

Axis Compensation

Application Note 140

The *Axis Compensation* module allows to compensate systematical position deviations of an axis. The axis compensation can significantly improve the absolute accuracy of the machine.

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1 Introduction

1.1 What is Axis Compensation

Axis compensation refers to a method counterbalancing a measurable absolute positioning error based on measurable input parameters. The positioning error is usually measured with an external calibration device and the resulting values can be used to correct the encoder positions. Sometimes this procedure is also called mapping.

Common effects to be compensated are:

- Encoder Alignment & geometric imperfections: The encoder is never perfectly parallel to the moving axis and never perfectly straight, which causes a discrepancy between the encoder feedback position and the actual position. For multi-axis systems, the alignment between different encoders additionally causes discrepancies. Similar effects are observable for geometric imperfections of the positioning system itself.
- Thermal Effects: As materials typically elongate with rising temperatures, thermal effects can play a significant role on the machine's geometry. This is usually not an issue if the machine can be measured and compensated at the same steady-state operating temperature. If the machine has a lot of transient operating points e.g. during start-up or varying operating conditions, a compensation reference measured at a single temperature profile might not be sufficient. In this case, temperature can be used as additional input to the compensation to further improve the absolute accuracy.

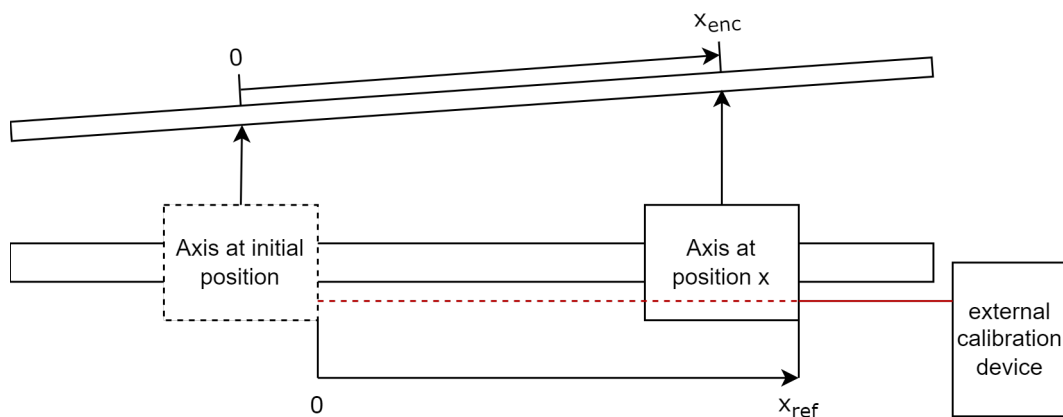


Figure 1: An (exaggerated) encoder misalignment causes the encoder feedback position x_{enc} to be bigger than the actual position x_{ref} , which means the executed absolute move will be shorter than intended

Other effects may as well be compensated, as long as they are time-invariant and a measurable variable(s) can be used as input for the compensation. For the Axis Compensation the correction value is added to the encoder position. In contrast *Cogging Compensation* is applied to the setpoint current. Therefore *Cogging Compensation* is offered as a separate tool by *Triamec Motion AG* and is thus not scope of this documentation or the axis compensation in general.

1.2 Compensation Tables (TAM Table)

The actual compensation values are stored in a table called *TAM Table*. *Triamec Motion AG* uses a spe-

cific binary file format *.TAMtbl* for this. It consists of a header and a flat list of numbers. For detailed information, refer to 4.1 and [AN124](#) [1].

1.3 Table lookup inputs (*Dimension Source, Dim(1-3)Source*)

In order to look up the correct compensation value in the compensation table described above, between one to three inputs, called *Dimension Source*, have be used, referring to 1D, 2D or 3D compensation. A *Dimension Source* is a *Register Address* of the same drive but not necessarily from the same axis. The corresponding *Registers* on the drive are called *Dim1Source*, *Dim2Source* and *Dim3Source*, which will be referred to as *DimSources* from now on. An unused/unset *DimSource Register* contains the value 0. A used/set *DimSource Register* contains on the firmware level the hex-value of the *Register Address* used as an input. Higher level software, such as the *TAM System Explorer* might display an alias e.g. the name of the *Register* instead of the hex-value.

1.4 Axis Compensation Commands

To control the activation of the axis compensation, the Register `Axes[.Commands.Compensations.Axis.Activation` is used. The following commands can be set:

- Disabled: The axis compensation is not active
- Evaluate: The axis compensation *TAM Table* and the *Dimension Source* are evaluated but the compensation will not be applied. The evaluation will throw errors in case of any mismatches.
- AddToEncoders: The axis compensation *TAM Table* and the *Dimension Source* are evaluated and if no error is thrown, the compensation will be activated.

Remark: `Homing.State = HomingDone` is necessary to apply the axis compensation.

1.5 Axis Compensation Output

In `Axes[.Signals.Compensations.Axis`, the current compensation output added to the encoder position (if activated) as well as the current *Dim(1-3)Index* can be observed.

