FAST MOVING TECHNOLOGY

CS9 external axis

Technical documentation

White paper

TSS.0000.002.04-E - 02/04/2024
CS9 external axis – Master document

A "readme.pdf" document may be delivered on the robot's DVD. It contains the documentation addenda and errata.

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History

Revision	Modification	Date (yyyy-mm-dd)	By
A	Initial release	2018-12-24	A.JAFFRE
B	Update with new tested drives	2020-11-08	A.JAFFRE
C	Improve description of each setting in externaxes.cfx	2022-07-29	A.JAFFRE
D	Add ExternKinEnable description Correct mistake in groundLink explanation Improve explanation of all items of externaxes.cfx	2023-04-18	A.JAFFRE
E	Add single set / multiple set of external axes explanation Add step by step SRS cell build and test	2024-03-26	A.JAFFRE

Version

That document has been tested with:

- SRC: s8.10.5
- Safety: 1.003 or 100.003 / SafePMT 3.0.0.28
- SYCON.net: the one delivered with SRS 2019.4.1

Keyword

external axis, rotary table, linear axis, interpolation, Stober drive

1 Preliminary

DANGER

Instructions drawing the reader's attention to the risks of accidents that could lead to serious bodily harm if the steps shown are not complied with. In general, this type of indication describes the potential danger, its possible effects and the necessary steps to reduce the danger.
It is essential to comply with the instructions to ensure personal safety..

SAFETY

Instructions drawing the reader's attention that its responsibility is engaged if the steps shown are not complied with.
It is essential to comply with the instructions to maintain the robot safety level.

Caution

Instructions directing the reader's attention to the risks of material damage or failure if the steps shown are not complied with. It is essential to comply with these instructions to ensure equipment reliability and performance levels.

ELECTRICAL risk

Instructions drawing the reader's attention to the risks of electrical shock.
It is essential to comply with the instructions to ensure personal safety.

Information

Supplies further information or underlines a point or an important procedure. This information must be memorized to make it easier to apply and ensure correct sequencing of the operations described.

2 Description

2.1 Which equipment's are concerned?

The present document applies to **synchronous** external axes connected onto J206 EtherCAT master of CS9 controller.

External axes are driven in an open loop by a VAL3 application which, by definition, is not secure.
We send a position command every 4ms to external axes, which means that we have a defined speed. It is assumed that they will respect position and speed.
The safety CPU of the robot controller has no knowledge of the presence of external axes. It is therefore impossible for it to safely control the external axes (stopping time, speed, position, ...).

SAFETY

There is no safety profile associated with that configuration, this means the robot and external axis must be in a closed space which can stop the robot at its maximum energy.

External axes motion is synchronized with arm motion, so tool path is controlled.

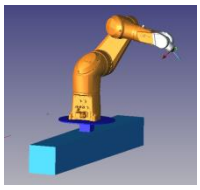
=> need external axis option (license)
=> can be done only with CS9 J206 EtherCAT fieldbus
=> need to have a drive with EtherCAT fieldbus following DSP402 specifications (see 2.3)

2.2 Which arrangement can be done?

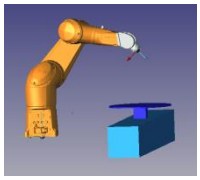
All external axes must be stacked one on the top of the previous one.

Robot / external axis position can be:

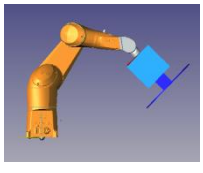
- Robot can be on top of all external axis



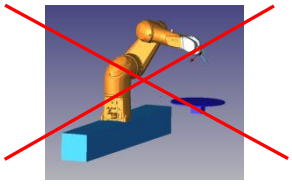
- Robot can be in front of all external axis



- All external axes can be on robot flange



- Above arrangement cannot be mixed



2.3 Which drives can be used?

Drive following DSP 402 specifications, settable into interpolated position mode and implementing phase lock loop.

Mandatory COE objects

- 0x6041: status word
- 0x6061: mode of operation display
- 0x6064: drive position feedback
- 0x6040: control word
- 0x6060: mode of operation
- 0x60C1: commanded position

Optional COE objects

- 0x6098: homing method

We must have drive's manufacturer support in integration and end user countries.

Only below drives have been tested and validated by STAUBLI:

- Stober SD6A + EtherCAT board EC6A (tested with 2 drives, Faverges, 20180315, AJAF)
- Stober SC6 (tested with 1 drive, Faverges, 20230222, AJAF)
- Kinco FD3 (Hangzhou, 20200214, LJIN)
- Parker C3 (Hangzhou, 20201030, JZHO)
- Sanyo Denki RS2 (Taiwan, 20201005, SPAI)

2.4 Single set of external axes or multiple set of external axes

Usually, you work with a single set of external axes.
Robot has a defined number of external axes and always work with them.
Examples:

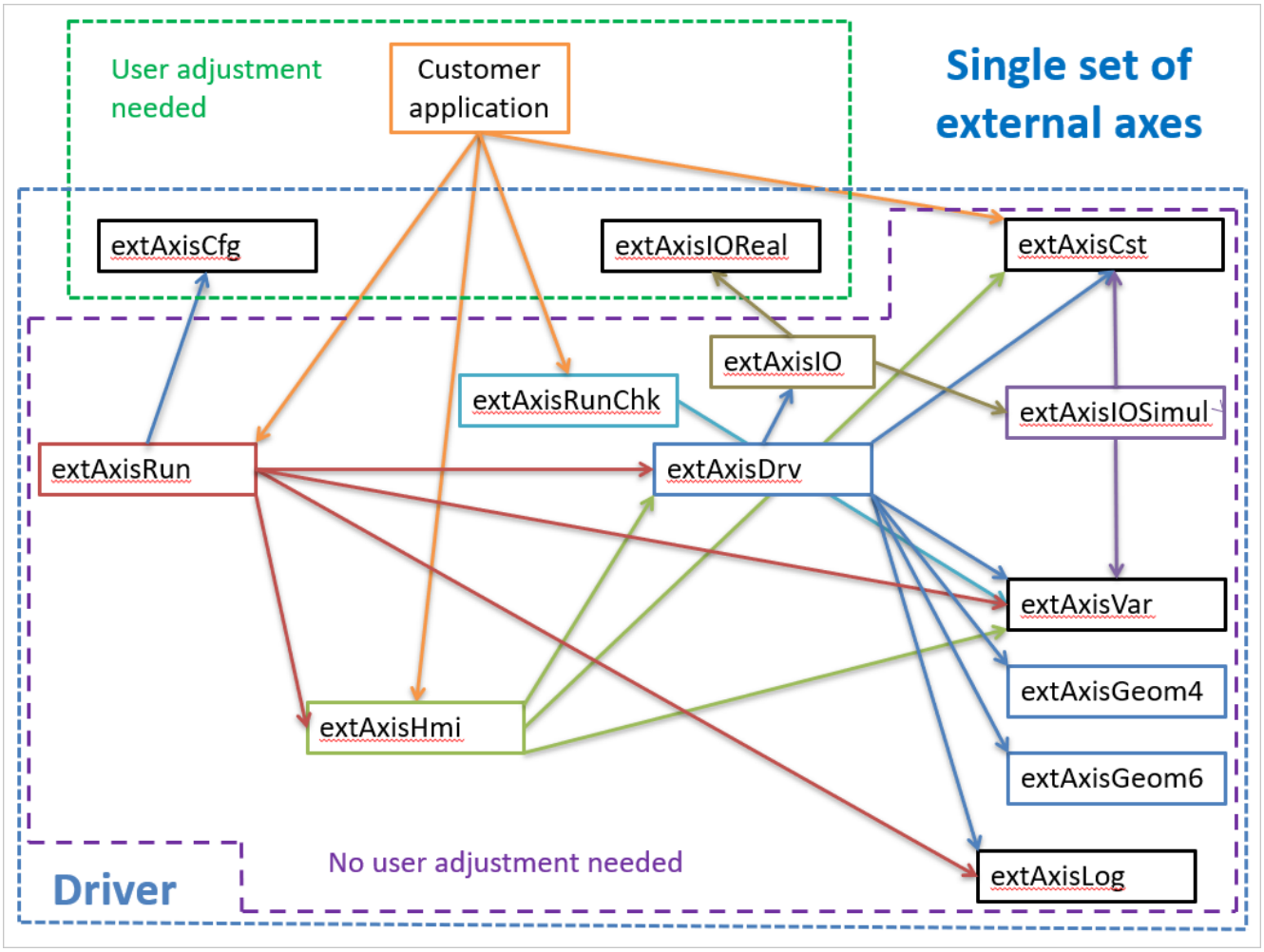
- Robot is in front of a rotary table: this is a single set use and the set contain only one axis.
- Robot is in front of a XY table: this is a single set use and the set contain two axes.

We speak about a multiple set of external axes when robot must work on different identical set of external axes.
Examples:

- Robot is in front of two rotary table. It works some time on one of it and some other time on the other one.
  This is a multiple set use and each set contain only one axis.
  Each axis is perfectly identical (same drive model and configuration, same gear box ratio).
  The only thing which changes is the rotary axis position regarding robot position.
- Robot has one XY table at his right and one XY table at his left:
  This is a multiple set use and each set contain two axes.
  Each axis is perfectly identical (same drive model and configuration, same gear box ratio).
  The only thing which changes are the position of each axis regarding robot position.

When working on multiple set of external axes, it is mandatory to have all set identical in term of drive model, configuration, gear box ratio.
For clarity, multiple set particularities are explained in appendix B Multiple set particularities

2.5 External axis driver structure



Information

You must build your own application which will use the external axis driver and make configuration / adjustment in “extAxisCfg” and “extAxisIOReal” (see below)

3 Installation

3.1 Hardware

All hardware (drive, motor, mechanics, …) must be wired and checked separately. You should be able to move the external axis properly from the drive.

