5 Regulation Tuning

5.1 In Brief

A wide variety of operating modes permit flexible configuration of drive and automation systems by using positioning, speed and current regulation. The built-in EtherCAT interface allows networking to multiple axes drives as well as online commanding by EtherCAT master units.

«Regulation Tuning» is an important attribute of EPOS3 EtherCAT. It is a procedure for automatic start-up of all relevant regulation modes, such as current, velocity and/or positioning control. This intelligent tool is easy to handle and substantially increases the use of the positioning control unit.

5.1.1 Objective

The present Application Note explains use of «Regulation Tuning» and features “in practice examples” suitable for daily use.

Contents

5.1.2 Scope

Hardware	Order #	Firmware Version	Reference
EPOS3 EtherCAT		2200h	Firmware Specification
EPOS3 70/10 EtherCAT	411146	2200h or higher	Cable Starting Set Hardware Reference

Table 5-40 Regulation Tuning – covered Hardware and required Documents

5.1.3 Tools

Tools	Description
Software	«EPOS Studio» Version 2.00 or higher

Table 5-41 Regulation Tuning – recommended Tools

5.2 Regulation Structures

EPOS3 EtherCAT can be interconnected within three essential regulation structures.

5.2.1 Current Control

To provide accurate motion control, given forces and/or torques within the drive system need to be compensated. Hence, EPOS3 EtherCAT offers a current control loop. The current controller is implemented as a PI controller.

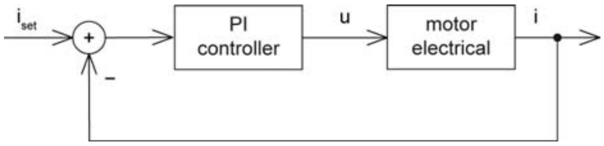

Figure 5-30 Regulation Tuning – Current Control

Current control can be operated either directly as the main regulator, or it serves as subordinated regulator in one of the two following cascade regulation structures.

5.2.2 Velocity Control (with Velocity and Feedforward Acceleration)

Based on the subordinated current control, a velocity control loop can be established. The velocity controller is implemented as a PI controller.

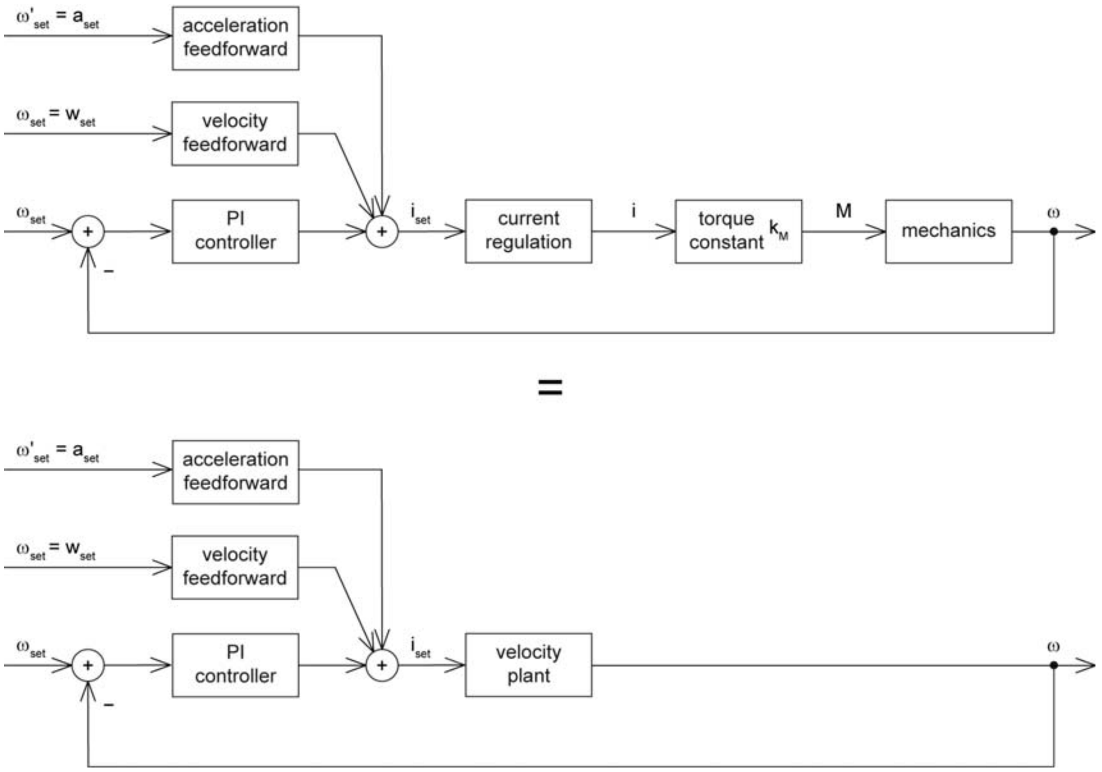

Figure 5-31 Regulation Tuning – Velocity Control

5.2.3 Position Control (with Velocity and Feedforward Acceleration)

Based on the subordinated current control, a position control loop can be established. The position controller is implemented as a PID controller.

