

ADV200

English

Electrical Line Shaft Application User Guide

GEFRAN

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1 Introduction

This manual contains all the information necessary for the design, wiring and configuration of a system based on the Electrical Line Shaft application for the ADV200.

Chapter 2 - "General description" provides information about system characteristics and functions.

Chapter 3 - "Connection diagrams and system interface" illustrates typical connection diagrams and the command interface for controlling the application via digital I/O or fieldbus.

Chapter 4 - "Commissioning" provides information about installing the application on the ADV200 drive.

Chapter 5 - "Control logic and sequences" contains detailed information about application functions and operating modes.

Chapter 6 - "List of Parameters" contains the complete list of system parameters with a description of their functions.

Chapter 7 - "Examples" contains a gear ratio calculation example and some guidelines for startup, tuning and performance check of the application.

1.1 Compatibility Application version / Drive firmware

ELS	Drive Firmware
1.0.32	6.X.X ; 7.X.X

2 General description

The Electrical Line Shaft application allows a group of drives to operate in a previously defined position with respect to a "master" reference; this position reference may be provided by the feedback from a motor, a line encoder or a specific communication interface. The drives that follow the master position reference are called "slaves"; the position ratio between the master and slaves can be changed proportionally by means of a parameter called "electronic gear ratio".

The Electrical Line Shaft application requires at least firmware version 5.00 of the ADV200 drive with the relative optional encoder signal acquisition cards and for the Fast Link system bus; some typical configurations are illustrated in section 3.3 "Possible master-slave configurations".

Characteristics of the Electrical Line Shaft application for the ADV200:

- Slave axis homing function that enables the use of an external sensor, encoder marker and freeze encoder signal for axis phasing; user-definable zero offset.
- Slave axis incremental positioning function with user-definable trapezoidal speed profile.
- Slave axis jog function with different ramps and speeds for service movements.
- Electrical line shaft function with master position reference selectable between encoder repetition or Fast Link system bus interface. Possibility of "chain"-type configurations (each slave acts as master for the next slave) or "equal ranking" (one master for all slaves).
- Electronic gear ratios selectable from previously defined settings; possibility of continuously changing the ratio (Slip function).
- Phase trim function to change the position of the slave with respect to the master while the slave follows the master.
- Slave position error signal with dual threshold setting (warning, alarm).

2.1 Fields of application

The Electrical Line Shaft application is particularly recommended for use in the following sectors:

Material Handling

- 2 or 3-axis gantries
- Stackers / De-stackers
- Pick & Place

Transport

- Trolleys
- Hoisting equipment
- Vehicles on rails

Logistics

- Rack feeders for automated warehouses
- Shuttles

3 Connection diagrams and system interface

The input and output signals of the Electrical Line Shaft application for ADV200 drives and the relative sequences are managed by a superordinate control device such as a PLC or IPC.

The application can thus be controlled via discrete digital I/O (digital input and output terminals on the ADV200 regulation card and any expansion cards, such as EXP-IO-D6A4R1-ADV); the use of a fieldbus interface (Profibus, Devicenet, Canopen, EtherCAT) allows more flexible management (virtual I/O, positioning and phase variation). Moreover, the fieldbus configuration channel enables access to all drive and application parameters in read and write mode.

3.1 Control via digital inputs and outputs

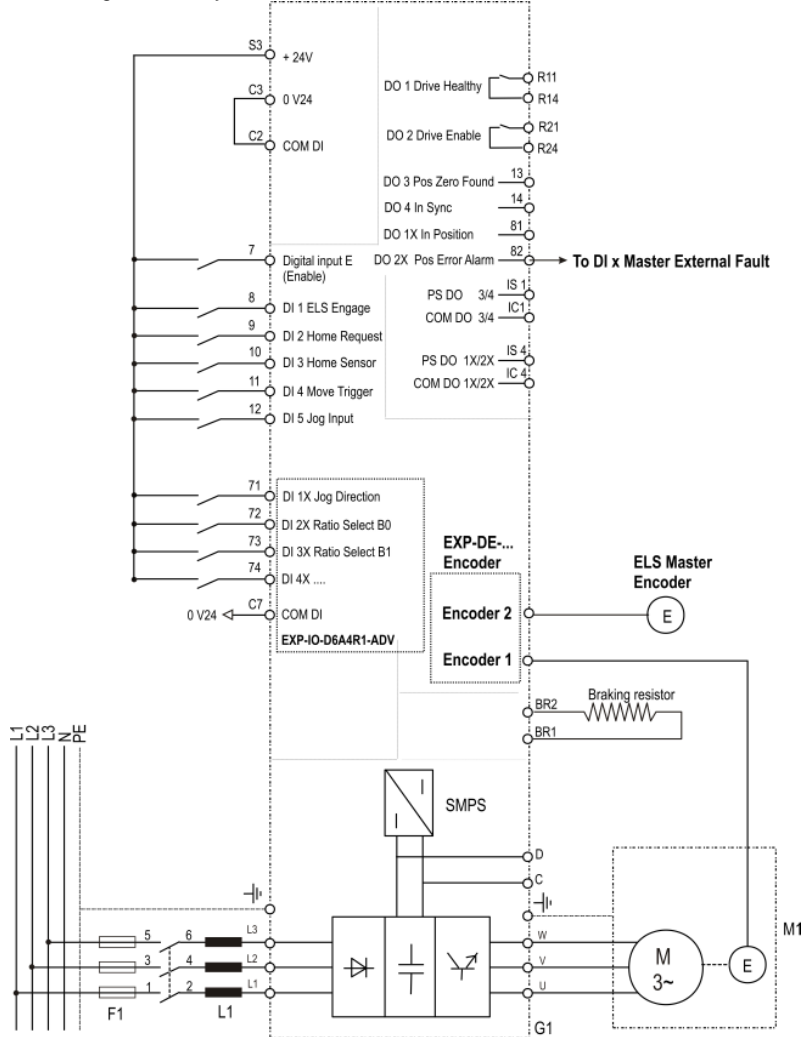
The example below shows a typical configuration of the digital inputs and outputs of the drive with the EXP-IO-D6A4R1-ADV expansion card.

This configuration enables zero searches using a sensor and positioning operations by selecting one of the first 16 available position presets.

The digital input signals must be set as shown in the figure in the ELS / DIGITAL INPUTs menu.

The digital outputs relating to the application must be set in the ELS / DIGITAL OUTPUTs menu.

Figure 3.1: Layout of I/Os ADV200 slave with EXP-IO-D6A4R1-ADV



Recommended programming of I/O terminals (regulation + expansion)

<i>Dig Input E</i>	<i>Enable (not programmable)</i>	<i>Digital output 1</i>	<i>Drive healthy</i>
<i>Dig Input 1</i>	<i>ELS Engage</i>	<i>Digital output 2</i>	<i>Drive Enable</i>
<i>Dig Input 2</i>	<i>Home Request</i>	<i>Digital output 3</i>	<i>Pos Zero Found</i>
<i>Dig Input 3</i>	<i>Home Sensor</i>	<i>Digital output 4</i>	<i>In Sync</i>
<i>Dig Input 4</i>	<i>Move Trigger</i>	<i>Digital output 1X</i>	<i>In Position</i>
<i>Dig Input 5</i>	<i>Jog Input</i>	<i>Digital output 2X</i>	<i>Pos Error Alarm (*)</i>
<i>Dig Inp 1X</i>	<i>Jog Direction</i>		
<i>Dig Inp 2X</i>	<i>Ratio Select B0</i>		
<i>Dig Inp 3X</i>	<i>Ratio Select B1</i>		

(*) Connect to the digital input of the master drive programmed as "External Fault"

NB! The ADV200 drive requires the installation of the EXP-IO-D6A4R1-ADV optional card in slot 1, and of the EXP-FL-XCAN-ADV optional card for the Fast Link system bus, which can be used to send the position reference between the master and slaves.
The two optional cards cannot therefore be installed simultaneously on the same drive.

