Application Note

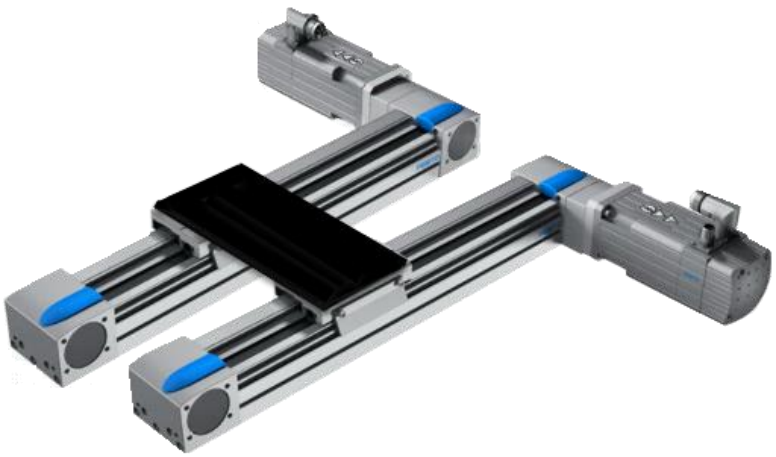
FESTO

CMMT-AS Parallel Axis
Synchronous Position Relative 1

CMMT-AS-xx

When 2 physical axis of are mechanically connected together by the load or other means (examples: gantry system X/X' coupled by a Y-Axis or 2 x ESBF rods attached), then it is necessary to synchronise these axis with an electronic alignment (Master to Slave).

This application note discusses the required settings to control the 2 x parallel linear axis in Synchronous Position Relative1 mode using CMMT-AS-xx controllers.



Title ..... CMMT-AS Parallel Axis Synchronous Position Relative 1
Version 1.20
Document no. 100343
Original ..... en
Author ..... Festo
Last saved 02.11.2022

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Internet: http://www.festo.com

Table of contents

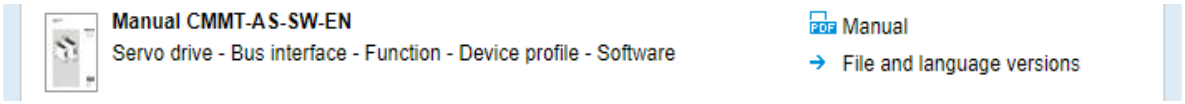
1 Components/Software/Firmware used

Type/ Name	**Version Software/ Firmware**	**Description**
CMMT-AS-C4-3A-MP-S1 (Master)	V31.0.7.10	Firmware
CMMT-AS-C2-3A-EP-S1 (Slave)	V22.0.3.88	Firmware
Festo Automation Suite	V2.4.0.442	Software
CMMT-AS Plug-in	V2.4.1.23	Software
RSLogix 5000/ Logix Designer 5000	V20.04	Rockwell Programming Software
1769-L30ERM	V20.019	CompactLogix 5370 Controller

Table 1.1: 1 Components/Software used

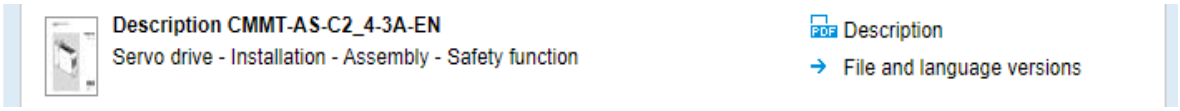
1.1 Recommended Manuals

A) CMMT-AS Software/Function/Fieldbus/Device Profile Manual



Reference:
https://www.festo.com/net/en_ca/SupportPortal/Downloads/648237/725657/CMMT-AS-SW_manual_2022-04i_8173126g1.pdf

B) CMMT-AS Wiring & Installation Manual

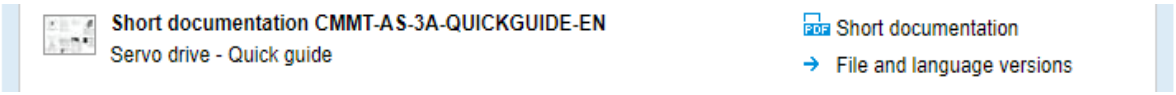


Reference:
https://www.festo.com/net/en_ca/SupportPortal/Downloads/648246/720730/CMMT-AS-C2_4-3A-_manual_2022-03e_8173941g1.pdf

C) CMMT-AS Wiring & Installation Safety Function Manual

Reference:
https://www.festo.com/net/en_ca/SupportPortal/Downloads/648247/720882/CMMT-AS-_-S1_manual_2022-03e_8173923g1.pdf

D) CMMT-AS Short Documentation/Quick Guide Manual



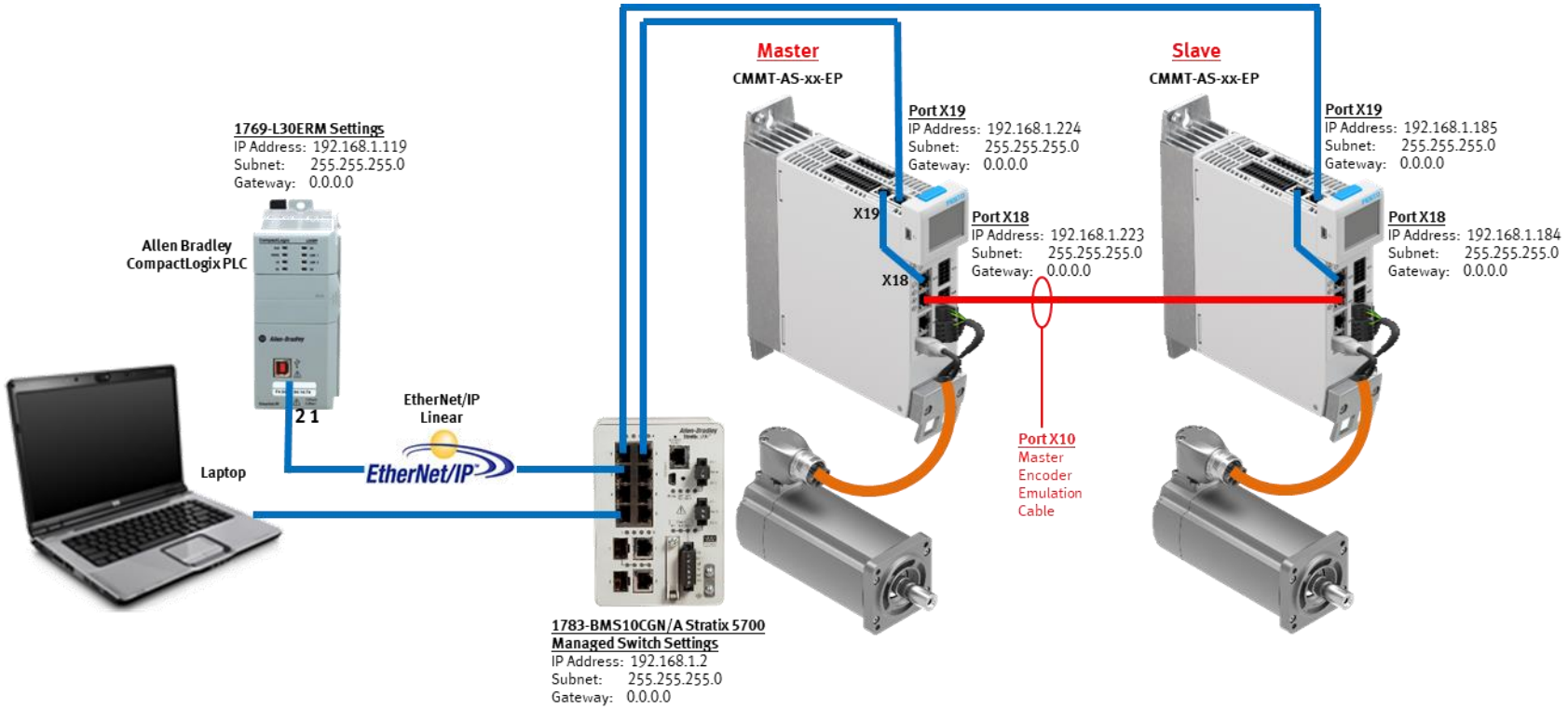
Reference:
https://www.festo.com/net/en-gb_gb/SupportPortal/Downloads/629760/696705/CMMT-AS-3A-QUICKGUIDE_2019-05_8100291g1.pdf

1.2 Attachments/Dependencies

None

1.3 Network Topology of the tested systems

Please refer to the picture below and make sure all wires are correctly placed and connected. The user manuals (reference provided in section 1.1 Recommended Manuals) will need to be referenced for other wiring not shown here.



2 Overview of Required Steps

1. Both the **Master and Slave axis must use a multi-turn absolute encoder**.
2. Mechanically align the two axis
3. Reference both axis so they have the same absolute position value (perfect electronic alignment)
4. After each power off (examples: after activation of STO or SBC or the CTRL-EN removed), the electronic alignment of the two axes is required. This is accomplished using the PLC code and Fieldbus to read the Master axis position and then execute the Slave axis to the same absolute position.
5. After electronic alignment is completed, then the Slave axis executes an Up Synchronisation, Relative 1 command and the axis are then in Synchronisation
6. It is up to the PLC to monitor the status and positions of both Master and Slave and react if errors or position errors are observed.

Up synchronisation, "synchronous position, relative 1" mode

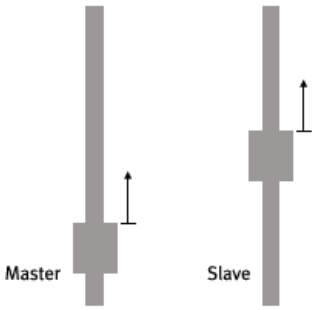


Fig. 116: Synchronous position, relative (example)

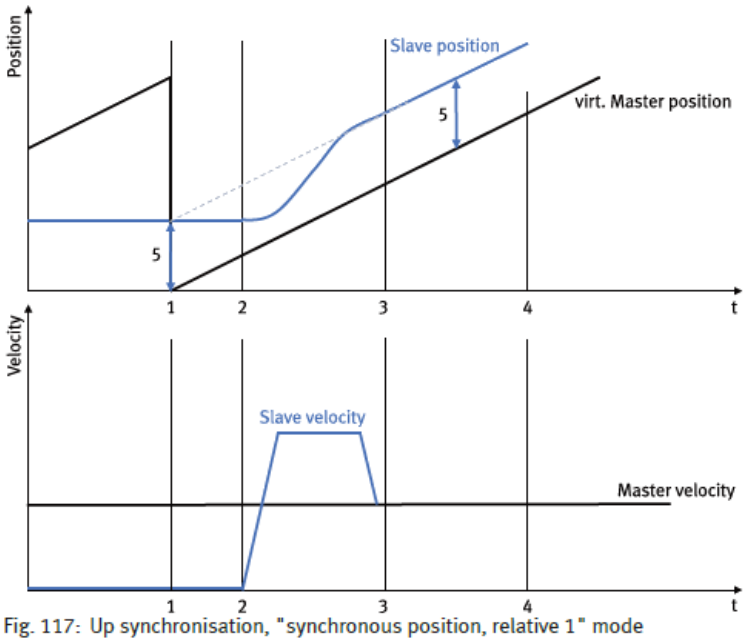


Fig. 117: Up synchronisation, "synchronous position, relative 1" mode

Caption	
1	"Synchronous position, relative 1" mode is executed.
2	Start Sync Pos (start of up synchronisation)
3	Master Sync Pos (target at which up synchronisation must be competed.)
4	End Sync Pos (start of down synchronisation)

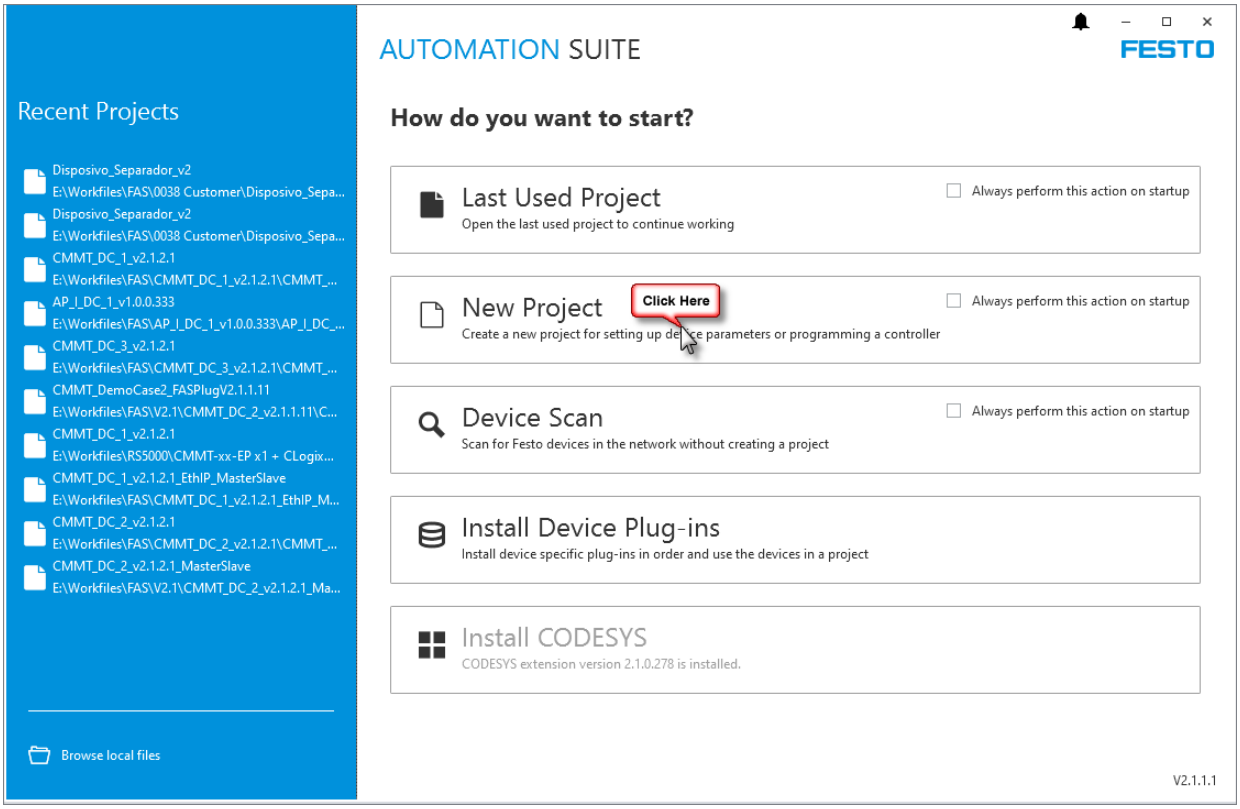
Tab. 640: Legend for up synchronisation, "Synchronous position, relative 1" mode

At position (1), the Sync mode is executed, the virtual master position is set to 0 and the current slave position (5) is detected. If the virtual master axis reaches the position (2) "Start Sync Pos", it is up synchronised to the sum of virtual master position and recorded slave position.
On completion of up synchronisation the slave is relative to the position at which the sync mode was executed. If synchronisation is completed, the slave reports the status “Slave synchronous”.
Synchronisation must be completed before "Master Sync Pos".
Between positions (3) and (4), the slave reports the status "Master Sync Pos" reached. If the virtual master axis exceeds the position (4) "End Sync Pos", the down synchronisation is initiated.
Example: the slave is at 200 mm and the master position at 50 mm, Master Sync Pos = 100 mm and the sync mode is started (virtual master position = 0). After reaching the position "Master Sync Pos", the master position is at 150 mm, the slave at the absolute position of 300 mm and moves synchronously with the virtual master position.

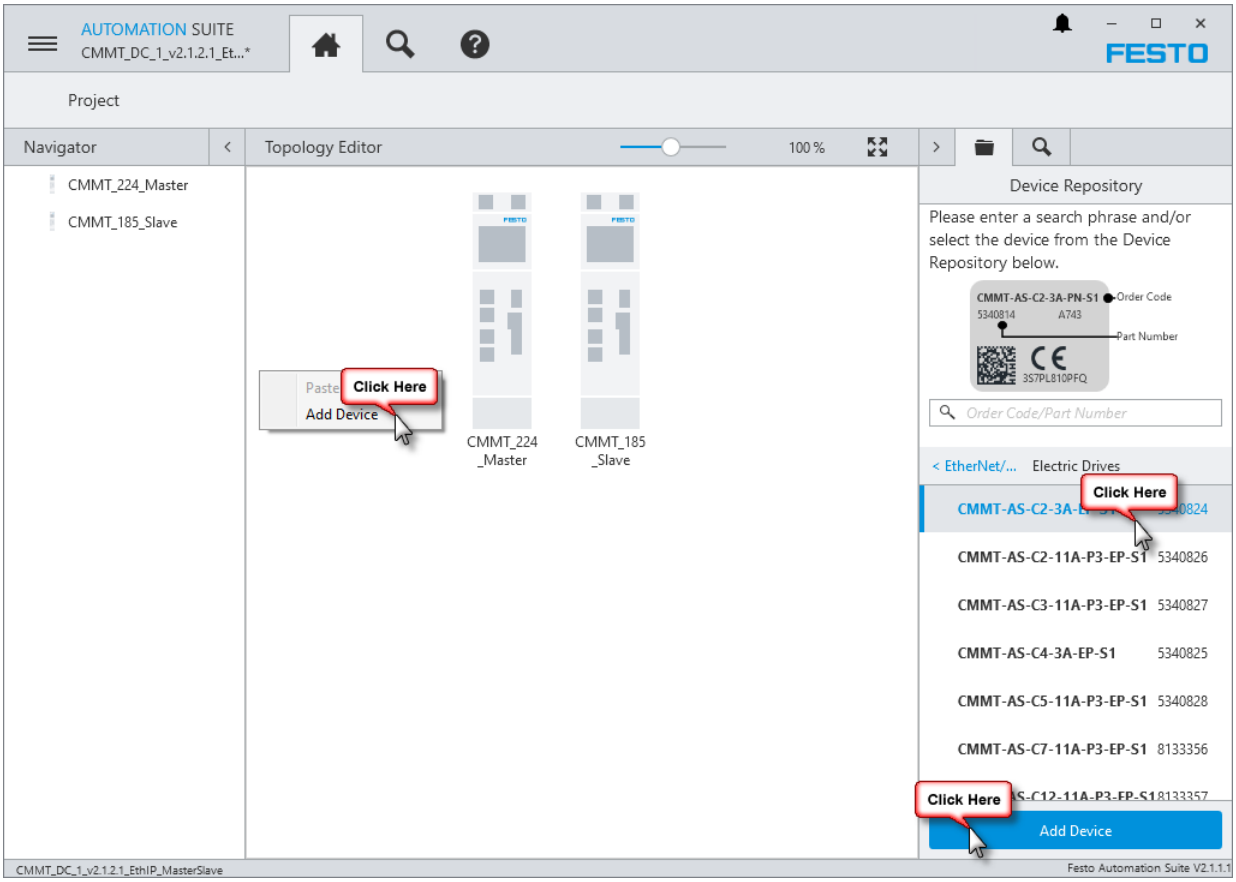
3 Project Configuration

3.1 Create New Project

Start a new project

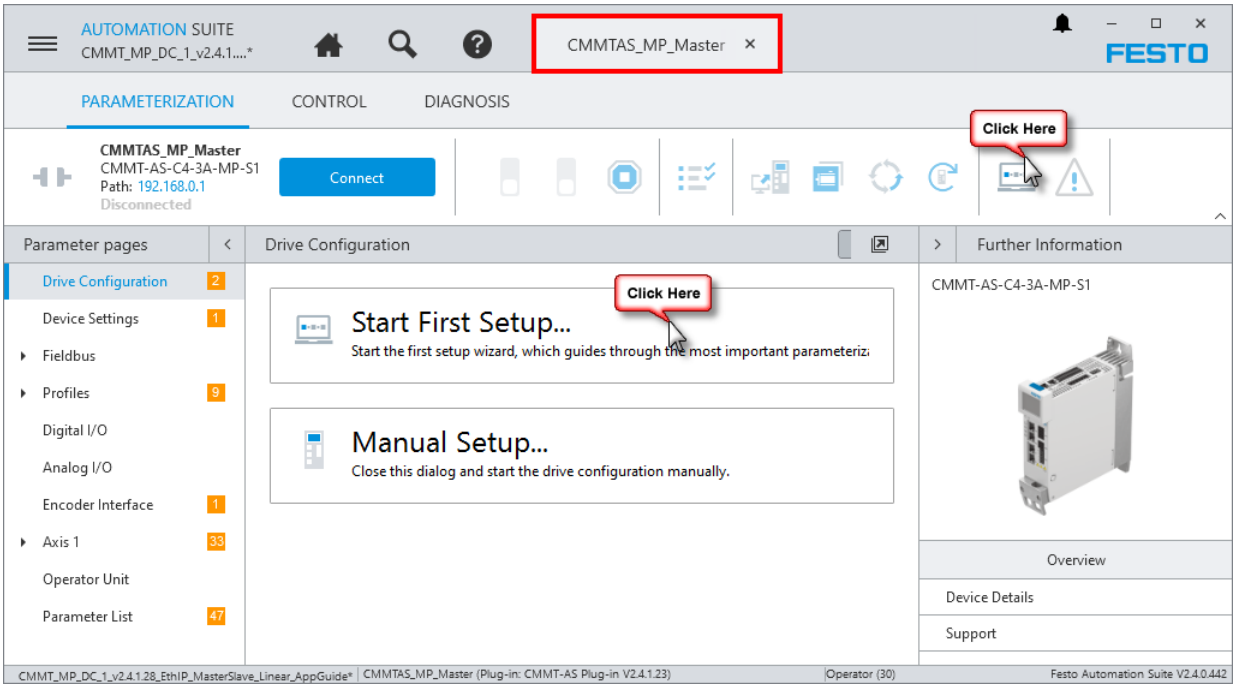


Add the 2 x CMMT-xx-xx controllers you have purchased for the application and name them accordingly



