TECH NOTE - Calculating resulting force

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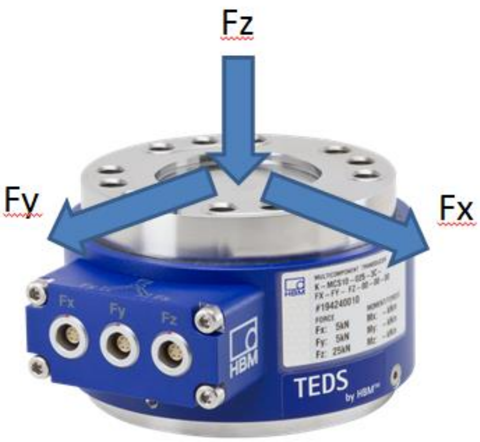
Brief description

A lot of test engineers in aerospace, machinery and automotive ask for custom made sensors from HBM. These types of sensors measure force [N] and torque [Nm] in any degree of freedom and are called multi component sensors (MCS) or multi axis transducers. The picture below shows a 3-component-transducer. There are transducers with up to six components available, to measure force and torque in each of the three dimensions.



Together with the sensor a so called compensation matrix is delivered. This matrix defines the cross-talk or cross influence between the 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 to the protocol delivered. An example how a calculation with such matrix looks like is shown below. There is a difference between using a TEDS and a non-TEDS sensor. Both scenarios are described in this document.

Calculation example

The mathematical function for a 3x3 compensation matrix multiplied with a vector of input signals looks like this:

$$\begin{pmatrix} F_x \\ F_y \\ F_z \end{pmatrix} = \begin{bmatrix} K_{11} & K_{12} & K_{13} \\ K_{21} & K_{22} & K_{23} \\ K_{31} & K_{32} & K_{33} \end{bmatrix} \times \begin{pmatrix} U_{Fx} \\ U_{Fy} \\ U_{Fz} \end{pmatrix}$$

Let’s define some coefficients and input values and calculate Fz:

$$K_{31} = 0.013990;\ K_{32} = 0.007853;\ K_{33} = 1.000012;\ U_{Fx} = 500;\ U_{Fy} = 800;\ U_{Fz} = 15000$$

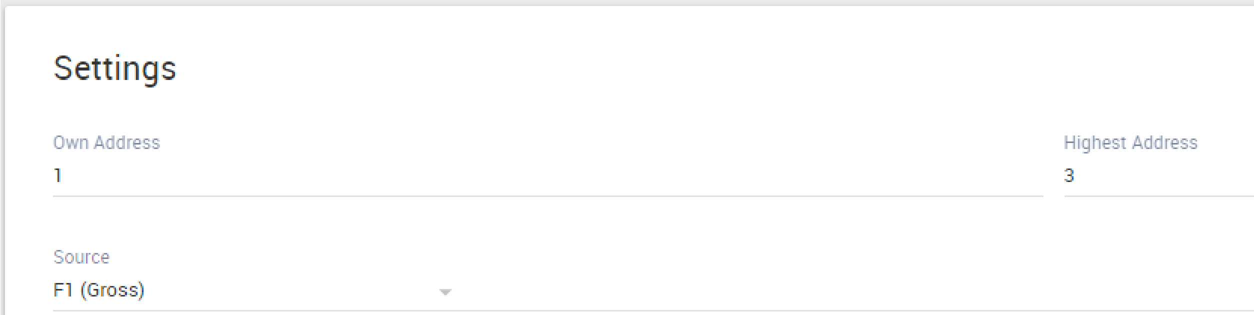
$$Fz = K_{31} * (Ufx) + K_{32} * (Ufy) + K_{33} * (Ufz)$$

