10   DUAL LOOP CONTROL

CONTENT

10.1   In Brief

In applications where gearheads (subsequently called "gears"), spindles, or belt systems are used to trans-mit the motor rotation to the load, imperfections of these transmission elements do have an influence on the performance of the load position control. If very accurate load positioning is required, it is common practice to add an additional encoder at the load side to measure the exact load position. Such drive systems con-tain two encoders; one on the motor shaft (so-called "auxiliary encoder") and one on the load side (so-called "main encoder").

SCOPE

Hardware	Order #	Firmware version	Reference
EPOS4		0150h	Firmware Specification
EPOS4 Disk 60/8 CAN	688770	0170h or higher	
EPOS4 Disk 60/8 EtherCAT	688772	0170h or higher	
EPOS4 Disk 60/12 CAN	688775	0170h or higher	
EPOS4 Disk 60/12 CAN SSC	709859	0170h or higher	
EPOS4 Disk 60/12 EtherCAT	688777	0170h or higher	
EPOS4 Disk 60/12 EtherCAT SSC	709862	0170h or higher	
EPOS4 Module 24/1.5	536630	0150h or higher	
EPOS4 Compact 24/1.5 CAN	546714	0150h or higher	
EPOS4 Compact 24/1.5 EtherCAT	628092	0150h or higher	
EPOS4 Module 50/5	534130	0150h or higher	
EPOS4 Compact 50/5 CAN	541718	0150h or higher	
EPOS4 Compact 50/5 EtherCAT	628094	0150h or higher	
EPOS4 Module 50/8	504384	0150h or higher	
EPOS4 Compact 50/8 CAN	520885	0150h or higher	
EPOS4 Compact 50/8 EtherCAT	605298	0150h or higher	
EPOS4 Module 50/15	504383	0150h or higher	
EPOS4 Compact 50/15 CAN	520886	0150h or higher	
EPOS4 Compact 50/15 EtherCAT	605299	0150h or higher	
EPOS4 50/5	546047	0150h or higher	
EPOS4 70/15	594385	0150h or higher	

Table 10-88   Dual loop control | Covered hardware and required documents

TOOLS

Tools	Description
Software	«EPOS Studio» Version 3.5 or higher

Table 10-89   Dual loop control | Recommended tools

10.2 Overview

With two encoders present in the system both position measurements can be used for feedback control in order to improve performance of the load position control. This control method, the use of the two feedbacks of both motor and load side, is called dual loop control. The structure of the EPOS4 dual loop control is shown in ➔Figure 10-143.
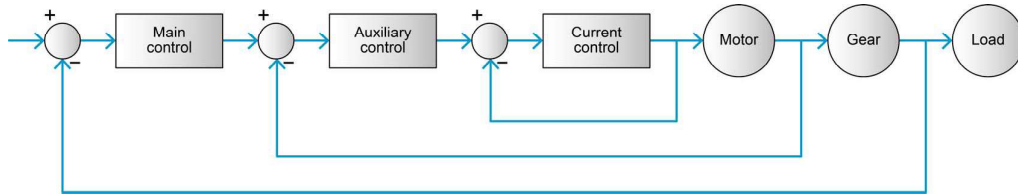
Figure 10-143   Dual loop control | Control structure

The EPOS4 dual loop control consists of two distinct control loops:

- **Auxiliary control loop** – controls the velocity of the motor and gives the motor current reference as its output
- **Main control loop** – controls the position of the load and gives the motor velocity and acceleration references as its outputs

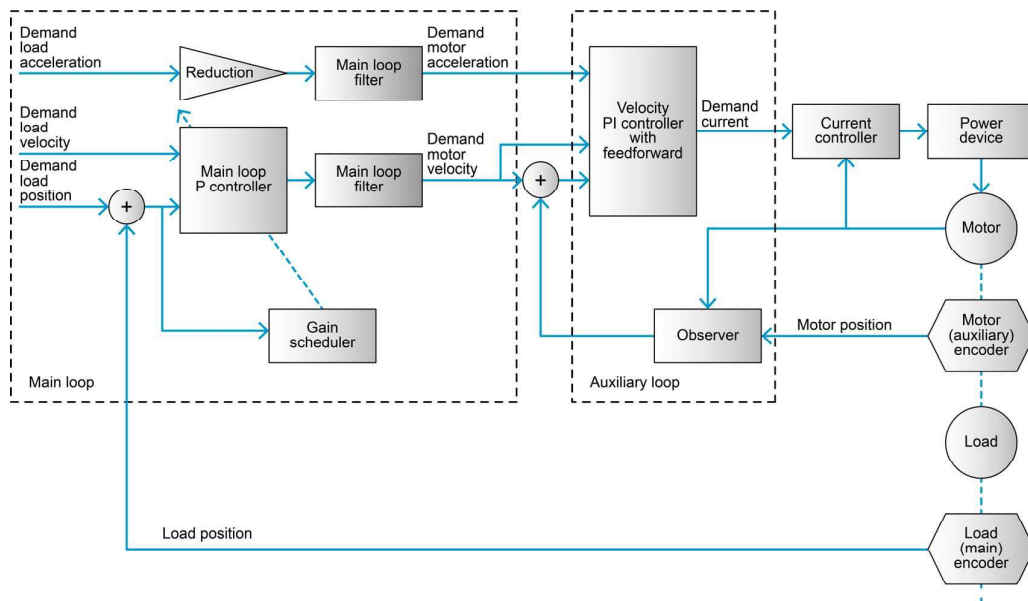A more detailed structure of EPOS4 dual loop control is shown in ➔Figure 10-144.

