TECH NOTE :: Data Acquisition and Analysis in Dyno Testing

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Abstract

This Tech Note mainly deals with data acquisition and analysis in dyno testing focussing combustion engines, hybrids, turbo charger, gearbox, complete drivetrain or even full vehicles.

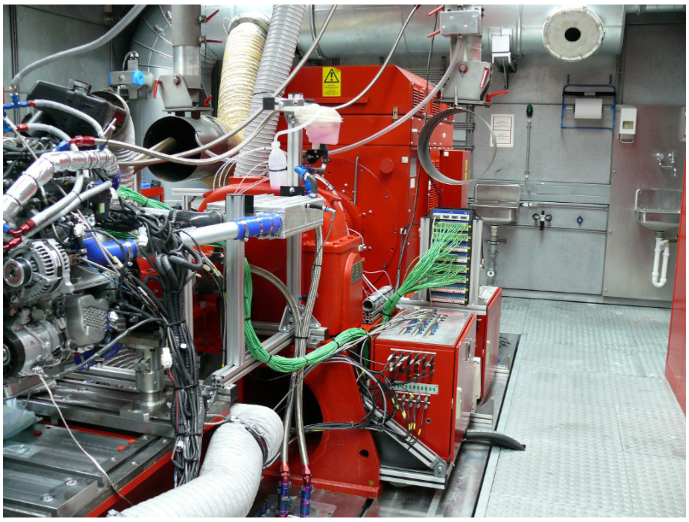
HBM is the number one in offering high quality products for **torque** and **speed** measurement in the world-wide dyno testing market. In general we see a growing demand for **new dynos** testing electric drives but the even larger market is **retrofitting existing dynos**, equipping them with new sensors and measurement technology. HBM focusses on this specific application offering the full measurement chain consisting of sensors, electronics, software and service - a clear benefit for users in dyno testing.

In a wider range many of the following aspects are valid too in a variety of fields engineering compressors, pumps or in general shaft based machines or generators.

In automotive industry "engine or in general powertrain development" is one of the **main engineering disciplines**. The challenges in this field are enormous, dealing with a high number of variants of all kind of aggregates – from **combustion engines** (Gasoline, Diesel, Methanol, LPG) to **electric drives** supplied by an energy storage or fuel cell or combinations of technologies (**hybrids**). And there is still room for invention and improvement by for example **down-sizing** engines or improvement by high performance **turbo chargers**.

All efforts in this engineering domain targeting **fuel consumption**, energy **efficiency**, reduced **emission**, reduced **noise** (acoustics), high **performance** and are engineered under extreme **time and cost pressure** from idea to start of production (SOP).

Moving people or freight from A to B seems to be simple but brings all engineering disciplines together – mechanical, thermo-dynamics, chemical, electrical, electronics and software. Therefore **powertrain dyno testing** has to deal with the highest complexities in terms of pure amount of input channels, different type of transducers and sensors, different busses, protocols and software needed to stimulate, simulate and analyse all important aspects of and around the system under test. Several vendors play a major role in the testing market when it comes to **control**, **automation**, **data acquisition**, **simulation** and **optimizing** software parameters of electronics. HBM is the leading supplier for **torque and speed sensors**, **data acquisition systems** and **analysis software**. Since decades HBM is a key player in dyno testing with torque and speed measurement flanges like T12, T10 or the T40. These torque flanges are standardized in many dyno test stands all over the world delivering maximum noise immune digital outputs. The **modular QuantumX data acquisition** system can be scaled to any amount of channels, offer high performance, universal inputs and high accuracy and thus stands for flexibility and efficiency in dyno testing.



In modern test cells even parts can be tested in a realistically simulated environment including all integration and real-life aspects including driving situations.

Torque and rotational speed of rotating shafts are major quantities in this kind of application. For combustion engines in addition **angle and position** of all pistons in the cylinders are additionally needed. In addition to that other physical quantities like pressure, temperature, acceleration, strain, flow and so forth need to be measured and analysed in parallel and in direct relation to each other over time, frequency or angle.

Optimizing engineering and testing methods from virtual test and simulation to physical testing of system components or complete vehicles is the only constant from idea to series production (SOP). Driving engineering efficiency towards fully integrated process and data flow is another driving factor.

