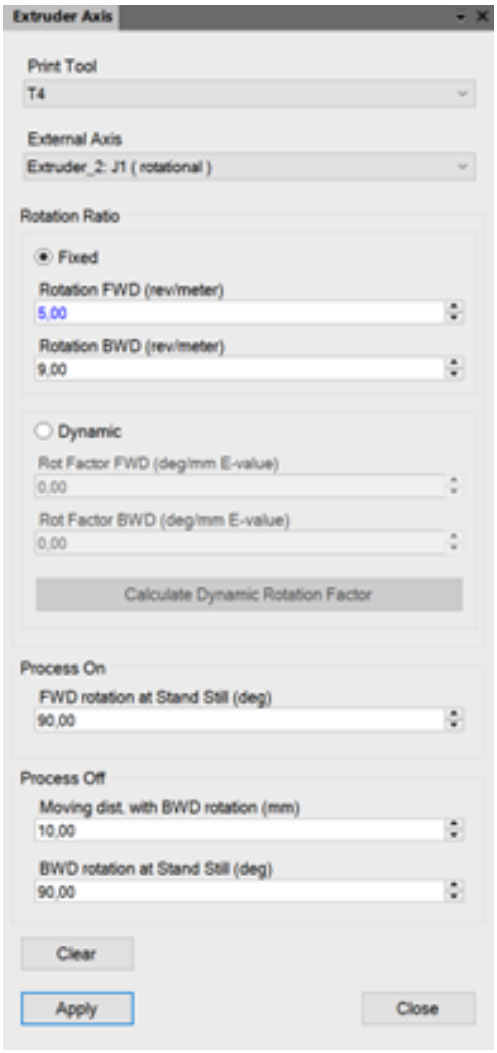
Extruder Axis

	Options	Description
 xx2000002177	**Print Tool**	Determines the Print Tool the settings should be assigned to. Up to six print tools can be used in a print program, each with unique settings.
	External Axis	Lists all uncoordinated rotational axes in the system. External axes where the *base frame* is not moved are considered as uncoordinated.
	Rotation Ratio (Rotation (rev/meter)	Determines the number of revolutions the extruder screw should rotate during a distance of one meter (1000 mm) when the process is turned *ON*. The ratio can be Fixed or Dynamic. • **Fixed - Rotation FWD**: The rotation ratio will be the same for all layers when the extruder is rotating forward. **Fixed - Rotation BWD**: The rotation ratio will be the same for all layers when the extruder is rotating backwards. • **Rotation**: Used for fixed rotation ratio. Determines the number of revolutions the extruder screw should rotate for a distance of one meter (1000 mm) when the process is turned *ON*. • **Dynamic - Rot Factor FWD** The rotation of the extruder screw will be calculated from the **Rotation Factor** and the E-value (extrusion distance) in the G-code. This ratio can vary depending on the E-value in the G-code. Dynamic can only be used with G-code files that has absolute E-values, or G-code files where the E-values are changed to zero with the *G92* command. **Dynamic - Rot Factor BWD** : Used to calculate the **Rotation Ratio** and **Rotation Factor** for the Extruder backward rotation before **Process Off** points. • **Rotation Factor**: Used to calculate the screw rotation when **Dynamic rotation ratio** is *Active*. **Rotation Factor** is equal to the number of degrees the screw rotates per millimeters of E-value. This value can either be calculated or assigned manually. • **Calculate Dynamic Rotation Factor**: To calculate the **Rotation Factor**, from G-code file, the total distance between the first process *ON* coordinate point to the next process *Off* coordinate point (along with all points in between) is calculated. This distance is then compared with the E-value at the *Off* coordinate point and the **Rotation ratio** to calculate the Rotation Factor.

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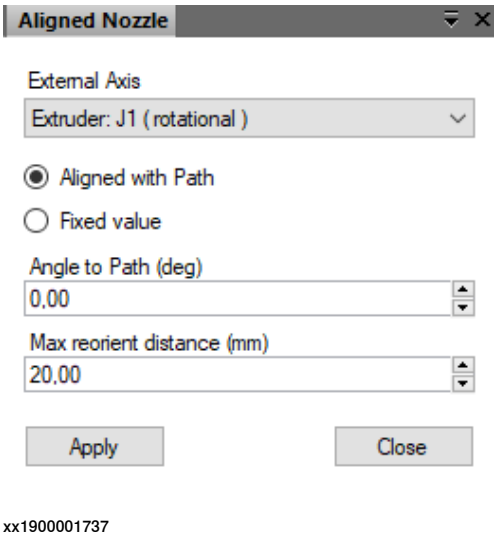
	Options	Description
	Process On - FWD rotation at Stand Still	The number of degrees the extruder screw should rotate before the robot starts to move from a process on point. This is used to avoid gaps in the printed product.
	Process Off	• **Moving dist. With BWD rotation**: The distance before the process *Off* position, the extruder screw should rotate in the reverse direction. This is used to avoid too much material getting dispensed at the process *Off* position. • **BWD rotation at Stand Still**: The number of degrees the extruder screw should rotate when the robot has stopped in the process *Off* position. This is used to regulate material dispensing.
	Clear	Removes settings for all Print Tools.
	Apply	The settings will be saved to the selected Print Tool, up to six parallel settings can be applied.

Aligned Nozzle

	Options	Description
 xx1900001737	**External Axis**	Lists all uncoordinated rotational axes in the system. External axes where the base frame is not moved are considered as uncoordinated.
	Aligned with Path	Select this option to align the extruder with the path.
	Fixed value	With this option, the extruder will rotate to the selected value and then stop movement.
	Angle to Path / Value	When **Aligned with Path** is selected, this value specifies the Offset angle between the nozzle and the direction of path. When **Fixed value** is selected, this value specifies the fixed angle for the nozzle.
	Max reorient distance	When **Aligned with Path** is selected, this value specifies the maximum reorient distance. If the distance between points in the G-code exceeds this value, extra coordinate points are added.

From G-code

Reads and uses external axes values from the G-code file provided that the G-code file follows the defined syntax as specified in *Workflow of the 3D Printing PowerPac on page 59*. While using this option, calculations or verifications of the movements are performed as specified in the g-code file.

Note

While using this option, 3D Printing PowerPac will not perform any calculations or verifications of movements, hence the reachability check will not be reliable.

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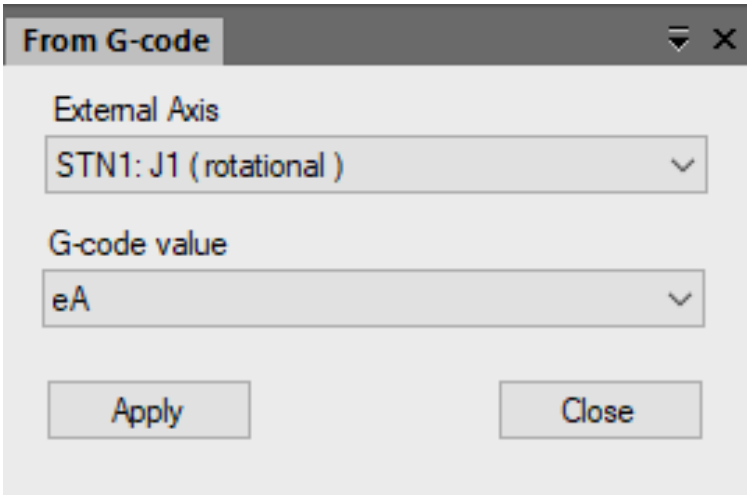


xx2100002170

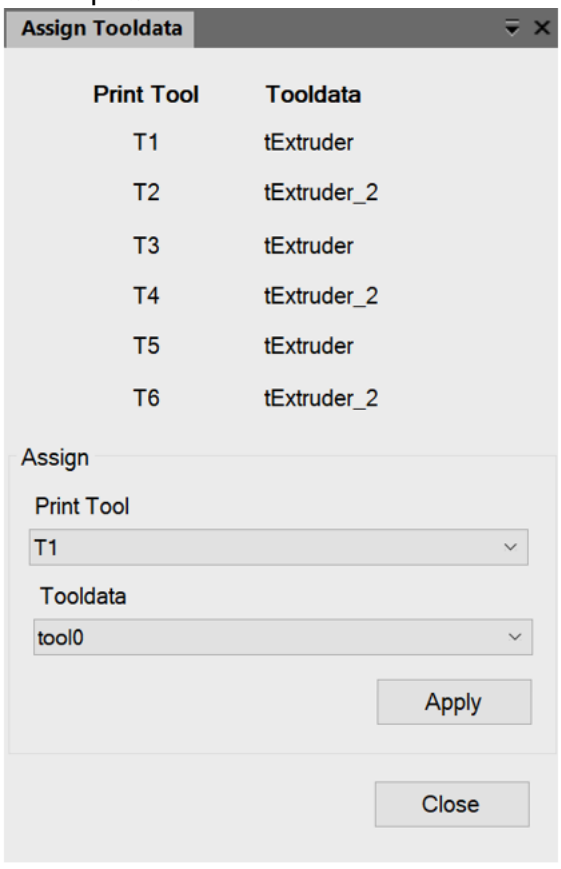
Print Tools Setup

Use the **Print Tools Setup** to include up to six different print tools in the same print.

The following options can be selected from the drop-down.

Tooldata:

Assign Tooldata: Select Print Tool and Tooldata that should be assigned together, then click **Apply**. The Tooldata list will be updated.



xx2300001992

Print Tool: Select the tool for assigning Tooldata.

Tooldata: The active tooldata in the station will be assigned to all print tools by default. The first tool T1 will be linked to the active Tooldata in RobotStudio. Any change in the active **Tooldata** gets reflected in T1 and vice versa.

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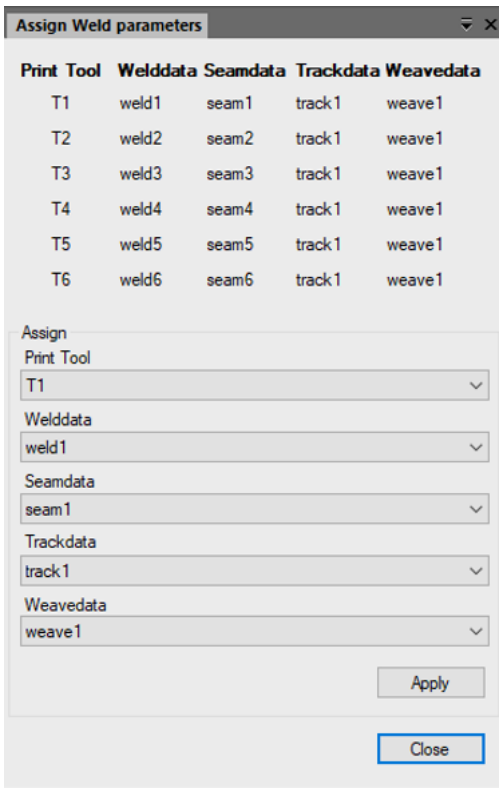
Weld Parameters:



xx2300001994

For Arc processes, weld parameters will be defined for each Print Tool. Welddata can be assigned to the selected tool, this option will only be enabled if the robot supports welding and the 3DP option **Arc** is installed.

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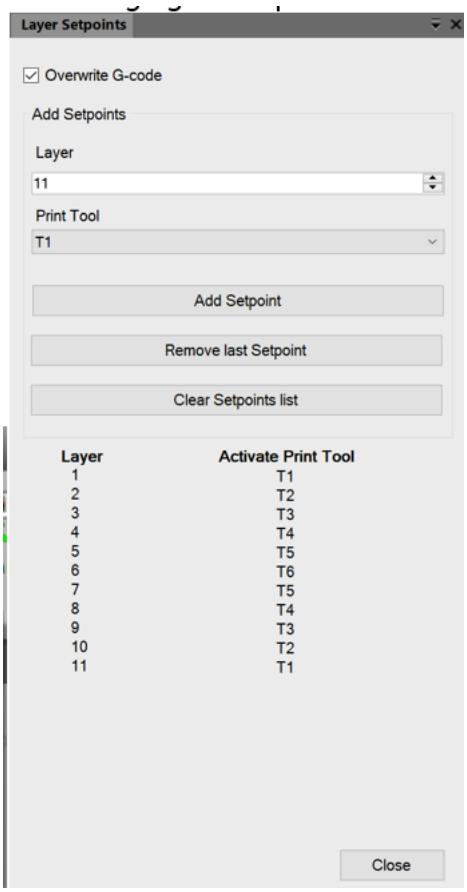
Layer Setpoints:



xx2300001993

- A digital I/O signal *(doPrintTool1_3DP - doPrintTool6_3DP)* indicates the active Print Tool.
- Active Print Tool is controlled from G-code, 3DP reads the G-code commands (T0 – T5) for changing active print tool.

  A layer setpoints list can be defined to change active print tool at the beginning of a layer. This will overwrite the G-code commands for changing active print tool.
- Integrated Extruder Axis settings will be unique for each print tool, each of these print tools can be controlled by its robot external axis.

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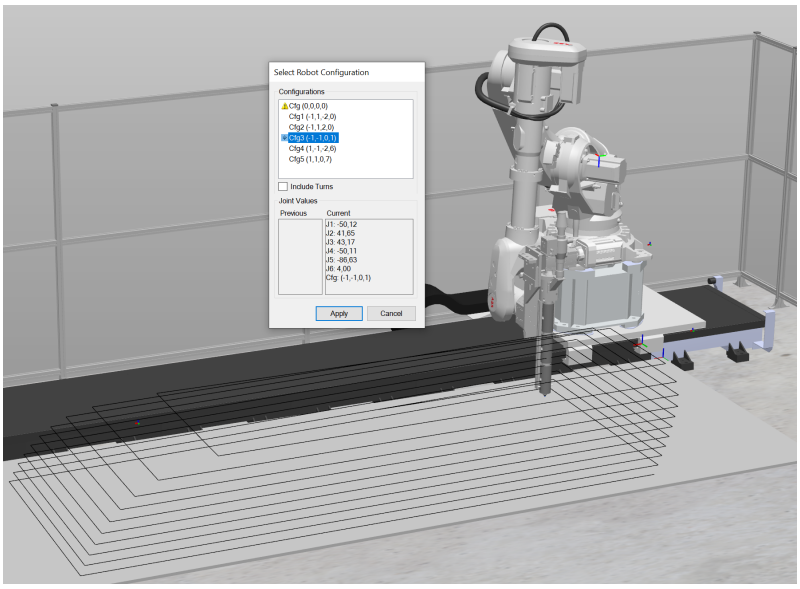
Check Reach

Bounding Box

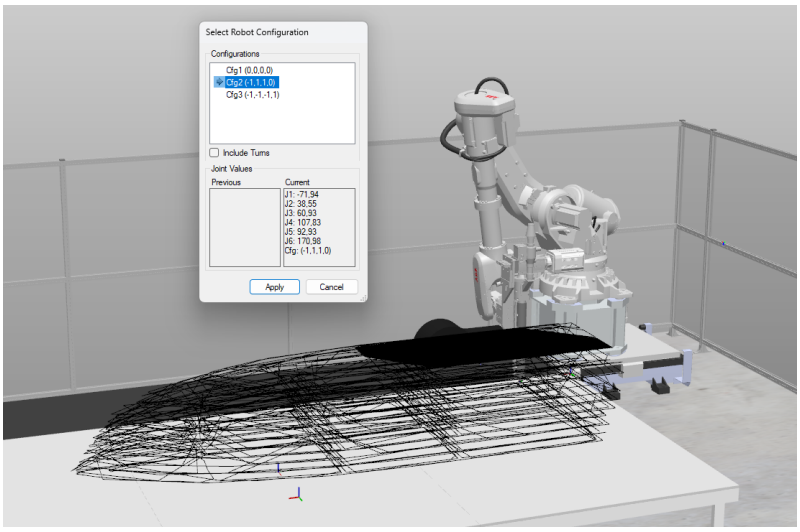
Generates a bounding box around the part to be printed and verifies that the robot can move along it. Robot arm configuration for the first bounding point must be manually selected.



xx2000001781

Check Points

With this option, the reachability check is performed using a selected set of points in the print path. This option provides greater accuracy while performing reachability checks, but demands more time.



xx2200002045

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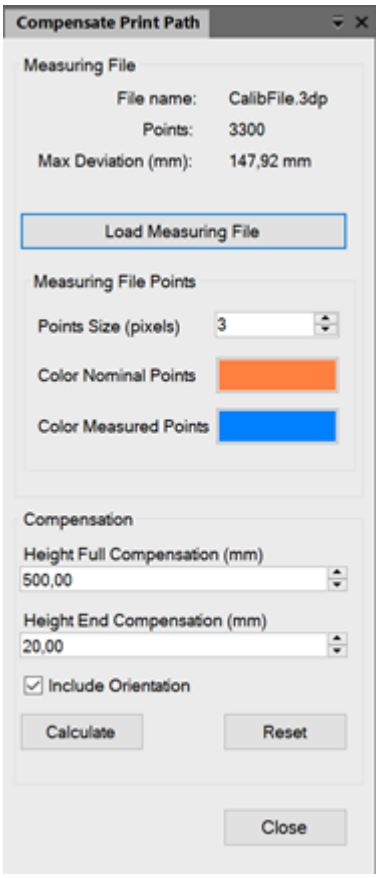
Compensate Print Path

To calibrate/level a print path, select **Compensate Print Path**.



Options	Descriptions
Load Measuring File	Loads the measuring file.
Height Full Compensation	Specifies the height up until the print path to be fully compensated.
Height End Compensation	Specifies the height where the compensation should stop. If **Height Full Leveling** is lower than **Height End Leveling**, the compensation starts to reduce from **Height Full Compensation** and stops at **Height End Compensation**.
Include Orientation	When selected, targets orientation also will be changed to follow the print surface.