$$Fz = 0{,}013990 * (500) + 0{,}007853 * (800) + 1{,}000012 * (15000)$$

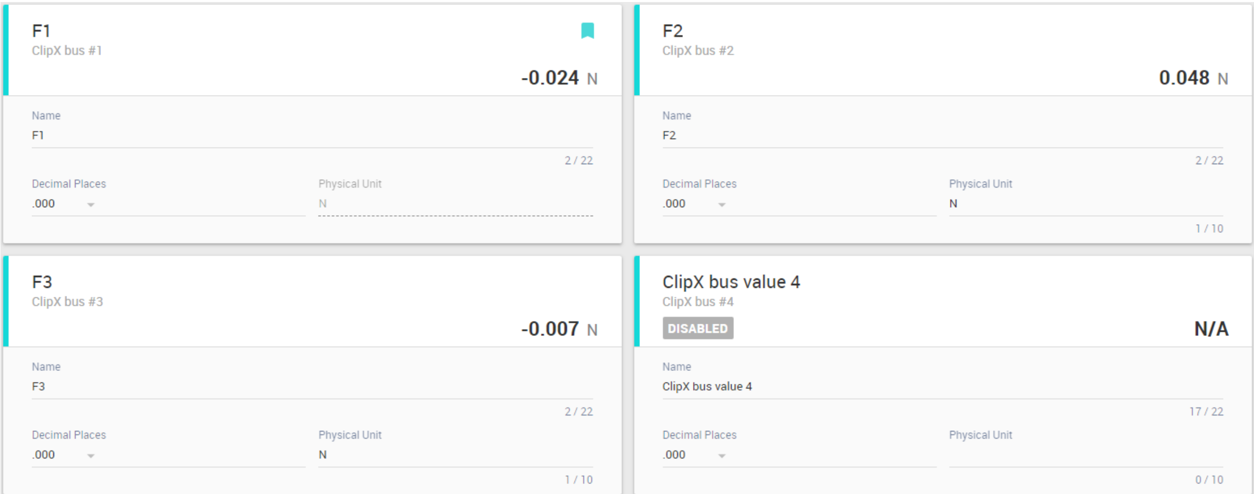
$$\underline{Fz = 15013{,}46\ N}$$

Transmit measurement values via ClipX bus

Go to the ClipX bus section. Give the devices an address (1 to 3). Enter 3 as highest address for all devices. Select the signal that should be sent on the bus as source.



After giving all signals on the bus a name the result looks like this. **Repeat for all amplifiers.**