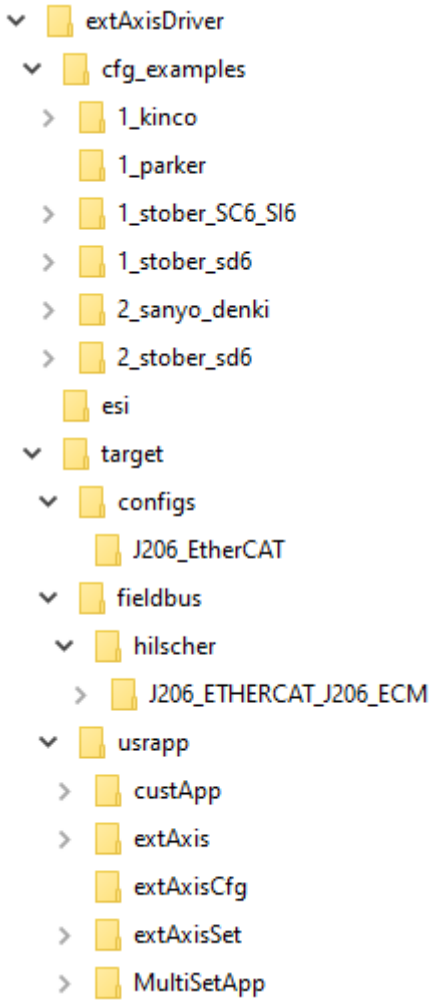
3.2 Software

Be sure to have a SRC version that is >= 8.10.5 (this version contains some bug fixing dedicated to External Axes) and to have installed the corresponding version of the **expansion, recorder and** (**motion or velocity) addon**.

Also, external axes license must be activated (it is a software option, and it is necessary to buy it)

3.3 SRS

Get the external axis driver from STAUBLI technical database (extAxisDriver.zip) and unzip it on your computer. You should get the following folder structure:



Build an SRS cell as usual and save it.

From the unzipped extAxisDriver, copy all contents of target “folder” into the “usr” of your SRS cell.

4 Configuration

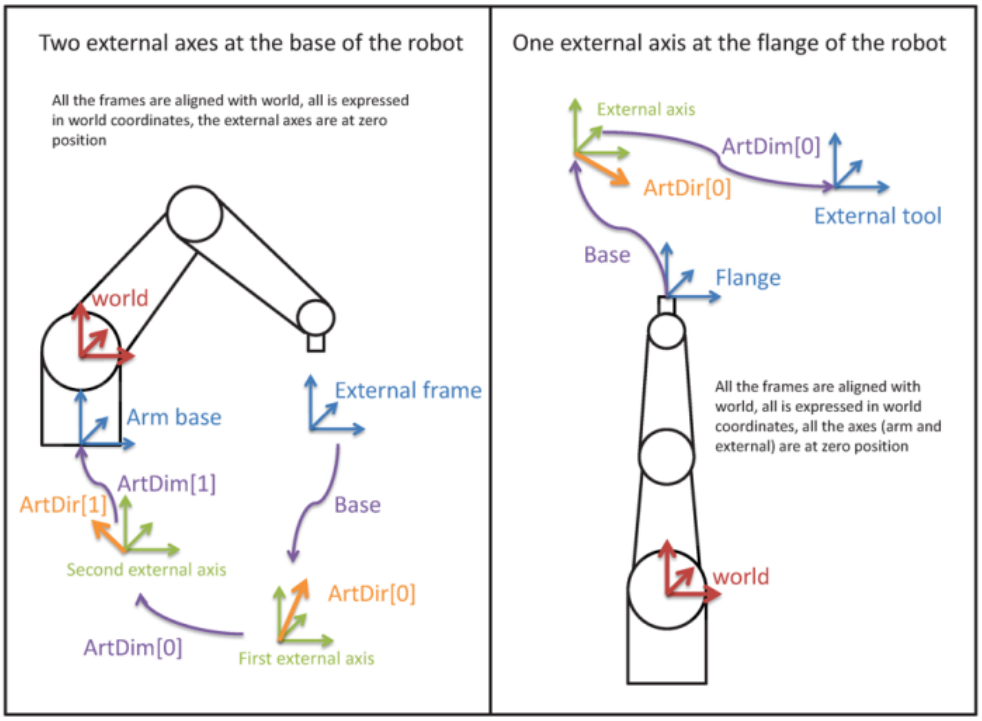
4.1 External axes description (externaxes.cfx)

With an editor (notepad++ https://notepad-plus-plus.org/), open “externaxes.cfx” file located in “/usr/configs” folder of your SRS cell.

Adapt number of lines to suit number of external axes for: ArtType, ArtDir, ArtDim, JntToDrvMatrix, MinJntPos, MaxJntPos, NomJntVel, NomJntAcc, MaxJntVel, MaxJntAcc, MaxManuJntVel, DrvDelay, DrvCountPerTurn, DrvOffset

Adjust:

- NbOfAxes: number of external axes
- ArtType: prismatic or rotoid
- LinkedToFlange: external axes linked to the flange (true) or to the arm base (false)
- GroundLink: 0 if robot is mounted on external axes, number of external axes if the robot is on the ground.
- ArtDir: unit vector of the external axis expressed in world frame when all joints are at 0 position
- ArtDim: position of the next axis in the chain relatively to the current one.
- Base: position of the first external axis relatively to the external frame or to the flange
- ExternKinEnable: input which allow to select arm only or arm + external axis
- JntToDrvMatrix: gearbox ration and coupling
- MinJntPos, MaxJntPos: minimum and maximum joint position of external axis
- NomJntVel, NomJntAcc: nominal joint velocity and acceleration of external axis
- MaxJntVel, MaxJntAcc: maximal joint velocity and acceleration of external axis
- MaxManuJntVel: maximal joint velocity in manual mode for external axis
- DrvDelay: drive transmission delay
- DrvCountPerTurn: encoder resolution
- DrvOffset: drive position offset



4.2 Detailed configuration

4.2.1 NbOfAxes

Define how many external axes we have.

Example with 2 external axes:

```
<Uint name="NbOfAxes" value="2" />
```

4.2.2 ArtType

For each external axis, define its type between prismatic or rotoid.
You must have one line per axis.
Axis index is the same as shown on above picture

Example with a rotary table in front of the robot, in robot world X axis.
Rotary table is parallel to XY plane.

```
<ArtType>
  <String name="ArtType[0]" value="rotoid" />
</ArtType>
```

Example with robot installed on the top of a linear rail

```
<ArtType>
  <String name="ArtType[0]" value="prismatic" />
</ArtType>
```

Example with robot installed on the top of an XY table

```
<ArtType>
  <String name="ArtType[0]" value="prismatic" />
  <String name="ArtType[1]" value="prismatic" />
</ArtType>
```

Example with 2 axes, a rotary table is installed on the top of a linear rail which is in front of the robot

```
<ArtType>
  <String name="ArtType[0]" value="rotoid" />
  <String name="ArtType[1]" value="prismatic" />
</ArtType>
```

4.2.3 LinkedToFlange

Define if external axes are linked to the flange (true) or to the arm base (false)

Example with external axes linked to robot base:

```
<Bool name="LinkedToFlange" value="false" />
```

4.2.4 GroundLink

Useless when linkedToFlange is true. Define number of the first axis which is after the ground. From a kinematic point of view, external axes are before robot axes. Axes numbering start at 0.

Example with a rotary table (joint 0) in front of the robot. Robot (joints 1 to N) is on the ground

```
<Uint name="GroundLink" value="1" />
```

Example with robot (joints 1 to N) installed on the top of a linear rail (joint 0), which is on the ground.

```
<Uint name="GroundLink" value="0" />
```

Example with robot (joints 2 to N) installed on the top of an XY table (joint 0 and 1), which are on the ground.

```
<Uint name="GroundLink" value="0" />
```

Example with 2 axes, a rotary table (joint 0) is installed on the top of a linear rail (joint 1) which is in front of the robot (joints 2 to N), which is on the ground.

```
<Uint name="GroundLink" value="2" />
```

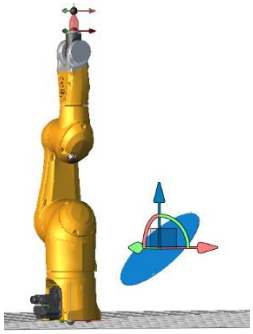
4.2.5 ArtDir

Define the unit vector (https://en.wikipedia.org/wiki/Unit_vector) of external axis expressed in world frame, when joints are all at 0 position.
In simple case, with axes parallel to robot world:

- rotoid axis: around which world axis did it rotate?
- prismatic axis: in which world axis direction did it move?

Example with a rotary table in front of the robot, in robot world X axis.
Rotary table is parallel to XY plane.

```
<VectCartArray name="ArtDir" >
    <VectCart index="0" x="0" y="0" z="1" />
</VectCartArray>
```

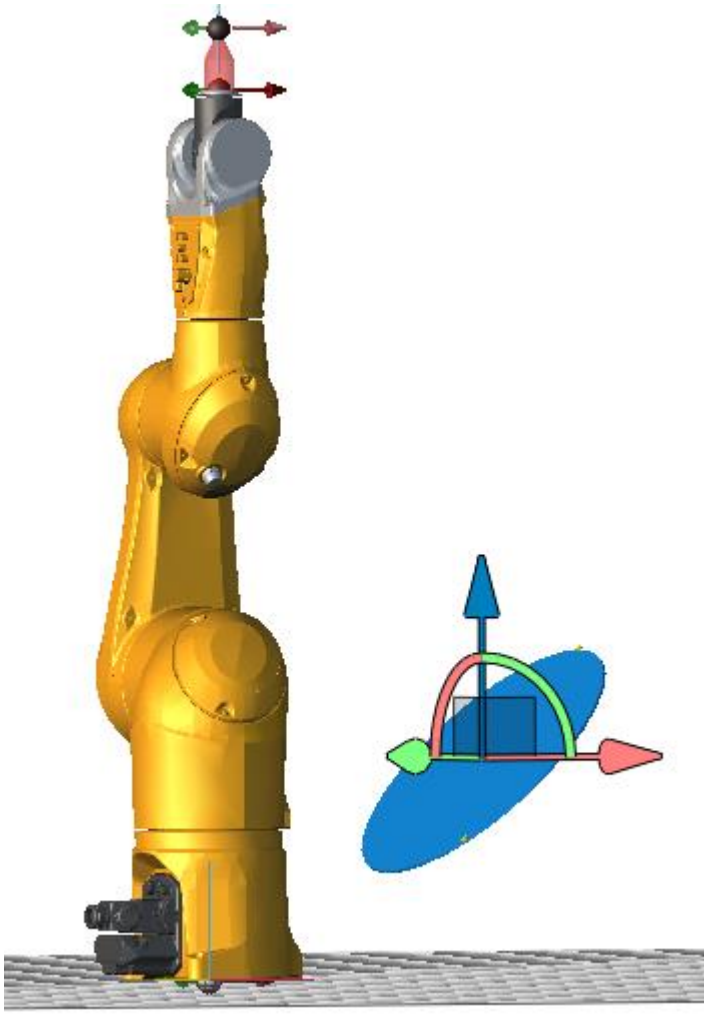


Example with a rotary table in front of the robot, in robot world X axis.
The rotary table is inclined 45° around robot world Y axis