HBMs most flexible data acquisition solution **QuantumX** and its software **catman** are the best choice for quicker and highly reliable data in powertrain testing leading to quicker innovation. Key installations show a **70% improvement in efficiency** when using modern data acquisition tools in testing compared to existing ones. Retrofitting existing test benches with new and modern tools is more than a trend in industry. Especially in new test benches, driven by the need for higher dynamics, more and more users want to get away from fixed and old-style 19 inch general purpose inputs build in racks, but want to use a modern and flexible data acquisition tool which can be set-up according to its task from 4 to some hundred channels in type and speed. Target: increase testing time, handling more variants, reduced setup times and quicker analysis. QuantumX DAQ can process data in real-time and in parallel for online or post-process analysis. In modern test benches real-time means integration into an Ethernet based real-time bus with a central master running simulation and control algorithms.

This TECH NOTE will guide you from the idea and task of dyno testing, over data acquisition to data analysis and names many important aspects from HBM point of view.

Dynamometer (Dyno)

Dynamometer test stands or in short **dynos** are a perfect way for putting a pre-defined reproducible simulated load to a system under test for further optimization of:

- Functional design (mechanical, thermal, fluid, electrics, electronics, …)
- Power and efficiency (fuel variants and consumption, typical rpm over torque diagram, shift quality, …)
- Emission (hydrocarbons, NOx, CO, CO2, ….)
- Durability (thermal, mechanical, …) long term and stress testing
- Noise, Vibration, Harshness

There are different types of Dynos in use:

- Inertial based > Spinning mass (large heavy drum) based
  - Cannot load the engine, torque is interpolated by how fast it takes to spin the drum

- Water Brake based > Water pump based
    - High load capacity
    - Uses something similar to a torque converter in an AT to load the engine.
- Eddy Current based > EM brake
    - High power applications
    - Low inertia, very responsive
- Electric motor based > AC or DC : Flexible control apps
    - Has the ability to both load the engine and motor it
    - Useful for measuring the amount of friction when the engine is motored.

Furthermore we need to differentiate between engine dynos and chassis dynos testing the complete drivetrain including engine and gearbox.

Typical Transducers and Sensors in Dyno Testing

Dyno testing has got the highest demand in using all kind of different sensors, transducers or in general data acquisition inputs. All kind of physical quantities need to be acquired in a time synchronous way for data analysis in the domains time, frequency or angle:

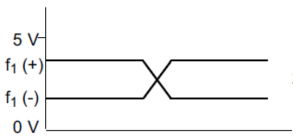
- Physical field: mechanical, hydraulics, thermal, electrical or mixed systems
- Quantities: force, strain, torque, pressure, temperature, displacement, speed, position, acceleration, flow, voltage, current and many more.
- Electrical sensor / transducer / technology: thermocouple, Pt100, direct voltage, current clamp, shunt, strain gage bridge, inductive bridge, LVDT, IEPE, piezo-resistive bridge, piezo electrics and many more
- Data protocols: digital pulses (PWM), SSI, CAN bus and variants, FlexRay,

Torque and Speed

In general torque and speed of rotating shafts belong to the basics for rotational analysis and mechanical power calculation.

In automotive, marine and energy applications torque flanges from HBM are widely in use. Many customers use the T12 torque transducer with increased accuracy in terms of temperature and linearity for a precise efficiency analysis in ranges from 100, 200, 500 Nm or 1, 2, 3, 5 and 10 kNm. T12 is specified with an accuracy class of 0.03. The T12 transfers torque information via digital pulses around a mid-band frequency, e.g. 60 ± 30 kHz. The higher the mid-band frequency the shorter the group delay time (320 µs at 10 kHz versus 250 µs at 60 kHz). The resolution/accuracy is slightly reduced as a result of the extended signal range (0.03 at 10 kHz / 0.25 at 60 kHz).

The **digital differential output** looks like this:



The torque signal can also be transmitted as standardized voltage signal but using true digital signals offer highest electromagnetic noise immunity and allowing longer cable lengths. Especially in modern test cells this plays an important role as high frequency inverters and high dynamic electric AC drives are in use.