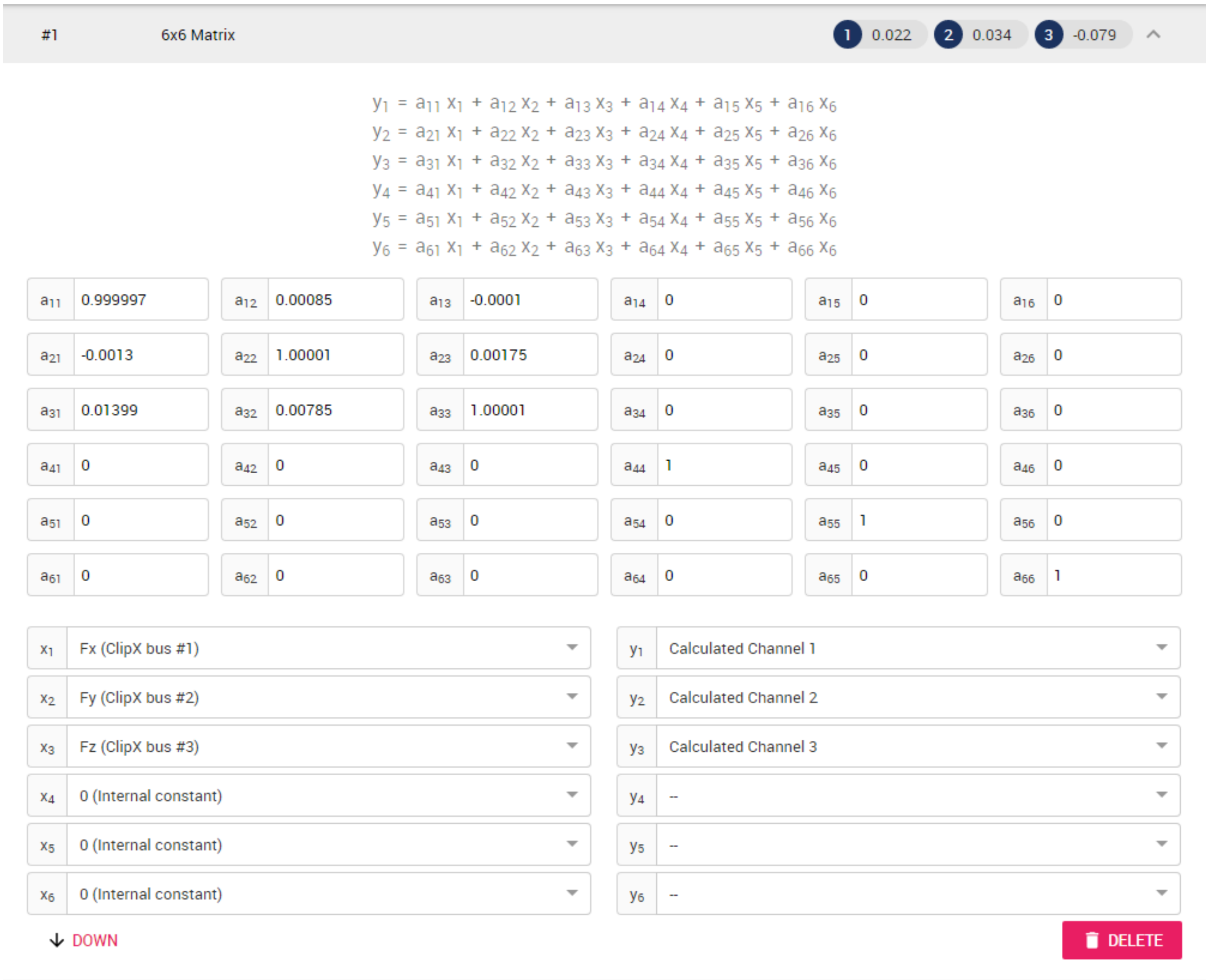


Compensation Matrix with TEDS

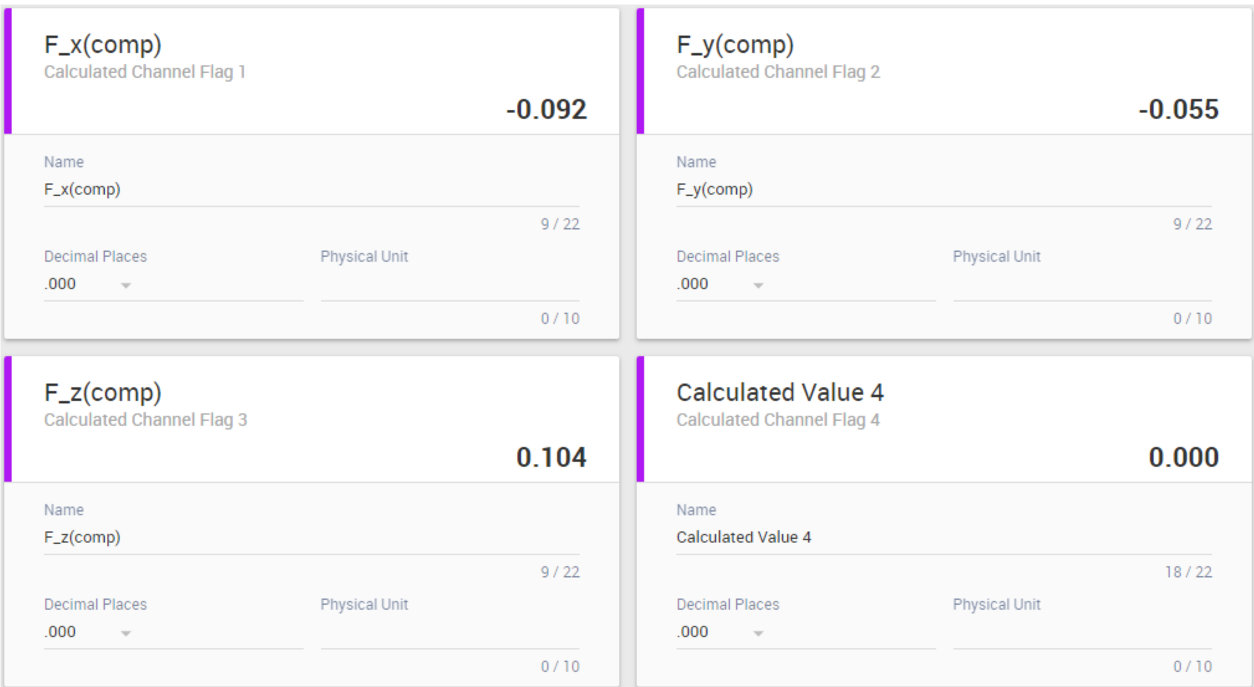
In the calibration protocol that is delivered with the MCS, there are two different matrixes available. The one below is used for a sensor that features TEDS.

