1 Content

2 Introduction

The described functions in this application note are included in servo positioning controllers of the product family ARS 2000 starting with the following revision of standard firmware if not noted otherwise:

3.5.0.1.5

If applicable please contact your supplier for an update or visit Metronix homepage on http://www.metronix.de.

3 Implementation of linear motors

For the realisable task a translational motion is required in the multiplicity of applications. Linear axis are used frequently. On this the rotary motions of a standard servo motor will be set into the desired linear motion via gear drives or e. g. ball screw drives. However these additional mechanical elements generate a mechanical loss and are subject to mechanical limitations. Again this has a negative effect to the accessible process cycle times.

Linear motors belong to the group of direct drives. These convert the supplied electrical energy ”directly“ into a linear motion. Initially linear motors were throughout special motors in customized designs. Today many linear motors are already offered from standard series. As these are designed as three phase synchronous motors, they can be operated with just a few steps in the parameterization software with the standard firmware of servo positioning controller ARS 2000.

Common in synchronous servo drives the commutating position has to be known when first switching on the drives. Construction conditioned linear measuring systems are being applied to linear motors. These are either performed as absolute or total incremental systems. At total incremental encoders the absolute position information is missing based on one revolution. Therefore a procedure for automatic determination of the commutating position at controller enabling is required.

A special parameter is the construction of linear motors. Compared to standard servo motors the less compact design leads to a worse heat transfer in most cases. Hence the normal i^2t times for motors are less than the one for standard servo motors.

Basically linear motors can be classified into two groups: ironless and iron cored motors. For the most part motors are ironless. This characteristic is relevant for the choice of the procedure of determination of the commutating position.

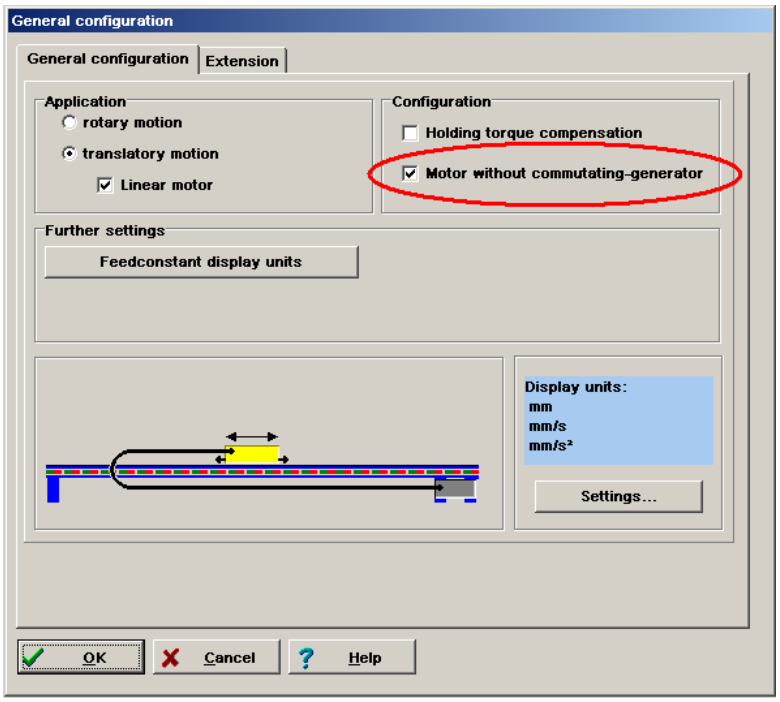
The following chapters describe the required parameterization and offer some information about the available procedures of determination of the commutating position.

4 Parameterization for linear motors

4.1 Base parameterization

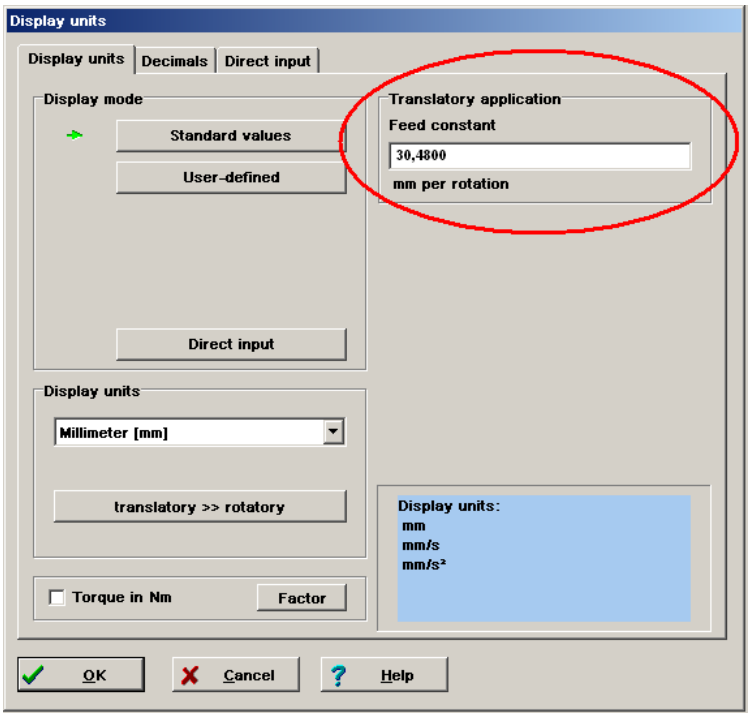
When operating a linear motor you need to differ if the motor has got an encoder with or without commutating signal. In most cases incremental encoder systems or length measuring systems (e. g. with serial communication) are used. In doing so the specification of the electrical impulse at digital encoders respectively the period length at analogue encoders is always required.