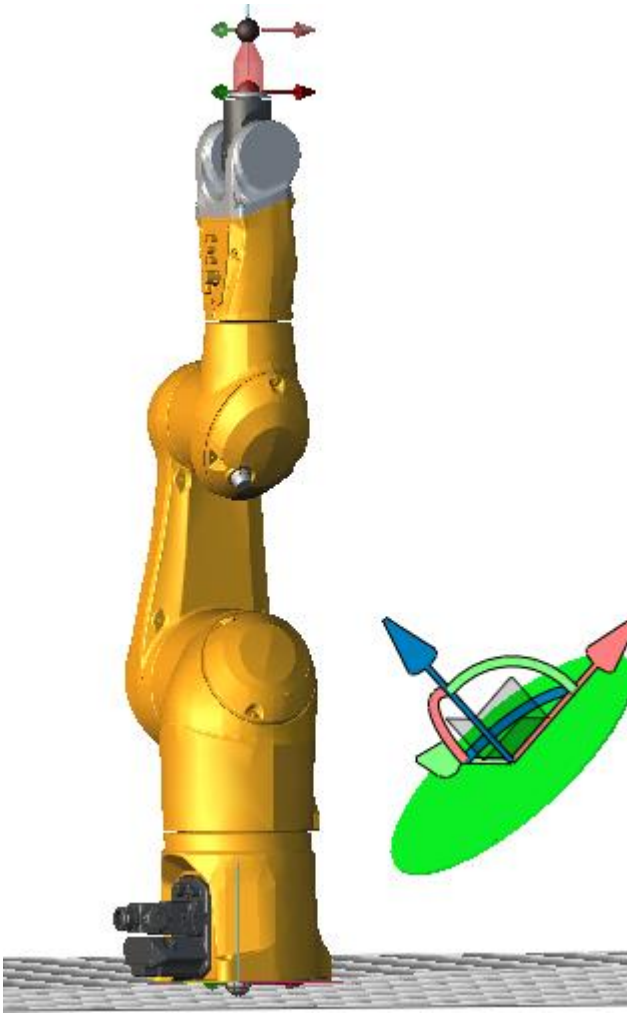
```
<VectCartArray name="ArtDir" >
    <VectCart index="0" x="-0.707106781" y="0" z="0.707106781" />
</VectCartArray>
```

Unit vector can be computed in VAL3:

```
// Table rotate -45° around Y axis -> RY
trRotation={0,0,0,0,-45,0}
// Table will rotate around Z axis
trMainDirection={0,0,1,0,0,0}
// Compute unit vector
trCompute=trRotation*trMainDirection
```



Frame returned by $XframeLink



Aligned frame, which is a child of $XframeLink frame with a -45° rotation on RY

The frame returned by $XframeLink VAL3 instruction will not consider tilt of rotary table.
If you need to have a frame aligned with external axis direction, you will have to add a child frame properly oriented onto the frame returned by $XframeLink.

Example with robot installed on the top of a linear rail, with the rail parallel to robot world Y axis and in opposite direction

```
<VectCartArray name="ArtDir" >
    <VectCart index="0" x="0" y="-1" z="0" />
</VectCartArray>
```

Example with robot installed on the top of an XY table, with table parallel to robot world

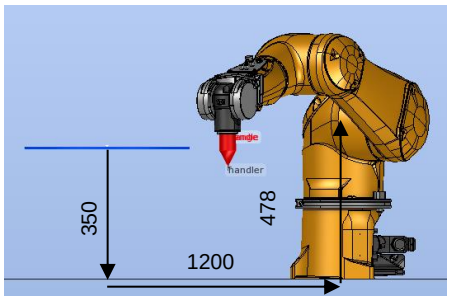
```
<VectCartArray name="ArtDir" >
    <VectCart index="0" x="1" y="0" z="0" />
    <VectCart index="1" x="0" y="1" z="0" />
</VectCartArray>
```

Example with 2 axes, a rotary table is installed on the top of a linear rail which is in front of the robot.

```
<VectCartArray name="ArtDir" >
    <VectCart index="0" x="0" y="0" z="1" />
    <VectCart index="1" x="0" y="1" z="0" />
</VectCartArray>
```

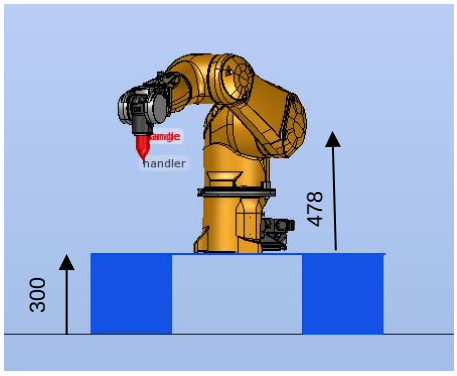
4.2.6 ArtDim

Define the position of the next axis in the chain relatively to the current one.



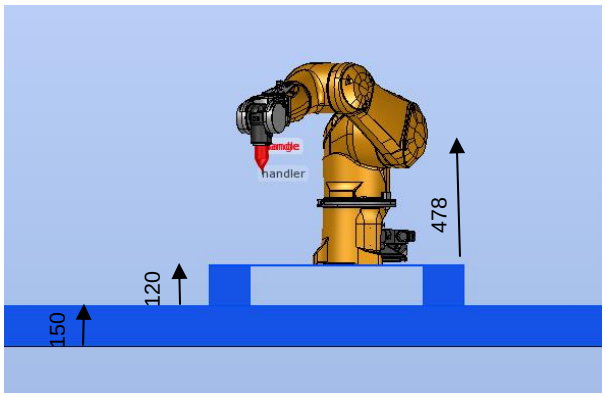
Example with a rotary table in front of the robot, in robot world X axis, at 1200mm, height 350mm from the ground. Robot world at 478mm from the ground. Rotary table is parallel to XY plane.

```
<VectCart index="0" x="-1200" y="0" z="128" />
```



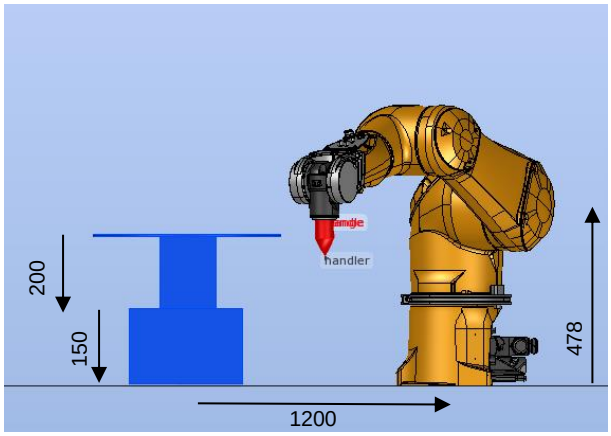
Example with robot installed on the top of a linear rail. Robot world at 478mm from base

```
<VectCart index="0" x="0" y="0" z="778" />
```



Example with robot installed on the top of an XY table. Robot world at 478mm from base

```
<VectCart index="0" x="0" y="0" z="150" />
<VectCart index="1" x="0" y="0" z="598" />
```



Example with 2 axes, a rotary table is installed on the top of a linear rail which is in front of the robot. Robot world at 478mm from the ground

```
<VectCart index="0" x="0" y="0" z="-200" />
<VectCart index="1" x="-1200" y="0" z="328" />
```

4.2.7 Base

Define the position of the first external axis relatively to the external frame or to the flange.

Example with a rotary table in front of the robot, in robot world X axis.
Rotary table is parallel to XY plane.
We want to have the external frame 20.3mm higher than the axis.

```
<VectCart name="Base" x="0" y="0" z="-20.3" />
```

Example with robot installed on the top of a linear rail

```
<VectCart name="Base" x="0" y="0" z="0" />
```

Example with robot installed on the top of an XY table.
External frame at the level of the first external axis.

```
<VectCart name="Base" x="0" y="0" z="0" />
```

Example with 2 axes, a rotary table is installed on the top of a linear rail which is in front of the robot.
External frame on the top of the rotary table.

```
<VectCart name="Base" x="0" y="0" z="0" />
```

4.2.8 ExternKinEnable

Define which input is used to switch between arm only mode (0) or arm with external axis (1).

Example with a virtual IO:

```
<String name="ExternKinEnable" value="VirtualIOBoards\ExternalAxis\%Q0" />
```

4.2.9 JntToDrvMatrix

Define the ratio between motor degree and obtained movement.
That is the number of motor degree that we need to do to get a 1mm displacement or 1° rotation of the external axis.

Example with a rotary table in front of the robot, in robot world X axis. We need to do 180° on the motor to get a 1° rotation of rotary table

```
<JntToDrvMatrix>
  <Value line="0" column="0" >180</Value>
</JntToDrvMatrix>
```

Example with robot installed on the top of a linear rail. We need to do 180° on the motor to get a 1mm displacement on linear rail.

```
<JntToDrvMatrix>
  <Value line="0" column="0" >180</Value>
</JntToDrvMatrix>
```

Example with robot installed on the top of an XY table. We need to do 180° on first motor to get a 1mm displacement on table X axis and 91.14177609° on second motor to get a 1mm displacement on table Y axis.

```
<JntToDrvMatrix>
  <Value line="0" column="0" >180</Value>
  <Value line="0" column="1" >0</Value>
  <Value line="1" column="0" >0</Value>
  <Value line="1" column="1" >91.14177609</Value>
</JntToDrvMatrix>
```

Example with 2 axes, a rotary table is installed on the top of a linear rail which is in front of the robot. We need to do 180° on rotary table motor to get a 1° rotation of rotary table and 91.14177609° on linear rail motor to get a 1mm displacement on that linear rail.

```
<JntToDrvMatrix>
  <Value line="0" column="0" >180</Value>
  <Value line="0" column="1" >0</Value>
  <Value line="1" column="0" >0</Value>
  <Value line="1" column="1" >91.14177609</Value>
</JntToDrvMatrix>
```

4.2.10 MinJntPos, MaxJntPos

Define the minimum and maximum joint position (deg or mm) of external axis, at the axis level. Expressed in degree for a rotoid axis and in millimeter for a prismatic one. Don’t forget that you need to be able to make axis zero so, depending on the type of zeroing, you may need to have additional range.