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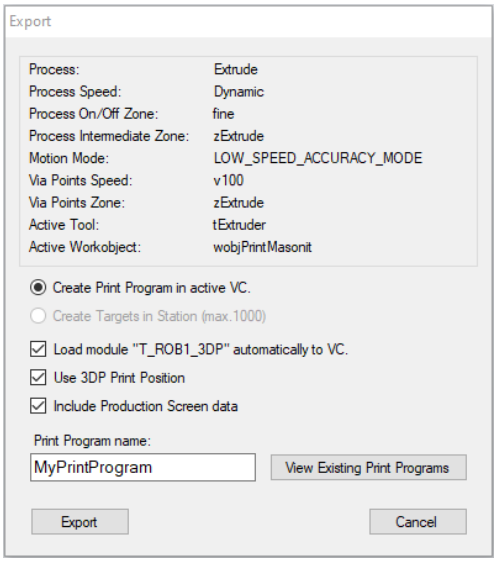
Export

Exports the G-code to RAPID modules, or to targets in the active RobotStudio *station*. The **Export** browser displays details of the selected RAPID settings.



xx1900001739

Options	Description
Create Print Program in active VC.	This option gets enabled during Export. Creates RAPID modules. Requires the 3D Printing RobotWare installed in the robot controller.
Create Targets in Station	Creates targets in the active RobotStudio station. This option gets enabled only when the number of targets remain less than or equal to 1000.
Load module "T_ROB1_3DP" automatically to VC	Loads the *T_ROB1_3DP* module automatically to the active *virtual controller*. This module is generated by the 3D Printing PowerPac and is unique for each export. Do not select this check-box, if print queue must be used.
Use 3DP Print Position	The print position values (X, Y and RZ) will be used during the print instead of the Workobject Object Frame values in the robot controller.
Include Production Screen data	Data files and pictures used for the Production Screen will be added to the exported print program.
Print Program name	Type a name for the new exported print program. If the print program already exists, a warning window gets displayed.
View Existing Print Programs	Expands the window with a list of all existing print programs in the controller.
Export	Starts the export. A control will be made that the *Path Tune – Distance* filter is active. If not, a warning window gets displayed. A control is made to check that the external axis values for all external axes are defined. If not, a warning window gets displayed.

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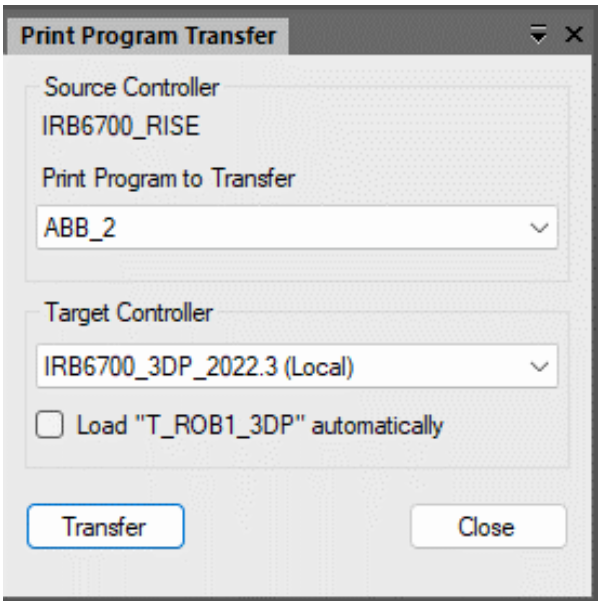
Transfer

Use this feature for transferring the exported print program to a selected controller that is connected to RobotStudio. The print program selected for transfer will be placed in the correct folder structure in the target controller. If the target controller already has a print program with same name as that of the selected print program, the user will be prompted to overwrite the existing program. 3D Printing powerpac uses the transfer function instead of the standard RobotStudio File Transfer.



xx2200001225

Pack Program

Use this feature to pack and unpack print programs. Two options are available, **Pack Print Program** and **Unpack Print Program**.

Pack Print Program

The selected print program will be saved to a compressed file with the extension *.prg3dp*.

While creating the *.prg3dp* file, the user will be prompted to choose to delete the print program in the source controller.

Unpack Print Program

The selected *.prg3dp* file will be unpacked to the selected controller that is connected to RobotStudio.

Delete

Deletes a Print Program in a controller that is connected to RobotStudio.

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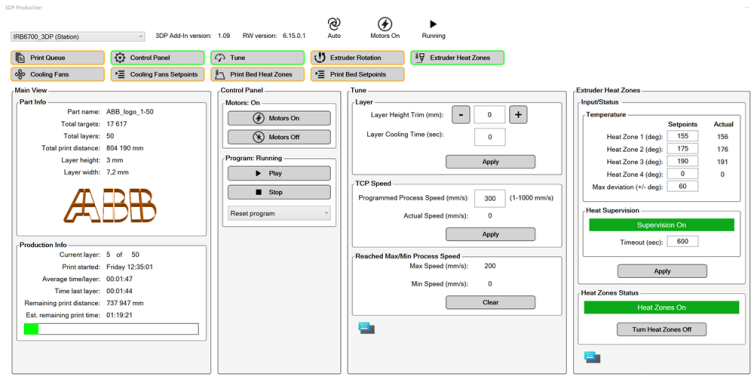
Production Screen

Overview

Production Screen is an optional representation of the 3D Printing FlexPendant user interface for monitoring the production phase. Here, all 3D Printing Production windows can be opened and viewed simultaneously during the printing operation. This feature was developed for working with a touch screen.



xx2300000258

The default view of the Production Screen contains a ribbon that shows the details of the selected controller, and buttons for controlling various views.

xx2300000260

All controllers connected to RobotStudio are included in the drop-down list, both virtual robot controllers and real robot controllers. To get full functionality, the selected controller should be in *Auto* mode. Additionally, 3DP Add-In version, RobotWare version, and controller status will be displayed here.

xx2300000261

The **Main View** visible by default, all other views can be customized as required. The number of visible buttons vary according to the 3DP RobotWare Add-In options. Open views are denoted by a green colored border around the corresponding button and the border turns into orange color when the view is hidden.

Exporting the product image along with the print program

A picture of the 3DP product preview can be captured and included in the print program to be visualized in the Production Screen.

1. On the **3DP** tab, in the **RAPID** group, click **Export** and then click **Product Image**.

   All objects in the station will be hidden except for the product preview. The background color changes to white.
2. In the **Product Image** browser, click the **Print Screen** button.

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A snapshot of the graphical window will be saved which then can be exported with the print program.

3 On the **3DP** tab, in the **RAPID** group, click **Export**, the **Export** dialog opens.

4 In the **Print Program name** box, enter the name and click the **Export** button.

The image of the part will be included in the exported print program.

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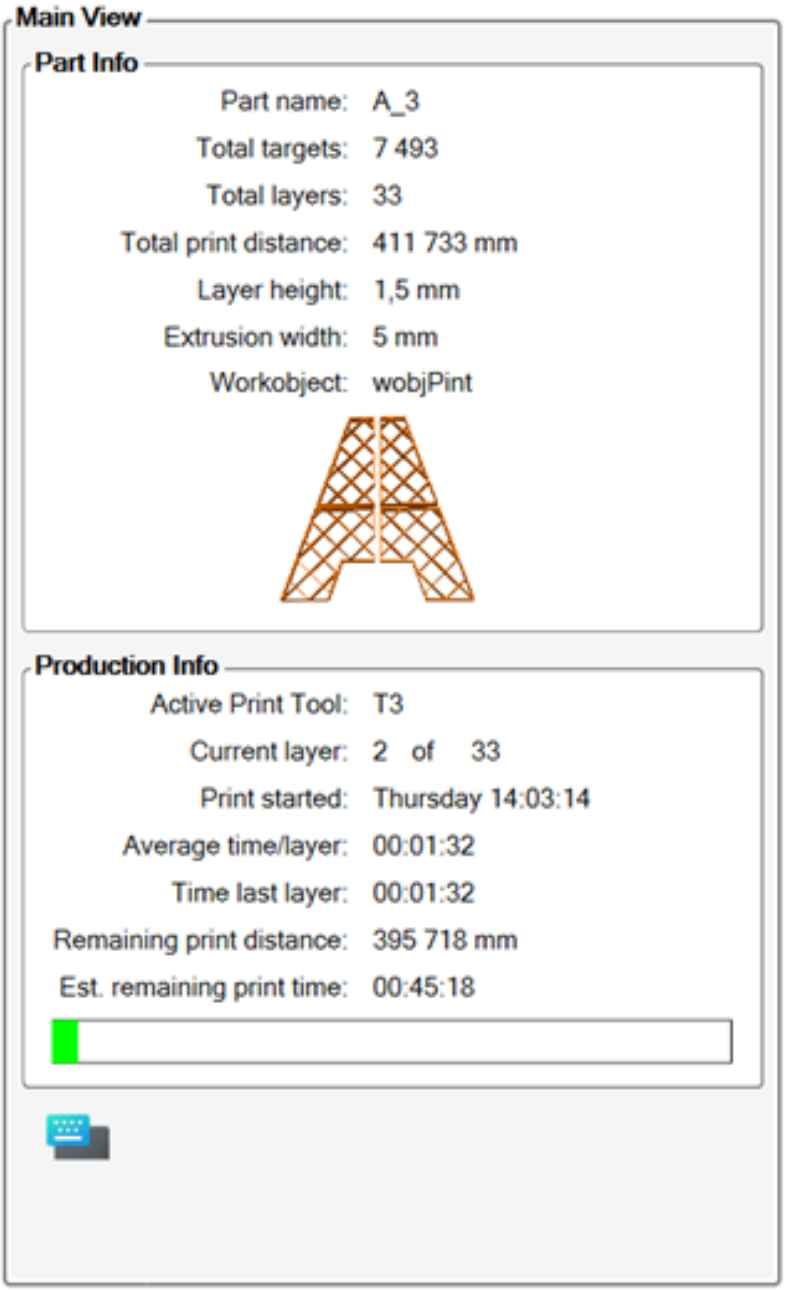
Main view

The Main View is visible by default, it contains **Part Info** and **Production Info**. **Part Info** contains information about the current printing part. **Production Info** displays details of the ongoing printing process. It contains a progress bar that reflects the current print progress status. Teach Pendant messages called from RAPID are also displayed, supported RAPID instructions are *TPErase*, *TPWrite*, *TPReadNum*, *TPReadDnum*, *TPReadFK*.



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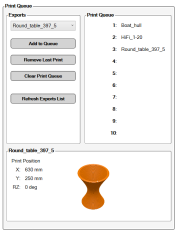
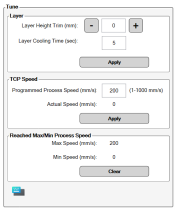
Navigating the Production Screen

View	Description
Station Messages  xx2300002059	Optionally select this feature when configuring the system to display preset messages. When the **Station Messages** option is selected, a text file will be added to the system where customized station messages can be added. These messages will be triggered at preset events.
Print Queue  xx2300000277	This functionality is similar to the **Print Queue** available on the 3D Printing FlexPendant user interface. If the selected print export contains the print position, and a picture of the 3DP product, these will be displayed.
Control Panel  xx2300000278	Use **Control Panel** to start/stop program execution, and to turn motors On/Off and reset program pointer(set program pointer to main), the controller must be in *Auto* mode.
Tune  xx2300000279	For tuning the print process in production. This functionality is similar to the **Tune** available on the 3D Printing FlexPendant user interface. The blue icon at the bottom of the view opens Windows on-screen keyboard.

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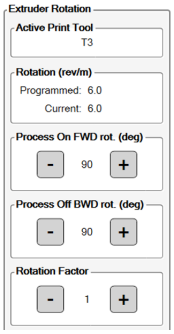
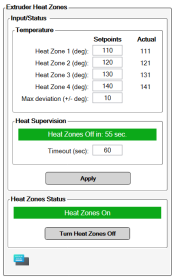
View	Description
Extruder Rotation  xx2300000280	This functionality is similar to the **Extruder Rotation** available on the 3D Printing FlexPendant user interface.
Extruder Heat Zones  xx2300000281	This functionality is similar to the **Extruder Heat Zones** available on the 3D Printing FlexPendant user interface. The blue icon at the bottom of the view opens Windows on-screen keyboard.
Cooling Fans  xx2300000282	This functionality is similar to the **Cooling Fans** available on the 3D Printing FlexPendant user interface. The blue icon at the bottom of the view opens Windows on-screen keyboard.
Cooling Fans Set-points  xx2300000283	This functionality is similar to the **Cooling Fans Setpoints** available on the 3D Printing FlexPendant user interface. The blue icon at the bottom of the view opens Windows on-screen keyboard.
Print Bed Heat Zones  xx2300000284	This functionality is similar to the **Print Bed Heat Zones** available on the 3D Printing FlexPendant user interface. The blue icon at the bottom of the view opens Windows on-screen keyboard.

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View	Description
Print Bed Setpoints  xx2300000285	This functionality is similar to the **Print Bed Setpoints** available on the 3D Printing FlexPendant user interface. The blue icon at the bottom of the view opens Windows on-screen keyboard.

Station Messages

Optionally select this feature when configuring the system to display preset messages. When **Station Messages** option is selected, a text file will be added to the system *HOME\3DP_ MESSAGES\ 3DP_messages.txt* where customized station messages can be added. These messages are triggered with I/O communication from a PLC or from other control system. The *3DP_messages.txt* file contains example messages that can be used as template while adding custom messages.

Message Syntax

A message text must be written in the following syntax.

1I Header Text.\Information text for message 1. Severity=Information.

A message written in this syntax appears as shown here:

xx2300002060

Item	Description
Message number	The chronological order of the message in the message queue.
Severity	There are three defined levels of severity, I,W and E. This letter should be added directly after the message number without space, and decides the severity of the message. • I=information • W=warning • E=error.
Header Text.	Message header.
\Information text for message 1	If the message text should be divided into a message header followed by a message text, "\" should be used to indicate the separation between header and the following text.

Displaying messages with acknowledgement and I/O handshake between PLC and robot

Workflow

Continues on next page

Continued

There is no upper limit to the number of messages that can be added to *3DP_messages.txt*.

1. Group Input *giMessage* is set to the value (Message number) by the PLC, followed by Digital Input *diNewMessage*.
2. The **Station Messages** button blinks in accordance with the message severity level (blue=Information, Orange=Warning, Red=Error).
3. The user clicks the button to display the message.
4. When the message is handled, the user click **Acknowledge** which sets the Digital Output *doAckMessage* to high.
5. The PLC acknowledges by setting *giMessage* and *diNewMessage* to zero.
6. The message window gets closed.

Displaying multiple messages without acknowledgement and I/O handshake between PLC and robot

Workflow

A maximum of 31 messages can be added to *3DP_messages.txt*. The Group Input *giMessages* should be defined with a range of 32 bits. Bit 1 to 31 will indicate the messages.

1. The PLC sets one bit for each message that should be displayed, so for example, if message 1, 2 and 3 should be displayed, bit 1,2 and 3 should be high which gives *giMessages* a value 7.
2. The **Station Messages** button blinks with blue color.
3. The user clicks the button to display the messages.
4. When the PLC changes *giMessages* value, the **Station Messages** gets updated automatically.

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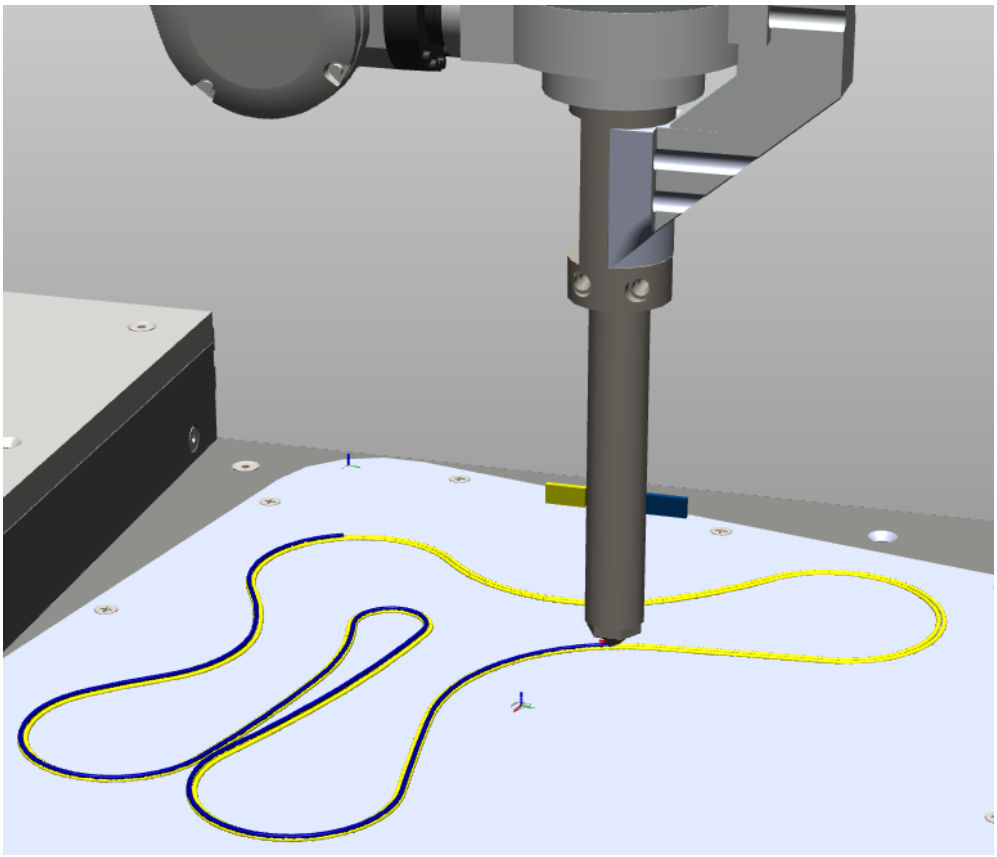
Continued

Process Trace

Visualizes the material extrusion during simulation. The *TCP* position that was recorded during simulation gets replaced by a circular tube along the trace. To activate **Trace**, open the **Tube Trace** window.



xx1900001756

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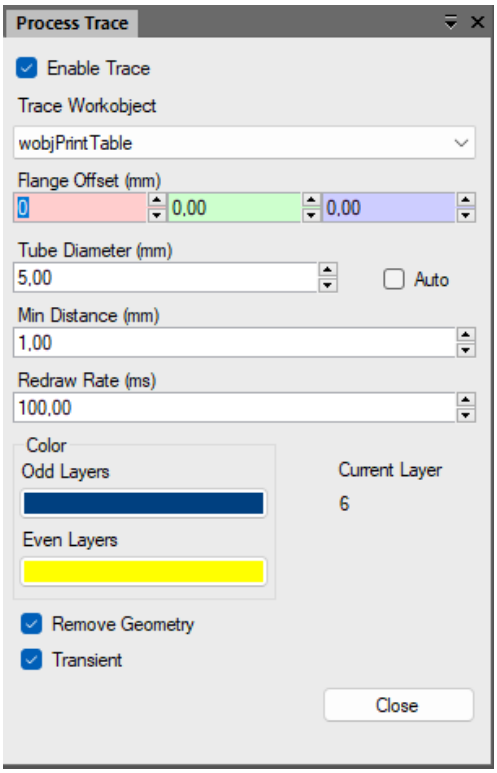
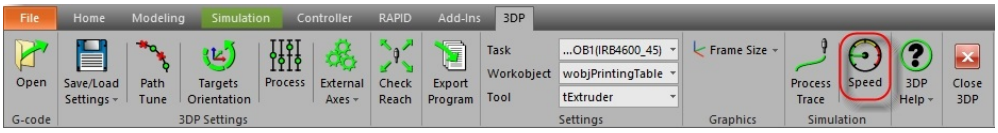
Continued

	Options	Description
 xx1900001757	**Enable Trace**	To activate and deactivate the trace.
	Trace Workobject	The *workobject* that the trace should relate to. Used when the workobject is moved by a *mechanism*.
	Flange Offset	Specifies the Offset between trace and *TCP*.
	Tube Diameter	The diameter of the tube trace. If **Auto** is in selected state, the diameter is read from the RAPID code, which is read from the G-code.
	Min Distance	The min distance between the recorded points used to build up the trace. The shorter the distance, the higher the computers CPU load, this worsens simulation performance.
	Redraw Rate	The time interval in milliseconds between the redraw of the tube trace. The shorter the time, the higher the computers CPU load, this worsens simulation performance.
	Color	The color of the trace. Different colors can be selected for odd and even layers.
	Remove Geometry	When this field is in the selected state, the *geometry* of tube part gets removed. This improves the simulation performance.
	Transient	When this field is in the selected state, the tube gets transient, and it disappears when the simulation stops. This improves simulation performance.

