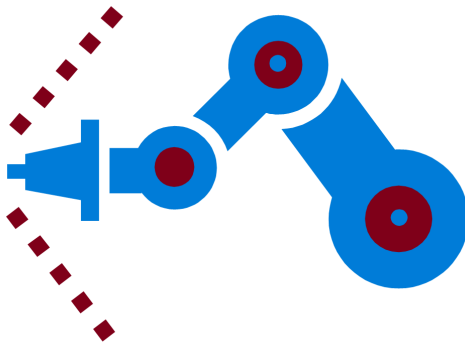


User manual

Modeling and control of an industrial robot

Version 1.0

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1 Introduction

In this document you will find instructions on how to use the Robomatic 3000 to control an industrial robot. Our product consists of a simulation program for the robot and a LabView program from where you can control the robot. To use these programs you will need Matlab/Simulink and LabView installed on the computer you intend to connect to the robot.

Both the simulation model and the control program have two different modes, joint control and trajectory. In the joint control you can control the joint angles from one set of angles to another and in the trajectory you will be able to move the tool from point A to point B in a straight line.

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2 Hardware

This section includes information about the hardware and the setup of the robot.

2.1 Coordinate System

When you want to control the robot in trajectory mode it is important to know how the coordinate system is defined. The coordinate system of the robot is shown in Figure 1.

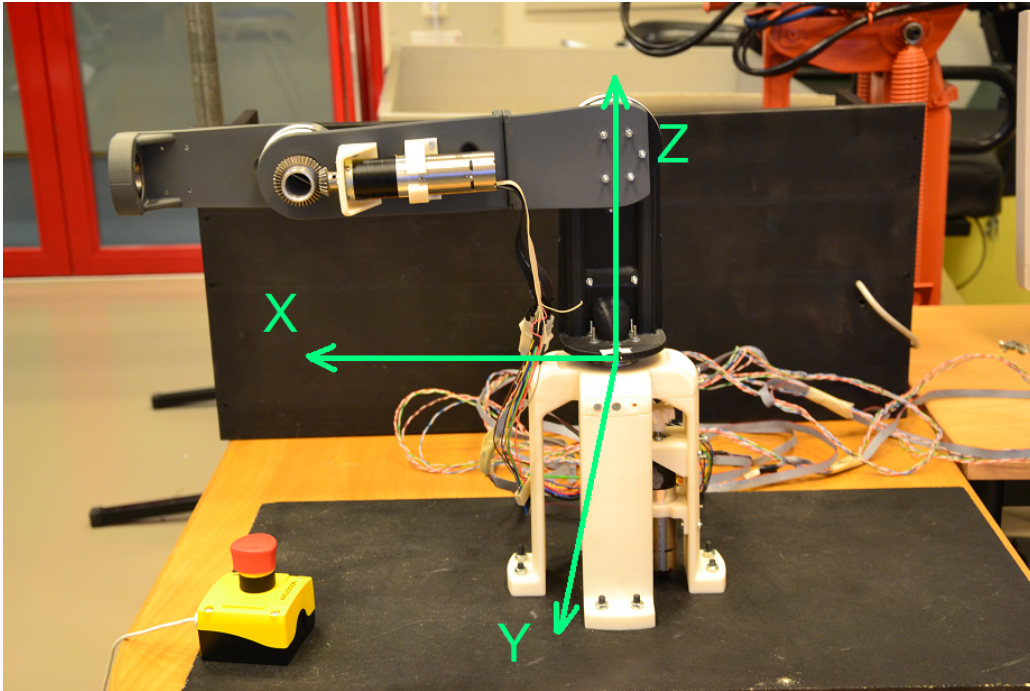


Figure 1: The coordinate system of the robot.

2.2 Robot Setup

Here you find information on how to connect the robot to your computer. An overview of the setup is shown in Figure 2.

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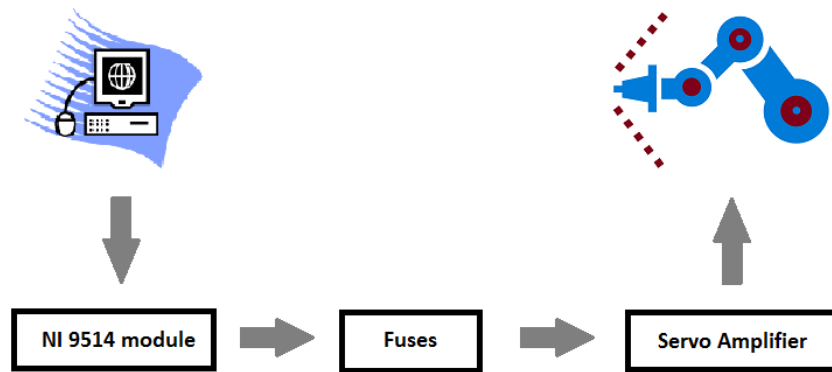
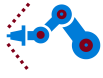
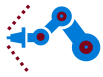


Figure 2: Overview of the setup.