Example with a rotary table in front of the robot, in robot world X axis. When allow to turn 10 x 360° in negative direction and 1000 x 360° in positive direction.

```
<MinJntPos>
  <FloatArray name="MinJntPos" >
    <Float index="0" value="-3600" />
  </FloatArray>
</MinJntPos>
<MaxJntPos>
  <FloatArray name="MaxJntPos" >
    <Float index="0" value="360000" />
  </FloatArray>
</MaxJntPos>
```

Example with robot installed on the top of a linear rail. 0 is close to one of the linear rail extremities and the length is 4900mm. We put 50 mm margin in negative to ensure zeroing success and 50mm margin from linear rail end.

```
<MinJntPos>
  <FloatArray name="MinJntPos" >
    <Float index="0" value="-50" />
  </FloatArray>
</MinJntPos>
<MaxJntPos>
  <FloatArray name="MaxJntPos" >
    <Float index="0" value="4850" />
  </FloatArray>
</MaxJntPos>
```

4.2.11 NomJntVel, NomJntAcc

Define nominal joint velocity (deg/s or mm/s) and acceleration (deg/s² or mm/s²) of external axis, at the axis level. You have to take into account nominal capabilities of motor, drive and the mechanics. Value must be the most restrictive one. An approximative value for acceleration is 10 times the velocity.

```
<NomJntVel>
  <FloatArray name="NomJntVel" >
    <Float index="0" value="100" />
  </FloatArray>
</NomJntVel>
<NomJntAcc>
  <FloatArray name="NomJntAcc" >
    <Float index="0" value="1000" />
  </FloatArray>
</NomJntAcc>
```

4.2.12 MaxJntVel, MaxJntAcc

Define maximal joint velocity (deg/s or mm/s) and acceleration (deg/s² or mm/s²) of external axis, at the axis level. You have to take into account maximum capabilities of motor, drive and all mechanics. Value must be the most restrictive one. An approximative value for acceleration is 10 times the velocity.

```
<MaxJntVel>
  <FloatArray name="MaxJntVel" >
    <Float index="0" value="120" />
  </FloatArray>
</MaxJntVel>
<MaxJntAcc>
  <FloatArray name="MaxJntAcc" >
    <Float index="0" value="1200" />
  </FloatArray>
</MaxJntAcc>
```

4.2.13 MaxManuJntVel

Define maximal joint velocity (deg/s or mm/s) in manual mode for external axis, at the axis level. Remember that cumulated movement speed must not exceed 50 deg/s or 250mm/s.

```
<FloatArray name="MaxManuJntVel" >
  <Float index="0" value="75" />
</FloatArray>
```

4.2.14 DrvDelay

Define drive transmission delay (s). That is the time it takes between real drive position and its full process by robot controller. This is adjusted by trials. You make a program with TCP synchronized with a fixed point on the external axis. When start moving, TCP will be late, stay late during movement and then reach position when stop. You need adjust DrvDelay until TCP stay synchronized with external axis from movement start to end.

```
<DrvDelay>
  <FloatArray name="DrvDelay" >
    <Float index="0" value="0.008" />
  </FloatArray>
</DrvDelay>
```

4.2.15 DrvCountPerTurn

Define encoder resolution. It is the number of points per revolution (ppr). Can be real resolution or resolution of simulated encoder.

```
<DrvCountPerTurn>
  <UintArray name="DrvCountPerTurn" >
    <Uint index="0" value="65536" />
  </UintArray>
</DrvCountPerTurn>
```

4.2.16 DrvOffset

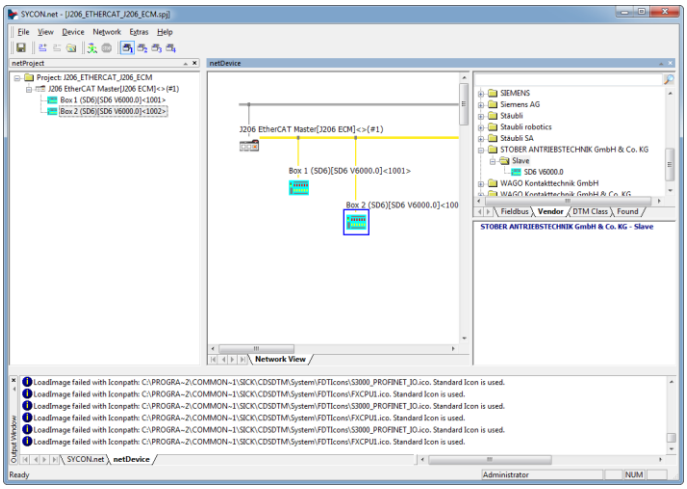
Define drive position offset in degree. When doing axis zeroing, what should become the current motor position?

```
<DrvOffset>
  <FloatArray name="DrvOffset" >
    <Float index="0" value="0" />
  </FloatArray>
</DrvOffset>
```

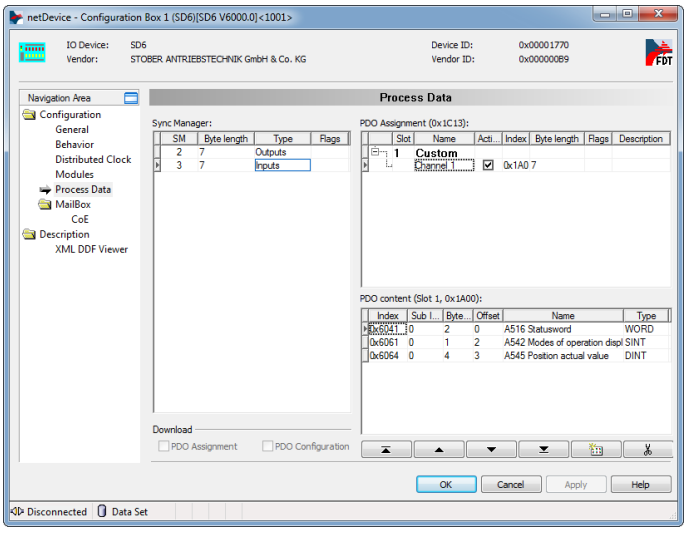
4.3 SRS

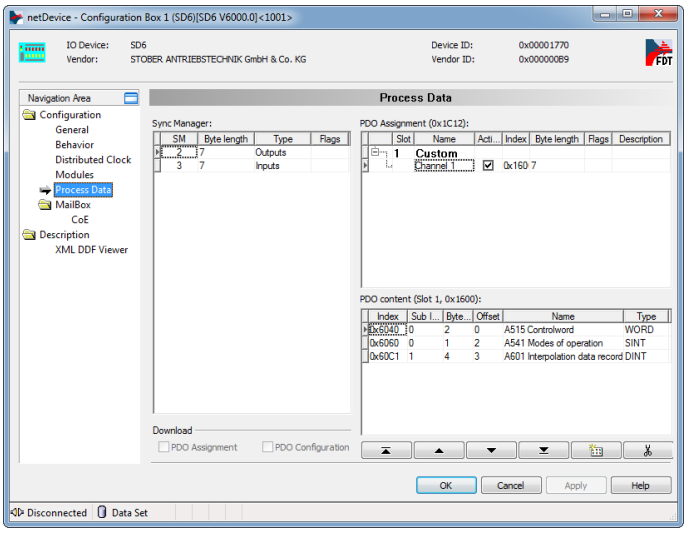
4.3.1 I/O

- Open “Physical IOs”, select “J206_EtherCAT” and “Edit board”.
- Adjust the number of boxes to the number of external axes.

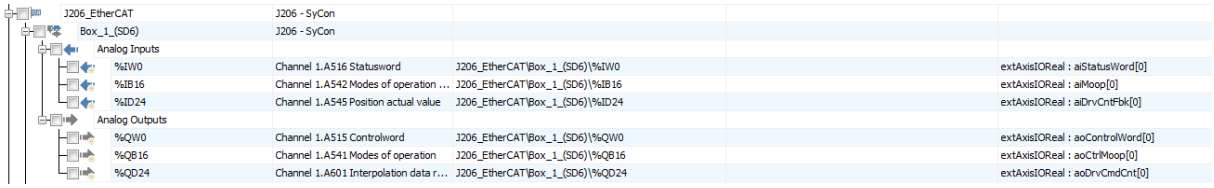


- All boxes must have the same below settings





- Check / adjust IO links.
  IOs must be linked to variables as showed below:



J206_EtherCAT	J206 - SyCon			
Box_1_(SD6)	J206 - SyCon			
Analog Inputs				
%IW0	Channel 1.A516 Statusword	J206_EtherCAT\Box_1_(SD6)\%IW0		extAxisIOReal : aiStatusWord[0]
%IB16	Channel 1.A542 Modes of operation ...	J206_EtherCAT\Box_1_(SD6)\%IB16		extAxisIOReal : aiMoop[0]
%ID24	Channel 1.A545 Position actual value	J206_EtherCAT\Box_1_(SD6)\%ID24		extAxisIOReal : aiDrvCntFbk[0]
Analog Outputs				
%QW0	Channel 1.A515 Controlword	J206_EtherCAT\Box_1_(SD6)\%QW0		extAxisIOReal : aoControlWord[0]
%QB16	Channel 1.A541 Modes of operation	J206_EtherCAT\Box_1_(SD6)\%QB16		extAxisIOReal : aoCtrlMoop[0]
%QD24	Channel 1.A601 Interpolation data r...	J206_EtherCAT\Box_1_(SD6)\%QD24		extAxisIOReal : aoDrvCmdCnt[0]

  This must be done in “extAxis\extAxisIOReal”

4.3.2 Driver settings

This must be done in “extAxis\extAxisCfg” in case of single set of axes

Open corresponding “extAxisCfg-settings” program.

Adjust values to suit your needs (default values should be OK in most cases).

Turn ON or OFF logs for debugging external axis driver and choose desired verbosity (debug is the most verbose). Logs will be output onto a rotating file buffer and logger.

