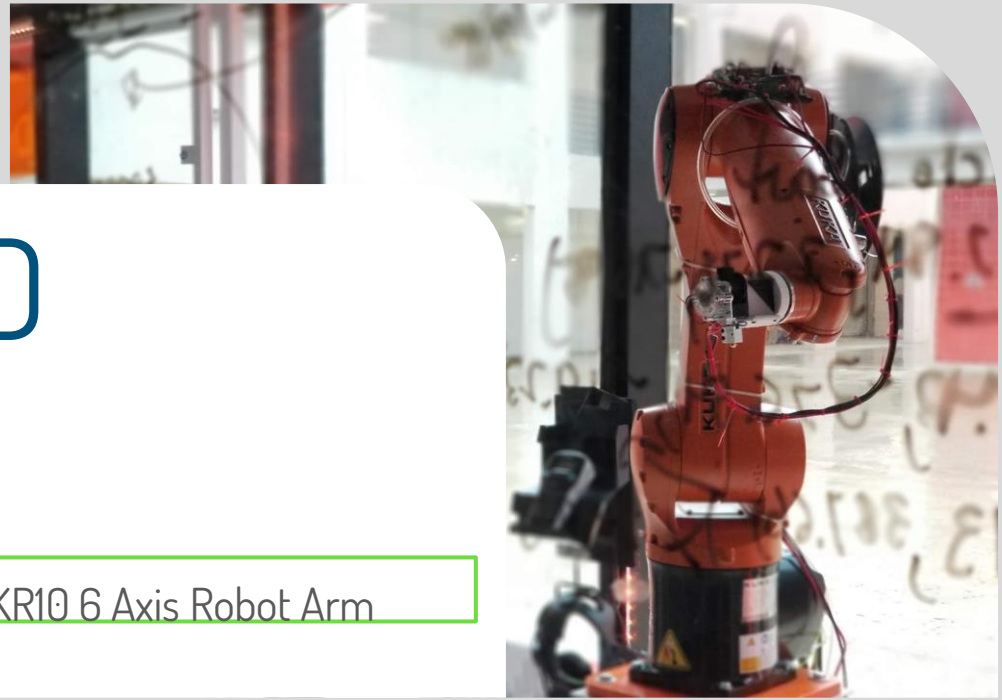
Robot 3D Printing



With the Kuka KR10 6 Axis Robot Arm

Advanced Lesson

Robotics Academy | FIU Communication, Architecture + The Arts | NSF

00 Introduction

01 Safety

02 Workflow

03 Programs Needed

04 Hardware Set Up

Robot Operator

05 Calibration

Robot Programmer

06 Software Set Up

Robot Programmer

07 Printing

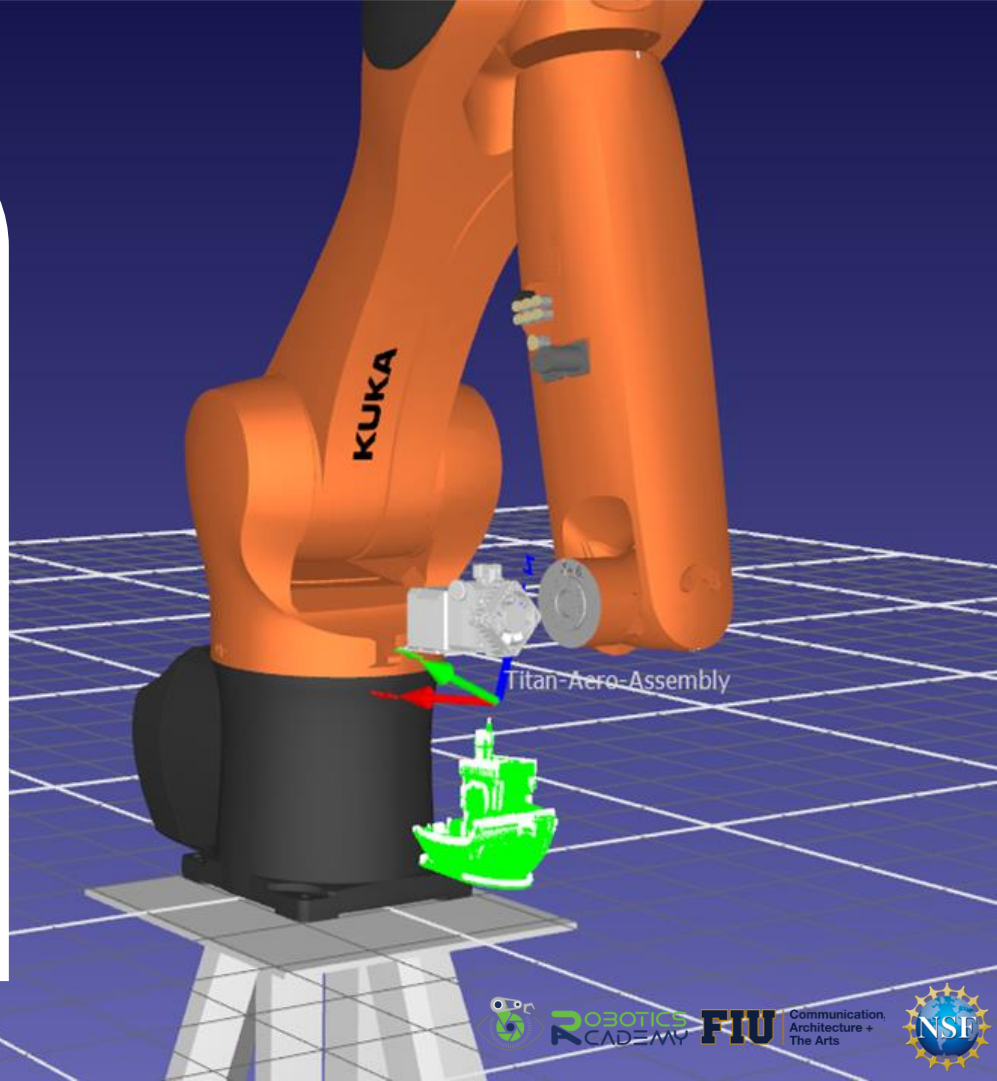
08 Keywords

00 Introduction

This tutorial is for using a 6 axis robot arm to 3D print using fused filament fabrication (FFF/FDM.)

The instructions are tailored for the custom hardware in the FIU RDF Lab, but the general process is the same regardless of equipment differences.

Having some experience using a regular 3D printer is helpful, but not required.



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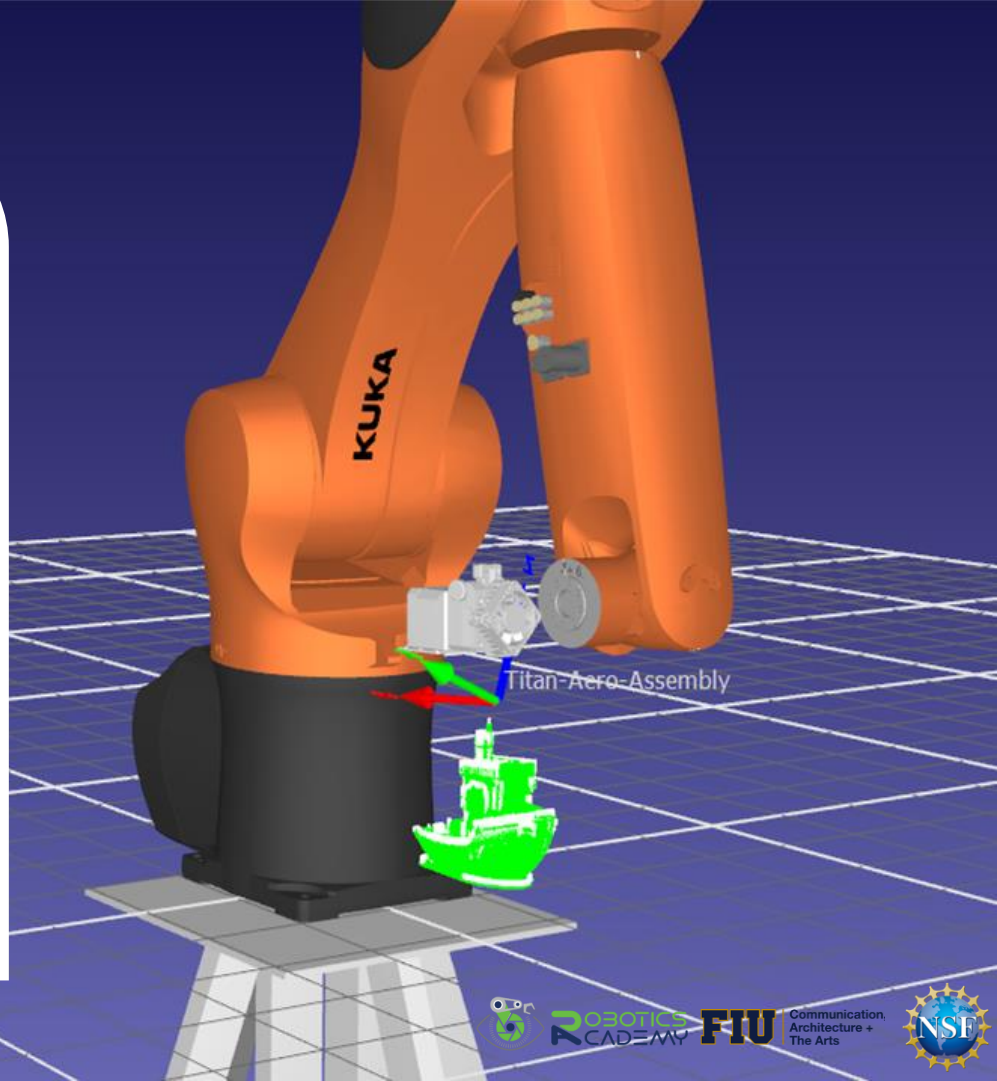
Goals:

Robot Operators will learn how to properly safely run the 3D printing tool and troubleshoot potential hardware issues.

Robot Programmers will learn how to program robot 3D printing projects from scratch using RoboDK.

System Integrators will learn how to develop and implement robot 3D printing systems with a focus on design, engineering, and safety considerations.



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01 Safety

All Robot Users

Robot Operators

- Hot Surfaces - Heating block, nozzle, extruded filament
- Fire Hazard - Jams, thermal runaway
- Pinch Points - Extruder gears, between end effector and work piece
- Robot Collisions - Collision recovery, operator safety

Robot Programmers

- Thermal Runaway
- Jams
- Robot Collisions

System Integrators

- Engineering Controls - closed work cell, safety fence, air filtration, interlocks, thermal runaway watchdog
- Smoke Detection
- Filtration
- Fire Suppression - C02 to prevent electronics damage

Picture Credit

02 Workflow

All Robot Users

Hardware Diagram

01

Calibration

02

Software Setup

03

3D Printing

04

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03 Programs Needed

All Robot Users

RoboDK

3.8.4 or latest

To program and remotely control the robot arm.

PronterFace

(2014.08.01)

To monitor and remotely control the extruder module.

Ultimaker Cura

4.1.0

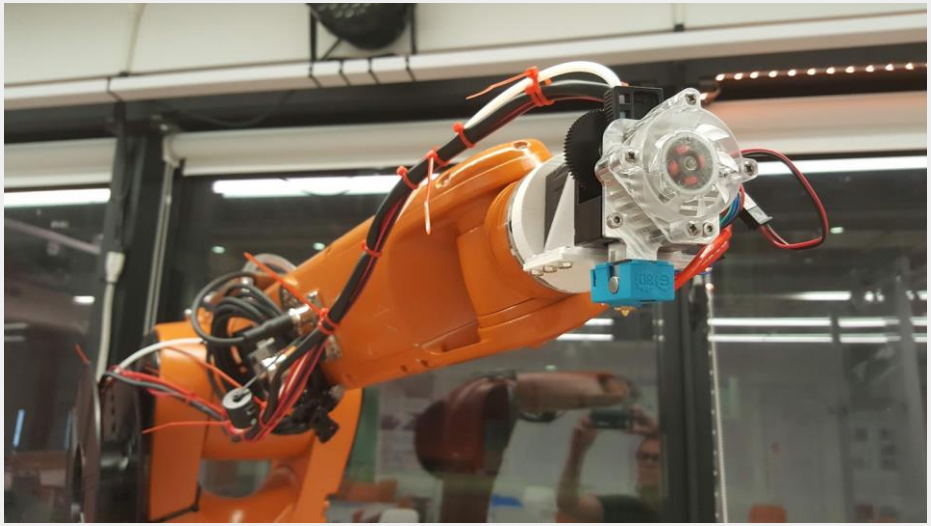
To “slice” and convert 3D models into machine readable code.