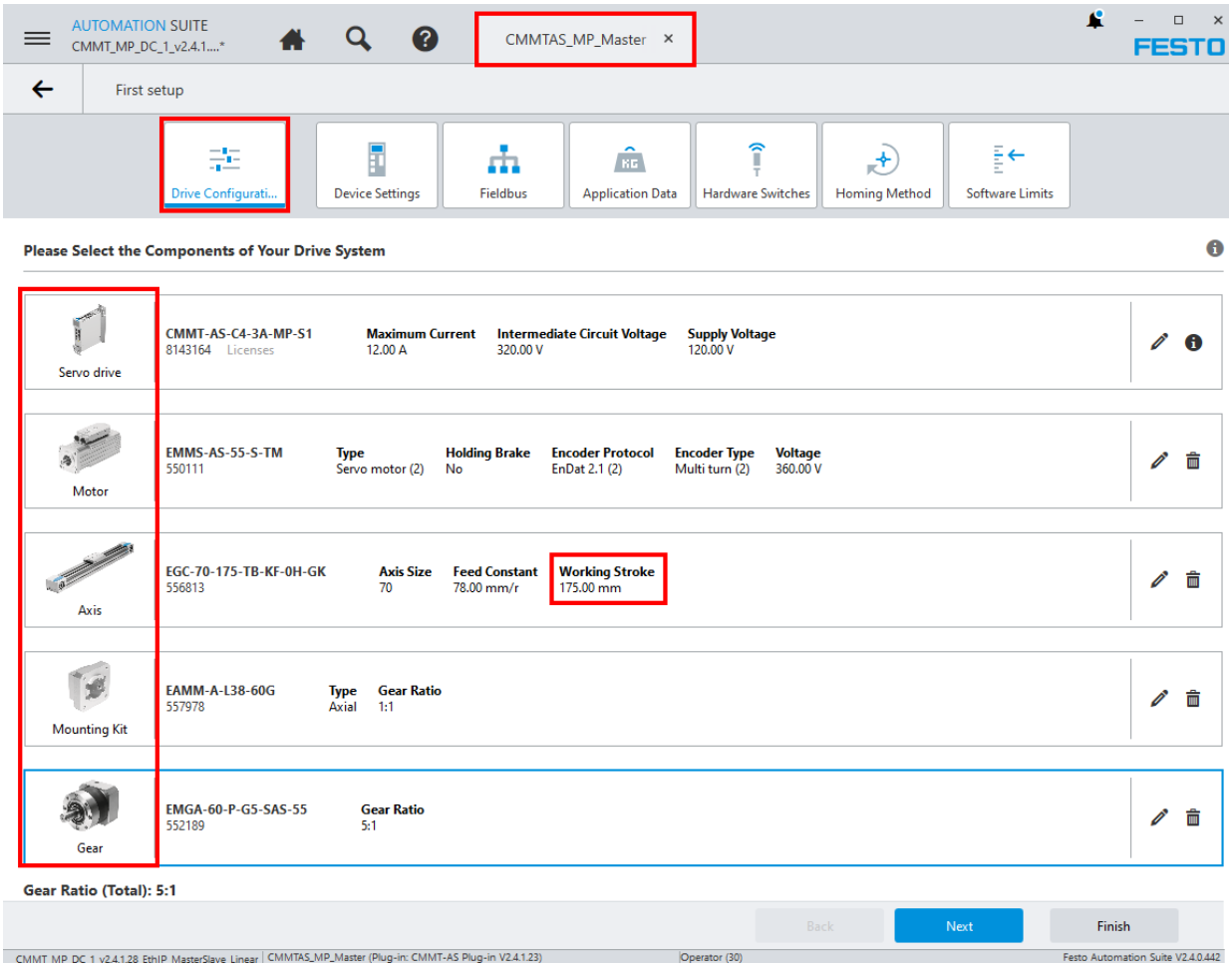
4 Master Axis General Setup

4.1 First setup - Start Wizard



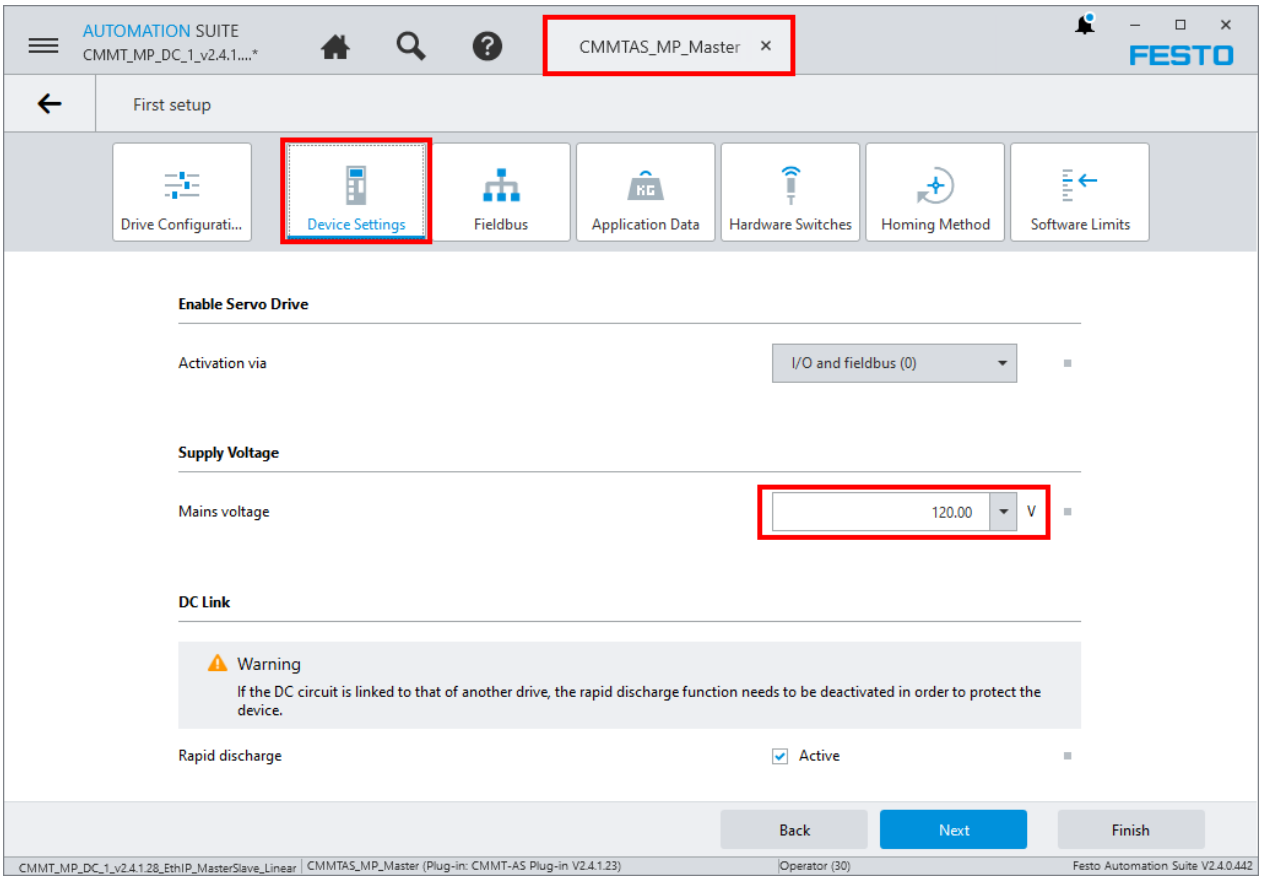
4.2 First setup - Drive Configuration

This application considers the maximum range of 175 mm



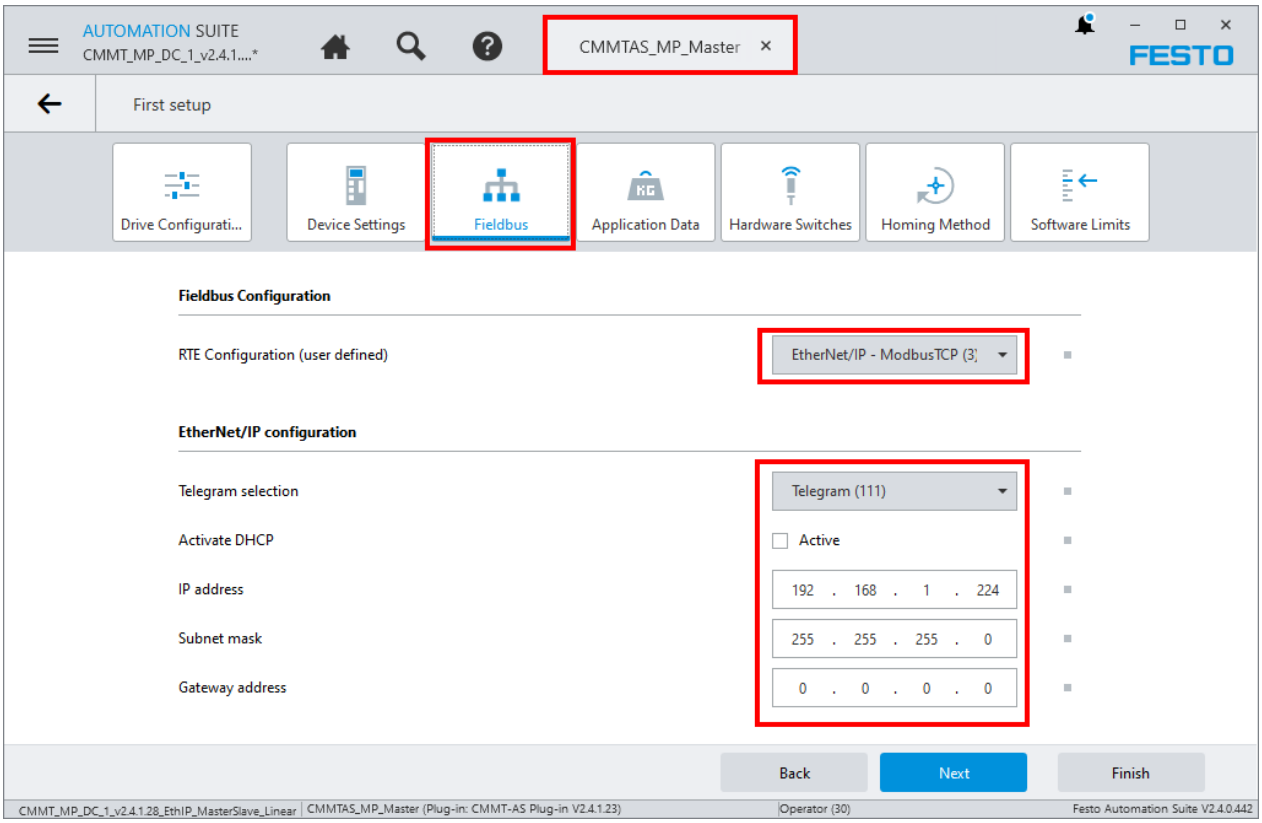
4.3 First setup - Device Settings

Consider the application Supply Voltage and modify from default if needed



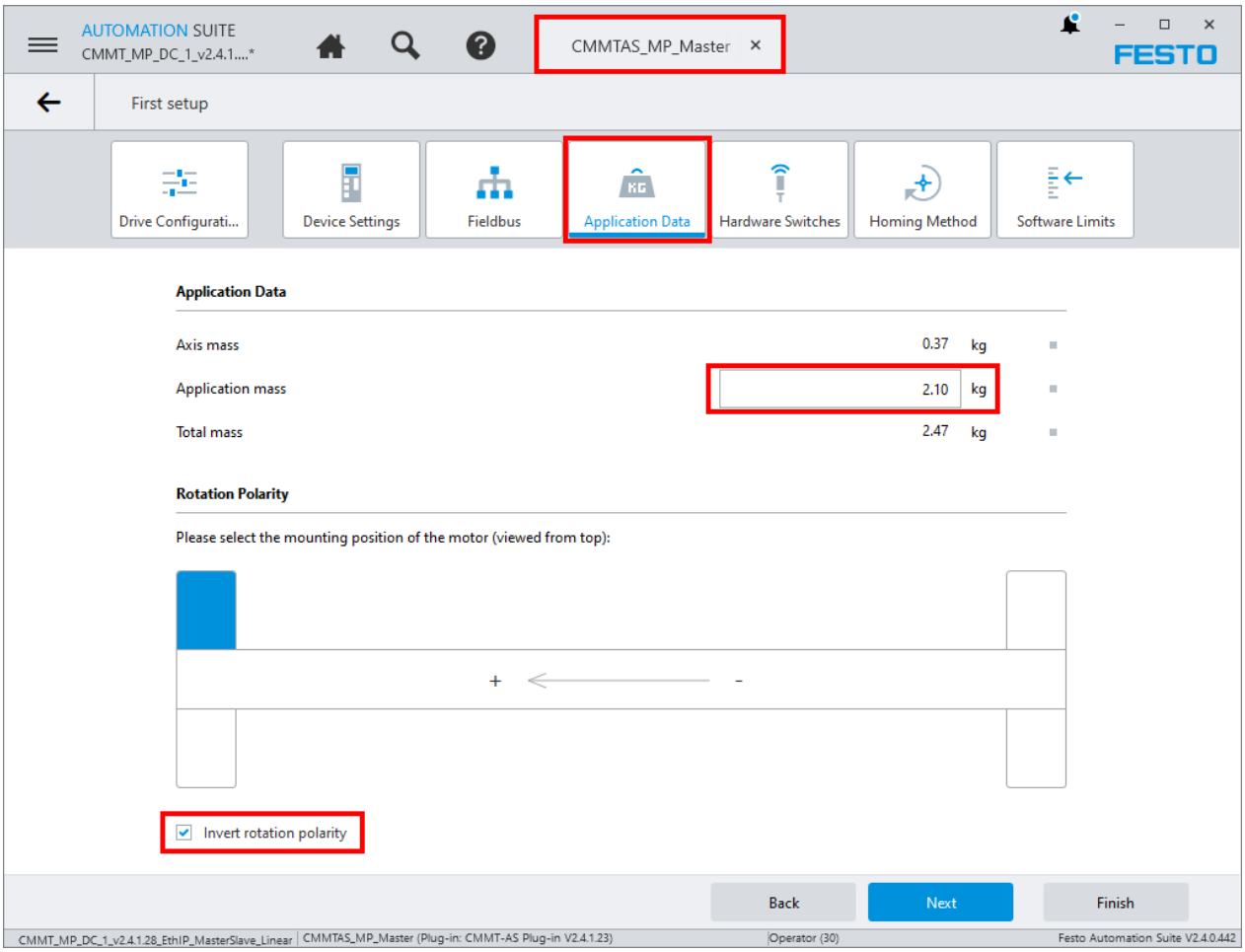
4.4 First setup - Fieldbus

Select EtherNet/IP – Modbus (3) for the RTE ethernet ports and Telegram 111, then modify the IP Address

