



Using Induction Motors and Siemens G120 Drives with Fixed Length Actuators and SSI Encoders

Revised April 6, 2020

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# Using Induction Motors and Siemens G120 Drives with Fixed Length Actuators and SSI Encoders

# Preface

This tech note is focused on the application of using SSI multiturn absolute encoders with the CU250S2 controllers. It assumes that the reader has a working knowledge of commissioning G120 drives. If you need further assistance, please don't hesitate to contact us at C & E.

# **General Scope**

For this discussion, we will consider positioning with an induction motor that causes something to move within a fixed distance or angle of rotation. This can be done by actuators that use gears, belts, ball or roller screws, racks and pinions, etc. The motor causes the actuator to move the load while an absolute multi-turn encoder monitors position. A drive controller turns the motor while monitoring the encoder. When the load approaches the destination, it is slowed down and stopped at the desired point. For this discussion, we are focusing on motion within a fixed range of travel, rather than continuously in one direction.

# Why Position using G120 drives with Encoders?

There are various methods for controlling motion of fixed length actuators, ranging from very simple to precision servo controls. Each application should be evaluated to determine what method is the most cost effective over the useful life of the system.

Some critical parameters to be evaluated include the required positioning accuracy and repeatability, the distance and time for each move, the mass of the product and tooling that will be moved, and how much variation there will be in the mass that is moved. Another key factor is whether the positions to be moved to are fixed or if they vary from cycle to cycle or product to product.

One traditional method of position control with induction motors is to use limit, photo, or proximity switches to detect when product is approaching the desired position. The switch triggers the stopping of the motion. This relatively inexpensive approach works reasonably well when the product mass, desired stopping position and speed of the actuator are constants. However, if any of those factors change, then either manual adjustment or additional control logic are required to compensate for the change. Frequently, reliable positioning is unattainable under those circumstances.

Using a G120 drive and an absolute multiturn encoder to monitor and control position not only addresses those problems, but adds flexibility and often increased performance to the solution. By continually monitoring position, the drive controller can adjust for changes in product size and inertia and stop at the desired position with a high level of repeatability. It also provides the capability to move to any position within the range of motion of the actuator upon command, with different speeds and acceleration. This flexibility often yields higher production rates, improved quality, and reduced machine setup and maintenance.

# Equipment

The drives that we recommend for this application are Siemens G120 units with CU250S-2 controllers or G120D with CU250D-2 controllers. These high end drives have expanded interfaces including encoder inputs in several formats and connection types. They also have the capability of controlling position and extended safety functions when ordered with the appropriate licenses. They can be ordered with Modbus RTU, Profibus DP, Profinet / Ethernet IP, or CANopen communications to interface with a wide variety of control networks, or operate standalone via hardwired terminals.



The Control Units CU250S-2 differ with regard to the type of fieldbus.

	Designation	Order number	Fieldbus
	CU250S-2	6SL3246-0BA22-1BA0	USS, Modbus RTU
	CU250S-2 DP	6SL3246-0BA22-1PA0	PROFIBUS DP
ar Hi	CU250S-2 PN	6SL3246-0BA22-1FA0	PROFINET IO, EtherNet/IP
1	CU250S-2 CAN	6SL3246-0BA22-1CA0	CANopen

The CU250S-2 control modules are matched with PM240-2 power modules sized for motors from 0.5 to 400 HP. Other accessories include Basic or Intelligent Operator Panels, backup memory cards with license files, grounding shields, NEMA 1 enclosures, filters, and braking resistors.

Many types of standard induction motors can be used for these applications, but there are some considerations. The motors must be properly sized for the application so that they run within the rated operating conditions for the specific motor. That must include duty cycle, speed, torque, and importantly cooling. Many induction motors are not designed to run at slow speeds with high torque. This is particularly true of totally enclosed fan cooled (TEFC) motors, but also applies to other configurations as well. We can assist with motor recommendations if you define the required operating conditions.

Encoders should be multi-turn absolute and can have Siemens DriveCLiQ interface or a specific

configuration of the SSI protocol. While the use of incremental or single turn encoders is also supported by the CU250S-2 controllers, they require homing to a known reference point on power up. This is often difficult if not impossible with some actuators. This paper is based upon using an Encoder Products A36SB-06MB-1312SIAGV4-AC6 SSI encoder. A link to the data sheet is in the Reference Section. Check with your C & E Motion Specialist before using other encoders, as not all SSI configurations are supported by the G120 units.