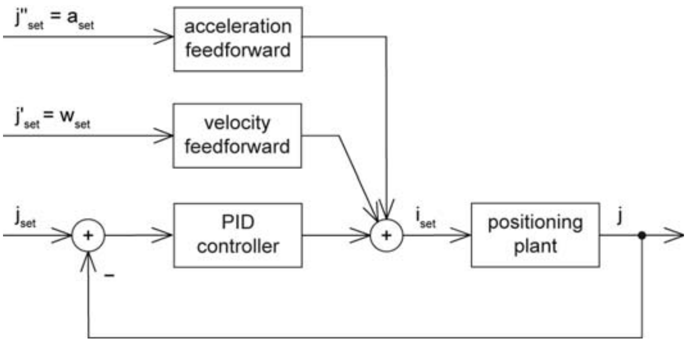

Figure 5-32 Regulation Tuning – Position Control

To improve the reference action of the motion system, position control is supplemented by feedforward control. Velocity feedforward compensates for speed-proportional friction, whereas known inertia can be taken into account by acceleration feedforward.

5.3 Working Principle

«Regulation Tuning» is based on three features:

1) **Identification and modelling** of the plant.
2) **Mapping** model parameters of the plant to derivate controller parameters (PI, PID, feedforward).
3) **Verification** of the resulting regulation structure.

5.3.1 Identification and Modelling

For identification, the plant is activated by a two-point element – positive and negative current of varying amplitudes, which are based on motor parameters – until a stable oscillation of a fixed amplitude is achieved. This experiment is repeated at a different frequency. The characteristics of the oscillations represent substantial properties of the plant.

Hence, the modeling parameters of a simple mathematical model of the plant can be calculated.

5.3.2 Mapping

Now, the model parameters serve for calculation of controller parameters (PI or PID, respectively) and of feedforward velocity and acceleration parameters.

The validity range of the regulation parameters is characterized, among other aspects, by the regulation bandwidth which is determined as well.

5.3.3 Verification

To achieve proper operation with the gained motion control parameters, the system reaction is verified with a motion profile corresponding to the calculated bandwidth.

5.4 Regulation Tuning Wizard

«Regulation Tuning» is a procedure for automated parameterization of the three above mentioned motion controller types (current, velocity and positioning regulation) including position control's feedforward parameters.

For successful Regulation Tuning, correct setup of system parameters in Startup Wizard is essential. Particularly important are…

- Motor data,
- Encoder data, and
- Communication with the PC.

Initiating the "Regulation Tuning Wizard"

1) Complete standard system configuration (Startup Wizard) in «EPOS Studio».
2) Select ¤Wizards¤ and select ¤Regulation Tuning¤.

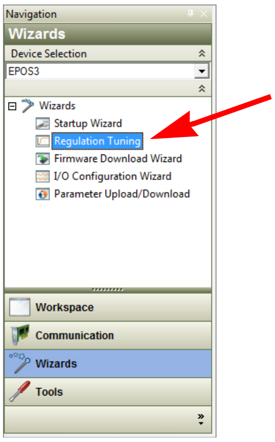

Figure 5-33 Regulation Tuning Wizard

3) Select one of the two modes (for details ➔"Tuning Modes" on page 5-51):
   – ¤Auto Tuning¤
   – ¤Expert Tuning¤.

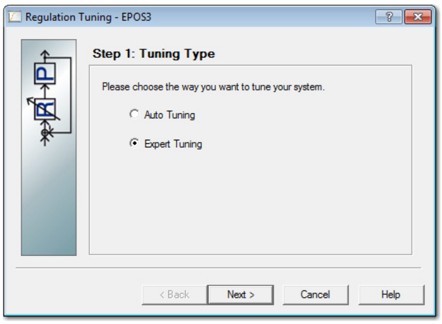

Figure 5-34 Regulation Tuning Mode Selection

5.5 Tuning Modes

5.5.1 Auto Tuning

Auto Tuning is the Regulation Tuning's "very-easy-to-use option". The only thing needed to accomplish automated tuning is to push the start button. A message will inform you that the system will move during the subsequent procedure. Upon confirming the message, Auto Tuning will commence. All required settings are already implemented, so Auto Tuning can parameterize the motion system for most common load cases without further help.

Under certain conditions (strong motor cogging torque, unbalanced friction, low position sensor resolution, etc.) however, or to cover particular requirements (wear, noise or energy optimized operation), Expert Tuning may be used.

5.5.2 Expert Tuning

Expert Tuning offers additional self-describing options for optimum regulation behavior. The following example illustrates tuning using Position Control. Handling of Current Control or Velocity Control however are similar.

Expert Tuning's user interface is divided in four sections:

a) Cascade

b) Identification

c) Parameterization

d) Verification:

Cascade

Provides information on the selected cascade structure.