Extruder.py/ M_RunCode.py Scripts

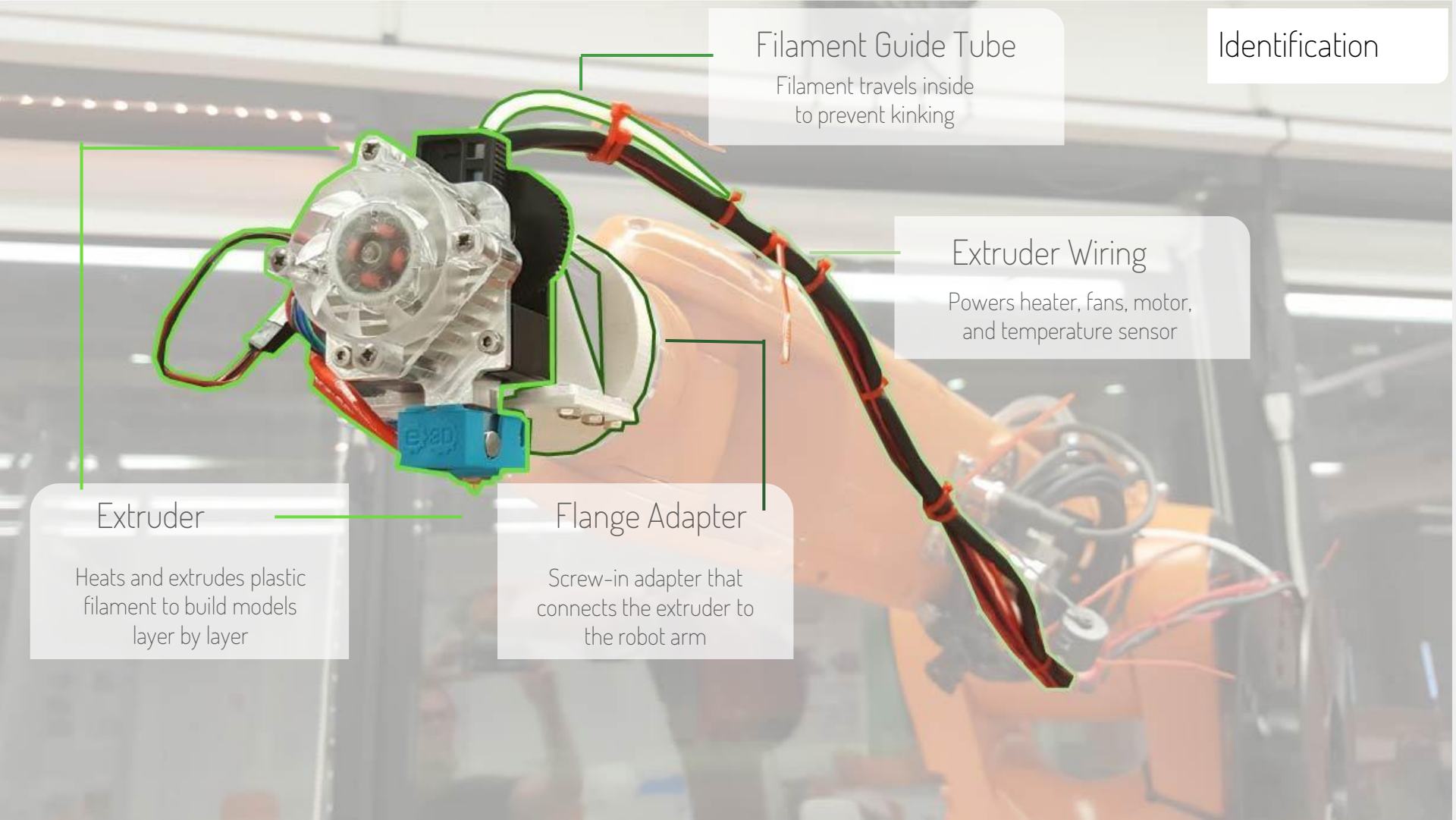
To start and stop the extruder module while printing.

04 Hardware Setup

Kuka KR10 Robotic Arm



Identification



Filament Guide Tube

Filament travels inside to prevent kinking

Extruder Wiring

Powers heater, fans, motor, and temperature sensor

Extruder

Heats and extrudes plastic filament to build models layer by layer

Flange Adapter

Screw-in adapter that connects the extruder to the robot arm

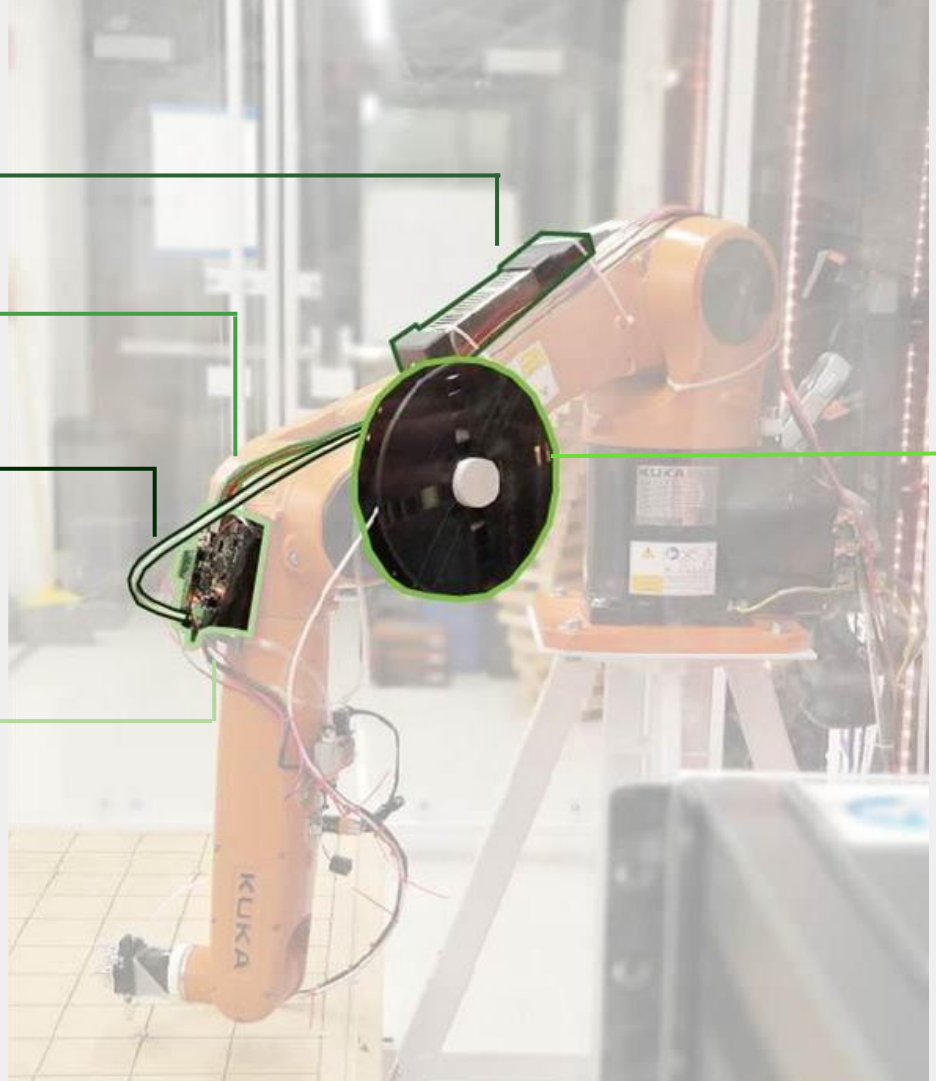
Identification

Smoothieboard Power Supply

Smoothieboard Network Cable (red)

Smoothieboard Power Cable (white)

Smoothieboard Extruder module control board



Filament Spool
Holds the plastic filament to be fed into the extruder

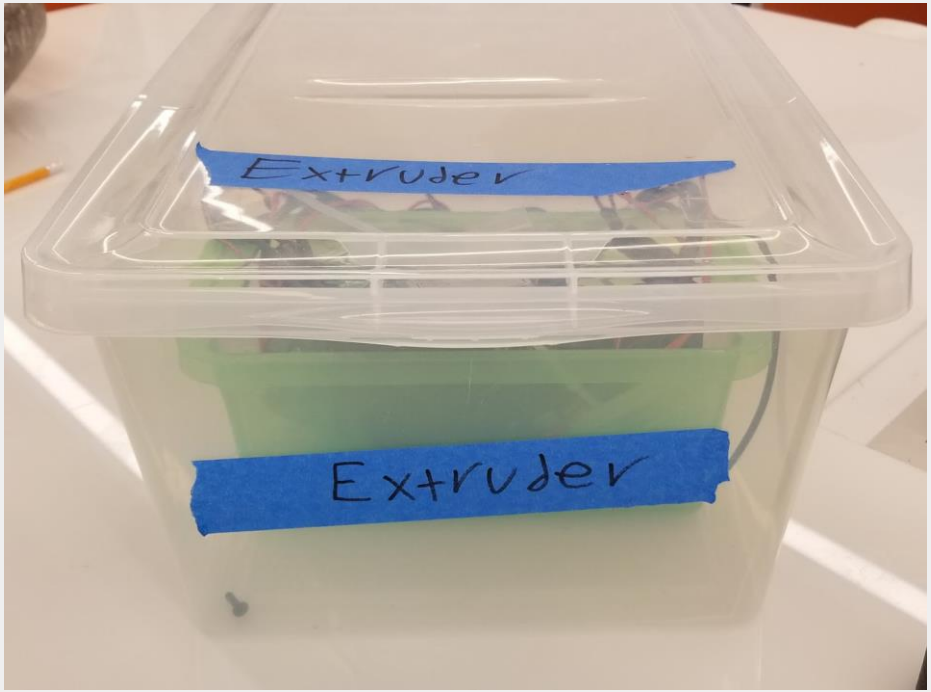
Hardware Setup

Extruder Parts Box

The hardware needed is located in the clear plastic box labeled “Extruder” in the robot cell. If you can not located the box please ask a lab employee.

The box contains:

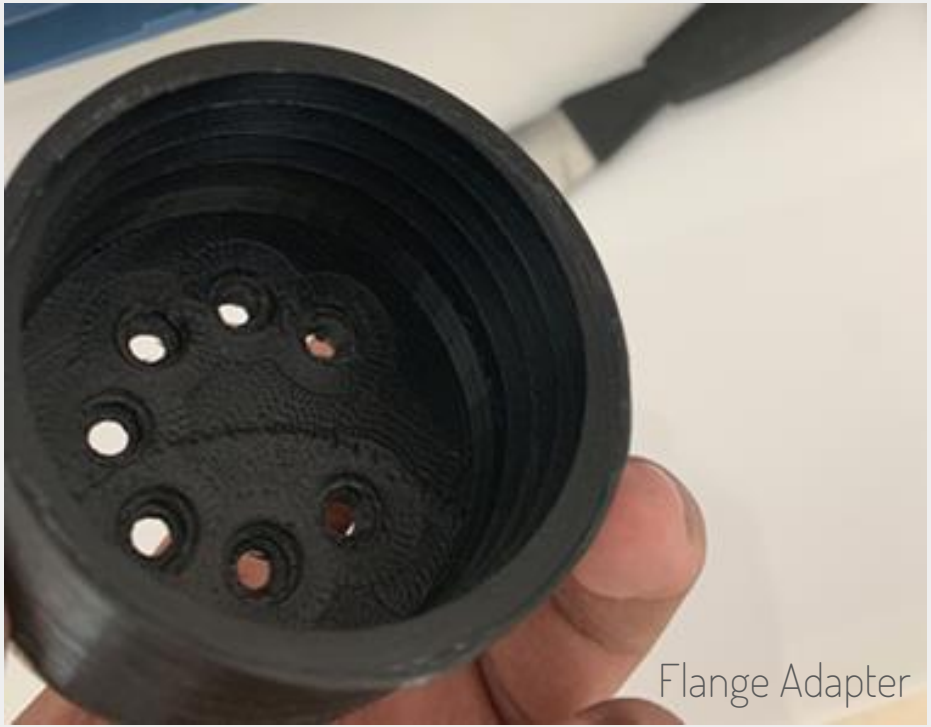
- Extruder module
- Smoothieboard module
- Power supply module
- Assembly tools (Allen/hex key)



Hardware Setup

Installing Flange Adapter

Remove the flange adapter from the Extruder container.