3.2 Control via fieldbus interface

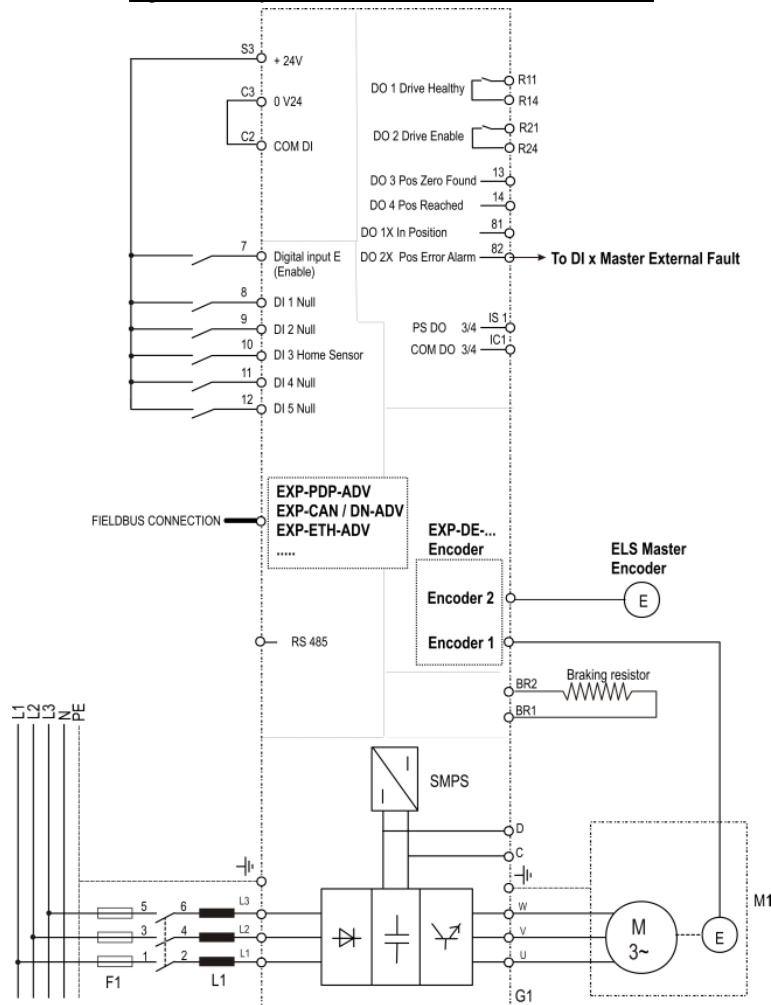
The example below shows a typical configuration of the digital inputs and outputs provided with the drive regulation card and an assignment of process data on a fieldbus interface card; the latter must be installed in slot 3 dedicated to expansion cards.

Since process data are assigned in the parameters in the drive COMMUNICATION menu, the settings described below are applicable regardless of the type of fieldbus used.

The digital input signals must be set as shown in the figure in the DIGITAL INPUTS menu, where they are assigned to the regulation card terminals or to the control word bits (Word decomp).

The digital output signals must be set as shown in the figure in the DIGITAL OUTPUTS menu, where they are assigned to the regulation card terminals or to the status word bits (Word comp); an application status word can also be mapped in the process channel (see **IPA 12036 Status Word Mon**), bringing together all the digital output signals defined in the DIGITAL OUTPUTS menu so that the Word comp can be used for other signals.

Figure 3.2: Layout of I/Os ADV200 with EXP-...Fieldbus



Recommended programming of I/O terminals (regulation only)

<i>Dig Input E</i>	<i>Enable (not programmable)</i>	<i>Digital output 1</i>	<i>Drive healthy</i>
<i>Dig Input 1</i>	<i>Null</i>	<i>Digital output 2</i>	<i>Drive Enable</i>
<i>Dig Input 2</i>	<i>Null</i>	<i>Digital output 3</i>	<i>Pos Zero Found</i>
<i>Dig Input 3</i>	<i>Home Sensor</i>	<i>Digital output 4</i>	<i>Pos Reached</i>
<i>Dig Input 4</i>	<i>Null</i>	<i>Digital output 1X</i>	<i>In Position</i>
<i>Dig Input 5</i>	<i>Null</i>	<i>Digital output 2X</i>	<i>Pos Error Alarm</i>

(*) Connect to the digital input of the master drive programmed as "External Fault"

Assignment of process data

<i>Fieldbus M->S1</i>	<i>Word Decomp</i>	<i>Fieldbus S->M1</i>	<i>Status Word Mon</i>
<i>Fieldbus M->S2</i>	<i>Ramp ref 1</i>	<i>Fieldbus S->M2</i>	<i>Word Comp</i>
<i>Fieldbus M->S3</i>	<i>Target Pos (**)</i>	<i>Fieldbus S->M3</i>	<i>Actual Pos</i>
<i>Fieldbus M->S4</i>	<i>...</i>	<i>Fieldbus S->M4</i>	<i>Error Pos</i>
<i>Fieldbus M->S5</i>	<i>...</i>	<i>Fieldbus S->M5</i>	<i>Motor Speed</i>
<i>Fieldbus M->S6</i>	<i>...</i>	<i>Fieldbus S->M6</i>	<i>Output Current</i>

(**) automatically assigned with parameter "Target Source = From FB W3"

NB! (*) There should preferably be a direct connection between the "Pos Error Alarm" or "Drive Healthy" digital output on the slave axis and the "External fault" digital input on the master drive; if that is not possible, an emergency stop mechanism must be provided at the superordinate control level (PLC) to stop the master drive in case of a fault on the slave drive(s).

3.3 Possible master-slave configurations

The **IPA 11394 Master Pos Source** application parameter is used to select the source for the position reference to which the slave axis is connected during operation in electrical line shaft mode. The master position reference may come from an encoder or from the Fast Link communication interface.

3.3.1 Master electrical line shaft from encoder

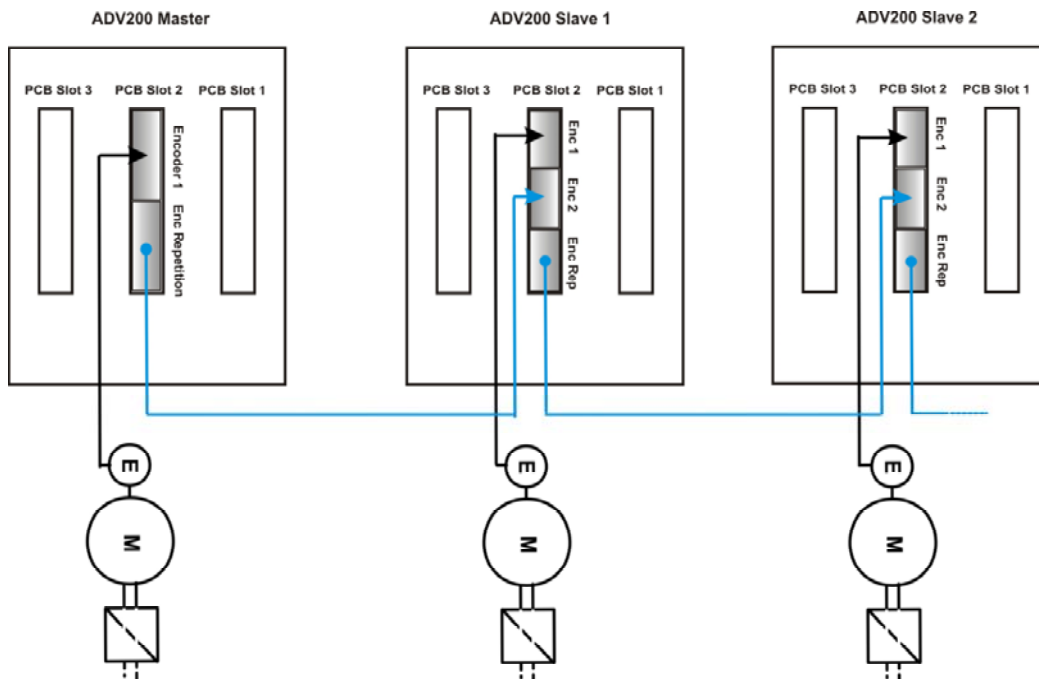
In this case the master position reference comes from an encoder, which may be installed on a motor or connected directly to the machine.

For the slave axis, the **IPA 11394 Master Pos Source** parameter must be set to “**Encoder 2**”.

In configurations with at least 2 slave axes, it is possible for each slave axis to be the master position reference for the next slave or to use the same master encoder for all the slaves.

An example of a configuration in which each slave axis acts as the master position reference for the next slave is shown in the figure below.

