TECH NOTE :: PMX Matrix Compensation

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Author: Michael Guckes, Silvan Ettle
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Short Description

This document explains how to compensate the cross talk of measured values by using matrix compensation. In this example a multicomponent transducer is used, which is able to measure force values within all degrees of freedom.

Required Material

In order to realize this example, the following components are necessary:

- 1x PMX system (incl. supply)
- 1x Transducer (3-component-transducer)
- 1x Calibration protocol (coefficient-compensation-matrix)

Introduction

More and more test engineers in aerospace, machinery and automotive request custom made sensors from HBM. These types of sensors measure force [N] and torque [Nm] in the requested degree of freedom and are called multi component or multi axis transducers. The picture below shows a 3-component-transducer. There are transducers with up to six components possible, if torque should be measured as well.

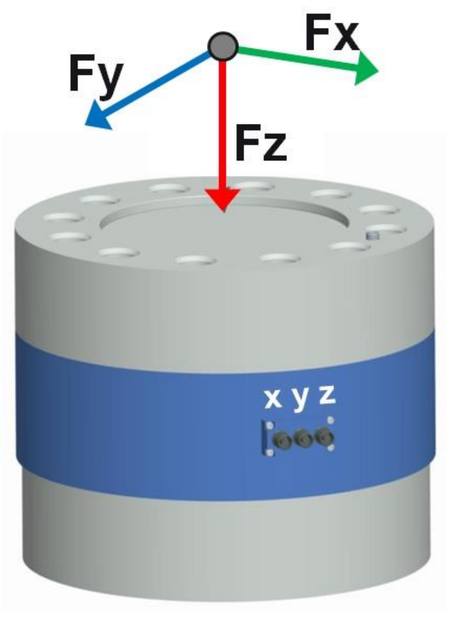

Figure 1: Degrees of freedom at 3-component-transducer

Basic infomation

HBM delivers together with the sensor itself a so called compensation matrix. The matrix itself shows the cross-talk or cross influence between components, i.e. *Fx* to *Fy* and so on. *Ufx*, *Ufy* and so forth are the raw signals measured in mV/V; *K11, K12* … are the coefficients.

Multiplication of the measured quantities with the matrix results in fully compensated force and torque values in X, Y and Z direction. *Fx, Fy* … are compensated real outputs in N or kN according the protocol delivered. A matrix example is shown in *figure 2* below.

Matrix Kompensation Übersprechen *Matrix compensation cross talk*		Eingang: [mV/V] *Input:*		Ausgang: [kN] (kompensiert) *Output:* (compensated)
		Ufx	**Ufy**	**Ufz**
		[mV/V]	[mV/V]	[mV/V]
Fx	[kN]	**3,1674**	**0,0027**	**-0,0020**
Fy	[kN]	**-0,0044**	**3,1683**	**0,0328**
Fz	[kN]	**0,0443**	**0,0249**	**18,6809**

$$\begin{pmatrix} Fx \\ Fy \\ Fz \end{pmatrix} = \begin{bmatrix} K_{11} & K_{12} & K_{13} \\ K_{21} & K_{22} & K_{23} \\ K_{31} & K_{32} & K_{33} \end{bmatrix} \cdot \begin{pmatrix} Ufx \\ Ufy \\ Ufz \end{pmatrix}$$

Figure 2: Extract from a calibration protocol (without TEDS)

As shown in the figure above, the sensor signals (*Ufx, Ufy, Ufz*) are multiplied with the coefficient-matrix and eventually summed up for every line. The results are the values for force.
The results can be outputted directly on the device or again get parameterized as isochronous to be available in the system.

Tips on using TEDS

When using *TEDS*, different coefficients are used, because the signals don't need to be converted. These coefficients can be found in the calibration protocol as well.

Matrix Kompensation Übersprechen *Matrix compensation cross talk*		Eingang: [N] *Input:*		Ausgang: [N] (kompensiert) *Output:* (compensated)
		Ufx	**Ufy**	**Ufz**
		[N]	[N]	[N]
Fx	[N]	**0,999997**	**0,000855**	**-0,000108**
Fy	[N]	**-0,001387**	**1,000013**	**0,001755**
Fz	[N]	**0,013990**	**0,007853**	**1,000012**

Figure 3: Extract from a calibration protocol (with TEDS)

Calculation example

As follows the force value *Fz* is calculated exemplary with the input signals *Ufx, Ufy, Ufz* and the matrix from *figure 3*:

$$\begin{pmatrix} F_x \\ F_y \\ F_z \end{pmatrix} = \begin{bmatrix} K_{11} & K_{12} & K_{13} \\ K_{21} & K_{22} & K_{23} \\ 0{,}013990 & 0{,}007853 & 1{,}000012 \end{bmatrix} \times \begin{pmatrix} 500 \\ 800 \\ 15000 \end{pmatrix}$$

$$Fz = K_{31} * (Ufx) + K_{32} * (Ufy) + K_{33} * (Ufz)$$
$$Fz = 0{,}013990 * (500) + 0{,}007853 * (800) + 1{,}000012 * (15000)$$
$$\underline{Fz = 15013{,}46\ N}$$

Matrix-Compensation with TEDS

Open the *PMX* in the web-browser and add a new function under *calculated channels*. Select the *6x6-Matrix* in the category *Scaling* as shown below.

