



Product	AMD	Type/Series	C2000	Appl. Note Nr.	Delta C2000
Issued by	DEN	Author	Marcel Dorti	Release Date	July , 2016
Title	Positioning with C2000 and S7 Siemens in Profibus-DP				

Devices and special tools/equipment

- ✓ Delta C2000 + motor + encoder
- ✓ EMC-PG01 - Encoder Card
- ✓ S7-1500 with Profibus fw. 1.8 on – if lower, upgrade.
- ✓ TIA PORTAL V12/V13
- ✓ Profibus DP cable with connectors and resistors

Test setup
N/A

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1 Introduction

Positioning is one of the main applications of Drive Technologies and motion control, the necessity of positioning in industrial applications is quite wide, there are many applications where positioning could be applied, a process machine valve, a conveyor, the thread of a ball-screw, a lifter, a drilling machine pattern, a driving cart through an assembly line. Precise positioning (tenths of millimeters for CNC for example) takes into account many other factors and are driven by Servo-controllers like the Delta ASD family servo-drives, however C2000 can be used for a variety of positioning functions with all robustness of a power drive for non-precise application where millimeters or less are not a problem. In this application we are going to learn how to set a drive system with C2000 for positioning, and how to transfer a position setpoint using Profibus-DP from a S7-Siemens PLC with TIA PORTAL.

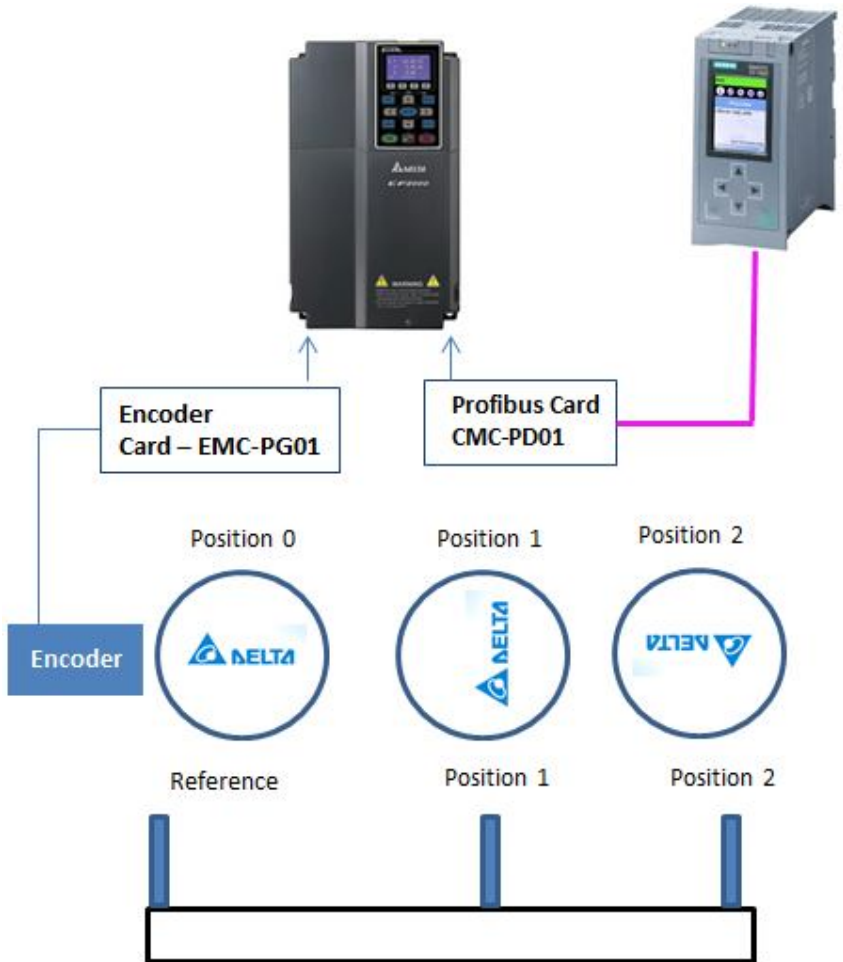


Figure 1 – Positioning system including C2000 with Encoder Card and Profibus Card, S7 1500 and Profibus Network

2 Connecting Hardware

To be able to work with positioning, you will need to install the encoder card EMC-PG01 and the Profibus-DP card CMP-01. Be sure to connect the Ground (GND) of the encoder card on the general GND, otherwise you may have encoder fault problems.



Figure 2 – C2000 with encoder card and Profibus card with no active Master in the system

3 Encoder hardware setting

Terminal description

Set by Pr.10-00~10-02, 10-16~10-18

Terminals		Descriptions
PG1	VP	Output voltage for power: +5V/+12V±5% (use FSW3 to switch +5V/+12V) Max. output current: 200mA
	DCM	Common for power and signal
	A1, /A1, B1, /B1, Z1, /Z1	Encoder input signal (Line Driver or Open Collector) Open Collector input voltage: +5~+24V (Note 1) It can be 1-phase or 2-phase input. EMC-PG01L: Max. input frequency: 300kHz EMC-PG02L: Max. input frequency: 30kHz(Note 2)
PG2	A2, /A2, B2, /B2	Pulse Input signal (Line Driver or Open Collector) Open Collector input voltage: +5~+24V (Note1) It can be 1-phase or 2-phase input. EMC-PG01L: Max. input frequency: 300kHz EMC-PG02L: Max. input frequency: 30kHz(Note 2)
PG OUT	AO, /AO, BO, /BO, ZO, /ZO, SG,	PG Card Output signals. It has division frequency function: 1~255 times Max. output voltage for Line driver: 5VDC Max. output current: 50mA EMC-PG01L Max. output frequency: 300kHz EMC-PG02L Max. output frequency: 30kHz SG is the GND of PG card. It is also the GND of position machine or PLC to make the ouput signal to be the common pivot point.

Figure 3 - Terminal description of Encoder Card EMC-PG01U

If you are using a Delta encoder embedded in a Delta permanent magnet motor (PM), PG1 will be enough for your configuration, just set **the correct voltage** to supply the encoder and connect the basic pins of an encoder: A1, A1/, A2, A2/ Z and Z/. VP (supply) and DMC (Signal GND). You will be able to see the green leds and the tracks flash when you spin the encoder axle.

If you are using other kinds of encoder, take further reading in C2000 manual in order to find more about the encoder connection with open collector pull-up resistors must be added, so take a look at chapter 3 of C2000 manual.

Naturally, setting the correct encoder for the proper application is fundamental for correct positioning. If your application requires fast response, check encoder frequency in order to be compatible with the sampling rate of the EMC-PG01 card.

4 Parameters for encoder and Profibus configuration

In order to use the encoder properly and as position reference, you will need to set some parameters in menu **10 – Speed Feedback**.

- ✓ **10 – 00:** Encoder type – Select your encoder type, = 1 to regular **ABZ HTL/TTL** encoders, 2 to Delta encoders, 3 to Resolvers, 4 for pulse encoders, and 5 for MI8 frequency input. If you are using a regular ABZ HTL/TTL encoder, please, make 10 – 00 = 1.
- ✓ **10 – 01:** Number of pulses per revolution of the encoder, i.e. 1024, 2048 ppr.
- ✓ **10 – 02:** Encoder signal: From tracks A and B, who leads encoder to **CW** or **CCW** direction, this is an important encoder information: Take a look at parameter 10-02 in C2000 manual to find more about the types of encoder signal. In this application note, =1 was used.

Table 1 - Important parameters for C2000 encoder setting

10-00	Type of encoder
10-01	PPR of the encoder
10-02	Encoder type of signal

For Profibus setting, you need to go to menu **09 – Communication**

In order to make possible the connection between the S7 Profibus master, some parameters must be set:

- ✓ **09 – 70 = 3** (address of the slave)
- ✓ **00 – 20 = 8** (Set frequency from Communication card CMP-PD01)
- ✓ **00 – 21 = 5** (Command from Communication card CMP-PD01)
- ✓ **11 – 40 = 5** (Position command comes from Communication card CMP-PD01)
- ✓ **09 – 30 = 1** (60XX coding)

Table 2 - Important parameters for Profibus-DP setting

9-70	Profibus Address
00-20	Frequency Source
00-21	Operation source
11-40	Position source
09-30	60XX coding

5 Setting the motor configuration

Even though PM motors are more indicated for positioning tasks, you can use either a PM or an IM motor in order to perform it.