Hardware Setup

Installing Flange Adapter

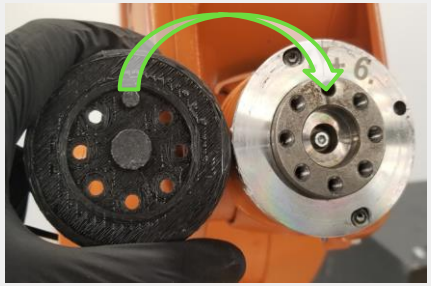
Line up the guide peg with the hole on the flange that has no screw threading.

Use the 7 small black screws in the extruder container to secure the flange adapter into place.

Ensure the flange adapter is attached snugly and is parallel with the robot flange, Adjust as required.

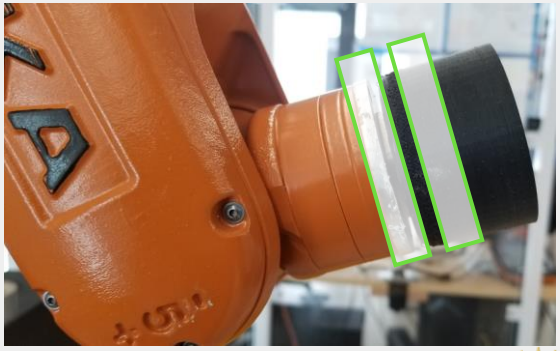
Do not overtighten the screws.

Step 1



Step 2

Step 3



Hardware Setup

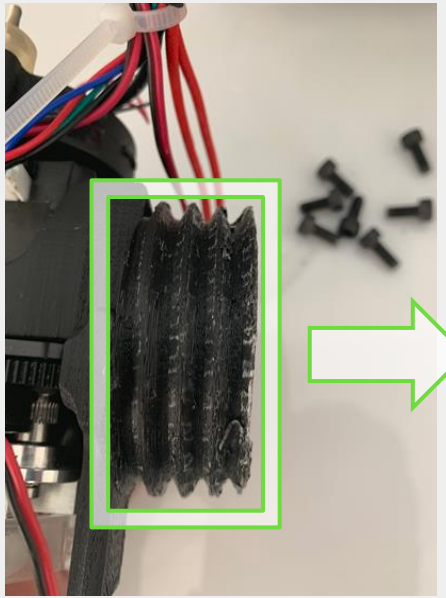
Installing Extruder Module

Remove the extruder module from the Extruder container.

The extruder mount features oversized threads used to attach the extruder to the flange adapter.

Hold the extruder module and cabling while screwing the threaded end into the flange adapter.

Turn the extruder clockwise gently until it stops turning. Do not overtighten.



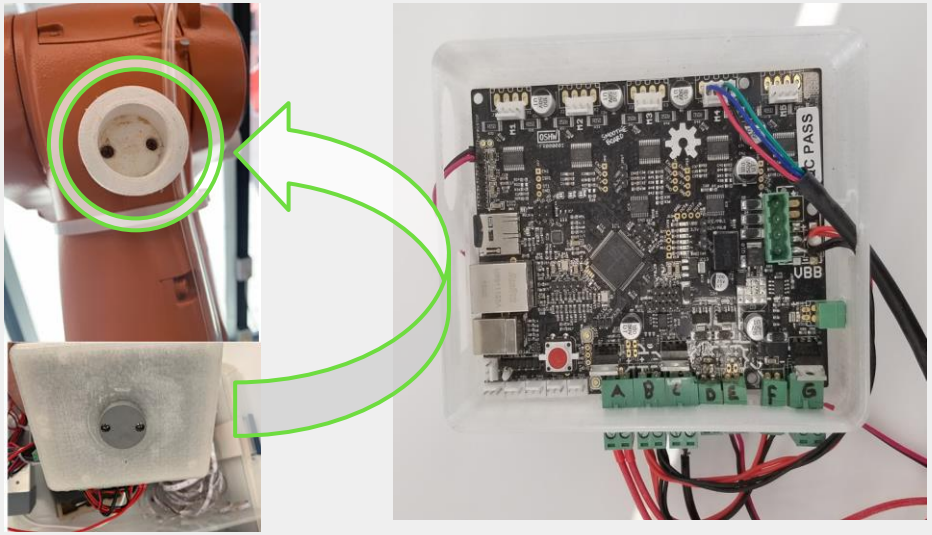
Hardware Setup

Smoothieboard Installation

After the extruder is in place:

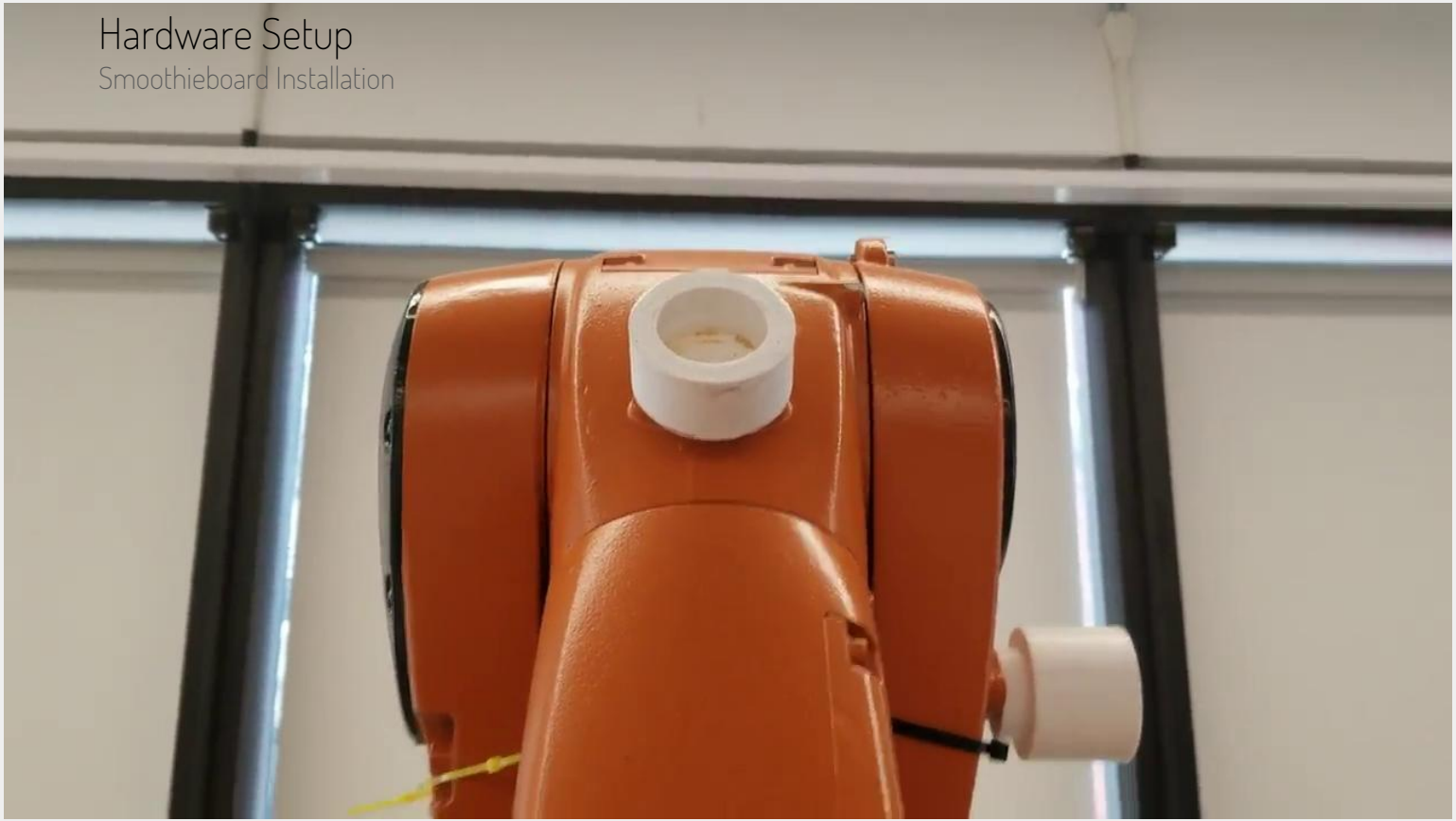
Attach the smoothieboard to top of the robot by aligning the cylindrical plug beneath the smoothieboard with the corresponding socket on the top of the robot arm. Insert the cylindrical plug into the socket and press it firmly into place.

NOTE:
*The hole for the wire harness should be on the bottom.



Hardware Setup

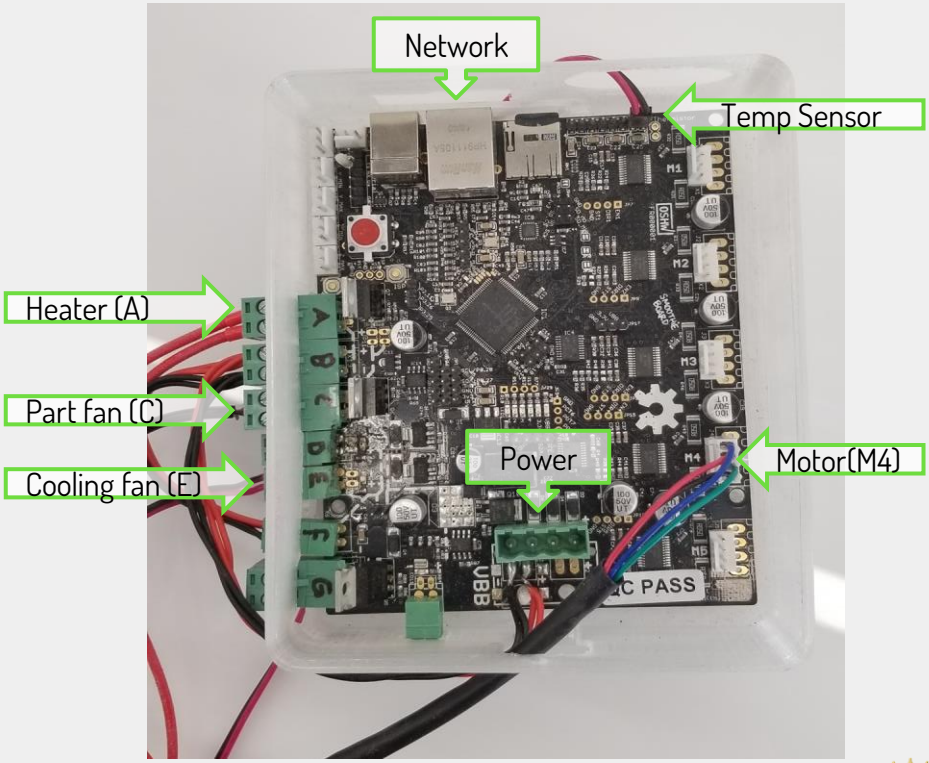
Smoothieboard Installation



Hardware Setup

Smoothieboard Setup

1. Smoothieboard Wiring
2. Smoothieboard Power
3. Smoothieboard Network



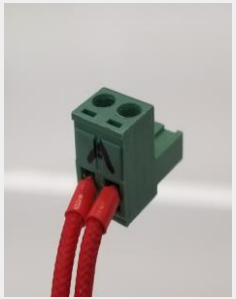
Hardware Setup

Smoothieboard Wiring

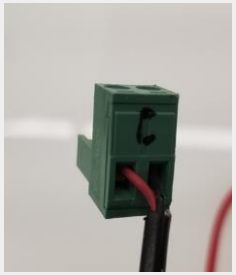
Connect the **extruder heater cable** (connector “A”) to **port “A.”**