Speed Sensors and RPM calculation

There are several sensors on the market for rotational measurement which can be directly or indirectly mounted to a shaft or comes together with the torque flange.

For accurate angle, speed and direction measurement of shafts high resolution digital encoders can be used.

HBM torque flanges T12 and T40 can be delivered with an integrated high resolution encoder with 1024 or 2048 pulses per round on 2-lanes, 90° phase shifted for direction and zero index for position.

Counting the amount of pulses gives you information on angle.
Example: 1024 pulse = 360°.

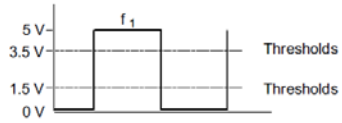
Direction is detected in terms of whatever lane delivers the first rising edge.
Example: positive counting = right direction. Negative counting = left direction.

In general amount of pulses per time gives you information on speed. On instrumentation side this can be solved by a frequency based input and scaling calculating rounds per minute (rpm).

One type of sensor is the so called **Encoder** used for high resolution speed and angle information. In most of the cases they are based on photo-electric rotational measurement generating digital TTL pulses with two lanes (A, B dealing with direction and speed) and index (position). Two factors affect the quality of this data:

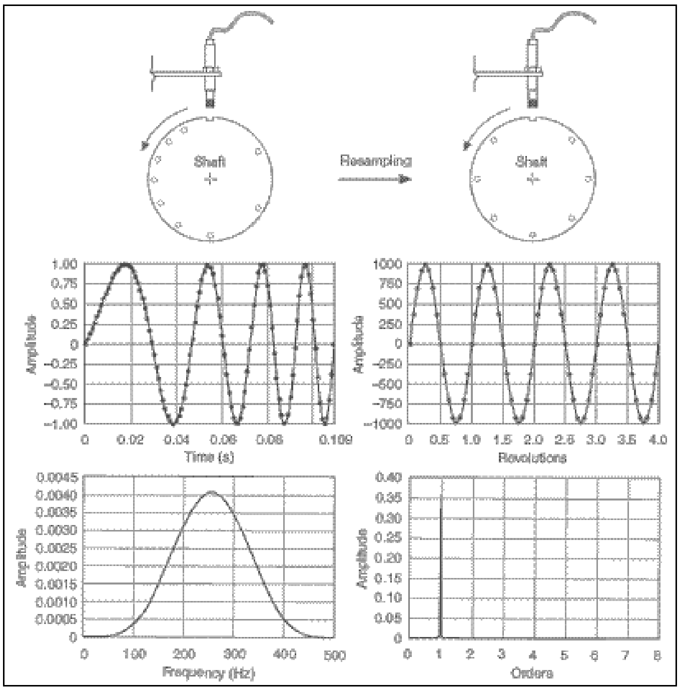
- Number of pulses per revolution (referred to as PPR). Higher PPR values result in better resolution.
- Symmetry of pulses. The symmetry of one pulse to the next can play a role in how consistent the RPM readings are. Symmetrical pulses give more accurate data.

Other typical signal types for speed, direction and angle measurement are **digital single pole** (with / without direction).

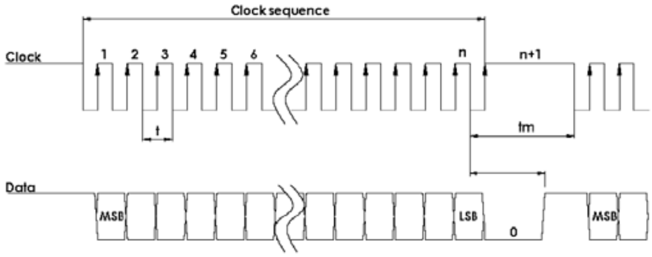


This signal type can also be used as counter or frequency input.

Typical for combustion engines are **passive inductive pick-ups** or **proximity** sensor which is an AC coupled inductive proximity sensors (one lane analog pulse) measuring pulses on the crank wheel mainly to detect absolute engine position and speed. Typical crank wheels are 30:3 or 60:2. The missing gap or gaps give note on the absolute position of the pistons in the engine and can be detected as reference in the module.



Some large scale ship engines use **absolute digital encoders** such as SSI type which deliver absolute position by a pre-defined protocol. An initial reference movement is not needed in this case.