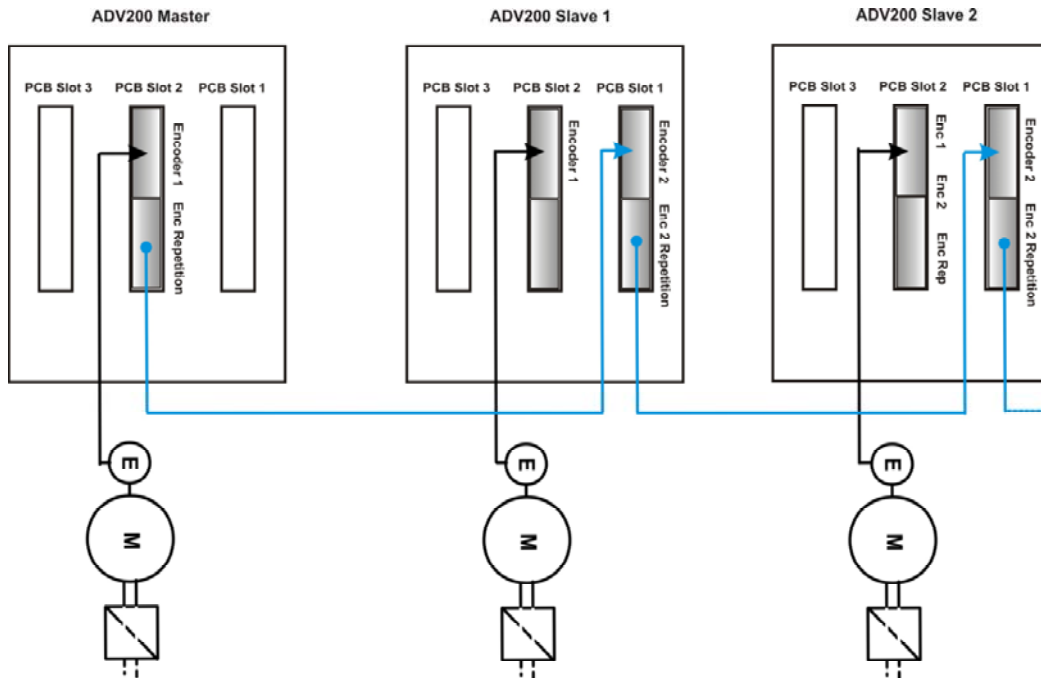
Figure 3.3: Cascade repetition of encoders between slave axes



In this case, each slave axis needs an optional card with a double digital encoder input (type EXP-DE-I2R1F2-ADV); the encoder emulation output of this card repeats the Encoder 1 input, i.e. the motor encoder of the slave axis.

The figure below shows an example of configuration in which the master axis motor encoder is repeated to all the slave axes.

Figure 3.4: Master encoder repeated to all slaves



In this case the master encoder must be read and repeated by a second encoder card, in addition to that needed for the encoder installed on the motor of the slave axis and of the same type (EXP-DE-I1R1F2-ADV). The choice between these two configurations depends on the type of application; the former, for example, is for cascade control of synchronised conveyor belts, the latter for multiple-column hoists.

3.3.2 Master electrical line shaft from Fast Link communication interface

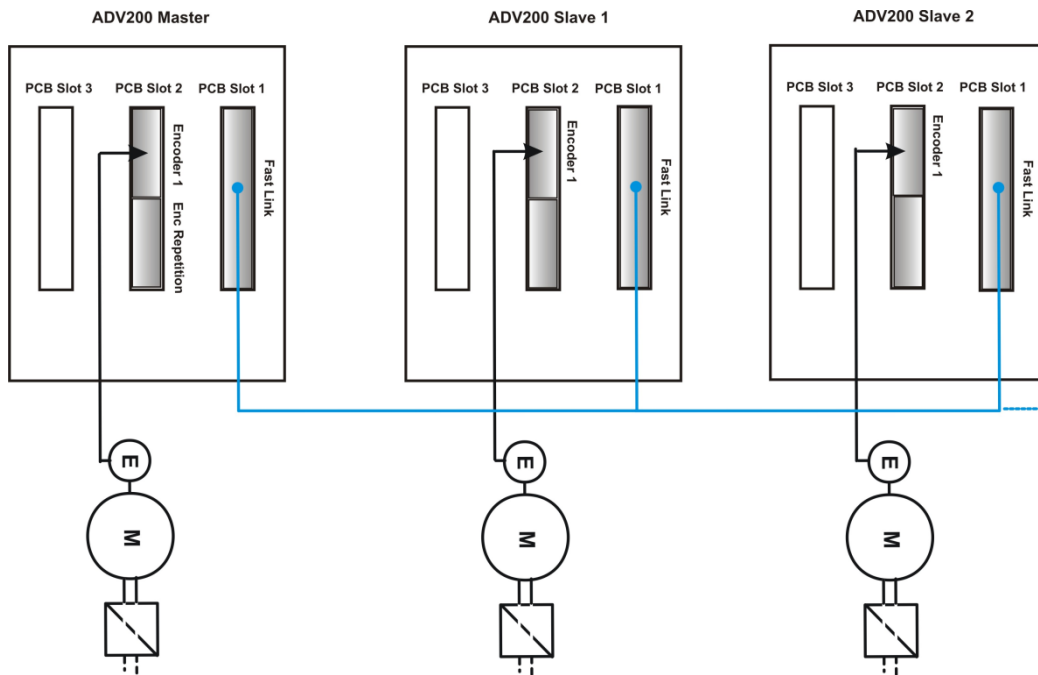
The Fast Link EXP-FL-XCAN-ADV optional card is the optical fibre synchronous communication interface for the ADV200. Reference should be made to the specific user guide for details about installation and configuration of the optional card.

For the Electrical Line Shaft application, the Fast Link card must be installed on all the slave axes and, as a general rule, also on the master axis; some "mixed" configurations are however possible, for instance if the master axis position reference comes from an encoder, the first slave axis can receive it using a card with a double digital encoder input and thus send it via Fast Link to the other slave axes.

For the slave axis, the **IPA 11394 Master Pos Source** parameter must be set to **"FastLinkPosRev"**.

Since each node of the Fast Link network can in turn re-transmit the entire data block received or immediately replace one or more of the data in that block with its own data, the same configurations as those described in the case of position references from the encoder are possible.

Figure 3.5: Position references on the Fast Link interface



Description of Fast Link communication parameter settings.

Case 1 – Master Encoder repeated to all slaves (IPA 11394 Master Pos Source = "FastLinkPosRev")

Parametro Fast Link	Master	Slave 1	Slave n
IPA 5702 Fast Link Address	1	2	n+1
IPA 5710 FL sync slave type	Off	Off	Off
IPA 5712 FL N Fwd slave chg	0	0	0
IPA 5714 FL Fault enable src	Digital Input E mon	Digital Input E mon	Digital Input E mon
IPA 5730 FL Fwd 1 src	E1 Virtual position	Null	Null
IPA 5732 FL Fwd 2 src	E1 Revolution	Null	Null

Case 2 – Cascade repetitions of encoders (IPA 11394 Master Pos Source = “FastLinkPosRev”)

Parametro Fast Link	Master	Slave 1	Slave n
IPA 5702 Fast Link Address	1	2	n+1
IPA 5710 FL sync slave type	Off	Off	Off
IPA 5712 FL N Fwd slave chg	0	2	2
IPA 5714 FL Fault enable src	Digital Input E mon	Digital Input E mon	Digital Input E mon
IPA 5730 FL Fwd 1 src	E1 Virtual position	E1 Virtual position	E1 Virtual position
IPA 5732 FL Fwd 2 src	E1 Revolution	E1 Revolution	E1 Revolution

4 Commissioning

4.1 General information

This section describes a standard application commissioning procedure.

The preliminary operations for commissioning ADV200 drives are described in chapter 7 of the "ADV200 Quick Start Guide - Specifications and connection".

4.2 Requirements

The Electrical Line Shaft application for ADV200 drives requires at least firmware version 5.00 of the drive with the relative optional cards for encoder signal acquisition.

The ADV200 firmware version supports asynchronous (ASY) and synchronous (SYN) motors.

To install the application you must have a PC, version 1.6.27 or higher of the Gefran GF Express software with Catalog, the drive RS485 - PCI COM connection kit and the set-up CD.

The Electrical Line Shaft application set-up CD contains an automatic procedure that copies the required files in the specific folders of the GF Express catalog. Once this is complete, the set-up procedure normally requires the following files with the paths as shown:

The files in the Electrical Line Shaft application

```
adv_els_5_00_asy_v1_0__A1.fl12 (asynchronous motors – application 1)
adv_els_5_00_asy_v1_0__A2.fl12 (asynchronous motors – application 2)
adv_els_5_00_syn_v1_0__A1.fl12 (synchronous motors – application 1)
adv_els_5_00_syn_v1_0__A2.fl12 (synchronous motors – application 2)
```

are copied to

```
...\Programmi\Gefran\Catalog\Drives\Inverter\ADV200\ADV200_5_X_0\Service\
Applications\
```

Drive and Electrical Line Shaft application parameter structure files

```
adv_els_5_00_asy_v1_0.gft
adv_els_5_00_syn_v1_0.gft
```

to

```
...\Programmi\Gefran\Catalog\ Drives\Inverter\ADV200\ADV200_5_X_0
```

4.3 Initial operations

- Check the connections, paying particular attention to shielding (see standard wiring diagrams) in order to reduce interference to a minimum, especially on encoders.
- Set the **IPA 558 Application Select** parameter to the application where you wish to load the Electrical Line Shaft (Application 1 or Application 2).
- If the Electrical Line Shaft application firmware is not already installed, download it using the GF-Express "Download firmware" utility. You can either download the application only, or the entire drive firmware including the application; the latter option is useful if the version of the unit firmware is not compatible.
- Files called "nomefile__A1.fl12" enable the firmware to be downloaded to Application 1, files named "nomefile__A2.fl12" enable the firmware to be downloaded to Application 2.