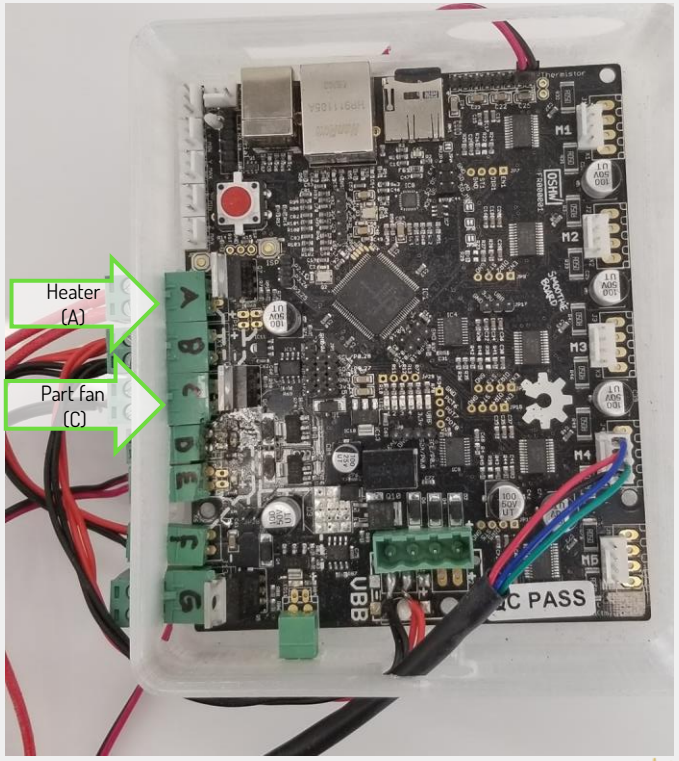
Connect the **extruder part cooling fan cable** (connector “C”) to **port “C.”**

Step 1



Step 2





Hardware Setup

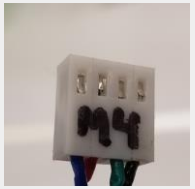
Smoothieboard Wiring

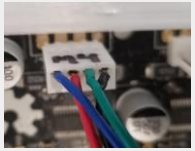
Connect the **extruder cooling fan cable** (connector "E") to **port "E."**

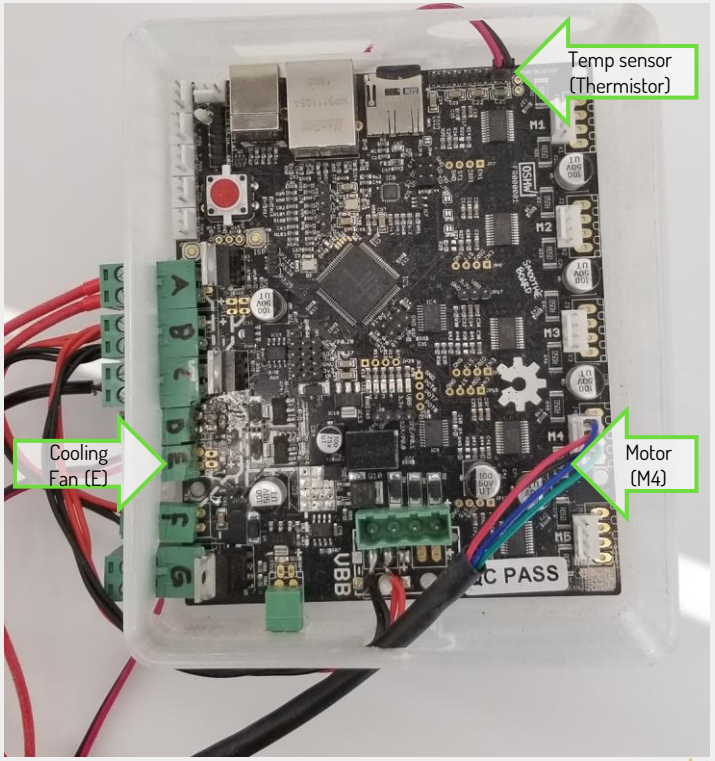
Connect the **extruder motor cable** (connector "M4") to the **white port "M4."**

Step 3

Step 4





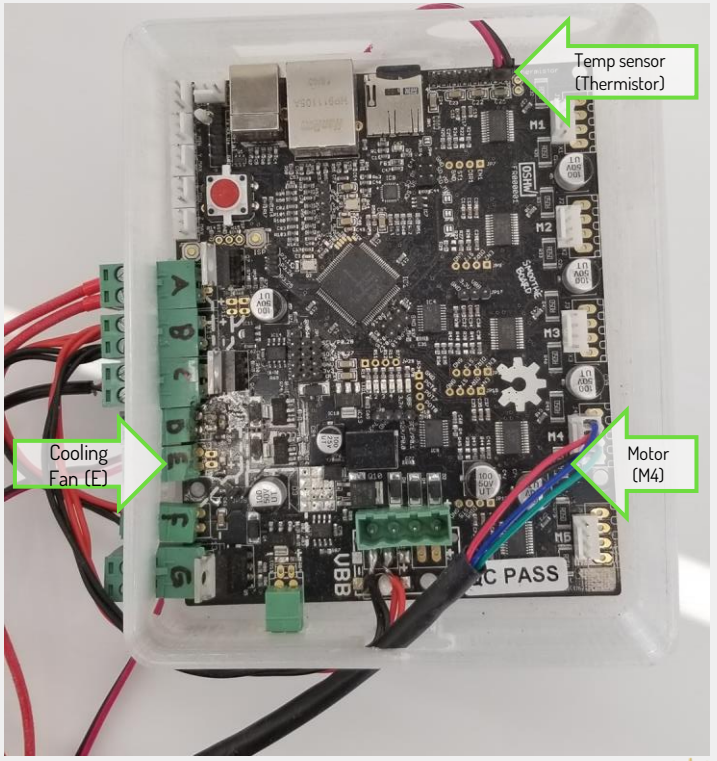


Hardware Setup

Smoothieboard Wiring

Step 5

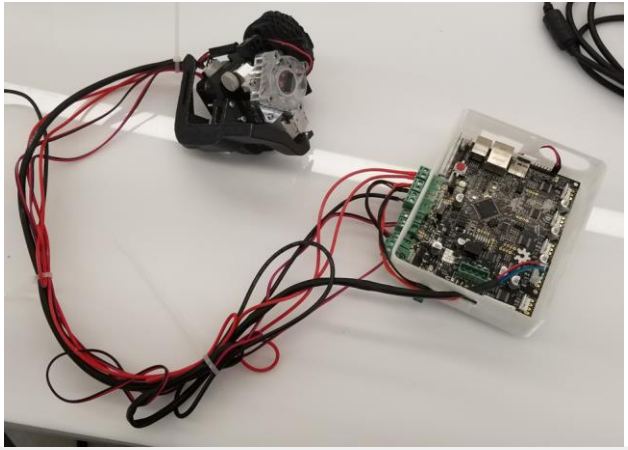
Connect the **extruder temperature sensor cable** (two red and black wires ending in a black connector) to the two pins next to the label that says **“Thermistor.”**
* Note: The direction this cable is inserted does not matter.

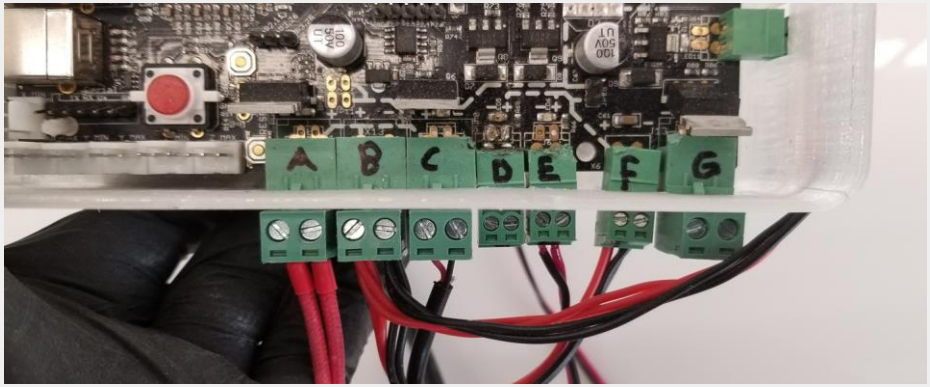


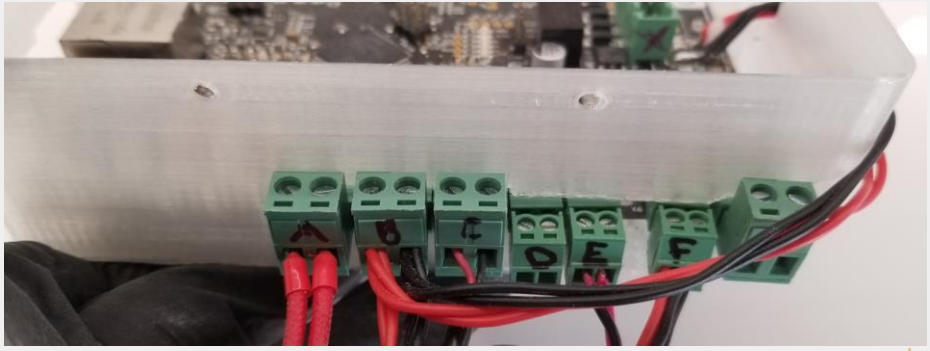
Hardware Setup

Smoothieboard Wiring

Connect the **Smoothieboard** as shown.







Hardware Setup

Smoothieboard Network and Power

Attach the orange ethernet cable to the top of the smoothieboard.

Retrieve the power supply (Top right) from the Extruder box and attach it to the back of the robot arm using zip ties. Plug the white power cable into the green terminal with the X on it.

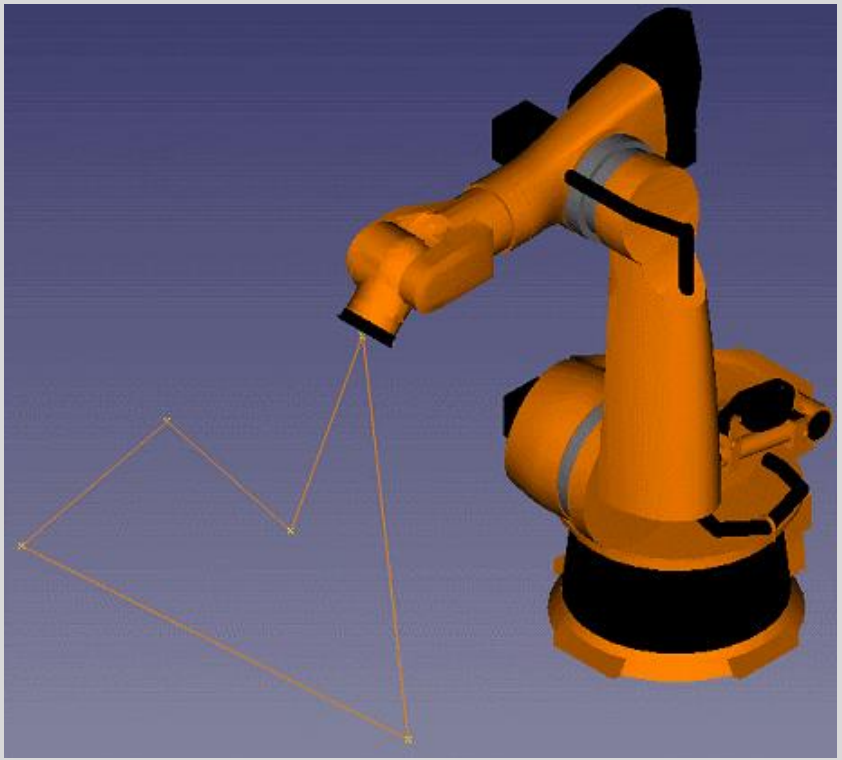
*Note: The smoothieboard can be damaged by plugging it into the wrong terminal.