Speed

When clicked, the simulation speed will change from 100% to *As fast as possible*. When clicked again, the simulation speed will go back to 100%. The **Speed** button is only enabled during simulation.



xx1900001759

Importing RobotStudio Path

This feature requires RobotStudio premium license. With this feature, it is possible to import paths created in RobotStudio into 3D Printing PowerPac and then print shapes and objects created using these paths. While printing large products, it can in some cases replace G-code generated in a 3rd party software. To change the active Print Tool, a new action instruction *PrintTool* can be inserted with the argument 1 to 6. This feature is useful while generating test prints for tuning the print process.

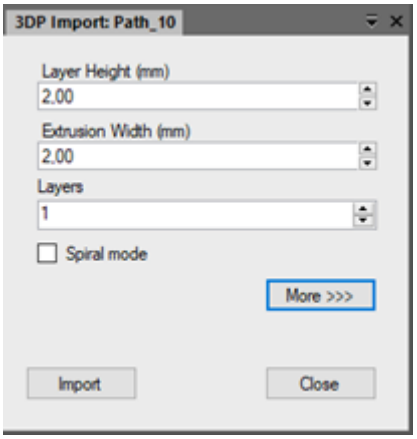
Workflow

1 In RobotStudio, using the required tools, create a path between two or more targets.

Continues on next page

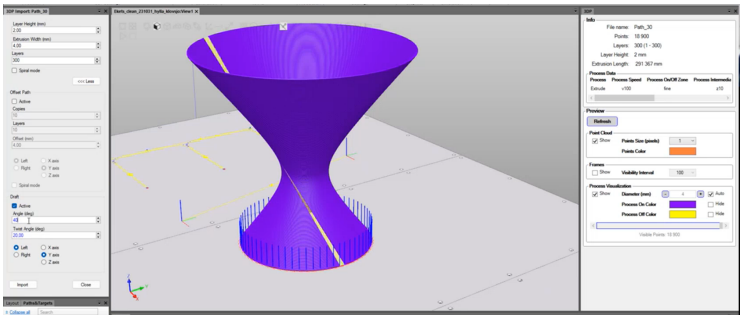
2 With 3DP open, in the Paths & Targets browser, right-click the path and then click, **3DP - Import Path** in the context menu.

3 The **3DP-Import** browser opens, here, enter values as required and then click **Import** to import this path to the 3D Printing PowerPac.



xx2300002061

4 To further customize and fine-tune your path or geometry click **More>>>** to extend **3DP-Import** browser with more options to customize the printed object.



xx2300002062

Note

These options can be used to experiment and further improve the geometry. User can create random objects in RobotStudio and then import them to the 3D Printing PowerPac and print them. Printing using this feature do not need a G-code file.

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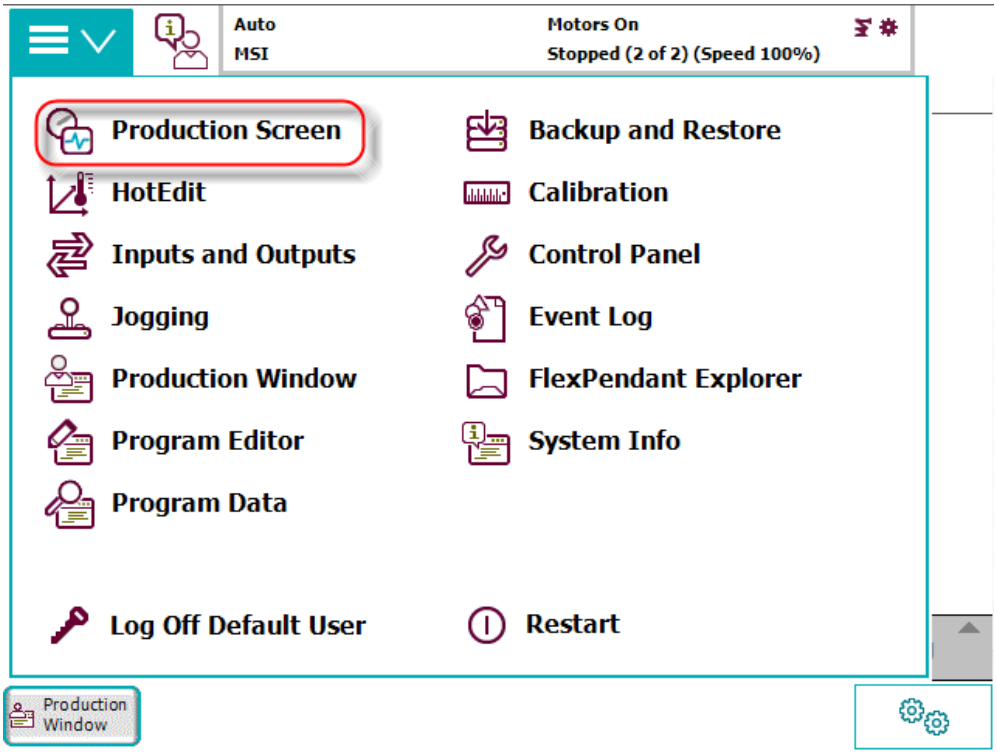
5 Navigating the 3DP FlexPendant User Interface for RobotWare 6 and 7

Overview

To handle 3D printing specific processes in the robot controller, 3D printing PowerPac includes a RobotWare Add-In. With this Add-In, **Production Screen** dedicated for 3D printing process gets installed in the FlexPendant user interface.

FlexPendant user interface for RobotWare 6



xx2000001034

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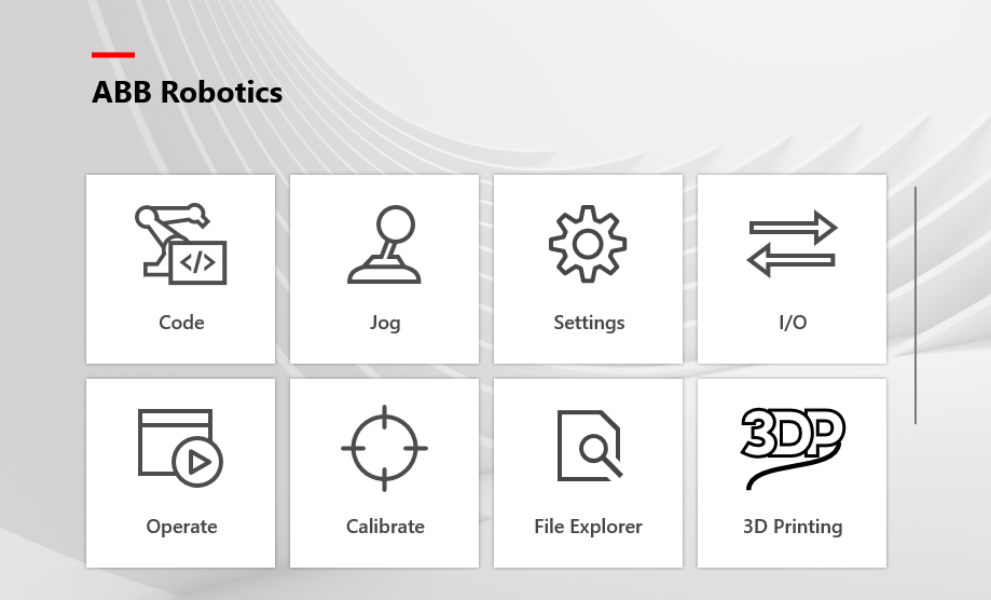
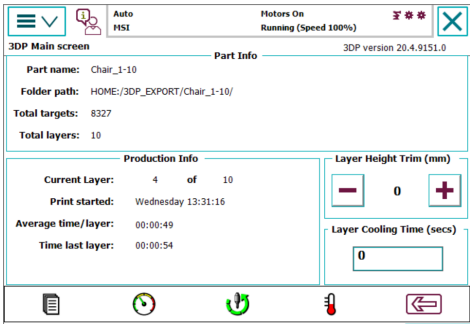
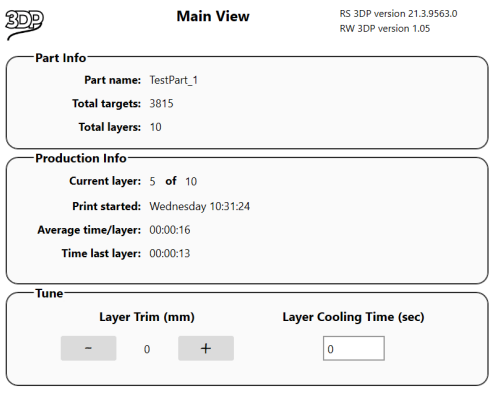
FlexPendant user interface for RobotWare 7



xx2100002171

3DP Main screen

	Options	Descriptions
FlexPendant user interface for RobotWare 6  xx2000002178 **FlexPendant user interface for RobotWare 7**  xx2100002172	**Part info**	Details of the active part such as name, total targets and total number of layers of the printed product are displayed.
	Production Info	The printed layer in comparison with the total number of layers of the printed product. • **Current Layer**: Displays the number of the printed layer. • **Print started**: The weekday and time the last print started. • **Average time/layer**: The average printing time per layer for the layers printed so far. • **Time last layer**: The time taken to print the previous layer.
	Layer Height Trim	Option to fine-tune layer height(mm) during print process.
	Layer Cooling Time	Option to add a cooling time(seconds) between each printed layer. This option is useful in welding process where the layers must be cooled down before adding sub-sequent layers.

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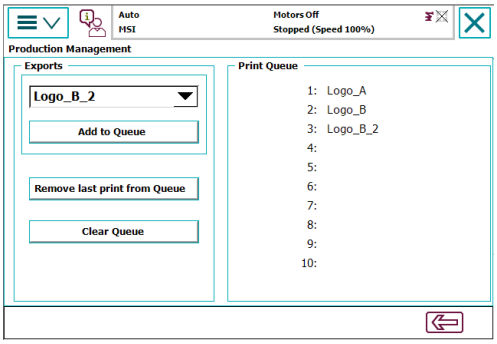
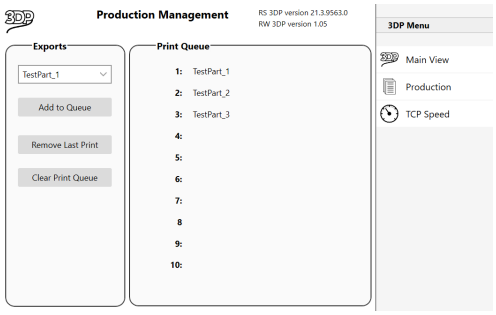
Continued

Production Management screen

	Options	Descriptions
Used for setting up a *Print Queue* to be used with *PrintScheduleManual* procedure. **FlexPendant user interface for RobotWare 6**  xx2000001041 **FlexPendant user interface for RobotWare 7**  xx2100002173	**Exports**	Displays all exported prints placed under *HOME\3DP_EXPORT*.
	Add to Queue	Selected print from the combo box is added to the print queue.
	Remove last print from Queue	Option to remove the last print in the queue. **Note** During program execution, print programs can be added or deleted to the print queue. The first print in the queue cannot be removed while executing *PrintScheduleManual*. **ACTIVE** gets displayed aside the current print.
	Clear Queue	Option to clear the queue. **Note** During program execution, print programs can be added to or deleted from the print queue. The first print in the queue cannot be removed while executing *PrintScheduleManual*. **ACTIVE** gets displayed aside the current print.

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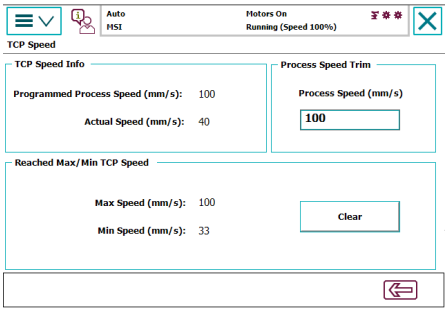
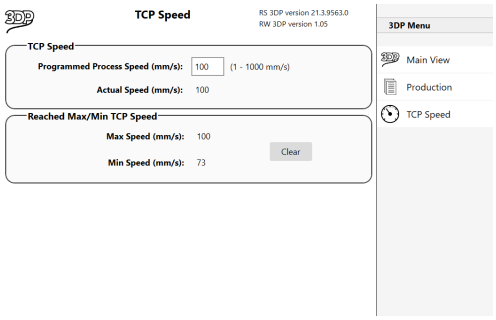
Continued

TCP Speed

	Options	Descriptions
FlexPendant user interface for RobotWare 6  xx2000001783 **FlexPendant user interface for RobotWare 7**  xx2100002174	**TCP Speed Info**	This group displays the following data: • Displays the programmed process TCP speed (*v3DPprocess.v_tcp*) in millimeters /seconds. • Displays the actual TCP speed in millimeters /seconds.
	Process Speed Trim	It is possible to change the programmed process TCP speed during print process. These changes are not persistent and active only during the current print.
	Reached Max/Min TCP Speed	Records the maximum and minimum TCP speed that the process has reached. Press the **Clear** button to delete the recording.

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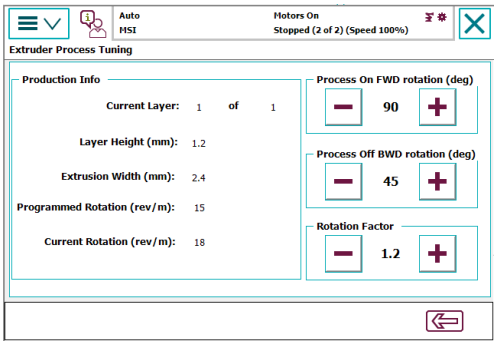
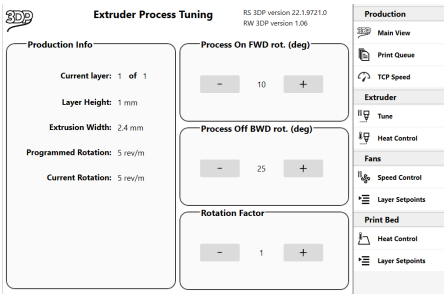
Continued

Extruder Process Tuning

	Options	Descriptions
Only available when the option **3D Printing Integrated Extruder** is used. Used for tuning the extruder axis during a print. These changes are not saved and it is active during the current print only. **FlexPendant user interface for RobotWare 6**  xx2000001040 **FlexPendant user interface for RobotWare 7**  xx2200000210	**Production Info**	Displays current layer. Displays layer height defined in the G-code. Displays extrusion width defined in the G-code. Displays programmed rotation ratio for the extruder screw. Displays the current rotation ratio (programmed value * rotation factor).
	Process On FWD rotation.	To change the forward rotation at process *ON* instructions. 1 degrees step plus or minus.
	Process Off BWD rotation.	To change the backward rotation at process *Off* instructions. 1 degrees step plus or minus.
	Rotation Factor	The rotation factor is set to *one* by default. The programmed rotation ratio is multiplied with the **Rotation Factor**. 0.05 step plus or minus(+/-). Minimum factor = 0.5, maximum factor = 2.0.