NB! ADV200 drive is supplied with the PID application installed in Application 1; to avoid overwriting this application, we recommend downloading the firmware to Application 2.

- Send a "Drive reset" command.
- Open the drive parameters file containing the Electrical Line Shaft parameters (.gfe)

- Send the “Load default drive values” command from the E@syDrive Parameters menu to load the default parameters.
- Send a “Save parameter into target” command, then “Drive reset”.

4.4 Drive parameters managed by the application

Each time the Electrical Line Shaft application is launched some drive parameters are set as a function of the application, as follows:

DRIVE CONFIG menu

IPA 552 Regulation mode = Flux vector CL
IPA 556 Control mode select = Speed

REFERENCES menu

IPA 650 Speed ref 1 src = Dig speed ref 1

In order to ensure correct operation of the application, these settings must be saved and not modified.

COMMANDS menu

During application boot-up no pre-setting of COMMANDS parameter menu is done; nevertheless, in order to allow correct application related commands decoding, it is advisable to set following parameters as shown below.

IPA 1000 Commands remote sel = Digital
IPA 1018 Digital Enable src = Digital input E mon
IPA 1020 Digital Start src = Digital input E mon
IPA 1042 FR forward src = Null
IPA 1044 FR reverse src = Null

As an alternative, if slave drive control is fully performed via fieldbus, it is possible to assign parameters IPAs 1018 and 1020 to a single digital command, such as Bit X decomp mon.

Note! Each drive configured as a slave in electrical line shaft mode must be configured so that its absolute **maximum speed** is higher than that of the master, to ensure an adequate operating margin during master capture transients or during phase correction.

5 Control logic and sequences

5.1 Application control modes

The input and output signals of the Electrical Line Shaft application for ADV200 drives and the relative sequences are managed by a superordinate control device such as a PLC or IPC.

The application can thus be controlled via discrete digital I/O (digital input and output terminals on the ADV200 regulation card and any expansion cards, such as EXP-IO-D6A4R1-ADV); the use of a fieldbus interface (Profibus, Devicenet, Canopen, EtherCAT) allows more flexible management (virtual I/O, positioning and phase variation). Moreover, the fieldbus configuration channel enables access to all drive and application parameters in read and write mode.

Note on assignment of commands and application signals

In addition to the physical and virtual digital inputs, each selection list for assigning application commands (jog, zero search, positioning, capture in electrical line shaft mode) contains the “**Digital Param**” item: when this item is assigned, the corresponding command can be managed via a local interface parameter, generally located in the same sub-menu or in the DIGITAL INPUTS menu.

For example, if the Move Trigger Source command is set to Digital Param, the positioning command is only activated via the IPA 11506 Digital Move Trigger parameter (Off / On) from GF Express or the drive keypad.

As far as application signals are concerned, in addition to those assigned directly to the digital outputs in the DIGITAL OUTPUTS menu, each sub-menu relating to the various functions contains the relevant signal flags (“Mon” parameters).

5.2 Jog function

The jog function is used to perform service movements of the axis controlled by the Electrical Line Shaft application independently of the master axis.

To define the source of the jog command, set the **IPA 11502 Jog Input Source** parameter in the DIGITAL INPUTS menu of the application.

The speed and acceleration parameters are assigned, respectively, via parameters **IPA 11308 Jog Speed**, **IPA 11310 Jog Accel** and **IPA 11312 Jog Decel** in the POSITION menu of the ADV200 drive. The motor starts the acceleration ramp when the jog command is activated. The jog speed is maintained for as long as the command remains active and the deceleration ramp starts when the command is disabled. The direction of rotation of the motor is defined by assigning parameter **IPA 11316 Jog Direction Source** in the POSITION menu of the application.

5.3 Zero search

Zero searches are performed to move the slave axis to a predetermined position using an external digital signal referred to as zero sensor. The zero search configuration parameters are contained in the HOME REFERENCE menu.

The zero search procedure is generally launched by activating the digital input signal assigned via the **IPA 11706 Home Request Source** parameter; the zero sensor digital input signal is assigned via the **IPA 11708 Home Sensor Source** parameter while the speeds used during the procedure are defined by the **IPA 11700 Home Speed** and **IPA 11702 Home Creep Speed** parameters. The former is used until the sensor is engaged for the first time, the latter when said sensor is cleared.

The strategy for engaging and clearing the zero sensor is established via the **IPA 11710 Home Direction** parameter: this is set to determine the direction of rotation of the motor until the zero sensor is engaged and that used subsequently to clear the sensor; the zero search can also be performed without the motor turning at all.

At the end of the zero search, the **IPA 12000 Actual Pos** parameter is reset. The axis can also then be made to run a positioning procedure at a position set via the **IPA 11704 Home Offset Move** parameter.

Zero search activity is signalled by the **IPA 12022 Home Busy Mon** flag or a digital output configured as “**Home Busy**”.

When the procedure is complete this is signalled by the **IPA 12058 Home Complete Mon** flag or by a digital output configured as “**Pos Zero Found**”.

5.4 Positioning

At the end of the zero search, positioning can be performed independently of the slave axis. This is always done in **incremental** mode, i.e. the target position is always referred to the actual position of the slave axis; this may be necessary if the slave axis has to reach an exact position before synchronous capturing of the master. The main parameters for configuring the positioner are located in the POSITION menu.

The unit of measure for positioning is defined in user units (u.u.) via the **IPA 11318 User unit per rev** parameter, which indicates the number of user units associated with one revolution of the slave axis position encoder (Encoder 1).

The target position is generally specified via the **IPA 11300 Target Pos** parameter.

The source for the target position can be assigned directly to a datum coming from the fieldbus interface, using the **IPA 11298 Target Source** parameter.

Positioning profile data for speed (maximum), and the acceleration and deceleration ramps can be set, respectively, via the **IPA 11302 Move Speed**, **IPA 11304 Move Accel** and **IPA 11306 IPA Move Decel** parameters.

Positioning speed is specified in user units per second (u.u./s), while acceleration and deceleration are expressed in user units per second squared (u.u./s²).

Positioning is launched by activating the digital input signal assigned via the **IPA 11500 Move Trigger Source** parameter in the DIGITAL INPUTS menu; the end of the procedure is indicated by the setting (0->1) of the **In Position** digital output signal, available as a flag (IPA 12060) or assignable to a digital output in the DIGITAL OUTPUTS menu.

5.4.1 Correction of the position of the slave axis in electrical line shaft mode (phase trim)

The Move Trigger positioning command and the target position specified can also be used during synchronous capture of the master by the slave, or when the ELS Engage command is active: in this case the position of the slave axis can be adjusted with respect to the master axis (*phase trim*).

Activation of the positioning command with a target position other than zero with the slave capturing the master triggers a transient during which the phase ratio between the master and slave axes in electrical line shaft mode is temporarily lost; to reach the new position reference, the speed of the slave axis, required in order to maintain the synchronous phase ratio, is adjusted by the value calculated by the position profile generator. As a result, during said transient, the slave axis moves at a hyper-synchronous or hypo-synchronous speed, depending on the sign of the specified target position.

5.5 Electrical line shaft function

The electrical line shaft function works in a master-slave configuration, where the master (which may be a drive) specifies a position reference that the slave must follow. The slave axis receives and processes the information from the master encoder to determine its speed reference in order to minimise the difference between its position and that of the master maintaining the selected electronic gear ratio.

The electrical line shaft function consists of two parts: one, called *feed-forward generation*, which reads the speed of the master encoder and calculates the ideal speed reference for the slave axis in relation to the selected ratio; the other, called *feedback control*, calculates the position error as the difference between the position of the master encoder and that of the slave and, taking into account the selected ratio, sends it to a PID controller to be corrected.