2 Axis Compensation Wizard

2.1 What is the Axis Compensation Wizard

In order to simplify and accelerate the process of setting up an axis compensation, *Triamec Motion AG* provides a specific software tool called *Axis Compensation Wizard*. It consists of the following base functionalities for each axis:

- Parse compensation data from a *.csv* file to the binary *.TAMtbl* format used for *TAM Tables*
- Get and set the axis compensation *TAM Table*
- Get and set the *Dimension Source* e.g. the input parameter(s) used to look up compensation values
- Activate and deactivate the axis compensation

All business logic used in the *Axis Compensation Wizard* is accessible via the TAM API. This allows you to integrate all functionalities in your own UI or using them in automation code.

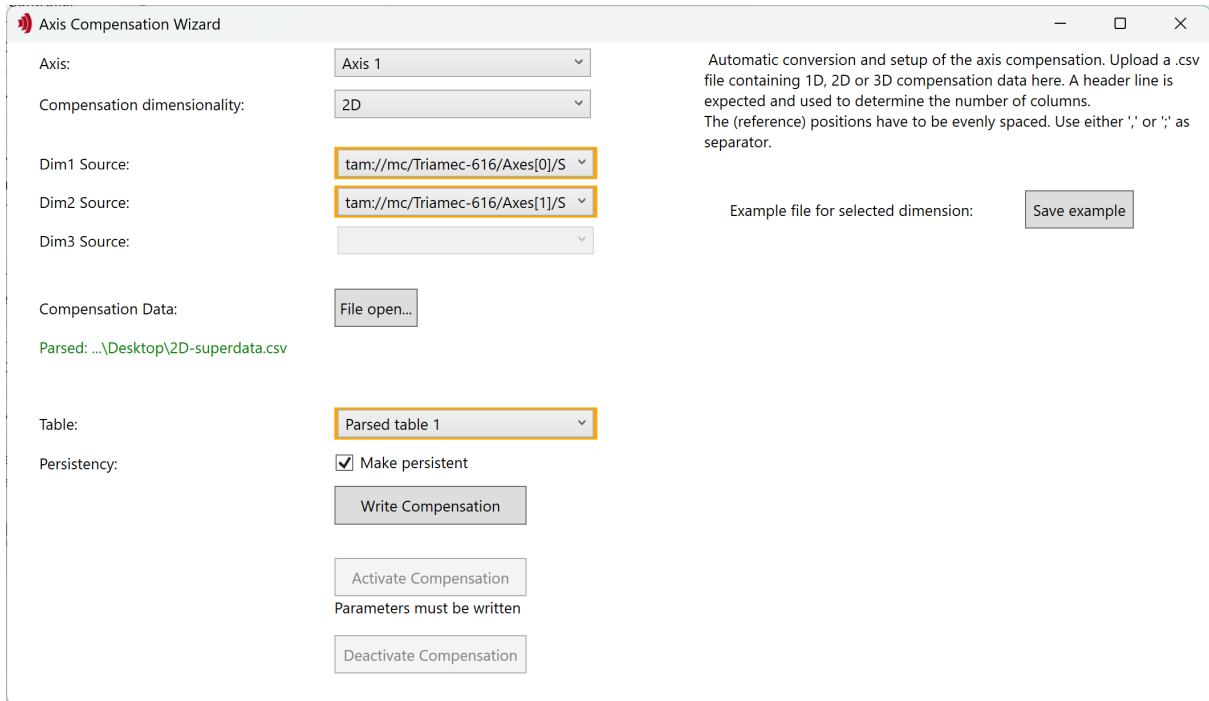


Figure 2: The Axis Compensation Wizard with an unwritten compensation

2.2 Opening the Wizard

The Axis Compensation Wizard can be opened and used either as a Standalone Application by opening the `AxisCompensationWizard.exe`, which can be found in the same folder as the `TamSystemExplorer.exe` or from within the TAM System Explorer in the top menu `Assistant > Axis Compensation Wizard` as shown in Figure 3.

Remark: Due to the flash wear error described in 2.4, it is generally recommended to use the *Axis Compensation Wizard* within the *TAM System Explorer*

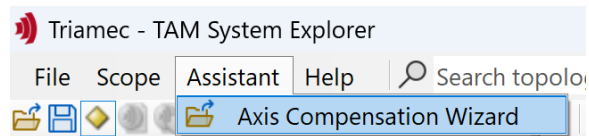


Figure 3: Opening the Axis Compensation Wizard from within the TAM System Explorer

2.3 Input file format

Currently the following file formats can be parsed:

- Comma separated values (.csv):
 - ♦ Lines that start with `//` e.g. comments are ignored by the parser (can be used for metadata)
 - ♦ A header line is expected and has to be separated with the below listed separator as it will be used to determine the number of columns
 - ♦ Accepted separators are `,` and `;`



- ◆ The first columns specify the reference values – one column per dimensionality, followed by columns with the compensation values
- ◆ One or more compensation columns which share the same reference values are possible. The Assistant will allow to select which compensation column to apply to the selected axis
- ◆ Each line (except the header line) must contain a reference value for each compensation dimension and a compensation value (one for each table). Therefore $\#columns = dimensionality + \#tables$

Example files can be generated and saved in the Wizard itself, see below.