5 Building SRS cell, step by step

5.1 SRS cell configuration

1- Do as usual to build your cell by importing an existing robot or using the wizard.
2- Install addons: expansion, motion, recorder (available on Staubli technical database Home / Softwares / Stäubli Robotics Controls, VAL3 version of your robot).
3- In SRS cell tree, make a right click on the controller.
4- Controller configuration.
5- In “Options” tab, check externalAxis.
6- In “Add Ons” tab, check expansion, motion, recorder.
7- Click Ok.
8- Get and unzip, in a folder, external axis driver (available on Staubli technical database in Home / Softwares / VAL 3 examples, CS9 External Axis).
9- Move in “target” folder, CTRL+A, CTRL+C (copy all).
10- In SRS cell tree, right click on the controller, Explore.
11- Move in “usr” folder, CTRL+V (paste all what has been copied).
12- Go back in file explorer which show the folder where you have extract external axis driver.
13- Move in “cfg_examples” and in the folder corresponding with your drive brand.
14- If they exist, select folders “configs”, “fieldbus”, “usrapp”, CTRL+C (copy them).
15- Go to file explorer which shows “usr” folder of your SRS controller.
16- CTRL+V (paste), replace existing files.
17- Move in “configs” folder.
18- Edit, with a text editor (Notepad++ for example), “externaxes.cfx” and adjust its contents to match your configuration.
19- In SRS cell tree, right click on the controller, “Physical Ios”, unfold “J206_EtherCAT”
20- Click “Edit board” button.
21- Select “SyCon”, Ok
22- If you do not have already import de drive description file:
    - Click on “J206 EtherCAT Master”
    - “Network”, “Import Device Descriptions”
    - At window bottom, select “EtherCAT DDF” in “File type”.
    - Move to the folder where you have extract external axis driver.
    - Go in “esi” folder.
    - Select esi (.xml file) corresponding to your drive.
    - Ok.
23- If needed, adjust the number of boxes to match your real number of drives.
24- Save and close SyCon
25- “Physical Ios” must show now the proper number of drives.
26- In SRS cell tree, right click on the controller, “Open Application”.
27- Go in “extAxis\extAxisIOReal” and open “extAxisIOReal.pjx”.
28- Select “Data” tab.
29- Unfold “extAxisIOReal”.
30- Unfold “aio”.
31- For each analog input/output, adjust the size to number of drives.
32- For each box visible in the “J206_EtherCAT” branch of “Physical Ios”,
    - Unfold box branch in “Physical Ios” tree,
    - Drag and drop each of the io’s from “extAxisIOReal”, “aio” of “Data” cell tree onto the corresponding “Physical IO” “Analog Inputs” or “Analog Outputs”.
        - aiDrvCntFbk -> Analog Inputs corresponding to “Position actual value”.
        - aiMoop -> Analog Inputs corresponding to “Modes of operation display”.
        - aiStatusWord -> Analog Inputs corresponding to “Statusword”.
        - aoControlWord -> Analog Outputs corresponding to “Controlword”.
        - aoCtrlMoop -> Analog Outputs corresponding to “Modes of operation”.
        - aoDrvCmdCnt -> Analog Outputs corresponding to “Interpolation data record”.

- aoDrvCmdPos -> Analog Outputs of virtual IO board, SRS_3D block for SRS simulation for proper axis.

33- “Save All”.
34- Right click on “extAxisIOReal”, “Close Application”.
35- In SRS cell tree, right click on the controller, “Open Application”.
36- Go in “extAxis\ extAxisIOSimul” and open “extAxisIOSimul.pjx”.
37- Select “Data” tab.
38- Unfold “extAxisIOSimul”.
39- Unfold “aio”.
40- For each analog input/output, adjust the size to number of drives.
41- For each drive visible in the “VirtualIOBoards” branch of “Physical Ios”,
    - Unfold drive branch in “Physical Ios” tree,
    - Drag and drop each of the io’s from “extAxisIOSimul”, “aio” of “Data” cell tree onto the corresponding “Physical IO” “Analog Inputs” or “Analog Outputs”.
        - aiDrvCntFbk -> Analog Inputs corresponding to “drvPosFbk”.
        - aiMoop -> Analog Inputs corresponding to “moop”.
        - aiStatusWord -> Analog Inputs corresponding to “statusWord”.
        - aoControlWord -> Analog Outputs corresponding to “controlWord”.
        - aoCtrlMoop -> Analog Outputs corresponding to “ctrlMoop”.
        - aoDrvCmdCnt -> Analog Outputs corresponding to “drvCmdPos”.
        - aoHomingMethod-> Analog Outputs corresponding to “homingMethod”.
        - aoDrvCmdPos -> Analog Outputs of virtual IO board, SRS_3D block for SRS simulation for proper axis.
42- “Save All”.
43- Right click on “extAxisIOSimul”, “Close Application”.
44- Close “Physical Ios” tab.
45- “Home”, “Show3D view”.
46- Import or build your external axes 3D.
47- If needed, for each external axis, “Edit reference frame” and place it at axis origine.
48- Place them like what was set in “externaxes.cfx”.
49- For each external axis,
    - Right click on it, “Edit component”.
    - In 3D tree, unfold “Root” branch”.
    - Select proper item.
    - Right click on it
    - “Extract as joint”
    - In Property window:
        - Select “Joint Type”
        - Input “Minimum” value for that axis
        - Input “Maximum” value for that axis
        - Click on the chain at the right of “Value”.
        - Click on “+” at the right to add a joint value.
        - Save and close Component editor tab.
50- Back to SRS 3D view, for each external axis,
    - Select it in 3D view.
    - In property window, in the “Signals” area, click on the 3 dots corresponding to joint value.
    - Unfold “VirtualIOBoards”.
    - Unfold “SRS_3D”.
    - Select analog output “axis3DPos” corresponding to the drive number.
    - Right click on external axis in 3D view, Jog.
    - Move it with the slider and check it move as expected in 3D.

5.2 3D simulation check

51- In “Control Pad”, check “Synchronization Enabled”
52- Set “Synchronization Mode” to “Emulator”.
53- Set “Working Mode” to “Manual”.
54- OK.
55- Start “Control Pad” by clicking on the green arrow.
56- In cell tree, right click on controller, show emulator.
57- Click on the home button.
58- “Settings”.
59- “Profiles”.
60- In “Current Profile”, select “maintenance”, key in the password, click “Login”. Green check must appear at the left of “maintenance”.
61- Click on the home button.
62- “IO”.
63- “Board”.
64- “VirtualIOBoards”.
65- “SRS_3D”.
66- Change value of axis3DPos corresponding to your axes and check that they move in 3D.
67- Click on the home button.
68- Turn arm power OFF.
69- “VAL 3”.
70- “Disk”.
71- Load “CustApp”.
72- Run “CustApp” application.
73- Check that you get all green check. If not, correct the issue and retry.
74- “Ok”
75- Turn arm power OFF if needed.
76- “EXTAXES DBG”.
77- Click on “Homing”.
78- Check that drive step changes and that external axis position became 0 on the teach and in SRS 3D.
79- Change working mode to automatic.
80- Turn arm power ON.
81- Check that indicator changed to “Operation Enable”.
82- Press “Move hold” button.
83- In the drop-down list at the top, select “Jog”.
84- Press “+” / “-“ and check that corresponding axis is moving in 3D.
85- In the drop-down list at the top, select “Return to main application”.
86- “TEACH PAGE” allows to teach test points taking into account robot position and external axes position.
87- “START CYCLE” will allows to have robot and external axes move along all teached points.
88- “End CYCLE” will allows to stop the cycle.

6 Upload

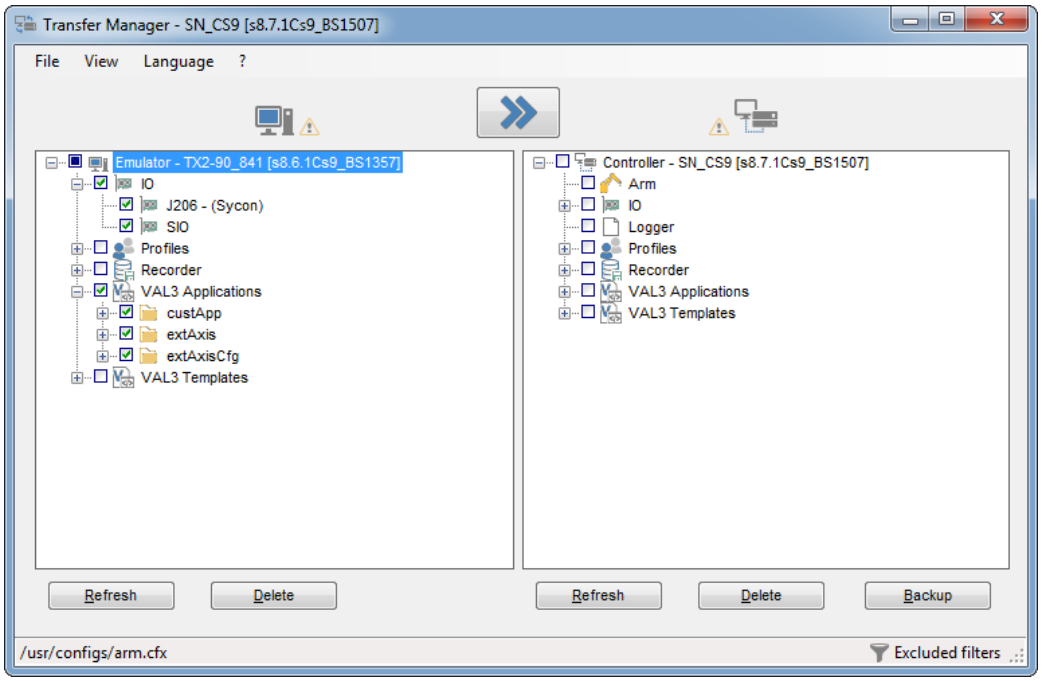
6.1 External axes description (externaxes.cfx)

That file cannot be send using SRS, “Transfer Manager”.

You must use a client FTP software (filezilla https://filezilla-project.org/) to send that file into “/usr/configs” folder of the controller.

6.2 Application and configurations

Use SRS, “Transfer Manager” to upload J206 configuration, SIO (serial line) and all VAL3 applications.



6.3 Controller

When all has been sent to the controller, reboot it to let it read and take into account all changes (externaxes.cfx, J206 configuration, SIO configuration).

7 First commissioning

7.1 Drive manual movements

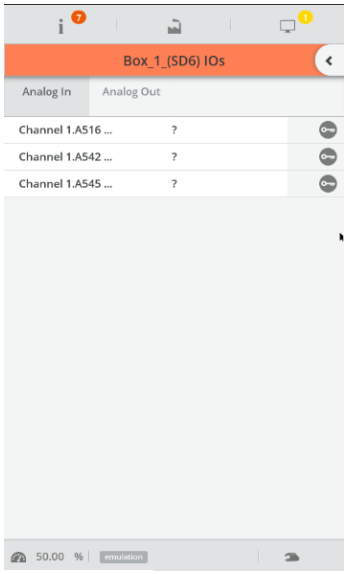
From the drive itself, check that you can move each external axis.