The electrical line shaft mode can be enabled for each slave via digital command assigned with the **IPA 11504 ELS Engage Source** parameter in the DIGITAL INPUTS menu.

When captured, the slave axis moves to the selected ratio with the master following a linear ramp, the duration of which is specified in milliseconds via the **IPA 11444 ELS Sync Time** parameter.

The use of a linear ramp means that during capture the slave is "delayed" with respect to the master; this delay is subsequently corrected by applying an overspeed. This correction phase is signalled by the **Sync Correction Mon** flag in the LINE SHAFT menu, or by a digital output programmed as "**ELS Correction**".

The source for the master position reference is selected via the **IPA 11394 Master Pos Source** parameter; at present the local parameter IPA 11396 Digital Master Pos, "Encoder 2" or Fast Link can be specified.

The electrical line shaft ratio is calculated by application as follows:

$$\text{Ratio} = \text{Mstr/Slv PPR Ratio} \cdot (\text{Ratio n Num} / \text{Ratio n Denom})$$

where parameter **IPA 11398 Mstr/Slv PPR Ratio** represents the ratio between resolutions of master and slave encoder, and parameters **Ratio n Num** and **Ratio n Denom**, with $1 \leq n \leq 4$, take into account mechanical factors as 32 bit float ratio. An example of calculation for gear ratio starting from application mechanical data can be found at section 7.1.

Electronic gear ratio selection from a maximum of 4 values is possible via two digital commands that can be set using the **IPA 11416 Ratio Select B0** and **IPA 11418 Ratio Select B1** parameters.

The ratio currently used in the electrical line shaft mode is indicated by the dedicated monitor parameters, namely **IPA 12062 Actual Ratio Mon**, which indicates the value of the ratio, and **IPA 12084 Ratio Select Mon**, which indicates the ratio "aimed at" by the selection commands.

5.5.1 Correction of the electrical line shaft ratio (slip)

In applications where the electrical line shaft ratio is not numerically defined, for instance due to mechanical tolerances, or where it is subject to variation in time due to mechanical wear, thermal dilatation, etc, the Slip function, which allows fine tuning of the ratio, may be useful.

The slip function allows the electrical line shaft ratio to be increased or decreased continuously using two respective digital commands that can be assigned with parameters **IPA 11432 Slip Pos Src** and **IPA 11434 Slip Neg Src**. The slip ratio can vary between -1...+1 and changes to the ratio are calculated as:

$$\text{Ratio} = \text{Ratio} \times (1 + \text{Slip Ratio})$$

where:

$$\text{Slip Ratio} (n+1) = \text{Slip Ratio} (n) \pm \text{Slip Increment}$$

The **IPA 11436 Slip Increment** parameter defines the minimum change applied to the slip. The rate at which this is increased or decreased is modified by means of two timers that can be set with **IPA 11428 Slip T1** and **IPA 11430 Slip T2**. A change equal to a single Slip Increment is applied to the activation edge of an increase/decrease slip command; if the command remains active for a time equal to at least T1 [ms], the slip is subsequently updated at a rate of $F1 = 1/T1$ [increments /sec]; if the command remains active for another time equal to at least T2 [ms], the slip is subsequently updated at a rate of $F2 = 1/T2$ [increments /sec].

5.5.2 Monitoring of the position of the master with the slave not captured and recovery

In some applications the difference in the position between the master and slave must be monitored even when the latter is not capturing the master in electrical line shaft mode and, in some cases, this must be recovered the next time the slave captures the master.

For this purpose the **IPA 11446 Engage Recovery** parameter is used, to recover any difference in position that has built up between the master and slave while operating independently the first time the slave recaptures the master in electrical line shaft mode.

There is a digital command that can be assigned with the **IPA 11448 Engage Rst Src** parameter to reset the difference that has accumulated during independent operation. Activating this command on the slave before the ELS Engage command allows it to capture the master from the instantaneous position of the slave, even when the Engage Recovery command is set to “On”.

5.6 Application block diagram

Electrical line shaft application can be schematized as in following picture.

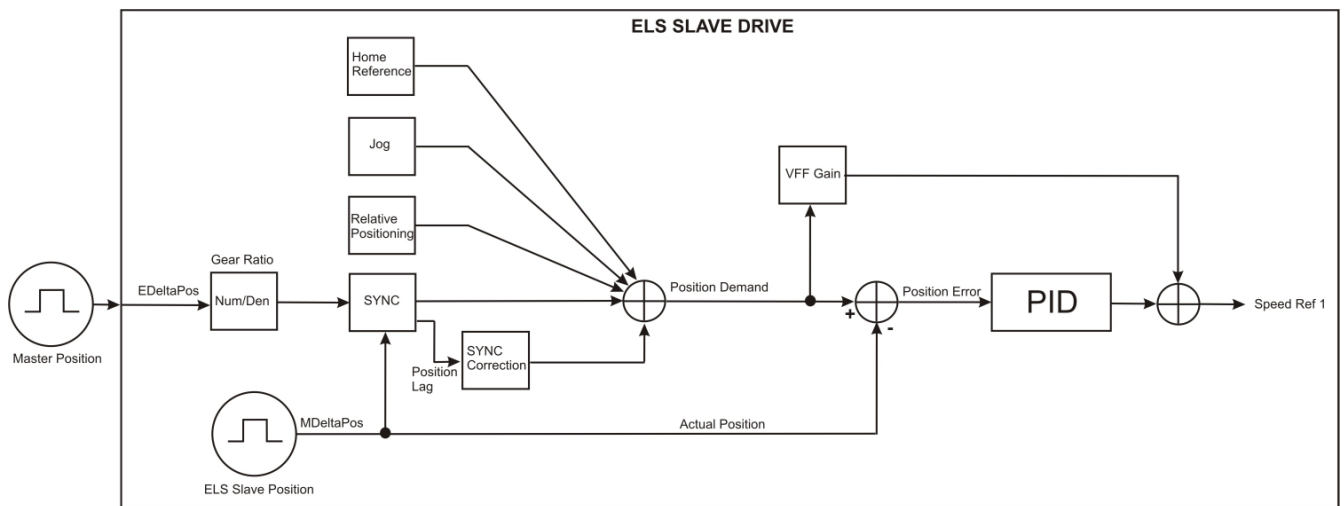


Figure 3.6: Electrical line shaft application block diagram

All application functions, from synchronous operation in line shaft mode to relative positioning, axis jogging and homing, are performed in position control.

Master encoder position variations are scaled according to gear ratio and used by line shaft engage software block (SYNC) to generate time- based engagement profile, which is completed within **ELS Sync Time** parameter.

“SYNC Correction” software block deals with master – slave position error monitoring, in order to manage recoveries, gear ratio changes and phase trimming.

“Home Reference”, “Jog” and “Relative Positioning” software blocks generate position setpoints as well, each of them managed by overhead control in a mutually exclusive way.

“Position Demand” setpoint ,produced by software blocks above described, is the actual sum of all terms; this is directly generating feed-forward part of speed demand for slave drive.

Position error, calculated as difference between Position Demand and slave motor actual position, is processed by PID regulator and generates speed correction for slave drive, resulting in Speed Reference 1 setpoint.

6 List of Parameters

This section contains the list and description of the parameters, which are grouped according to the sub-menus of the ELS in the parameters file of the drive where the application is installed.

6.1 SERVO PID menu

This menu contains the general application configuration parameters.

lpa	Parameter Name	User type	Target type	Unit	Default	Min	Max
11200	P Gain	Long	Long	-	100	0	1000
11202	I Gain	Long	Long	-	0	0	1000
11204	D Gain	Long	Long	-	0	0	1000
11206	VFF Gain	Long	Long	-	3500	0	1000
11208	OV Gain	Long	Long	-	0	0	1000
11210	Anti Wind Up	Long	Long	-	65535	0	65535
11212	Pos Error Warn	Long	Long	u.u.	180	1	32767
11214	Pos Error Alarm	Long	Long	u.u.	270	1	32767
11216	Pos Error Warn Time	Int	Int	ms	250	0	16384
11218	Pos Error Alarm Time	Int	Int	ms	500	0	16384
12000*	Actual Pos	Long	Long	u.u.	-	-	-
12002*	Demand Pos	Long	Long	u.u.	-	-	-
12004*	Error Pos	Long	Long	u.u.	-	-	-
12024*	PosError Warn Mon	Bool	Bool	-	-	-	-
12026*	PosError Alm Mon	Bool	Bool	-	-	-	-

P Gain Setting of the proportional gain of the PID controller in position feedback control mode.

I Gain Setting of the integral gain of the PID controller in position feedback control mode.

D Gain Setting of the derivative gain of the PID controller in position feedback control mode.