Step 1

Step 2

05 Calibration

Robo DK



Picture Credit

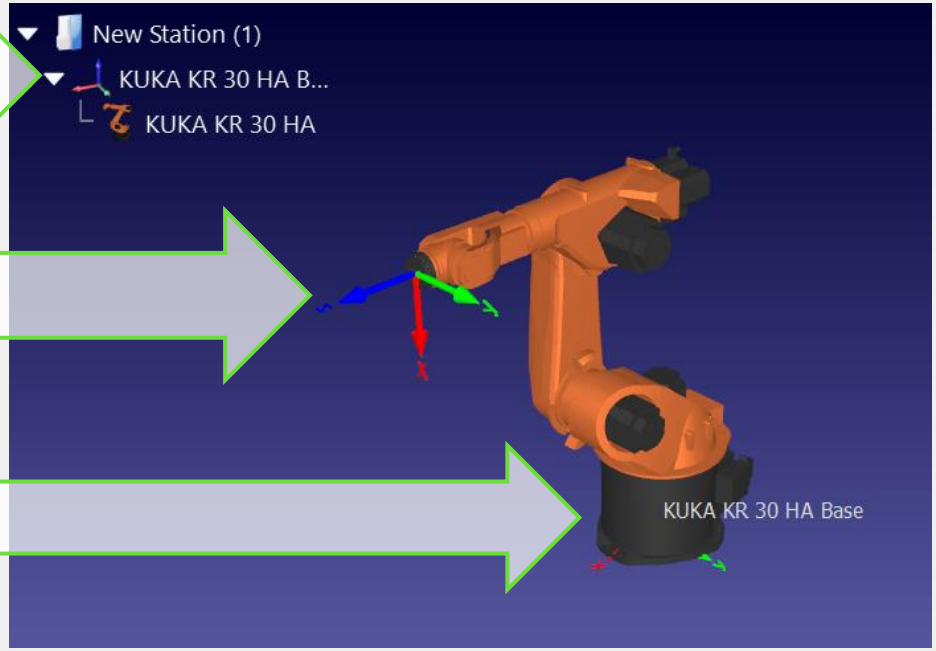
RoboDK
Reference Frames

RoboDK uses **Reference Frames** to orient and place objects in space.

Reference frame for the robot itself

Reference frame for the robot flange (where the tool attaches)

Reference frame for the robot itself (the bottom center of the robot base)



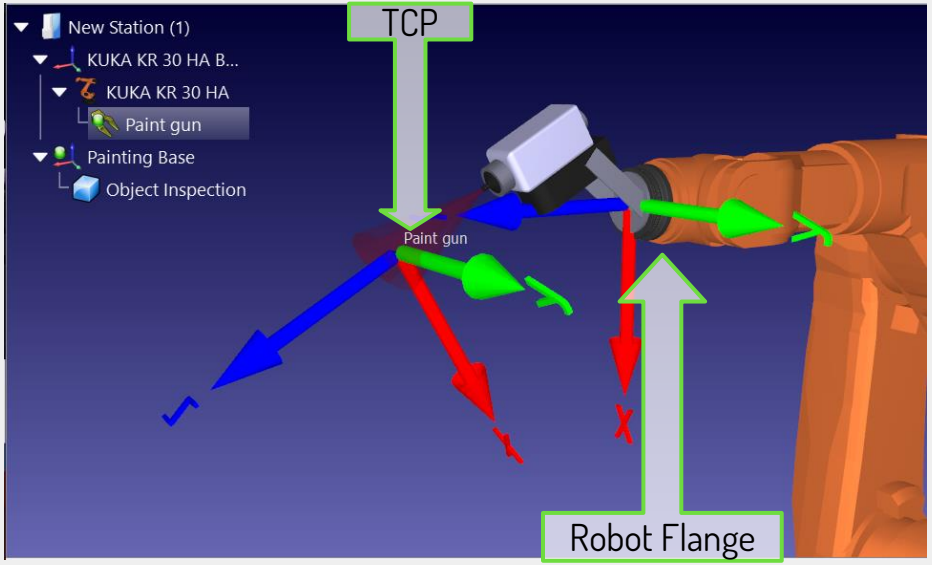
TCP

Tool Center Point

The Tool Center Point (TCP) is the “tip” of the tool.

The nozzle of the 3D printer is the Tool Center Point.

This is the most important measurement for robot programming!



Calibration

RoboDK

Once the extruder is properly installed on the robot, use RoboDK to setup the robot.

A RoboDK Station named RDF Calibration has been created to help.

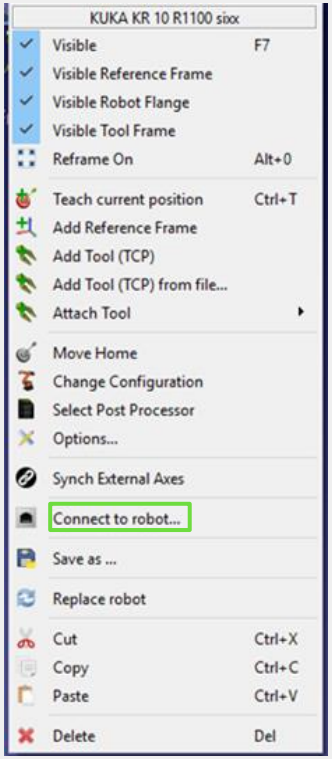
Open RDF Calibration, right click **KUKA KR 10 R1100** in the hierarchy and select **connect to robot**.

Ensure the **Robot IP/COM** is 192.168.1.200 and the **Robot port** is 7000.

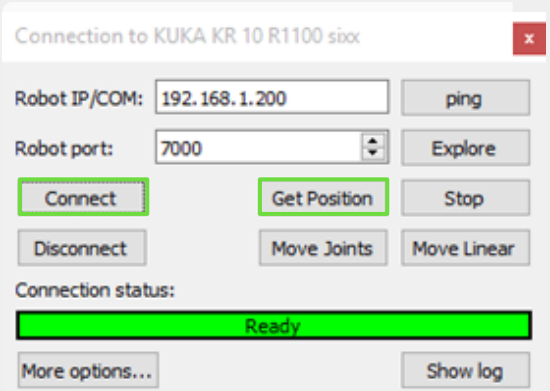
Click **Connect** and then **Get Position**.

Step 1

Step 2



Information to Input



Calibration Troubleshooting

"Cannot connect to Robot"

Error Message: **"Cannot connect to robot:"**

Ensure **Robot IP/COM** is set correctly (192.168.1.200)

Ensure **Robot port** is set correctly (7000)

Check connection by selecting **ping**.
If correct it will display **SUCCESSFUL** in green.

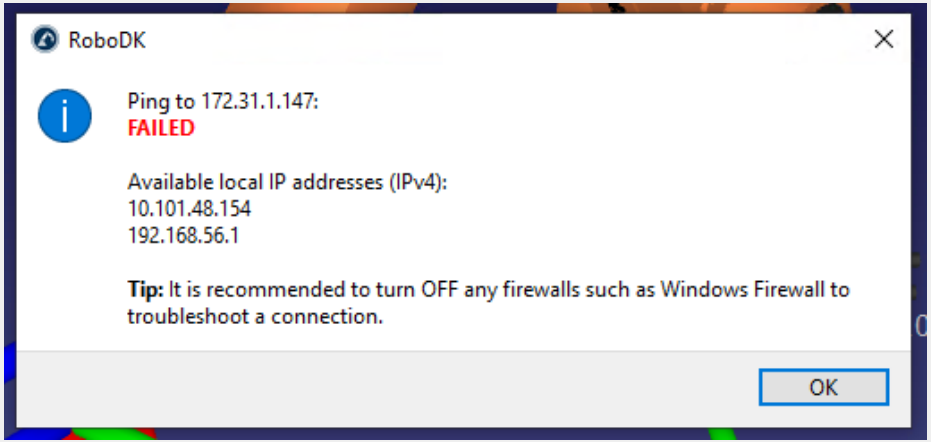
Calibration Troubleshooting

"Failed"

Error Message: **"FAILED"**

Ensure the **KR C4 cabinet** (the robot computer) is connected to computer via Ethernet

Integrators: Ensure **RoboDK drivers** and **KUKAVARPROXY** are correctly set up on cabinet, including firewall rules.



Calibration Troubleshooting

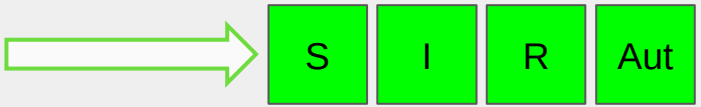
Robot does not move

If the robot does not move when running a program:

Ensure that **RoboDKSync35** program is running on the teach pendant with **four green boxes** displayed on the top of the teach pendant screen.

Check the **emergency stop** button is not engaged.

Ensure that teach pendant is set to **auto** mode, not T1, T2, or EXT.



Calibration

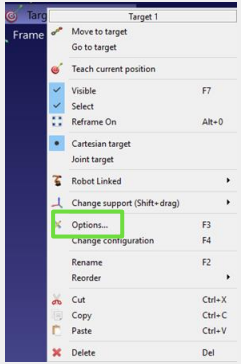
RoboDK

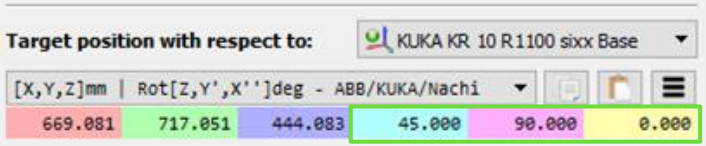
Left click the **Target Icon** in the top menu.
This will create a target item named **Target 1**.

Right click **Target 1** in the hierarchy and select **Options**.
In the pop-up menu change the numbers in the **light blue, pink,** and **yellow** fields to 45.000, 90.000, 0.000 as shown.
Leave the Red, Green, and Blue alone.

Step 1

Step 2





Calibration

RoboDK

Right click **Tool 1** in the hierarchy and select **Options**.

Calibration

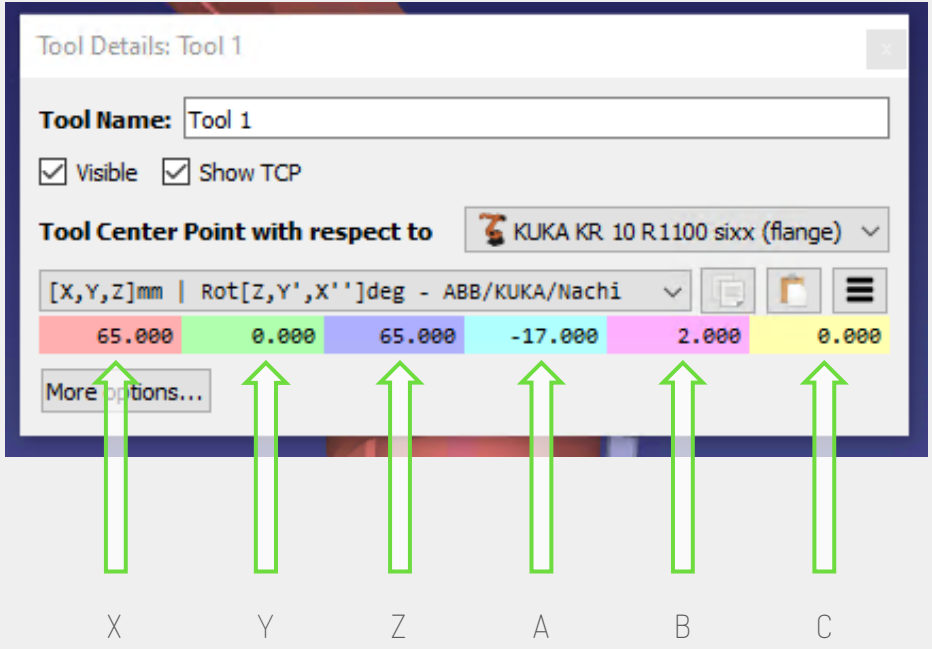
RoboDK

In the menu that appears, you will see:
Position values: X (Red), Y (Green), Z (Blue)
Rotation values A (Light Blue), B (Pink), C (Yellow)

X and Z values are used to determine the distance from the flange to the tip of the extruder.

A and B values display the Flange offset rotation.

The default values display the current Extruder setup - these values should be calibrated each time the extruder is installed.