The CU250S-2 drive controller uses a DB15 connector for SSI encoder input. The pin out from the drive connector to the encoder is per the following chart.

Function	G120 DB15P	G120D M12-8	EPC Cable	EPC M12 pinout
	pinout X2100	pinout X10.	color code	
	1			
Clock +	2	5	Green	3
Clock -	3	6	Yellow	4
Power Supply +	4	2	Brown	2
Power Supply +	5			
	6			
GND	7	7	White (GND)	1
			Blue (Preset)	7
			Red (Dir)	8
	8			
	9			
	10			
	11			
	12			
	13			
Data -	14	4	Pink	6
Data +	15	3	Gray	5
	Shield			

Notes:

Preset (establish zero position ) and Dir (Direction) must be tied to GND to prevent unexpected changes.

This table includes wiring to the G120D with CU250D-2 controller, which functions like the CU250S-2 but is built to IP67 standards.

The DB15P (male) connectors are available from many sources.

The M12-8 connectors that we use are Turck BS 8281-0 field installable.

# **Drive Commissioning**

Use the Commissioning Wizard in StartDrive to commission the drive.

Application class: Select [0] Expert, then Next:

Commissioning Wizard	×
	Application class
<ul> <li>Application class</li> <li>Setpoint specification</li> <li>Open-loop/closed-loop</li> <li>Defaults of the setpoi</li> <li>Defaults of the setpoi</li> <li>Drive setting</li> <li>Drive options</li> <li>Motor</li> <li>Motor holding brake</li> <li>Important parameters</li> <li>Drive functions</li> <li>Encoders</li> <li>Measuring system</li> <li>Mechanical system</li> <li>Summary</li> </ul>	Application class: [0] Expert All setting options of the wizard are available. Conline help
	<e back="" next="">&gt;&gt; Finish Cancel</e>

Setpoint specification: You must make a fundamental decision as to where the position loop and setpoint are to be handled. If you are closing the position loop in the PLC using Technology Objects, then you should select Ramp function in the PLC and Data exchange to the drive. That is required for synchronized axes and optional for independent axes.

If you plan to use PLC Function Blocks like SINA\_Pos or C&E's FB300 to control the position moves in the drive using Basic Positioner, use the center option.

If positioning is to be done completely in the drive, select Ramp function in the drive.



These selections determine if the drive is to be configured to run in speed mode with the PLC controlling when to stop or in Basic Positioner mode where the drive closes the position loop. It also affects the setpoint and command sources and which telegrams can be configured.

**Open-loop/closed-loop:** If the PLC is controlling the ramp functions, leave Basic positioner unchecked. If the drive is controlling the ramp functions, check Basic positioner. Also select [21] Speed control (with encoder) as the control type. Then click Next,



#### Defaults of the setpoints / command sources:

The configuration options here depend upon what was selected in the Setpoint specification.

If the PLC is selected for Ramp Function and/or Data exchange, then the I/O configuration will be [7] Fieldbus with data set changeover. That sets up the drive with the default control to come from the plc but includes an alternate local control if DI3 is true (On).

If all control is local to the drive and Basic Positioner is selected, then [12] Standard I/O with analog setpoint is the default. That may be changed based upon how you want to wire the control signals. Consult the Commissioning Manual for the options.

Commissioning Wizard		×
	Defaults of the setpoints/command sources Selection of a predefined interconnection of the inputs/outputs and, if required, the fieldbut telegram. Can be changed later user-specifically.	5
Application class	Select the default of the I/O configuration:	
Setpoint specification	[7] Fieldbus with data set changeover	-
Setpoint specification	DI 0: p1055[1] BI: Jog bit 0	~
𝒞 Open-loop/closed-loop	DI 1: p1056[1] BI: Jog bit 1 DI 2: p2103[1] BI: 1. Acknowledge faults p2104[0] BI: 2. Acknowledge faults	
Defaults of the setpoi	DI 3: p810 BI: Command data set selection CDS bit 0	
Drive setting	DO 0: r52.3 CO/BO: Status word 1: Fault present DO 1: r52.7 CO/BO: Status word 1: Alarm present	
Drive options	AO 0: r21 CO: Actual speed smoothed AO 1: r27 CO: Absolute actual current smoothed	
Motor		
Motor holding brake		
Important parameters		~
Drive functions	Telegram configuration:	
	[1] Standard telegram 1, PZD-2/2	-
Encoders		
Summary	Speed setpoint 16-bit	ľ
	Online help	
		1
	Kext >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>	

If the PLC is controlling Ramp function, then set the Telegram configuration to [1] Standard telegram 1, PXD-2/2.