Each motor are connected to a servo amplifier that controls the current to the motor. The servo amplifier are then connected to a NI 9514 module via fuses. The NI 9514 modules are placed in a National Instruments Real time controller device (NI cRIO 9022) that communicates with the computer through an Ethernet cable.



3 Simulation

The simulation model consists of nine Matlab files and one Simulink file. Out of these files the ones you are interested in using is called `robomatic.mdl` and `robotTrajectory.m`. You will need to have all the Matlab and Simulink files in the same folder on your computer. After you open Matlab you have to make sure your working folder is the folder that contains all your files. To do this press the browse button at the top of the Matlab window next to the address field that shows you what the current folder is right now, see Figure 3. After that simply find the folder that contains the files and press OK.

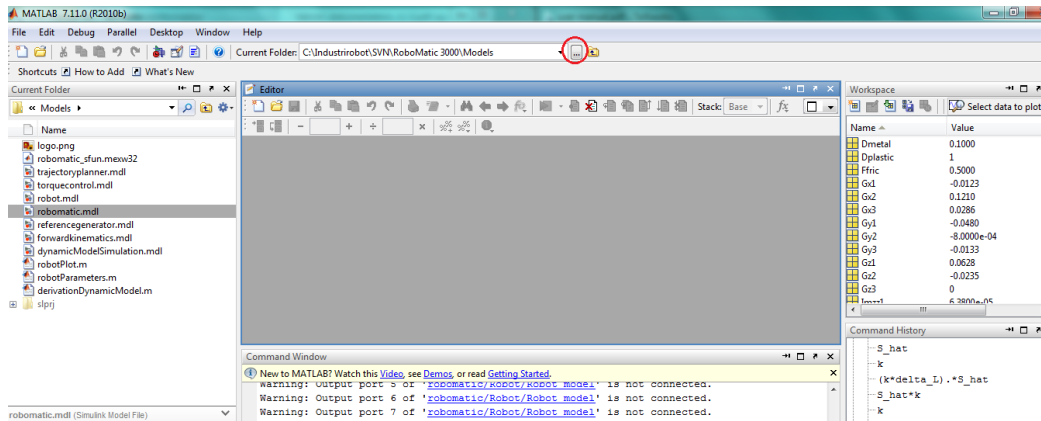


Figure 3: Browsing in Matlab.

The next step is to open the simulation model, to do this you can simply double click on the file named `robomatic.mdl` under current folder to the left in your screen.

3.1 User interface

When you open `robomatic.mdl` you will see the top level of the simulation interface, see Figure 4. The components that are of interest to you are marked with red.

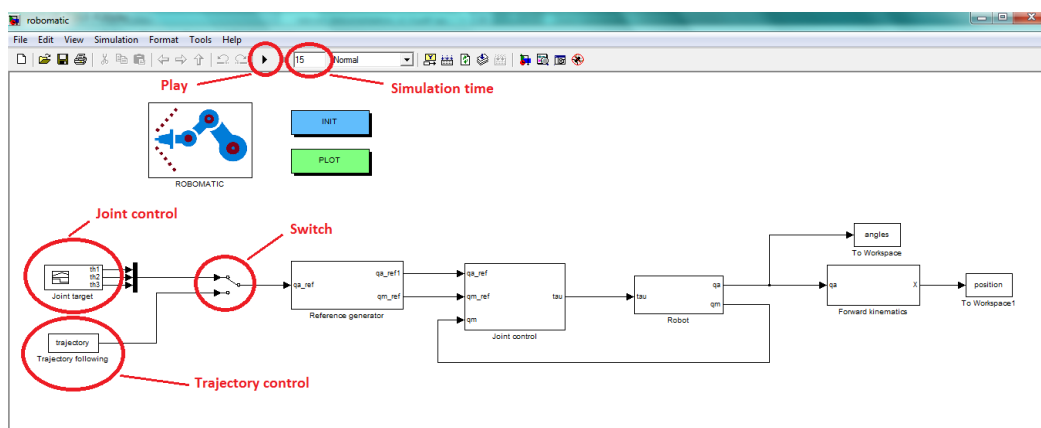


Figure 4: The simulation user interface.