No commutating information is available of linear motors with absolute incremental encoder systems. In these cases the checkbox **motor without commutating encoder** has to be marked. The firmware of servo positioning controller ARS 2000 will then run the automatic determination of the commutating position process at controller enabling, in case this position is not known yet.



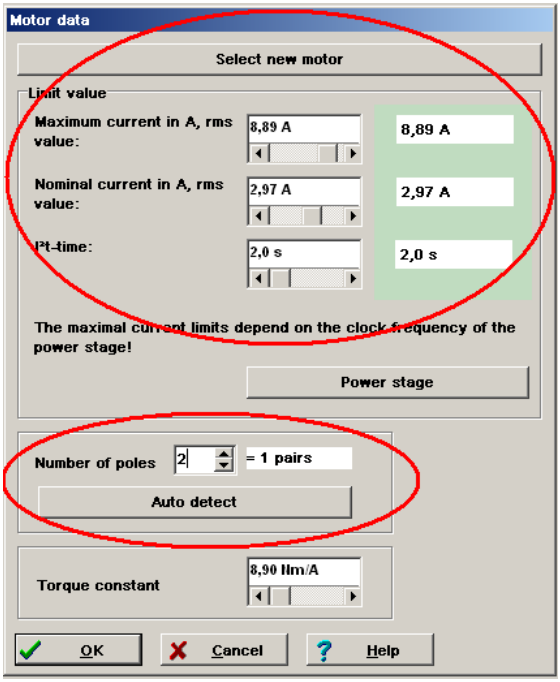
To achieve a translational display of parameters in the parameterizing program Metronix ServoCommander, one has to activate the **Parameters – Application parameters – General configuration** in the window as well as the option **translatory motion** and the checkbox **linear motor.**

These settings as well as the specification of a feed constant at the indicating device in the window **Options – Display units** only have an effect to the diagram within the parameterizing program. They have no effect to the firmware of the servo positioning controllers ARS 2000.



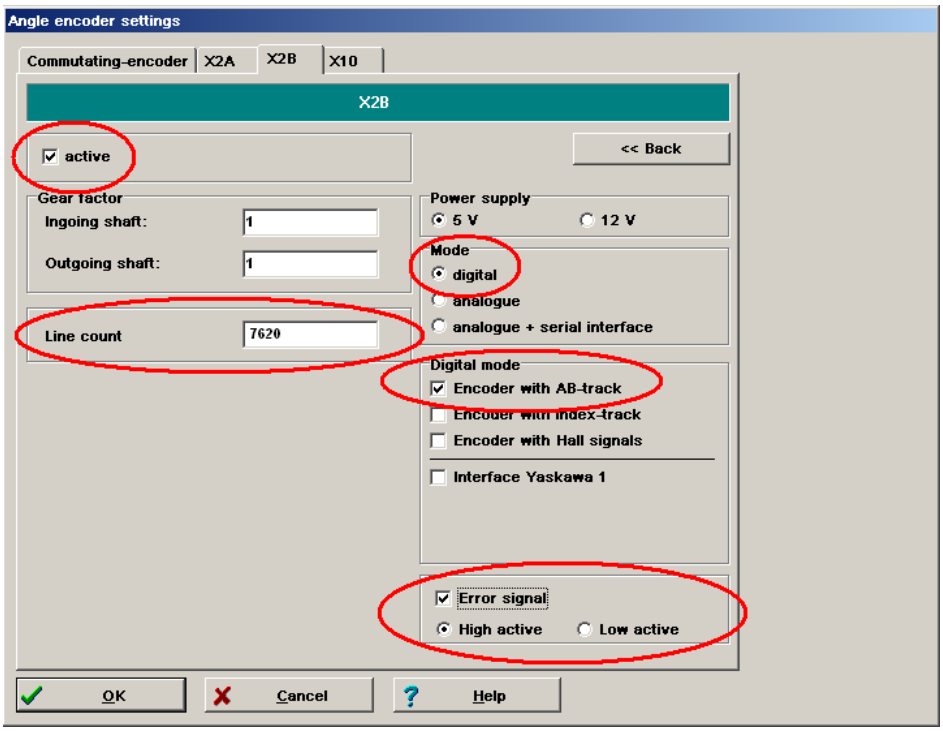
Further necessary information has to be set up:

- Menu **Parameters – Device Parameter – Motor data**:
  - i²t-time motor
    The values are to be taken from the data sheet of the motor.
  - Number of pole pairs
    At linear motors this value will be set to 1 pole pair in general. All further settings always correspond to this value, e. g. setting of electrical impulse of encoders.
  - Nominal current and maximum current
    The values are to be taken from the data sheet of the motor. Special attention needs to be paid on which scaling factor the current is indicated. The parameter is set as root-mean-square value.