If the PLC is set only for Data Exchange and the drive is in Basic Positioner mode, then set the Telegram configuration to [111] SIEMENS telegram 111, PZD-12/12.

Drive setting:

Standard: Look at the motor nameplate to determine the appropriate selection. [0] IEC-Motor (50 Hz, SI units), [1] NEMA motor 60 Hz, US units) ( HP) or [2] NEMA motor (60 Hz, SI units) ( Kw).

Drive unit line supply voltage: Set the incoming voltage to the drive.

Power unit application: Select the overload setting. This sets limits in the drive based upon current draw and timing to ensure adequate temperature control of the internal components in the drive. Click Next when finished.

Commissioning Wizard	×
	Drive setting Selection of motor standard and load cycle.
Application class	Standard:
Setpoint specification	[1] NEMA motor (60 Hz, US units)
𝞯 Open-loop/closed-loop	Drive unit line supply voltage: 480 V
𝕺 Defaults of the setpoi	Power unit application:           [0] Load duty cycle with high overload for vector drives
Drive setting	[0] Load duty cycle with high overload for vector drives
O Drive options	Permissible overload at high overload (HO)
Motor	% A 200% overload for 3 s
Motor holding brake	200 150% overload for 57 s
Important parameters	
Drive functions	Base load for 240 s 50- Base load HO
Encoders	0 60 120 180 240 300 t(s)
Measuring system	
Mechanical system	
Summary	
	<back next="">&gt; Finish Cancel</back>

#### Drive Options:

Stopping loads with short deceleration times may require a braking resistor. If used, check the box and enter the maximum braking power per the nameplate.

If an external filter or line reactor is used, select the appropriate entry.

	Drive options		
	Configuration of optional braking resis	tor and drive filter.	
Application class	Braking resistor	Maximum braking power:	2.00 hp
Setpoint specification	Drive filter type motor side:		
🕏 Open-loop/closed-loop	[0] No filter		•
🕏 Defaults of the setpoi			
Drive setting			
Drive options			
Motor			
Motor holding brake			
Important parameters			
Drive functions			
Encoders			
Measuring system			
Mechanical system			
Summary			
	<pre>&lt;&lt; Back Next &gt;&gt;</pre>	Finish	Cancel
	<< back Next >>	Pintsn	Cancel

#### Motor:

Generally you will be entering motor data for an induction motor. If you have a Siemens motor, then you may be able to select the order number from a list. Once you have entered data in the fields from the motor nameplate, click Next.

Commissioning Wizard				
	Motor			
	Specification	of motor type and motor data.		
Solution class	Motor configu	iration		
	Enter motor of	data		
Setpoint specification	Select motor	type		
✓ Open-loop/closed-loop	[1] Induction	motor		•
Defaults of the setpoi Drive setting	Select the con Star Motor data	nnection type for your motor and 87	Hz operation:	
Onversering	Parameter	Parameter text	Value	Unit
Solutions	p304[0]	Rated motor voltage		Vrms
o brive options	p305[0]	Rated motor current		Arms
Motor	p307[0]	Rated motor power	0.25	
	p309[0]	Rated motor efficiency	0.0	1
Motor holding brake	p310[0]	Rated motor frequency	60.00	
	p311[0]	Rated motor speed		1 rpm
Important parameters	p335[0]	Motor cooling type	[0] Non-ventil	
Drive functions	Parallel mo	otor connection	N	umber: 1
Encoders	Temperature	sensor:		
Measuring system	[0] No senso	r		•
Mechanical system				
Summary				
	<< Back	Next >>	Finish	Cancel

Motor Holding Brake:

Holding brakes are electromechanical devices that are released by the drives when motion is enabled. With G120 drives, they are typically interfaced via a 6SL3252-0BB00-0AA0 Brake relay or a 6SL3252-0BB01-0AA0 Safe brake relay actuated directly by the power module. Using mode [1] Motor holding brake acc. to sequence control will delay the opening of the brake slightly after motor power is applied to allow torque to build up so that the load doesn't drop back. In a similar manner, the brake will be closed just before full power is removed from the motor so that it is fully engaged before torque is released.