Figure 10-144   Dual loop control | Control structure in detail

The two loops are implemented with the following sampling periods:

$$T_{Auxiliary} = 0.4ms$$

$$T_{Main} = 1.2ms$$

10.3 Auxiliary Control Loop

The inputs of the auxiliary control loop are the desired motor velocity and acceleration (which are gathered from the main control loop) and the measured motor position from the auxiliary encoder. These inputs serve as basis to calculate the desired motor current that is then sent to the current controller. The auxiliary control loop consists of a PI speed controller with feedforward and an observer for motor velocity estimation. Find a detailed description on their structure in ➜chapter "2.3.2 Velocity Regulation (with Feedforward)" on page 2-14. The object dictionary entries relevant to the auxiliary control loop are given in ➜Table 10-90.

Symbol	Unit	Name	Index	Subindex
$K_{P\omega\_Auxiliary}$	$\dfrac{mA \cdot s}{rad}$	Auxiliary loop P gain	0x30AE	0x20
$K_{I\omega\_Auxiliary}$	$\dfrac{mA}{rad}$	Auxiliary loop I gain	0x30AE	0x21
$FF_{\omega\_Auxiliary}$	$\dfrac{mA \cdot s}{rad}$	Auxiliary loop FF velocity gain	0x30AE	0x22
$FF_{\alpha\_Auxiliary}$	$\dfrac{mA \cdot s^2}{rad}$	Auxiliary loop FF acceleration gain	0x30AE	0x23
$l_{\theta\_Auxiliary}$	1	Auxiliary loop observer position correction gain	0x30AE	0x30
$l_{\omega\_Auxiliary}$	Hz	Auxiliary loop observer velocity correction gain	0x30AE	0x31
$l_{T\_Auxiliary}$	$\dfrac{mNm}{rad}$	Auxiliary loop observer load correction gain	0x30AE	0x32
$r_{Auxiliary}$	$\dfrac{\mu Nm}{rpm}$	Auxiliary loop observer friction	0x30AE	0x33
$J_{Auxiliary}$	$g \cdot cm^2$	Auxiliary loop observer inertia	0x30AE	0x34

Table 10-90   Dual loop control | Auxiliary control loop parameters – Object dictionary entries

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10.4   Main Control Loop

The inputs of the main control loop are the desired load position, velocity and acceleration (which are gathered from the path planner) and the measured load position from the main sensor. The outputs of the main control loop are the desired motor velocity and acceleration.

The key elements of the main control loop are the proportional controller, gain scheduler, and the main loop filter which are subsequently described in detail. The respective object dictionary entries are given in
➔Table 10-91.

Symbol	Unit	Name	Index	Subindex
$K_{LowMain}$	$\frac{1}{s}$	Main loop P gain low bandwidth	0x30AE	0x01
$K_{HighMain}$	$\frac{1}{s}$	Main loop P gain high bandwidth	0x30AE	0x02
H	1	Main loop gain scheduling weight	0x30AE	0x03
FC_A	1	Main loop filter coefficient a	0x30AE	0x10
FC_B	1	Main loop filter coefficient b	0x30AE	0x11
FC_C	1	Main loop filter coefficient c	0x30AE	0x12
FC_D	1	Main loop filter coefficient d	0x30AE	0x13
FC_E	1	Main loop filter coefficient e	0x30AE	0x14
$F_{on/off}$	1	Dual loop configuration miscellaneous	0x30AE	0x40

Table 10-91   Dual loop control | Main control loop parameters object dictionary entries

10.4.1   Proportional Controller

The velocity reference for the auxiliary control loop is calculated as sum of the multiplication of the tracking error (as seen by the main encoder) with the main loop proportional gain, and the load velocity reference scaled by the drivetrain amplification ratio. The resulting reference is limited to the maximal permitted motor speed.

$$\omega_{ReferenceAuxiliary} = K_{Main} \cdot (\theta_{Desired} - \theta_{Measured}) + GearRatio \cdot \omega_{ReferenceMain}$$

10.4.2   Gain Scheduler

The main loop proportional gain does not have a fixed value. Its value is continuously modified by the gain scheduler based on the load position tracking error value. Particularly, with a large tracking error, this block sets a high control gain in order that the load position quickly approaches the desired reference. On the other hand, when the tracking error is small (as the actual position almost reaches the reference), this block reduces the gain value in order to have less aggressive control and to avoid negative effects caused by backlash and other nonlinear phenomena. The governing equation of the gain scheduler is as follows:

$$K_{Main} = K_{HighMain} + (K_{LowMain} - K_{HighMain})e^{-H|(\theta_{Measured} - \theta_{Desired})}$$

The parameters K_{Main}, $K_{HighMain}$, and H are the tuning parameters that can either be manually set or they can be automatically calculated in an auto tuning procedure. The shape of the gain scheduling function for different values of the gain scheduling weight H is shown in ➜Figure 10-145.
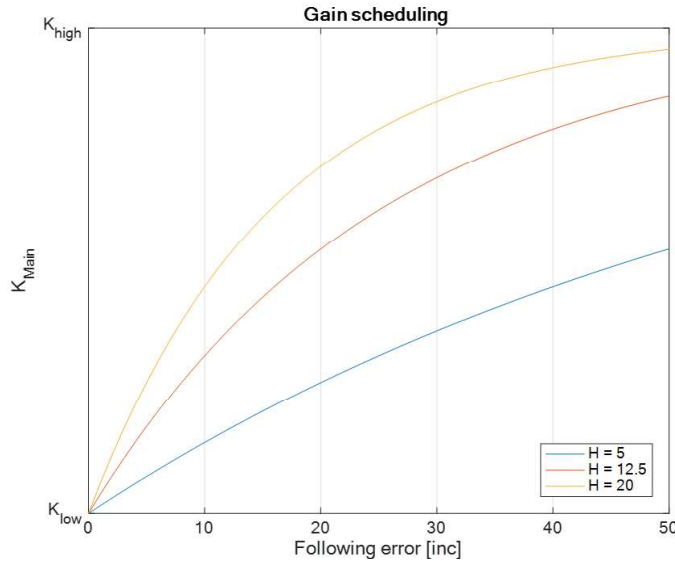