Another value than given in the setting of the number of poles > 1 is necessary, if e. g. the periodic length of an analogue encoder does not correspond with the integral multiple to the periodic length. In this case the number of poles needs to be increased in a way that the amount of poles lengths and the amount of periodic lengths is reached in an integral measure. The stated electrical impulse can then be determined via the amount of poles lengths.

- Menu **Parameters – Device parameters – Angle encoder settings – tab X2B**:
  - Active encoder settings to X2B
    The settings need to be transferred by „SAVE+RESET“. A corresponding button will show up in the window of the menu.
  - Setting of Line count
    The values are to be taken from the data sheet of the encoder. The set number of poles has to be taken into consideration. See below respectively settings “Motor data”.
  - Encoder mode with corresponding settings
    These settings are to be taken from the data sheet of the encoder. Important: The correct setting for voltage supply.
  - If applicable activating of error signal analysis



In the case of an analogue encoder the option ”analogue“ has to be chosen. Here the periodical signal length (e. g. a sine period) corresponds to a registered impulse.

The parameter **line count** is to be diverted from the number of impulses, which are read over a track of the stated pole pair number. This can be calculated from the measures of pole pair length and sine period.

<u>Example for a digital signal:</u>
Signal period = 4 µm
Pole pair length = 30.48 mm
Number of pole pairs = 1
=> Line count = (number of pole pair * pole pair length) / signal period
= 30.48 mm / 4 µm = 7620

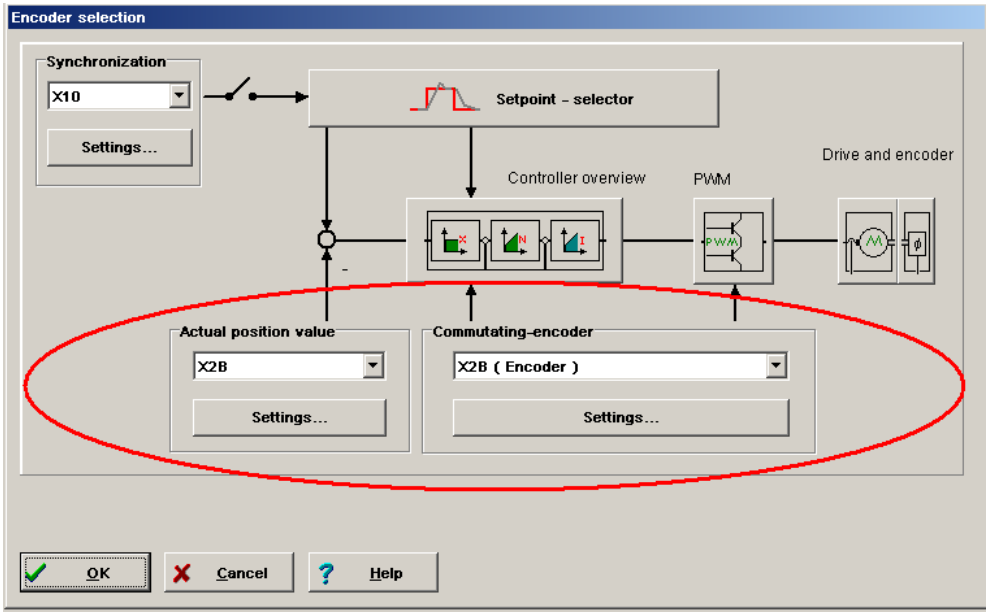
<u>Example for an analogue signal:</u>
Signal period = 20 µm
Pole pair length = 40 mm
Number of pole pairs = 1
=> Line count = (number of pole pair * pole pair length) / signal period
= 40 mm / 20 µm = 2000

At pure serial encoders (only EnDat 2.2) the serial position information is to be specified instead of the sine period of the measuring step of serial position information as well as the track which corresponds to one bit.