Option [3] allows for the brake command to be issued from the PLC.

Commissioning Wizard		×
	Motor holding brake	
	Selection and configuration of the motor holding brake.	
<ul> <li>Application class</li> <li>Setpoint specification</li> <li>Open-loop/closed-loop</li> <li>Openaluts of the setpoi</li> <li>Defaults of the setpoi</li> <li>Drive setting</li> <li>Drive options</li> <li>Motor</li> <li>Motor holding brake</li> <li>Important parameters</li> <li>Drive functions</li> <li>Encoders</li> <li>Measuring system</li> <li>Mechanical system</li> </ul>	Selection and configuration of the motor holding brake.          Motor holding brake configuration:       [1] Motor holding brake acc. to sequence control         Brake opening time:       Brake closing time:         100 ms       100 ms         Additional configuration options for the motor holding brake can be four the corresponding masks of the function view.	Ind in
Summary		
	<pre></pre>	Cancel

Important parameters:

The Reference speed is used to set the 100% range that is used with telegrams and drive commands to vary frequency set to the motor. Usually the synchronous speed of the motor.

The Maximum speed is used to limit how fast the motor is allowed to run.

The ramp up and down times set the acceleration rates used during normal operation of the drive. The OFF3 (quick stop) time sets how fast the drive will be commanded to stop during emergencies. Note that if there is a mass with a high inertia that must be stopped, the Ramp-down times need to be long enough for the drive and resistors to dissipate the energy.

The Current limit defaults to 150 % of full load amps.

Commissioning Wizard	×
	Important parameters
	Specification of the most important dynamic response data.
Application class	Synchronization of the speed of the drive with the speed of the PLC:
Setpoint specification	Reference speed: 1800.000 1 rpm
𝞯 Open-loop/closed-loop	Maximum speed: 1800.000 1 rpm
Oefaults of the setpoi	Configuration of ramp-up and ramp-down time:
Drive setting	Ramp-up time: 10.000 s
Drive options	OFF1 ramp-down time: 10.000 s
Interest Motor	OFF3 (quick stop) ramp-down time: 0.000 s
Solution Motor holding brake	These OFF1 and OFF3 ramp-down times apply for faults or a Safe Stop.
Important parameters	
Drive functions	Configuration of the current limit:
Encoders	Current limit: 0.99 Arms
Measuring system	
Mechanical system	
Summary	
	≪Back Next ≫ Finish Cancel

#### Drive functions:

The Technology application parameter is used to automatically select parameters which apply specifically to certain applications. For example, the output is adjusted to variable torque in the case of pumps and fans. Consult the manuals for details. For positioning, the typical selection is [0] Standard drive.

Motor identification is a one-time measurement of critical motor and cable parameters that are used to determine output values to the motor. For positioning, mode [11] Identify motor data and optimize speed controller, operation is recommended during commissioning, although this may need to be done without the motor connected to the load.

If enabled, a test is performed the first time that the drive is set to run mode during commissioning. The drive will enable and "hum", but the motor will not move during the stationary measurement. The motor will turn during the speed controller optimization. Once the testing is complete, the values must be copied to the drives ROM memory to prevent the test from running at future power on cycles.

General practice is to set the Motor identification to [0] Inhibited in the Wizard, and then enable it during the online commissioning of the drive. That does require strict attention to commissioning steps, but prevents accidental running of the tests under potential crash conditions.



Encoders:

The drives can accommodate up to two encoders. One encoder is always used to measure motor speed. Depending upon mechanics, it can also be used for position. Optionally a second can be used to measure the position. For this discussion, only one encoder is used for both functions, the Encoder Products A36SB-06MB-1312SIAGV4-AC6SSI.

It is interfaced through a D-Sub interface marked X2100 on the drive. The encoder configuration for this unit is [3082] SSI, Multiturn 4096, 24 V, 8192 resolution.