For **IM motors**, use the following configuration taken from the Quickstart Manual:

Induction Motor (IM) for FOC+PG

Use the following steps:

1. Install the drive and connect mains power and the motor.
2. Set Pr00-02=9 (50Hz defaults) or 10 (60Hz defaults).
3. Set Pr01-00 (Max freq), Pr01-01 (Base freq) and Pr01-02 (Base voltage) acc. to motor name plate.
4. Set Pr05-01. IM Motor rated current acc. motor name plate.
5. Set Pr05-02. IM Motor rated power acc. motor name plate.
6. Set Pr05-03. IM Motor rated speed acc. motor name plate.
7. Set Pr05-04. IM Motor #poles acc. motor name plate.

8. With rotating unloaded motor:

Set Pr05-00=1 and press RUN for dynamic auto-tuning with **rotating** motor.

Check Pr05-05 (IM No-load current), Pr05-06 (IM Stator resistance), Pr05-07 (IM Rotor resistance), Pr05-08 (IM Lm) and Pr05-09 (IM Lx).

With non-rotating loaded motor (to be used when motor load cannot be decoupled from the shaft):

Set Pr05-00=2 and press RUN for static auto-tuning with **non-rotating** motor.

Check Pr05-06 (IM Stator resistance), Pr05-07 (IM Rotor resistance), Pr05-08 (IM Lm) and Pr05-09 (IM Lx).

Enter the no-load current in Pr05-05 (IM No-load current) manually.

9. Power off and install the encoder card and connect the encoder (PG) to PG1 channel. Power on.
10. Set Pr10-00=1 (ABZ incremental encoder)
11. Set Pr10-01 acc. to the encoder ppr.
12. Set Pr10-02=1 or 2, depending on the encoder direction of rotation.
13. Set Pr00-11=3 for FOCPG mode.
14. Press to RUN the motor. If there's a fault message PGFx, check the encoder wiring and change Pr10-02=2.
15. Inertia tuning:

First with unloaded motor:

- Pr11-00=2
- Set speed command to $\frac{2}{3}$ of motor rated speed acc. to Pr05-03.
- Set acc. time Pr01-12=1~1.5s and dec. time Pr01-13=1~1.5s.
- Rotate the motor FWD and REv subsequently until Pr11-01 is stable. Press RUN . Pr11-00 will be 0 again.

Then with loaded motor:

- Pr11-00=2

- Set speed command to $\frac{2}{3}$ of motor rated speed acc. to Pr05-03.
- Set acc. time Pr01-12=1~1.5s and dec. time Pr01-13=1~1.5s.
- Rotate the motor FWD and REV subsequently until Pr11-01 is stable. Press RUN . Pr11-00 will be 0 again.

If needed, the inertia value can be entered manually in Pr11-01.

16. ASR bandwidth (ASR=Automatic Speed Regulation)

Automatic bandwidth setting:

Pr11-00=1 (or odd): Set Pr11-02 to Pr11-05.

Manual bandwidth setting:

Pr11-00=0 (or even): Set Pr11-06 to Pr11-11.

Permanent Magnet motor (PMFOC+PG)

Use the following steps:

1. Install the drive with option card EMC-PG01U and connect mains power and the motor, in this case ECMA.

See Chapter 5 and 6. Power on.

2. Set Pr00-02=9 (50Hz defaults) or 10 (60Hz defaults).

3. Set Pr01-00 (Max freq), Pr01-01 (Base freq) and Pr01-02 (Base voltage) acc. to motor name plate.

4. Set Pr05-33=1 to select PM motor.

5. Set Pr05-34. PM Motor rated current acc. motor name plate.

6. Set Pr05-35. PM Motor rated power acc. motor name plate.

7. Set Pr05-36. PM Motor rated speed acc. motor name plate.

8. Set Pr05-37. PM Motor #poles acc. motor name plate.

9. Set Pr05-38. PM Motor inertia.

10. Set Pr05-00=5 and press RUN for dynamic auto-tuning with **rotating** motor.

Check Pr05-39 (PM Stator resistance), Pr05-40 (PM Ld), Pr05-41 (PM Lq) and Pr05-43 (PM Ke).

11. Set Pr10-00=2 (ABZ Delta encoder)

12. Set Pr10-01 acc. to the encoder ppr.

13. Set Pr10-02=1 or 2, depending on the encoder direction of rotation.

Set Pr05-00=4 for magnetic angle detection which is set in Pr05-42. Press RUN

In case of PGFx error, change Pr10-01.

In case the motor runs in the wrong direction, switch 2 phases in UVW to the motor.

For Delta ECMA motor Pr05-42=0° or 360° and can be set directly.

15. Set Pr00-11=4 for PM FOCPG mode.

16. Power off/on.

17. Inertia tuning with unloaded motor:

- Pr11-00=2

- Set speed command to $\frac{2}{3}$ of motor rated speed acc. to Pr05-03.

- Set acc. time Pr01-12=1~1.5s and dec. time Pr01-13=1~1.5s.

- Rotate the motor FWD and REV subsequently until Pr11-01 is stable. Press RUN. Pr11-00 will be 0 again.

18. ASR bandwidth (ASR=Automatic Speed Regulation)

Automatic bandwidth setting:

Pr11-00=1 (or odd): Set Pr11-02 to Pr11-05.

Manual bandwidth setting:

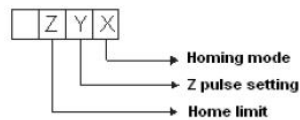
Pr11-00=0 (or even): Set Pr11-06 to Pr11-11.

Now with the Motor tuned we can start our new configuration of the positioning.

6 Homing

Incremental encoders do not keep the track of the encoder position, every time they are powered off and on again, they must be referenced to a local 0 point in their rotary movement. The process of finding this external reference sensor and set its position to zero is called **Homing**. You have to define 3 MI to do homing, one for a PL (Positive Limit), one for NL (Negative Limit) and one for ORG (Origin), which is the 0, the reference of the positioning.

Homing should be always monitored in any kind of machine, if the machine loses its reference point, positioning may damage mechanical limits. The C2000 manual contains all graphs of position x speed for homing (listed in Figure). There are many ways of setting how homing is performed on parameters: **00-40**: Homing mode:



Note: Forward run = clockwise (CW)
Reverse run = counterclockwise (CCW)

- X**
- 0: Forward run to home. Set PL forward limit as check point.
 - 1: Reverse run (CCW) to home. Set NL reverse limit (CCWL) as check point.
 - 2: Forward run to home. Set ORG : OFF→ON as check point.
 - 3: Reverse to home. Set ORG : OFF→ON as check point.
 - 4: Forward run and search for Z-pulse as check point.
 - 5: Forward run and search for Z-pulse as check point.
 - 6: Forward run to home. Set ORG: ON→OFF as check point.
 - 7: Reverse run to home. Set ORG : ON→OFF as check point.
 - 8: Define current position as home.
- Y**
- Set X to 0, 1, 2, 3, 6, 7 .
 - 0: reverse run to Z pulse
 - 1: continue forward run to Z pulse
 - 2: Ignore Z pulse
- Z**
- When home limit is reached, set X to 2, 3, 4, 5, 6, 7 first.
 - 0: display error
 - 1: reverse the direction

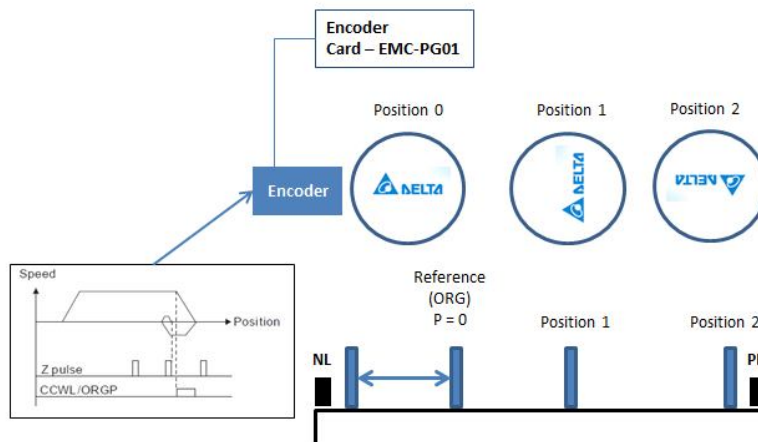


Figure 4 - Homing position x speed diagram, Y=0, X=0 or Y=0, X=2. . The 0 is set on the previous Z track of the encoder.
The 0 is set on the previous Z track position of the encoder

Table 3 - Important Parameters for Homing

00-40	Homing Mode
00-41	Low speed of Homing
00-42	High speed of Homing
02-01	=45 - PL Limit Switch
02-02	=44 - NL Limit Switch
02-03	=45 - ORG point

You can also enable a digital input MI (=47) and 00-10 =3 to start the homing activity, however, we are going to do this through a PLC command, and if your MI is set to 47 it may not work properly. When testing homing, do it in low speed, and once you can get it set, you can increase homing speed.