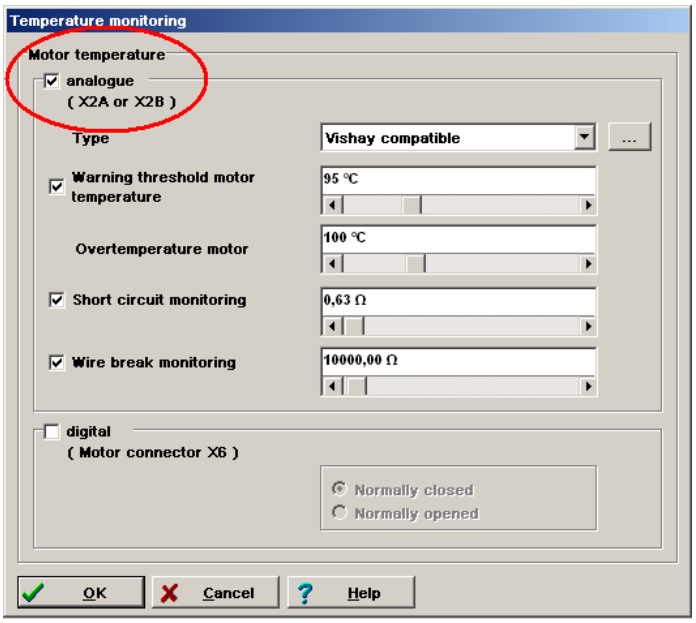
Usually absolute incremental encoders have no marker pulse. These can be available in rotatory direct drives and can be used in case of correcting a non-rational proportion between electrical impulse and pole pair length. The marker trace needs to be activated for such applications. When a marker pulse occurred, an offset angle needs to be diagnosed and saved at least once. This offset angle will then be taken at runtime with the first occurrence of the marker pulse.

A one-off determination and backup of the commutating encoder for the offset angle in case of an absolute length measure system (e. g. LC 483 of company Heidenhain) needs to be carried out.

- Review of encoder feedback settings in the menu **Operating mode – Encoder selection:**
  Both encoder feedbacks for the commutating encoder as well as for the actual position value, needs to be set to „X2B“.



- Optional: menu **Parameters – Device parameters – Temperature monitoring**:
  - Activation of analogue or digital temperature sensors

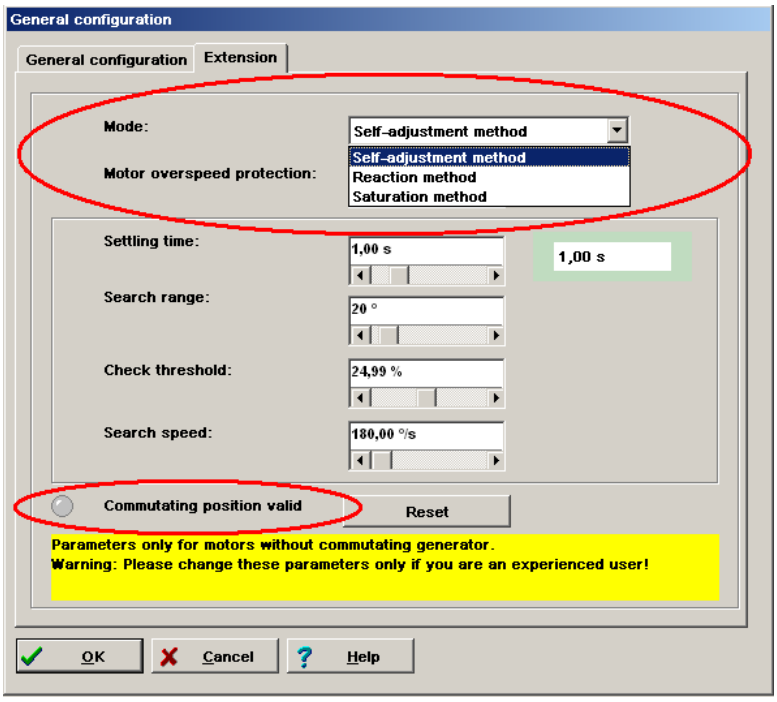


4.2 Method for the determination of the commutation condition

Important:

The setting for the phase order for the reaction method and the saturation method need to have a valid value. These can not be established by neither of both automatic procedures. First of all it has to be determined and saved at least once before e. g. starting the function for automatic determination of the offset angle.

At linear motors and encoders without commutating signal, the automatic determination of the commutating position needs to be chosen for this procedure. This takes part in the window **Parameters – Application parameters – General configuration** on the tab **Extension**:



The settings for the shown parameter ”Motor overspeed protection“ for encoders without commutating signals is not identical with the setting for overspeed protection, which can be accessed via the menu **Parameters - Safety parameters**.

An appropriate procedure is basically determined by the construction and structure of the motor. There are three different procedures to be chosen from:

- **Self-adjustment method**

  This procedure moves the drive controlled via a double search intermittent. In doing so a jerkily motion can occur at the beginning depending on the start position. Not suitable for vertical applications.

- **Reaction method** (recommended)

  For all units without stopping advice, suitable for horizontal and vertical applications. For determination of the commutating position a small motion (basically motionless) would be enough.

- **Saturation method**

  This procedure is qualified for ironless drives. Further it requires a locked motor, as during the procedure for the determination of the commutating position no motion of the drive is approved (motionless). This is suitable for horizontal and vertical applications.