VFF Gain Setting of the speed feed forward generation gain.

OV Gain Setting of the gain relating to the component proportional to the speed at which the speed output of the feed forward generation part changes.

Anti Wind Up Setting of the limit for the integral component of the PID controller in position feedback control mode.

Pos Error Warn Setting of the position error threshold (u.u.) between the master and slave which, when exceeded, generates a warning.

Pos Error Alarm Setting of the position error threshold (u.u.) between the master and slave which, when exceeded, generates an alarm.

Pos Error Warn Time Setting of the latency (ms) of the position error warning.

Pos Error Alarm Time Setting of the latency (ms) of the position error alarm.

Actual Position This parameter displays the actual position of the motor in user units.

Demand Position This parameter displays the position reference in user units.

- Error Pos** This parameter displays the actual position error in user units.
- PosError Warn Mon** This parameter displays the state of the position error warning.
- PosError Alm Mon** This parameter displays the state of the position error alarm.

6.2 POSITION menu

The parameters in this menu are used to configure the independent motion of the slave axis, in jog or positioning mode.

Ipa	Parameter Name	User type	Target type	Unit	Default	Min	Max
11298	Target Source	Enum	Int		From IPA 11300	-	-
11300	Target Pos	Long	Long	u.u.	360	-	-
11302	Move Speed	Long	Long	u.u./s	3600	0	32767
11304	Move Accel	Long	Long	u.u./s ²	3600	0	32767
11306	Move Decel	Long	Long	u.u./s ²	3600	0	32767
11308	Jog Speed	Long	Long	u.u./s	90	0	32767
11310	Jog Accel	Long	Long	u.u./s ²	1800	0	32767
11312	Jog Decel	Long	Long	u.u./s ²	1800	0	32767
11314	Digital Jog Dir	Bool	Bool	-	Off	-	-
11316	Jog Direction Source	Enum	Int	-	Digital Param	-	-
11318	User Unit Per Rev	Long	Long	u.u.	360	1	32767
12020*	Move Busy Mon	Bool	Bool	-	-	-	-
12060*	In Position	Bool	Bool	-	-	-	-
12088*	Jog Direction Mon	Bool	Bool	-	-	-	-
12100*	Target Position Mon	Long	Long	-	-	-	-

- Target Source** This is used to select the source of the target position in positioning mode or to set the new position in relation to the master in electrical line shaft mode (phase trim).
From IP 11300 indicates that the position reference source is the IPA 11300 Target Pos parameter.
From FB W3 indicates that the position reference source is the third parameter in the fieldbus process data buffer.
- Target Pos** Setting of the target position in user units. The target position is always calculated starting from the actual axis position.
- Move Speed** Setting of the maximum speed reference value used by the profile generator during positioning, expressed in user units per second.
- Move Accel** Setting of the acceleration used by the profile generator during positioning, in user units per second squared.
- Move Decel** Setting of the deceleration used by the profile generator during positioning, in user units per second squared.
- Jog Speed** Setting of the maximum speed in jog mode in user units per second.
- Jog Accel** Setting of the acceleration used in jog mode in user units per second squared.
- Jog Decel** Setting of the deceleration used in jog mode in user units per second squared.

Digital Jog Dir	Local setting for the direction of rotation of the motor in jog mode. <u>Off</u> Clockwise rotation (motor shaft seen from the front). On Anti-clockwise rotation (motor shaft seen from the front).
Jog Direction Source	This parameter is used to select the source for the digital command to set the direction of rotation of the motor in jog mode.
User Unit Per Rev	Setting of the number of user units (u.u.) corresponding to 1 revolution of the slave axis motor encoder. The units used for the speed (u.u./s) and for acceleration and deceleration (u.u./s ²) also depend on this setting for the position units of measure.
<i>Example: the default position settings are 360 units per encoder revolution, 3600 u.u./s for the positioning speed (corresponding to 10 revolutions per second, or 600 rpm) and 3600 u.u./s² for the ramps (corresponding to 1 second to reach 600 rpm).</i>	
Move Busy Mon	Monitor flag active (On) for the entire duration of a positioning operation.
In Position	Monitor flag active when a positioning operation has been completed.
Jog Direction Mon	Monitor flag for the direction of rotation selected in jog mode.
Target Position Mon	Monitor of current target position in user units.

6.3 LINE SHAFT menu

This menu is used to configure the electrical line shaft operating mode.

Ipa	Parameter Name	User type	Target type	Unit	Default	Min	Max
11394	Master Pos Source	Enum	Int	-	Encoder 2	-	-
11396	Digital Master Pos	Long	Long	u.u.	0	-	-
11398	Mstr/Slv PPR Ratio	Float	Float	-	1	-1000	1000
11400	Ratio 1 Num	Float	Float	-	1	-9999.00	9999.00
11402	Ratio 2 Num	Float	Float	-	1	-9999.00	9999.00
11404	Ratio 3 Num	Float	Float	-	1	-9999.00	9999.00
11406	Ratio 4 Num	Float	Float	-	1	-9999.00	9999.00
11408	Ratio 1 Den	Float	Float	-	1	1.00	9999.00
11410	Ratio 2 Den	Float	Float	-	1	1.00	9999.00
11412	Ratio 3 Den	Float	Float	-	1	1.00	9999.00
11414	Ratio 4 Den	Float	Float	-	1	1.00	9999.00
11416	Ratio Select B0	Enum	Int	-	Digital Param	-	-
11418	Ratio Select B1	Enum	Int	-	Digital Param	-	-
11420	Digital Ratio B0	Boolean	Boolean	-	Off	-	-
11422	Digital Ratio B1	Boolean	Boolean	-	Off	-	-
11424	Mechanical Num	Int	Int	-	100	0	32767
11426	Mechanical Den	Int	Int	ms	100	1	32767
11428	Slip T1	Int	Int	ms	75	0	1000
11430	Slip T2	Int	Int	-	250	0	1000
11432	Slip Pos Src	Enum	Int	-	Digital Param	-	-
11434	Slip Neg Src	Enum	Int	-	Digital Param	-	-
11436	Slip Increment	Float	Float	-	0.01	0	1
11438	Digital Slip Inc	Boolean	Boolean	-	Off	-	-
11440	Digital Slip Dec	Boolean	Boolean	-	Off	-	-
11442	Slip Ratio	Float	Float	-	0	-1	1
11444	ELS Sync Time	Int	Int	-	0	0	32767
11446	Engage Recovery	Boolean	Boolean	-	Off	-	-
11448	Engage Rst Src	Enum	Int	-	Digital Param	-	-
11450	Digital Engage Reset	Boolean	Boolean	-	Off	-	-
12016*	In Sync Mon	Boolean	Boolean	-	Off	-	-
12018*	Sync Correction Mon	Boolean	Boolean	-	Off	-	-
12062*	Actual Ratio Mon	Float	Float	-	-	-	-
12064*	Actual Ratio Den	Int	Int	-	-	-	-
12066*	Actual Ratio Num	Int	Int	-	-	-	-
12074*	Engage Pos Error	Long	Long	-	-	-	-
12084*	Ratio Select Mon	Int	Int	-	-	-	-

Master Pos Source Setting of the master position reference source in electrical line shaft mode.
Digital Param indicates that the master position reference source in electrical line shaft mode is parameter IPA 11396 Digital Master Pos.
Encoder 2 indicates that the master position reference source in electrical line shaft mode is associated with the encoder 2 input.
FastLinkPosRev indicates that the position reference source is the IPA 11300 Target Pos parameter.

Digital Master Pos Local setting of the master position reference in electrical line shaft mode.