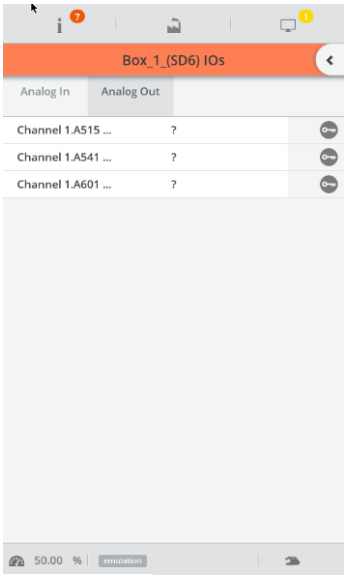
7.2 Working IO's

Do not start any application.

CS9 and drive must be ON.

On the teach pendant, go in IO, Boards, J206 EtherCAT. For each drive, check that you have analog input and analog output giving values, at least 0. If you got a question mark (?), EtherCAT dialog is not working. You must solve that issue before going to the next paragraph





7.3 IO's direct driving

On the teach pendant, go in IO, Boards, J206 EtherCAT, Analog output.

Set Modes of operation to 7.

In Control Word, input successively: 0, 3, 6, 7, 15, 31.
This should bring your drive to "Operation enable" state (check on the drive or on the drive software to know drive status). If not, you must solve the issue.

You can then bring it back to "Switch on disable" by inputting successively: 31, 15, 7, 6, 3, 0.

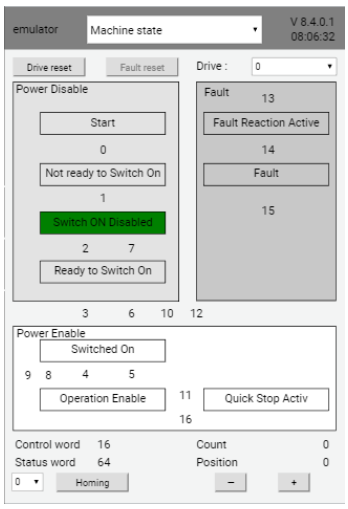
7.4 Use of debug screens

Open the example empty application named “custApp” and run it in automatic mode.

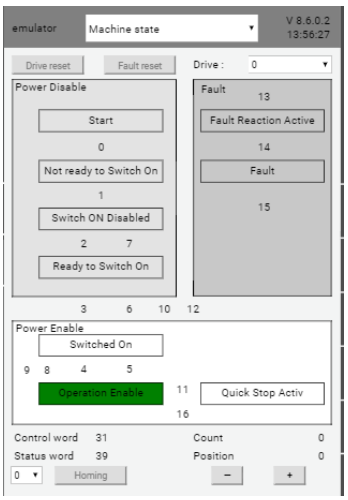
Press the “EXTAXES DBG” button. you will reach the “Machine state” screen.

Check each drive state, without arm powered.
Make “Drive reset” if needed.
Make “Homing” if needed.
Each drive must be on “Switch On Disabled” state before trying to turn, arm power. If not, you must solve the issue.

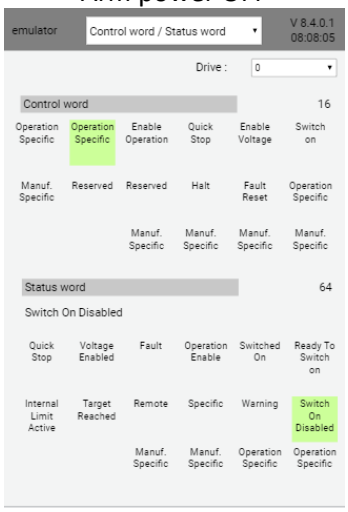
Turn arm power ON and check each drive, status change.

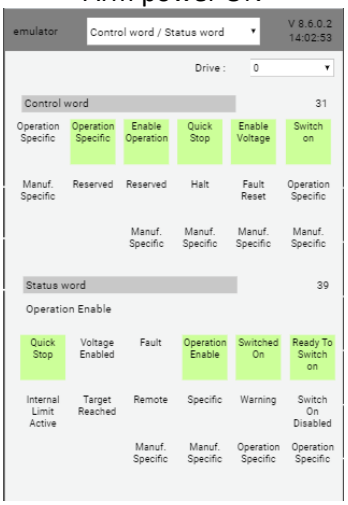


Arm power OFF



Arm power ON





When arm can be turn ON and OFF without any issue, switch to the “Jog” screen and try to move each external axis in both directions.

8 First synchronous movement

8.1 Custom app

The External axes library is provided with a basic example of application: **this application is not a part of the library**; it is only an example of customer interface that interacts with the library. It was done mainly as a tool for Appendix A

8.2 Start the standard custom app application

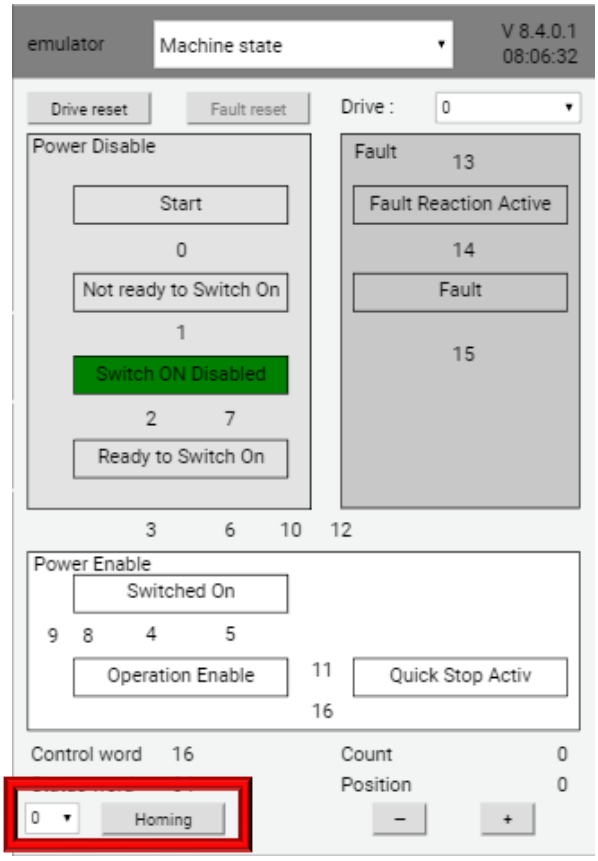
Launch the application custApp, you will see the “check configuration” page:

That controls that the basic configuration for External axes is done properly

8.3 Do homing if needed

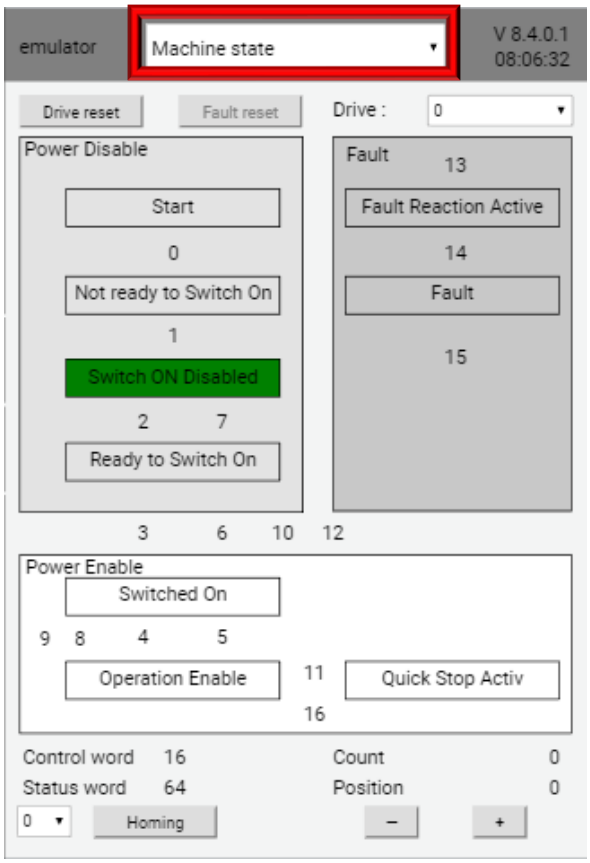
If you press ok, you will access to this page:

Press EXTAXES DBG to access to the external axes drive library configurator:



Press Homing during power off to perform the homing of the Ext Axes. If everything is ok, the Drive state will change from “Switch ON Disabled” to “Operation Enable” and turn back to “Switch ON Disabled”

8.4 Teach your first point

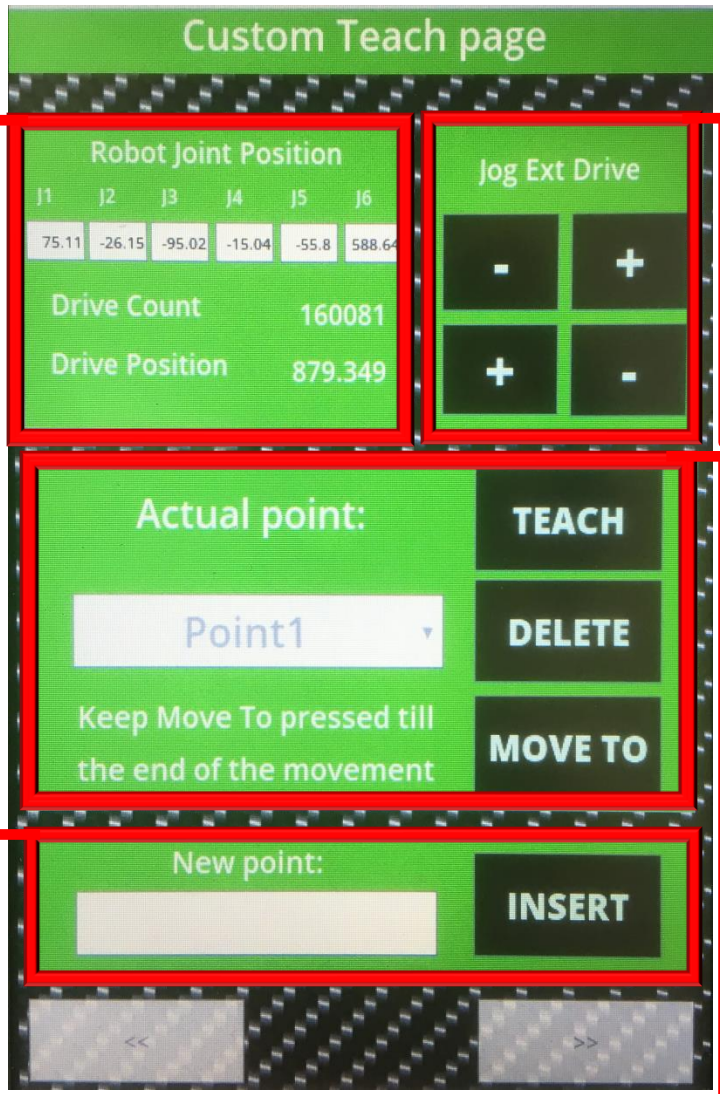


Press the upper tab and select “return to main application” to get back to the main application page. Press “TEACH PAGE” to reach the teaching page

In this page you can:

Jog the external axes drive

1. See the actual joint position of the robot, the External drive count value and the external drive position.
2. Write the name of a new point and add it in the point list (each point will contain the robot and external axes position)
3. Select a point, teach the position, delete it or move the robot and the axes to it



B: Position

In the example application there is a task that continuously reads the position of the arm and loads, from the external axis library, the position of the 7th axes

A: jog ext Drive

Each plus and minus has the same behavior: it is only a matter of comfort for the user to choose which one press

C: New point

Press the input white square and type the desired name of the new point. After press INSERT to add this new point in the list.