Unfavourable settings can lead to the case that the automatic determination of the commutating position can not be proceeded successfully anymore. Settings are only to be performed by experts respectively after consultation!

LED ”commutating position valid“

The display will show that the commutating position has been determined successfully. This status will be deleted e. g. when an encoder error occurs. This display is only relevant for motors with encoders without commutating signal.

Reset

The button serves as a help for starting. Through this the setting of the parameter at the first adjustment of a drive to an application is made easier. By resetting the status “commutating position valid” the process will then again be started at issuing the controller enable. In doing so the procedure can be activated systematically.

In most cases those are linear motors with ironless motors. Therefore the so called “reaction method” is suited ideally. This procedure is even working at motors, which are lying stopper in a vertical assembly.

In assemblies where the motor can not be moved anymore, this ”reaction method“ is not applicable and will show an error. If the motor is in such manner locked, the commutating position can only be determined via the saturation characteristic of the motor alternatively. So this has to show a corresponding saturation characteristic – seen physically. Often ironless motors are not “ideally ironless”. The commutating position can show the resulting small saturation reaction. If necessary this should be tested experimentally.

The procedure should be selected based on the assembly. In addition these can complicate the edge conditions of determination. At very tight motors good results can be supplied due to shortness of impulses in the saturation process for unlocked horizontal assemblies. Currently neither of those procedures will show a measurable figure of merit. So the quality of the determination can only be rated by plausibility check in comparison to a commutating angle, which can be automatically rated in a „normal way“.

The **Self-adjustment method** was supported as the first procedure when implementing the product servo positioning controller ARS 2000. With the later introduced methods **Reaction** and **Saturation method** significant improvements with regard to repeatability, required motion area and elapse time can be reached. Therefore we recommend the change to one of these two methods.

Relevant parameters to adjust the process of determination of the commutating position to the application can result from this by selecting the procedure. Accordingly the interface will change. Further explanations are to be taken from the software manual respectively the online help.

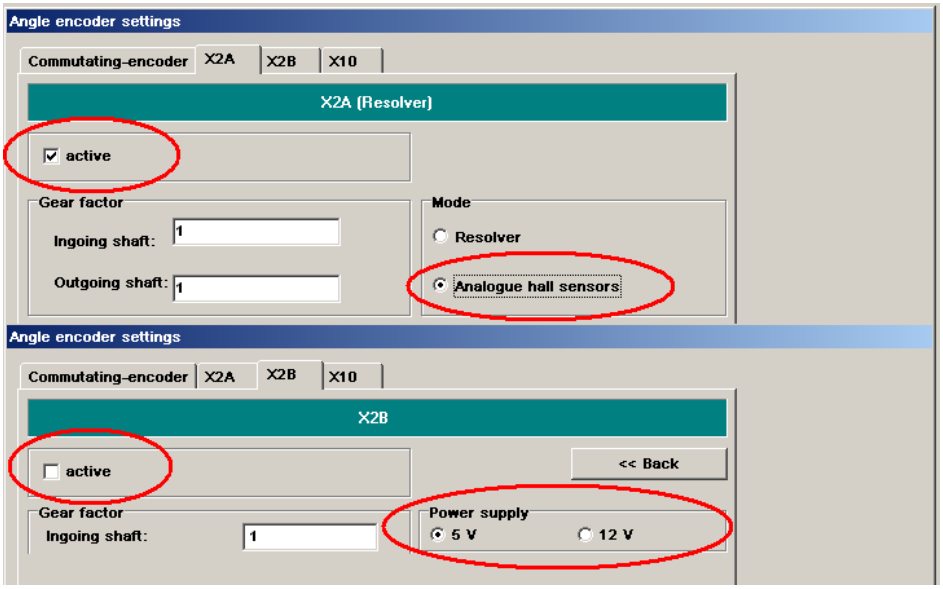
In the following characteristics of the methods are additionally commentated:

The **Reaction method** can lead to large motions at high current. The current pulse is designed in a way, that the drive can accelerate and decelerate. Too high pulses might not be able to stop the motor in time for the next pulse. Due to this the result is going to be faked or useless. In case like these (e. g. very smooth running motors) the current is to be decreased by the reducing-factor.

The **Saturation method** hardly needs parameterization. However if the drive is not slowed down “good enough”, small motions can occur and lead to false measurement. In this case the amplitude can be used to reduce the measuring.

A special form of drives are motors with encoders, which supply a virtual analogue incremental signal (1 Vss) via a pole pair length. In this case the encoder is to be connected

to X2A and from there the option button **Analogue hall sensors** is to be chosen. A supply voltage of 5 VDC has to be picked off by the encoder interface X2B in this case.