Figure 10-145   Dual loop control | Gain scheduling function for different values of main loop gain scheduling weight

10.4.3   Main Loop Filter

The main loop filter is used to filter out the output of the proportional controller in the main control loop. An identical filter is applied to the acceleration feedforward signal before it is passed to the auxiliary control loop. The purpose of this filter is to remove the part of the frequency spectrum that may cause strong oscillations in the system (resonant oscillations caused by the elasticity of the drivetrain) from the control loop. The transfer function of the second order filter is as follows:

$$G_{Filter}(s) = \frac{FC_A \cdot s^2 + FC_B \cdot s + FC_C}{s^2 + FC_D + FC_E}$$

All filter coefficients can be estimated automatically during the auto tuning procedure. The filter can also be turned off by changing the $F_{on/off}$ value. With $F_{on/off} = 0$, the filter is turned off, with $F_{on/off} = 2$, the filter is turned on. To reactivate the turned off filter, the parameter $F_{on/off} = 0$ must be first set to $F_{on/off} = 1$, then to $F_{on/off} = 2$ for correct calculation of the filter parameters.

WHEN SHOULD THE MAIN LOOP FILTER BE USED?

Dual loop control can be configured such that the use of the filter in the main control loop is disabled. Using the filter brings the most benefits with an elastic drivetrain that causes resonant oscillation in a certain frequency range. In such case, the main loop filter may be used to eliminate these frequencies from the closed loop control and prevent undesirable oscillations. However, if the drive train is rigid, the filter is of not much use. However, if a high resolution main encoder is used, the main loop filter may also be turned off without any influence on the control performance.

10.4.4 Transport Delay of the Control Loop

The total transport delay of the dual loop controller is always smaller than

$$T_{Auxiliary} + T_{Main} = 1.6 \text{ ms}$$

10.5 Proper Use of Dual Loop Control

Dual loop control should be employed when a gear with backlash is used and/or when the drivetrain between motor and load has dynamic properties which influence the performance of the load position control (for example, with an elastic shaft connecting motor and load).

The dual loop control structure has two degrees of freedom, as it uses both position measurements of the load and the motor. This allows reduction or even elimination of any negative effects of the drivetrain, such as backlash and elasticity. This leads to fast and accurate control of the load despite the fact that a dynamically complex drivetrain is used. Of course, the limitations of dual loop control are given by the limitations of the drive system as a whole. If the motor and drivetrain are setup in a way that a certain velocity and precision cannot be reached, dual loop control may not be able to change this fact. In addition, for a good performance of the dual loop controller, the resolution of the main encoder must not be less than the resolution of the auxiliary encoder.

If the drivetrain between motor and load does not feature any dynamic or nonlinear effects, the advantages of using dual loop control are minor. In this case and due to the fact that it is simpler to tune and parametrize, the use of standard PID position control with either an auxiliary or a main encoder is recommended instead.

10.6 Best Practice Examples

The load position control can be configured by choosing either PID position controller (for detailed description ➔chapter "2.3.3 Position Regulation (with Feedforward)" on page 2-18) or dual loop position controller. If the PID position controller is used, the main sensor can be located either on the motor or on the load (if both exist in the system). If dual loop position controller is selected, both the main encoder (on the load side) and the auxiliary encoder (on the motor side) must be present in the system and be properly configured. ➔Figure 10-146 illustrates the correct configuration of dual loop control.
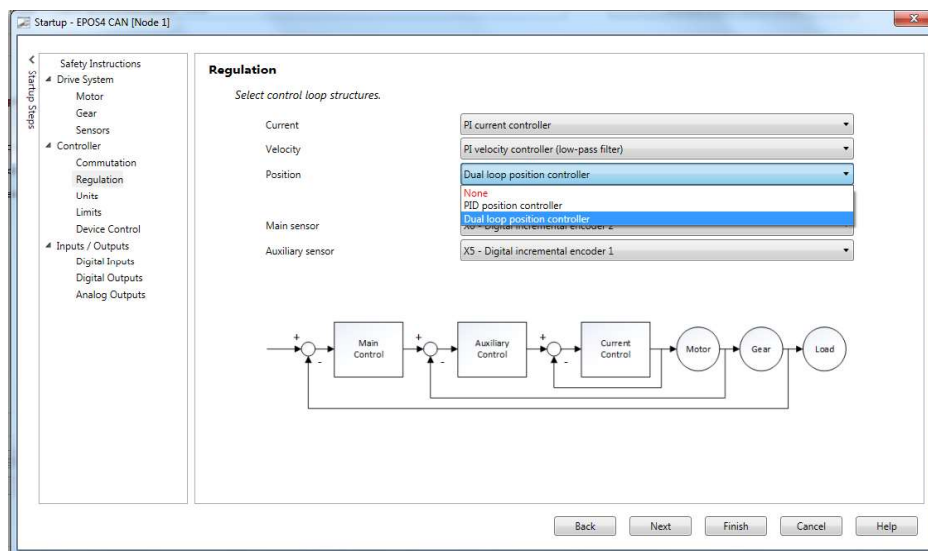

Figure 10-146   Dual loop control | Configuration

The following examples demonstrate the advantages of using dual loop control in eliminating the negative effects of backlash and elastic motor load coupling. They also illustrate how the auto tuning procedure in the dual loop control structure works.