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The first thing you have to do after you have opened the simulation model is to initiate all the robot parameters. To do this just double click on the button labeled "INIT". After that you have to choose if you want to simulate the joint target or a trajectory. A double click on the switch will change between the modes.

3.2 Joint control

In the joint control you can set the target angles by double clicking on the joint control block. You can either pull the lines by clicking and dragging or click the lines twice and enter a value in the box highlighted in Figure 5. In this block you can also generate other signals, for example square waves, triangle waves etc. Predefined are three step signals and if you want to generate other signals you can click the Signal menu button and choose new. This is not recommended if you are not used to working in Matlab/Simulink.

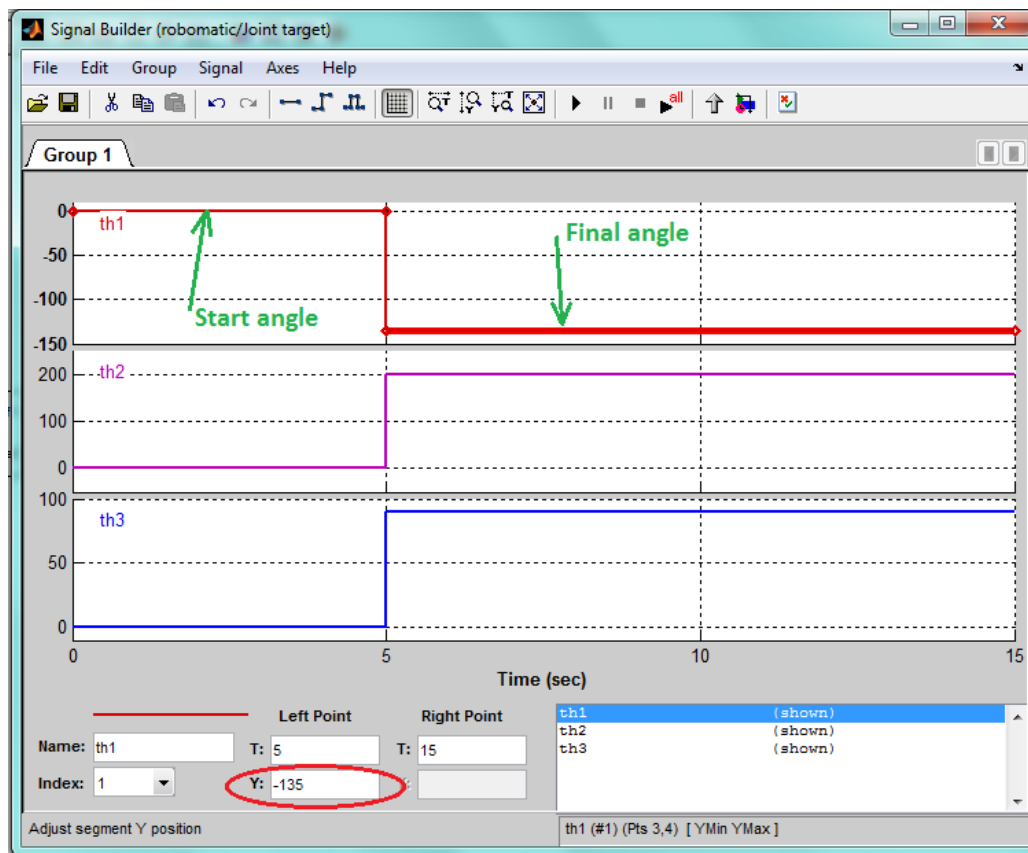


Figure 5: Joint control interface.

3.3 Trajectory control

In the trajectory mode you have to specify the start position, starting angle set and target position in another file called `robotTrajectory.m`, Figure 6 shows you where to set these values. By double clicking "INIT" in the Simulink model a file will be created that contains the joint angle positions for the given straight line movement from point A to



point B. If the trajectory you have chosen is not valid you will get an error when you try to simulate.

```
1 %% Initialize parameters
2 clc
3 clear all
4 close all
5 robotParameters;
6
7 %% Input variables
8 A = [0.35, -0.1, 0.2]; % Initial position
9 Start_set=1; % What set of angles you want to start with
10
11 B = [0 0.2 -0.1]; % Final position
12
13 %% Calculating input parameters for calotrajectory.m
14 q0_all = inverse(A(1),A(2),A(3),L1,L2,L3); % All initial angles
15 q0 = q0_all(1:3,Start_set)'; % Chosen initial angles
16 N = 1000; % Number of samples
17 Vmax = 0.1; % Trajectory maximum speed ~ Vmean
18 %%
19 % Set initial angles for simulation model
20 qa1_0 = q0(1)*pi/180;
21 qa2_0 = q0(2)*pi/180;
22 qa3_0 = q0(3)*pi/180;
```

Figure 6: robotTrajectory.m in Matlab.