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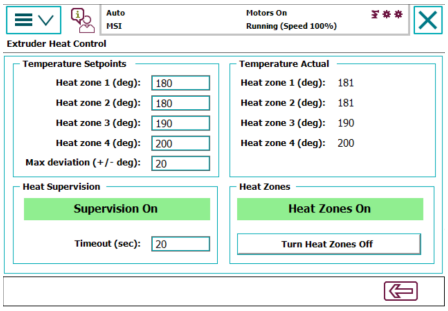
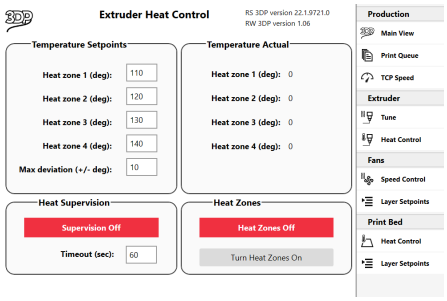
Continued

Extruder Heat Control

	Options	Descriptions
Only available when the option *3D Printing Integrated Extuder* and the addition *Extruder Heat Control* is used. **FlexPendant user interface for RobotWare 6**  xx2000001785 **FlexPendant user interface for RobotWare 7**  xx2200000211	**Temperature Set-points**	This group displays the following fields: • To set the temperature for heat zones 1 – 4. • To set the maximum allowed temperature deviation (plus and minus).
	Temperature Actual	Displays the actual temperature at heat zones 1 – 4.
	Heat Supervision	This field indicates the supervision status during various events using color schemes . • **Supervision** *Off*: The supervision of the heat zones is not active. This is indicated by red color on the FlexPendant. • **Supervision** *ON*: The supervision is ON and the extruder screw is rotating. This is indicated by green color on the FlexPendant. • **Heat Zones Off in: xx sec**: The supervision is *ON* but the extruder screw stands still. The display shows the remaining time for a *timeout*, during timeout the heat zones will be turned *Off*. This is indicated by green color on the FlexPendant. • **Supervision Timeout**:The heat zones are turned *off* when the extruder screw stops its movement and remains immovable for a longer time span than the set timeout value. This is indicated by orange color on the FlexPendant. • **Temperature Error**: One or more of the heat zones deviates more in temperature than the *Max deviation*. The heat zones are turned *Off*. This is indicated by orange color on the FlexPendant.
	Heat Zones	Displays the *ON* or *Off* status of the heat zones. To turn *ON* or *Off* the heat zones.

Fan Control

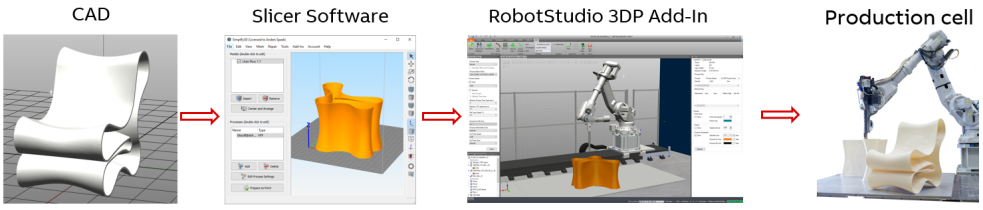
This feature can be used for controlling cooling fans during the printing process. To use this feature, the option *Fan Control* must be selected while configuring the system. Refer *Fan Control on page 82* for more details.

Print Bed Control

This feature can be used for controlling the temperature of print bed heat zones during the printing process. This feature is available when the option *Print Bed Heat Control* is used. Heat zones 4, 8, 12, 16 or 20 can be selected when configuring the system. Refer *Print Bed Control on page 85* for more details.

6 Workflow of the 3D Printing PowerPac

Overview



xx1900001758

The 3D Printing PowerPac requires a well-defined G-code file as the basic prerequisite. The G-code file contains information about the process, position, speed (F values), orientation(optional) and E-dimension (E values) of the CAD file.

Note

While converting the CAD file using a slicer software, select appropriate G-code options for obtaining a well-defined G-code file.

A G-code file contains coordinate values, the following examples are taken from a G-code file.

- G1 X90.909 Y52.573 F4800
- G0 X80.909 Y42.573 E1089.0241
- G1 X29.841 Y-10.451 Z3.646 nX0.076 nY-0.073 nZ0.994 E22.777
- G1 F4000 E40.581 X227.382 Y-12.473 Z33.825 nX0.0559 nY-0.0176 nZ0.9983 eA-127.008 eB93.231

These parameters are detailed in the following table.

Parameter	Represents	Description
G1 or G0	Prefix for line with coordinate data	Mandatory, the 3D Printing PowerPac reads coordinate data with these prefixes.
E	E-dimension Unit: mm	Mandatory, indicates the amount of material extruded while printing. It is used to determine if the process is *On* or *Off*. When the process *Extrude* is used, it can also be used for calculating the dynamic rotation of the extruder screw.
X, Y, Z	Coordinate data Unit: mm	Mandatory, the prefixes for X,Y and Z coordinate data.
F	Speed Unit: mm/minute	Optional, this value is used for calculating the dynamic speed for process speed settings.
nX, nY, nZ	Orientation data Unit: radians	Optional, the 3D Printing PowerPac will read the data as the orientation in the Euclidean coordinate system.
eA, eB, eC, eD, eE, eF	External axes values	Optional, external axes values. 3D Printing PowerPac will not perform any calculations or verifications of movements, hence the reachability check will not be reliable.

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Continued

To determine the state of the process, that is, *ON* or *Off*, the 3D Printing PowerPac interpret the G-code as follows:

- **Process ON**

  A line with the prefix G1 and an E-value.
- **Process Off**

  A line with the prefix G1 without an E-value, or a line with the prefix G0.

7 Advanced 3D printing features

7.1 No external axis, fixed workobject

Overview

No external axis, fixed workobject is the most common scenario in 3D printing. Here, the printing area/ boundary of the printed object is confined within the *work envelope* of the robot. Hence no external axis is required to extend the printing area beyond the work envelope.

Prerequisites

- Virtual controller with the 3DP option enabled. The virtual controller also requires options corresponding to the scenario where 3DP will be used, for example, 3D printing Arc, 3D printing Dispense and so on.
- Define workobject and tool in RobotStudio, the 3D Printing PowerPac requires an active workobject and tooldata.
- G-code file with the required parameters.

Procedure

1 On the **3DP** tab, click **Open**, and then select the required *G-code* file. The **Import G-code file** window opens.

2 In the **Import G-code file** window, Click **Import** to import the entire G-code file.

To import a part of the G-code file, select the **Active** check-box to enable partial import and then enter the number of layers or points, and click **Import**.

3 The object gets imported and will be placed relative to the active *workobject*. Fine-tune the position of the printing object using RobotStudio functions to position the workobject. In the **3DP** window, click **Refresh** to update the position of the printing object in the preview.

> **Note**
>
> Use the options under **Preview** in the **3DP** window to customize the preview. The **Preview** group box provides options for visualizing the printed object in various formats and colors.

4 On the **3DP** tab, click **Path Tune**, the **Tune** window opens. Use the following options to optimize the printing path by removing *via points*.

- Under **Remove Via Points**, click the **Active** check-box and then enter the minimum distance. Observe the reduction in the number of points in the **3DP** window.
- To remove via points from a straight line, under **Remove Aligned Via Points**, click the **Active** check-box and then enter the **Max Rad**. Observe the reduction in the number of points in the **3DP** window.
- Under **Check bounding Points**, click the **Active** check-box to check robot's reachability in the printing area. Observe that the preview of

Continues on next page

the printing object has changed to a bounding box with four extreme points defining the corners of each layer. During export, select **Create targets in station** and verify the reachability using the *Autopath* feature. If all targets are reachable, uncheck **Check bounding Points** and continue to the next step.

5 On the **3DP** tab, click **Path Tune**, and then select **Constant Orientation** or **Aligned Orientation** depending on the type of the extruder nozzle. Select **Aligned Orientation** if the nozzle must reorient according to the direction of the printing path.

   Select a suitable orientation and click **Close**. Orientation settings are persistent.

6 On the **3DP** tab, click **Process**, the **Process Setting** window opens.

7 Select the **Process**, and the suitable **Process Motion Mode** as required by the robot model, and then select the **Process point Settings** required for the printing process.

8 On the **3DP** tab, click **Save** to save the 3DP settings to an *xml* file.

   The settings file can be reused in trial simulations where G-code files are imported. When a G-code file is imported, the process and path tune settings will not be available. These settings can be restored by importing the saved *xml* settings file.

9 On the **3DP** tab, click **Export Program**. Create a new folder under *Home\3DP_EXPORT* or select an empty folder to place all RAPID modules.

10 Click the **RAPID** tab, in the **Controller** browser, click the **RAPID** node to view the RAPID modules. Verify the RAPID program.

11 Click **Play** to view the simulation.

7.2 Robot with coordinated rotational external axis

Overview

Robot with a turn table is a good example for coordinated rotational *external axis*. Here the printing area/the boundary of the printed object extends beyond the *work envelope* of the robot but it can be accommodated by using a turn table(rotational external axis). A rotational external axis is used such that the printing area is rotated to fit within the work envelope of the robot.

The following steps correspond to a scenario where the configuration contains an extruder and a turn table, hence the work flow has been modified to include the settings of the turn table and the extruder.

Prerequisites

- Virtual controller with the 3DP option enabled. The virtual controller also requires options corresponding to the scenario where 3DP will be used, for example, 3D printing Arc, 3D printing Dispense and so on.
- Define workobject and tool in RobotStudio, the 3D Printing PowerPac requires an active workobject and tooldata.
- G-code file with the required parameters.

Procedure

1. On the **3DP** tab, click **Open**, and then select the required *G-code* file. The **Import G-code file** window opens.
2. In the **Import G-code file** window, click **Import** to import the entire G-code file.

   To import a part of the G-code file, select the **Active** check-box to enable partial import and then enter the number of layers or points, and click **Import**.
3. The object gets imported and will be placed relative to the active *workobject*. Fine-tune the position of the printing object using RobotStudio functions to position the workobject. In the **3DP** window, click **Refresh** to update the position of the printing object in the preview.

   > **Note**
   >
   > Use the options under **Preview** in the **3DP** window to customize the preview. The **Preview** group box provides options for visualizing the printed objects in various formats and colors.

4. On the **3DP** tab, click **Path Tune**, the **Tune** window opens. Use the following options and remove *via points* to optimize the printing path.
   - Under **Remove Via Points**, click the **Active** check-box and then enter the minimum distance. Observe the reduction in the number of points in the **3DP** window.
   - To remove via points from a straight line, under **Remove Aligned Via Points**, click the **Active** check-box and then enter the **Max Rad**. Observe the reduction in the number of points in the **3DP** window.

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- Under **Check bounding Points** click the **Active** check-box to check robot's reachability in the printing area. Observe that the preview of the printing object has changed to a bounding box with four extreme points defining the corners of each layer. During export, select **Create targets in station** and verify the reachability using the *Autopath* feature. If all targets are reachable, uncheck **Check bounding Points** and continue to the next step.

5 On the **3DP** tab, click **Path Tune**, and then select **Constant Orientation** or **Aligned Orientation** depending on the type of the extruder nozzle. Select **Aligned Orientation** if the nozzle must reorient according to the direction of the printing path.

   Select a suitable orientation and click **Close**. Orientation settings are persistent.

6 On the **3DP** tab, click **Process**, the **Process Setting** window opens.

7 Select the **Process**, in this case select the process **Extrude**.

8 Select the **Process Motion Mode** as required by the robot model, and then select the **Process point Settings** required for the printing process.

9 On the **3DP** tab, click **External Axes**, and then select **Coordinated Axes**.

10 In the **Coordinates Axes** window, select **External axis** for the turn table, and then select **Interpolate Constant Offset**, enter the values in the **Angle relative Base Frame(deg)** and **Min.Movement(deg)** fields. Click **Apply**.

   The selected settings will be displayed in the **3DP** window.

11 On the **3DP** tab, click **External Axes**, and then select **Extruder Axes**. The Extruder Axes window opens.

12 In the **Extruder Axes** window, select the external axis for the extruder . In the **Rotation Ratio** group, define the number of revolutions the extruder screw must rotate to dispense material for one meter distance in the **Rotation** filed. Select **Fixed** to retain this value throughout the printing process.

   Enter suitable values in the **Process On** and **Off** fields. These values are dependant on the type of the extruder, the type of material used in the printing process and the size of the nozzle.

   Click **Apply**. The selected settings will be displayed in the **3DP** window.

13 On the **3DP** tab, click **Save** to save the 3DP settings to an *xml* file.

   The settings file can be reused in trial simulations where G-code files are imported. When a G-code file is imported, the process and path tune settings will not be available. These settings can be restored by importing the saved *xml* settings file.

14 On the **3DP** tab, click **Export Program**. Create a new folder under *Home\3DP_EXPORT* or select an empty folder to place all RAPID modules.

15 Click the **RAPID** tab, in the **Controller** browser, click the **RAPID** node to view the RAPID modules. Verify the RAPID program.

   Click **Play** to view the simulation.

7.3 Robot with coordinated linear external axis

Overview

Robot on a track is a good example for coordinated linear external axis. This scenario is used for printing very large objects where the printing area/the boundary of the printed object extends far beyond the *work envelope* of the robot. Here the robot base needs to move on a track to accommodate the printing area.

This configuration requires a robot that is mounted on a track which has been configured for coordinated motion. Additionally, the orientation of extruder nozzle is set to *Aligned Orientation*, that is, the nozzle changes its orientation in the direction of path.

Prerequisites

- Virtual controller with the 3DP option enabled. The virtual controller also requires options corresponding to the scenario where 3DP will be used, for example, 3D printing Arc, 3D printing Dispense and so on.
- Define workobject and tool in RobotStudio, the 3D Printing PowerPac requires an active workobject and tooldata.
- G-code file with the required parameters.
- A robot system with a robot mounted on a track that is configured for coordinated motion.

Procedure

1. On the **3DP** tab, click **Open**, and then select the required *G-code* file. The **Import G-code file** window opens.
2. In the **Import G-code file** window, click **Import** to import the entire G-code file.

   To import a part of the G-code file, select the **Active** check-box to enable partial import and then enter the number of layers or points, and click **Import**.
3. The object gets imported and will be placed relative to the active *workobject*. Fine-tune the position of the printing object using RobotStudio functions to position the workobject. In the **3DP** window, click **Refresh** to update the position of the printing object in the preview.

   > **Note**
   >
   > Use the options under **Preview** in the **3DP** window to customize the preview. The **Preview** group box provides options for visualizing the printed objects in various formats and colors.

4. On the **3DP** tab, click **Path Tune**, the **Tune** window opens. Use the following options and remove *via points* to optimize the printing path.
   - Under **Remove Via Points**, click the **Active** check-box and then enter the minimum distance. Observe the reduction in the number of points in the **3DP** window.

Continues on next page

- To remove via points from a straight line, under **Remove Aligned Via Points**, click the **Active** check-box and then enter the **Max Rad**. Observe the reduction in the number of points in the **3DP** window.
- Under **Check bounding Points** click the **Active** check-box to check robot's reachability in the printing area. Observe that the preview of the printing object has changed to a bounding box with four extreme points defining the corners of each layer. During export, select **Create targets in station** and verify the reachability using the *Autopath* feature. If all targets are reachable, uncheck **Check bounding Points** and continue to the next step.

5 On the **3DP** tab, click **Path Tune**, and then select **Constant Orientation** or **Aligned Orientation** depending on the type of the extruder nozzle. For this scenario, select **Aligned Orientation** to reorient the nozzle in the direction of the printing path.

6 In the **Aligned Orientation** window, select the travel vector depending on which face of the tool must follow the path. Enter suitable values in the **Angle to Path** and **Max reorient** distance based on the tool alignment and the printing object.

Click **Close**. Orientation settings are persistent.

> **Note**
>
> The **Aligned Orientation** settings work only for the tool orientation where the z-axis points outwards from the nozzle.
>
> While using **Aligned Orientation** the joint limits for robot axis 6 must be increased.

7 On the **3DP** tab, click **Process**, the **Process Setting** window opens.

8 Select the **Process**, and the suitable **Process Motion Mode**, and then select the **Process point Settings** required for the printing process.

9 On the **3DP** tab, click **External Axes**, and then select **Coordinated Axes**, the **Coordinated Axes** window opens, perform the following settings.

- In the **External Axis** field , select the external axis for the track.
- If the robot must stay in a fixed position throughout the printing process,position the robot and track as required and then select **Fixed value**, and then click the **Read Current Pos**. The current position will be read and displayed in the **Value X-axis** field.
- If the distance between the TCP and the base of the track can remain constant throughout the printing process, select **Interpolate Fixed Offset** and then enter a suitable Offset value in the **Offset Linear X-axis** filed. This setting is used for elongated parts where the printed area extends in the X-axis but the printing distance in the Y-axis from the track is short.
- If the distance between the TCP and the base of the track must be dynamic, select **Interpolate Dynamic Offset** and then enter suitable Offset values in the fields. This setting is used while printing very large

Continues on next page

objects where the robot arm reaches out to print farther points in the Y-axis. When the robot prints the farthest point the Offset between the robot base and the TCP (*Min Offset Linear*) can be zero.

10 On the **3DP** tab, click **Save** to save the 3DP settings to an *xml* file.

The settings file can be reused in trial simulations where G-code files are imported. When a G-code file is imported, the process and path tune settings will not be available. These settings can be restored by importing the saved *xml* settings file.

11 On the **3DP** tab, click **Export Program**. Create a new folder under *Home\3DP_EXPORT* or select an empty folder to place all RAPID modules.

12 Click the **RAPID** tab, in the **Controller** browser, click the **RAPID** node to view the RAPID modules. Verify the RAPID program.

13 Click **Play** to view the simulation.

7.4 Compensating print path for irregular surfaces

Overview

Use the compensate print path feature for fine-tuning the print path for large objects that are printed on a non-flat surface. It can also be used while printing on a non-flat surface.

Workflow

1 **Create measuring path**

A path with a user-defined number of measure points is created in 3D Printing PowerPac. This path is configured as a standard print program using the *Calibrate* process. At export, a text file with the measure points (nominal points) is saved together with the print program.

2 **Measure the print bed with the print robot**

When the exported calibration program is executed, the robot, with a sensor (distance or contact) mounted on the robot, moves to each nominal point and measures the distance to the surface. The measured distances will be added to the text file along with the nominal points.

These steps are optionally performed to assess changes to the print bed since the last measurement.

3 **Compensate print path**

Before exporting a print path, it can be calibrated/compensated with help of the text file generated in the previous steps.

Create measuring path

The measuring path can be created for square or circular print beds.

On the 3D printing window, click **Start** and then click **Create Measuring Path**.