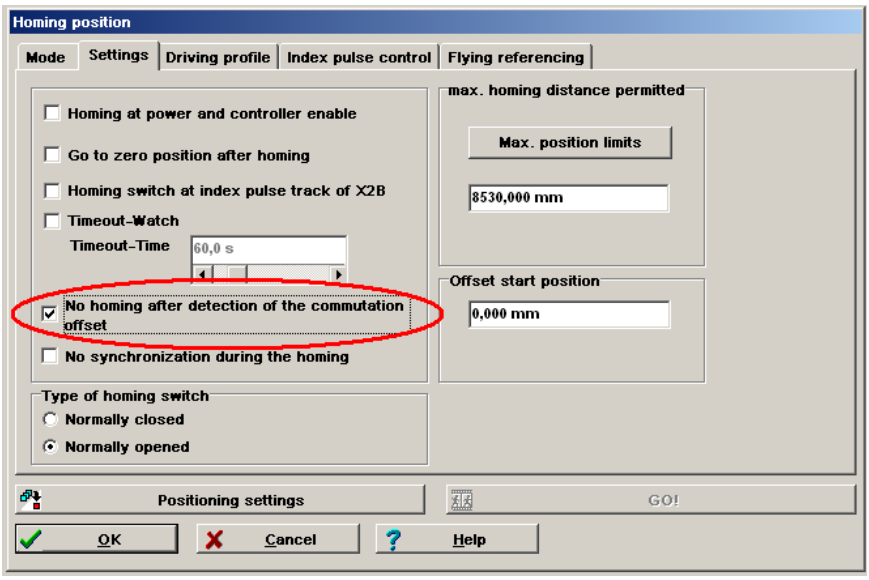


However these drives have an absolute position information applied to one revolution, similar to a resolver, and therefore do not count as **Motor without commutating-generator.** In line with initial operation of such a drive the offset angle of the commutating encoder will be determined one-time and in order to this will always be immediately available after resetting. These drives do not require the mentioned above parameterization, even though they are linear motors.

4.3 Alignment within the homing menu

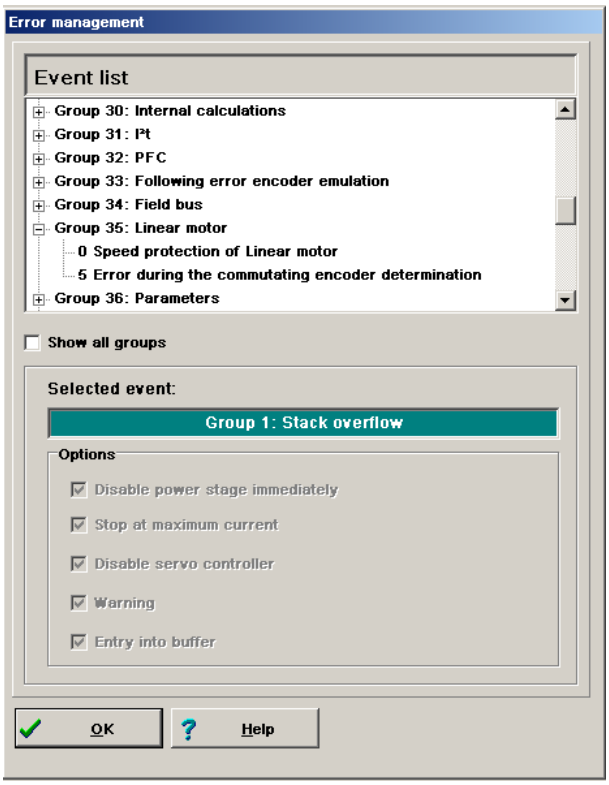
After determination of the commutating position of a **Motor without commutating-generator** the set homing procedure will start automatically. This operation is necessary, as the supply to a mechanical coordinate system is missing. This means, yet there is no relationship between e. g. a positive reference setting of a positioning operation for a linear motor of 10 mm absolute and a mechanical area, in which the positioning can be run.

When initiating a **motor without commutating encoder** it would be sensible to test the procedure for the determination of the commutating position without subsequent homing. For this the option ”No homing after detection of the commutating offset“ is to be chosen from the menu Homing position, tab settings.



5 Error management

Which operation condition of the servo positioning controller causes which reaction can be set in the window **Error/Error management**. The following window will appear:



With the aid of this window it will be specified how the servo positioning controller should react to an occurrence. The occurrence will then be classified into groups. Each group will

be dedicated to one reaction. For this the group will be selected (by mouse click) first of all. Then it will be dedicated to one reaction.
In the following the reactions are listed in an ascending order starting with the one of least priority:

1. Entry into buffer:
   The occurrence is merely saved in the error buffer. The occurrence will not be displayed. The application will continue running unaffectedly.
2. Warning:
   The occurrence will be displayed on the seven-segment display of the servo positioning controller for a short time.
3. Disable servo controller
   The applications will be shut up via emergency-stop chute.
4. Stop at maximum current:
   The drive will be brought to a hold with maximum current.
5. Disable power stage immediately:
   The drive will coast down as the power stage is switched of.