Systems used for these illustrations are rotative systems comprising a motor with attached encoder and a load with a respectively attached encoder. Motor and load are coupled with a gear and a shaft that can be rigid or elastic.

10.6.1 Use Case 1: System with high Reduction Gear, moderate Backlash, and no Coupling Elasticity

SYSTEM COMPONENTS

Item	Description	Setting
Controller EPOS4 Compact 50/8 CAN (520885)		
Motor maxon EC-4pole 30 brushless, 100 W (309755)	No load speed (line 2)	n_0 = 17500 rpm
	No load current (line 3)	I_0 = 505 mA
	Nominal current (line 6)	I_n = 7.74 A
	Terminal resistance (line 10)	R = 0.135 Ω
	Terminal inductance (line 11)	L = 0.017 mH
	Torque constant (line 12)	k_m = 9.8 mNm/A
	Rotor inertia (line 16)	J_{motor} = 18.3 gcm^2
Auxiliary encoder HEDL 5540 500 impulse, 3 channel, with Line Driver (110514)	Encoder counts per turn	500 pulses/revolution
Main encoder HEDL 5540 500 impulse, 3 channel, with Line Driver (110514)	Encoder counts per turn	500 pulses/revolution
Gear Planetary gear GP 32 HP Ø 32 mm, 4.0…8.0 Nm (324946)	Gear ratio	411:1 359424/875
Mechanical load connected via rigid coupling	Load inertia	J_{load} = 95.3 gcm^2

Table 10-92   Dual loop control | Use case 1: System components

In order to illustrate the advantage of using dual loop control for this configuration, regular PID position control is considered first. Thereby, the sensor on the load side is configured as the main sensor. After running the auto tuning procedure, the parameters of the PID position controller are automatically calculated and have the values listed in ➜Table 10-93.

Index	Subindex	Name	Value	Unit
0x30A1	0x01	Position controller P gain	95159.615	$\dfrac{mA}{rad}$
0x30A1	0x02	Position controller I gain	170609.607	$\dfrac{mA}{rad \cdot s}$
0x30A1	0x03	Position controller D gain	4247.317	$\dfrac{mA \cdot s}{rad}$
0x30A1	0x04	Position controller FF velocity gain	175.721	$\dfrac{mA \cdot s}{rad}$
0x30A1	0x05	Position controller FF acceleration gain	68.528	$\dfrac{mA \cdot s^2}{rad}$

Table 10-93   Dual loop control | Use case 1: PID position controller parameters

Using the path planner and executing the trajectory with the maximal velocity of 1 rpm, an acceleration of $1000\frac{rpm}{s}$, and a position change of 25 increments, the result obtained is as in ➜Figure 10-147.
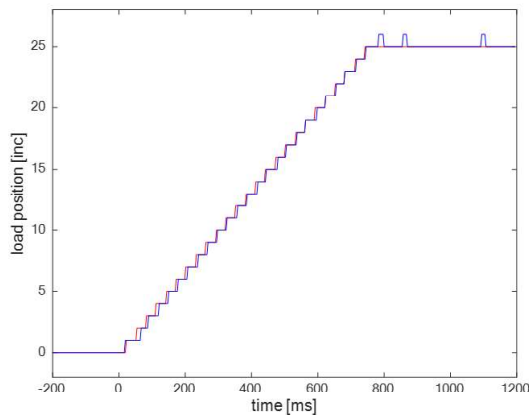

Figure 10-147   Dual loop control | Use case 1: Load position control with PID position controller

As seen, the reference tracking is generally good. However, after 700 ms (when the system should stop moving and keep the load position fixed), several short changes in the actual load position may be observed. These changes are caused by the backlash effects of the gear. Namely, the teeth of the gear are imperfect to their theoretical shape and they have some play between them. Whenever the system reverses the direction of motion or changes from movement to standstill, the use of a single loop controller may result in oscillations of the load position due to nonlinear effects introduced by the backlash.

Now, the use of dual loop control in the application will be considered to illustrate how the negative effects caused by the backlash can be eliminated.

The dual loop controller can also be tuned automatically by using the «Regulation Tuning Wizard». Before starting dual loop tuning, the current controller must be properly tuned. Auto tuning of the dual loop controller itself is done in two steps:

First, the auxiliary loop will be tuned using the respective dialog box given in ➔Figure 10-148.
Upon pressing the ¤Auto tune¤ button, an identification experiment is conducted in which all the mechanical parameters of the system relevant for the auxiliary loop are identified. In the tuning dialog box, stiffness and damping of the feedforward PI controller and the bandwidth of the observer used to calculate motor velocity can be adjusted. Moving the sliders to the right results in faster and more aggressive control in the auxiliary loop. By applying the test signal, a visual representation of the auxiliary loop performance is being produced. The auxiliary loop should be fast and aggressive without a lot of overshoot in the signal and it should be adjusted with the sliders until the desired performance is observed in the resulting test signal.
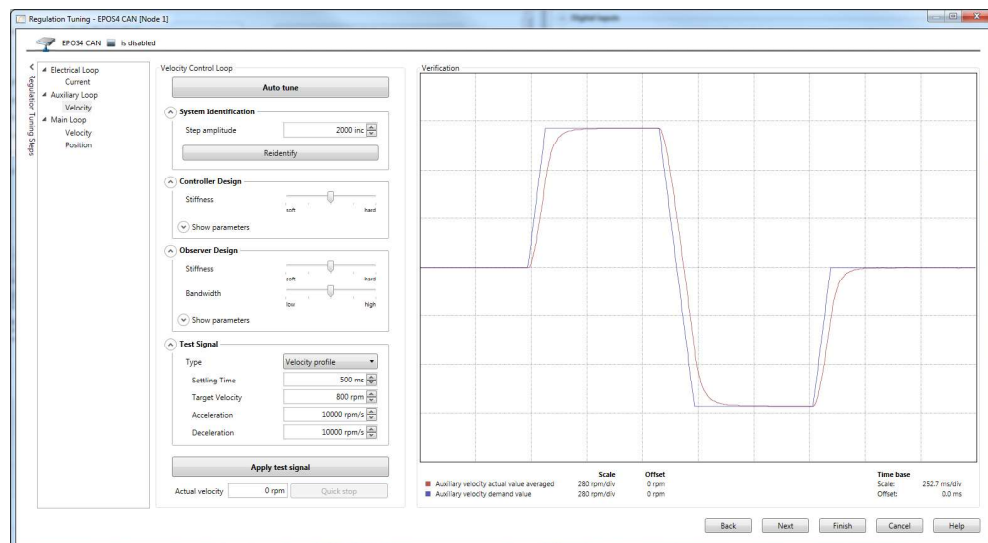