Square print bed	Circular print bed

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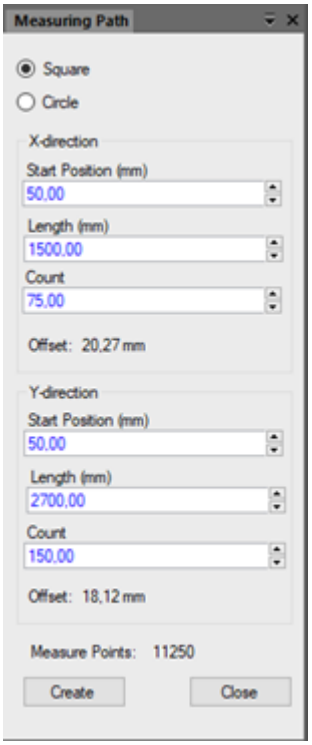

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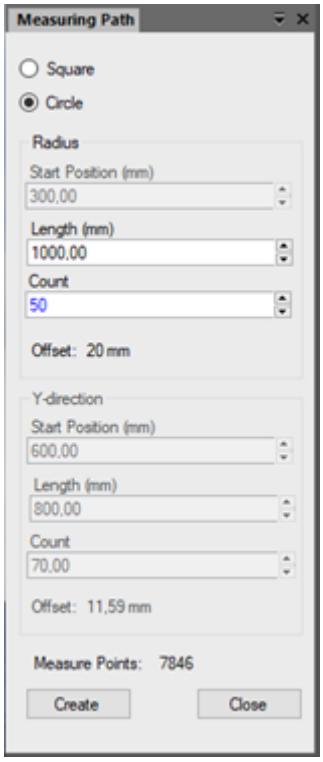
- **Start Position**: starting position in the X-direction relative to the active workobject's User Frame. The first measure point will be created here.
- **Length**: length in the X-direction, specifies the distance in the X-direction to be measured.
- **Count**: number of measurement points along the X-axis. The number of points decides the offset between the measure points.
- **Start Position**: start position in the Y-direction relative to the active workobject's User Frame. The first measure point will be created here.
- **Length**: length in the Y-direction. The distance in the Y-direction to be measured.
- **Count**: number of measurement points along the Y-axis. The number of points decides the offset between the measure points.



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- **Length**: the distance that should be measured from the User Frame. This will be the radius of the circle.
- **Count**: number of measurement points along the radius axis. The number of points will decide the Offset between the measure points.

Note

The X and Y values of the object frame must be zero (it must not be moved away from the user frame) for the workobject used while measuring path.

The *Measuring Path* is handled as a standard print program in the 3D Printing PowerPac, but with the process **Calibrate** selected.

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Measure the print bed with the print robot

To measure the print bed, a measure sensor must be mounted on the robot. It can be a contact sensor or a distance sensor. If a contact sensor is used, the signal from the sensor should be connected to the digital input *diMeasure_3DP*. If a distance sensor is used, the signal from the sensor should be connected to the analogue input *aiZvalue_3DP*.

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The exported measuring path starts as standard print program, hence, before the robot starts to move, the measurement method must be selected either on the FlexPendant or on the Production Screen.

If contact sensor is selected, the start height (+Z relative to the nominal point) and the stop height (-Z relative to the nominal point) for the search should be selected.

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If distance sensor is selected, the measuring offset should also be selected to assess the deviation of robot from the nominal point during measurements. The nominal value of the sensors also must be added, which will be subtracted from the sensors output value.

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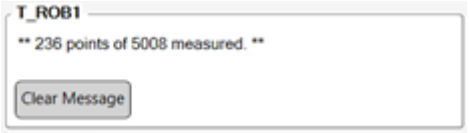
After adding offset values, the robot moves to each measurement point and saves the Z height value to the same measuring file as with the nominal values.



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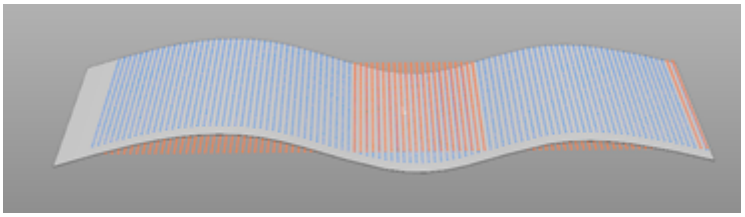
Compensating print path

Before exporting a print program, it can be calibrated/leveled with help of the measuring file. These calibration functions are demonstrated here using an exaggerated irregular surface (not flat).

1. To calibrate/level a print path, select **Compensate Print Path**.
2. In the **Compensate Print Path** browser, click **Load Measuring File**.

   Select the calibration file with the nominal and calibrated points. The file is named *CalibFile.3dp* and is stored in a subfolder called *Calib3DP* under the program folder for the measurement path.
   MySystem\HOME\3DP_EXPORT\MyCalibration\Calib3DP\CalibFile.3dp

   When a calibration file is loaded, the nominal and measured points are displayed in selected colors.



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3. To level the print path, under the **Compensation** group,
   - specify values in the **Height Full Compensation** to fully level the print path till the specified height.
   - specify the height where the leveling should stop in the **Height End Compensation**.

     If **Height Full Leveling** is lower than **Height End Leveling**, the difference will be compensated.
4. Select the **Include Orientation** check-box to adjust targets orientation to follow the print surface.
5. Click **Calculate**, to calibrate/level the print path. For certain prints, extra points must be added to achieve a correct result. To achieve this, In **Path Tune**, in the **Distance Filter** group, specify **Max distance**.

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8 RAPID modules

Overview

The RobotWare option *3DP RobotWare* must be installed in the robot controller(real and virtual) that hosts the 3D Printing PowerPac. The export from the 3D Printing PowerPac contains several RAPID program modules that are unique for the imported G-code file. These modules are used together with 3D Printing RobotWare Add-In modules.

Program modules

Module	Description

T_ROB1_MAIN_3DP	The 3DP entry point. Consists of a main procedure with a home position and a procedure call to *main3DP*. This module can be modified or replaced till the procedure call to *main3DP* is kept.
	`!*********************************************************`
	`!`
	`!  This is the 3DP entry point, modify the "Home" position, and`
	`!  if needed add via points to the printing area before start.`
	`!`
	`!*********************************************************`
	`PROC main()`
	`  MoveAbsJ jHome,v200,fine,tool0\WObj:=wobj0;`
	`  %"main3DP"%;`
	`  MoveAbsJ jHome,v200,fine,tool0\WObj:=wobj0;`
	`ENDPROC`
	xx1900001696

T_ROB1_3DP	Generated at export and is unique for each print. Has the file name *_T_ROB _load_me.mod* and should be loaded into **T_ROB1**. Shall not be modified.
Mod_3DP_x	Generated at export and is unique for each print. Shall not be modified. Will be deleted at the first print when the *Print_x* files are created.
Print_x	Generated at the first execution after export. Shall not be modified.

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Module	Description
T_ROB1_EVENTS_3DP	Consists of several event routines that are executed during the printing process, custom code can be added to these routines. • **InitEvent** Executed once at the beginning of printing. In *InitEvent* ,it is a commented procedure call to *StartChoice*. If this procedure call is uncommented, a question will be asked on the FlexPendant at the start of the printing process, if the print should start from beginning, or from the last printed point. This can be useful in a test phase where the print has been aborted and the program pointer has been lost. • **PrePartEvent** Executed once before the printing starts. • **PreProcessEvent** Executed before the process turns *ON.* • **PostProcessEvent** Executed after the process is turned *Off*. • **PostLayerEvent** Executed after printing a layer.The procedure is executed when the robot enters the programmed zone for the last point in the layer. • **PostPartEvent** Executed once after the printing process finishes. • **RestartPath** Used together with *StartChoice*. Based on the current setup, customer can enter the initial position where the printing must be started. • **PostQueueEvent** Executed after all parts in the FlexPendant print queue are executed. • **UserEvent_1** Executed when the text **UE1** is present in the G-code. The procedure is executed when the robot reaches the coordinates in the G-code line above **UE1**. • **UserEvent_2** Executed when the text **UE2** is present in the G-code. The procedure is executed when the robot reaches the coordinates in the G-code line above **UE2**. • **UserEvent_3** Executed when the text **UE3** is present in the G-code. The procedure is executed when the robot reaches the coordinates in the G-code line above **UE3**. • **UserEvent_4** Executed when the text **UE4** is present in the G-code. The procedure is executed when the robot reaches the coordinates in the G-code line above **UE4**.
T_ROB_1_ARC_DATA_3DP	Process data used with process *Arc*.
T_ROB_1_DISPENSE_DATA_3DP	Process data used with process *Dispense*.

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Module	Description
T_ROB1_EXPORTS_LIST_3DP	Contains a string array named *Prints* that displays the exported *print modules* that are placed under the folder *HOME\3DP_EXPORT*. This array is used for scheduling prints with the procedures *PrintScheduleAuto* and *PrintScheduleManual*. The array is automatically updated when a print is exported from the 3D Printing PowerPac, and when the **Production Management** screen is opened in the FlexPendant user interface. The print queue can accommodate a maximum of 20 different print programs.
T_ROB1_SCHEDULE_3DP	Contains procedures *PrintScheduleAuto* and *PrintScheduleManual*.
EXTRUDE_3DP	Available only with the option **3D Printing Integrated Extruder**. Contains the following instructions. • **ExtrudeL**: Move instruction for process *Extude*. Requires an instruction template for *ExtudeL* in the active station. All arguments to be defined in the **Process Settings** window. • **PurgeJ**: For purging the extruder. The robot moves to the selected point in joint motion and starts rotating the extruder. The rotation can be controlled from the FlexPendant. **Arguments**: **mecunit**: specifies the name of the mechanical unit of the extruder screw. **RotationSpeed**:specifies the rotation speed of the extruder in degrees/sec. • **PurgeL**:For purging the extruder. The robot moves linearly to the selected point and starts rotating the extruder. This rotation can be controlled from the FlexPendant. **Arguments**: **mecunit**:specifies the name of the mechanical unit of the extruder screw. **RotationSpeed**:specifies the rotation speed of the extruder in degrees/sec. **Note** To avoid extra rotation of the extruder screw after the purge has stopped, the external axis value for the extruder screw should be set to zero in the robtarget used in the *Purge* instruction.
T_ROB1_HEAT_CONTROL_3DP	Available only with the option **3D Printing Integrated Extruder – Heat Control**. Contains the instruction *ExtruderHeat*.
T_ROB1_FAN_CONTROL_3DP	Available only with the option **Fan Control**. Contains the instruction *FanControl*.
T_ROB1_BED_CONTROL_3DP	Available only with the option **Print Bed Heat Control**. Contains the instruction *PrintBedHeatControl*.

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9 Processes and features

Overview

By using features such as Fan control, Print bed control and so on, 3D Printing can be extended to various processes. This chapter describes such processes and the features that can be coupled with them to extend 3D Printing functionalities.

DispenseWare 3D Printing unique functions

When the process Dispense (DispL) is used together with an extruder screw, it is possible to send signals to the process equipment for reversing the direction of screw rotation at process *Off* points. It is also possible to start the screw rotation before the robot starts to move at process *ON*. The purpose of this function is to get a better process control at the process *ON* and *Off* points, and to improve the quality of the printed product.

3D Printing dispense data variables

data variables	Description
nPreTime (num)	The extruder screw must start its movement a little earlier than the robot movement to be ready to dispense material with the robot movement. **nPreTime (num)** is the extra time that the extruder takes to feed out material through the nozzle. Then the robot stands still (but the extruder screw rotates)at process *ON* (DispL\ON) point. At this point the analog output signal *aoPreFlow_3DP* will be *High*.
nPreFlow (num)	The value for the analog output *aoPreFlow_3DP*. Specifies the speed of the screw rotation.
nBwdFlow (num)	The value for the analog output *aoEqu1F1* at backward rotation.
nBwdTime (num)	The time the screw should rotate backwards.
bBwdEnabled (bool)	Enables the backward rotation of the screw.

3D Printing dispense I/O signals

Signal	Description
aoPreFlow_3DP	This analog output signal should be connected parallel with the analog output signal *aoEqu1F1* to the external process equipment. It is used together with *nPreTime* to rotate the screw at process *ON*, before the robot starts the movement.

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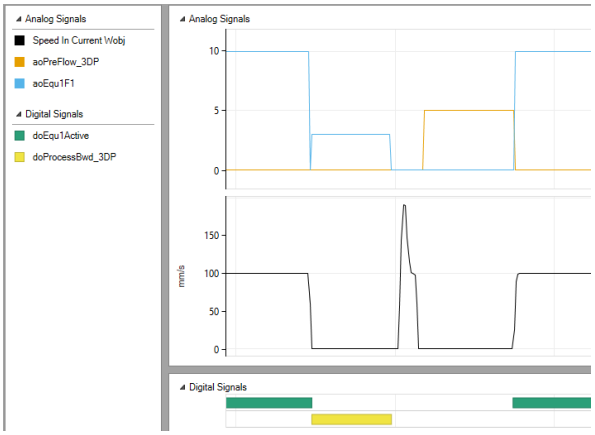
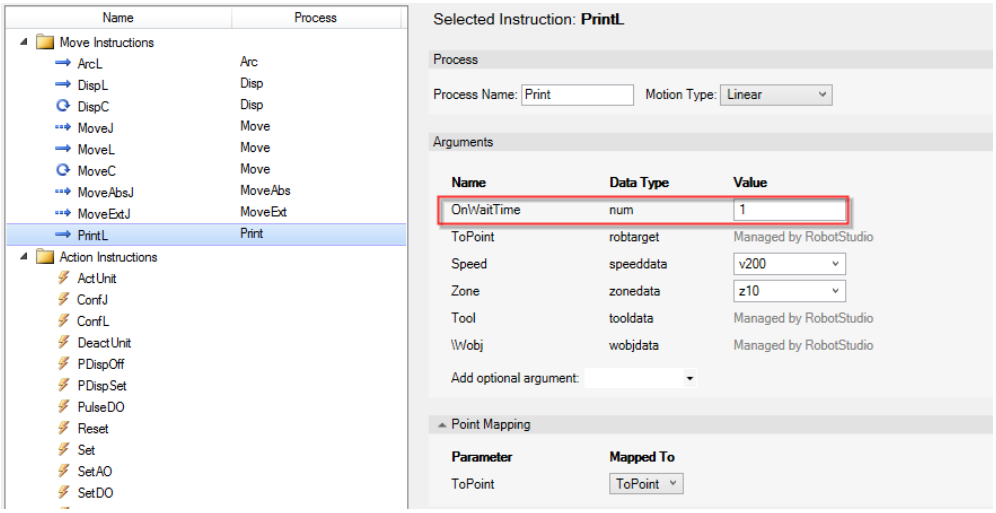
Signal	Description
doProcessBwd_3DP	This digital output signal triggers the external process equipment to rotate the screw backwards.  xx1900001697

Externally Controlled Extrusion

Externally Controlled Extrusion is a process similar to *DispenseWare* but customized for 3D printing, with only a subset of the functionality. The move instruction name for Externally Controlled Extrusion is *PrintL*.

An instruction template for *PrintL* has to be defined in the station.



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3D Printing Externally Controlled Extrusion data variables

- **nProcessOnWaitTime ((num)**

  The time the robot should stand still at process *ON* after the digital output *doProcess_3DP* is set to *High*. If the *nProcessOnWaitTime* value is greater than zero, the robot will stop in a fine point. This value is defined in the *instruction template* for *PrintL*.

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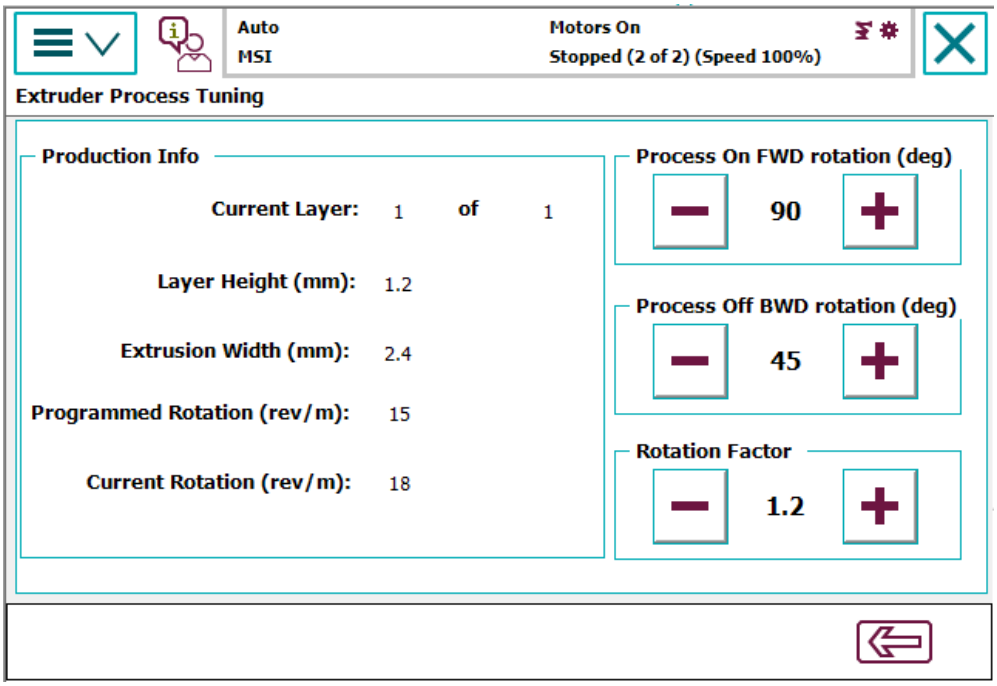
3D Printing Externally Controlled Extrusion I/O signals

Signal	Description
aoTCP_3DP	The *TCP* speed system signal output. Should be connected to the external process equipment. For more information see *Technical reference manual - System parameters*.
goEvalue_3DP	Relative extrusion distance (E-value) from previous point. Can be used to control the material flow with external process equipment.
doProcess_3DP	Internal signal for process *ON*. This is cross connected to the signal *doEquActive_3DP* with the condition that the task is executing.
doEquActive_3DP	Signal for process *ON*. This signal must be connected to the external process equipment.

Integrated Extruder

Integrated Extruder is used when the tool has an extruder screw controlled as an integrated axis. The move instruction name is *ExtrudeL*. An *instruction template* for *ExtrudeL* must be defined in the station. The rotation of the screw is defined in the **Extruder Axis** window.

It is possible to fine-tune the extruder process of an active print process during runtime using the **Extruder Process Tuning** screen of the FlexPendant GUI.