Some of the occurrences are so severe, that certain reactions can not be switched off. This can be noticed with the disabled checkbox on the interface (see example: "Disable servo controller", "Warning", "Entry into buffer").

The configuration can only be carried out as a complete occurrence. Not for individual occurrences within this group.

5.1 Error messages / Warnings

If an error occurs, the servo positioning controller ARS 2000 displays an error message cyclical in the seven-segment display of the servo positioning controller ARS 2000. The error message is a combination from an E (for error), a main index and a sub index, e. g.: **E 0 1 0**.

Following error settings are to be tested and set accordingly prior to putting a linear motor in operation:

- **03-x Over temperature motor analogue respectively digital:**
  Setting is carried out in the menu "Parameters – Device parameters – Temperature monitoring".
  Recommended setting in the menu "Error management":
  - Retain default-setting "Disable servo controller".

- **04-x Over temperature power stage and DC-bus.**
  Recommended setting in the menu "Error management":
  - Retain default-setting "Disable servo controller".

- **08-x Angle encoder**
  If this error occurs the encoder system, its feeder and the settings be checked in the menu "encoder, tab: X2B".
  Recommended setting in the menu "Error management":
  - Retain default-setting "Stop at maximum current".

- **17-0 Exceeding max. following error**
  Reference value will be set in the menu ”Safety parameter“.
  Recommended setting in the menu ”Error management“:
  - ”*Stop at maximum current“*

- **27-0 Warning threshold following error**
  Reference value will be set in the window ”Following error ranges”.
  Recommended setting in the menu ”Error management“:
  - *Depending on application*

- **31-x I²t verification of motor, servo positioning controller, PFC and brake resistor**
  Recommended setting in the menu ”Error management“:
  - *Depending on application*

- **35-0 Overspeed protection linear motor**
  Reference value will be set in the window ”Parameters – Application parameters – General configuration – Tab Expert“.
  Recommended setting in the menu ”Error management“:
  - *Default-setting retain “Stop at maximum current“.*

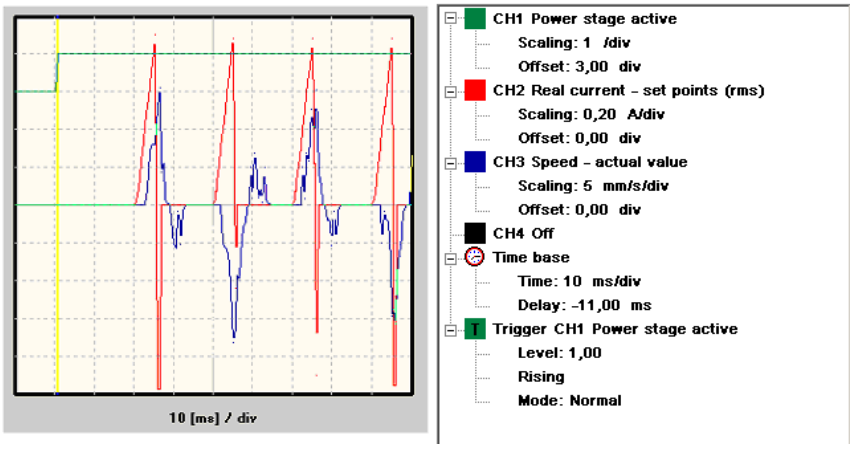
6 Appendix

For standard cases the chapters described in the appendix do not need to be noted by the user. They are described for reasons of better understanding as well as for special cases to the experienced user.

6.1 Measurement and quantification of the reaction process

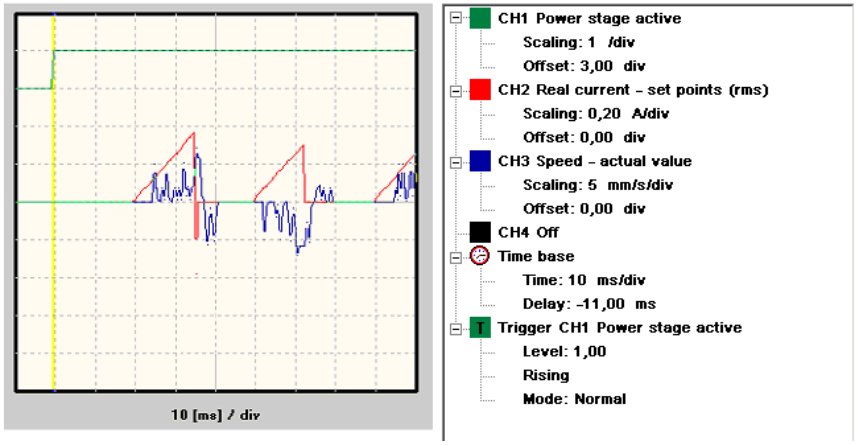
The motor will be carrying current at determination of the commutating position with the reaction process until the rotor will display a reaction about the actual value feedback. This can lead to vibrations depending on the design of the motor and total application. In individual cases it could therefore be advisable, to limit the current for this process percentaged. The parameter reduction in menu Basic configuration – Tab expert fixes this factor.