3.4 Starting the simulation

In the simulation time box you can choose for how long you want to simulate the model. Have in mind that if you choose a short simulation time and have specified a low maximum velocity of the robot motion the robot will not be able to reach its final position.

After you have set all the above options you just have to press play to start the simulation. When the simulation is done you can double click the Plot button to see some plots of the robots motion. In Figure 7 a plot of the arm angles is shown, and in Figure 8 the tool position in room coordinates is shown, after simulating a trajectory. If you want to see any other signals, just place a Scope in the Simulink diagram.

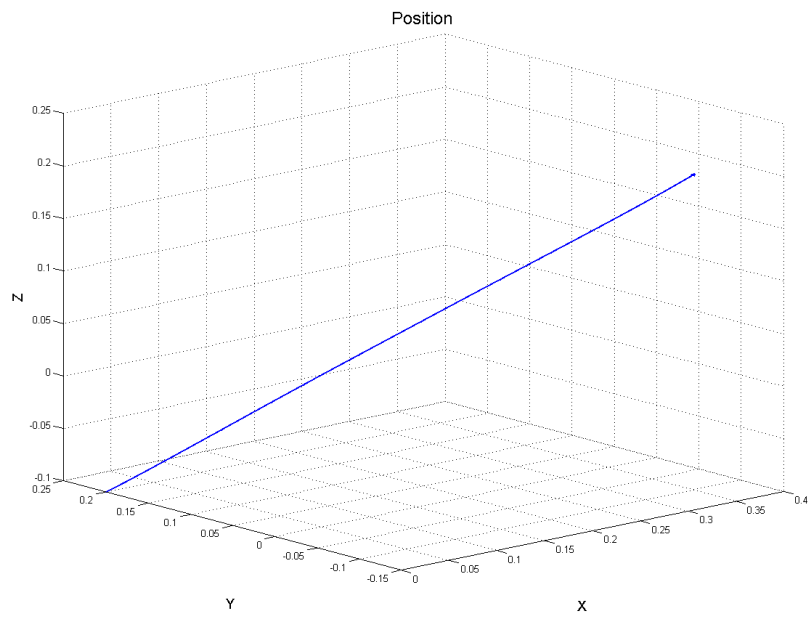


Figure 7: Example of a position plot.

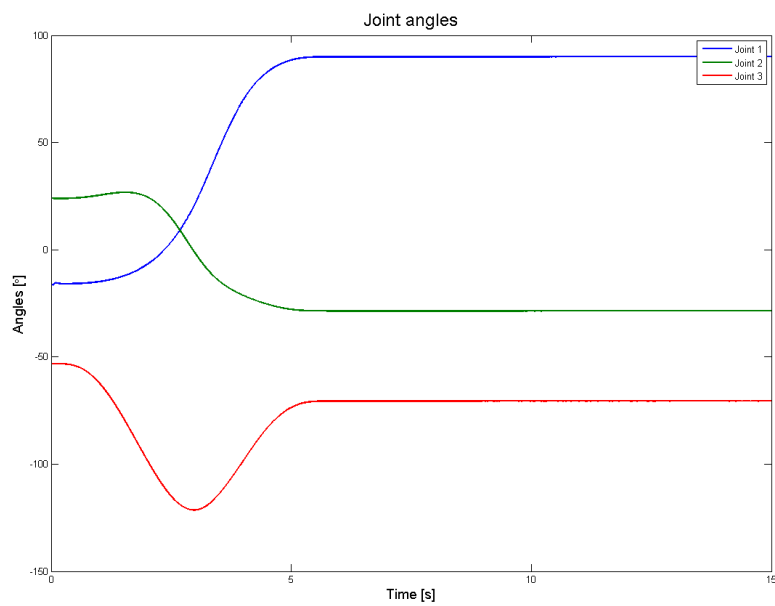


Figure 8: Example of an angle plot.