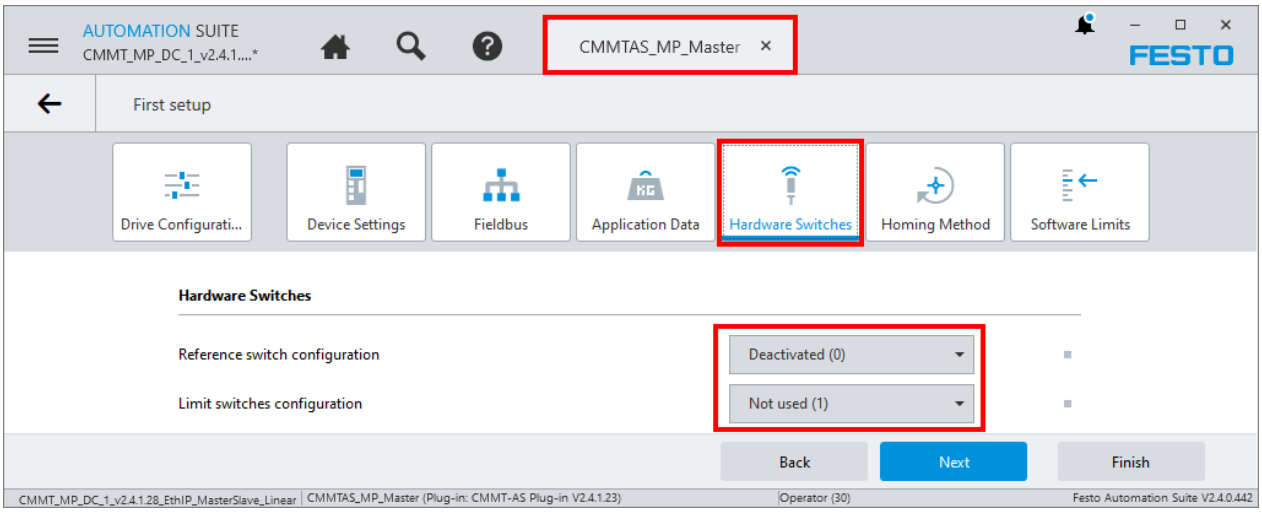


4.5 First setup - Application Data

Consider the application design

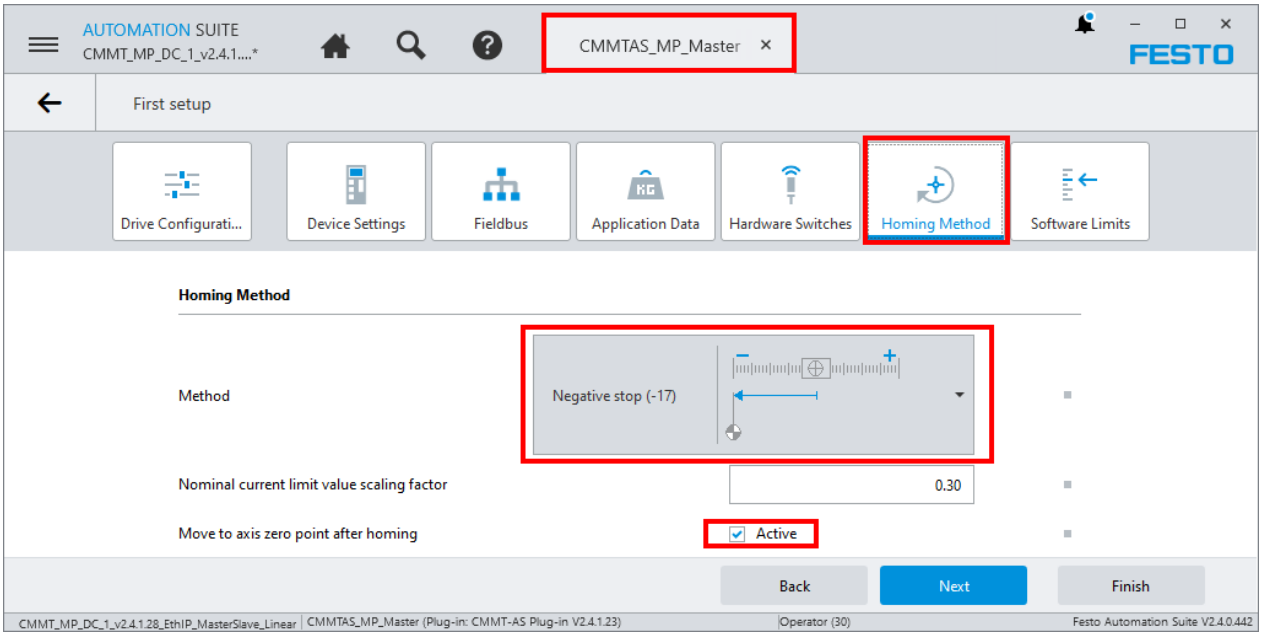


4.6 First setup - Hardware switches



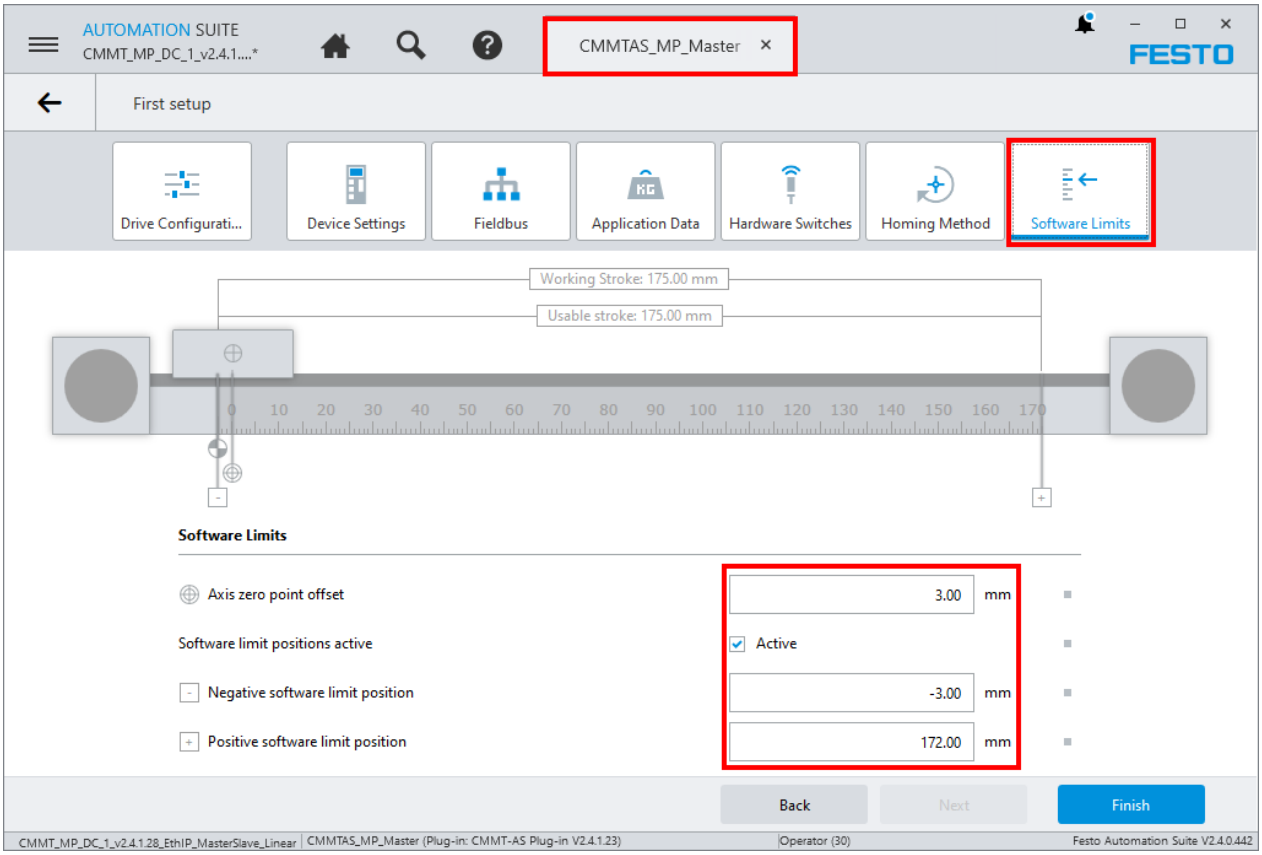
4.7 First setup - Homing Method

The simplest Homing method is current position (37) with no movement. This is because after the mechanical alignment, this allows the axis to reference and store the offset in the existing position without any movement. In this example, the Negative stop was used to have the Master offset from mechanical end of stroke, then the Slave Axis would be aligned to its physical zero later.



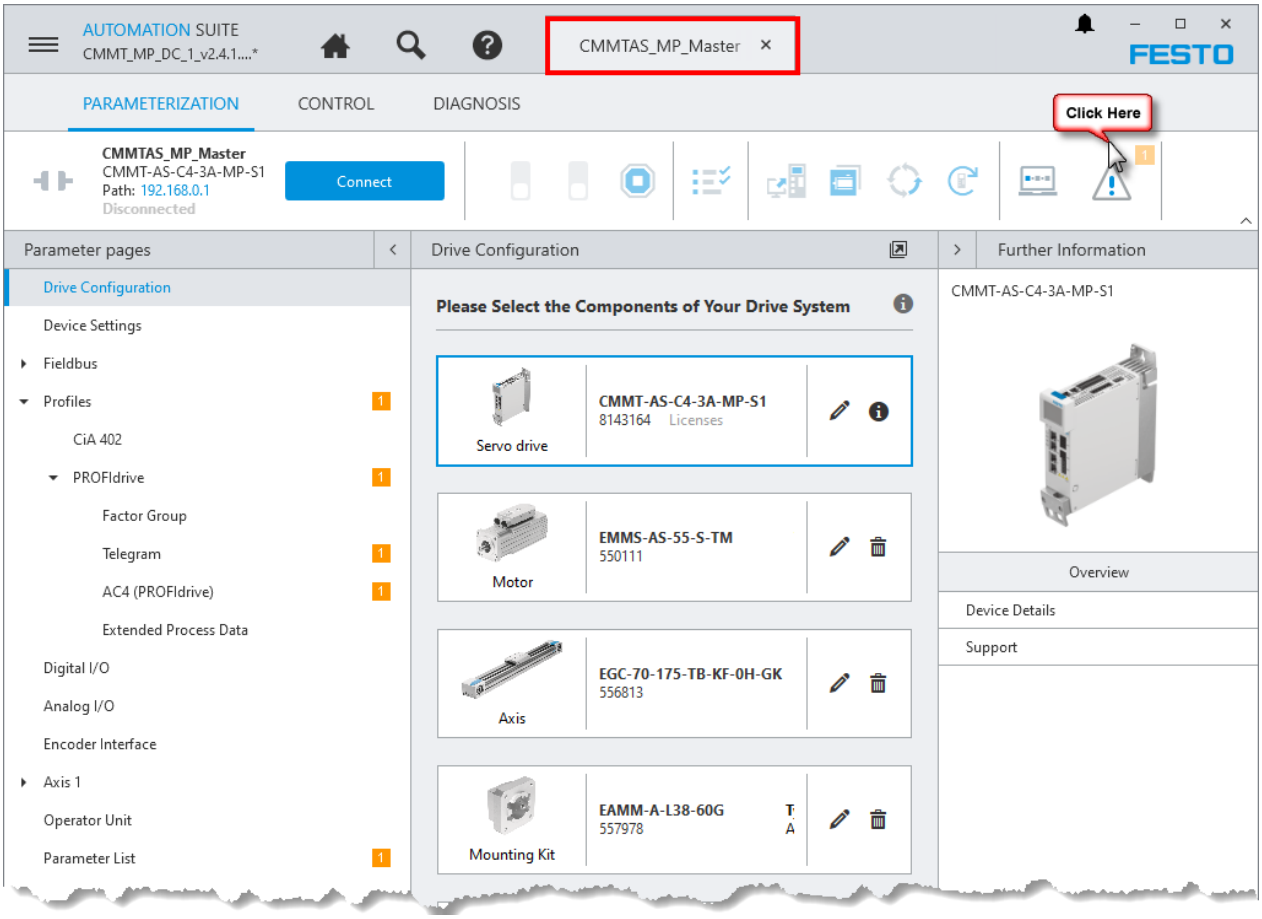
4.8 First setup - Software Limits

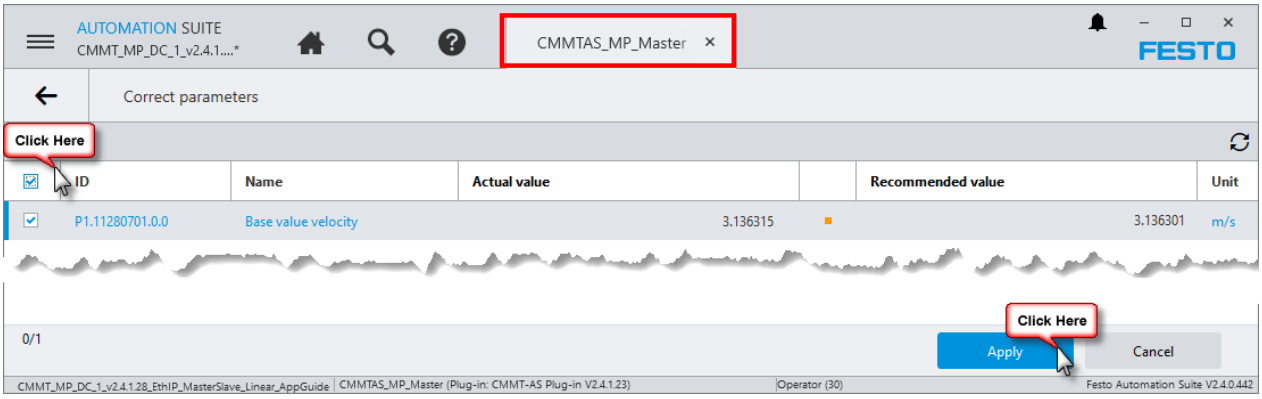
The Software Limits should be observed however, this depends on your application. A software limit larger than that of -3.00mm may be required to avoid mechanical limitations with the Slave alignment.



4.9 Correct Parameters

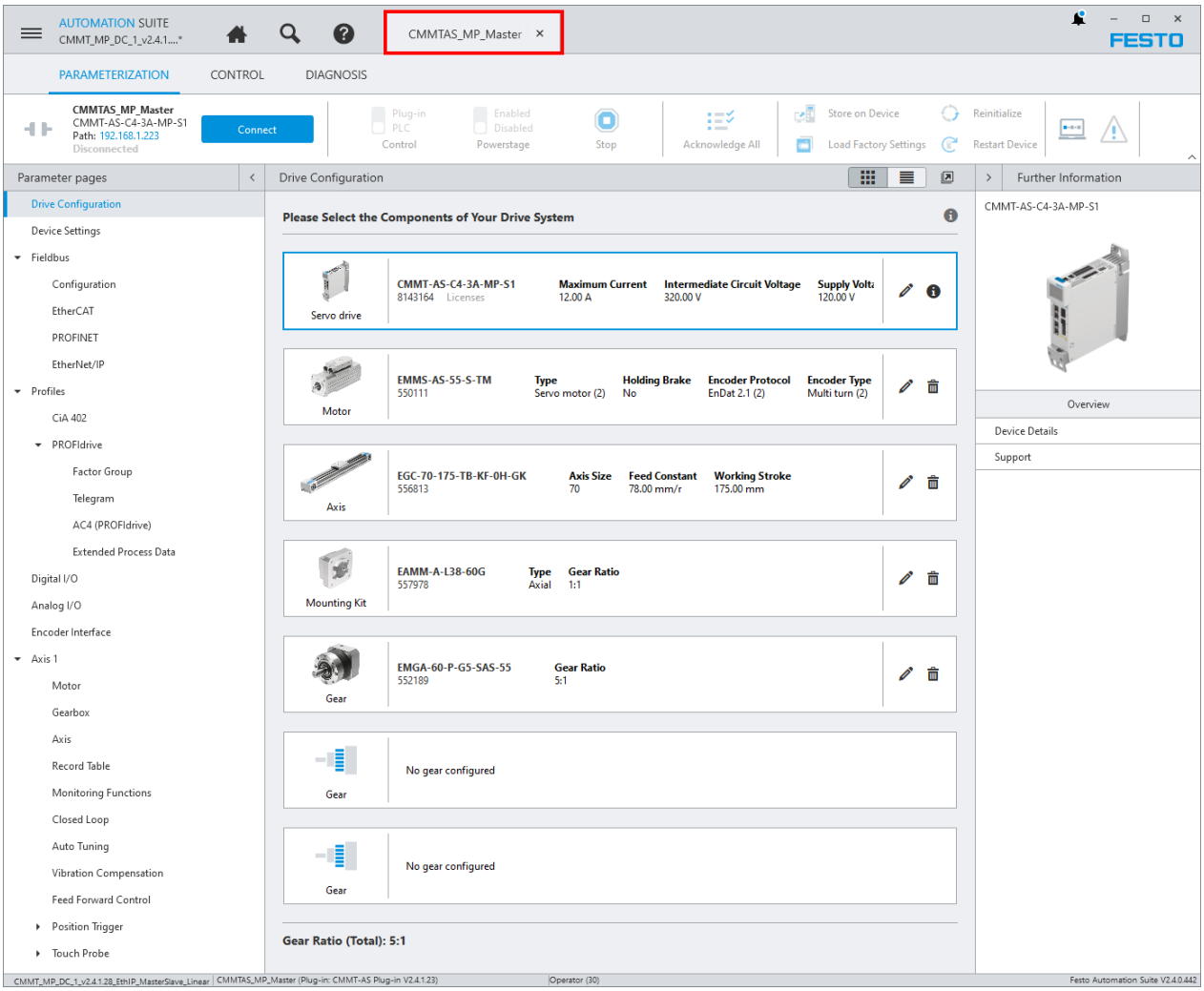
If you find orange adorners/indicators, these are warning to indicate unfavorable or inconsistent values and these may need to be modified. It is recommended to use the “Correct Parameters” function to modify the parameters with recommended values as shown below.





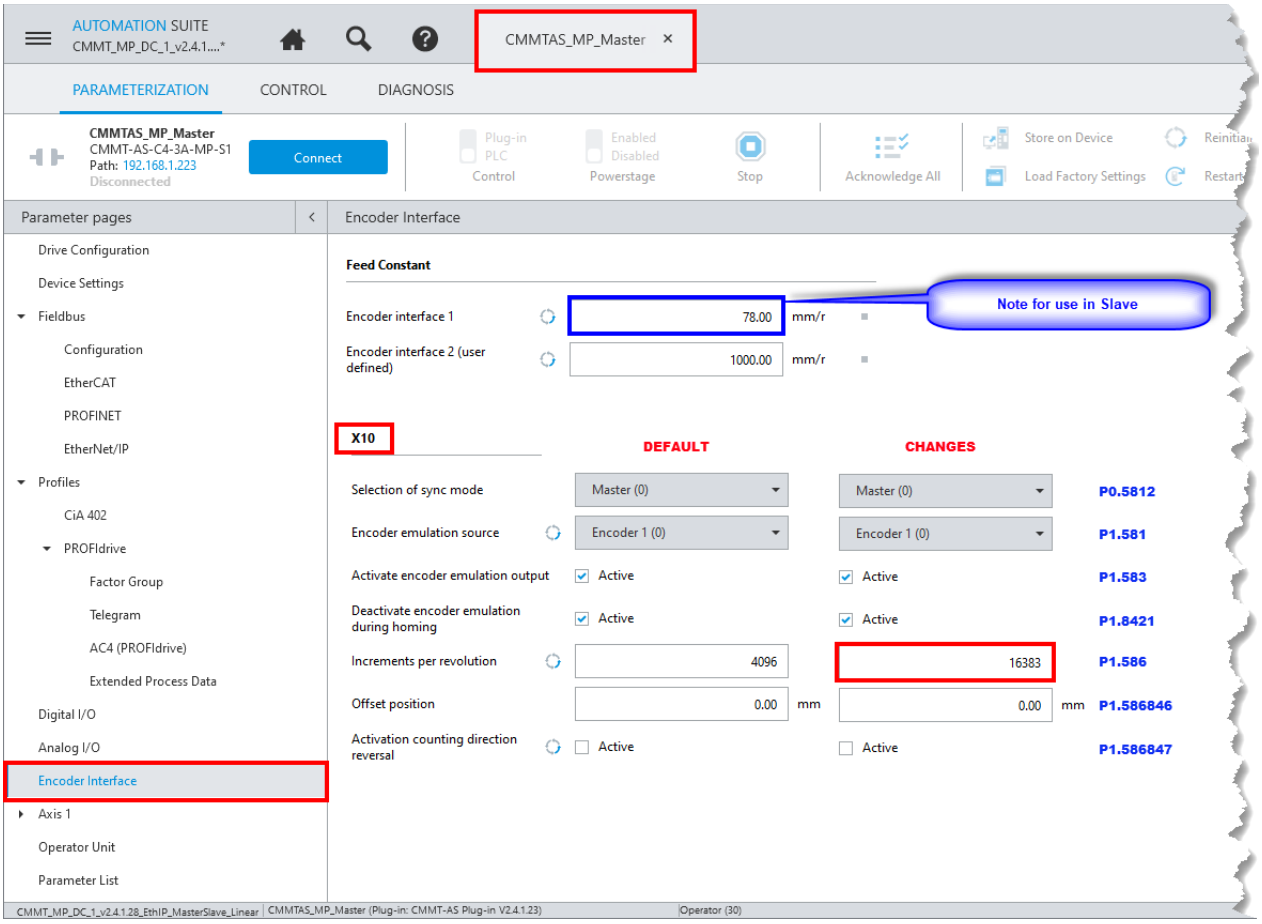
4.10 Setup Complete

Master axis general configuration is now complete.



5 Master Axis Changes Required for Parallel Axis

5.1 Encoder Interface



P1.581 Encoder Emulation Source
Encoder 1 (0) refers to the Primary encoder at connection X2
Encoder 2 (1) refers to the Secondary encoder at connection X3
Setpoint position (2), less noise is observed on the Slave, however the slave doesn't follow when Master is disabled because no setpoint is changed.