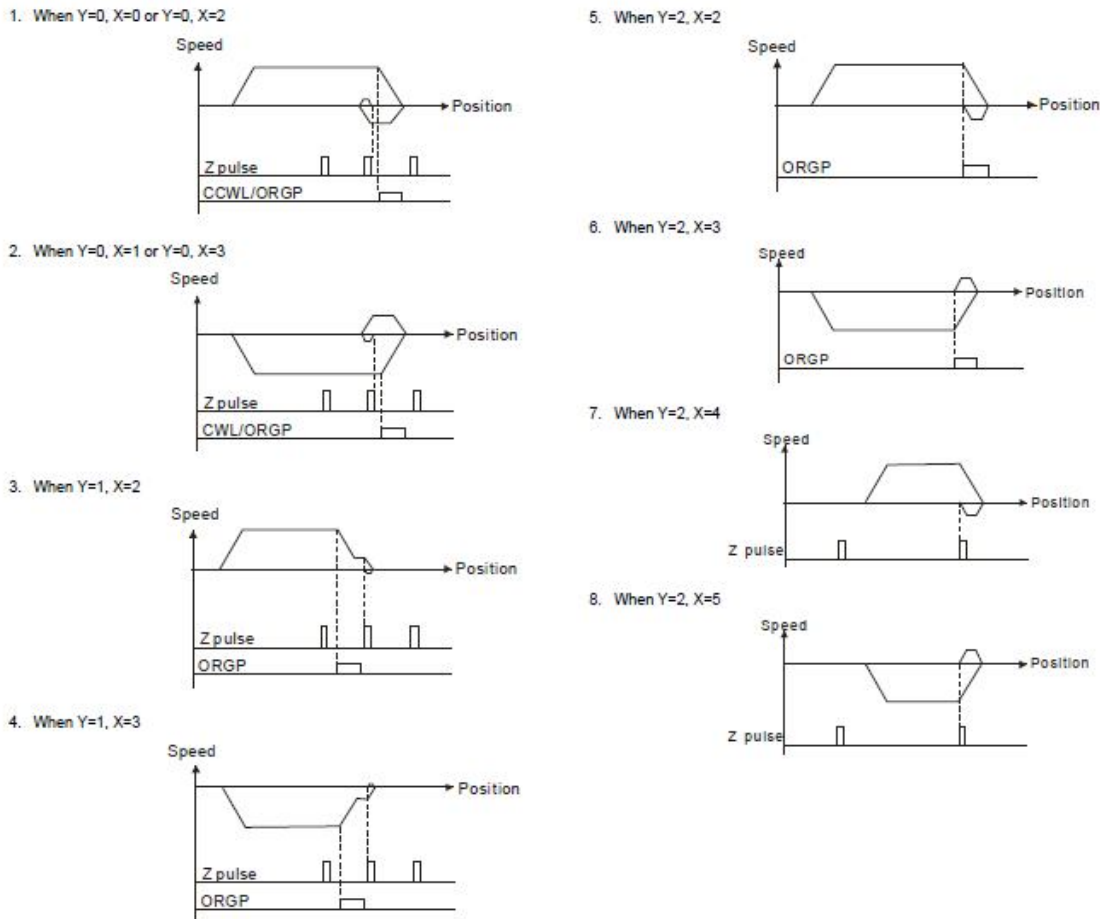


Figure 5 - Homing modes

7 Positioning

Besides a good tuning of the motor, and after homing is performed successfully. Positioning requires simply 4 things:

- ✓ Change the drive to position mode (P2P)
- ✓ Define relative or absolute positioning
- ✓ Define a position command
- ✓ Monitor the position command

These will be controlled via PLC, however, you should know those important parameters for positioning on Delta C2000.

Table 4 - Important parameters for Positioning

00-10	Control Method
00-12	P2P Position mode
11-40	Source of Positioning

11-40 Source of Positioning must be set to **5** – COMM CARD if you want to receive the position from a PLC through Profibus-DP. You can also use MI inputs to perform positioning, 11-40 = 0, and define MI inputs to position command.

The positioning reference unit in Delta C2000 are the number of your encoder pulses, (ppr) and the number of counts per revolution (cpr). Every turn of the motor completes the a number of counts (A,B,Z) and also pulses. In fact, we should consider, then the number of counts per revolution, which is the number of revolutions i.e. $2500 \times 4 = 10\ 000$, so every turn of a 2500 ABZ ppr encoder will carry 10 000 counts (count of A, B tracks).

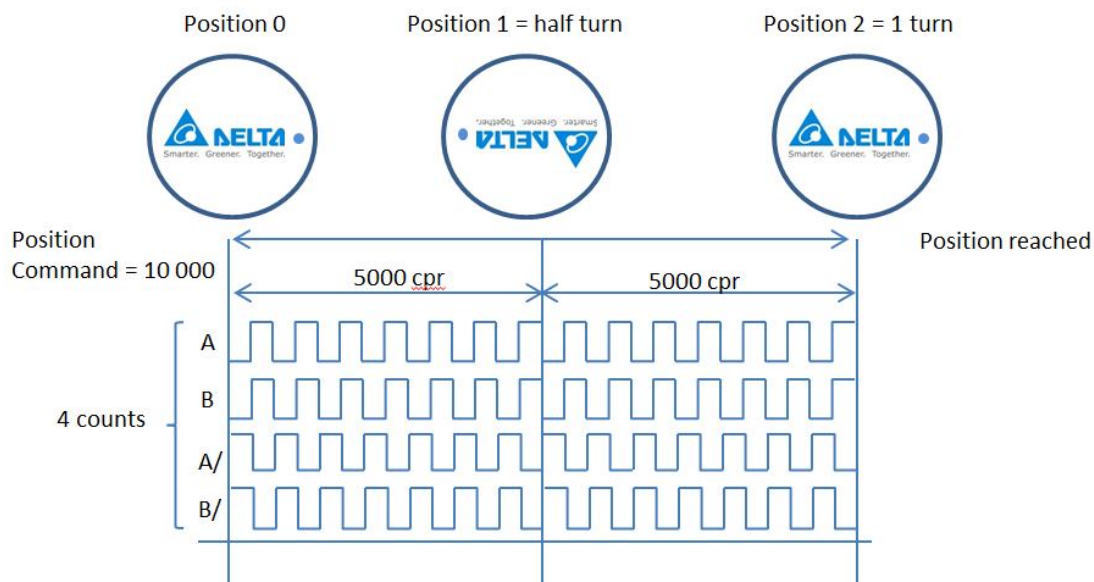


Figure 6 - Position diagram with one 2500 ppr encoder, $2500 \times 4 = 10\ 000$ counts, 1 turn.

When using a PLC, like in this application note, this is the command you will have to send through the Profibus PZD address memory. You can also use a fast frequency input for the positioning such as M18 and static commands for fixed positions, however those will not be covered in this application note. The pulses sent to the position command will **always** rely on the number of your encoder pulses.

If you have 1024 encoder, that will $1024 \times 4 = 4096$ will be your value for 1 turn, and naturally you should multiply this number for the number of turns you need the positioning command to follow. This way you can set position number based on the encoder pulses, which may give you a very precise way to place the rotor position.