Encoders are most commonly used. They offer a high resolution (typically 1 to 5000 PPR) and clearly defined, symmetrical pulses.

Pickup or Proximity sensors provide medium- or low-resolution sensing, depending on the number of pulses measured per revolution. The best method of using a proximity sensor is to sense the teeth on a gear. This type of sensing typically has options for 60, 120, or 240 PPR, and the pulses are relatively clearly defined and symmetrical, inductive with higher voltage level and need AC coupling. If a gear is not available, a proximity sensor can be used to sense the head of a bolt attached to the shaft. The drawback of this method is the low PPR (low resolution). If more than one bolt head is used, resolution improves, but pulses are often inconsistent and not symmetrical. In automotive applications

Sensors with a digital output signal can also be split for different purposes:

- One channel: speed measurement in "revolutions per minute" (RPM) important when monitoring speed of motors, conveyors, turbines, etc.
- Second channel: angle based measurement including a reference pulse for absolute position

When choosing sensors, make sure the resolution of the sensor is appropriate for the speed of the shaft.
For example, if you use a 5000-PPR encoder on a fast-moving shaft, the resulting pulses might exceed the maximum input frequency of the system, causing inaccurate readings.

There are two methods for determining RPM: the Frequency measurement method and the Period measurement method. Frequency measurement is better for fast-moving devices such as motors and turbines that typically turn in thousands of revolutions per minute. Period measurement is better for devices that move more slowly, such as shafts that turn in less than 10 RPM.

When using high PPR sensors, such as shaft encoders or proximity sensors sensing gear teeth, the easiest way to determine RPM is to monitor the pulse frequency from the sensor using a digital input and the Frequency based parameterization. Then calculate the RPM using this equation:

$$RPM = \frac{(Pulse\ Frequency\ in\ Pulses\ /\ second) * 60\ second\ /\ minute}{Sensor\ Pulses\ /\ minute} = \frac{Revolutions}{minute}$$

Or:

$$RPM = \frac{(Pulse\ Frequency) * 60}{Sensor\ Pulses\ (PPR)} = \frac{Revolutions}{minute}$$

RPM = min^{-1}

Frequency = Hz
Pulses per Round = PPR

When using frequency measurement as a method of monitoring RPM, the key factor is the number of pulses being sensed per revolution, or the PPR. This method works well with high PPR sensors and works poorly for low PPR sensors.

The equation becomes:

$$RPM = \frac{Pulse\ Freqency * 60}{600} = \frac{Pulse\ Frequency}{10} = Pulse\ Frequency * 0.1$$

- At a pulse frequency of 1 Hz, the shaft speed is 0.1 RPM.
- At a pulse frequency of 2 Hz, the shaft speed is 0.2 RPM.
- At a pulse frequency of 100 Hz, the shaft speed is 10 RPM.

For slow turning shafts measuring the pulse period is the best method of measuring RPM are proximity sensors sensing a bolt head or photoelectric sensor. Period is the time from the start of one pulse to the start of the next pulse. This equation shows the relationship between frequency and period:

$$\mathbf{Frequency} = \frac{\mathbf{1}}{\mathbf{Period}}$$

When using period measurement to monitor RPM, calculate the RPM using this equation:

$$RPM = \frac{60}{Pulse\ Period * PPR}$$

The main issue when using period measurements occurs when the PPR is greater than 1 and the pulses are not symmetrical. For example, when shaft speed is constant and you are sensing two bolt heads per revolution, if the bolts are not exactly evenly spaced, the periods will be different, causing the RPM indication to be erratic. When using the Period method, you configure the digital input with the Period feature.