A popup will show the result of this

D: Actual point

Select a point in the Actual point list. If the point selected is not the last one, DELETE will remove it from the list.

TEACH will save the joint value of the robot and of the 7th axes in the selected point.

Press MOVE TO and the movehold button at the same time will move the robot and the 7th axes at the selected point

A popup will show the result of this routine

8.5 Launch the trial trajectory

Turn back to the main page, change the working mode of the robot to automatic mode, be sure to have a low monitor speed, turn the power on and press “Start Cycle”: the robot will do a trajectory following all points added

in the teach page. The order of points will be the same as in the combo “Actual point” (the system has to be in automatic mode, with power on and motion mode “arm+External Axes” in EXTAXES DBG -> configuration)

Press “END CYCLE” to stop the execution of the automatic cycle

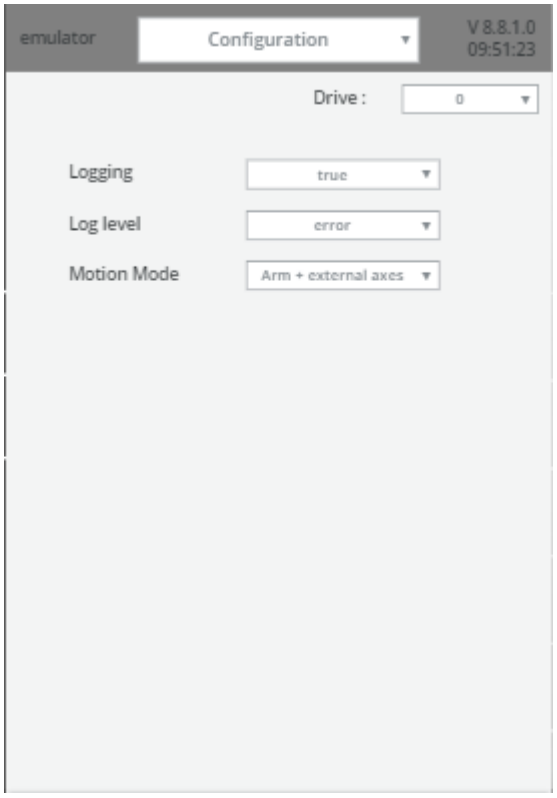
9 Trouble shooting

If it is not possible to enable power:

- Be sure to work with the correct SRC version
- Check licenses and disable what is not necessary
- Control that IoMap file is not creating any conflict

If the system is in power on state and it is possible to move only the robot:

- Check in configuration that Motion Mode is Arm + ExternalAxes.
  If it is arm only, movements of the drive are inhibited by software



Appendixes

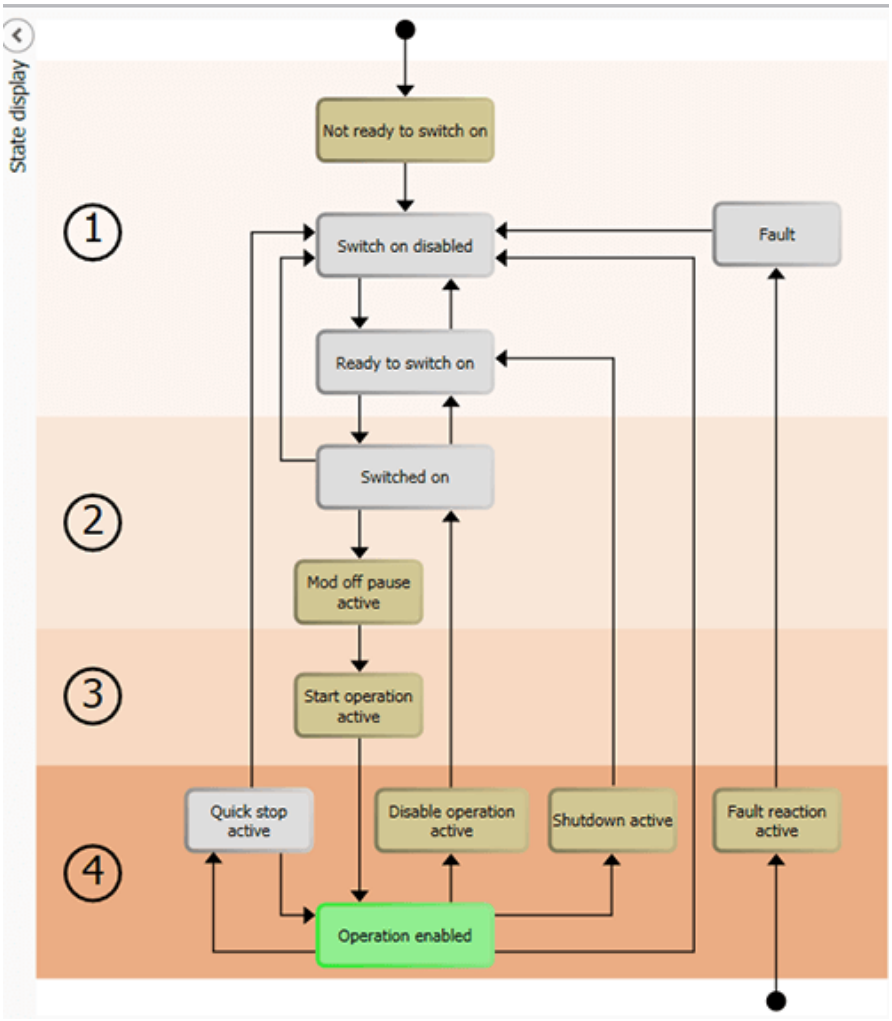
A How to test your own drive and add it to the “official supported drive list”

A.1 Prerequisites

Before testing a new drive that is not yet in the available drive list, be sure that the drive has these features:

- **EtherCAT slave fieldbus**
  Your drive must have an EtherCAT board, to interact with the CS9 J206 EtherCAT master

- **DSP402 specifications**
  Your drive must follow the DSP402 specifications; like having below state diagram and support control word and status word.



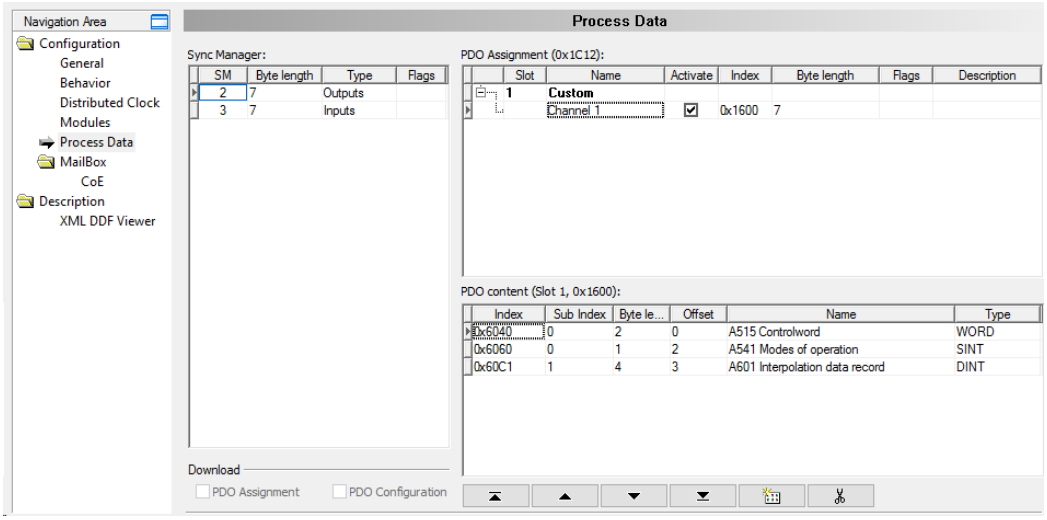
The Control Word contains essential information such as: Enable voltage, Quick stop, Enable Operation, and Fault Reset. The Status Word provides information that is sent from the drive device back to the controller. The Status Word contains information like Fault, Voltage Enabled, Warning, etc. Both the Control and Status Words leave bits open so they can be defined by the manufacturer. This gives the device manufacturer some flexibility to implement custom functions.

- Drive must be settable to Interpolated position mode (n° 7)

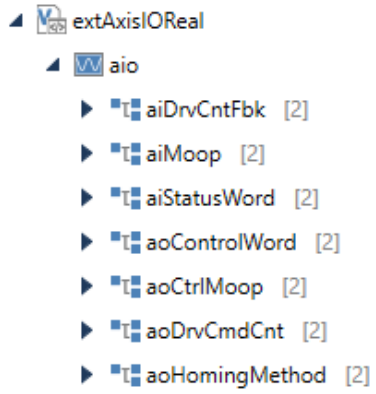
- Drive must implement phase lock loop (PLL) on SYNC signal

A.2 How to test the Drive

- Add the ESI file of the new drive in the J206 EtherCat line using Sycon
- Open usrapp\extAxis\extAxisIOReal and check that the EtherCat variables of your drive:



are correctly connected to the Val3 aio variables:



Usually the name in Sycon, received by the Esi file, explains the function of the variables and it is easy to understand what the corresponding connection is. Note that the “homing method” is optional variable, so if your drive has 6 variables it will work well

- Follow this document till the end of chapter 7

A.3 What need to be sent to Faverges to insert the new drive in the supported drive list for External Axes CS9

- A **video** showing the application running: it is important that the video clearly shows the synchronous movement between the axes and the robot

- The English **manual of the tested drive** (if it is possible also the manual of the EtherCat board)