8 Setting the Profibus-DP Hardware configuration

Open TIA PORTAL, open a new project, recognize CPU and general hardware topology and insert Delta C2000 .gsd file into the hardware configuration.

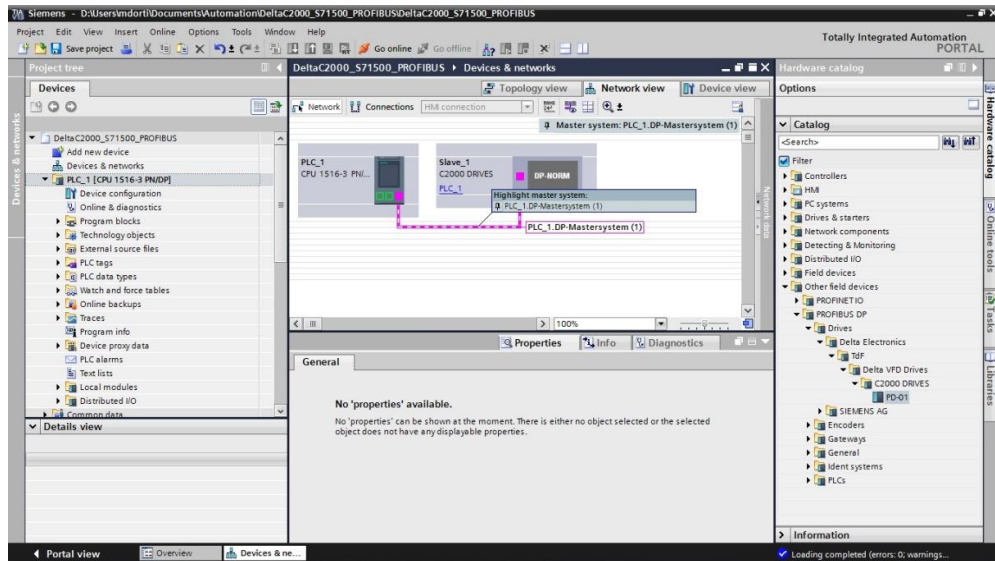


Figure 7 - Initial configuration of Hardware Setup with C2000

Double click on device configuration C2000 -> Device view -> Double click on Delta C2000 icon to open general hardware properties. Set the proper registers in decimal for **control word**, **mode selection** and **positioning double word**.

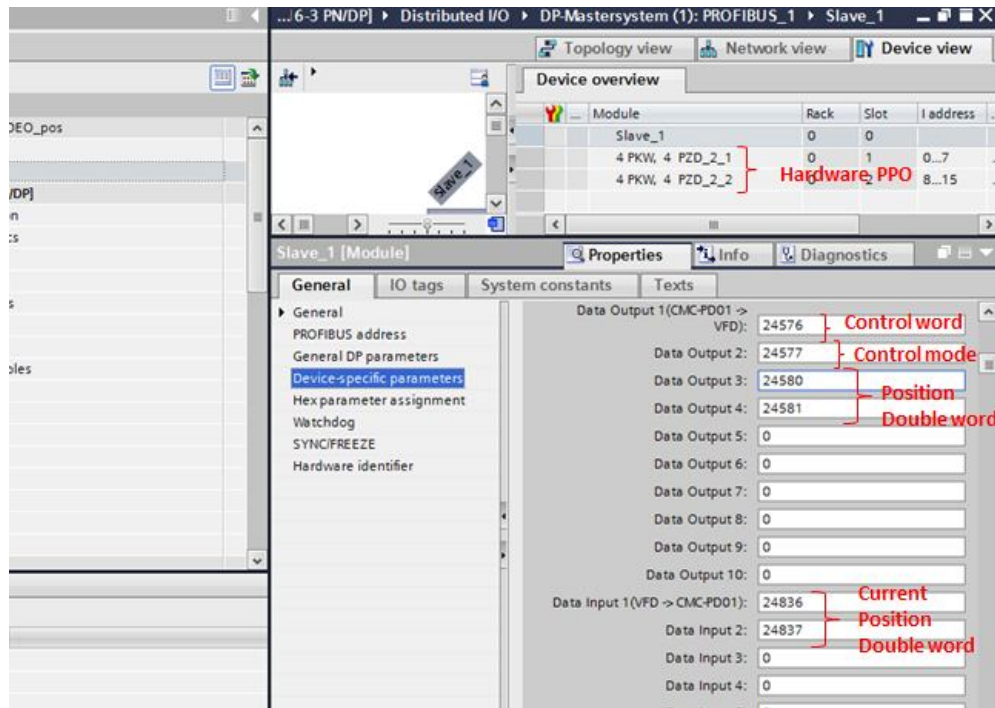


Figure 8 - Device general parameters – Positioning (Data sent TO / FROM THE drive)

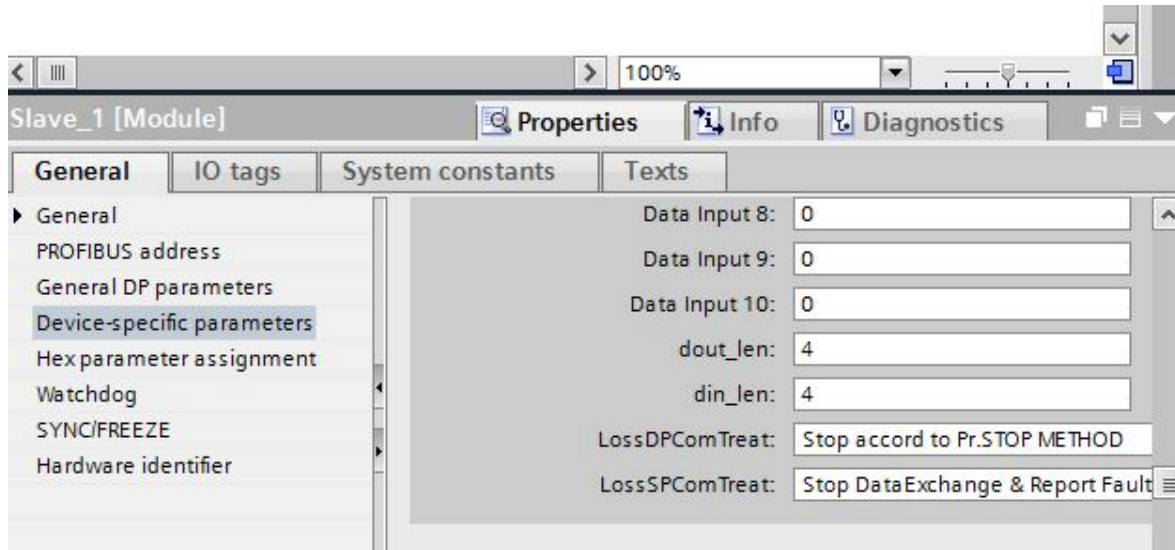


Figure 9 - Be sure to set dout_len and din_len to 4. According to the PZD PPO set