P1.583 Activate Encoder Emulation
Encoder 1 (0) refers to the X10 encoder connection.
When this has been chosen, regardless of the presence of the cable connection, the top LED is active solid green.
Turning this on allows Encoder Emulation by the Master.

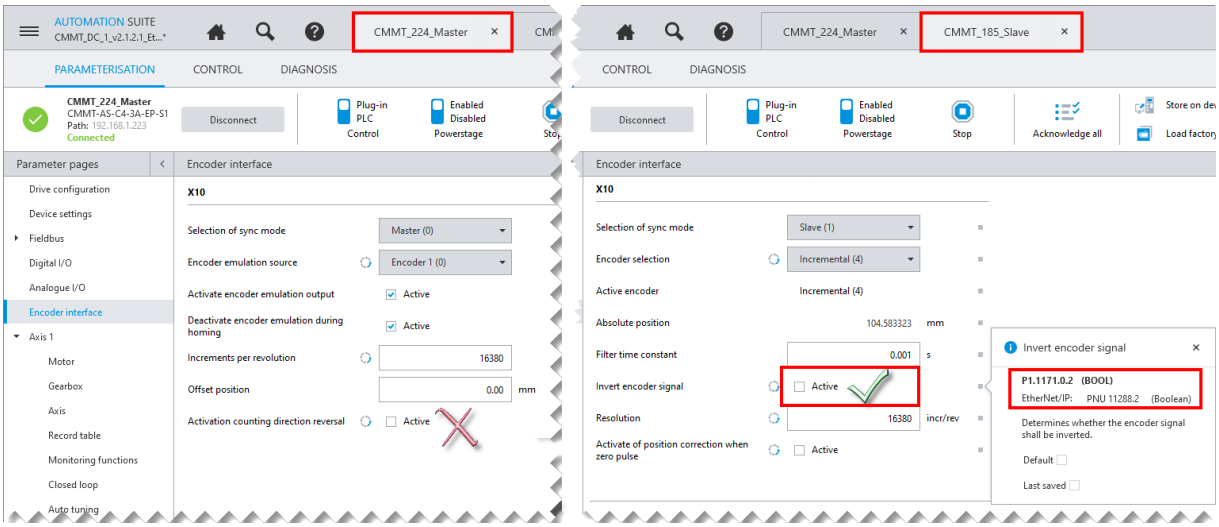
P1.8421.0.0 Deactivate Encoder Emulation During Homing
The state of this is irrelevant because the Master and Slave axis both have Multi-Turn Absolute Encoders and once homed are not homed gain.

P1.586 Increments per revolution
16383 Increments per revolution allows for better tuning when in Synchronisation (The greater the selected value the lower the resulting noise on the connected slave axes).

Caution

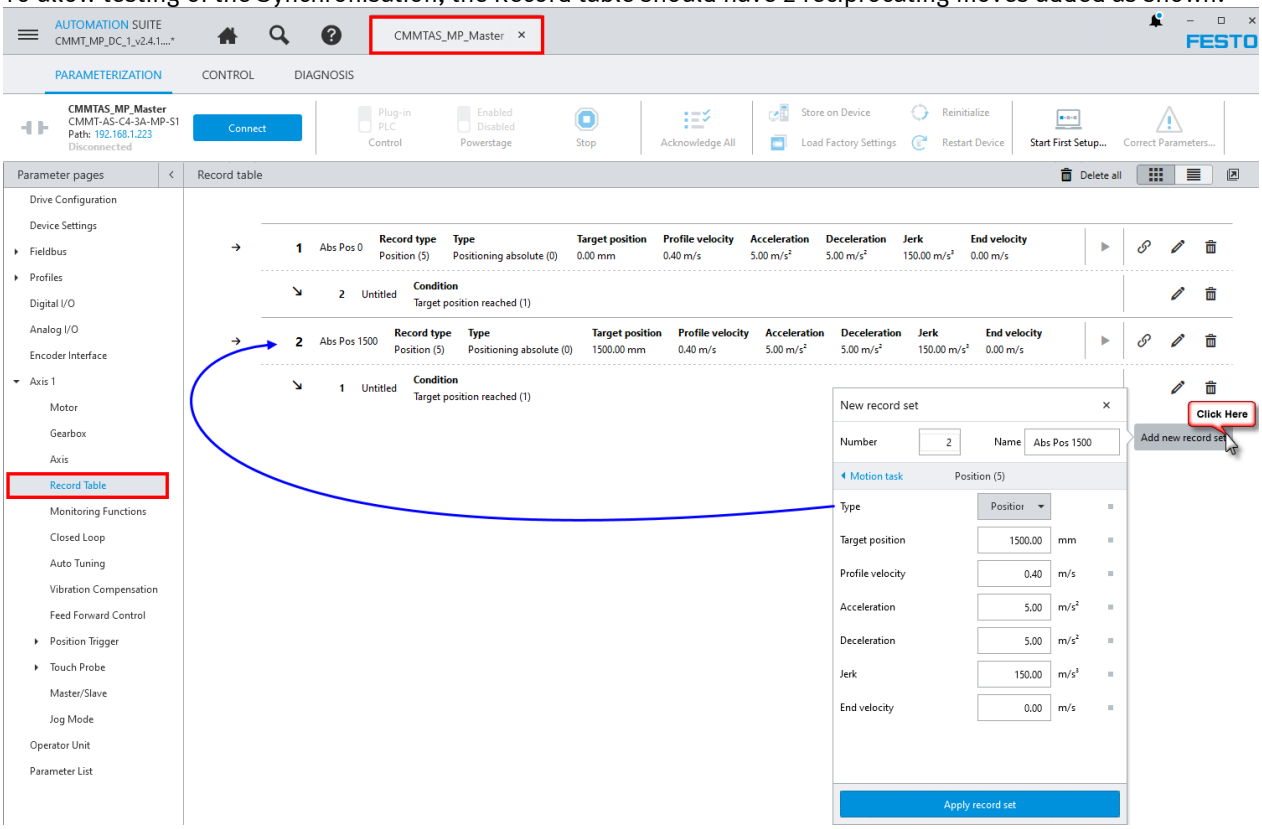
- **The same resolution per revolution should be set in the Master and slave drive.**
- **DO NOT USE THE VALUE "16384" (only allowed in Master on older software versions) See note for Slave axis parameter P0.10040.2.0 Increments per revolution**

When it is necessary to adjust the direction of rotation in an application, the Px.1171 direction reversal should be used in the slave drive.



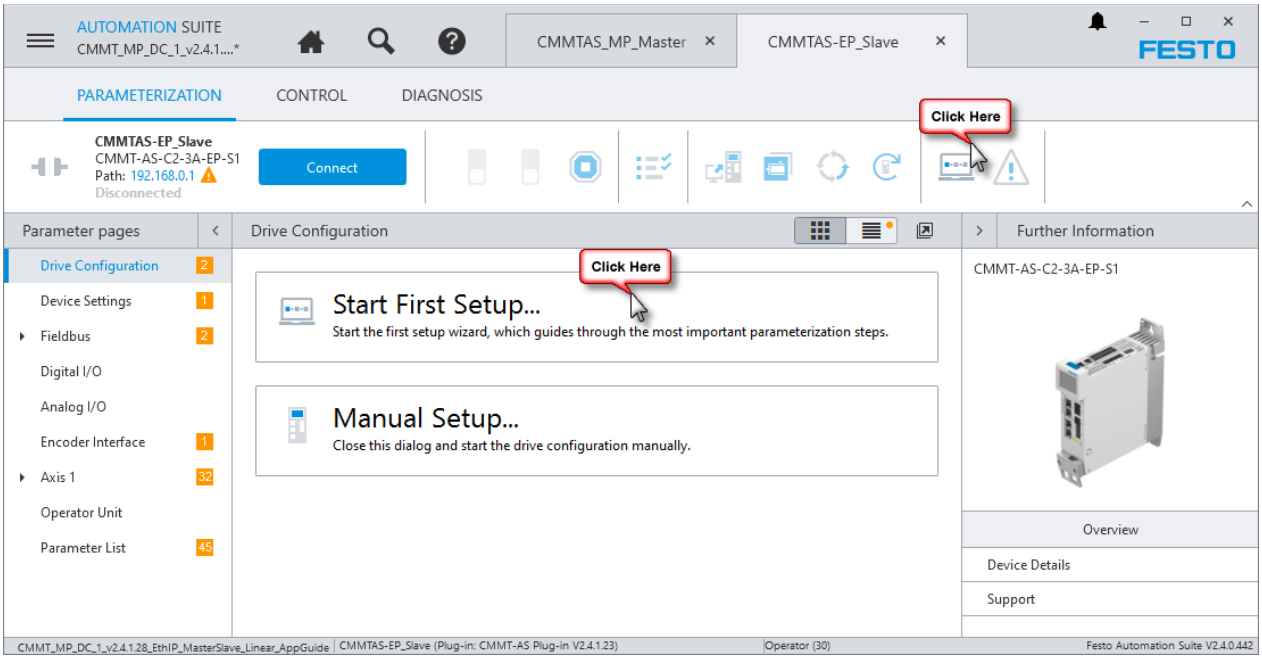
5.2 Record Table

To allow testing of the Synchronisation, the Record table should have 2 reciprocating moves added as shown.



6 Slave Axis General Setup

6.1 First setup - Start Wizard

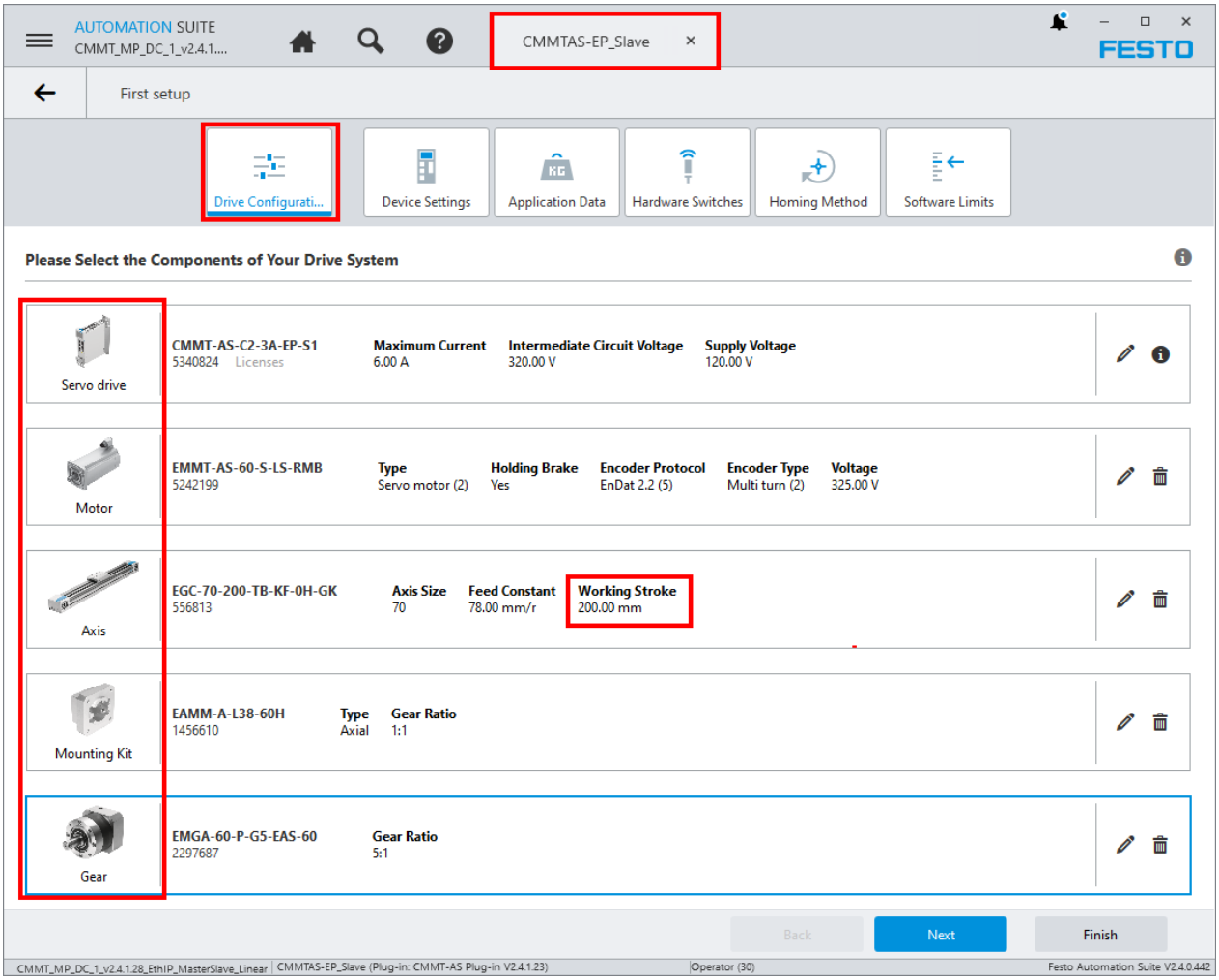


6.2 First setup - Drive Configuration

Configure the hardware selected for the application.
NOTE: Working Stroke -› In this example, the Master and Slave physical axis stroke are both 175mm, however, it is recommended to configure the value of the Slave Working Stroke slightly larger (200mm which provides a physical 15mm buffer). This concept is to avoid the Slave from entering an software overtravel status and losing the synchronisation at any time.

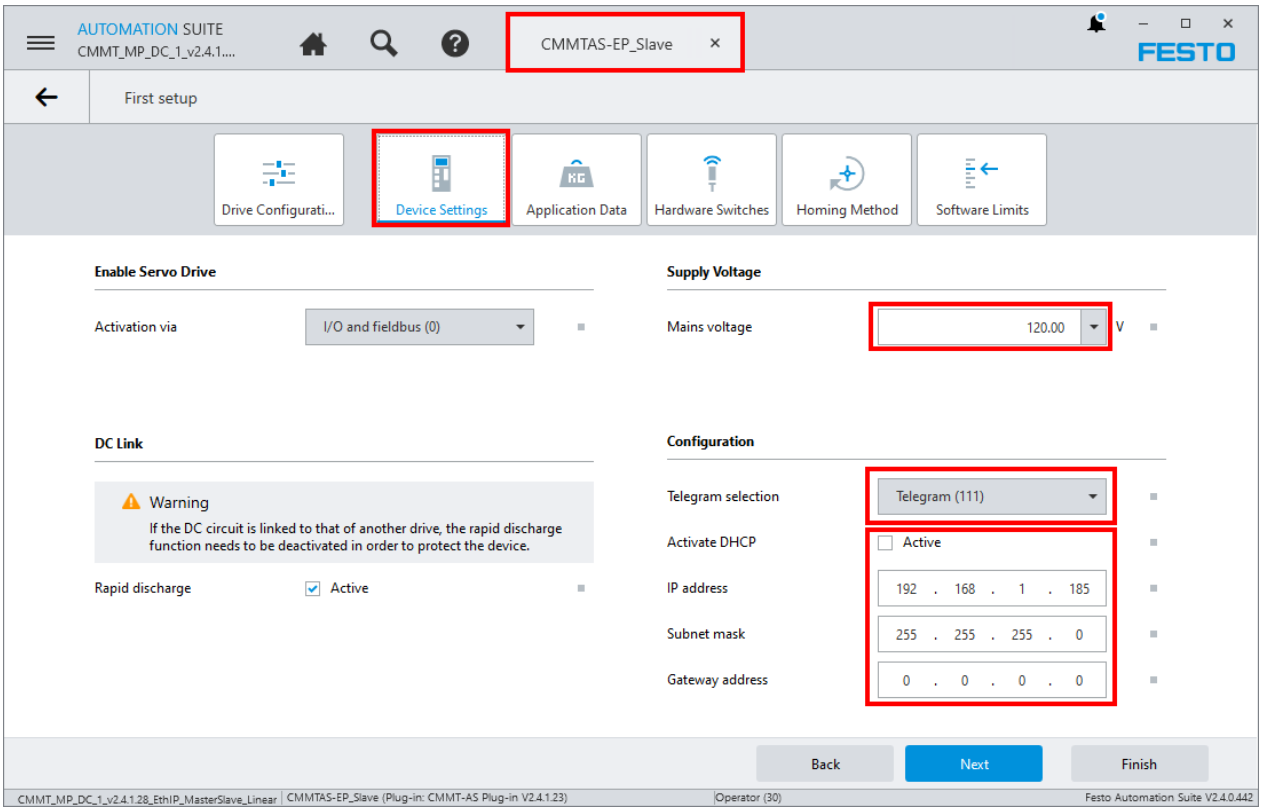
Caution

The Slave axis should not be able to encounter a software or hardware limit otherwise it can lose synchronisation which could cause an issue depending on the monitoring of the higher order PLC (Programmable Logic Controller).