Mstr/Slv PPR Ratio	Setting of the resolution ratio between the master encoder and slave encoder in electrical line shaft mode; expressed as the ratio between the rated impulses/revolutions of the respective encoders.
Ratio n Num	Setting of the electrical line shaft ratio numerator n ($1 \leq n \leq 4$).
Ratio n Denom	Setting of the electrical line shaft ratio denominator n ($1 \leq n \leq 4$).
Mechanical Num	Setting of the numerator of the mechanical ratio between master and slave, used in zero search and positioning mode only.
Mechanical Den	Setting of the denominator of the mechanical ratio between master and slave, used in zero search and positioning mode only.
Slip T1	Setting of the first timer (ms) for maintaining the frequency $F1 = 1/T1$ at which the slip is increased/decreased in electrical line shaft mode.
Slip T2	Setting of the second timer (ms) for maintaining the frequency $F2 = 1/T1$ at which the slip is increased/decreased in electrical line shaft mode.
Slip Pos Src	This parameter is used to select the source for the digital slip increase command in electrical line shaft mode.
Slip Neg Src	This parameter is used to select the source for the digital slip decrease command in electrical line shaft mode.
Slip Increment	Setting of the minimum change to slip in electrical line shaft mode.
Digital Slip Inc	Local setting for the digital slip increase command in electrical line shaft mode.
Digital Slip Dec	Local setting for the digital slip decrease command in electrical line shaft mode.
Slip Ratio	Actual slip value monitor.
ELS Sync Time	Setting of the ramp time (ms) for the slave axis to bring the electrical line shaft ratio from zero to the currently selected value.
Engage Recovery	<p>This parameter is used to activate monitoring and recovery of the difference in position that accumulates when the master and slave work independently (slave not engaged in electrical line shaft mode).</p> <p>Off Accumulated position difference is ignored; slave engages master at ELS Engage command current position. Slave is anyway recovering accumulated position difference due to already moving master.</p> <p>On Accumulated position difference is recovered at first re-engagement command for slave.</p>

Note! Each drive configured as a slave in electrical line shaft mode must be configured so that its absolute **maximum speed** is higher than that of the master, to ensure an adequate operating margin during master capture transients or during phase correction.
During these transients slave speed can reach maximum limit and thus overtake master speed.

Engage Rst Src	This parameter is used to select the source for the digital command to reset the difference in position between the master and slave.
Digital Engage Reset	Local setting for the digital command to reset the difference in position between the master and slave.
FL Master PPR	Setting of the resolution of the master encoder if using the FastLink interface.

In Sync Mon	Monitor flag active during operation in electrical line shaft mode.
Sync Correction Mon	Monitor flag active during slave capture of the master and during slave phase correction in electrical line shaft mode.
Actual Ratio Mon	Monitor of the actual electrical line shaft ratio in use.
Actual Ratio Den	Monitor of the actual electrical line shaft ratio denominator in use.
Actual Ratio Num	Monitor of the actual electrical line shaft ratio numerator in use.
Engage Pos Error	Monitor of the difference in position accumulated during independent slave operation.
Ratio Select Mon	Monitor of the actual electrical line shaft ratio number selected (1...4).

6.4 DIGITAL INPUTS menu

This menu is used to assign the digital commands for the electrical line shaft application functions.

Ipa	Parameter Name	User type	Target type	Unit	Default	Min	Max
11500	Move Trigger Source	Enum	Int	-	DigIn1	-	-
11502	Jog Input Source	Enum	Int	-	DigIn2	-	-
11504	ELS Engage Source	Enum	Int	-	DigIn3	-	-
11506	Digital Move Trigger	Boolean	Boolean	-	Off	-	-
11508	Digital Jog Trigger	Boolean	Boolean	-	Off	-	-
11510	Digital ELS Engage	Boolean	Boolean	-	Off	-	-
12006*	Move Mon	Boolean	Boolean	-	Off	-	-
12008*	Jog Mon	Boolean	Boolean	-	Off	-	-
12010*	ELS Engage Mon	Boolean	Boolean	-	Off	-	-
12038*	Command Word Mon	Int	Int	-	-	-	-

Move Trigger Source	This parameter is used to select the source for the digital command to launch a positioning operation.
Jog Input Source	This parameter is used to select the source for the jog digital command.
ELS Engage Source	This parameter is used to select the source for the digital command to capture the master in electrical line shaft mode.
Digital Move Trigger	Local setting for the digital command to launch a positioning operation.
Digital Jog Trigger	Local setting for the digital command to launch jog operation.
Digital ELS Engage	Local setting for the digital command to capture the master in electrical line shaft mode.
Move Mon	Monitor flag active during positioning or phase correction in electrical line shaft mode.
Jog Mon	Monitor flag active during jog operations.
ELS Engage Mon	Monitor flag active when the slave is capturing the master in electrical line shaft mode.
Command Word Mon	Electrical line shaft application control word monitor. This contains the commands defined in the DIGITAL INPUTS menu, in the same order and starting from the least significant bit.

6.5 DIGITAL OUTPUTS menu

This menu is used to assign the digital outputs for the electrical line shaft application signals.

IpA	Parameter Name	User type	Target type	Unit	Default	Min	Max
11600	Digital Out 1 Source	Enum	Int		Drive Healthy	-	-
11602	Digital Out 2 Source	Enum	Int		Zero Speed	-	-
11604	Digital Out 3 Source	Enum	Int		In Sync	-	-
11606	Digital Out 4 Source	Enum	Int		Move Busy	-	-
12028*	Digit Out 1 Mon	Boolean	Boolean		Off	-	-
12030*	Digit Out 2 Mon	Boolean	Boolean		Off	-	-
12032*	Digit Out 3 Mon	Boolean	Boolean		Off	-	-
12034*	Digit Out 4 Mon	Boolean	Boolean		Off	-	-
12036*	Status Word Mon	Int	Int		-	-	-

Digital Out <i>n</i> Source	<p>This parameter is used to assign the signal flags relating to the electrical line shaft application to digital output <i>n</i> of the ADV200 ($1 \leq n \leq 4$).</p> <p>True Digital output always active (high).</p> <p>Drive Healthy indicates that there are no drive faults.</p> <p>Zero Speed indicates that the motor speed is below the drive zero speed threshold.</p> <p>In Sync indicates that the slave is working in electrical line shaft mode capturing the master.</p> <p>ELS Correction indicates that the slave is capturing the master in electrical line shaft mode.</p> <p>Move Busy indicates that the slave is engaged in a positioning operation or that phase correction is underway in electrical line shaft mode.</p> <p>Pos Error Warn indicates that the position error warning threshold has been exceeded in electrical line shaft mode.</p> <p>Pos Error Alarm indicates that the position error alarm threshold has been exceeded in electrical line shaft mode.</p> <p>Pos Zero Found indicates that the slave has completed the zero search procedure successfully.</p> <p>In Position indicates that the slave has completed a positioning operation.</p>
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Status Word Mon	<p>Electrical line shaft application status word monitor. Single bits coding is set as follows:</p> <p>Bit 0 ELS Move mon</p> <p>Bit 1 ELS Engage mon</p> <p>Bit 2 Home Sensor mon</p> <p>Bit 3 In Sync mon</p> <p>Bit 4 Correction mon</p> <p>Bit 5 Move Busy mon</p> <p>Bit 6 Home Sensor mon</p> <p>Bit 7 Home Busy mon</p> <p>Bit 8 Error Warning mon</p> <p>Bit 9 Error Alarm mon</p> <p>Bit 10 Home Complete mon</p> <p>Bit 11 In Position mon</p>
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Nota! Electrical shaft application status word is automatically mapped on fieldbus data 2 of ADV200. Therefore, this data has to be mapped as following:

IPA 4190 Fieldbus S→M2 ipa = 4194

IPA 4192 Fieldbus S→M2 sys = Mdplc 16

6.6 HOME REFERENCE menu

Ipa	Parameter Name	User type	Target type	Unit	Default	Min	Max
11700	Home Speed	Long	Long	u.u./s	180	0	32767
11702	Home Creep Speed	Long	Long	u.u./s	90	0	32767
11704	Home Offset Move	Long	Long	u.u.	90	0	32767
11706	Home Request Source	Enum	Int		DigIn 4	-	-
11708	Home Sensor Source	Enum	Int		DigIn 5	-	-
11710	Home Direction	Enum	Int		CW ON CCW OFF	-	-
11712	Digital Home Request	Boolean	Boolean		Off	-	-
11714	Digital Home Sensor	Boolean	Boolean		Off	-	-
12012*	Home Request Mon	Boolean	Boolean		Off	-	-
12014*	Home Sensor Mon	Boolean	Boolean		Off	-	-
12022*	Home Busy Mon	Boolean	Boolean		Off	-	-
12058*	Home Complete Mon	Boolean	Boolean		Off	-	-

- Home Speed** Setting of the first reference sensor search speed (u.u./s) during the zero search.
- Home Creep Speed** Setting of the first reference sensor clearing speed (u.u./s) during the zero search.
- Home Offset Move** Setting of the position (u.u.) to be reached following completion of the zero search.
- Home Request Source** This parameter is used to select the source for the digital command to launch a zero search.
- Home Sensor Source** This parameter is used to select the source for the zero search sensor digital input.
- Home Direction** Setting of the reference sensor engage/clear strategy in the zero search. This parameter establishes the initial direction of rotation in the sensor search and the subsequent direction of rotation used to clear it.
- CW ON CW OFF** Start in clockwise direction, clear in clockwise direction.
- CW ON CCW OFF** Start in clockwise direction, clear in anti-clockwise direction.
- CCW ON CW OFF** Start in anti-clockwise direction, clear in clockwise direction.
- CCW ON CCW OFF** Start in anti-clockwise direction, clear in anti-clockwise direction.
- NO MOVEMENT** Zero search with no movement (zero on-the-spot)
- Digital Home Request** Local setting for the digital command to launch the zero search.
- Digital Home Sensor** Local setting for the digital input of the zero search reference sensor.
- Home Request Mon** Monitor flag of the start zero search command.
- Home Sensor Mon** Monitor flag of the digital input of the zero search reference sensor.
- Home Busy Mon** Monitor flag active during the zero search.
- Home Complete Mon** Monitor flag active when the zero search is complete.