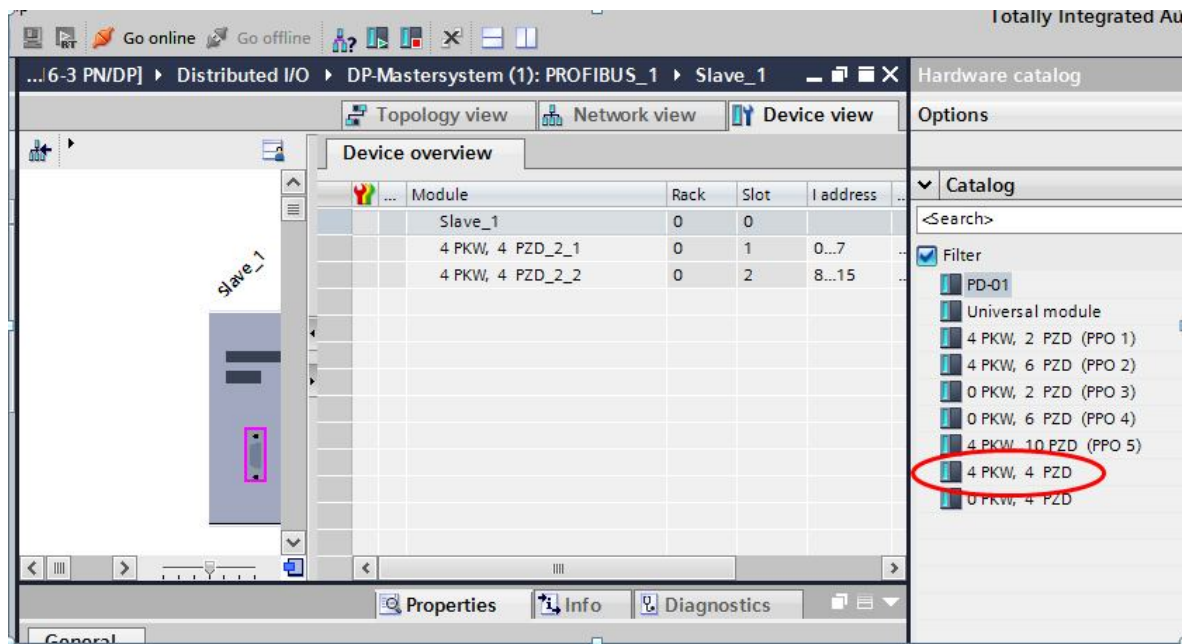


Figure 10 - Set the PPO on the Device view, double click on 4 PKW_4 PZD

Table 5 - Addresses of the registers for positioning and function

Dec	hex	Description
24576	6000	Control word
24577	6001	P2P Mode
24580	6004	Position command word 1
24581	6005	Position command word 2
24836	6104	Actual position word 1
24837	6105	Actual position word 2

9 Programming the blocks and OB1

Now it is time to finally send a position command from the CPU to Delta C2000 through Profibus, set a new tag table with the following tags.

Tag table_1				
	Name	Data type	Address	R
	1WORD_SND	Word	%MW20	
	2WORD_SND	Word	%MW22	
	3DWORD_SND	DWord	%MD24	
	4WORD_SND	Word	%MW26	
	1DWORD_RCV	DWord	%MD40	
	3WORD_RCV	Word	%MW44	
	4WORD_RCV	Word	%MW46	
	Error_SND	Word	%MW50	
	Error_RCV	Word	%MW52	
0	1WORD_INPUT	Word	%MW60	
1	2WORD_INPUT	Word	%MW62	
2	3DWORD_INPUT	DWord	%MD64	
3	SND/RCV_DATA_ON/OFF	Bool	%M70.0	
4	<Add new>			

Figure 11 - Tags for positioning with C2000

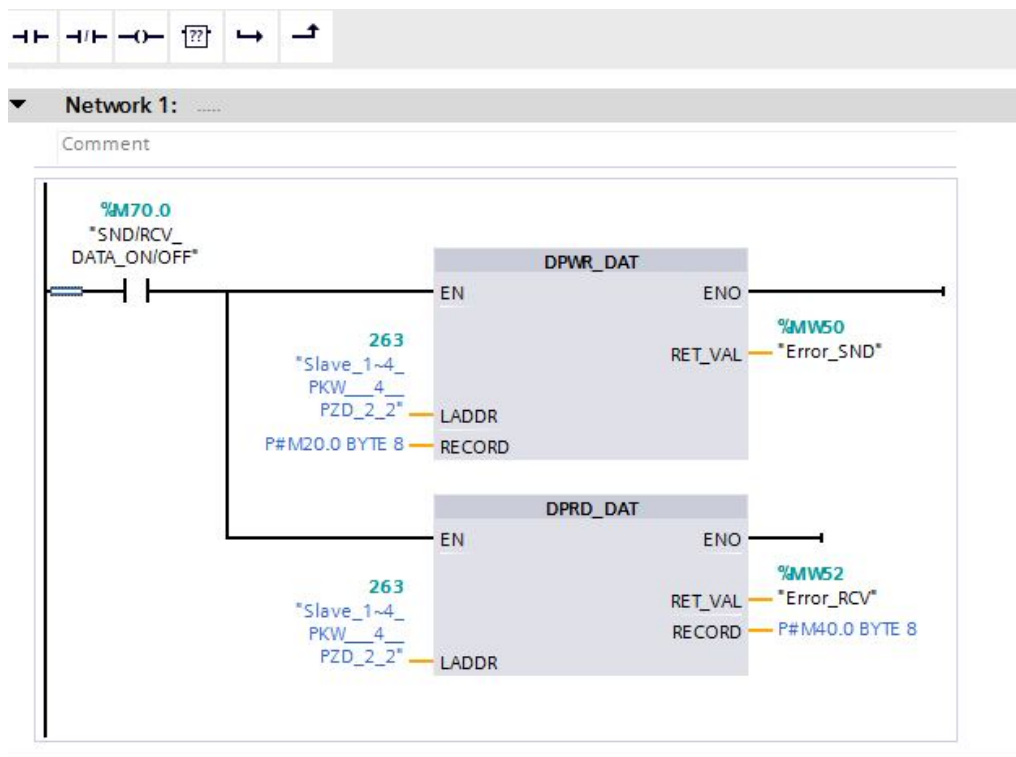


Figure 12 - Set DPWR_DAT and DPRD_DAT instructions like in the picture, find them in