2.4 UI Elements

Axis

Select the axis you want to apply the compensation to. You can still use *DimSources* from other axes as long as they are on the same drive. All axes found during the start up of the application are shown. Later connected/disconnected drives are not added/removed.

Compensation dimensionality

Select the dimensionality for your compensation. Necessary to parse files correctly and activate the necessary *DimSources*.

DimSource

Select which register(s) to use as an input to the compensation. All enabled inputs must contain a valid register address. Also external signals can be used as *DimSource* by mapping these signals to one of the available Application.Float registers.

Remark: Currently there is only a shortlist of possible Registers available to be used. Adding a custom register by address will be possible in future versions.

Compensation Data

Select a file to parse tables from. Not necessary if the table to be used is already set on the axis.

Table

Select which table to use for the compensation. The list consists of the already uploaded table (if available) and/or parsed tables generated from the uploaded Compensation Data.

Persistency

Select if the table shall be persistent or volatile. A volatile table will be lost after a reboot of the drive. Writing or deleting a persistent table causes flash wear. You can change the persistency state of an already uploaded table.

Remark: Writing many persistent tables in a short amount of time can lead to a flash wear error. In such a case, wait some minutes before writing a new table. Use the *Axis Compensation Wizard* within the *TAM System Explorer* to be aware if this error occurs.

Write Compensation

Write all (changed) parameters to the drive. Changed parameters are indicated by an orange border around the parameter. If no parameter changed or the chosen parameters are incompatible, writing will not be possible.

Activate Compensation

Activate the compensation. This is not possible if the compensation is changed (unwritten), the selected settings are incompatible or if the compensation already is activated.

Deactivate Compensation

Only possible if the compensation is active.

3 Implementation

3.1 Compensation Sign

It is assumed that the value for the axis compensation Δx is provided as the difference between the external reference position x_{Ref} and the encoder position x_{Enc} .

$$\Delta x = x_{Ref} - x_{Enc} \quad (1)$$

Accordingly the axis compensation Δx is added to the encoder position x_{Enc} by the drive to reconstruct the reference position x_{Ref} .

3.2 Enabling of the Compensation

When enabled, the compensation is smoothed with a ramp to avoid a jump. The duration of the ramp is 10ms.

The compensation is only applied, if the axis is homed.

3.3 Interpolation Type

For the compensation within the set-points linear interpolation is used for one dimensional interpolation bilinear interpolation for two dimensional interpolation and trilinear for three dimensional interpolation.

4 Advanced Topics

4.1 Compensation Tables detailed (*TAM Table*)

The actual compensation values are stored in a table called *TAM Table*. *Triamec Motion AG* uses a specific binary file format *.TAMtbl* for this. It consists of a header and a flat list of numbers. For detailed information, refer to [AN124](#) [1]. In the case of an axis compensation, float values are used. In order to find the correct return value in the flat list of numbers, the corresponding index of the list element has to be determined. A variable used for this index lookup (meaning it is an input to the table) is called



Dimension Source. The firmware calculates this index based on the *Dimension Source* value and the following 3 parameters:

- *StartValue*: The *Dimension Source* value of the first data point in this dimension
- *Distance*: The *Dimension Source* value between data points in this dimension
- *Size*: The number of data points in this dimension

Depending on its dimensionality, a *TAM Table* is associated with 1 to 3 such *Dimension Sources*. The flat list approach means that the reference positions have to be equidistant in each dimension used, such that they can be described with the 3 parameters listed above. This lookup is executed at a frequency of 10kHz. All tables can be accessed via the file system described in [AN124](#) [1].

4.2 TAM API

All functionalities of the *Axis Compensation Wizard* are accessible in the *TAM API* (.NET) via the Triamec.Tam.UI [NuGet](#). All business logic used in the *Axis Compensation Wizard* is located in the top-level class `AxisCompensator`. This allows you for example to program your own automated axis compensation set up. Further information about the TAM API can be found in the [TAM API Developer Manual](#) [2].

References

- [1] “Triamec Drive File System”, AN124_Filesystem_EP005.pdf, Triamec Motion AG, 2023
- [2] “TAM API Developer Manual”, SWNET_TamApiDeveloperManual_EP048.pdf, Triamec Motion AG, 2024

Revision History

Version	Date	Editor	Comment
001	2021-09-14	dg	How to setup axis compensation
002	2023-04-26	dg, sm	General update, doc template, adapt to updated Tama program
003	2024-06-14	ns	Add Wizard, remove Tama program
004	2024-06-26	ns	Add TAM API remark, update UI element section

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