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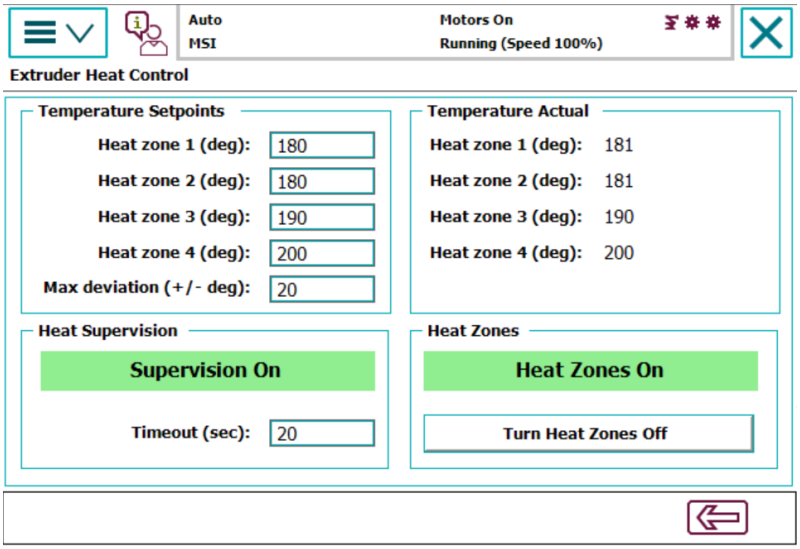
Extruder Heat Control

Overview



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Extruder Heat Control is an optional addition to Integrated Extruder for controlling and monitoring the extruder heat elements (heat zones). Up to four heat zones can be controlled and monitored. The setpoints for the heat zones are defined in the Extruder Heat Control screen of the FlexPendant GUI.

Arguments and descriptions

The heat zones can be turned *ON* or *Off* from the FlexPendant GUI or from RAPID with the instruction *ExtruderHeat*.

- The following example shows how this instruction is used for turning *Off* all heat zones.

  ```
  ExtruderHeat\Off;
  ```

- The following example shows how this instruction is used for turning *On* all heat zones. It also shows how to use arguments to keep the program execution wait till all heat zones reach the selected setpoint value minus 50% of the selected max deviation.

  ```
  ExtruderHeat\WaitZone1\WaitZone2\WaitZone3\WaitZone4;
  ```

Arguments	Description
\Off	Add this argument to turn *Off* all heat zones. In the absence of this argument, the setpoint values of all heat zones will be set to the value defined in the FlexPendant.
\WaitZone1	With this argument, the program execution waits till the heat zone 1 reaches (the selected setpoint value) minus (50% of the selected max deviation).
\WaitZone2	With this argument, the program execution waits till the heat zone 2 reaches (the selected setpoint value) minus (50% of the selected max deviation).
\WaitZone3	With this argument, the program execution waits till the heat zone 3 reaches (the selected setpoint value) minus (50% of the selected max deviation).
\WaitZone4	With this argument, the program execution waits till the heat zone 4 reaches (the selected setpoint value) minus (50% of the selected max deviation).

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Heat control I/O signals

goSetpointHeatZone1_3DP	Group output. Temperature setpoint zone 1. Should be connected to the extruder heat control system.
goSetpointHeatZone2_3DP	Group output. Temperature setpoint zone 2. Should be connected to the extruder heat control system.
goSetpointHeatZone3_3DP	Group output. Temperature setpoint zone 3. Should be connected to the extruder heat control system.
goSetpointHeatZone4_3DP	Group output. Temperature setpoint zone 4. Should be connected to the extruder heat control system.
giActualHeatZone1_3DP	Group input. Temperature actual value zone 1. Should be connected to the extruder heat control system.
giActualHeatZone2_3DP	Group input. Temperature actual value zone 2. Should be connected to the extruder heat control system.
giActualHeatZone3_3DP	Group input. Temperature actual value zone 3. Should be connected to the extruder heat control system.
giActualHeatZone4_3DP	Group input. Temperature actual value zone 4. Should be connected to the extruder heat control system.
doHeatZonesOn_3DP	Digital Output. High when one or more of group outputs signals of the heat zones are greater than zero. This can be used in combination with the group outputs.
doHeatError_3DP	Digital Output. High when a heat error occurs. Can be connected to an external equipment such as operator panel to indicate a heat error when it occurs.
doExtruderActive_3DP	Digital Output. High when the extruder screw starts rotating. Low when the screw stops rotating and the *supervision time* passes. Can be connected to an external equipment such as operator panel to indicate specific events like robot stop and heat zones being turned *Off*.

nnMaxExtruderHeatZoneSetpoint (num):

Max allowed Heat Zone setpoint value. Default value is set to 350, but can be changed via RAPID instruction, for example:

```
nMaxExtruderHeatZoneSetpoint:=600;
```

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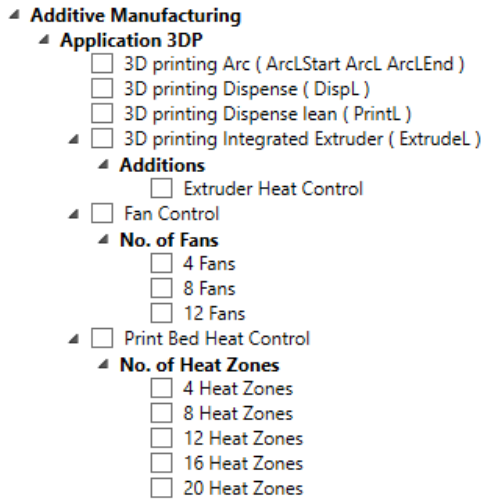
Fan Control

This feature can be used for controlling cooling fans during the printing process. To use this feature, the option *Fan Control* must be selected while configuring the system.



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The number of fans (4,8 or 12) can be selected as required while configuring the system. When the selected fan number is 13, all configured fans will be affected. The output signals for the *Fan Control* are one digital output signal (*doFanX_3DP*) together with one analog output signal (*aoFanX_3DP*) for each configured fan.

Use the following methods for controlling the fans. These methods can be used in combination.

- From G-code with M106 and M107 commands
- From the FlexPendant by manually setting the signal values
- From the FlexPendant with the Layer *Setpoints List*
- From RAPID with the instruction *FanControl*

From G-code with M106 and M107 commands.

The arguments P and S are optional.

Parameter	Represents	Description
M106	prefix for line with fan control data	Mandatory, the 3D Printing PowerPac identifies and reads fan data with this prefix.
S	Fan speed (PWM value 0-255)	Optional, the 3D Printing PowerPac reads fan speed ranging from fan Off (fan speed = 0) to 100% (Maximum fan speed = 255). If omitted, sets fan to the default speed of 255.
P	Fan unit	Optional, this value is used to identify the fan the command applies to. If omitted, the command will be applied to the default fan (P1).

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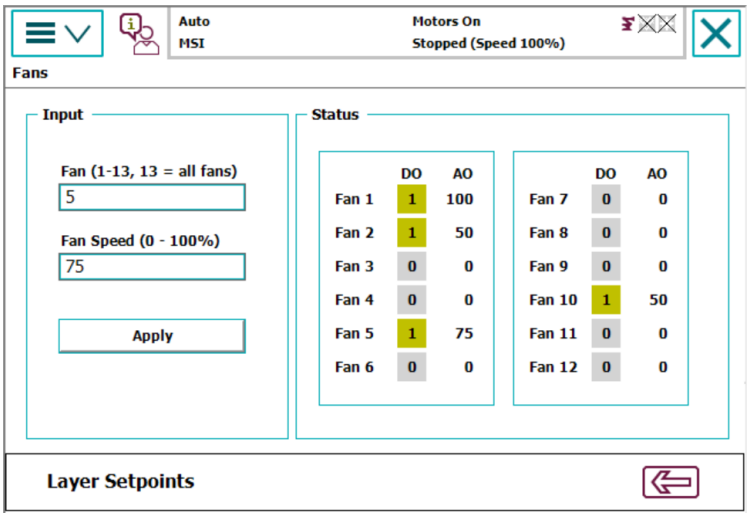
From the FlexPendant by manually setting the signal values

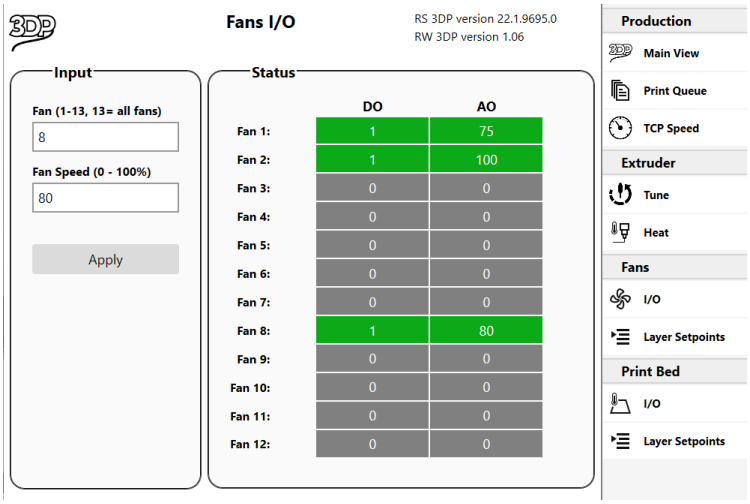
Signal values for fan control can be set manually from the FlexPendant as displayed in the following image.

FlexPendant user interface for RobotWare 6



xx2200000129

FlexPendant user interface for RobotWare 7



xx2200000130

Inputs	• **Fan**: The fan to be changed. Fan 13 will affect all fans. • **Fan Speed**: The speed of the fan in percentage. • **Apply**: To apply the selected values.
Status	Displays the status of the digital and analog signals for the fans.

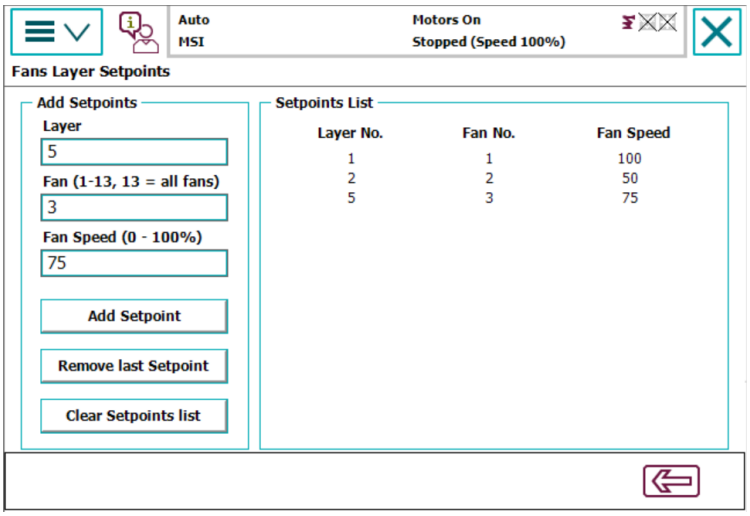
Continues on next page

Continued

From the FlexPendant with the Layer Setpoints List.

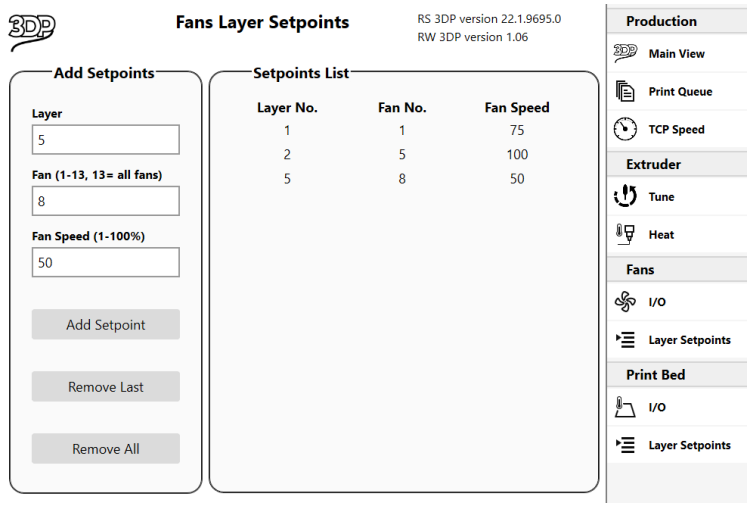
Layer setpoints for controlling fans can be set from the FlexPendant. The fan(s) speed will be changed at the beginning of the selected Layer No.

FlexPendant user interface for RobotWare 6



xx2200000131

FlexPendant user interface for RobotWare 7



xx2200000132

Add Setpoints	• **Layer**: The layer in which the selected fan will change speed. The change will take place at the beginning of the selected layer. • **Fan**: The fan to be changed. Fan 13 will affect all fans. • **Fan Speed**: The speed of the fan in percentage (0-100). • **Add Setpoints**: Adds setpoint to the list. • **Remove last Setpoint**: Removes the last setpoint from the list. • **Clear Setpoints list**: Clears the whole list.
Setpoints List	List with all added setpoints. The list contains maximum 15 setpoints.

Continues on next page

From RAPID with the instruction FanControl.

The following example shows how this instruction is used for turning Off all heat zones. The digital output signal will be set to zero for all fans, and the analog output for all fans will be set to zero.

```
FanControl\AllFans,0;
```

The following example shows how this instruction is used for turning On fan no. 5 with the speed set to 50%. The digital output signal will be set to 1 for fan no. 5, and the analog output for fan no. 5 will be set to 50%.

```
FanControl\Fan_5,50;
```

Arguments	Description
\AllFans	Add this argument to set the speed on all fans.
\Fan_1	Sets the speed of fan no. 1. Used together with the *FanSpeed* argument (0-100%).
....	….
\Fan_12	Sets the speed of fan no. 12. Used together with the *FanSpeed* argument (0-100%).
,XXX;	The fan speed (argument *FanSpeed*), 0-100%.

Fan control I/O signals

doFan_1_3DP	Digital output. High when the signal **aoFan1_3DP** >0. Can be connected to the fan control system.
....	....
doFan_12_3DP	Digital output. High when the **aoFan12_3DP** >0. Can be connected to the fan control system.
aoFan_1_3DP	Analog output. The fan speed in % (0 – 100). Can be connected to the fan control system.
....	....
aoFan_12_3DP	Analog output. The fan speed in % (0 – 100). Can be connected to the fan control system.

Print Bed Control

This feature can be used for controlling the temperature of print bed heat zones during the printing process. This feature is available when the option *Print Bed Heat Control* is used. Heat zones 4, 8, 12, 16 or 20 can be selected when configuring the system.

The output signals for the *Print Bed control* are listed here:

- one digital output (**doPrintBedHeatZoneX_3DP**) signal.
- one group output (**goSetpointPrintBedHeatZoneX_3DP**) signal.
- one group input (**giActualPrintBedHeatZoneX_3DP**) signal for each configured Heat Zone.

When *Heat Zone no. 21* is selected, all configured heat zones will be affected. A digital output error signal (**doPrintBedHeatError_3DP**) goes *High* if the group input signal deviates more than the selected *Max deviation value* compared to the group output value.

Continues on next page

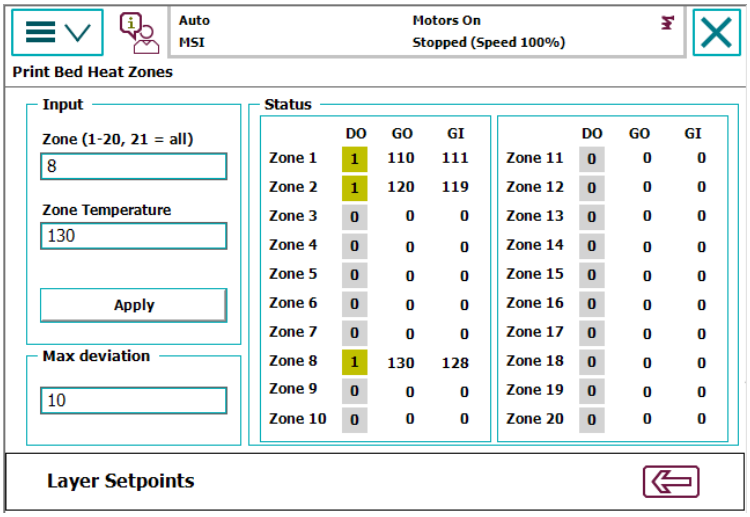
Continued

The Print Beds can be controlled by the following ways:

- From the FlexPendant by manually setting the signal values.
- From the FlexPendant with the Layer Setpoints List.
- From RAPID with the instruction *PrintBedControl*

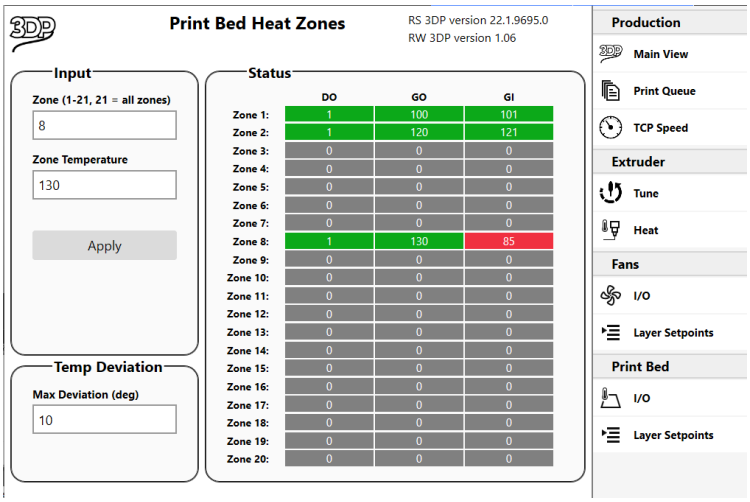
From the FlexPendant by manually setting the signal values.

FlexPendant user interface for RobotWare 6



xx2200000133

FlexPendant user interface for RobotWare 7



xx2200000134

Inputs	• **Zone**: The heat zone to be changed. Zone 21 will affect all heat zones. • **Zone Temperature**: The heat zone temperature setpoint value. • **Apply**: To apply the selected values.
Status	Displays the status of the digital output signal, the group output signal, and the group input signal for each heat zone.