Extended Communications -> Distributed IO -> Others

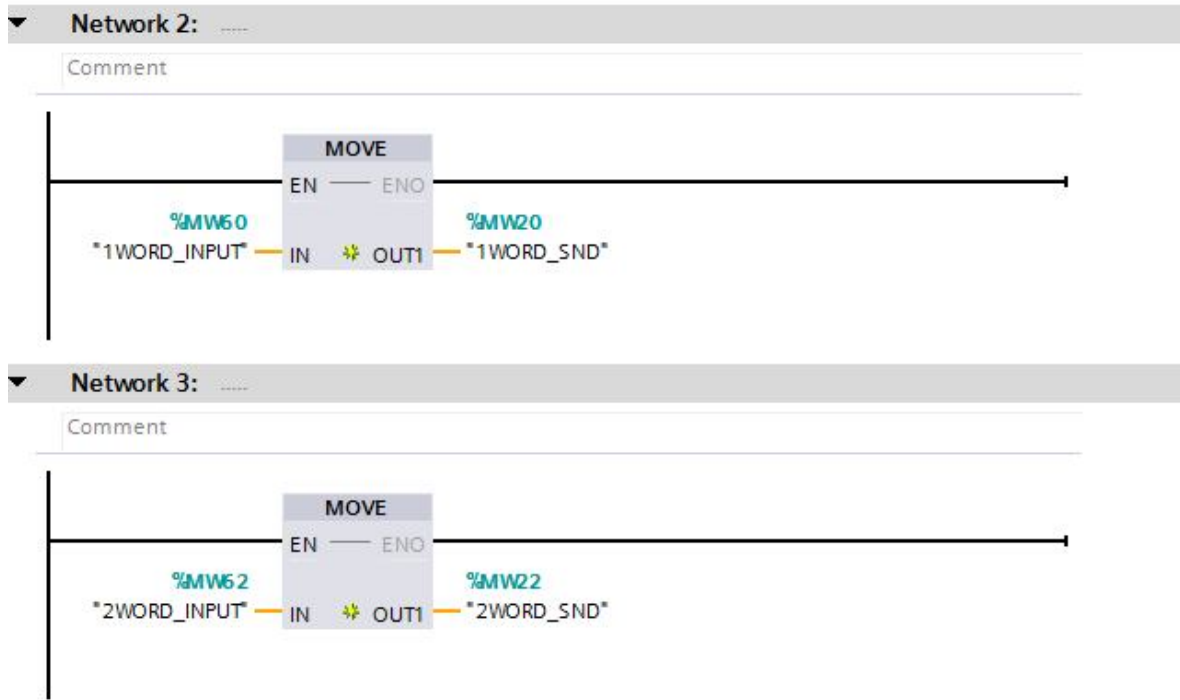


Figure 13 - Insert Network 2 and Network 3

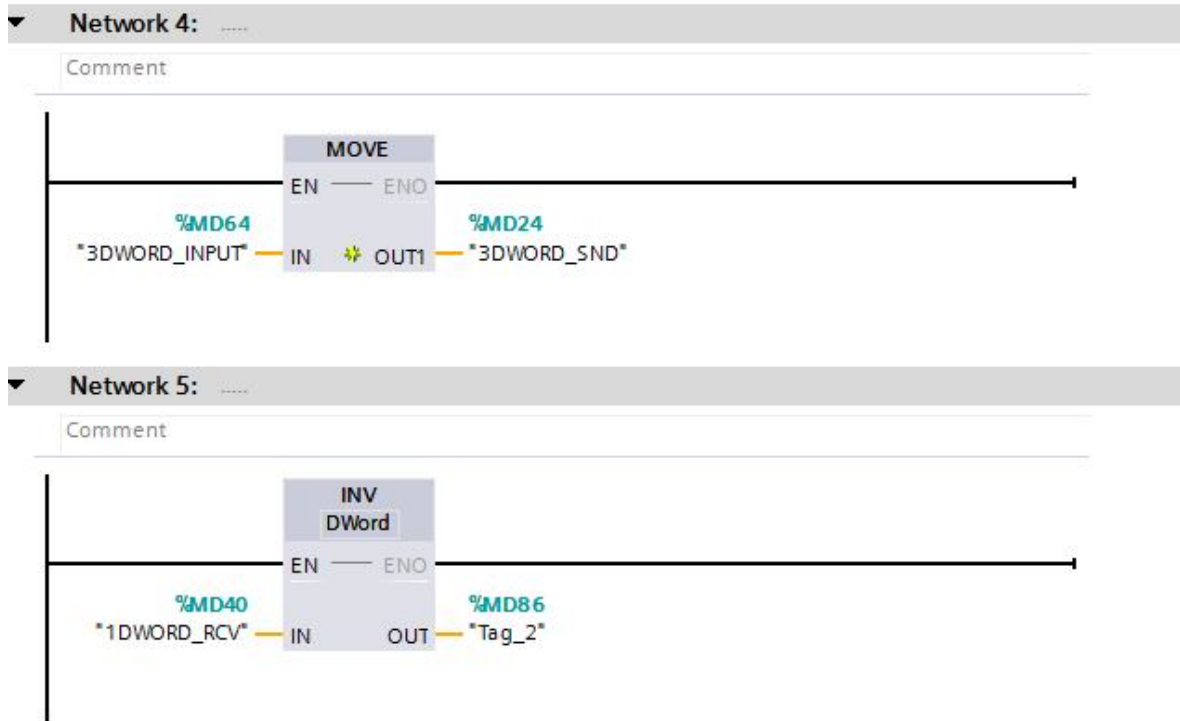


Figure 14 - Insert Network 4 and 5

10 Testing positioning with a Watch Table

Go to PLC tags again and copy the tag_list (Ctrl +C), open a new watch table and paste it there (Ctrl+V), this way you will be able to monitor all the words which go to Delta C2000 and the data which comes from it.



	Name	Address	Display format	Monitor value	Modify value
1	*1WORD_SND*	%MW20	Hex		
2	*2WORD_SND*	%MW22	Hex		
3	*3DWORD_SND*	%MD24	Hex		
4	*1DWORD_RCV*	%MD40	Hex		
5		%MW40	Hex		
6		%MW41	Hex		
7		%MW42	Hex		
8		%MW43	Hex		
9	*3WORD_RCV*	%MW44	DEC		
10	*4WORD_RCV*	%MW46	DEC		
11	*Error_SND*	%MW50	Hex		
12	*Error_RCV*	%MW52	Hex		
13	*1WORD_INPUT*	%MW60	Hex		16#0081
14	*2WORD_INPUT*	%MW62	Hex		16#0003
15	*3DWORD_INPUT*	%MD64	Hex		16#5EDF_FFF8
16	*SND/RCV_DATA_O...	%M70.0	Bool		
17	*4WORD_SND*	%MW26	Hex		

Figure 15 - Watch table to be monitored, you can modify and read values from the words here

Homing via Profibus-DP

Insert in the 1WORD_INPUT, in hex the number **16#0080** (Control word), and then on 2WORD_INPUT 16#0003 (Homing mode), then set 1WORD_INPUT to **16#0081**. Click on the thunder to modify values every time you change a value on the control word. Then the motor will start spinning searching for the ORG point, reference. When it obtains a high level in the digital input assigned on parameter **02-03 = 45** (ex. MI3) here, and then a low level. It will follow the homing mode 00-40, and then set the position as a zero, you will be able to see the position **setting 00-04 = 21** or on the first double word received 1DWORD_RCV tag, above mentioned.



Positioning via Profibus-DP (Absolute)

Insert in the 1WORD_INPUT, in hex the number **16#0084** (Control word), and then on 2WORD_INPUT 16#0001 (P2P mode), now you need to set the 3DWORD_INPUT, which is the position command. Insert the position as explained below and then **modify the value** (thunder), then set 1WORD_INPUT to **16#0085**.

Positioning via Profibus-DP (Relative)

Insert in the 1WORD_INPUT, in hex the number **16#0080** (Control word), and then on 2WORD_INPUT 16#0001 (P2P mode), now you need to set the 3DWORD_INPUT, which is the position command as explained below, modify the value (thunder) and then set 1WORD_INPUT to **16#0081**.

Example 1

In this example the encoder is 2500 pulses per revolution, so $2500 \times 4 = 10\,000$, each 10 000 counts the rotor will have completed 1 turn. So we must get 10 000 in decimal and convert it to hexadecimal, which = 2710_0000 hex. Remember we are using a double word for this, 2 bytes. So we should send on the 3WORD_INPUT = 2710_0000 hex.

Siemens PLCs use Motorola Architecture and they will invert the bytes when you send them via Profibus-DP from a S7 Siemens PLC. So, the PLC will really send to Delta C2000, the value of 0000_2710 hex, which will make the rotor advance 10 000 counts, or 1 turn.

CAUTION: If you send 0000_2710 hex from a S7 PLC will it send to C2000 2710_0000 hex and that is quite a high value of counts and it will rotate forever for this value in decimal is equal to 655360000.

Normal byte transmission (hex)	
byte 1 0000	byte 2 2710

Siemens Motorola byte transmission (hex)	
byte 2 2710	byte 1 0000

Example 2

In this example, with the same encoder we want to make more turns, example, 30 turns, if the every 10 000 counts we get one turn, we will need 300 000 counts for 30 turns, so let's get 300 000 in decimal and convert it into hexadecimal, which is equal to 493E0 hex. Now we have a 5 digit value in hex, but the convention is the same, we will have to separate them in the double word and change the order of the bytes, so we will send 300 000 counts, on 3DWORD_INPUT = 93E0_0004 hex.

Table 6 - Correct byte order for Siemens controllers

Normal byte transmission (hex) – WRONG for S7		
byte 1		byte 2
493E		0000
Siemens Motorola byte transmission (hex)		
byte 2		byte 1
93E0		0004