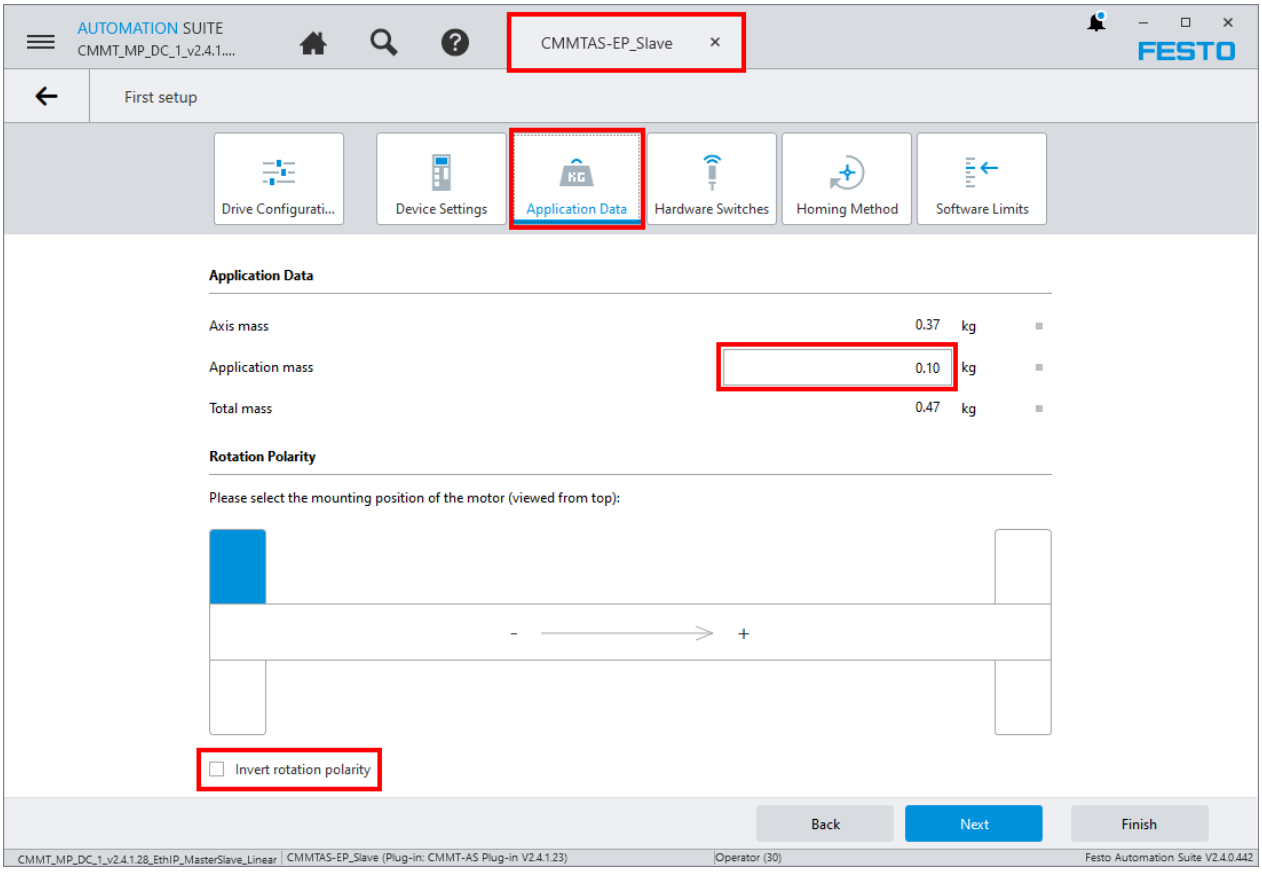
6.3 First setup - Device Settings

Consider the IP Address and Supply Voltage and be certain that Telegram 111 is selected

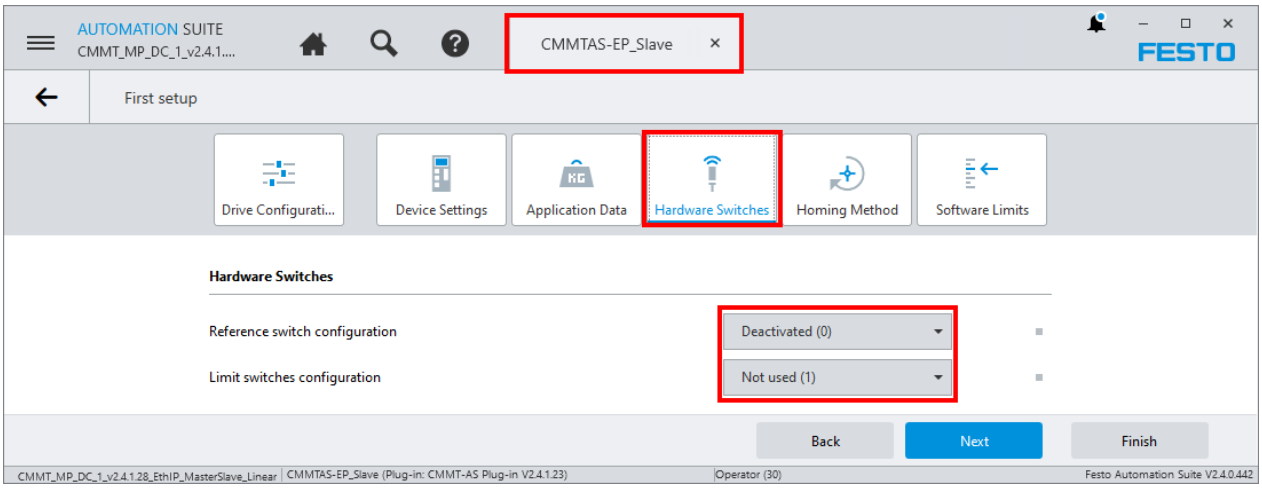


6.4 First setup - Application Data

Consider the application design.

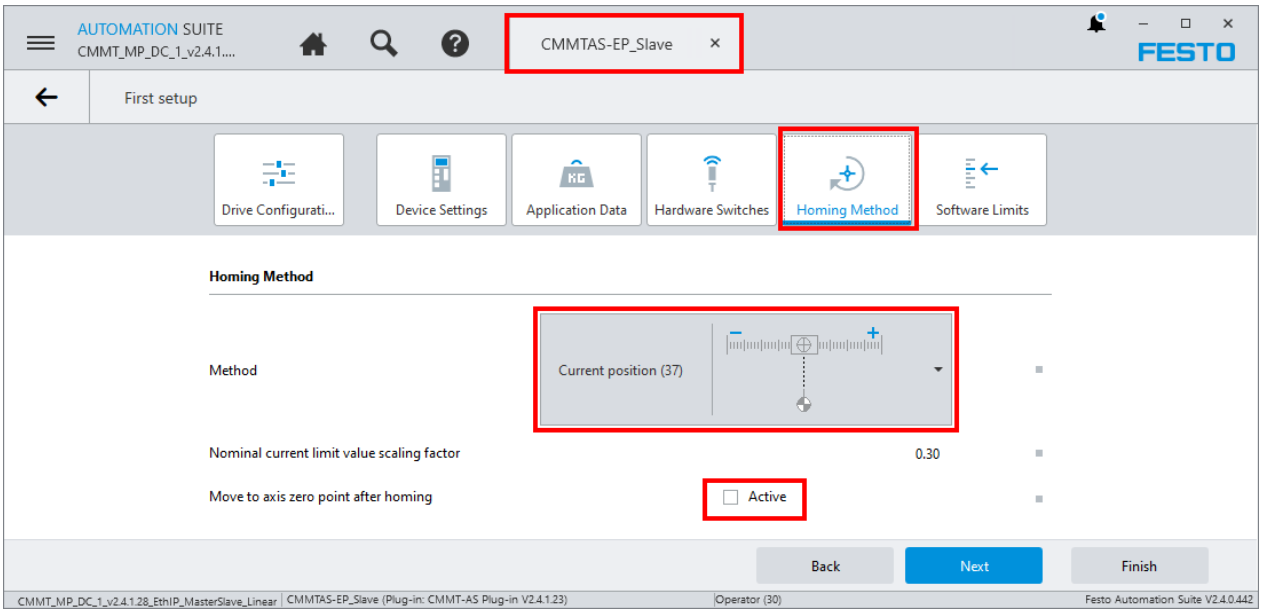


6.5 First setup - Hardware switches



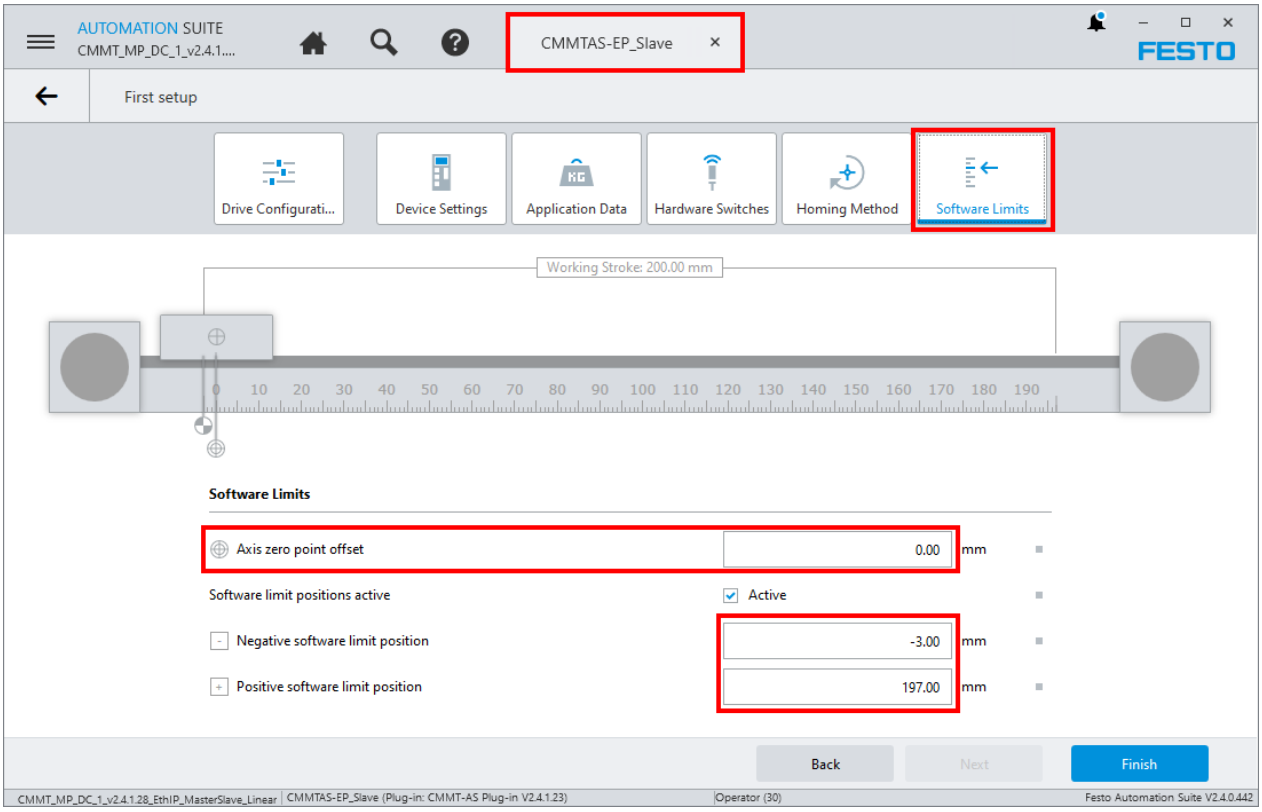
6.6 First setup - Homing Method

The simplest Homing method is current position (37) and the Move to Axis zero point after homing should be unchecked/disabled. These settings allow the axis to reference and store the offset in the current position without any movement.



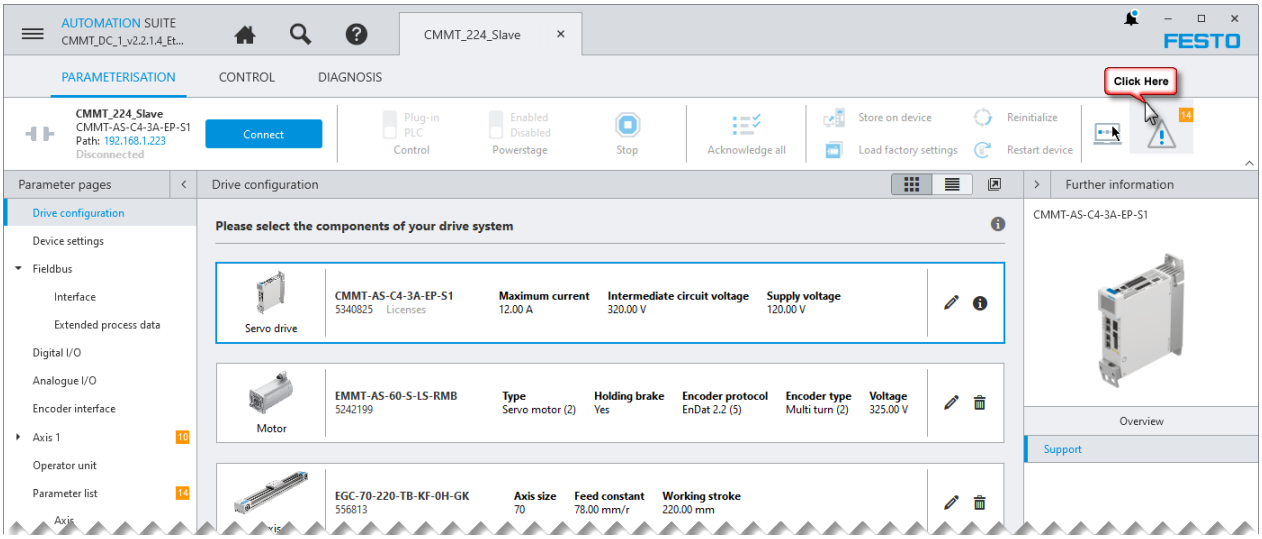
6.7 First setup - Software Limits

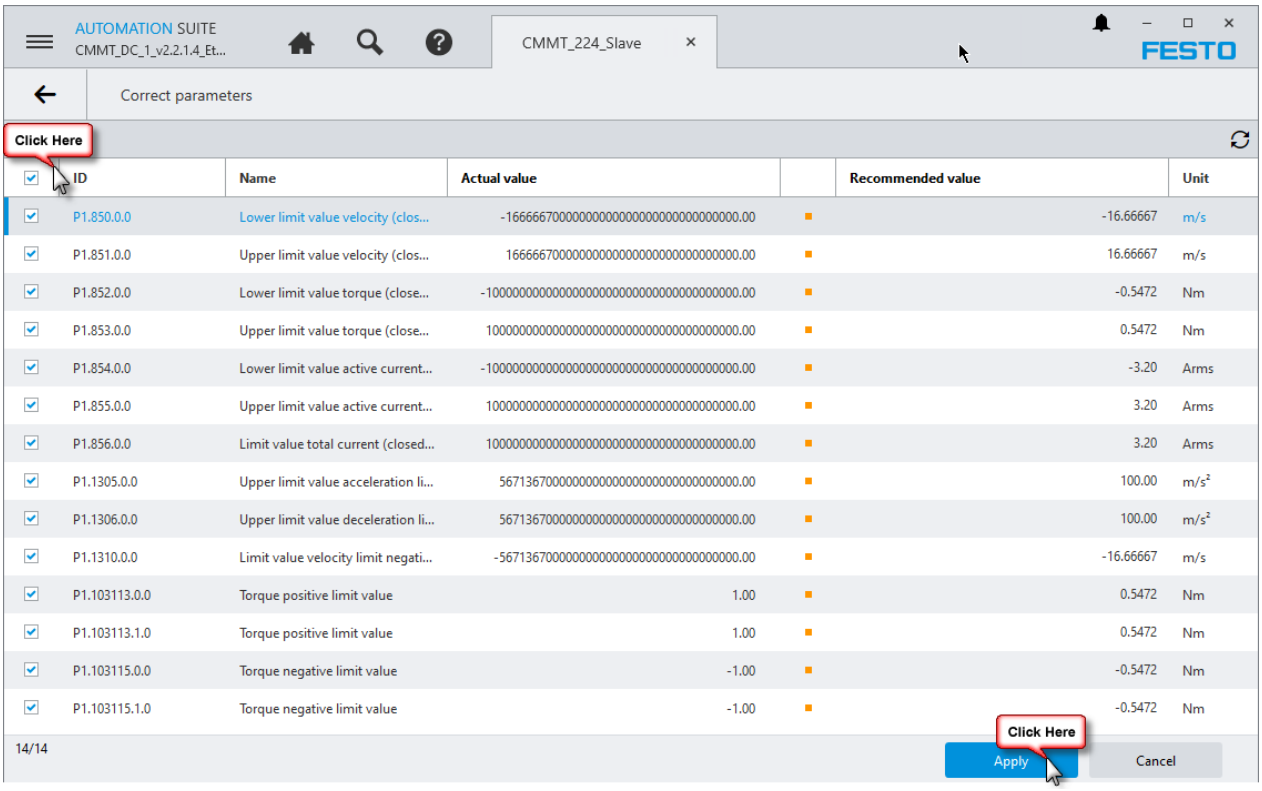
The Axis zero point offset should be configured as 0.00mm because during the execution of reference/homing, The Master position will already be at 0.00mm and the slave needs to match this position.
The Software Limits should be active (default) in this step.
The default values for negative/positive position limits should be adequate because the values of the slave should be beyond the physical stroke at either end of the axis (this was discussed earlier in section “First setup - Drive Configuration”).



6.8 Correct Parameters

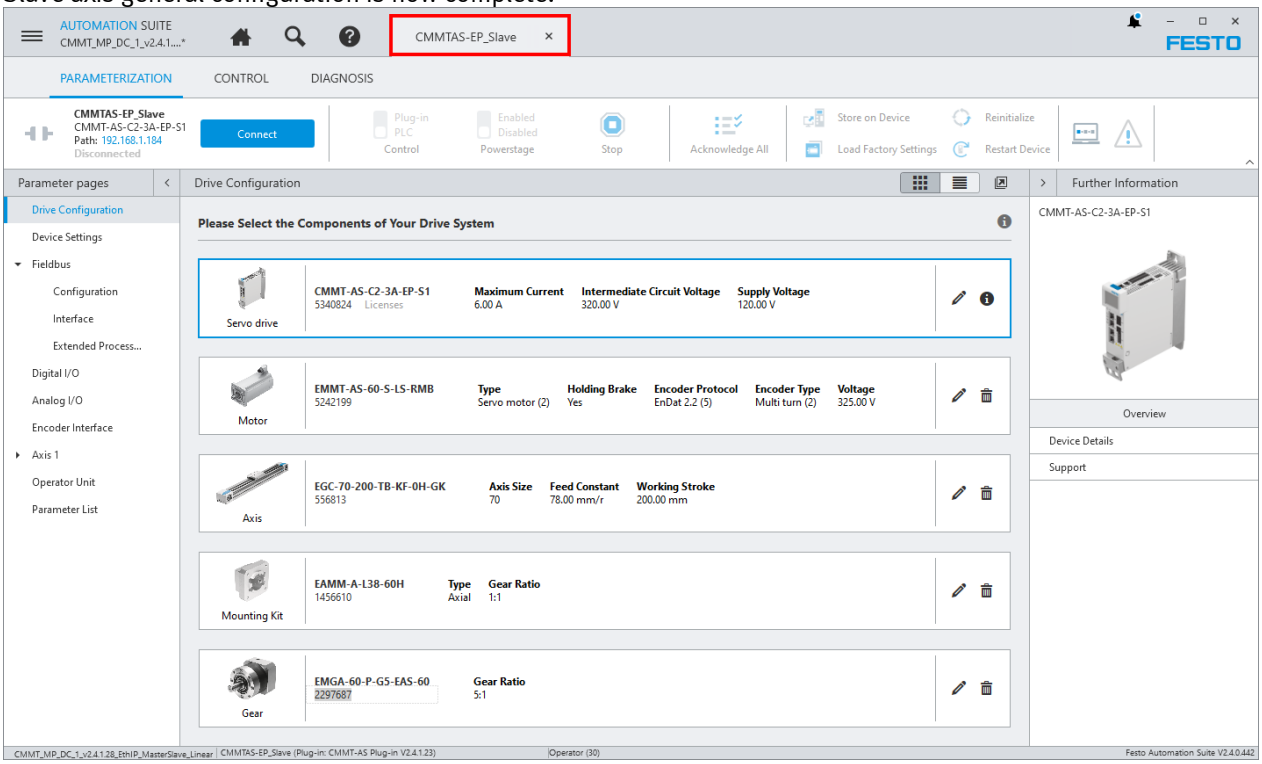
If you find orange adorners/indicators (example shown here), these are warning to indicate unfavorable or inconsistent values and these may need to be modified. It is recommended to use the “Correct Parameters” function to modify the parameters with recommended values as shown below.