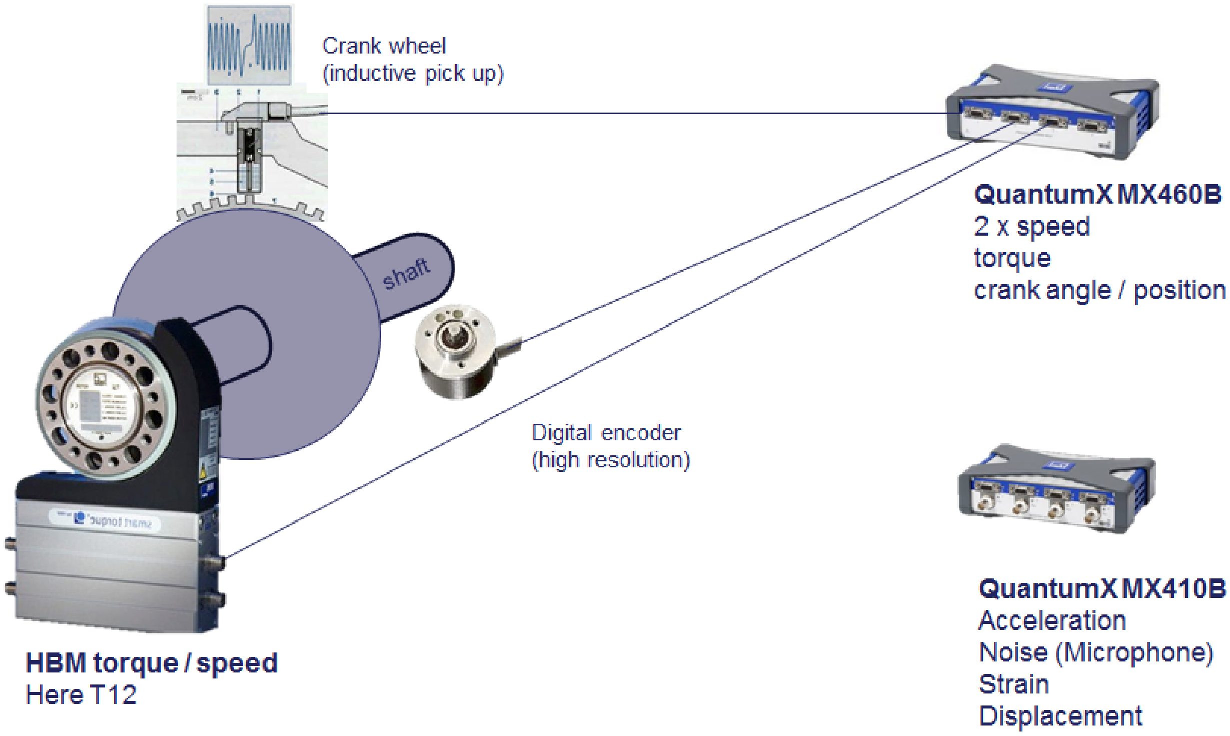
QuantumX Data Acquisition

The modern and fully scalable QuantumX data acquisition system and catman software from HBM are a perfect bundle for demanding test and measurement tasks with some significant benefits in comparison to existing solutions:

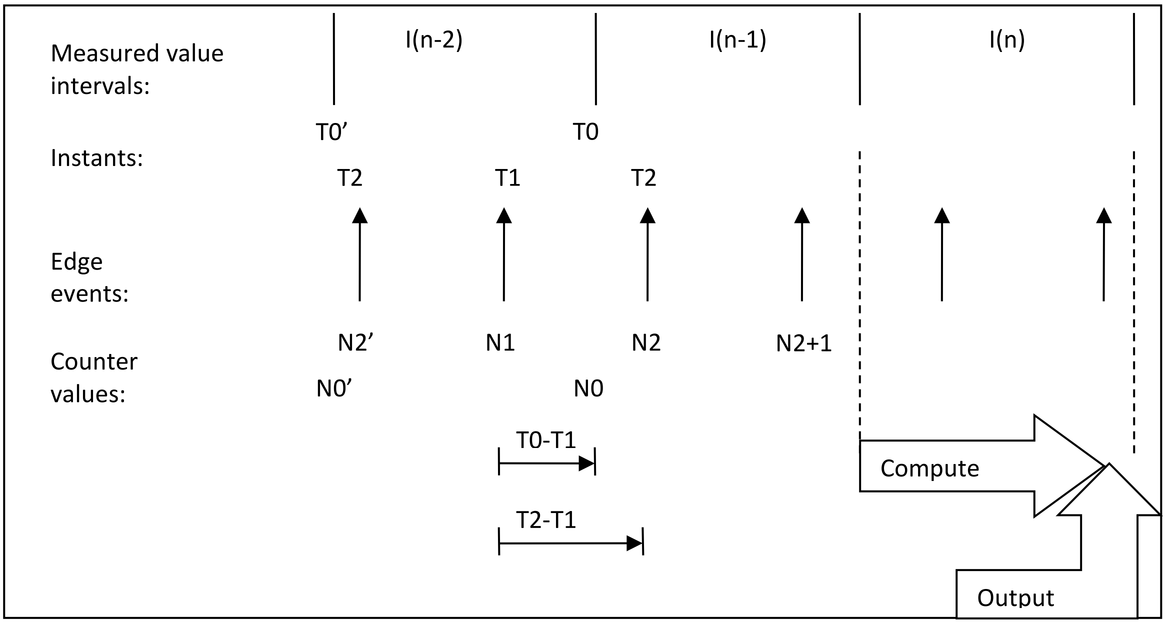
- from small to high channel count applications based on modern Ethernet technology
- universal inputs combined with TEDS support allows you to connect all kind of different sensors to every channel in a short period of time
- superb analog channels with 24 Bits AD resolution, Galvanically isolated and patented noise suppression methods lead to fast setup times without ground loops and with maximum quality of data
- highly dynamic inputs and bandwidth allow system analysis in time and frequency domain
- time synchronized overall system of all inputs
- with catman a powerful and easy to use software package for online and post-process analysis in time, angular and frequency domain
- parallel integration in real-time to EtherCAT®.