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**

When using TEDS the sensor scaling is done automatically. To apply the matrix, go straight to the calculated channels section. Create a new Function Block as a 6x6 Matrix. This Matrix can also be used for MCS with less than 6 channels. Now simply enter the coefficients from the calibration protocol and set the inputs x1, x2, x3 to the corresponding force signals Fx, Fy, Fz. The results y1, y2, y3 are the compensated values of Fx, Fy, Fz.

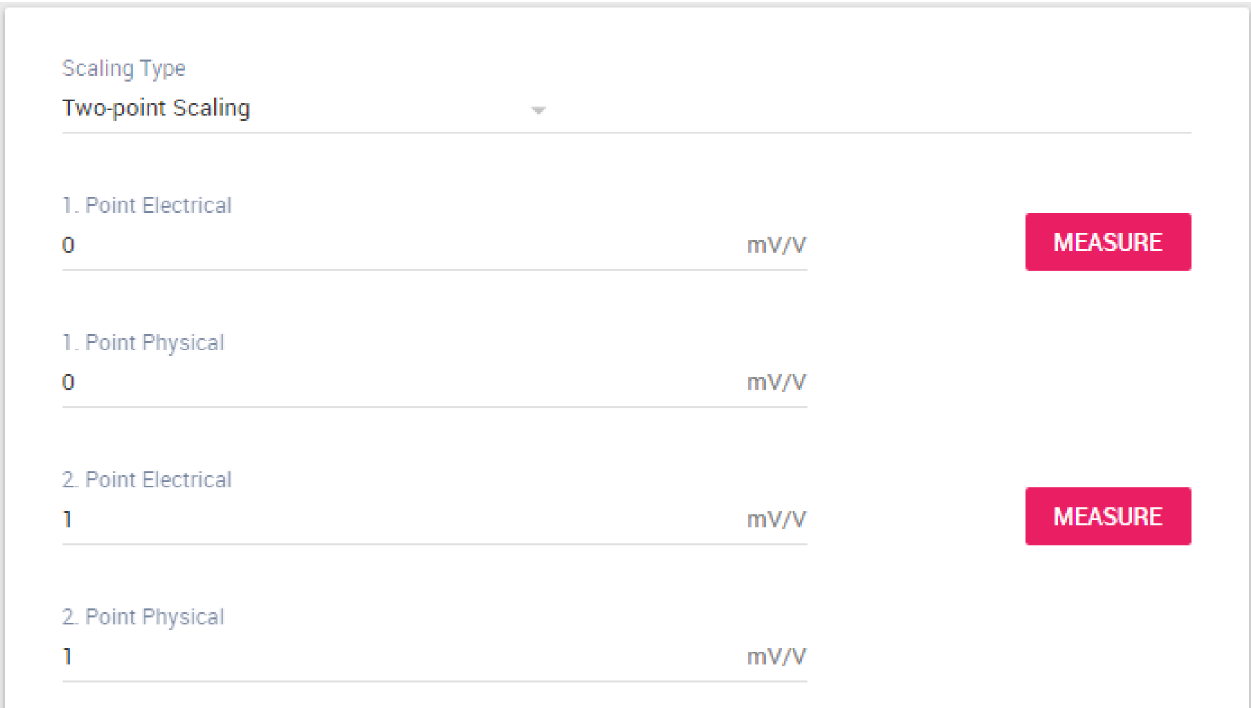


The result is shown in the corresponding calculated channels.



Matrix-Compensation without TEDS

Basically the procedure is identical, whether the sensor features TEDS or not. However, TEDS make the procedure much easier. There are two main differences when not having TEDS. To use the compensation matrix without TEDS, first apply a 1:1 scaling in mV/V for each sensor. This has to be done, because the matrix itself contains the scaling already. Therefor go to the amplifier section of each module and set the scaling according to the screenshot below.



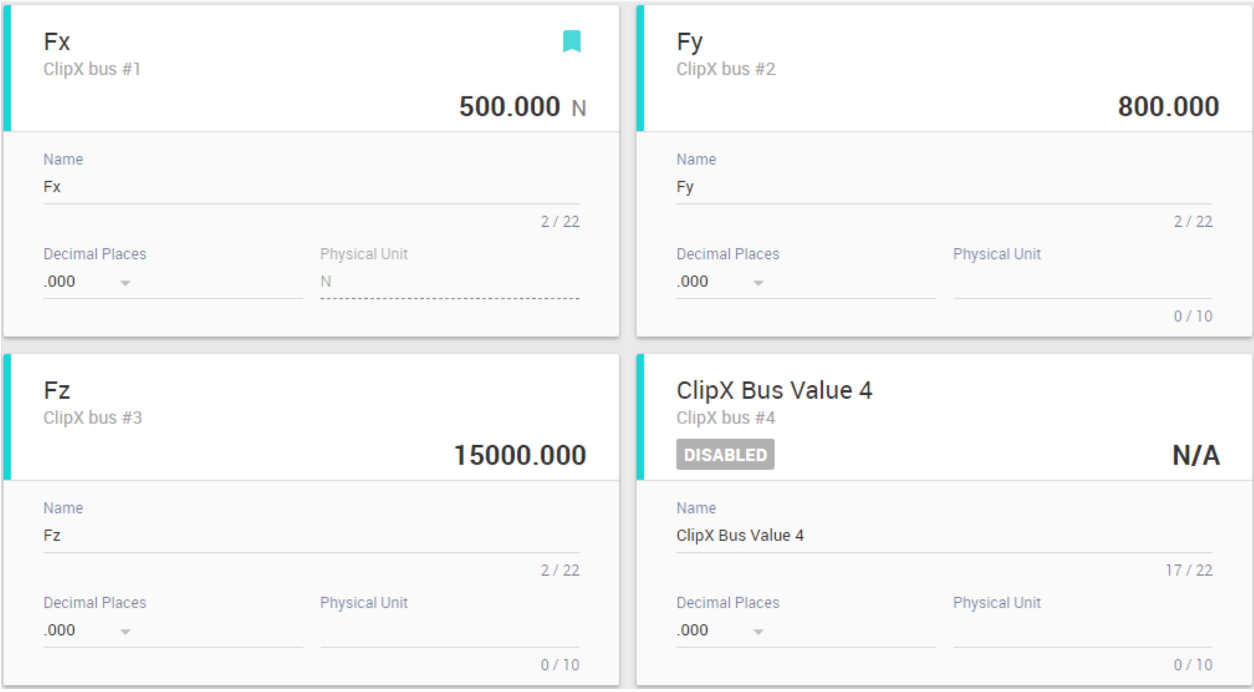
Then the matrix for non-TEDS sensors has to be entered the same way as described before. The conversion into the physical unit (here: kN) is already applied within matrix. That's it.