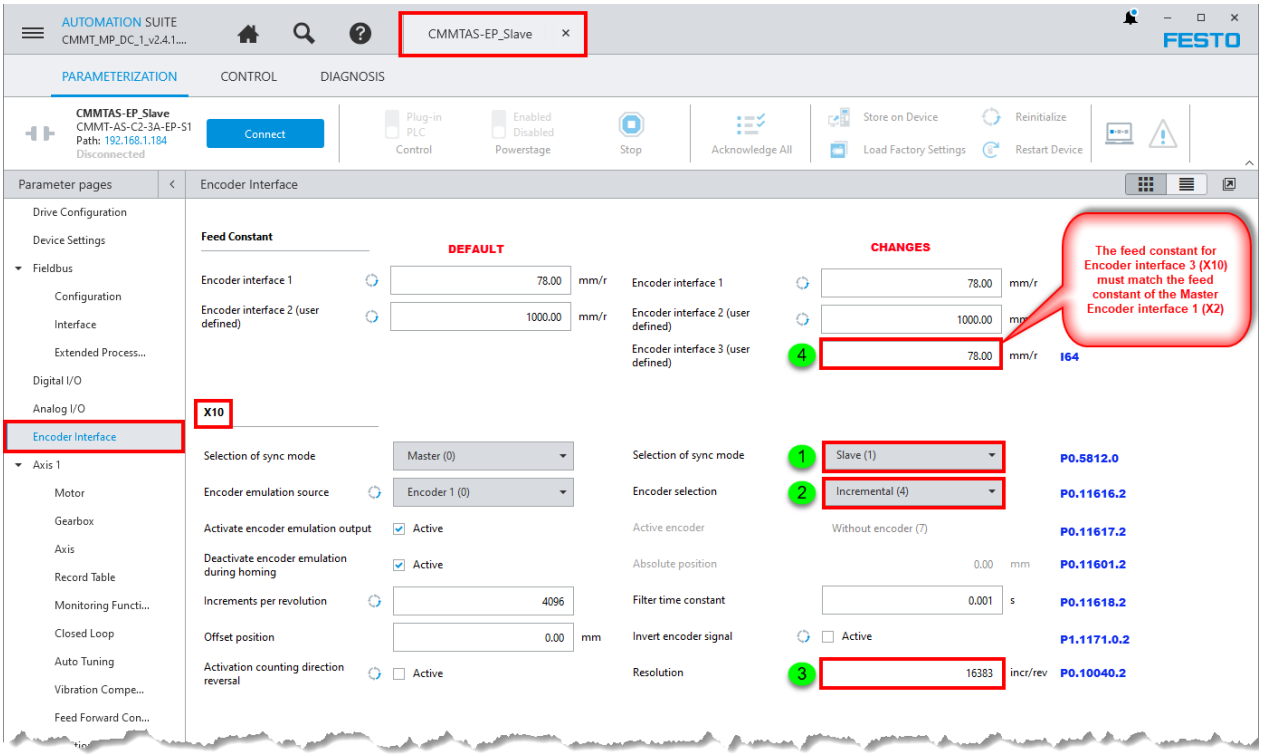
6.9 Setup Complete

Slave axis general configuration is now complete.



7 Slave Axis Changes Required for Parallel Axis

7.1 Encoder Interface



I64
The feed constant for Encoder interface 3 [X10] must match the Master feed constant.
Here we tell the controller how to convert the increments per revolution after the gear into position units.

P0.5812 Selection of Sync Mode
Here we configure as Slave(1) for obvious reasons.

P0.11616.2.0 Encoder selection
The Master X10 port emulates an Incremental Encoder so this is selected here.

Caution

If actual values are transmitted to the slave as position signals (P1.581 Encoder Emulation Source = Encoder 1 or Encoder 2), increased noise may occur due to the torque feed forward control in the synchronous phase. The torque feed forward control is switched off by setting parameter Px.968 to 0.

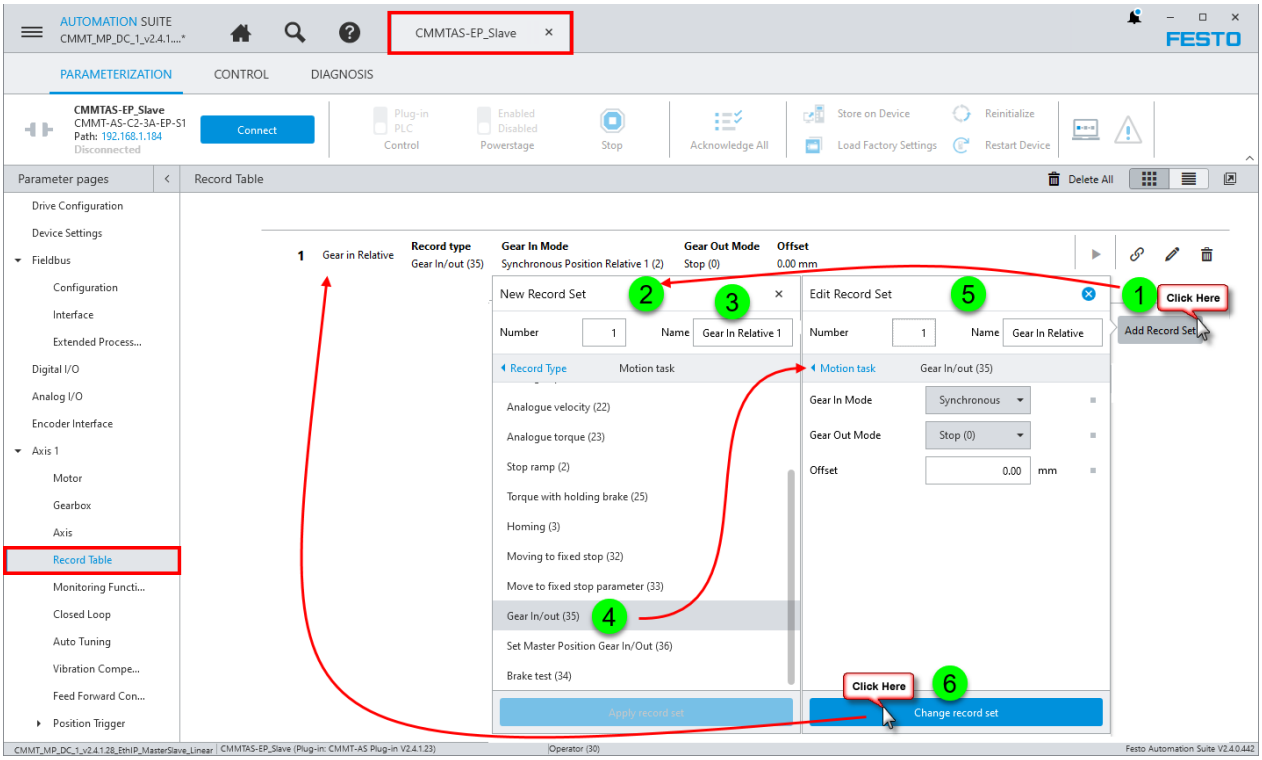
P0.10040.2.0 Increments per revolution
16383 Increments per revolution allows for better tuning when in Synchronisation.

Caution

- **The same resolution per revolution should be set in the Master and slave drive!**
- **DO NOT USE THE VALUE "16384" for parameter P0.10040.2.0 Increments per revolution. This will result with an exception in the firmware when re-initializing the drive (div/0) and the hardware will need to be replaced (cannot be fixed onsite).**
  The firmware release V19.0.4.72 is supposed to address this issue.

7.2 Record Table

The Record Table needs to have the shown Gear In **Synchronous Position Relative 1** mode added.
This will be used to place the Slave axis in synchronisation when desired.



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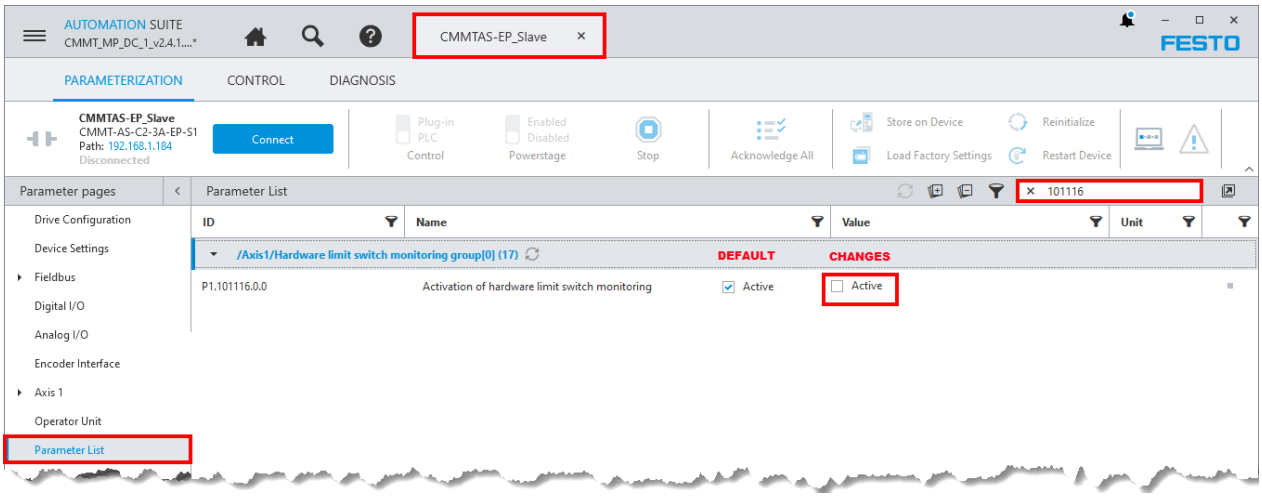
7.3 Parameter List



P1.101116.0.0 Hardware Limits Disabled
This option should be disabled to prevent undesirable behavior while in sync.

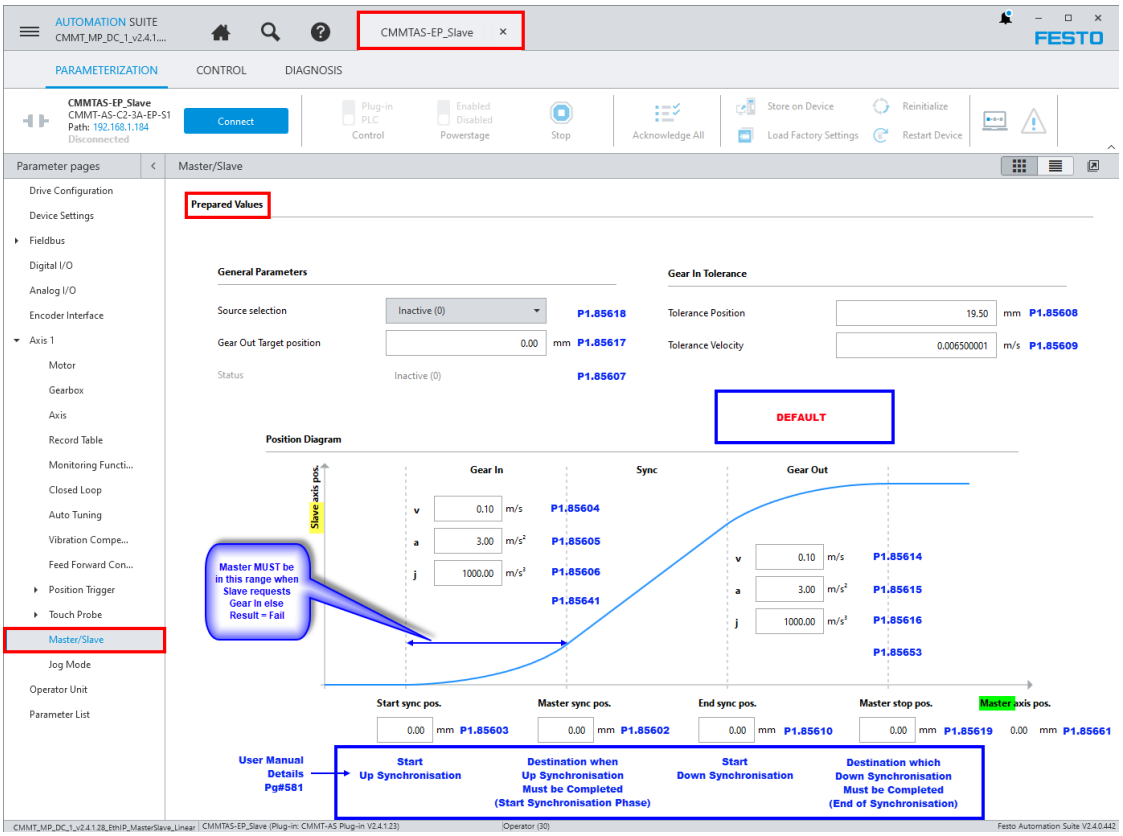
Caution

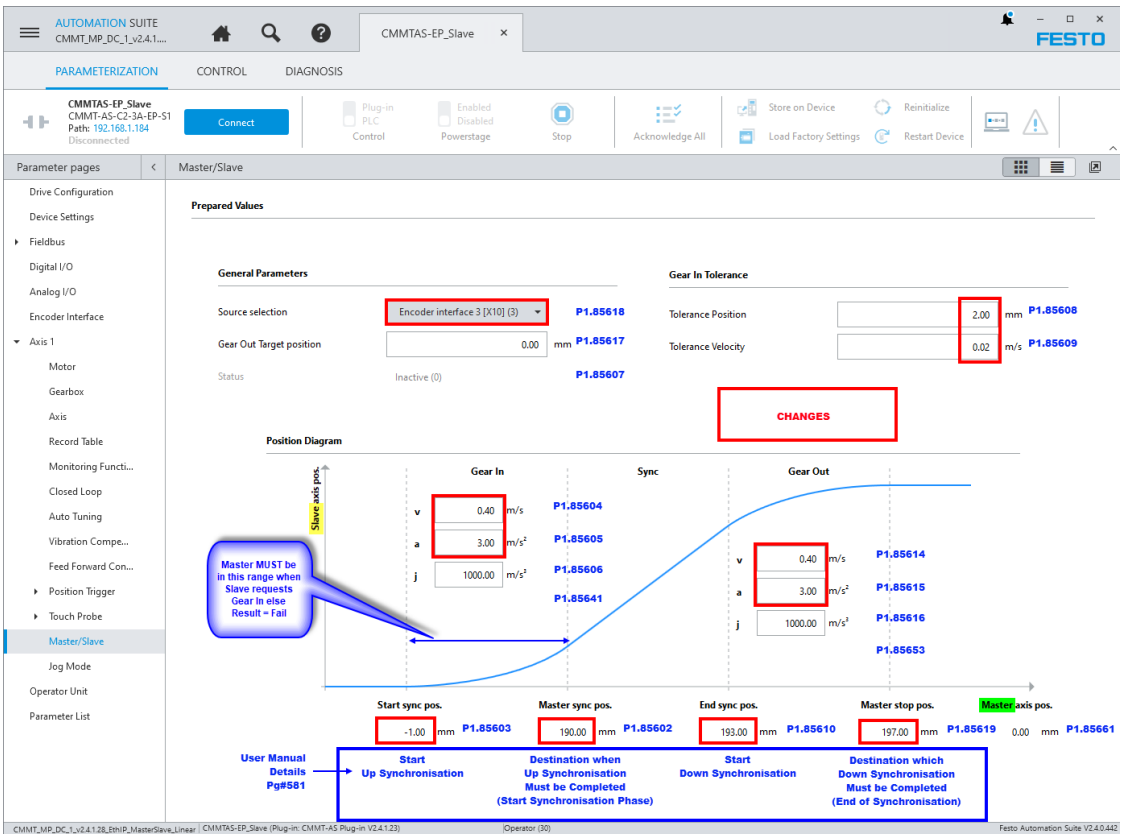
If the Slave axis is in synchronisation to the Master and a Hardware limit is encountered, the slave will be inhibited by the limit and will NOT follow the Master.

7.4 Master/Slave

The Slave axis Master/Slave page needs to be configured based on the Device Configuration Axis Working Stroke. In this example, the Master and Slave physical axis stroke are both 175mm. The Slave is configured with 200mm (197mm Software Limit) to avoid loss of synchronisation. In order to correlate with the Slave Software limit and avoid losing synchronisation, the Master Sync Pos./End Sync Pos. and Master Stop Pos. are all configured with values greater than the Master axis physical stroke up to the unachievable Slave Stroke including the positive software limit.

The Encoder Interface 3 [X10] (3) needs to be selected so the Slave considers this as the Virtual Master Position.

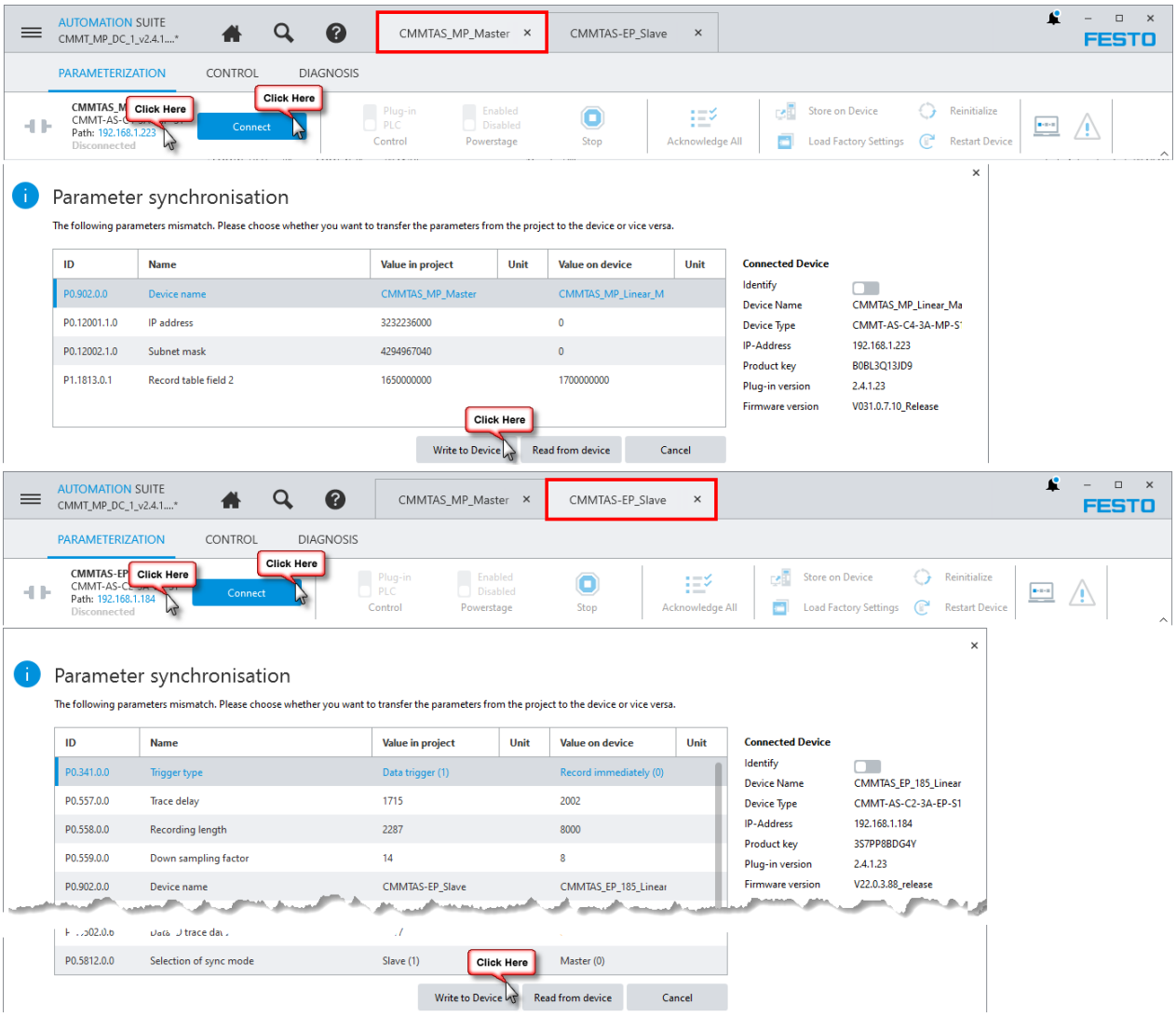




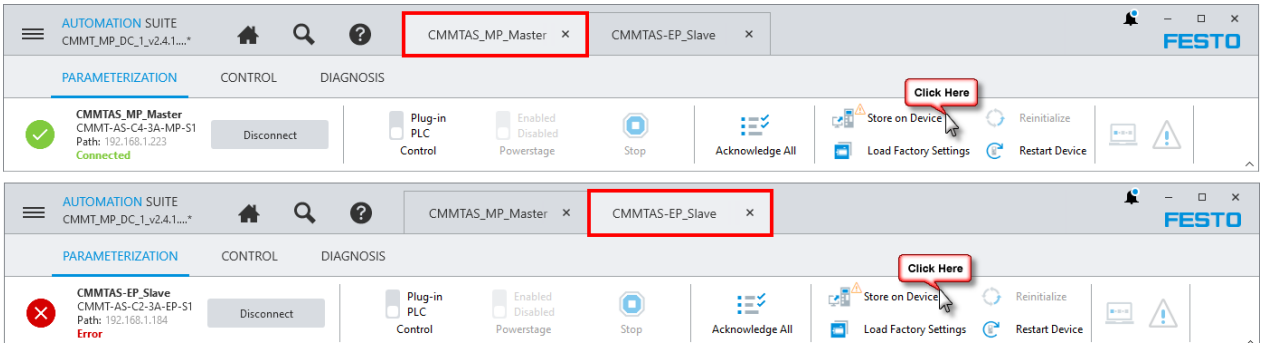
8 Commissioning Steps

8.1 Download both axis configurations

The motor controller should have factory defaults, however, if a parameter synchronisation window appears, make certain to select “Write to Device”