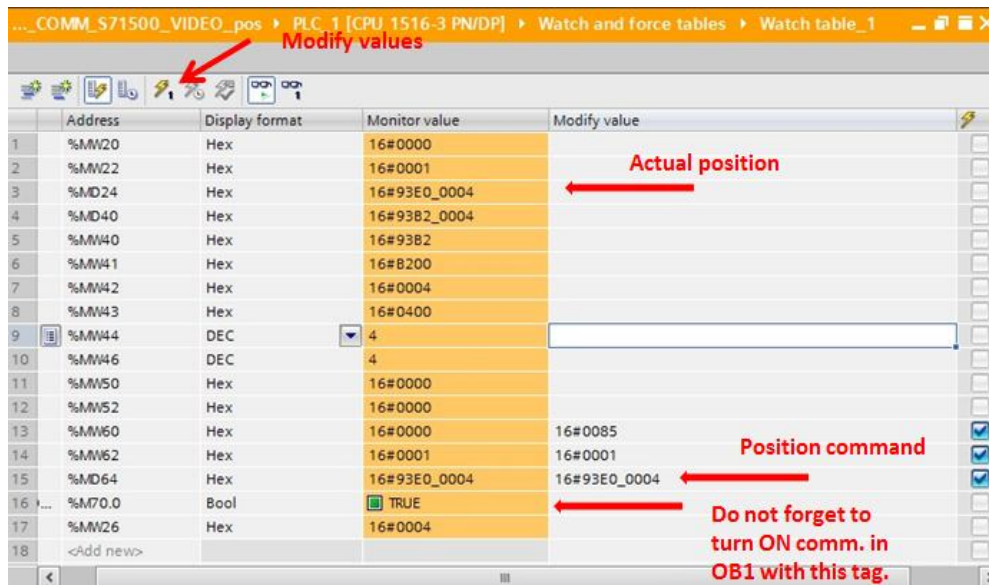


Figure 16 - Position command and Actual position

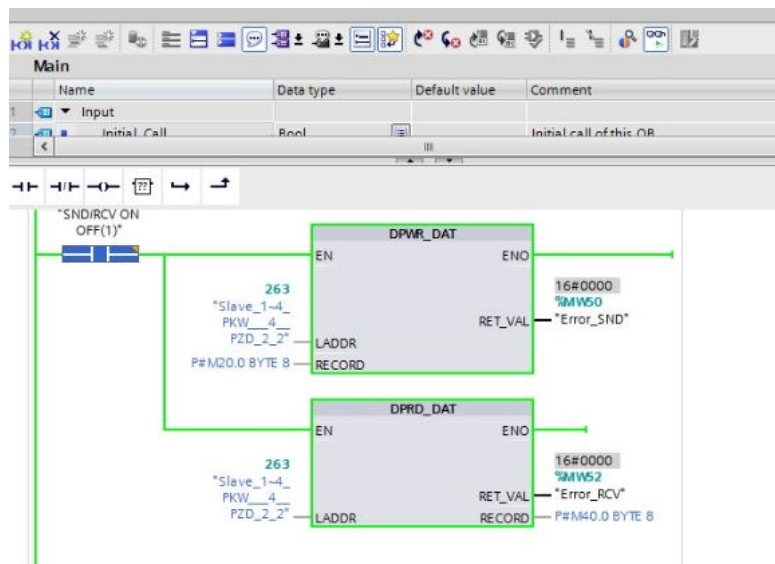


Figure 17 - Monitor with the glasses and enable communication

Sending a signed position (-)

Once you have performed the homing task and the positioning task. You might want to set a negative position. This is possible, to send a position with negative (-). You will have to convert the number in hexadecimal of 3WORD_INPUT to negative (bit by bit) and then use it as a position command. S7 1500 has a block for that, it is called NEG.

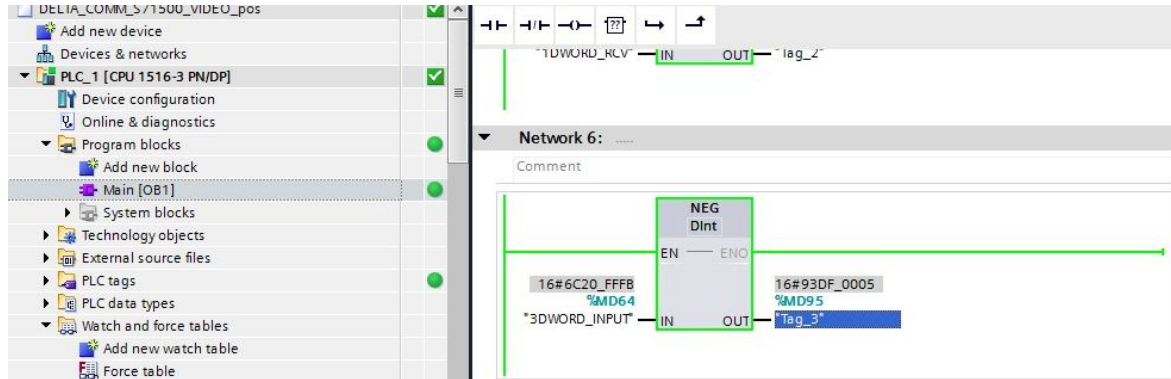


Figure 18 - Invert block to make position command in hex negative

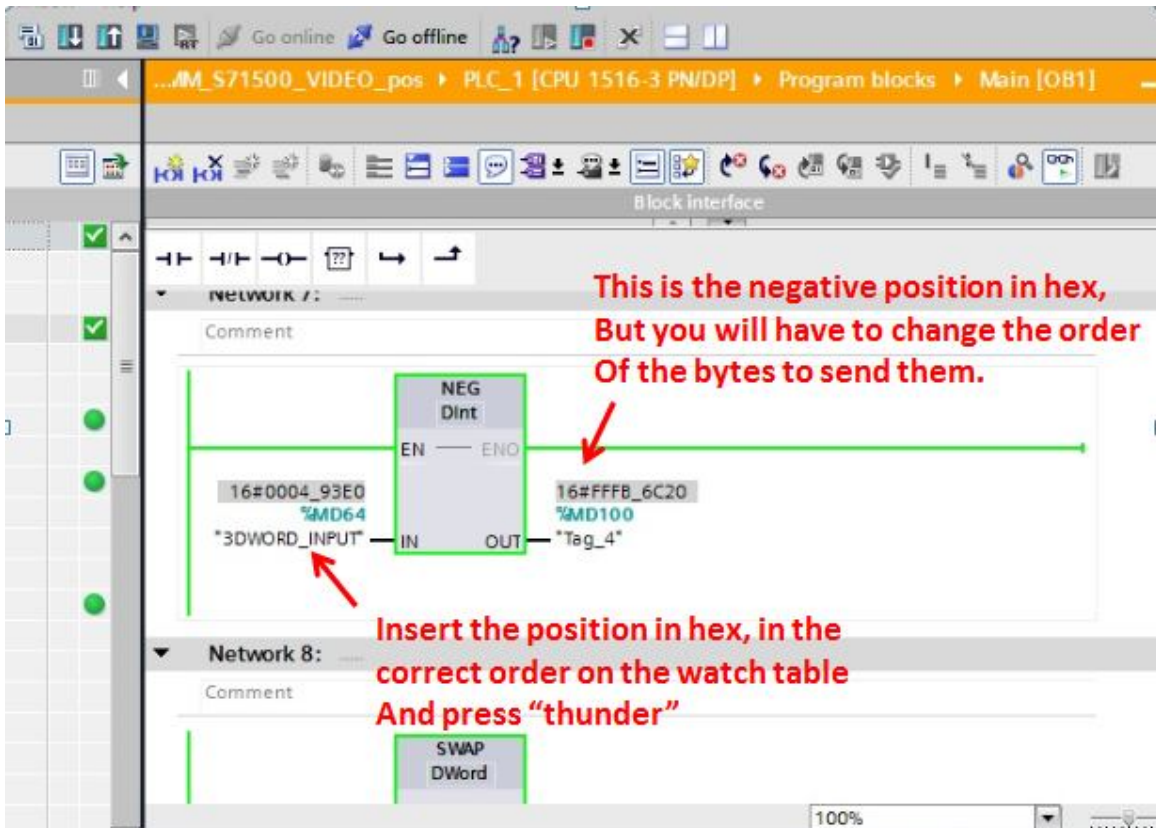


Figure 19 - Converting a position to negative using NEG block

...JO_VIDEO_pos ▶ PLC_1 [CPU 1516-3 PN/DP] ▶ Watch and force tables ▶ Watch table_1

Thunder

	i	Name	Address	Display ...	Monitor value	Modify value
1		*1WORD_SND*	%MW20	Hex		
2		*2WORD_SND*	%MW22	Hex		
3		*3WORD_SND*	%MD24	Hex		
4		*1DWORD_RCV*	%MD40	Hex		
5		*3WORD_RCV*	%MW44	Hex		
6		*4WORD_RCV*	%MW46	Hex		
7		*Error_SND*	%MW50	Hex		<input type="text"/>
8		*Error_RCV*	%MW52	Hex		
9		*1WORD_INPUT*	%MW60	Hex		16#0084
10		*2WORD_INPUT*	%MW62	Hex		16#0001
11		*3DWORD_INPUT*	%MD64	Hex		16#6C20_FFFB
12		*SND/RCV_DATA_O...	%M70.0	Bool		
13		<Add new>				

84 to set, thunder, 85 thunder to go.