Figure 10-148   Dual loop control | Use case 1: Auxiliary loop tuning dialog box

Then the main loop can be tuned by using the main loop tuning dialog box. Upon pressing the ¤Auto tune¤ button, an identification experiment is executed in which the transfer function of the system drivetrain together with the auxiliary loop control is identified.

CONSIDERATIONS

- Running the experiment for tuning of the main loop makes sense only if the auxiliary loop has been tuned before. The auxiliary loop controller is used as a part of the main loop identification experiment and its parameters influence the calculation of the parameters in the main control loop.

- The Bode plot of the experimentally determined transfer function and its fit are displayed in the ¤Identification¤ tab. Based on this Bode plot, an impression on the characteristics of the system to be controlled can be gained. For example, if the Bode plot is relatively straight, it means that the motor/load coupling is rigid. On the other hand if a resonant peak (a lob in the Bode plot) can be observed, it means that the coupling is elastic and that the controller will try to handle this elasticity by the use of the main loop filter.

- The ¤Verification¤ tab in the dialog box contains the test signal of the resulting controller. The «Bandwidth» of the controller can be adjusted using a slider. Higher bandwidth means faster and more aggressive control behavior. However, it should be noted that for each system there are limitations on the achievable closed loop bandwidth and that the auto tuning algorithm will consider these limitations when calculating the main loop parameters. The other two sliders may be used to set the «Bandwidth ratio» and the «Gain scheduling weight». These parameters influence the elimination of the backlash effects and should be adjusted such that no backlash effects (as shown in ➜Figure 10-147) are visible in the verification signal. Increasing the «Gain scheduling weight» (moving the slider to the right) and decreasing the «Bandwidth ratio» (moving the slider to the left) has a positive effect on eliminating the negative effects caused by the backlash. The main loop tuning dialog box is shown in ➜Figure 10-149 and ➜Figure 10-150.
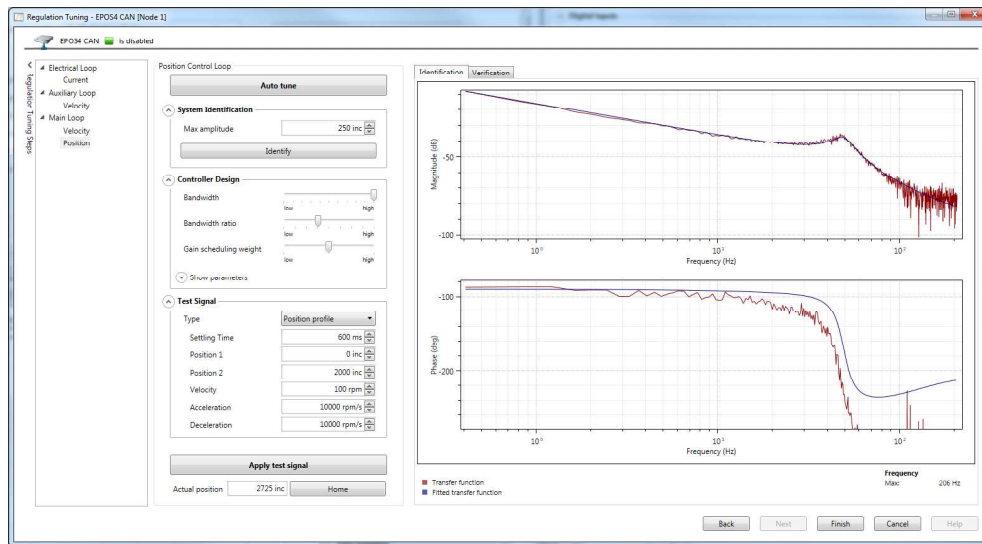