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**

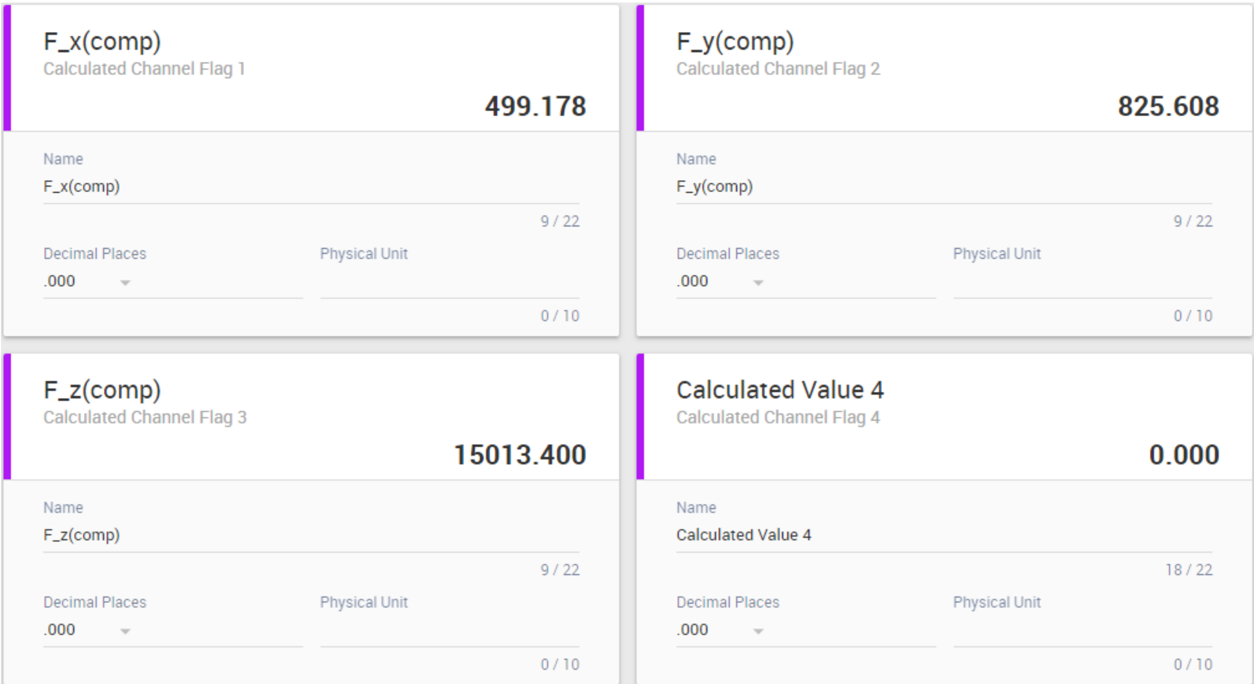
$$\begin{pmatrix} Fx \\ Fy \\ Fz \end{pmatrix} = \begin{bmatrix} K_{11} & K_{12} & K_{13} \\ K_{21} & K_{22} & K_{23} \\ K_{31} & K_{32} & K_{33} \end{bmatrix} \cdot \begin{pmatrix} Ufx \\ Ufy \\ Ufz \end{pmatrix}$$

Test run

Now some test signals are simulated to show the effect of the matrix compensation. The force in Z-direction is influenced by forces in X- and Y-direction. For this demonstration the values of the theoretical calculation from the beginning of the document are used.



Afterwards the values are manipulated with the compensation matrix. The result is shown below.



This demonstrates that there is a real error between compensated and non-compensated values. Therefore it is highly recommended to always make use of the compensation matrix.

Disclaimer

These examples are for illustrative purposes only. They cannot be used as the basis for any warranty or liability claims.