8.2 Store both axis configurations

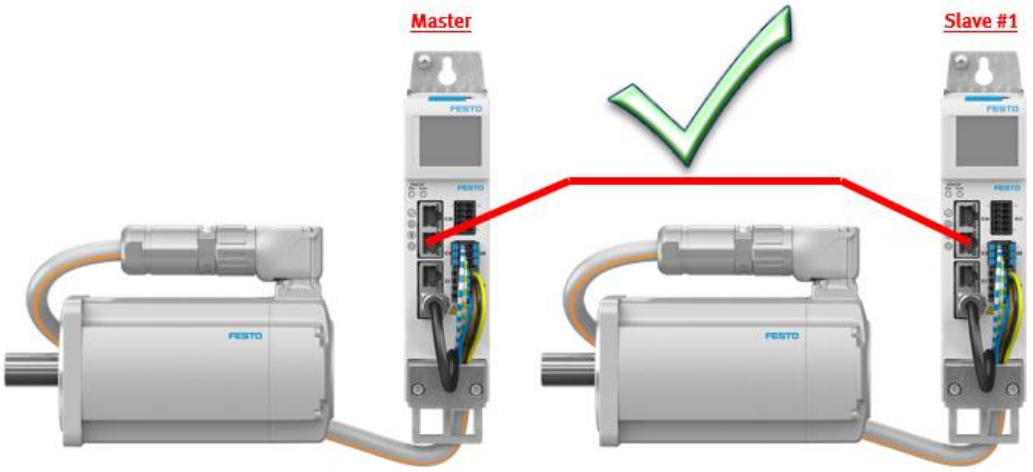


8.3 Master and Slave X10 physical connection

Confirm X10 connectors on the Master and Slave are physically connected

Caution

- **There is no physical wire break detection on the Slave and so monitoring position error in the PLC (Programmable Logic Controller) is required for error recovery.**

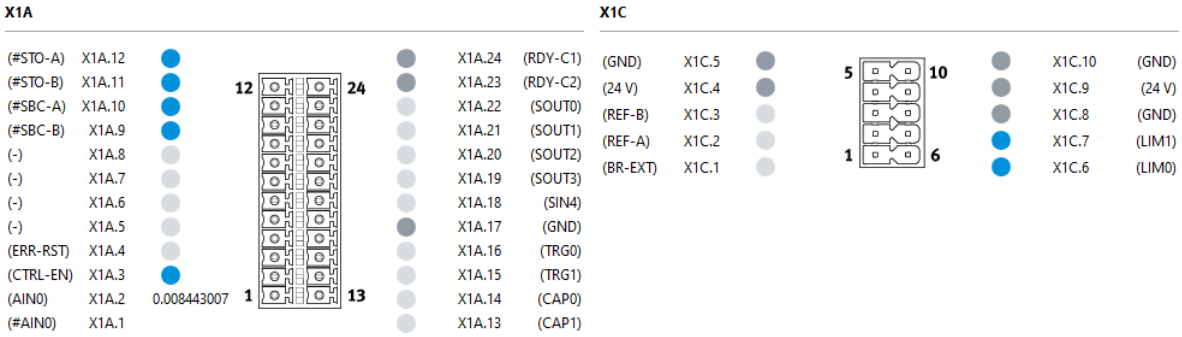


8.4 Hardware Control Enable Cross-Wiring

As mentioned in the **Caution** note above, the X10 EtherNet cable has no physical wire break detection in the Master or Slave controller software.

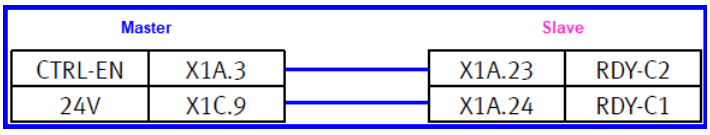
- In applications with rigid mechanical coupling, an offset between master and slave can lead to distortion, even mechanical destruction of the system. To avoid such risk, a reliable solution must be deployed.
- In the event of an error of the Slave, the Master should stop as soon as possible, in the best case with the delay dynamics of the Slave. Such a shutdown via the higher-level controller is usually subject to the update time of the fieldbus system and the cycle time of the controller. Therefore, hardware control enable cross-wiring is recommended in this case. The Master can be enabled by a ready signal, physically via the potential-free contact RDY-C1/C2 of the Slave. If the Slave now goes into error state, the CNTRL-EN of the Master will be removed, which leads to a stop ramp and following stop. The Master can also be enabled again only if there is no more error in the Slave. If the hardware cross-wiring shown here conflicts with the safety circuit of the Master (CTRL-EN), the Master can also be disabled in the event of an error via a digital input and using the event table.
- In case of error to the Master, the Slave still will follow the Master's position. It must be ensured that Slave drive can follow the dynamics of the Master's stop ramp. If it cannot be guaranteed, cross-wiring is also recommended for the Slave.

8.4.1 Wiring IO (Inputs/Outputs) Connector Function



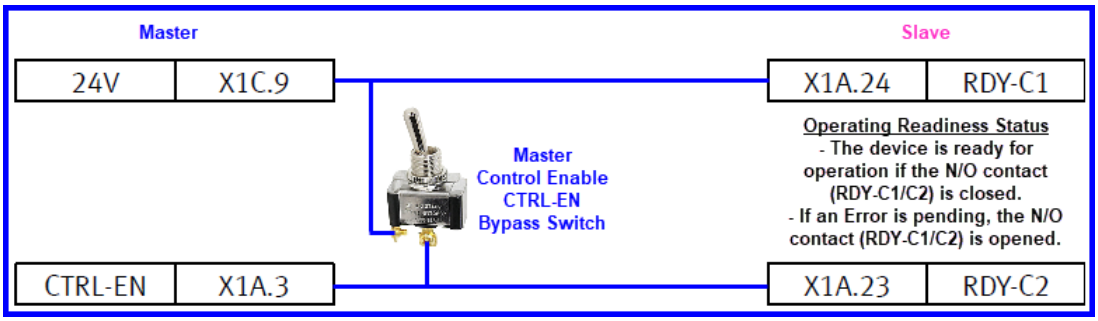
8.4.2 Wiring Example

The wiring shown here is very simple and will react very fast to an error on the Slave.



8.4.3 Wiring Example With Bypass

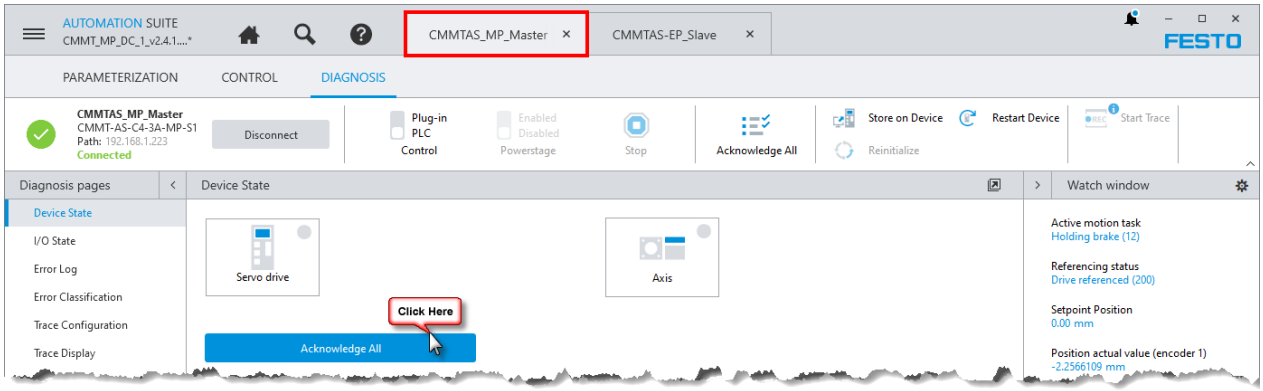
If the user feels they will need to bypass this condition in certain circumstances, they could wire as follows:



8.5 Master and Slave cycle power

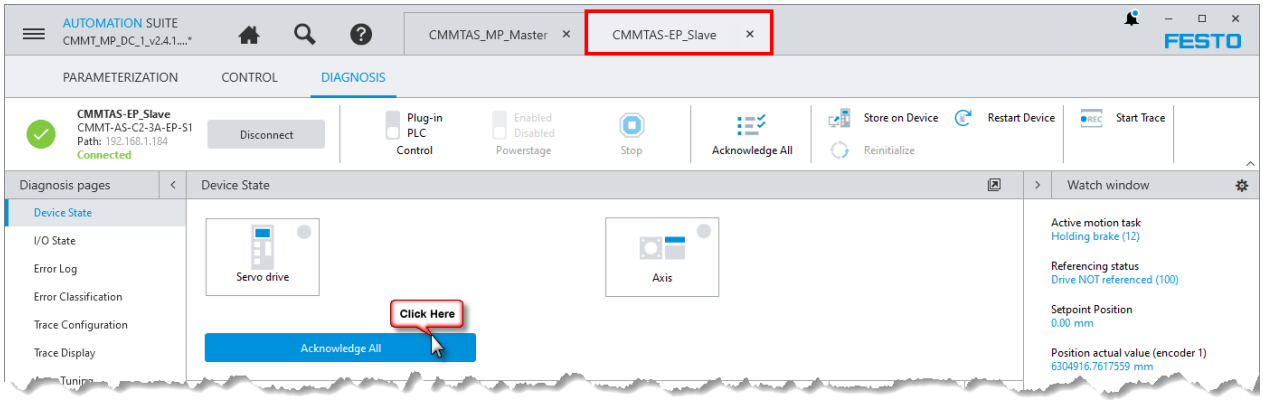
8.6 Master axis Acknowledge Faults

Go online with the CMMT Master axis and acknowledge any faults

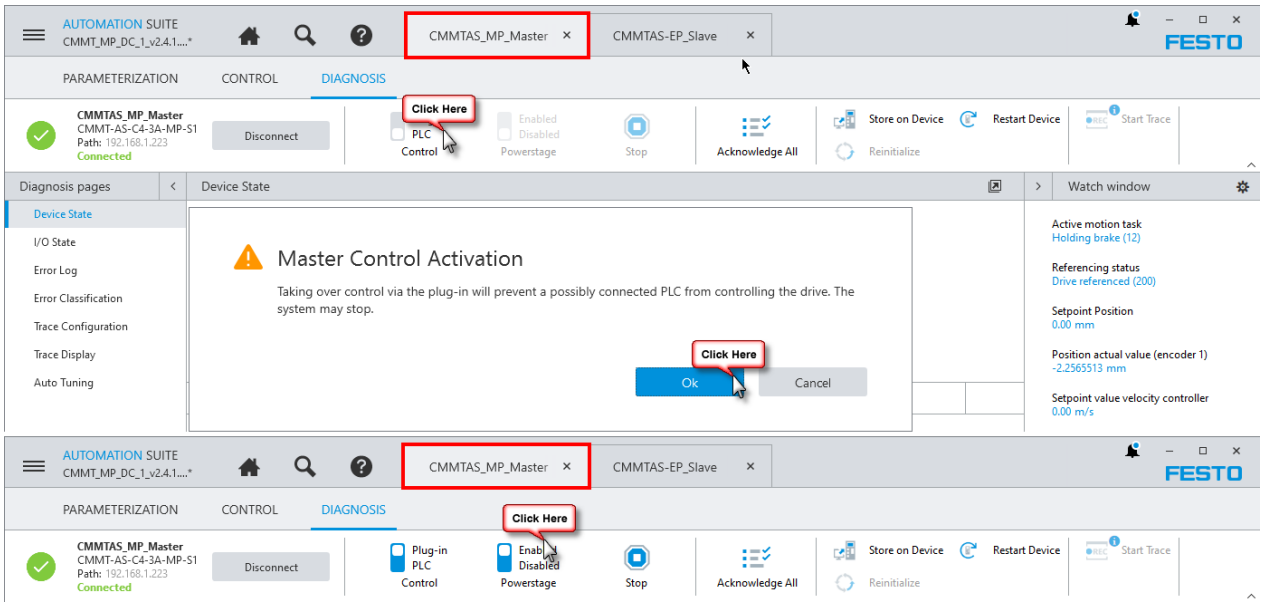


8.7 Slave axis Acknowledge Faults

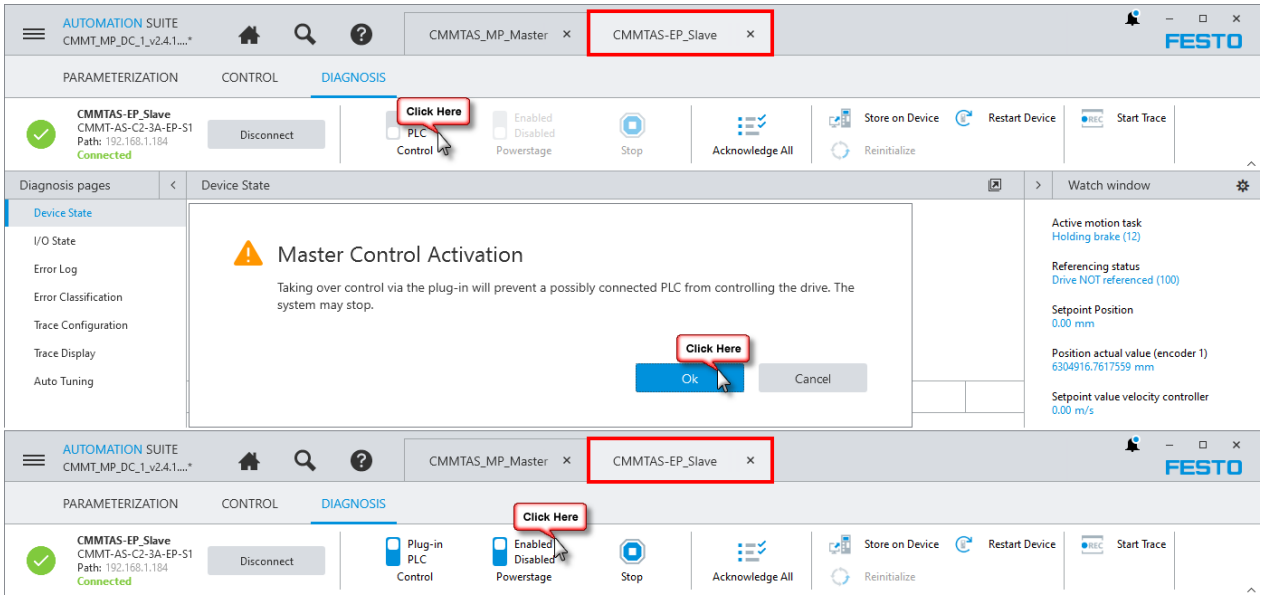
Go online with the CMMT Slave axis and acknowledge any faults



8.8 Master Enable Plug-in PLC Control and Powerstage

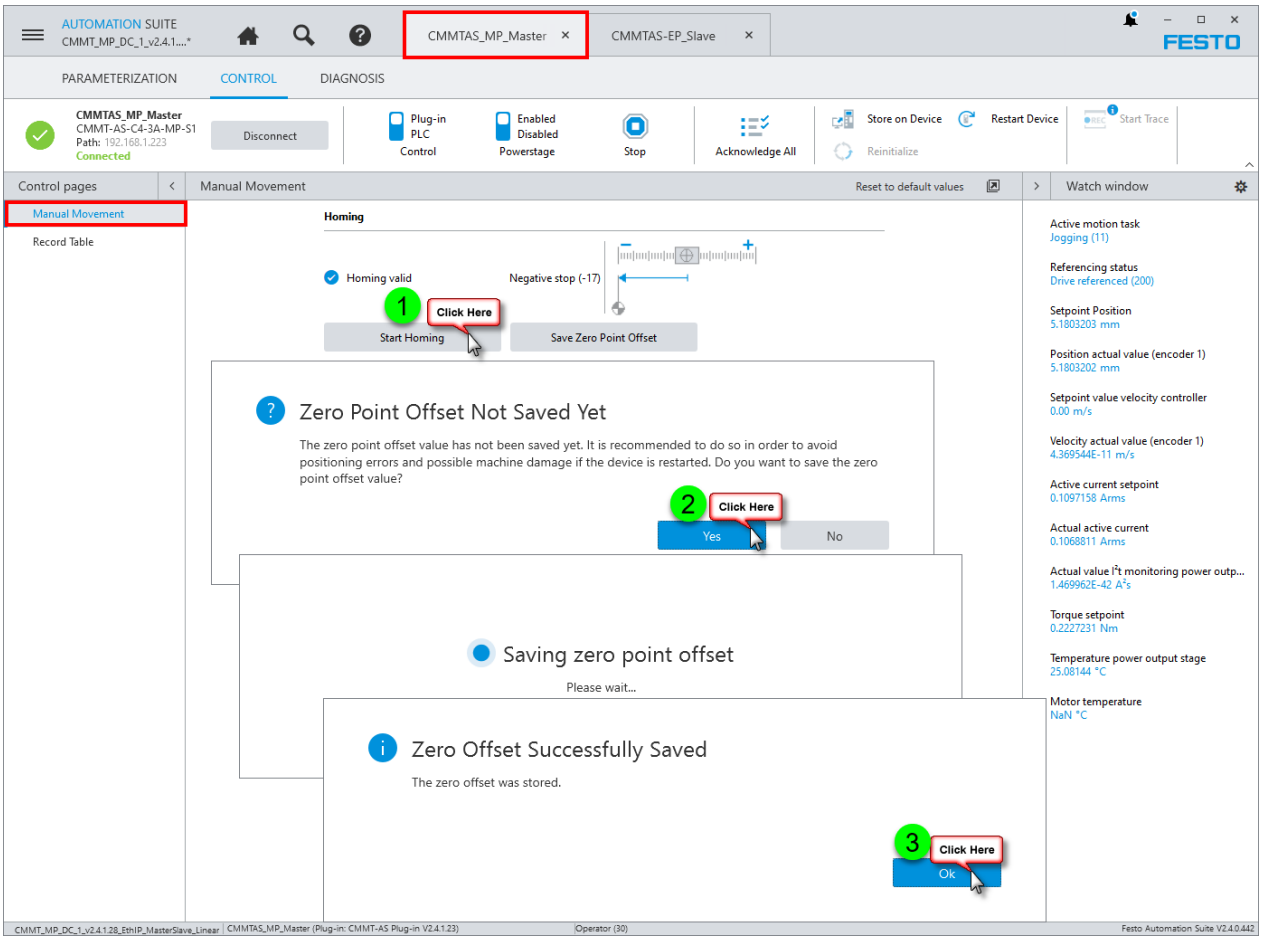


8.9 Slave Enable Plug-in PLC Control and Powerstage



8.10 Master Homing

As mentioned earlier, a different reference method may be required for the application.