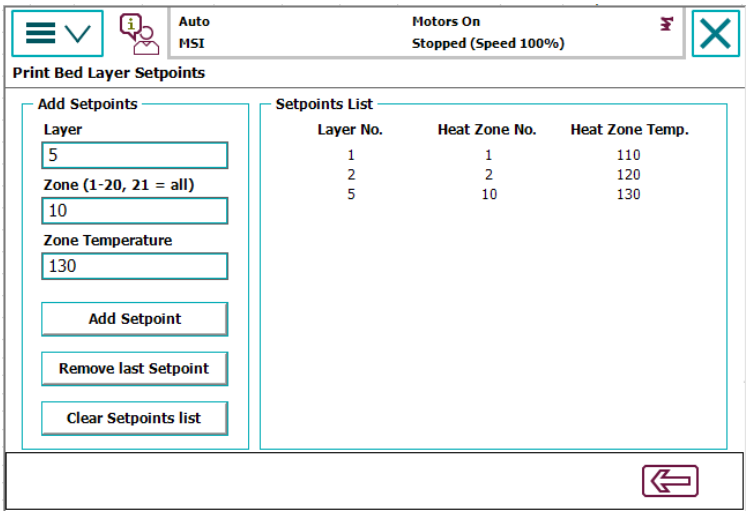
Continues on next page

Temp Deviation	The maximum deviation between the setpoint value (group output) and the actual value (group input). When the temperature deviates more than this value the digital output signal **doPrintBedHeatError_3DP** will be high.

From the FlexPendant with the Layer Setpoints List

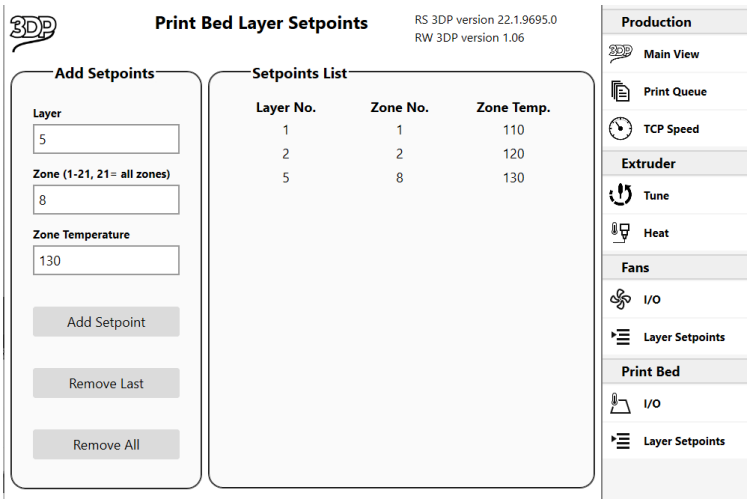
The heat zone(s) temperature changes at the beginning of the selected Layer.

FlexPendant user interface for RobotWare 6



xx2200000135

FlexPendant user interface for RobotWare 7



xx2200000136

Add Setpoints	• **Layer**: The layer where the selected heat zone changes status. This change will take place at the beginning of the selected layer. • **Zone**: The heat zone to be changed. Zone 21 will affect all heat zones. • **Zone Temperature**: The heat zone temperature setpoint value. • **Add Setpoint**: Adds setpoint to the list. • **Remove Last Setpoint/Remove Last**: Removes the last setpoint in the list. • **Clear Setpoints List/Remove All**: Clears the whole list.

Continues on next page

Continued

Setpoints List	List that contains all added setpoints. This list can contain maximum 15 setpoints.

From RAPID with the instruction PrintBedControl

The following example shows how this instruction is used for turning Off all heat zones. The digital output signal will be set to zero for all heat zones, and the group output for all heat zones will be set to zero.

```
PrintBedHeatControl\AllHeatZones,0;
```

The following example shows how this instruction is used for turning On heat zone no. 5 with the temperature set to 110 degrees. The digital output signal will be set to 1 for heat zone 5, and the group output for heat zone 5 will be set to 110.

```
PrintBedHeatControl\HeatZone_5,110;
```

Arguments	Description
HeatZone_1	Sets the temperature of heat zone no. 1. Used together with the **HeatZoneTemp** argument.
....	….
HeatZone_20	Sets the temperature of heat zone no. 20. Used together with the **HeatZoneTemp** argument.
Wait	With this argument, the program execution waits till the heat zone reaches the selected setpoint value (**HeatZoneTemp**) minus 50% of the selected max deviation.
,XXX;	The heat zone temperature (argument **HeatZoneTemp**).

Print bed control I/O signals

doPrintBedHeatZone1_3DP	Digital output. *High* when the signal **goSetpointPrintBedHeatZone1_3DP >0**. Can be connected to the print bed heat control system.
....	....
doPrintBedHeatZone20_3DP	Digital output. *High* when the signal **goSetpointPrintBedHeatZone20_3DP >0**. Can be connected to the print bed heat control system.
goSetpointPrintBedHeatZone1_3DP	Group output. The temperature setpoint of the heat zone 1, must be connected to the print bed heat control system.
....	....
goSetpointPrintBedHeatZone20_3DP	Group output. The temperature setpoint of the heat zone 20, Must be connected to the print bed heat control system.
giActualPrintBedHeatZone1_3DP	Group input. The actual temperature of heat zone 1, must be connected to the print bed heat control system.
....	....
giActualPrintBedHeatZone20_3DP	Group input. The actual temperature of heat zone 20, must be connected to the print bed heat control system.
doPrintBedHeatError_3DP	*High* if the group input signal deviates more than the selected Max deviation value when compared to the group output value.

10 Production Management

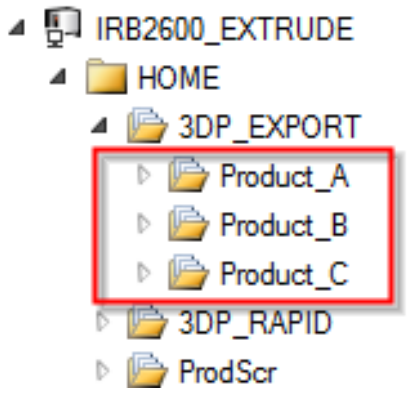
Overview

The print scheduling feature provides the flexibility for printing diverse products either through a customized/manual Print Queue or through I/O communication with PLC or other external equipment. This is achieved using two procedures *PrintScheduleManual* and *PrintScheduleAuto*.

Workflow of Manual Print Queue

Before setting a manual print queue, prepare the print programs for all products. A maximum of 20 exported print programs can be used for the print queue.

1 Export the print programs to separate folders under *HOME\3DP_EXPORT*.



xx2000001028

2 Add *PrintScheduleManual* to the *main* procedure.

```
!*****************************************************************
!
! This is the 3DP entry point, modify the "Home" position,
     and
! if needed add via points to the printing area before start.
!
!*****************************************************************
PROC main()
MoveAbsJ jHome,v200,fine,tool0\WObj:=wobj0;
.
.
.
PrintScheduleManual;
.
.
.
MoveAbsJ jHome,v200,fine,tool0\WObj:=wobj0;
ENDPROC
```

3 In the FlexPendant **Production Management** screen, under **Exports**, select the print program and then click **Add to Queue** to populate the **Print Queue**.

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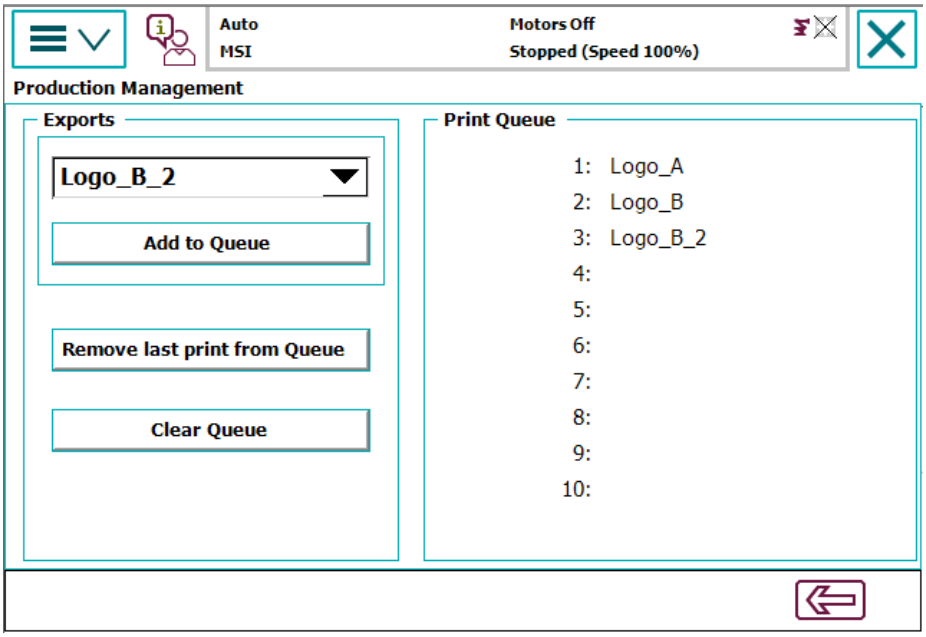
Continued

To print multiple copies of the same product, add multiple entries of the same print program to the print queue.



xx2000001041

Ensure that the module **T_ROB_1** not is loaded manually.

4 Start the program execution from the *main* procedure.

During program execution, print programs can be added or deleted to the print queue. Altering an *Active* print program is not allowed during execution. To stop an **Active** print program, set the program pointer to main. This will ensure the deletion of all programs in the queue.

PrintScheduleManual workflow

The *PrintScheduleManual* procedure facilitates the sequential printing of all print programs in the print queue.

1 During execution, the module **T_ROB1_3DP** corresponding to the first print program in the queue will be loaded.

2 Procedure **main3DP** in the loaded module will be executed and the part gets printed.

3 The module T_ROB1_3DP will be unloaded and the module T_ROB1_3DP corresponding to the next print program in the queue will be loaded. This will continue until the queue is empty.

If the queue not is full, print programs can be added to the queue during execution.

The print programs in the print queue are executed sequentially till the queue is empty. The program pointer exits *PrintScheduleManual* only when the queue become empty. Hence any instruction that are executed between print programs must be placed in the *PostPartEvent* procedure. For example, the extruder screw

Continues on next page

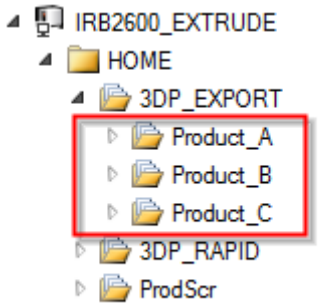
must be reset for an integrated extruder after every print. The instructions required for resetting must be placed in the *PostPartEvent* procedure.

```
!*********************************************************************************
!* For customer unique code that should be executed after the 3D
     printing has finished. *
!*********************************************************************************
PROC PostPartEvent()
IndReset M7DM1,1\RefNum:=0\Fwd;
RETURN;
ENDPROC
```

Automatic Print execution

In the *Automatic Print* execution, the print scheduling is achieved through I/O communication with a PLC or other external equipment. The print programs for all products must be ready before starting print execution. A maximum of 20 exported print programs can be used for the *Automatic Print* execution.

1 Export the the print programs to separate folders under *HOME\3DP_EXPORT*.



xx2000001026

2 Add *PrintScheduleAuto* to the *main* procedure.

```
!*************************************************************
!
! This is the 3DP entry point, modify the "Home" position,
     and
! if needed add via points to the printing area before start.
!
!*************************************************************
PROC main()
MoveAbsJ jHome,v200,fine,tool0\WObj:=wobj0;
.
.
.
PrintScheduleAuto;
.
.
.
MoveAbsJ jHome,v200,fine,tool0\WObj:=wobj0;
ENDPROC
```

Continues on next page

Continued

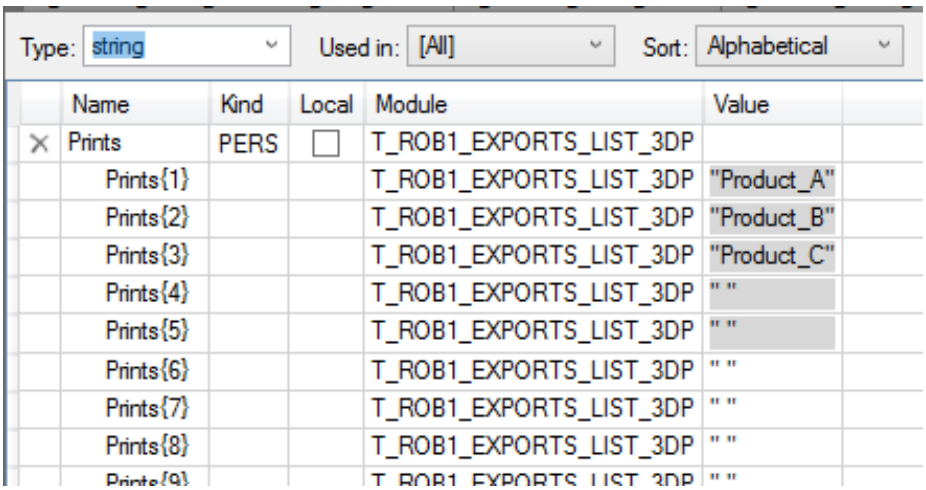
Production Management I/O signals

Signal	Description
giOrder_PLC	Group Input. Signal from PLC with order(print) number.
diOrderNew_3DP	Digital Input. Signal from PLC that a new order(print) number is ready to be read from **giOrder_PLC**.
goOrder_PLC	Group output. Signal from robot, used for handshake with PLC. Will be set to the same value as **giOrder_PLC**.
diOrderStart_3DP	Digital Input. Signal from PLC indicates that the print is ready to execute.
doOrderActive_3DP	Digital Output. Signal from robot. Is high during the print execution.

Workflow of PrintScheduleAuto

The following example depicts the I/O communication between various components in the print scheduling process.

1. The print in the folder *HOME\3DP_EXPORT\Product_B* should be executed. The PLC sets group input **giOrder_3DP** to the value for the next print (Product B) to be executed. The value points to an index in the string array *Prints*.



xx2000001027

   The index for **Product B** is **2**, hence the **giOrder_3DP** is set to **2**.
2. PLC sets the digital input **diOrderNew_3DP** to **1**.This signal from PLC indicates that a new order(print) number is ready to be read from **giOrder_PLC**.
3. Robot sets the group output **goOrder_3DP** to the same value as **giOrder_PLC**.
4. PLC sets digital input **diOrderStart_3DP** to **1** which indicates that the print is ready to execute.
5. Robot loads module **T_ROB1_3DP** from the selected folder.
6. Robot sets digital output doOrderActive_3DP to **1** which indicates the execution start.
7. PLC sets the digital input to **diOrderNew_3DP** to **0**.
8. Robot executes **main3DP** (the part will be printed).
9. Robot unloads module **T_ROB1_3DP** from the selected folder.

Continues on next page

10 Robot sets digital output **doOrderActive_3DP** to **0**.

The program pointer remains inside *PrintScheduleAuto* until it is set to main. This can be done using the FlexPendant. Hence any instruction that must be executed between print programs must be placed in the *PostPartEvent* procedure. For example, the extruder screw must be reset for an integrated extruder after every print. The instructions required for resetting must be placed in the *PostPartEvent* procedure.

```
!*****************************************************************************
!* For customer unique code that should be executed after the 3D
     printing has finished. *
!*****************************************************************************
PROC PostPartEvent()
IndReset M7DM1,1\RefNum:=0\Fwd;
RETURN;
ENDPROC
```

RAPID code for PrintScheduleAuto

The *PrintScheduleAuto* RAPID code snippet can be used as a template while customizing the communication for various PLCs. An encrypted code snippet is available as part of the 3D Printing installation.

```
PROC PrintScheduleAuto()
VAR num Answer;
VAR string Path;
SetDO doOrderActive_3DP,0;
SetGO goOrder_3DP,0;
WHILE TRUE DO
WaitDI diOrderStart_3DP,0;
WaitDI diOrderNew_3DP,1;
!** New print order from PLC. **
SetGO goOrder_3DP,giOrder_3DP;
!** Handshake with PLC **
WaitDI diOrderStart_3DP,1;
!** Reply from PLC that handshake was ok. **
Path:= ExportsFolder +Prints{giOrder_3DP}+"/";
Load\Dynamic, Path+"_T_ROB_load_me.mod"\CheckRef;
SetDO doOrderActive_3DP,1;
!** Signal to PLC that the robot is active with the current order.
     **
WaitDI diOrderNew_3DP,0;
!** The PLC turns Off the "new order" signal. **
%"main3DP"%;
UnLoad Path+"_T_ROB_load_me.mod";
SetDO doOrderActive_3DP,0;
ENDWHILE
ERROR
IF ERRNO=ERR_LOADED THEN
TPErase;
TPWrite "T_ROB1_3DP already loaded.";
TPReadFK Answer,"Unload and try again.","","","","","OK";
```

Continues on next page

Continued

```
Stop;
RETRY;
ENDIF
ENDPROC
```

While using this template, the following lines must not be altered. The I/O communication modules can be altered according to the production environment.

- `Path:= ExportsFolder +Prints{giOrder_3DP}+"/";`
  `Load\Dynamic, Path+"_T_ROB_load_me.mod"\CheckRef;`
- `UnLoad Path+"_T_ROB_load_me.mod";`

A Terminology

A

Add-In

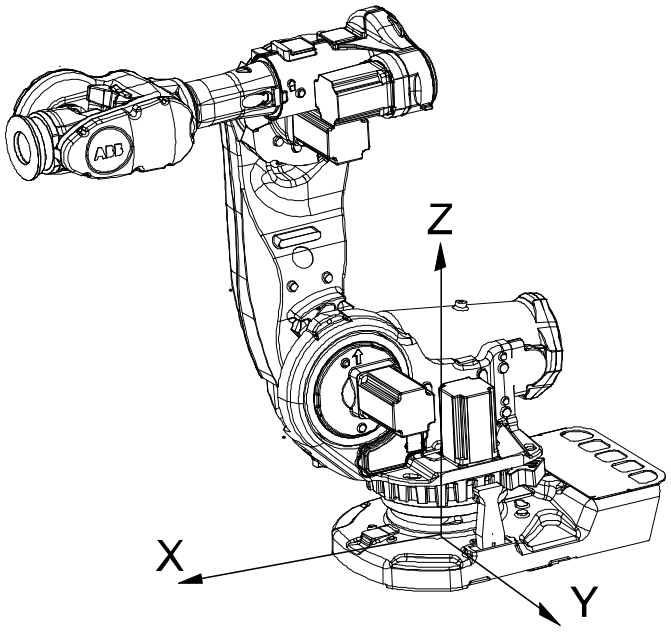
A software program that expands the capabilities of RobotStudio or RobotWare. Creating Add-Ins is the recommended way for third party developers to add new features into RobotWare or RobotStudio.