QuantumX MX840B and MX410B are the two universal types of modules.

QuantumX **MX460B** is the specialist for shaft based measurement and analysis supporting all kind of digital sensor and transducer outputs acquiring torque, speed, angle, direction and position. In addition to that the module can calculate a **Torsional Vibration Analysis (TVA)** in a real-time. The results are harmonic natural frequencies (Eigen) and amplitudes can be sent to the Automation System (AuSy) via EtherCAT. The software catman can analyse the TVA as well.



Digital measurement with MX460B is one of the best in the market. In simple words a forward-backward counter is used counting the inputs' edge events and outputs the counter value. The problem is that the edge events can occur at any time within the measurement interval pattern. The result would have a high level of uncertainty. This jitter can be reduced by interpolation of counter values. Time and counter value for the last edge before and the first edge after the sampling instant are stored to determine the interpolated measured value for a sampling instant T0. To be able to know when the first edge occurs after T0, the calculation needs to be started correspondingly later. If the calculation is delayed for too long a time, however, this means that the output is delayed. Therefore, calculation of the sampling instant T0 starts exactly one measuring interval later. Time is counted at a clock frequency of around **98 MHz**. The sampling rate of the measured values is lower by a factor of 1024, i.e. at 100 kS/sec with a maximum bandwidth of 40 kHz.



Counting with interpolation

The MX460B offers 3 measuring ranges for frequency or torque measurement with highest resolution and dynamic:

Resolution frequency measurement, min.	mHz	
Measuring range 20 kHz		1 (signal range: 0.1 ... 8192 Hz)
		2 (signal range: 8193 ... 16384 Hz)
		4 (signal range: 16385 ... 32768 Hz)
Measuring range 200 kHz		10 (signal range: 0.1 ... 65536 Hz)
		16 (signal range: 65537 ... 131072 Hz)
		32 (signal range: 131073 ... 262144 Hz)
Measuring range 1000 kHz		125 (signal range: 0.1 ... 1048576 Hz)

Example: T12 torque sensor with +/- 100 Nm and 60 ± 30 kHz digital output signals.
In other words + 100 Nm = 90 kHz signal.
This results in a MX460B digital measuring or counting range of 200 kHz and a resolution of 16 mHz (see above table) or far below 0,001 Nm which can be seen as no-loss and pure digital data acquisition.

	MX460B
Internal Clock	98.3 MHz
Data rate	100 kS/s
Counting Method	Interpolation
Frequency based torque measurement for 100 kHz signal	196 Hz noise with 96 kS/sec
Phase synchronicity	Due to interpolation high phase accuracy and less jitter in sync to analog inputs
Angle accuracy / Encoders	Due to interpolation high angle accuracy
On-board processing	Torsional Vibration Analysis (TVA)
Type of sensors	Encoders and inductive pickups

Internet link for more information!