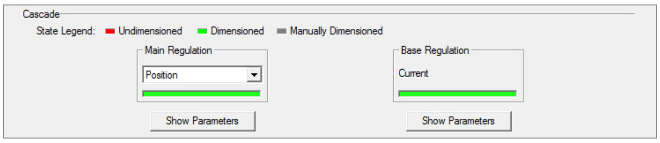

Figure 5-35 Expert Tuning – Cascade

The view is split into two panes; "Main Regulation" and "Base Regulation" (or subordinated regulation). Their respective status is displayed in colored bars:

- Red: Undimensioned – the controller is not yet parameterized.
- Green: Dimensioned – the controller is already parameterized.
- Grey: Manually Dimensioned – the control parameters are being set manually (➔"Manual Tuning" on page 5-53).

Click ¤Show Parameters¤ to view/alter the currently set values.

Velocity control can be viewed and adjusted (in "Main Regulation" window), even if the position was originally defined to be the main controlled variable. However, in order to avoid inconsistencies with the position main regulations, current control cannot be changed. If velocity control's current regulation needs to be optimized, velocity must be defined as Main Regulation variable.

Now, Regulation Tuning is being executed in three steps:

Identification

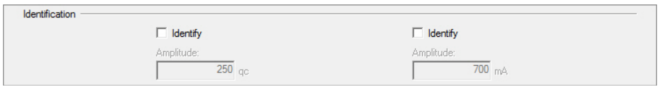

Figure 5-36 Expert Tuning – Identification

Tick ¤Identify¤ if identification of a new plant is necessary (e.g. if the plant properties have changed). In this case, the status of the corresponding controller, as well as all controllers of higher regulation hierarchy, will change to “Undimensioned” (red).

By adjusting the identification amplitude, nonlinear properties (e.g. Coulomb Friction) can be simulated appropriately and can be considered in the plant model by means of harmonic linearization. However, presetting already offers a good basis for plant identification for most applications.

Parameterization

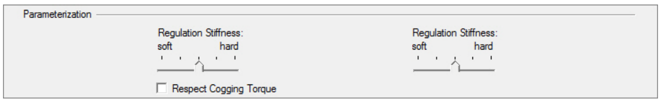

Figure 5-37 Expert Tuning – Parameterization

The calculated controller parameters can be modified to match given requirements by means of sliders:

- “Soft” means: slow regulation behavior, but well dampened.
- “Hard” means: quick regulation behavior, but less dampened.

Tick ¤Respect Cogging Torque¤ to achieve a hard, nevertheless well dampened motion regulation, which brings particular advantages for motors with high cogging torque. In case of unbalanced friction, the regulation behavior can be improved with this adjustment as well.

Verification

The verification of the resulting control system – including feedforward – permits examination of the overall performance. The verification can either take place with a movement profile (which takes bandwidth of the position regulation into account), or a step response. As interesting feature; in addition to the position, the corresponding current is recorded, too.

To zoom the recorded diagrams, crop the “area of interest” and click right.

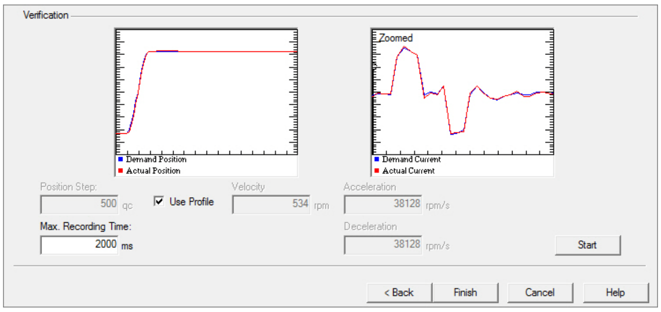

Figure 5-38 Expert Tuning – Verification

The parameters “Position Step”, “Velocity”, “Acceleration” and “Deceleration” are computed automatically. They can be adjusted only if the positioning controller is in state “Manually Dimensioned” (grey).

The parameter “Max. Recording Time” limits the time interval for data acquisition. This can be useful, if details concerning the beginning of the movement profile are of interest.

¤Start¤ launches Expert Tuning. ¤Finish¤ will save the obtained feedback and feedforward parameters in the EPOS3 EtherCAT and make them valid for all operation modes. ¤Cancel¤ will reject the results and returns to the starting situation.

5.5.3 Manual Tuning

In certain conditions, you might wish to change control parameters manually to see how the system reacts without performing automated system identification and modelling.

Also, the manual mode can be used…

- for fine tuning and optimization in very demanding applications, or
- if the outcome of Auto Tuning/Expert Tuning is not satisfactory.

Initiate Manual Tuning by selecting ¤Manually Dimensioned¤ in ¤Show Parameter¤ dialog (➔“Cascade” on page 5-51). As a result, the status will switch to “Manually Dimensioned” (grey), thus neither automated identification nor parameterization will be carried out. In addition, you can define the motion profile (➔“Verification” on page 5-52).

After ticking ¤Identify¤, or if you make any changes (➔“Parameterization” on page 5-52), Manual Tuning is terminated showing status “Undimensioned” (red).