4 Controller program

To start the LabView project, find and open the file called RoboMatic.lvproj. The file will automatically open with LabView. The next thing you need to do is to define the default position of the robot i.e the position where all the joint angles are zero.

4.1 Defining the default position

The default position you are going set up is shown in Figure 9. There are also markings on the robot showing the angle position for each joint.

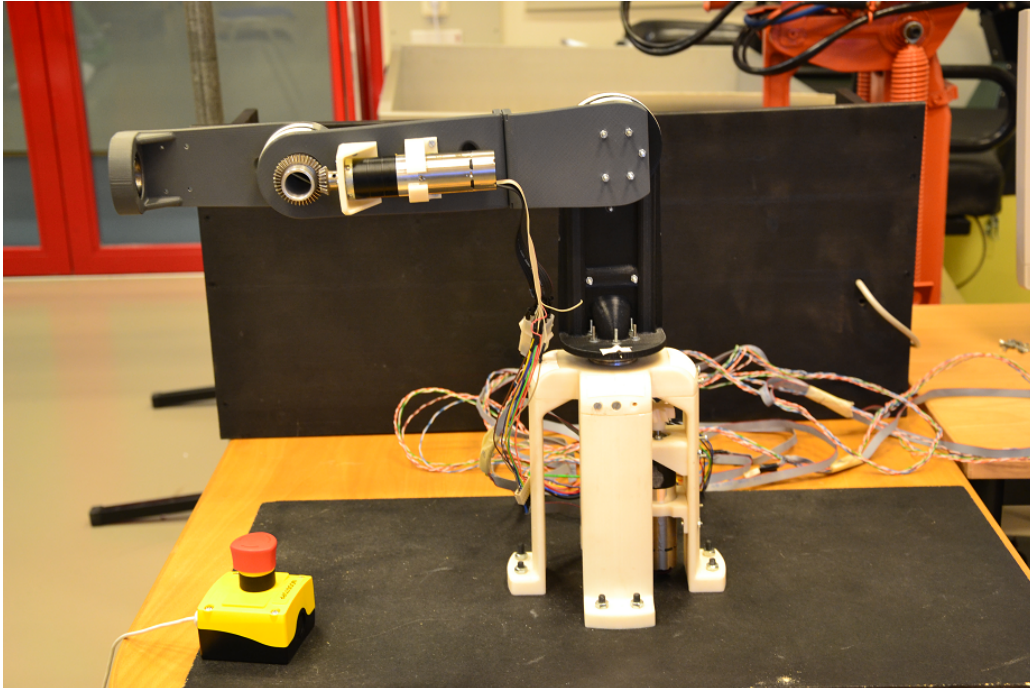


Figure 9: Default position of the robot.

You set the default position in the Interactive Test Panel. Each axis is set individually so you need to do this procedure once for each axis. To open the panel right click on the axis you want to set and choose Interactive Test Panel, see Figure 10

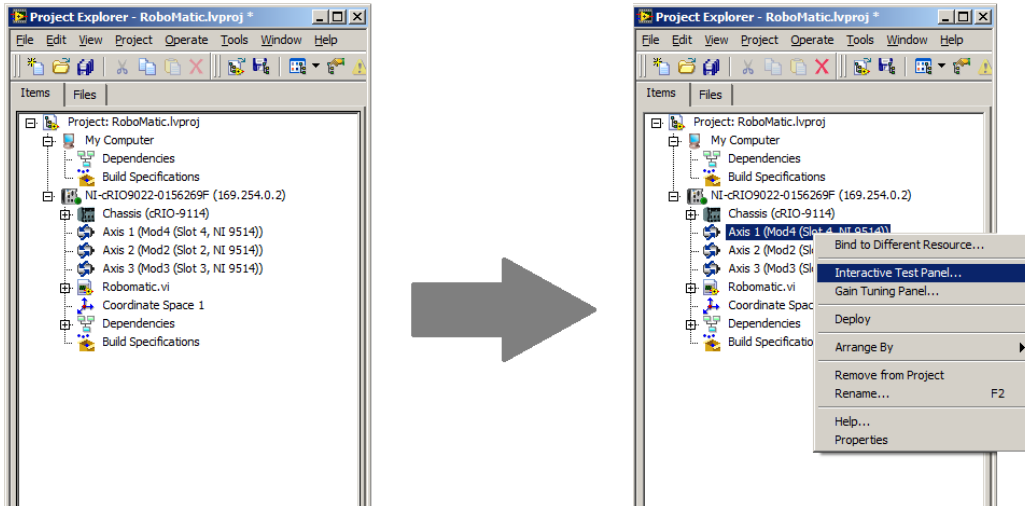
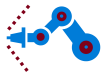


Figure 10: Opening the Interactive Test Panel.