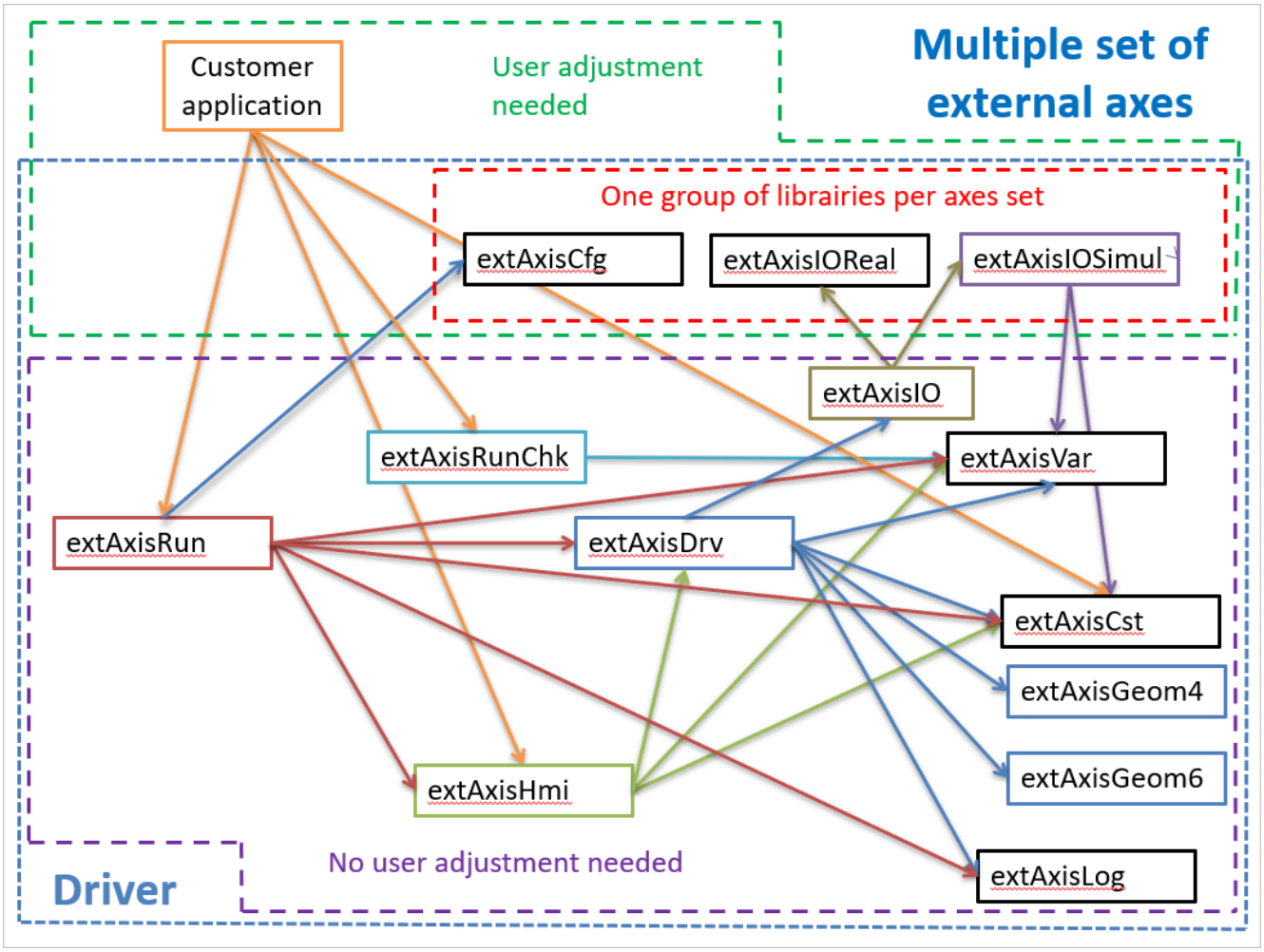
The .**ESI file** of the drive (the file that contains the EtherCat slave information) It is mandatory to have it to establish a communication with the J206 EtherCat Master and to import it into Sycon

A.4 End of the procedure

- Send the material explained previously to: robot.support.custo@staubli.com
- Faverges will check the material sent and will add your drive in the drive list. Everyone in the world that will need to use the same drive will benefit from the work done

B Multiple set particularities

B.1 External axis driver structure

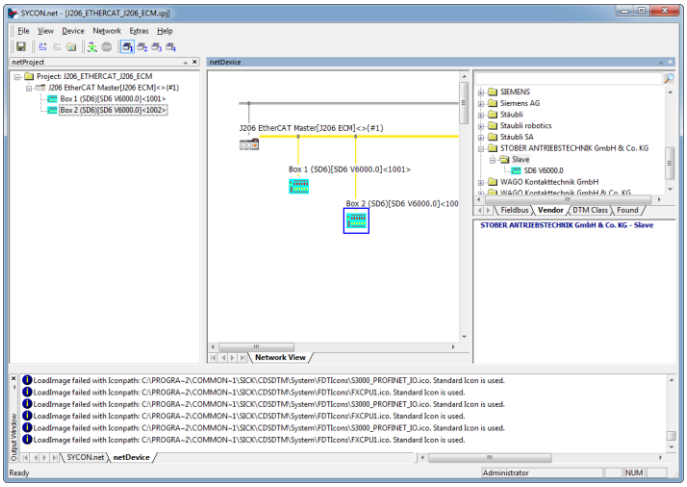


Information

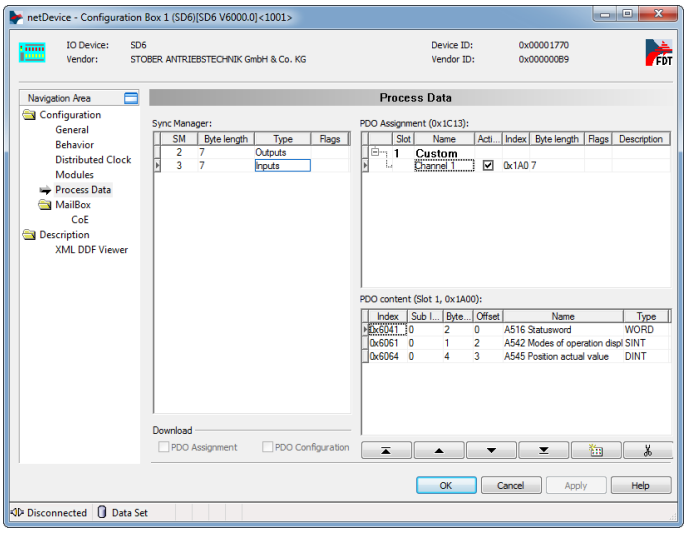
You must build your own application which will use the external axis driver and make configuration / adjustment in “extAxisCfg”, “extAxisIOReal” , “extAxisIOSimul” for each set of axes (see below)

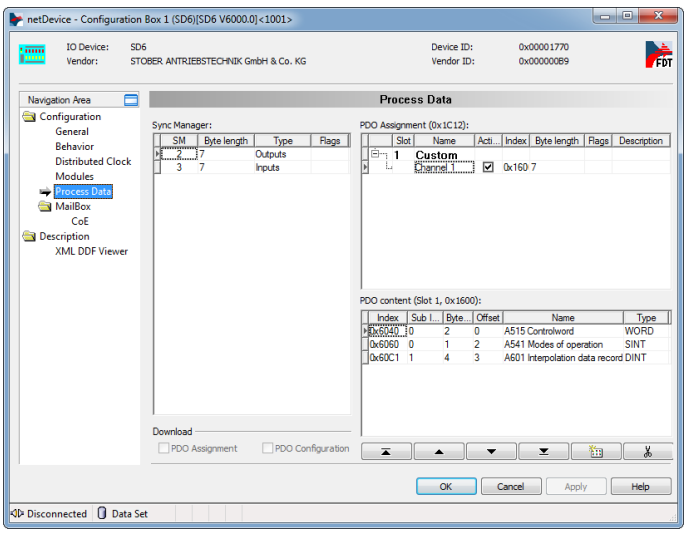
B.2 SRS, I/O

- Open “Physical IOs”, select “J206_EtherCAT” and “Edit board”.
- Adjust the number of boxes to the number of external axes.

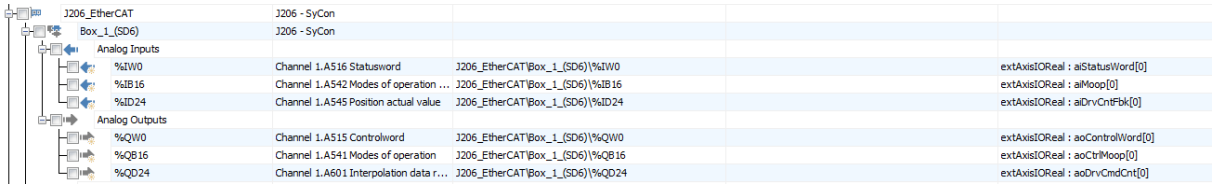


- All boxes must have the same below settings





- Check / adjust IO links.
  IOs must be linked to variables as showed below:



J206_EtherCAT	J206 - SyCon			
Box_1_(SD6)	J206 - SyCon			
Analog Inputs				
%IW0	Channel 1.A516 Statusword	J206_EtherCAT\Box_1_(SD6)\%IW0		extAxisIOReal : aiStatusWord[0]
%IB16	Channel 1.A542 Modes of operation ...	J206_EtherCAT\Box_1_(SD6)\%IB16		extAxisIOReal : aiMoop[0]
%ID24	Channel 1.A545 Position actual value	J206_EtherCAT\Box_1_(SD6)\%ID24		extAxisIOReal : aiDrvCntFbk[0]
Analog Outputs				
%QW0	Channel 1.A515 Controlword	J206_EtherCAT\Box_1_(SD6)\%QW0		extAxisIOReal : aoControlWord[0]
%QB16	Channel 1.A541 Modes of operation	J206_EtherCAT\Box_1_(SD6)\%QB16		extAxisIOReal : aoCtrlMoop[0]
%QD24	Channel 1.A601 Interpolation data r...	J206_EtherCAT\Box_1_(SD6)\%QD24		extAxisIOReal : aoDrvCmdCnt[0]

  This must be done in each “extAxisSet\xxxxx\extAxisIOReal” in case of multiple set of axes (xxxxx is the axes set name)

B.3 SRS, Driver settings

This must be done in each “extAxisSet\xxxxx\extAxisCfg” in case of multiple set of axes (xxxxx is the axes set name)

Open corresponding “extAxisCfg-settings” program.

Adjust values to suit your needs (default values should be OK in most cases).

Turn ON or OFF logs for debugging external axis driver and choose desired verbosity (debug is the most verbose). Logs will be output onto a rotating file buffer and logger.