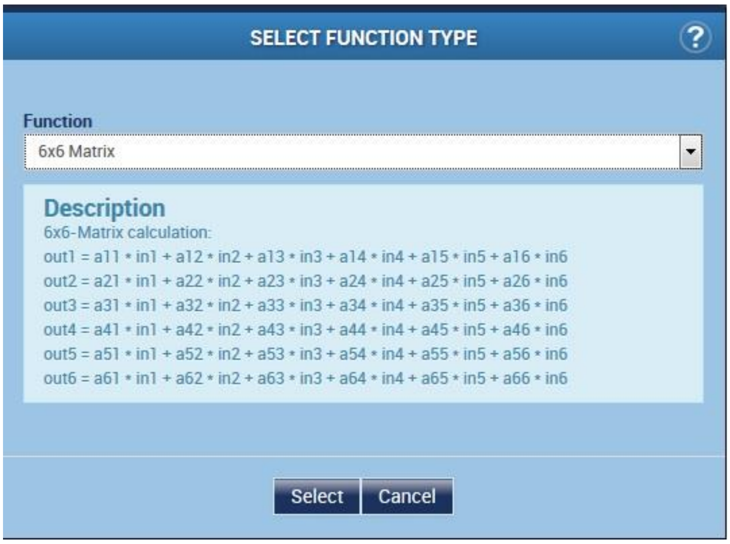

Figure 4: Select calculated channel 6x6 Matrix

The following field shows up, where the specific parameters can be filled in.

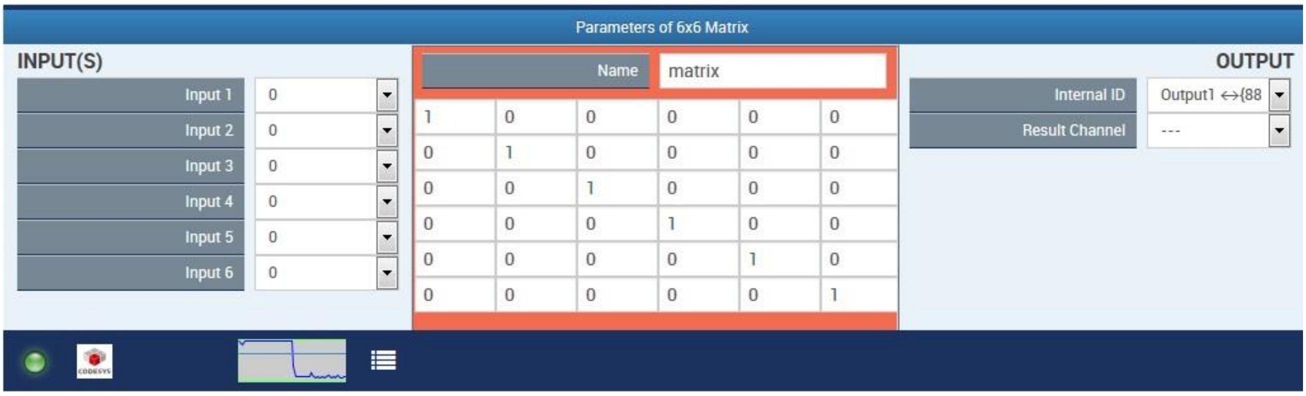

Figure 5: 6x6 Matrix blank

As first step choose the input channels of the signals which shall be compensated afterwards (1). Step two is to enter the values from the given coefficient-matrix <u>*for TEDS*</u> (here: figure 3) into the PMX matrix (2). As final step choose the signal output channels for the three output values (3).