Commissioning Wizard					×		
	Encoders						
Application class	Encoder selection						
Setpoint specification	Encoder 1	Enc	oder 2				
	Encoder 1				_		
Oefaults of the setpoi	Encoder interface						
Orive setting	[2] D-SUB interface						
Orive options	Encoder configuration Select standard encoder from li	ist	•	Encoder data			
Motor	Encoder type [3081] SSI, Singleturn, 24 V	Resolution 8192	^				
Solution Motor Holding brake	[3082] SSI, Multiturn 4096, 24 [3090] 4096, HTL, A/B, SSI, Si	8192					
Solution Important parameters	[3109] 2000 nm, TTL, A/B R di [9999] User-defined	- [9999] User-def					
Drive functions			Ξ		2		
Encoders			~	Details			
Measuring system					-		
Mechanical system					_		
Summary							
	«Back Next»			Finish Canc	el		
					_		
Encoder data					× No	ote: If you receive	
General Details					an	error message	
Gear ratio: Inversion					rel	ating to the fine	
Encoders	actual speed value actual position value					solution exceeding	
						bits, reduce the	
Fine resolution:						lue in G1_XIST2 to	
G1_X05T1: 11 Bit G1_X05T2: 9 Bit						—	
					lov	wer the resolution.	

#### Measuring System:



#### Mechanical System:

Siemens has a method for defining its measuring system that is different than many of its competitors, but that once understood makes configuration of the system very powerful. The basis of Siemens system is the Load Unit (LU for short). A load unit is an integer that represents the smallest unit of measure in engineering units that the load moves. It is entered into the system as the number of LU's that the load moves in one revolution of the output shaft. For example, if you want to measure the rotation of a turntable in hundredths of degrees, you will enter 36000 LU per revolution (360 degrees/rev times 100 LU's per degree = 36000 LU/rev).

The number of motor revolutions to load revolutions is the gear ratio through the system, in integer format. So if you have a ratio involving decimals, you may need to adjust the scale to get to integer format. Example a ratio of 2.5 / 1 can also be expressed as 25 / 10.

<ul> <li>Application class</li> <li>Setpoint specification</li> <li>Open-loop/closed-loop</li> <li>Defaults of the setpoi</li> </ul>	The position control is assigned to the following encoders Encoder_1 LU per load revolution (encoder resolution) 50331648 LU
<ul> <li>Defaults of the section</li> <li>Drive setting</li> <li>Drive options</li> <li>Motor</li> </ul>	Encoder pulse number 8192 Fine resolution 2048 LU per load revolution (pos. setpoint / act. val. resol.) Motor revolutions 36000 3 1
<ul> <li>Motor holding brake</li> <li>Important parameters</li> </ul>	Activate modulo offset  Position actual value / setpoint starts at 0 LU after  4500 LU
Orive functions	Load gearbox position tracking
Second Encoders	<ul> <li>Rotary axis</li> <li>Linear axis</li> </ul>
Measuring system	Virtual multitum resolution: 4096
Mechanical system	Tolerance window: 8388608.00
Summary	

Modulo is a system where the range repeats itself, like a turntable moving in only one direction with stations every 45 degrees. As shown above, enter a "1" to Activate modulo offset and enter 4500 LU's Position actual value / setpoint starts at 0.

Do not use Modulo for a fixed range actuator like a ball screw that moves within a range.

Load gearbox position tracking is used with multiturn encoders. Enter the number of encoder revolutions. The Tolerence window is calculated automatically at one fourth the product of the two encoder resolutions.

#### Summary

This is a listing of all of the selections that you made during commissioning. If you click in the listing and then press CTRL + A to select all, you can copy the contents and past them into a text document. Then click FINISH and save your work.

Commissioning Wizard	×
	Summary Please check the data entered and complete the configuration.
Application class	The following drive data has been entered:
Setpoint specification	Application class: Application class: [0] Expert
𝞯 Open-loop/closed-loop	Setpoint specification: Drive without PLC connection. Setpoint specification in the drive
Solution of the setpoi	Open-loop/closed-loop control type: Open-loop/closed-loop control operating mode: [21] Speed control (with encoder) Technology controller: No
Drive setting	Basic positioner: Yes Extended messages/monitoring: No Free function blocks: No
Orive options	Defaults of the setpoints/command sources:
S Motor	Macro drive unit: [12] Standard I/O with analog setpoint Drive setting:
Solution Motor holding brake	IECINEMA mot stds: [1] NEMA motor (60 Hz, US units) Drive unit line supply voltage: 480 V Power unit application: [0] Load duty cycle with high overload for vector drives
Simportant parameters	Drive options: Braking resistor active: No
Orive functions	Drive filter type motor side: [0] No filter
Second Encoders	Motor: Motor type selection: [1] Induction motor Motor connection type: Star
Measuring system	Motor 87 Hz operation: No Number of motors connected in parallel: 1 Rated motor voltage: 480 Vms
Mechanical system	Perform a power cycle manually after download (because interface selection p2030 has been changed). This is a necessary precaution to be taken before you perform any acti
Summary	
	< III >
	<cback next="">&gt; Finish Cancel</cback>