Calibration

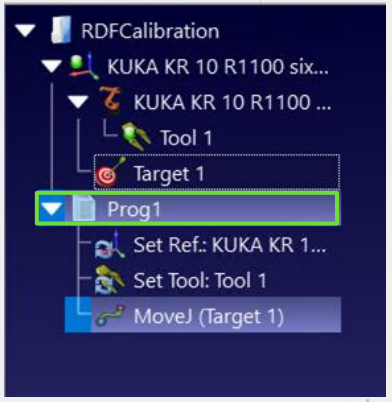
RoboDK

To calibrate the A and B values:

Select **Target 1** in the hierarchy and select the **MoveJ symbol**.

This will create a Program called Prog1.

Step 1



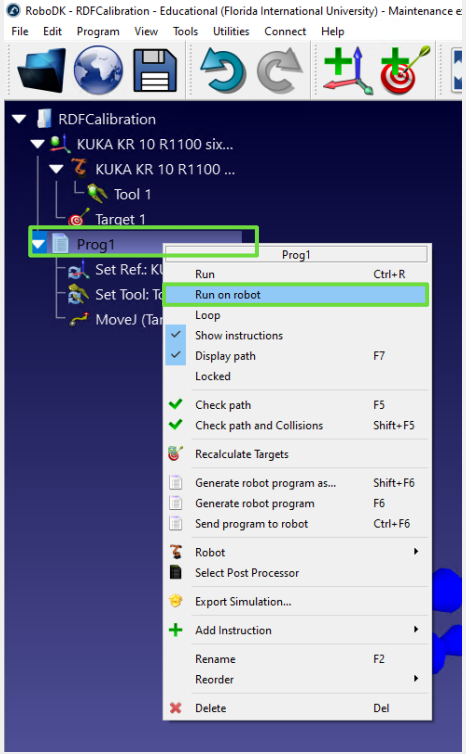
Calibration

RoboDK

Step 2

To calibrate the A and B values:

Right click **Prog1** and select **Run on Robot**.

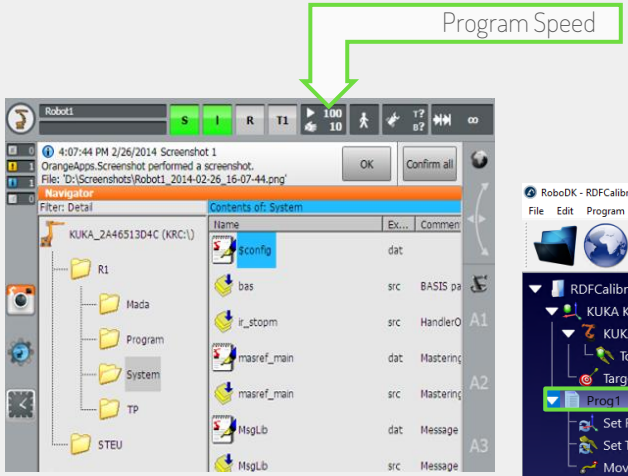


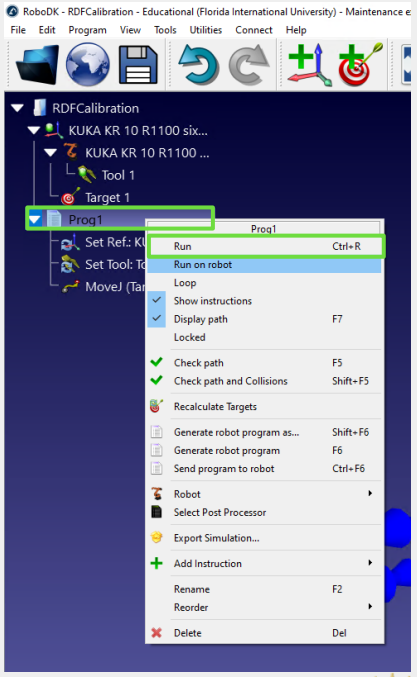
Calibration

RoboDK

Run **RoboDKSync35.src** on the Teach Pendant and set the Program speed to any number from **1-5.**

Once **RoboDKSync** is running, you can right click **Prog1** again and select **Run**.



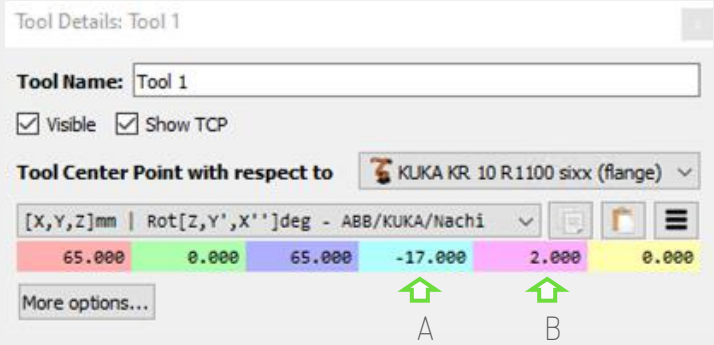


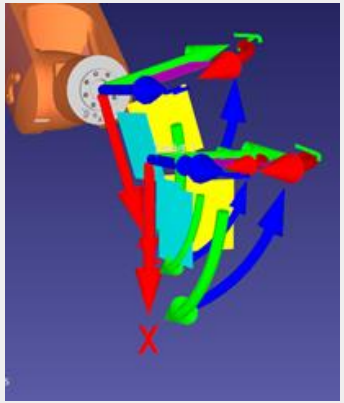
Calibration

RoboDK

If after running, the extruder is still not perpendicular to the floor, change the A and/or B values and run **Prog1** again until the extruder is perpendicular to the floor.

Once properly configured, it should look something like the image shown here.





Calibration

RoboDK

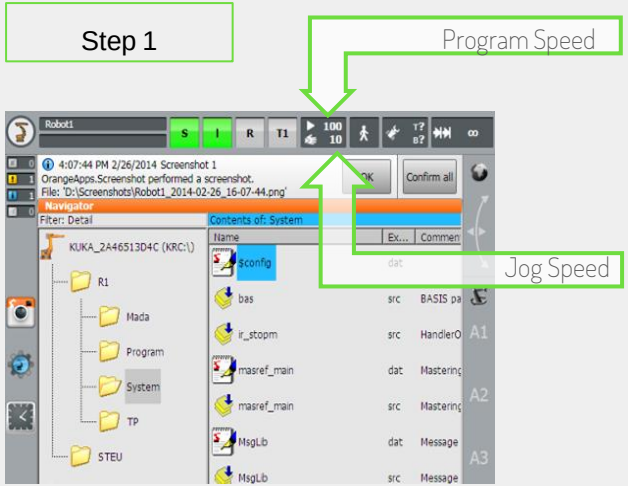
Now that the Extruder is properly calibrated the 3d print build surface must be calibrated.

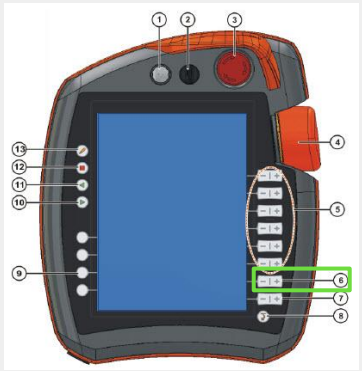
Begin by jogging the robot onto the print surface so that there is a small (<1mm) gap between the tip of the extruder and the build surface.

- Be careful to set the **jog speed** to **10 or less** to prevent collisions with the print surface.

*Jog Speed can be set by selecting the Jog Speed on the interface or by using the highlighted + - buttons on the teach pendant.

Step 1

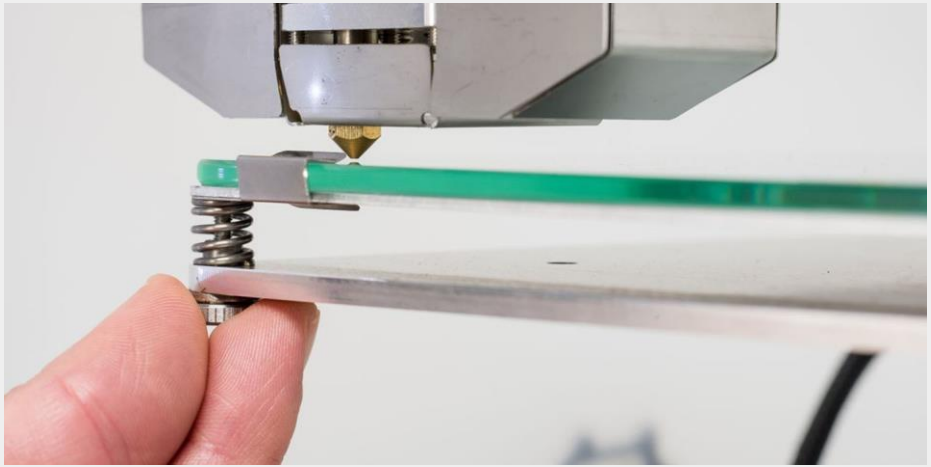




Calibration

RoboDK

Step 2



Slowly jog the extruder laterally around the build surface.

If the build surface is perpendicular to the extruder the offset will remain consistent. If the gap distance changes while jogging use the adjuster screws to calibrate the offset until it remains consistent.

*Calibrating the build surface offset will only be successful if the build area is moderately tilted relative to the extruder. Calibration will fail if the build surface is non-planar, ie. warped, bowed, bumpy, or otherwise damaged.

Picture Credit

Calibrations

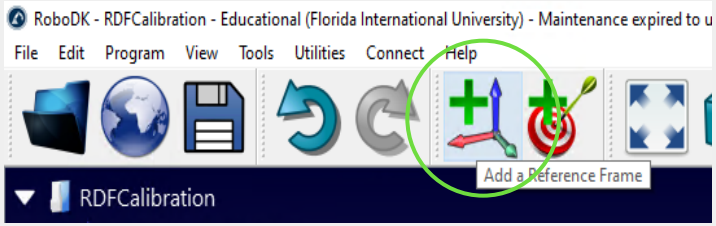
Calibrating Reference Frame

Select the **Reference Frame** icon shown below. This creates a Reference frame called **Frame 2**.

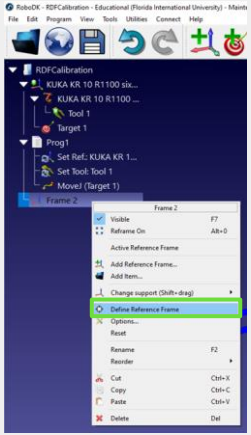
Right click **Frame 2** and select **Define Reference Frame**
The pop up menu is used to calibrate the build area.

Jog the extruder so that the tip of the extruder is 0.4 mm from one of the corners.

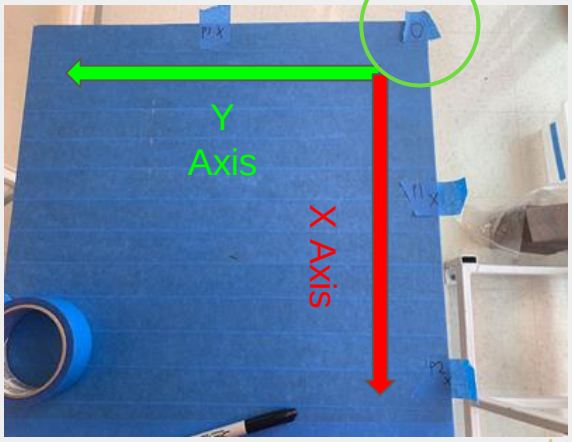
Step 1



Step 2



Step 3



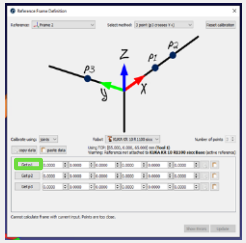
Calibrations

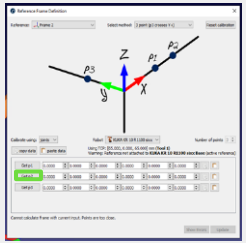
Calibrating Reference Frame

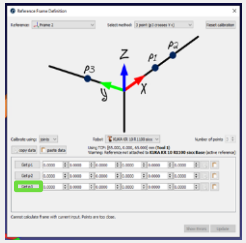
Jog halfway along the X Axis edge and move the extruder up or down so that it maintains a 0.4 mm gap. Open the **Connect to Robot menu** and select **Get Position** (This moves the robot in the simulation so that it matches the actual robot). Select **Get p1** in the **Define Reference Frame** menu.