When you have opened the Interactive Test Panel you first press the Status tab, see Figure 11. Then disable the drive and move the axis to the default position. You can make sure the drive is disabled by looking at the Drive Enabled box. Note: It is only one axis that will be disabled, the other two will be locked into place. When you are satisfied with the position press Enable drive to lock the axis into place, this is indicated by the Drive Enabled box turning green. Finally press the Reset Position button and close the window. Make sure to reset the position to zero. You could technically reset it at another position but since the different joints have different units per degree it is easiest to reset it to zero.

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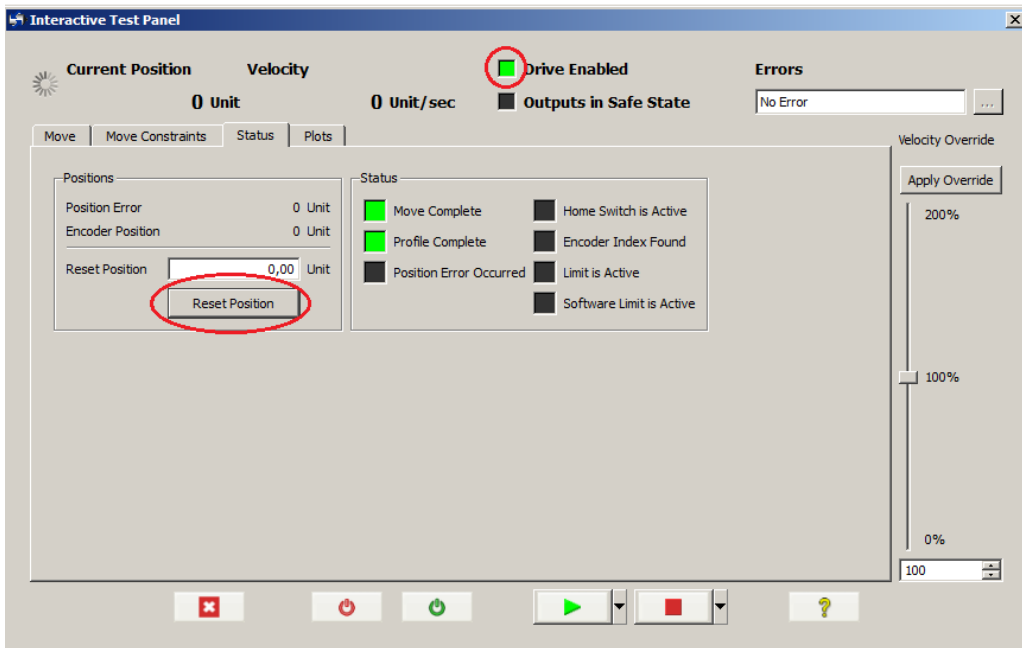
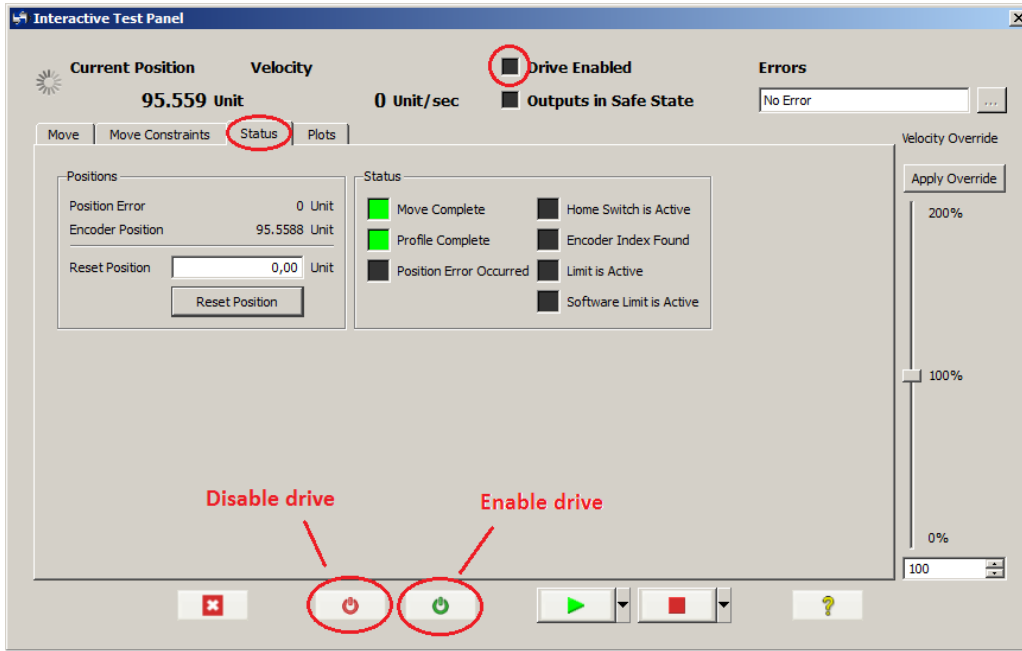
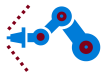
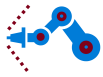