The following oscilloscope recording displays an identification at 100 %:



Though the curve of the current value of speed is interesting. The drive will accelerate due to the current rise and afterwards it will slowed down to speed 0 by an inverted current pulse. However at elastic assemblies these short pulses can lead to an oscillation of the mechanic as well as of the driving shaft. The measuring result will then be corrupted. The process does not provide a valid commutating position and will end with error 35-5.

The following image shows the same process with a current pulse reduced to 12.5 %:



Basically the reduction causes a change in ramp steepness. The drive is operated with less acceleration but in return it needs a longer time for one step. The excitation at vibratory mechanic is smaller and therefore the measuring more approvable. Which value is more

ideal for an application needs to be determined by testing and measuring if in doubt. The setting of value will be carried out via the transfer window.
An indicator could be considered when the current increases to a maximum at too little set current and then stays steady for a long time before the drive starts moving. In such cases the measurement period for the commutating position lengthens to an extreme.

6.2 Determination of I²t-motor

6.2.1 General information

The model of integral calculation „I²t-motor“ is being used in various Metronix drive controls.

The following is to be taken notice of:
The default value of 2 s can already be too long for motors with low thermal delay time in the winding. Therefore it is necessary that the I²t time delay is set exactly for the motor used. Most data sheets respectively the manufacturers of motors will state this time delay.
If this is not the case the following chapter will show you a sample calculation for the determination of I²t time.

6.2.2 Function of I²t-monitoring:

The I²t-monitoring in the ARS 2000 operates according to the principle of an integral calculation:

- In speed control cycle pult: $I\_int = I\_int + I\_q^2 - I\_rated^2$
- The threshold calculates: $I\_int\_lim = (I\_max^2 - I\_rated^2) * t\_iit\_max / 10\ ms$
- t_iit_max is the I²t time, also the time, the motor with I_max can carry a current before shutting down of the I²t takes place.
- When I_int excesses the threshold I_int_lim, a message will result from this and depending on parameterization the shutdown of the motor.

6.2.3 Calculation of I²t-time for an example motor

In the following sample calculation of the Cu-losses within the motor will be determined as well as the resulting I²t-time and current for the motor:

Motor data / set currents:

R_ph_ph	=	1.8 Ω (terminal resistance measured between two phases, motor hot)		
R_LL	=	3/2 * R_ph_ph	=	2.7 Ω
I_max	=	10 Arms		
I_rated	=	3.1 Arms		

Calculation Cu-losses at I_rated:

I_LL	=	I_max / sqrt(3)	=	1.79 Arms
P_Cu_rated	=	3 * I_LL_rated² * R_LL	=	26 W

Calculation of over temperature of winding at I_rated:

R_th_Cu-G = 2.5 °K/W thermal resistance winding - housing

=> ΔT_Cu-G_rated = 65 °C

R_th_G-L = 5.4 °K/W thermal resistance housing - air

=> ΔT_G-L = 140 °C

=> At T_U = 25 °C and operation with rated current the winding already reaches 165 °C !

=> Yet only 10 °C safety margin up to 175 °C !
(175 °C is the threshold of the winding's isolation class)

Calculation of Cu-losses at I_max:

I_LL = I_max / sqrt(3) = 5.77 Arms

P_Cu_max = 3 * I_LL_max² * R_LL = 270 W

Calculation of the winding's (theoretical) over temperature at I_max:

R_th_Cu-G = 2.5 °K/W thermal resistance winding - housing

=> ΔT_Cu-G_max = 675 °C

Operation period for operation with I_max:

For operation with maximum current the T_th_Cu winding's thermal delay time is of importance. For short operation periods with maximum current the housing temperature can be considered as steady. Resulting from this taken from the data sheet of the motor:

T_th_Cu = 14 s winding's thermal time delay time

Until reaching the temperature limit an increase of temperature by a maximum of ΔT_Cu-G_allowed = 10 °C is possible.

t_iit_max = ΔT_Cu-G_allowed / ΔT_Cu-G_max * T_th_Cu

=> t_iit_max = 200 ms

Conclusion:

At 25°C ambient temperature the motor is only allowed to run with the following parameters for I²t monitoring:

I_max = 10 Arms

I_rated = 3,1 Arms

t_iit_max = 200 ms

Further security stock is desirable for reasons of durability in terms of higher ambient temperatures and „safety“ for winding:

At 50°C ambient temperature and a maximum winding temperature of 155 °C the motor is only allowed to be operated according to the maximum for I²t monitoring with the following reduced parameters for rated current:

I_max = 10 Arms

I_rated = 2,5 Arms

t_iit_max = 200 ms