Figure 10-149   Dual loop control | Use case 1: Main loop tuning dialog box with the «Identification» tab active
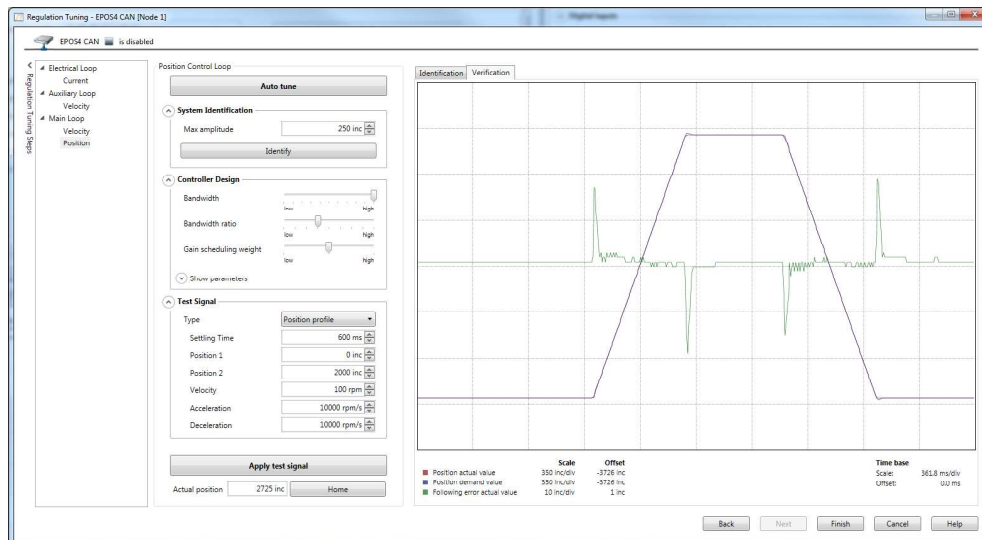

Figure 10-150   Dual loop control | Use case 1: Main loop tuning dialog box with the «Verification» tab active

Dual loop controller parameters obtained after the auto tuning procedure for the considered application example are given in ➔ Table 10-94.

Index	Subindex	Name	Value	Unit
0x30AE	0x01	Main loop P gain low bandwidth	221.34	$\dfrac{1}{s}$
0x30AE	0x02	Main loop P gain high bandwidth	44.268	$\dfrac{1}{s}$
0x30AE	0x03	Main loop gain scheduling weight	10.00	1
0x30AE	0x10	Main loop filter coefficient a	0	1
0x30AE	0x11	Main loop filter coefficient b	0	1
0x30AE	0x12	Main loop filter coefficient c	35530.0	1
0x30AE	0x13	Main loop filter coefficient d	376.0	1
0x30AE	0x14	Main loop filter coefficient e	35530.0	1
0x30AE	0x20	Auxiliary loop P gain	138.825	$\dfrac{mA \cdot s}{rad}$
0x30AE	0x21	Auxiliary loop I gain	2470.774	$\dfrac{mA}{rad}$
0x30AE	0x22	Auxiliary loop FF velocity gain	0.151	$\dfrac{mA \cdot s}{rad}$
0x30AE	0x23	Auxiliary loop FF acceleration gain	0.173	$\dfrac{mA \cdot s^2}{rad}$
0x30AE	0x30	Auxiliary loop observer position correction gain	0.950	1
0x30AE	0x31	Auxiliary loop observer velocity correction gain	751.283	Hz
0x30AE	0x32	Auxiliary loop observer load correction gain	0.030	$\dfrac{mNm}{rad}$
0x30AE	0x33	Auxiliary loop observer friction	0	$\dfrac{\mu Nm}{rad}$
0x30AE	0x34	Auxiliary loop observer inertia	20.48	$g \cdot cm^2$
0x30AE	0x40	Dual loop configuration miscellaneous	2	1

Table 10-94   Dual loop control | Use case 1: Dual loop load position controller parameters

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The use of dual loop control results in load position control shown in ➔Figure 10-151. As can be seen, negative effects caused by backlash are fully eliminated.
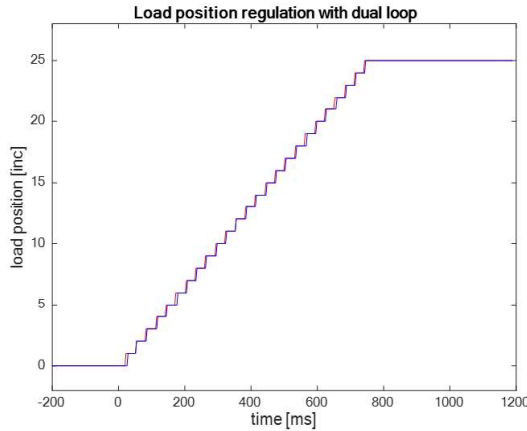

Figure 10-151   Dual loop control | Use case 1: Position control with dual loop controller

10.6.2   Use Case 2:
System with considerable Backlash and with Coupling Elasticity

SYSTEM COMPONENTS

Item	Description	Setting
Controller EPOS4 Compact 50/5 CAN (541718)		
Motor maxon EC-4pole 30 brushless, 100 W (309756)	No load speed (line 2)	n_0 = 17500 rpm
	No load current (line 3)	I_0 = 379 mA
	Nominal current (line 6)	I_n = 5.56 A
	Terminal resistance (line 10)	R = 0.248 Ω
	Terminal inductance (line 11)	L = 0.03 mH
	Torque constant (line 12)	k_m = 13.1 mNm/A
	Rotor inertia (line 16)	J_{motor} = 18.3 gcm^2
Auxiliary encoder HEDL 5540 500 impulse, 3 channel, with Line Driver (110514)	Encoder counts per turn	500 pulses/revolution
Main encoder HEDL 5540 500 impulse, 3 channel, with Line Driver (110514)	Encoder counts per turn	500 pulses/revolution
Gear Planetary gear GP 32 HP Ø 32 mm, 4.0…8.0 Nm (320247)	Gear ratio	14:1 676/49
Mechanical load connected via spring coupling FKZS 1225	Load inertia	J_{load} = 51.2 gcm^2

Table 10-95   Dual loop control | Use case 2: System components

The first steps in properly configuring the dual loop controller for this application example is to run the current controller auto tuning followed by the auxiliary loop auto tuning. Then, the main loop may be tuned. The identification experiment that is run as part of the main loop tuning identifies the transfer function of the system as seen by the main loop. The Bode plot of the identified transfer function is given in ➜Figure 10-152.