Figure 11: How to reset the position in Interactive Test Panel.



4.2 User interface

To open the user interface double click on Robomatic.vi in the Project Explorer. In Figure 12 you can see that each axis has a graph and an indicator showing its angle and angular velocity. There is also an indicator showing the current tool position. Besides this there are controls for the manual and automatic mode. Note that saturations on the joint angles are implemented, so that the robot does not collide with itself.

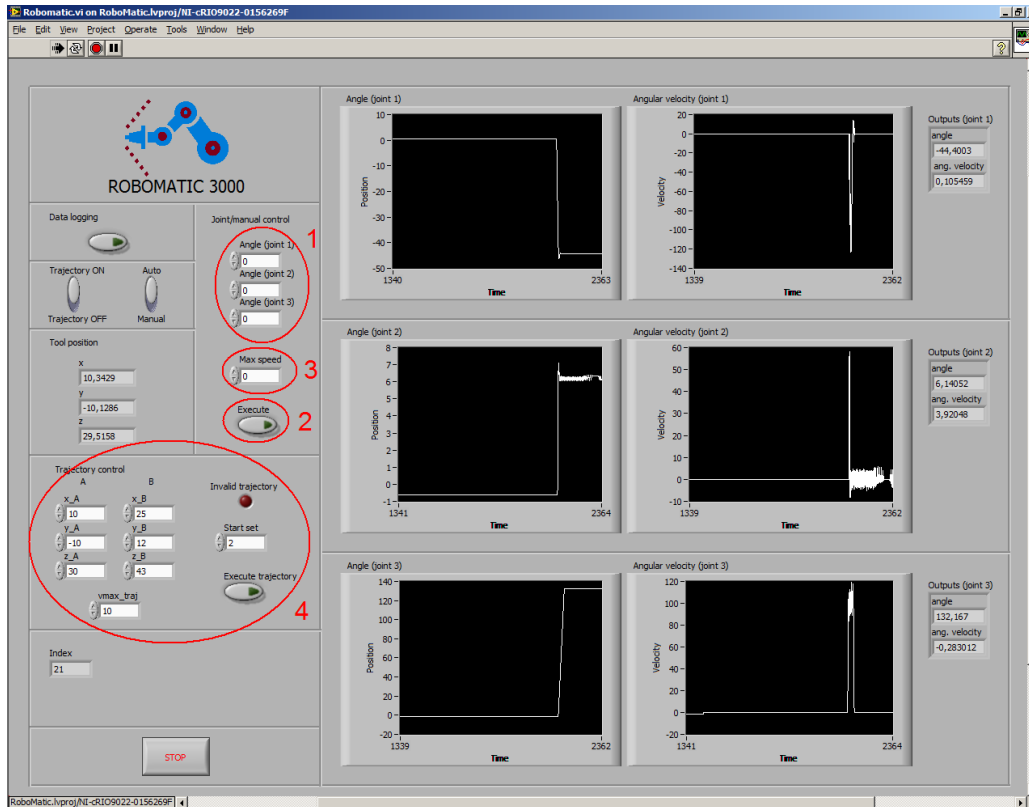


Figure 12: The user interface in LabView.

4.3 Manual mode

In the manual mode you can control each axis separately. Set the desired angle (1) in Figure 12 and press enter, the robot will then move the axis with reduced speed. This mode is mostly to confirm that the axis can move properly.

4.4 Automatic mode

In automatic mode you can choose to control the tool position or control the joint angles by switching the trajectory mode on and off.