Data Acquisition and Analysis Software

HBMs powertrain software catman is the perfect choice parameterizing all channels, monitoring limit values like torque, pressure, temperature or speed. Catman is able to visualize and analyse all sensor data in a graphical way in the following domains:

- y-over-t: any signal over time
- y-over-x: any signal over signal, for example torque over speed
- y-over-f: any signal over frequency (standard FFT, order, power, 2D-spectrogram)
- y-over- α in °: any signal over angle for cylinder position based engine analysis including peak detection in certain sections within 0 … 360° or 0 … 720° for cycle based

Crank angle based visualization and analysis is helpful in analysing combustion engines and its cycles with focus on injection, ignition or torsional vibration in self-defined sections around Top Dead Center (TDS) like 0 … 20 °, 280 … 320 ° and so forth. A reference channel is needed measuring angle information.

Example: Let’s say your engine goes up to 15,000 RPM and your digital encoder reads 1024 PPR.

You use T40B torque flange with 200 N·m measuring range.

Speed Sensor Datasheet

5 V symmetrical (RS422 type) with 2 square wave pulse signals approximately 90° phase shifted.

Pulses per revolution: 1024

Minimum speed: 0
Maximum permissible output frequency: 420 kHz
Reference Signal measuring signal / zero index

<u>RPM Scaling:</u>
Pulses per revolution from speed sensor: 1024 pulses

$$15000\ \frac{rev}{min} * 1024\ \frac{1}{rev} * \frac{min}{60\ s} = 256000\ \frac{1}{s} = 256\ kHz$$

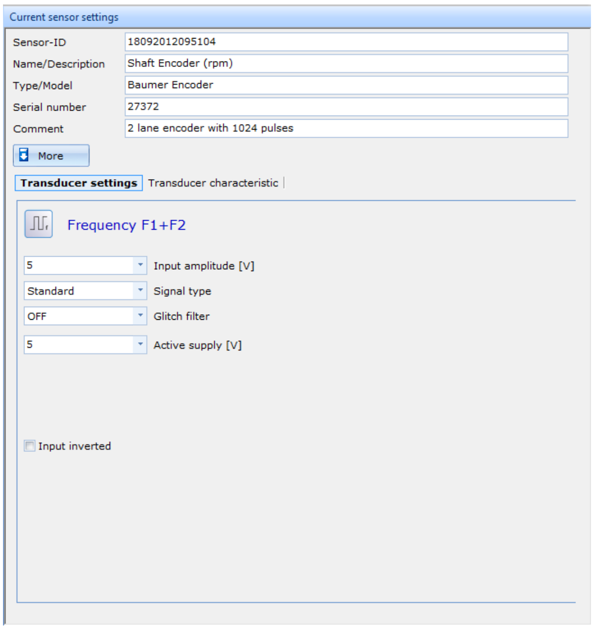
Engineering units [0 rpm] = electrical units [0 Hz]
Engineering units [15000 rpm] = electrical units [256 kHz]

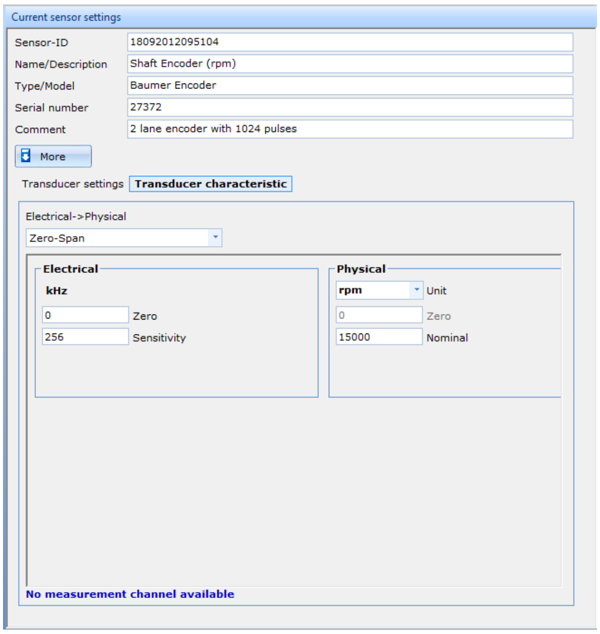
<u>Angular Accuracy</u>
MX460B datasheet claims:
360° / 1024 = 0,35°

<u>How to add the RPM speed sensor to the Sensor Database?</u>
Copy the equivalent sensor from the embedded reference list of sensors to your own user sensor database and adapt it according to your calibration data.