The Bode plot indicates that the drivetrain has a resonant frequency at 48 Hz. At this frequency, the Bode plot has a significant magnitude increase. The resonance is a direct consequence of the elastic coupling between the gear and the load.

In order to achieve good control with the dual loop controller, the resonance must be taken into account when designing the controller. In EPOS4 dual loop architecture this is done with the main loop filter, which is automatically designed to neutralize the negative effects of the resonance. The transfer function obtained by multiplying the automatically calculated main loop filter with the identified transfer function is shown in ➜Figure 10-152.
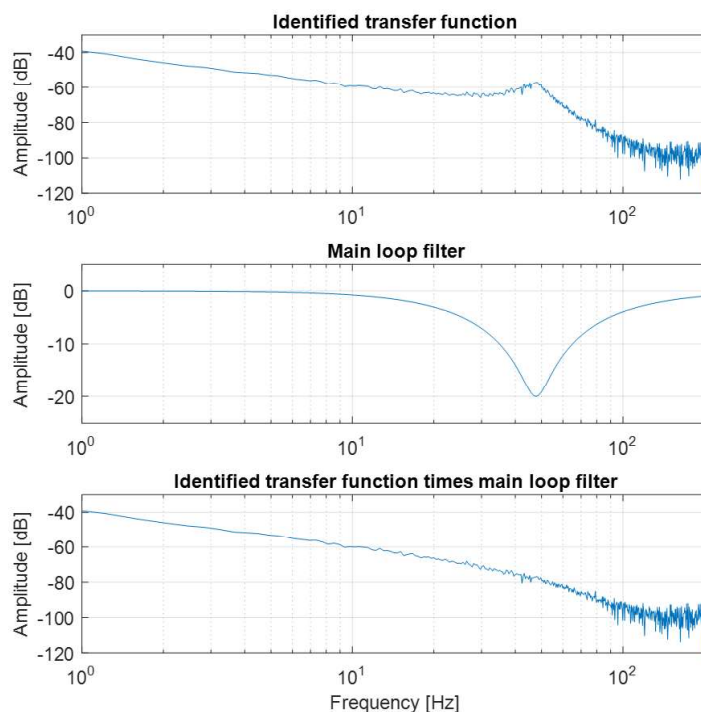

Figure 10-152   Dual loop control | Use case 2: Comparison of Bode plots

For cases with complex shapes of the identified Bode plot and if the automatic calculation of the main loop filter does not give satisfactory performance, the main identification parameters may be saved. To do so click right in the system identification area of the Regulation Tuning Wizard's main loop tuning dialog (➜Figure 10-153). Thereby, three files with the extension ".csv" are created. They contain the raw recorded experimental data, fitted zeros and poles, and the experimental transfer function estimate respectively. The saved values may be imported by an advanced calculation software and as such may be used to manually configure the filter parameters. Note that such manual parameter configuration requires expert knowledge.

After running main loop tuning, the dual loop controller parameters as to ➜Table 10-96 are obtained.
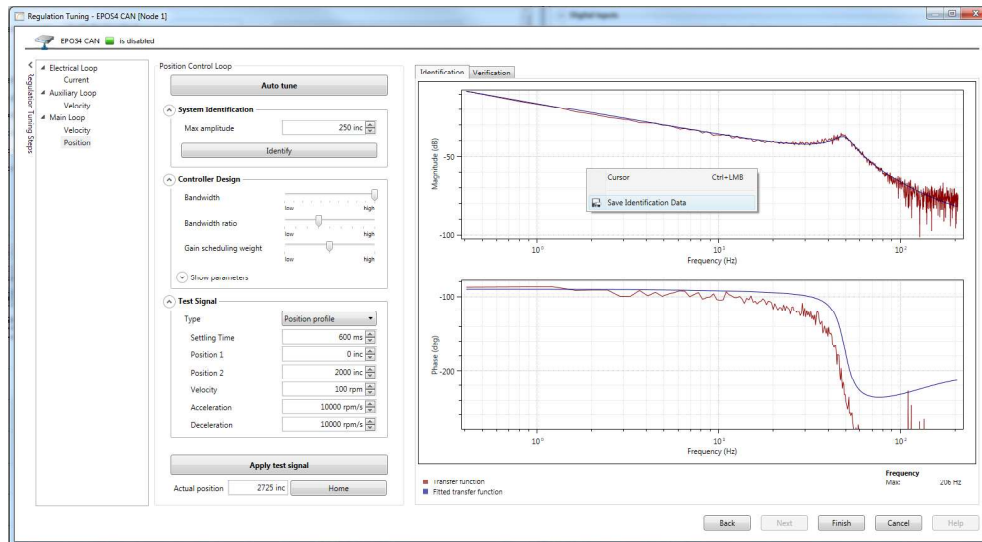

Figure 10-153   Dual loop control | Use case 2: Saving of the identification data

Index	Subindex	Name	Value	Unit
0x30AE	0x01	Main loop P gain low bandwidth	4.321	$\frac{1}{s}$
0x30AE	0x02	Main loop P gain high bandwidth	120.12	$\frac{1}{s}$
0x30AE	0x03	Main loop gain scheduling weight	10	1
0x30AE	0x10	Main loop filter coefficient a	1	1
0x30AE	0x11	Main loop filter coefficient b	42.846	1
0x30AE	0x12	Main loop filter coefficient c	93660.611	1
0x30AE	0x13	Main loop filter coefficient d	612.080	1
0x30AE	0x14	Main loop filter coefficient e	93660.611	1
0x30AE	0x20	Auxiliary loop P gain	112.32	$\frac{mA \cdot s}{rad}$
0x30AE	0x21	Auxiliary loop I gain	1109.41	$\frac{mA}{rad}$
0x30AE	0x22	Auxiliary loop FF velocity gain	0	$\frac{mA \cdot s}{rad}$
0x30AE	0x23	Auxiliary loop FF acceleration gain	0.18	$\frac{mA \cdot s^2}{rad}$

Continued on next page.