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4.4.1 Trajectory OFF

If you wish to control the target joint angles you can select the trajectory off mode. Set the desired target angles (1) and the angular velocity (3) in Figure 12, then press the execute button (2) in Figure 12.

4.4.2 Trajectory ON

If you wish to control the tool in a straight line from one point to another you can set the trajectory to ON. Note that you have to enter all the information under Trajectory control, (4) in Figure 12, before you start the program. Enter the desired start position and target position. For each position reachable for the robot there are theoretically 4 ways to set the angles for that position. In the Start set box you can choose what set of angles you want to start with. In the v_{max}_traj you can choose the desired maximum velocity.

When you have set all the options you can start the program. The robot will automatically move to the starting position with the chosen set of angles. If the robot does not move the trajectory is invalid. To start the trajectory simply press Execute trajectory, to reset the robot to the starting position press Execute trajectory again.

If the trajectory is invalid you can try using another set of starting angles, note that you have to stop the program, enter another start set and then start the program again.

4.5 Data logging

You can store data while running the robot. To start press the Data logging button and to stop just press the button again. Data regarding the joint angles and the tool position will be saved onto the NI cRIO 9022 controller. To access this data you enter the IP-address to the controller in the address field of your web browser. The IP-address is 169.254.0.2. The data will be located in the folder called Data, to save it onto your hard drive highlight the file you want and click the Save data button as shown in Figure 13.

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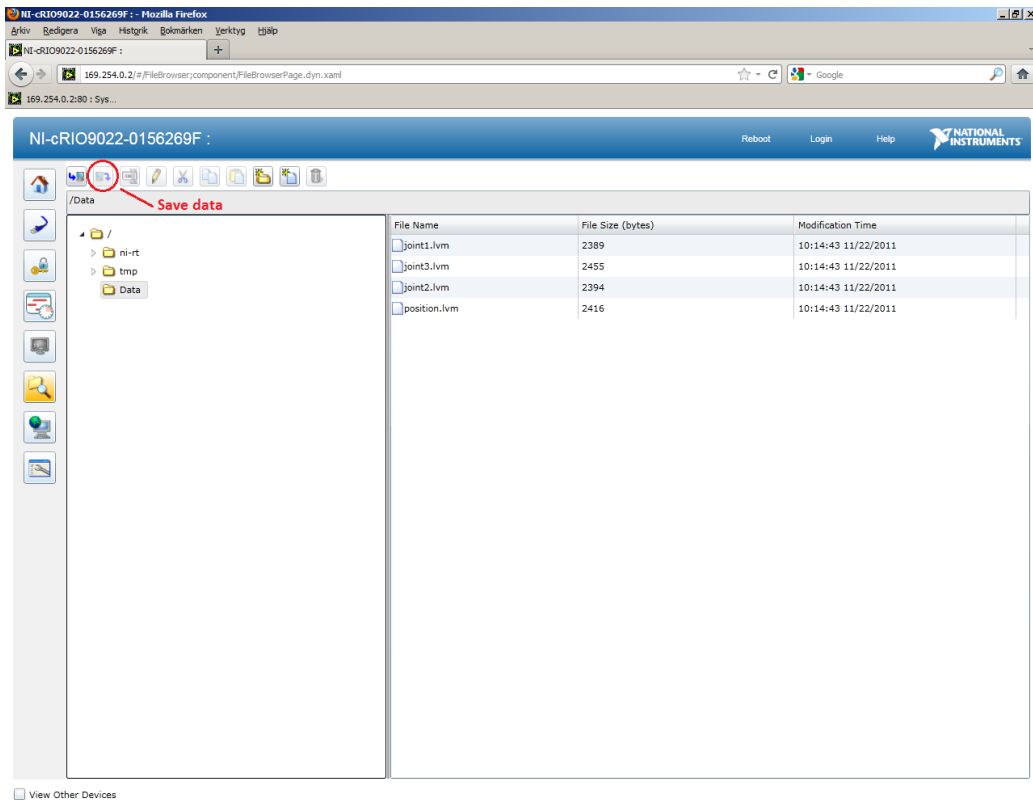
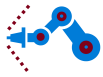


Figure 13: The NI cRIO 9022 controller interface.

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5 Troubleshoot

If the robot does not move or there are any other problem try the following:

1. Check that the emergency stop button is not pressed down
2. Check if any fuses are blown and make sure the controller is connected to the power source
3. Try restarting LabView
4. Make sure the network cable is connected and that the connection to the controller is not broken
5. Restart the controller by cutting the power
6. As a last resort try restarting both the computer and the controller