A RobotWare Add-In contains RAPID modules and configuration files that holds the code for loading the add-in and configuring it at start up. The Add-In may also include .xml files with event log messages in different languages. Add-Ins can be packaged using the RobotWare Add-In Packaging tool. You can download the tool from http://www.abb.com/abblibrary/DownloadCenter/

B

Base frame

The base coordinate system is called the Base Frame (BF). The base frame for a robot is located at the center of its foot. It describes the location of the robot in relation to the world coordinate system.



xx0300000495

C

Curve

A curve is a wire body like a line, circle, arc, polygon, polyline, or spline.

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Continued

Coordinate system

A coordinate system specifies the position and orientation of an object in the 3D space using three coordinates x, y and z. Orientation of an object can be specified either by using three angles or quadrants. RobotStudio allows using the following coordinate systems to define the orientation and placement of components. A coordinate system defines a plane or space by axes from a fixed point called the origin. Robot targets and positions are located by measurements along the axes of coordinate systems. A robot uses several coordinate systems, each suitable for specific types of jogging or programming. RobotStudio uses the following coordinate systems, World, Local, UCS, Active Work object, Active Tool.

- The base coordinate system is located at the base of the robot. It is the easiest one for just moving the robot from one position to another.
- The work object coordinate system is related to the work piece and is often the best one for programming the robot.
- The tool coordinate system or the Tool Center Point frame(TCP) defines the position of the tool the robot uses while reaching the programmed targets.
- The world coordinate system defines the robot cell, all other coordinate systems are related to the world coordinate system, either directly or indirectly. The world coordinate system has its zero point on a fixed position in the cell or station. This makes it useful for handling several robots or robots moved by external axes.

By default, the world coordinate system coincides with the base coordinate system. The user coordinate system is useful for representing equipment that holds other coordinate systems, like work objects.

E

External Axis

Moving equipment that is controlled by the robot controller (in addition to the robot) is denoted as an external axis, for example, track motion, a positioner, and so on.

F

Frame

Frame is the visual representation of a coordinate system in RobotStudio.

- Position of a component is represented with respect to World, Base and Work object frames.
- Orientation format is set to Quaternion or Euler angles.
- Position angle format is set to Angles.
- Presentation angle unit can be set to Degrees or Radians.

Face

Each surface of the body is called a face. Solid bodies are 3D objects, made up of faces. A true 3D solid is one body containing multiple faces.

Continues on next page

G

G-Code

Programming language for 3D printers that instructs the printer where and how to move.

Geometry

3D representation of real objects like box, cylinder and so on. CAD models of work pieces and custom equipment are imported as geometries to the station. Geometry consists of two layers; the mathematical representation of the curves and surfaces known as boundary representation (BReps), and the graphics layer, containing triangles that approximate the BReps. Graphics layer is used in collision detection and for visualizing the mathematical layer.

I

Instruction Templates

A RAPID instruction file (template) containing predefined argument values used to create new instructions. These templates can be created for RAPID instructions in the virtual controller.

J

Joint

A joint defines how links around are connected. The most common joint types are prismatic or linear. But there are also ball joints, cylindrical, and lock joints.

L

Library files

Library files are standalone external reusable files that are added to a RobotStudio station. The ABB product range of robots are downloaded as library files. Library files contain geometrical data and RobotStudio specific data. For example, when a tool is saved as a library file, its tool data is saved along with the CAD data.

Local origin

All objects have coordinate systems of its own called the local coordinate system. Object dimensions are defined with respect to this coordinated system. When the object's position is referred from other coordinate systems like WCS, the local origin of the object is used as the point of reference.

M

Mechanism

A mechanism is a graphical representation of a robot, tool, external axis, or device, various parts of a mechanism move along or around axes.

Module

RAPID code of the controller is structured into modules. A module contains several routines of type procedure, function or trap. Modules are of two types system and program.

Continues on next page

Continued

O

Offline

User is disconnected from a robot controller and is working with a virtual controller.

Orientation

The orientation of an object such as a line, plane or rigid body is it's placement in space. It is the imaginary rotation that is needed to move the object from a reference placement to its current placement. A rotation may not be enough to reach the current placement. It may be necessary to add an imaginary translation too. The location and orientation together fully describe how the object is placed in space. The above-mentioned imaginary rotation and translation may be thought to occur in any order, as the orientation of an object does not change when it translates, and its location does not change when it rotates.

Orientation formats available in RobotStudio are Quaternion, Euler angles and RPY angles.

Quaternion

A quaternion is a mathematical representation of orientation. They are points in space represented by their coordinates. A quaternion consists of four values between -1 and 1. The sum of its squares must be equal to one, that is, it has to be normalized (in which case it may be called unit quaternion).

Euler Angles

The term Euler implies that each angle is applied to the original coordinate system (before the rotations are applied). The angles describe orientations around different axes and in different order. The convention used in RobotStudio and for the IRC5 controller is Euler ZYX, which means the first values describe the angle to rotate around the z axis, the second value describes the orientation angle around the original Y-axis and the last value describes the orientation around original x-axis. There are also other conventions like Euler ZYZ, and Euler XYZ which ABB does not use.

RPY Angles

The RPY convention describes orientation with three angles, it is short for Roll, Pitch, Yaw. Any target orientation can be reached, starting from a known reference orientation, using a specific sequence of intrinsic rotations, whose magnitudes are the Euler angles of the target orientation. The difference compared to the Euler-convention is that each angle describes orientation around the new, rotated coordinate system. When rotating using the RPY convention, then the first angle describes orientation around x (same as Euler), but the second angle describes orientation around the y-axis of the rotated coordinate system (different from Euler), and the z-angle describes orientation around the rotated z axis. The RPY representation is equivalent of the Euler ZYX representation.

Offline programming

Robot programming using the virtual controller.

Online

User is connected directly to a robot controller through the network.

Continues on next page

P

Path

A path is a sequence of targets with move instructions that the robot follows.

Part

Top node of a geometry is called a part.

Pack & go

Way to share RobotStudio stations by combining the station and virtual controllers packaged into one file.

Positioner

A positioner is used to position a work piece for the robot to have better access. In arc welding, positioners are used to re-orient the work piece so that the weld is always done vertically due to gravity.

Position

Three coordinates that describe the x, and y and z- position of a point in a given coordinate system. In RobotStudio position of an object can be displayed relative to the reference coordinate systems World, Base and Work object.

R

RobotWare license

This license unlocks the RobotWare options, for example, robots and RobotWare options. To upgrade from RobotWare version 5.15 or earlier, replace the controller main computer and get RobotWare 6 licenses. Contact ABB Robotics service representative at www.abb.com/contacts.

RobotWare system

A set of software files that, when loaded into a controller, enables all functions, configurations, data, and programs controlling the robot. RobotWare systems are created in RobotStudio. These systems can be saved on a PC or on a control module. RobotWare systems can be edited by RobotStudio or the FlexPendant.

Robot Controller

A physical robot controller. It contains all functions needed to move and control the robot.

RobotWare

Set of software products used to configure a robot controller.

RAPID

Programming language for ABB robot controller.

Rail

A mechanism consisting of a linear axis with a carriage on which the robot is mounted.

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Continued

Robtarget

RobotStudio targets are translated to the RAPID data type robtarget during RAPID synchronization. It defines the position and orientation that the TCP shall reach. A robtarget defines a point in 3D space when it is associated with a work object. The position is defined based on the coordinate system of the work object, including any program displacement.

S

Station

A station is the 3D representation of the virtual robot cell. It is saved to a file with the extension *.rsstn.

Synchronization

The synchronization function converts targets, workobjects, tools and paths in the 3D environment to RAPID code in the virtual controller and vice versa.

System

A set of software files that, when loaded into a controller, enables all functions, configurations, data and programs controlling the robot system. These systems can be saved on a PC or on a control module. RobotWare systems can be created and edited in RobotStudio or FlexPendant.

Project

Projects add structure to the station data. It contains folders for structuring station data so as to keep related data together.

Singularity

Singularities are robot configurations where a manipulator loses one or more of its degrees-of-freedom and, therefore, cannot move in the corresponding direction(s).

T

Tool

A tool is an object that can be mounted directly or indirectly on the robot turning.

Tooldata

A tool is represented with a variable of the data type *tooldata*. Tooldata represents characteristics of a tool such as position and orientation of the TCP and the physical characteristics of the tool load.

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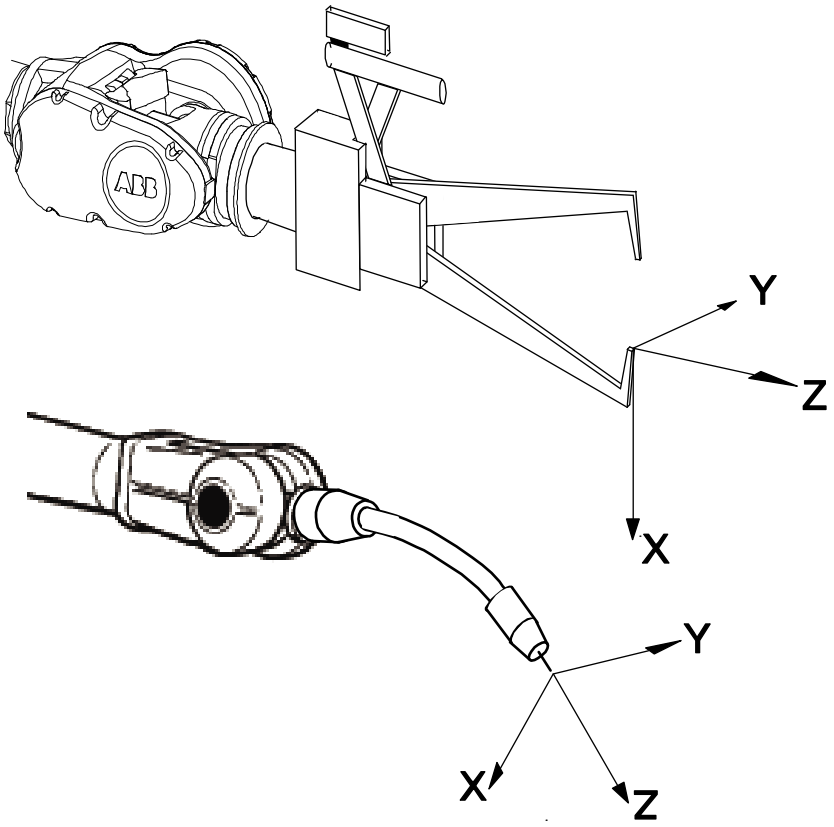
Tool Centre Point (TCP)

Refers to the point in relation to which robot's positioning is defined. It is the center point of the tool coordinate system that defines the position and orientation of the tool. TCP has its zero position at the center point of the tool. The tool center point also constitutes the origin of the tool coordinate system. Robot system can handle a number of TCP definitions, but only one can be active.



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Task

A task is an activity or piece of work. RobotStudio tasks are either Normal, Static or Semistatic.

Task frame

Represents the origin of the robot controller world coordinate system in RobotStudio.

Track motion

A mechanism consisting of a linear axis with a carriage on which the robot is mounted. The track motion is used to give the robot improved reachability while working with large work pieces.

Target

Target signifies the position to which the robot is programmed to move. It is a RobotStudio object that contains the position and orientation of the point that the robot must reach. Position data is used to define the position in the move instructions to which the robot and additional axes will move.

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Continued

As the robot is able to achieve the same position in several different ways, the axis configuration is also specified. Target object contains values that shows position of the robot, orientation of the tool, axis configuration of the robot and position of the additional logical axes.

V

Via Point

A coordinate point in the robot trajectory where the process is *Off*.

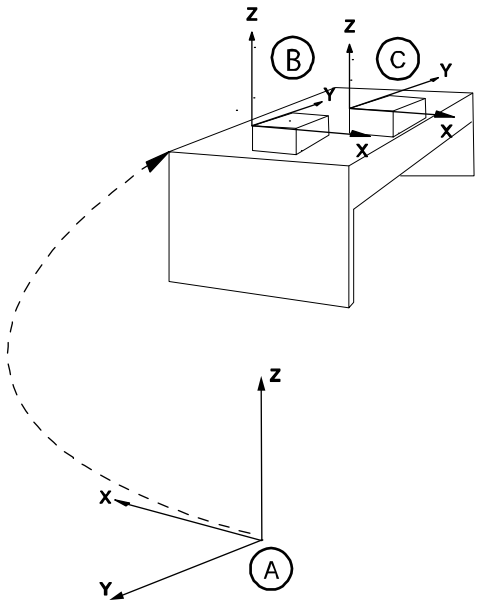
Virtual controller

A software that emulates the robot controller on the PC. It is used for offline programming and simulation. Virtual controller replicates the RobotWare system.

W

Work Object

A work object is a local coordinate system that indicates the reference position (and orientation) of a work piece. The work object coordinate system must be defined in two coordinate systems , the user coordinate system (related to the world coordinate system) and the object coordinate system (related to the user coordinate system). Work objects are often created to simplify jogging along the object's surfaces. Work objects should always be global to be available to all modules in the program.



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A	World coordinate system
B	Work Object coordinate system 1
C	Work Object coordinate system 2

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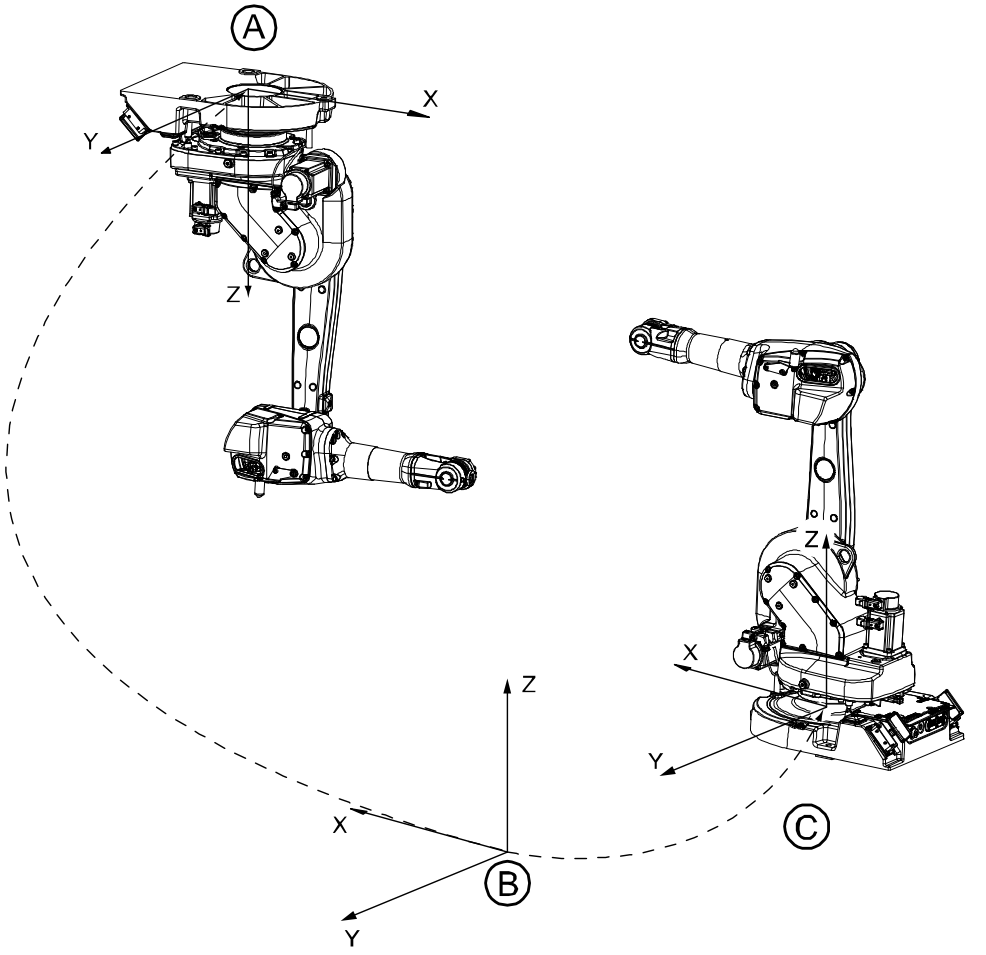
World coordinate system

The world coordinate system represents the entire station or the robot cell, all other coordinate systems are related to the world coordinate system, either directly or indirectly. The world coordinate system has its zero point on a fixed position in the cell or station. This makes it useful for handling several robots or robots moved by external axes. By default, the world coordinate system coincides with the base coordinate system.



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A	Base coordinate system for robot 1
B	World coordinate
C	Base coordinate system for robot 2

Wobjdata

A work object is represented with a variable of the data type *wobjdata*. It describes the work object that the robot welds, processes, moves within, and so on.

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Work Envelope

The defined area of space in which a robot can move is its work envelope. Work envelope for a robot is the maximum range of movement that can be visualized in 2D/3D graphics. Work envelope can be added to the station as a part, which can be saved in the station and exported as any geometry.

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ABB AB
Robotics & Discrete Automation
S-721 68 VÄSTERÅS, Sweden
Telephone +46 10-732 50 00

ABB AS
Robotics & Discrete Automation
Nordlysvegen 7, N-4340 BRYNE, Norway
Box 265, N-4349 BRYNE, Norway
Telephone: +47 22 87 2000

ABB Engineering (Shanghai) Ltd.
Robotics & Discrete Automation
No. 4528 Kangxin Highway
PuDong New District
SHANGHAI 201319, China
Telephone: +86 21 6105 6666

ABB Inc.
Robotics & Discrete Automation
1250 Brown Road
Auburn Hills, MI 48326
USA
Telephone: +1 248 391 9000

abb.com/robotics

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