Index	Subindex	Name	Value	Unit
0x30AE	0x30	Auxiliary loop observer position correction gain	0.8	1
0x30AE	0x31	Auxiliary loop observer velocity correction gain	502.74	Hz
0x30AE	0x32	Auxiliary loop observer load correction gain	11.21	$\dfrac{mNm}{rad}$
0x30AE	0x33	Auxiliary loop observer friction	0	$\dfrac{\mu Nm}{rad}$
0x30AE	0x34	Auxiliary loop observer inertia	20.6	$g \cdot cm^2$
0x30AE	0x40	Dual loop configuration miscellaneous	2	1

Table 10-96   Dual loop control | Use case 2: Dual loop load position controller parameters

The main loop filter is now used to eliminate the resonant effects. Therefore, turning the filter off may signifi-cantly reduce the controller performance, or even lead to controller instability as illustrated in
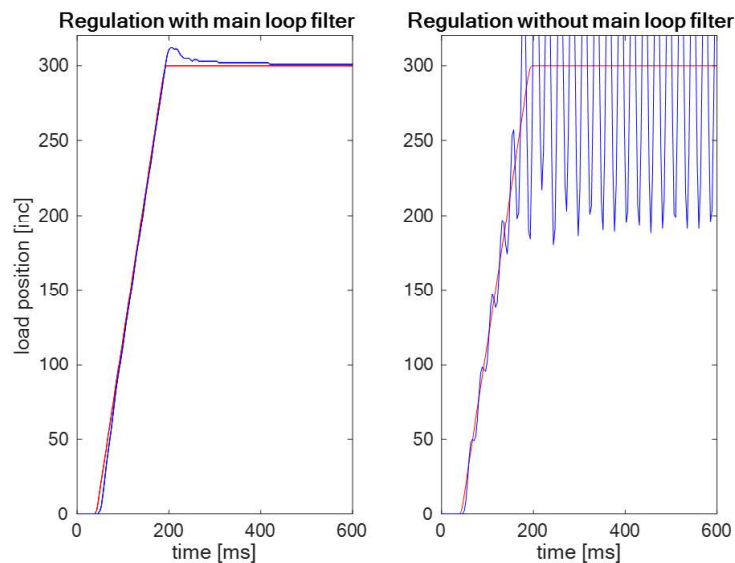➔Figure 10-154.

Figure 10-154   Dual loop control | Use case 2: Control performance with/without main loop filter

The reason for the controller to become instable when the filter is turned off lies in the fact that the system has a resonant peak. In order for the controller to remain stable even in the case when the main loop filter is not used, the controller bandwidth must be significantly reduced. However, in this case the oscillation at res-onant frequency of the system remains.

Due to strong backlash, the performance of the dual loop controller obtained by the default settings in the main loop auto tuning is not ideal. This is particularly the case in the phase where the load position is close to reaching the target. This can be improved by adjusting the sliders for «Bandwidth ratio» and «Gain scheduling weight». Thereby, moving the «Bandwidth ratio» slider to the left and the «Gain scheduling» slider to the right in order that the «Main loop P gain low bandwidth» and the «Main loop gain scheduling weight» are set to 15.32 1/s and 20 respectively will result in improved tracking performance (➜Figure 10-155).
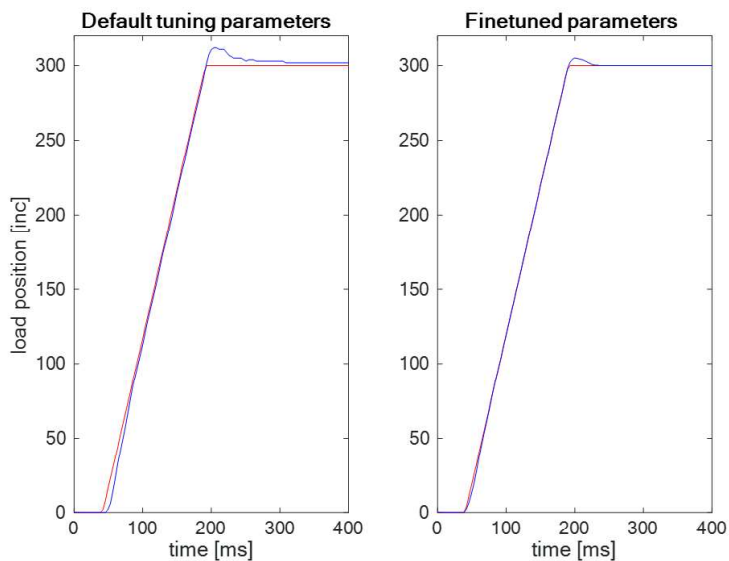

Figure 10-155   Dual loop control | Use case 2: Control performance with default/fine-tuned main loop parameters

10.7   Conclusion

If a gear with backlash is involved and/or if the coupling between the motor and the load is elastic, the described application examples show that using dual loop control results in better control performance than using a PID position controller. In addition, using the main loop filter in the dual loop controller structure is suggested when the drivetrain has a clearly prominent resonant frequency. If not the case, the main loop filter can be turned off especially with a high resolution main encoder.