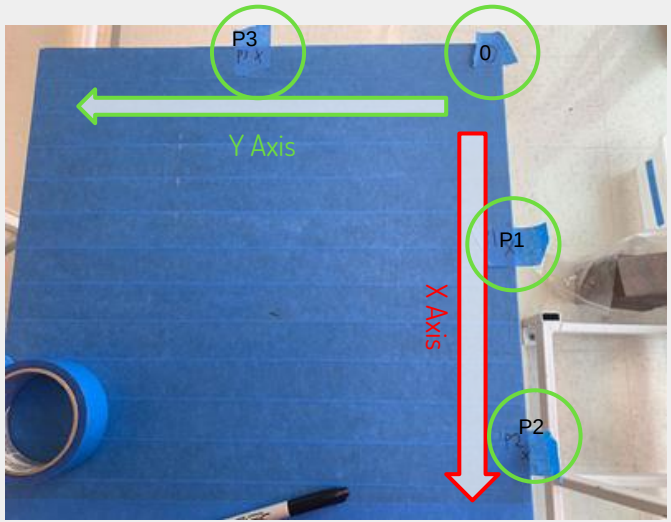
Continue jogging along the X Axis edge approximately half of the remaining distance and once again move the extruder so that it maintains a 0.4 mm gap. Select **Get Position** and **Get p2.**

Jog the extruder halfway along the Y Axis edge following the same procedure and select **Get Position** and **Get p3.**







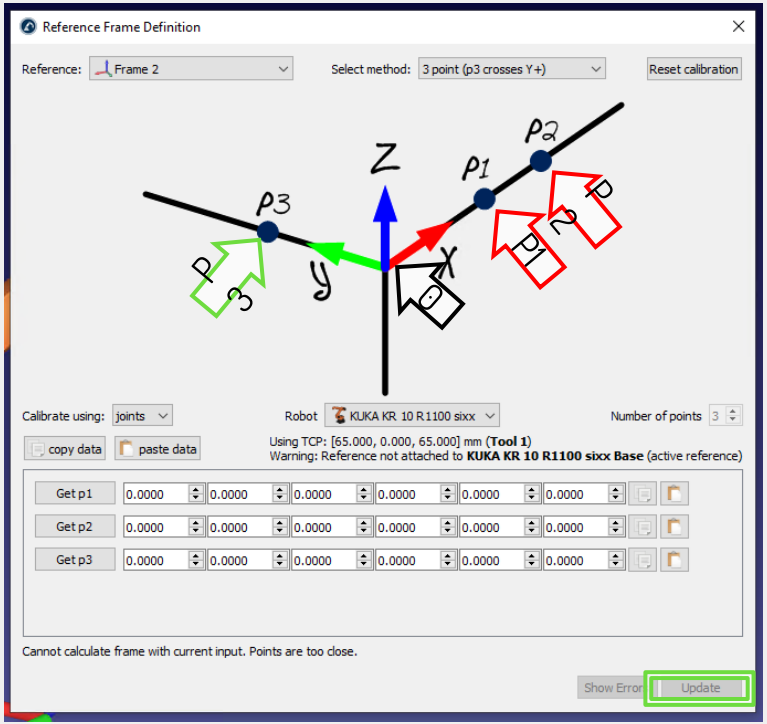


Calibration

RoboDK

After calibrating (Get p1, p2, and p3) select **Update** in the **Define Reference Frame menu.**

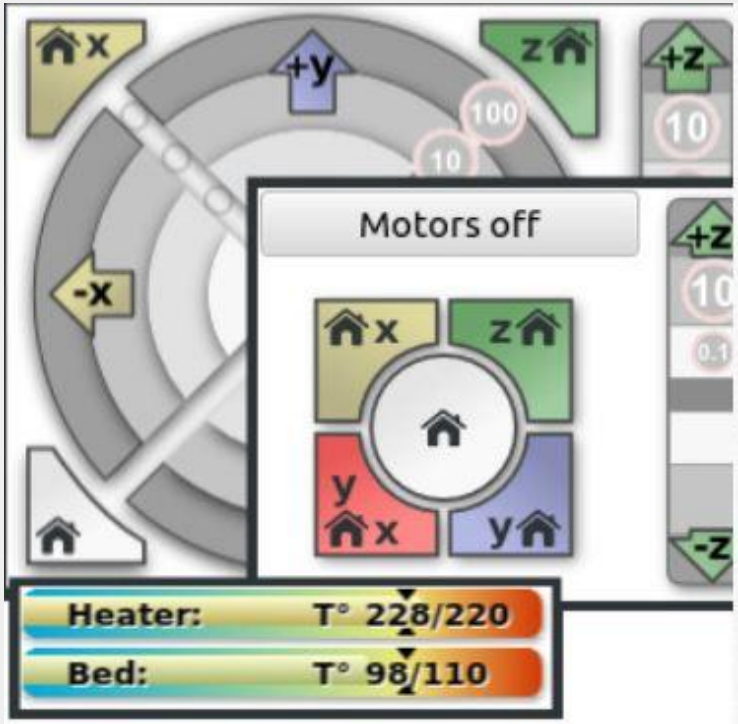
This coordinates the orientation of the reference frame with the actual 3d print build surface.



06 Software Setup

Pronterface is the software you will use for remotely controlling and monitoring the extruder module.

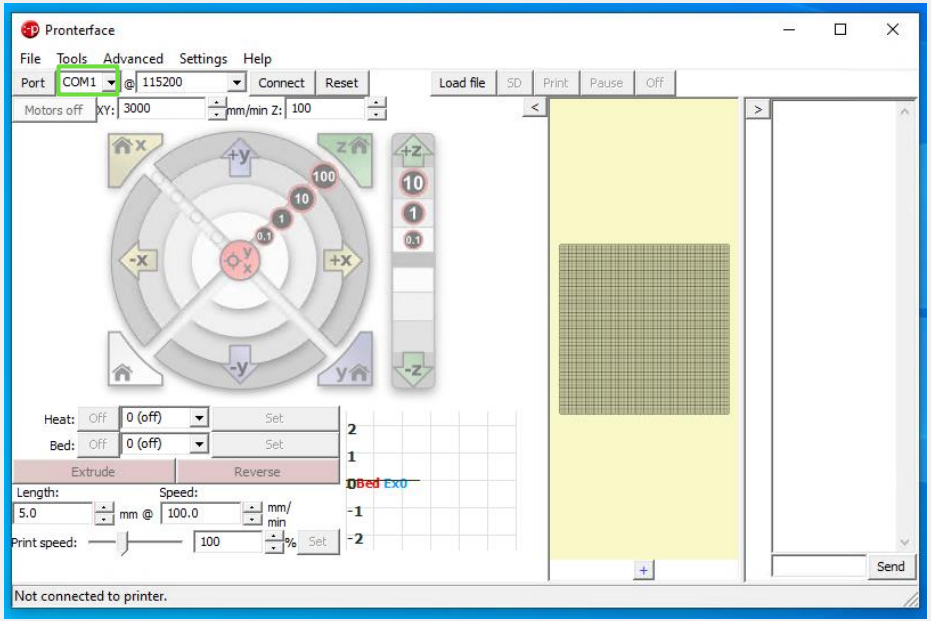
Download Pronterface Here



Software Set Up

Step 1

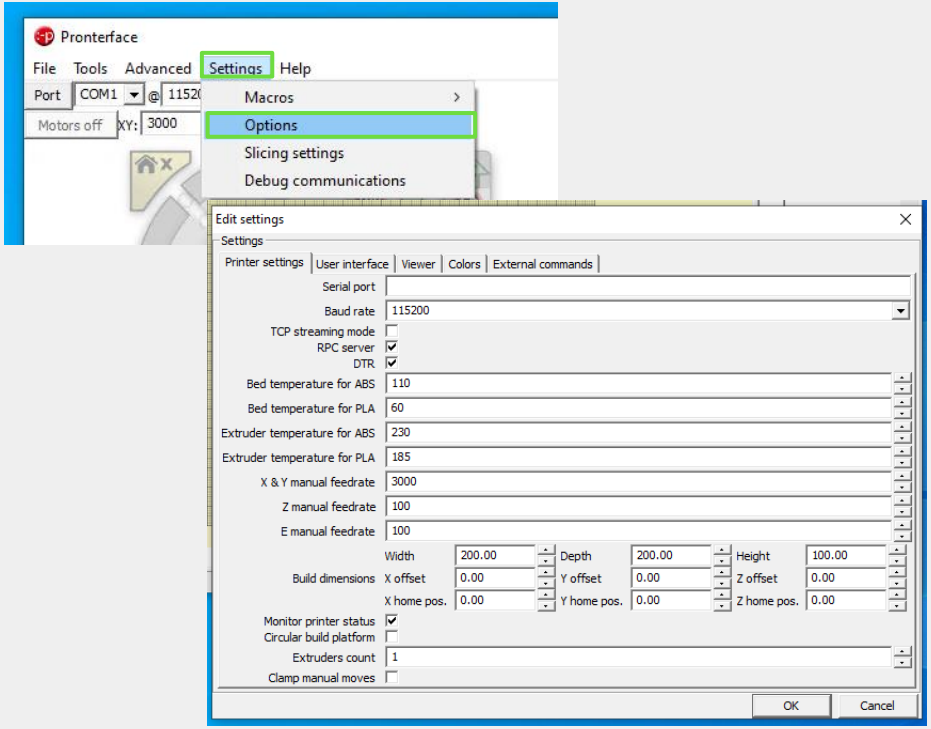
Open **Pronterface** and select the **Port Selection Menu** shown in the image to the right. It will display only **COM1**.



Software Set Up

Step 2

In the **Settings** drop down menu select **Options.**

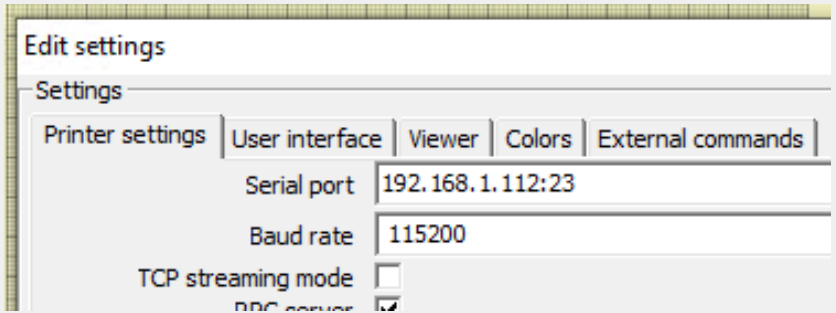


Software Set Up

Step 3

In the Serial port field input the following: **192.168.1.112:23**

Select **OK**



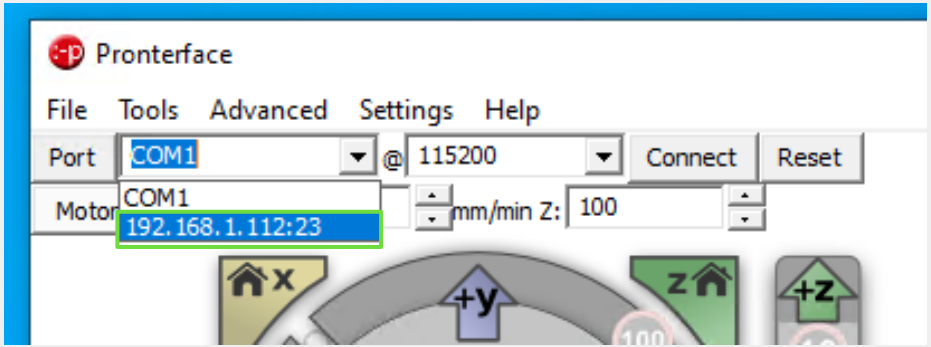
Software Set Up

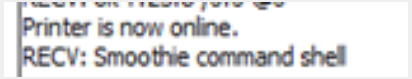
Step 4

Return to the **Port selection menu** and select **192.168.1.112:23**

Select **Connect**

Verify that the **Printer is now online** message appears indicating that the smoothieboard has been correctly configured.