6.7 EXCHANGE menu

lpa	Parameter Name	User type	Target type	Unit	Default	Min	Max

Menu accessed by service password.

6.8 ABOUT menu

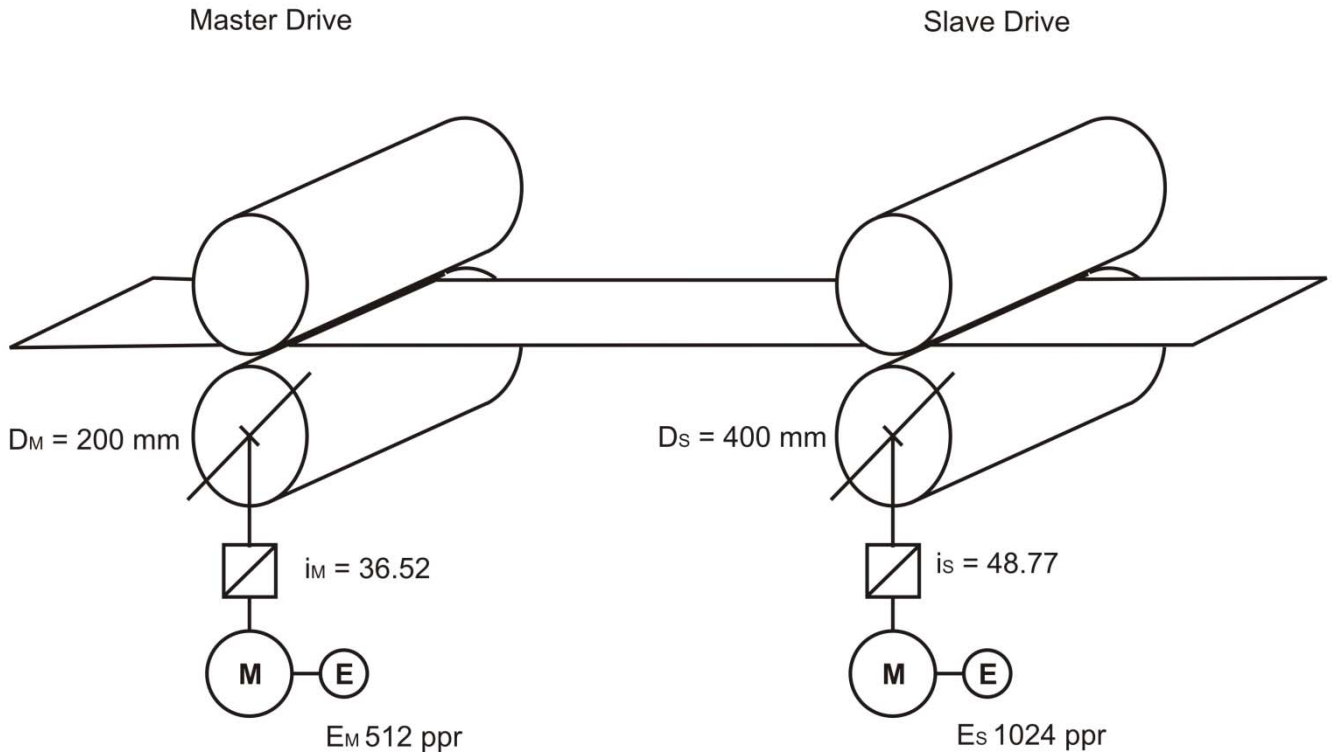
This menu contains the parameters that identify the electrical line shaft application.

lpa	Parameter Name	User type	Target type	Unit	Default	Min	Max
12092*	APPLVERSION	Float	Float	-	-	-	-
12094*	MDPLCVERSION	Float	Float	-	-	-	-
12096*	CONFVERSION	Float	Float	-	-	-	-
12098*	APPLDATE	Float	Float	-	-	-	-

7 Examples

7.1 Gear ratio calculation example

In the following application example some metal sheet passes through two stage rollers, which are commanded by different drives.



Data:

D_M master roller diameter

D_S slave roller diameter

i_M master gear ratio (3 stage helical-bevel gear with teeth no. 40/25, 33/8, 83/15)

i_S slave gear ratio (3 stage helical-bevel gear with teeth no. 47/23, 33/8, 81/14)

E_M master encoder resolution

E_S slave encoder resolution

Gear ratio can be calculated as master to slave position resolution ratios, defined as no. pulses counted by master and slave encoder respectively, corresponding to the same material displacement.

Thus:

$$\text{Ratio} = \frac{P_M}{P_S} \text{ where}$$

$$P_M = \frac{E_M i_M}{\pi D_M} \text{ master encoder position resolution [impulsi / mm]}$$

$$P_S = \frac{E_S i_S}{\pi D_S} \text{ slave encoder position resolution [impulsi / mm]}$$

So

$$Ratio = \left(\frac{E_M}{E_S}\right) \left(\frac{i_M D_S}{i_S D_M}\right)$$

Where the first factor can be set on parameter **IPA 11398 Mstr/Slv PPR Ratio**, while the second can be calculated as integer numbers ratio by using gear manufacturer's data.

It can be obtained the following:

$$Ratio = \left(\frac{1}{2}\right) \left(\frac{427616}{285525}\right)$$

And finally

Mstr/Slv PPR Ratio = 0.5

Ratio 1 Num = 427616

Ratio 1 Denom = 285525.

7.2 Startup, tuning and performance check

General notes about project

- Electrical shaft application is not suitable for systems where master and slave(s) are coupled by rigid mechanical connection.
- Drives must be equipped with braking units and braking resistors.
- Slave full scale speed must be higher than master one. In case of asynchronous motors, slave motor available torque in deflux mode speed range must be checked.
- "External Fault" signal from slave to master drive should always be connected, in such a way that master can stop as soon as slave drive fault occurs.
- Some applications (e.g. multi-column hoists) require all drives and motors same type.
- In case of external master encoder, use components with maximum resolution possible (preliminary check that maximum frequency input limit for ADVencoder option boards – 200 kHz for TTL line driver – is not overtaken).

Preliminary operations:

- Check cabling, commands assignments and safety cut-offs.
- Disconnect motors from driven mechanics.
- *Separately* startup master and slave(s) drives in "Flux Vector Closed Loop" regulation mode.
- Tune and test dynamic response of both drives' speed loops.
- Activate Electrical Shaft application on each slave drive and check general parameters (see section 4.4)
- Calculate and set slave gear ratio
- Check master encoder speed and position reading from slave drive when master is moving:
 - In case of master rotary encoder, check IPA 5150 Encoder 2 speed and IPA 5162 Encoder 2 position on slave drive
 - In case of Fast Link master, check parameters IPA 5750 FL Fwd 1 mon and IPA 5752 FL Fwd 2 mon
- With SERVO PID parameters set as default, check slave drive response during synchronous operation (engaged to master): enable master and slave, engage slave (ELS Engage ON), move master motor (also manually) and check that slave is correctly "copying" master movement.

Electrical shaft tuning:

- Set PID gains to zero (IPA 11200, 11202, 11204).

- Let master motor rotate at fixed speed, slave engaged to master.
- Set maximum allowed value for warning and alarm thresholds of slave position error (IPA 11212, 11214).
- Monitor slave speed and position error IPA 12004 Error Pos: starting from default value, set feed-forward gain in a way to get position error as much limited as possible, at least with the lowest variation speed.
- Set PID gains and monitor slave position error also during master speed changes; position error must be limited to pre-defined band during all dynamic conditions.
- Set warning and alarm thresholds of slave position error at values compatible with position error band.
- Connect motors to driven mechanics.
- Reset slave position error of slave in relation to master (activate command assigned by IPA 11448 Engage Rst Src).
- Engage slave to master.
- Check gear ratio setting; adjust by slip setting if required.
- Repeat dynamic tests to make sure PID gains are correct

Tuning procedure can be performed also with motors already connected to driven mechanics, if this is possible without damaging mechanical components.