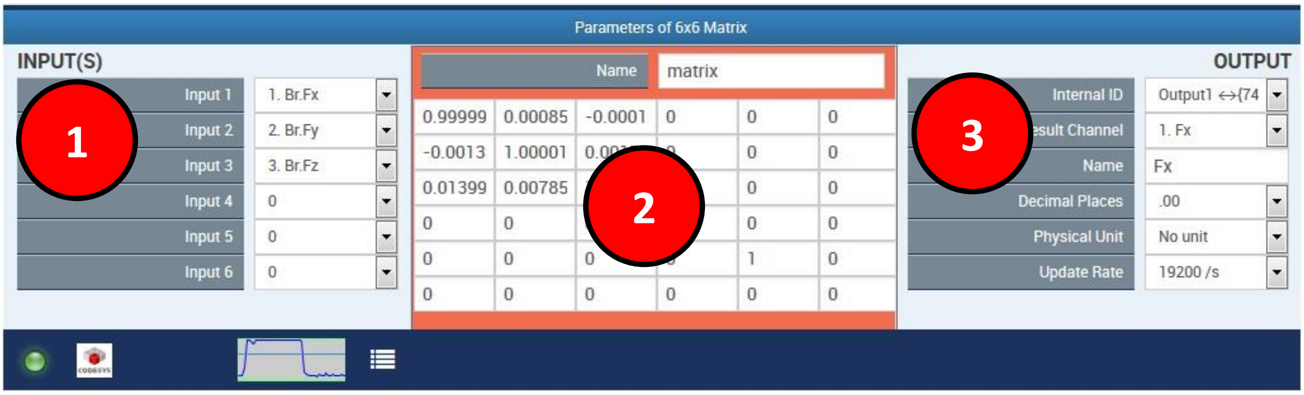

Figure 6: 6x6 Matrix with TEDS coefficients-matrix

Test run

Now some test signals are simulated to show the effectiveness of the matrix-compensation. The force in Z-direction is influenced by forces in X- and Y-direction. In *figure 7* the raw values, without compensation, are displayed. Those values were used for the theoretical calculation below *figure 3* as well.

Figure 7: Raw test signals (without compensation)

Afterwards the values are manipulated with the compensation-matrix. The result is shown in *figure 8*. To clarify the effect some *calculated channels* are created, those are not necessary for the basic application though.
In the first column there are the values after the manipulation by the compensation-matrix. The second column provides information about the difference between the raw values (*figure 7*) and the compensated values from column 1. Finally this difference related to the raw values is displayed in per cent in column 3.

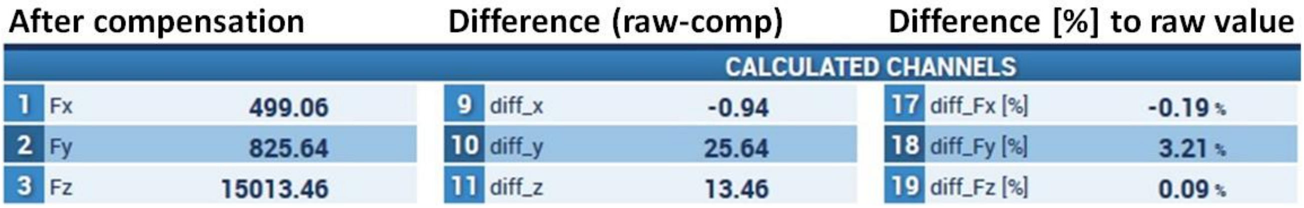

Figure 8: Compensated values and calculated channel for analysis

Matrix-Compensation without TEDS

Basically the procedure is identical, whether the sensor features *TEDS* or not. However, *TEDS* make the procedure much easier.
The illustration of the compensation-matrix in the test certificates (*figure 2*) requires a 1:1 scaling in mV/V, so in fact the actual electrical output of the sensor. A conversion into the physical unit (here: kN) is applied with the help of the matrix. Apply the sensor setting of the *PX455* as shown in *figure 9*.

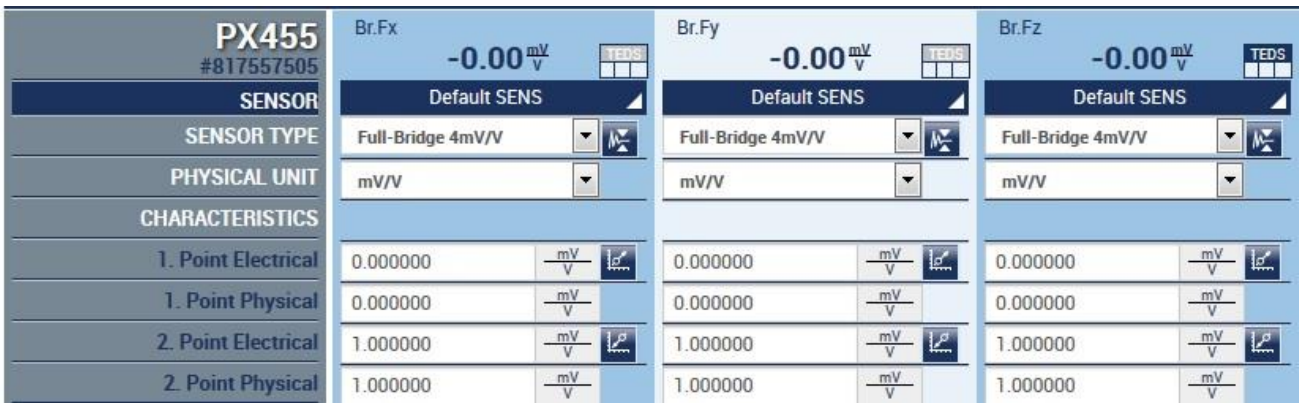

Abbildung 9: Sensorskalierung ohne TEDS

Afterwards the matrix (*figure 5*) has to be filled with the coefficients of the calibration protocol <u>without *TEDS*</u>.

Legal Disclaimer

These examples are simply for the purpose of illustration. They cannot be used as the basis for any warranty or liability claims.