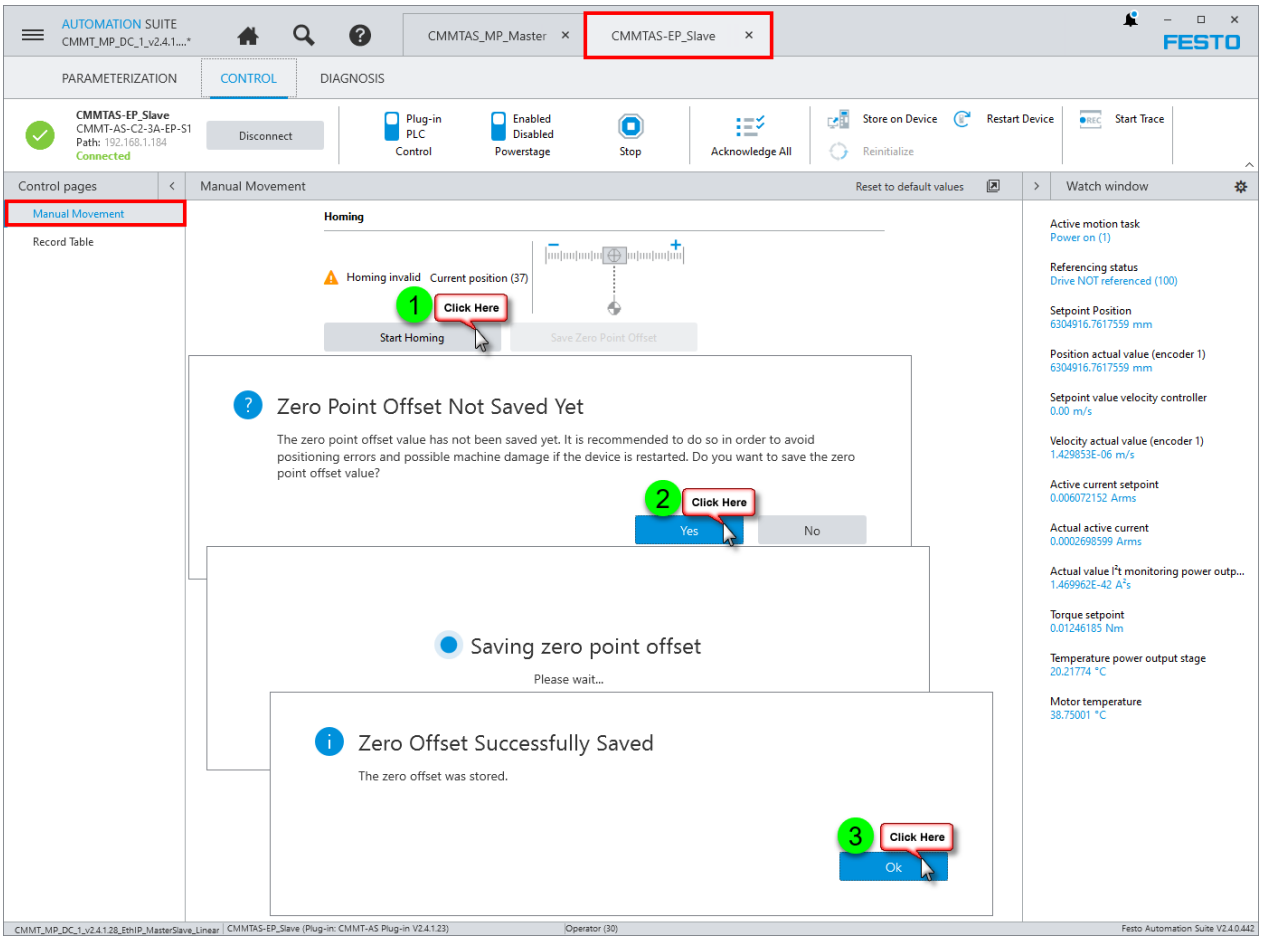


8.11 Master Slave Mechanical Alignment

Caution

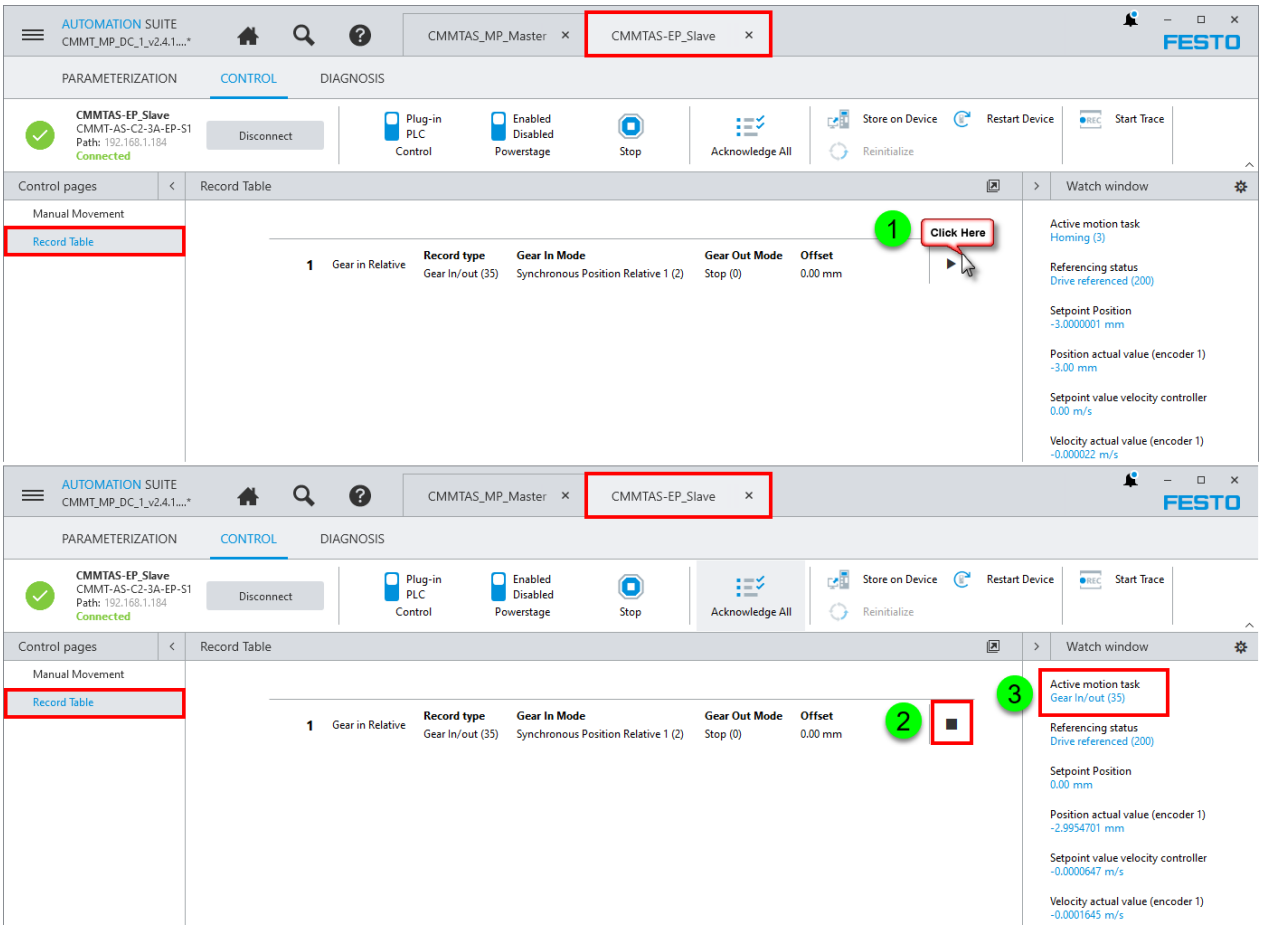
- At this point, the mechanical alignment between the Master and Slave axis should be carried out. Depending on the application, this may include moving the Master and Slave axes before or after they are enabled.
- Only after the Master and Slave axes have been aligned perfectly should the Slave axis now be referenced/homed and have the encoder position offset stored at their existing aligned positions!

8.12 Slave Homing

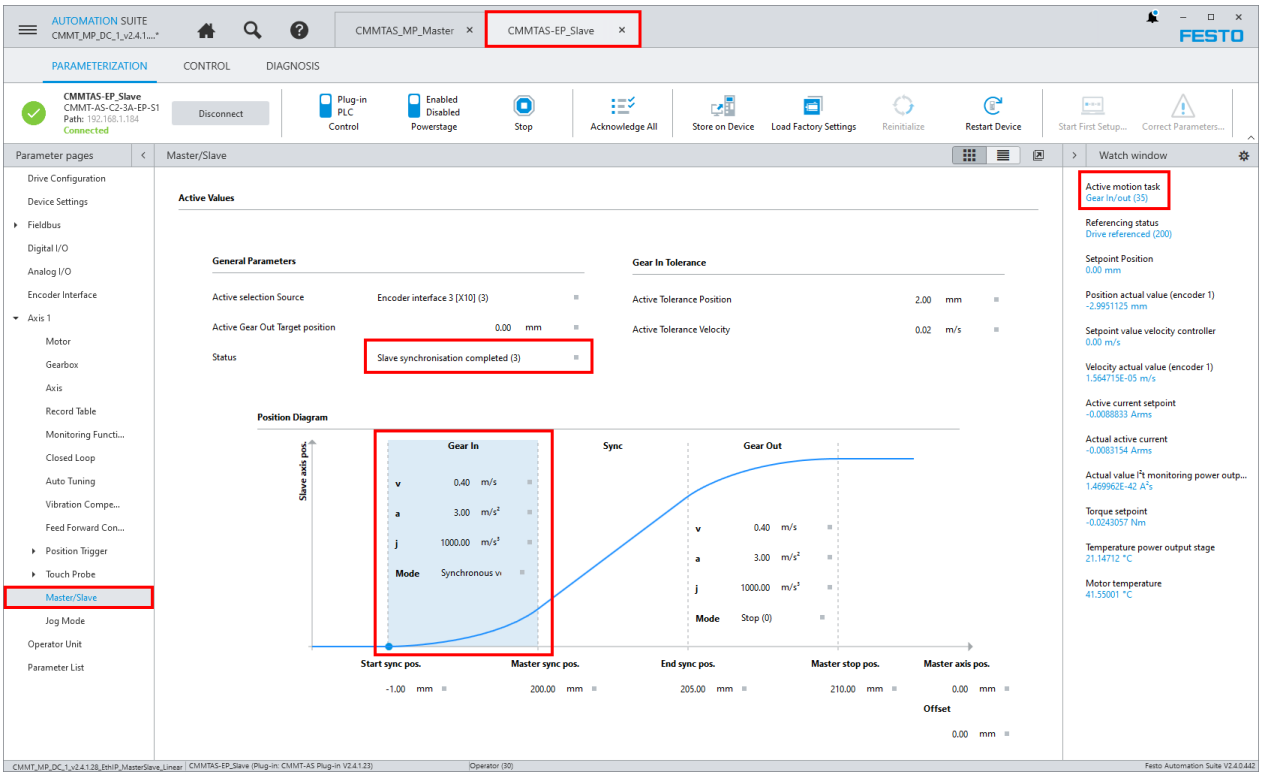


8.13 Slave Record Table

Execute the Record Table "Gear In Relative 1" move that was previously programmed



8.14 Slave Synchronisation is now Complete



9 Error Recovery

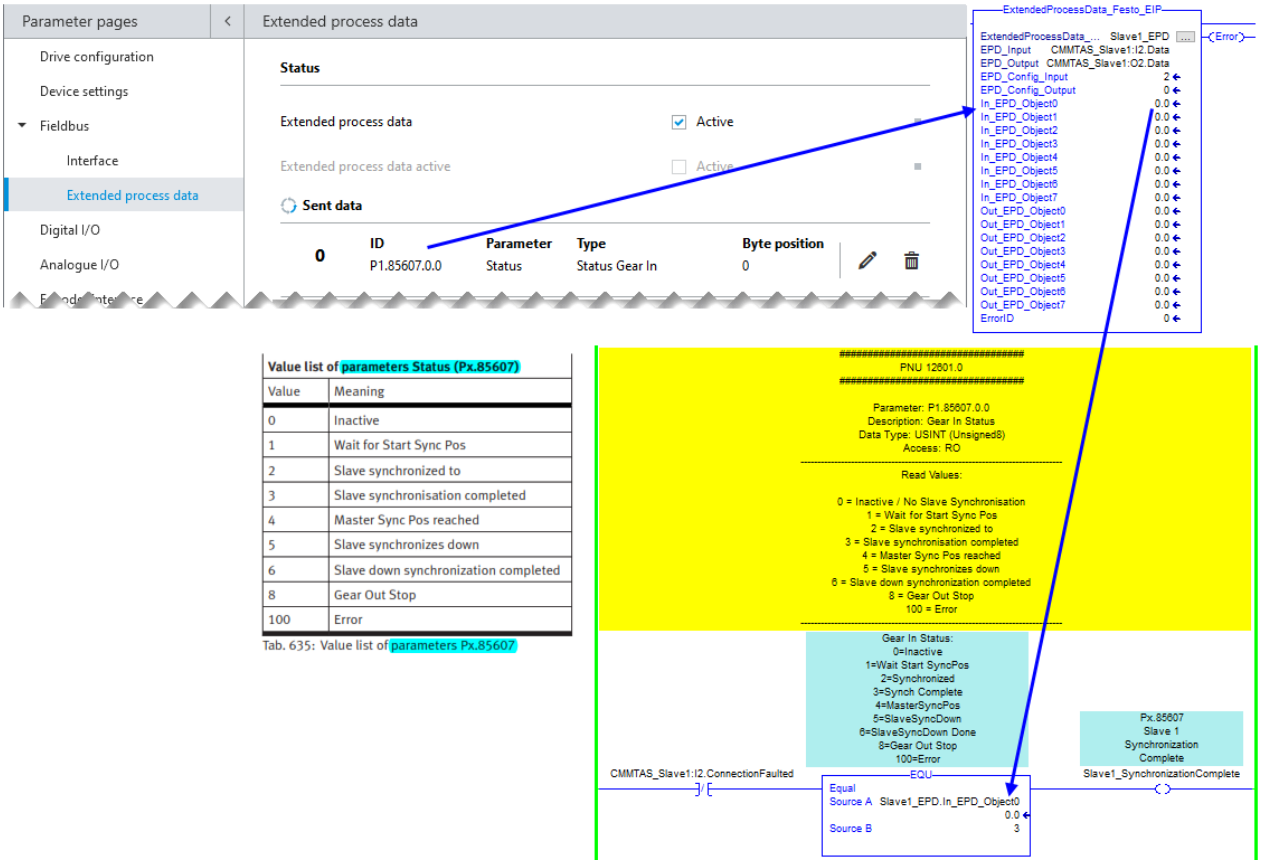
After each power off (example: after activation of STO or SBC or the CTRL-EN removed), the electronic alignment of the two axes is required.

The re-synchronisation is accomplished as follows:

1. Synchronisation is lost and both axis have stopped due to some situation.
2. The exact electronic alignment of the two axis is "likely" un-coupled by a small amount of position error.
3. Synchronisation is now required
4. All safeties and any other cause for the loss of synchronisation are restored and both the parallel axis are enabled.
5. The PLC (Programmable Logic Controller) reads the current setpoint or actual position (depends which is suited best for the application) of the master.
6. The PLC requests the Slave axis move to the same absolute position read from the Master and confirms movement is completed.
7. The PLC requests the Slave axis to execute the Record Type "Gear In/Out" Mode Synchronous Position Relative 1 (2).

		Record type	Gear In Mode	Gear Out Mode	Offset
1	Gear In Relative 1	Gear In/out (35)	Synchronous Position Relative 1 (2)	Stop (0)	0.00 r

8. To confirm Gear In / Slave Up synchronisation Completed (3) the user can read the parameter P1.85607.0.0. When the slave axis is within the position and velocity tolerance window and synchronised with the virtual master position, the value will be three. This can be done with a MSG instruction or via Extended Process Data (EPD) as shown here by example.



Value list of parameters Status (Px.85607)	
Value	Meaning
0	Inactive
1	Wait for Start Sync Pos
2	Slave synchronized to
3	Slave synchronisation completed
4	Master Sync Pos reached
5	Slave synchronizes down
6	Slave down synchronization completed
8	Gear Out Stop
100	Error

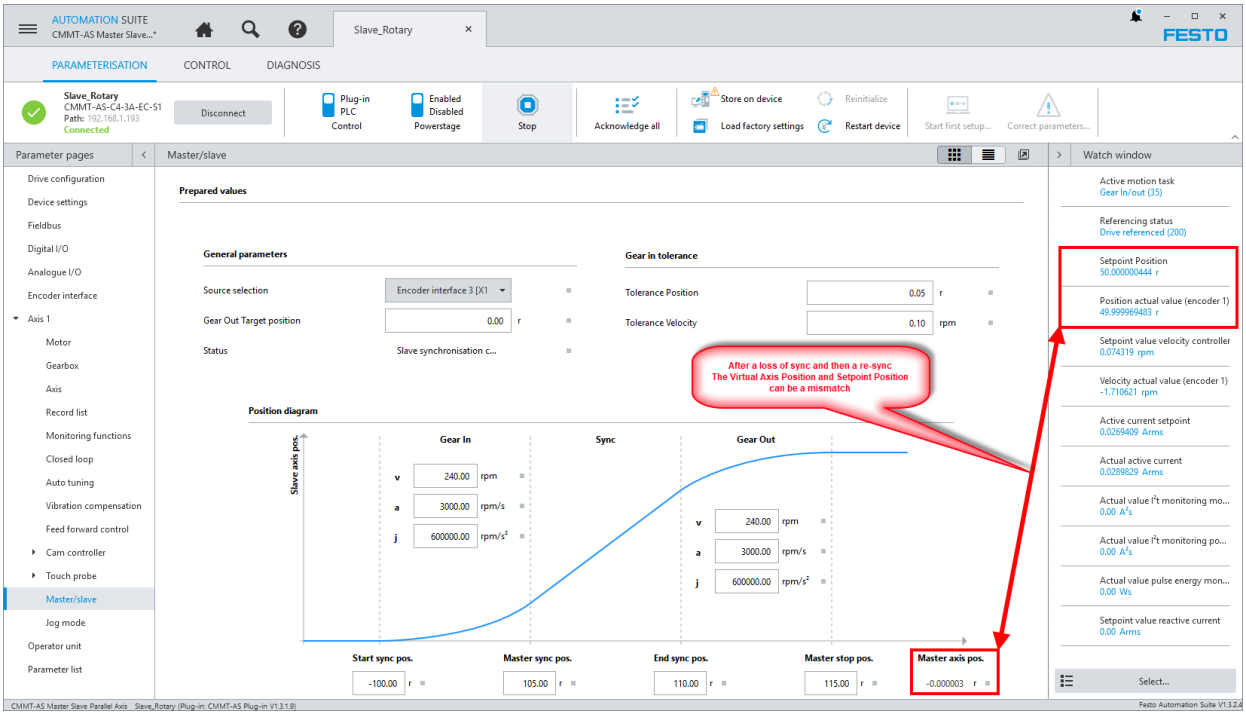
Tab. 635: Value list of parameters Px.85607

9. The electronic alignment of the two Parallel axis is now Completed
10. The PLC now goes back to monitoring the status and positions of both Master and Slave and reacts appropriately if errors or position errors are observed.

10 General Design Considerations

Caution

After a loss of sync and then a re-sync recovery, it is normal that the Master Axis Position (Virtual Master Position) and Setpoint or Actual Position are a mismatch.



Caution

Consider the possibility that the Emergency Stop electrical design which activates the STO or SBC or the CTRL-EN acts on the Master axis first so that the Slave axis can follow while the power stage is active. Then, after movement of the Master axis has halted (the slave following at all times with full power.