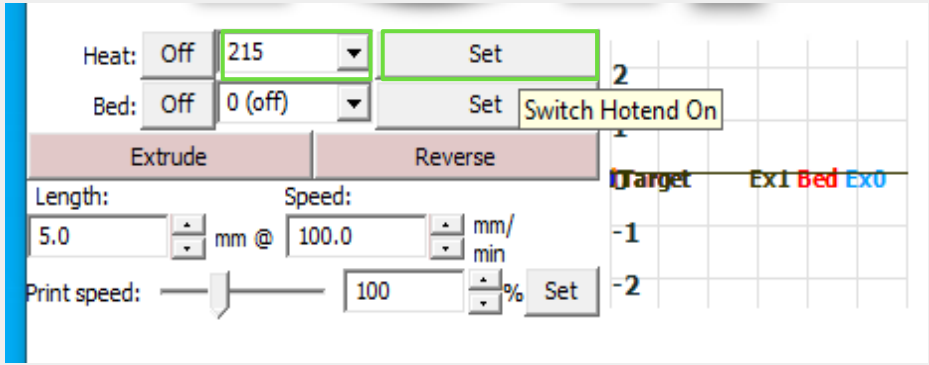
Software Set Up

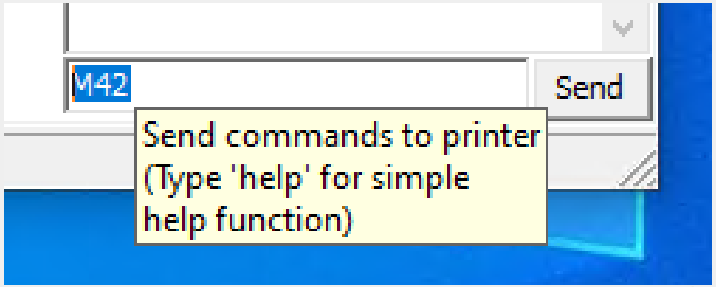
Step 5

In the **Heat** input field select or type **215** and select **Set**.

Once the extruder temperature reaches the selected value, the extruder is nearly prepared for use.

Type **M42** into the console and select **enter** on your keyboard to turn on the filament cooling fan. The extruder is now fully ready to print.

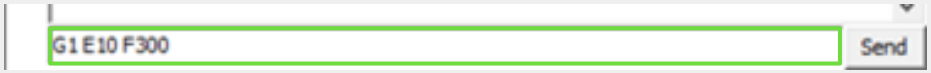




Test the Extruder

In the console, type **G1 E10 F300** and select **enter** on your keyboard. Verify that filament begins to exit the extruder nozzle.

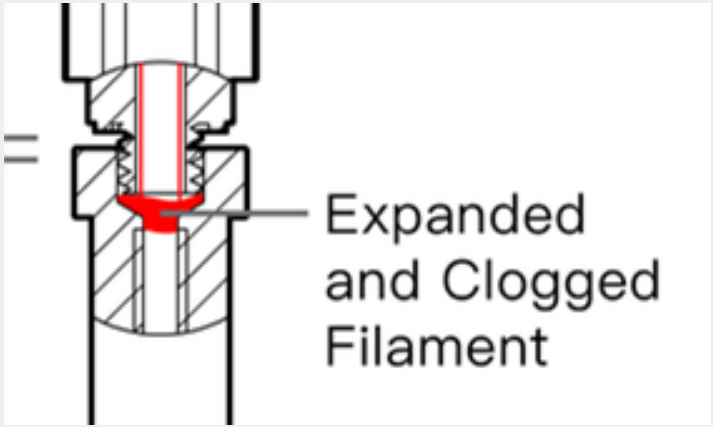
If filament does not extrude properly from the nozzle move on to troubleshooting.



Extruder Troubleshooting

If the extruder is not extruding properly select the yellow DISABLE STEPPER button. This will allow the extrusion gears to be manipulated manually.

Scenario 1:
Extrusion emerges **somewhat thicker** than the filament, before jamming moderately.
Solution: This can be solved by raising the extruder temperature to 280 or 290 and attempting to extrude again once the desired heat has been reached. It is then advisable to re-adjust the heat setting to a lower temperature to maintain a stable extrusion profile.
Make sure to disengage the **DISABLE STEPPER** button before attempting to extrude.



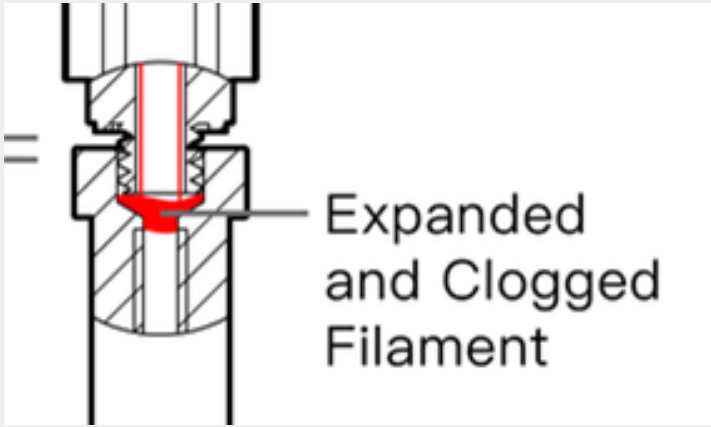
Picture Credit Picture Credit

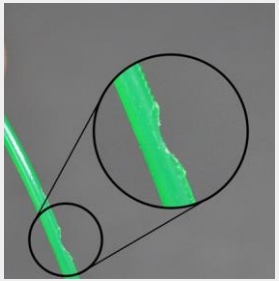
Extruder Troubleshooting

If the extruder is not extruding properly select the yellow **DISABLE STEPPER** button. This will allow the extrusion gears to be manipulated manually.

Scenario 2:
Extruder is seriously jammed.
Solution: First, while the extruder is still hot, loosen the filament by turning the silver knob and manually rotate the feed gear wheel while pulling the filament out of the extruder.
* Avoid touching the heater element!
If the filament can be removed this way, check the end of the filament for possible damage. If the filament appears to be nicked or shows semicircular "bite marks" it may be the incorrect material for the heat range specified. Try another spool of filament

Before extruding, click ENABLE STEPPER.
If the problem persists, ask the staff for help.





Picture Credit Picture Credit

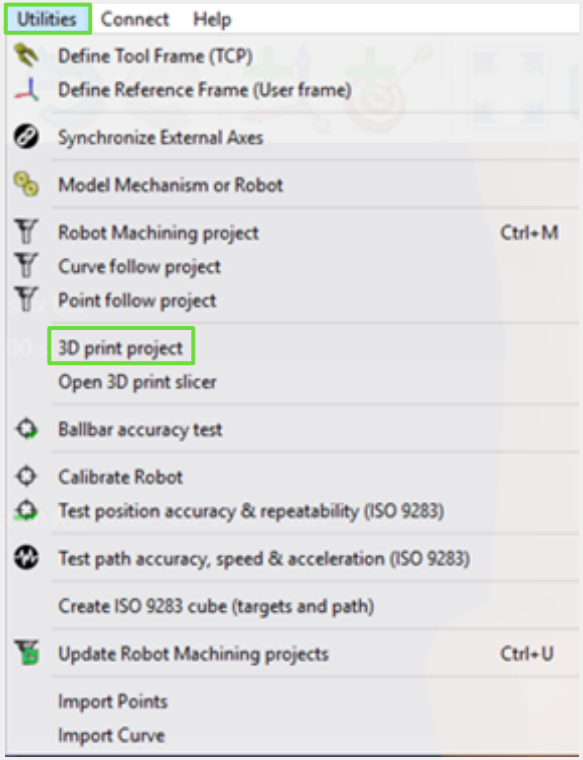
07 Printing

Setting up Print Project

Step 1

Select the **Utilities** dropdown menu and select **3D print project**.

Ensure that fields displaying **Robot**, **Reference Frame**, and **Tool** match the values input in previous configuration and calibration procedures.

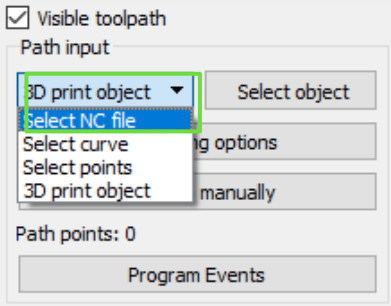


Setting up Print Project

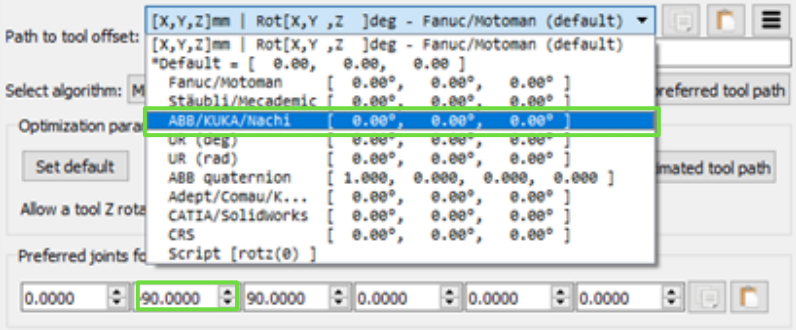
In the **Path Input** menu, from the **3d Print Object** drop down menu select **Select NC File**.

In **Path To Tool Offset** field select **Kuka default** from the drop down menu. Ensure that the value in the second (pink) field is set to -90 as shown.

Step 2



Step 3

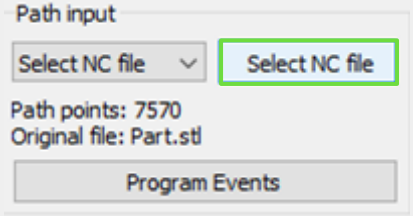


Setting up Print Project

Step 4

In the **Path Input** menu, select **Select NC file**.
This opens a browser for G-CODE files generated by Slicer software like Cura or Slic3r.

Note:
*For 3d printing applications using the robotic arm make sure to select **Disable Retractions** in the Slicer software settings.

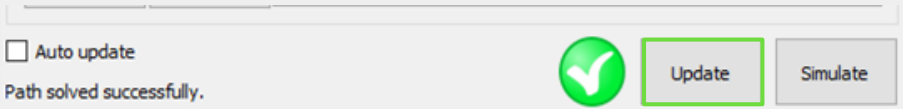


Setting up Print Project

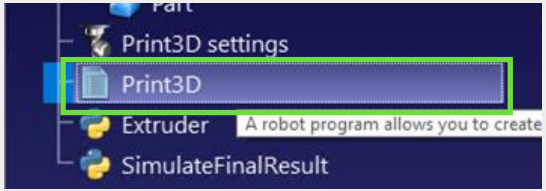
Browse for the desired gcode file and select **Update.** After the printing program finishes loading the file, double click the file name to launch a simulation. Verify that the robotic movements in the simulation appear correct.

Add the Extruder.py and M_RunCode.py files into the station.

Step 5



Step 6

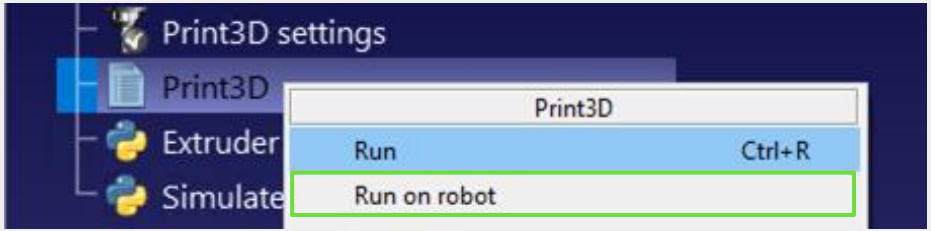


Setting up Print Project

Step 7

Select **Run on Robot** in the Print3D program.

This will begin the print. Monitor the printing process carefully, especially in the first several minutes. Be ready to stop the robot with the teach pendant should anything unexpected occur.



Terminology

Flange
Where tools connect to the robot arm.

Extruder
The part of the 3d printer which actually “prints” filament.

Reference Frame
How RoboDK determines where an object or tool is, relative to other objects or tools.

Thank you!

ROBOTICS CADEMY

FIU Communication, Architecture + The Arts