Application class:
Application class: [0] Expert
Setpoint specification:
Drive without PLC connection. Setpoint specification in the drive
Open-loop/closed-loop control type:
Open-loop/closed-loop control operating mode: [21] Speed control (with encoder)
Technology controller: No
Basic positioner: Yes
Extended messages/monitoring: No
Free function blocks: No

# Homing and Setting the Reference Position

There is one additional step that must be completed during the online commissioning phase: performing the initial absolute encoder adjustment.

First download the configuration from the previous section to the drive. Then go online.

Double click on the Parameter branch in the project tree to bring up the Parameter window in the Functional view.

Then drill down to the Homing > Configuring referencing screen under the Applications functions > Basic positioner.

In the center of the screen, click on the Active Homing block to bring up the encoder adjustment.



- Unive functions
- Safety Integrated
- Application functions
- Basic positioner
  - Limit
  - ▶ Jog
  - Homing
    - Configuring referencing
    - Diagnosing referencing
  - Traversing blocks
  - Direct setpoint input (MDI)
- Position control
- Communication
- Interconnections

Perforn	absolute enco	deradjustm	ent
state of absolute of	encoder adjustm	ent	
Absolute encoder	is not adjusted		
Home position co 0 I RAM data to EE	U	in the drive	)
		ок	Cancel

The Home position coordinate is entered as the number of load units in integer format that the current position is from the desired home position coordinate (HPC). If the current position is the home position, enter zero (0). If something else, enter the offset in integer format. Example, if the current position is 100 mm's from the desired home position and there are 1000 LU's per revolution of a ball screw with 10 mm pitch, then the HPC is 10000 LU's.

Check the box to save data in the drive, then OK.

# References and Useful Links

G120 CU250S-2 PN Manuals can be found at the Siemens Support Site:

https://support.industry.siemens.com/cs/search?search=CU250S-2%20PN&type=Manual&lc=en-US

#### **Operating Instructions**

https://support.industry.siemens.com/cs/document/109757229/sinamics-g120inverter-with-cu250s-2-control-unit?dti=0&lc=en-WW

#### Function Manual Basic Positioner

https://support.industry.siemens.com/cs/document/109757593/function-manual-basicpositioner?dti=0&lc=en-WW

#### List Manual

https://support.industry.siemens.com/cs/document/109751315/sinamics-g120-control-unitscu250s-2?dti=0&lc=en-WW

Getting Started https://support.industry.siemens.com/cs/document/109757229/sinamics-g120inverter-with-cu250s-2-control-unit?dti=0&lc=en-WW

Application Examples and Guides can be found at the Siemens Applications Site:

https://www.automation.siemens.com/mc-app/sinamics-applicationexamples/Home/Index?language=en

SINAMICS G: Axis positioning with the 'SINA\_POS' block

https://support.industry.siemens.com/cs/document/109736845/sinamics-g%3A-axispositioning-with-the-sina\_pos-block?dti=0&lc=en-WW

SINAMICS G: Guide for Commissioning a Position-Controlled Drive https://support.industry.siemens.com/cs/document/109479977/sinamics-g:-guide-for-

commissioning-a-position-controlled-drive?lc=en-ww

Information on Encoder Products SSI and other encoders can be found at:

http://www.encoder.com/

MODEL A36SB - ABSOLUTE SHAFT ENCODER http://encoder.com/core/files/encoder/uploads/files/datasheet-a36sb.pdf

Model A36HB - Absolute Hollow Bore encoder http://encoder.com/core/files/encoder/uploads/files/datasheet-a36hb.pdf

**TB-529** Understanding EPC's SSI Encoders http://encoder.com/core/files/encoder/uploads/files/TB-529.pdf

**TB-111** *M12 (12 mm) Connector Option* http://encoder.com/core/files/encoder/uploads/files/TB-111.pdf

### Acknowledgments

Screenshots are of StartDrive, Siemens drive commissioning software. All rights reserved.