Negative position, in Siemens bytes way of sending.

Figure 20 - Inserting a negative position command

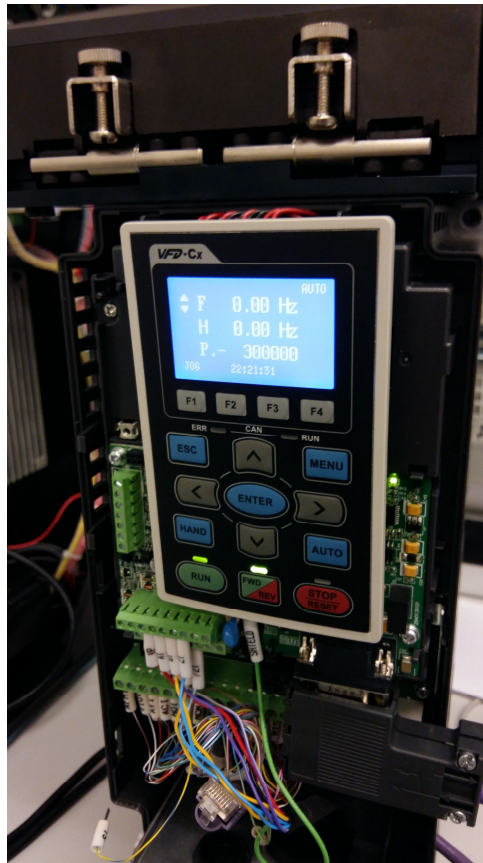


Figure 21 - Negative position command

11 Fine tuning for positioning

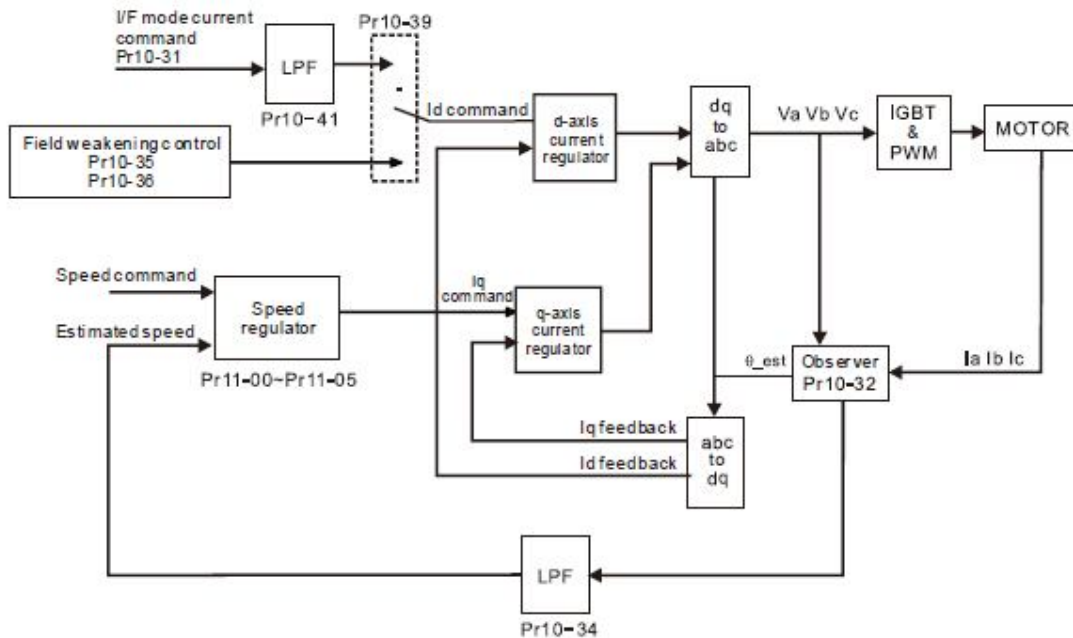


Figure 22 - PM FOC Sensorless control diagram

Table 7 - Advanced parameters for Fine Tuning

10-31	I/F Id level	Increases the magnetization current level
10-42	Rot Pos Det PLS	Detection time for position of the rotor
11-44	APR ACC TIME	Acceleration time of the Position Regulator
11-45	APR DEC TIME	Deceleration time of the Position Regulator
10-52	INJ MAGNETUDE	Magnitude of Injection Current
11-03	Low SPD ASR BW	Low speed Bandwidth of the Speed regulator
11-04	High SPD ASR BW	High speed Bandwidth of the Speed regulator
11-05	Zero Speed ASR BW	Zero Speed Bandwidth of the Speed Regulator

The tutorial is complete, but you might need some fine tuning depending on your application requirements. The following diagram shows you how to proceed with the tuning.

● Pr00-11=7 IPM Sensorless

Flow chart of adjustment when starting up with light duty

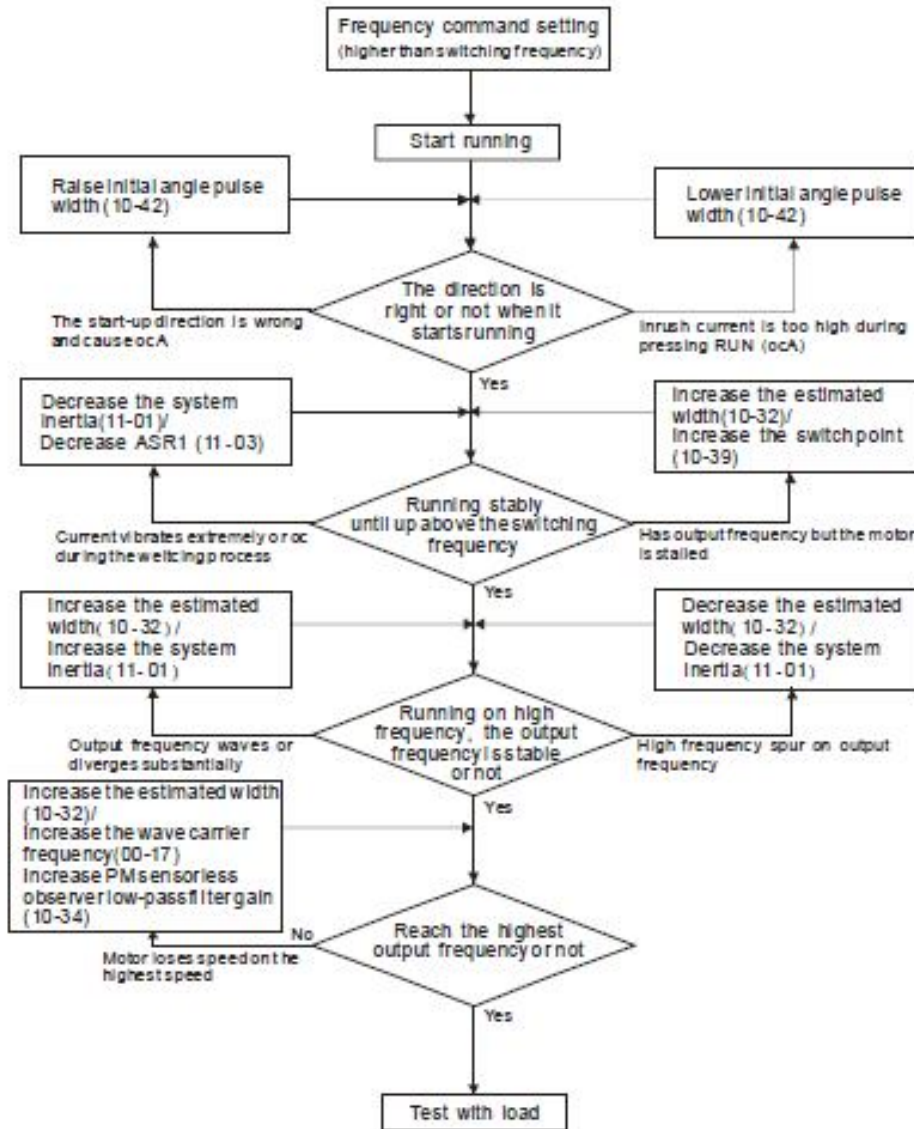


Figure 23 - Fine tuning according to C2000 manual