Modify the digital sensor datasheet according to your needs:

- meta data like sensor ID, name or description, serial number and a comment
- technical details like input type, voltage supply, etc. and the correct scaling





Angle measurement

Example: Let's say you use the same sensor like above and split its signal to another channel with different parameterization.

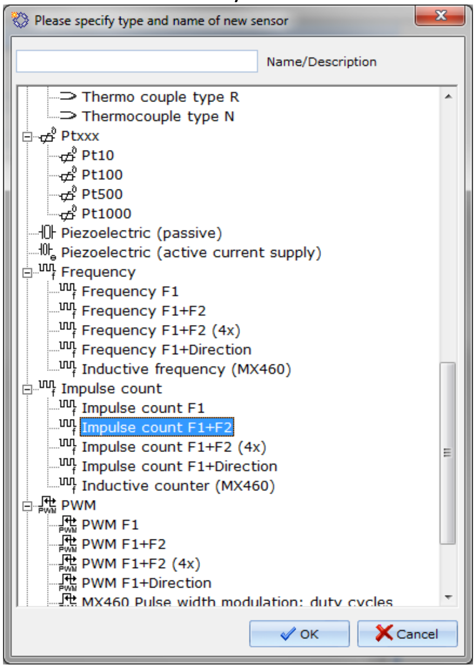
<u>Speed Sensor Datasheet</u>

5 V symmetrical (RS422 type) with 2 square wave pulse signals approximately 90° phase shifted.

Pulses per revolution: 1024

How to add the angle sensor to the Sensor Database?

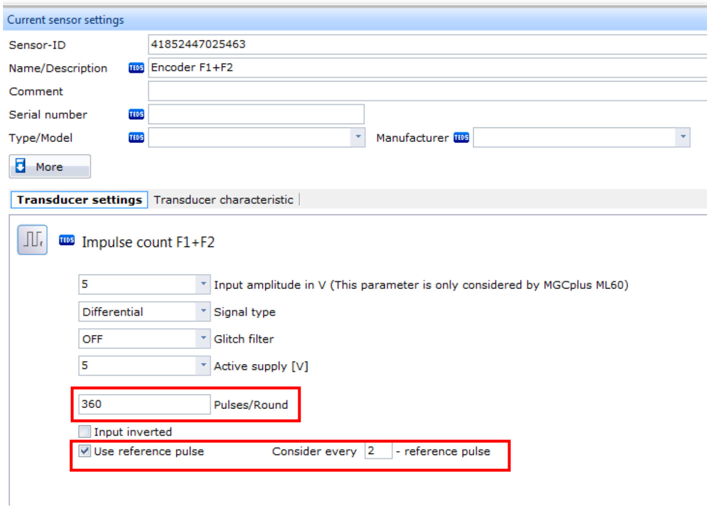
Take the correct entry from the reference list.



Adapt the digital sensor datasheet to your needs:

- meta data like sensor ID, name or description, serial number and a comment
- technical details like input type, voltage supply, etc. and the correct scaling

The **reference pulse** can be used to scale the measured pulses to an absolute angle before the reference signal (index) resets the value. For example you want to analyze your data in between 0 … 720°, so every second reference pulse shall be considered to reset the angle to 0!.



Angle Relation

With combustion engines the detected Top Dead Center (TDC) is used as zero reference and can be used to visualize signals from all inputs over angular (MX460 input signal).

Also the zero index of a high resolution encoder can be used. For this purpose the software can evaluate every second zero index. It is possible to shift the zero indexes logically adapting to the true mechanical mounting of the encoder.

Torque Transducer Setup in the software

HBMs torque flanges deliver digital signals for torque and rotational speed.

Adding a Torque Sensor to the Sensor Database in catman:

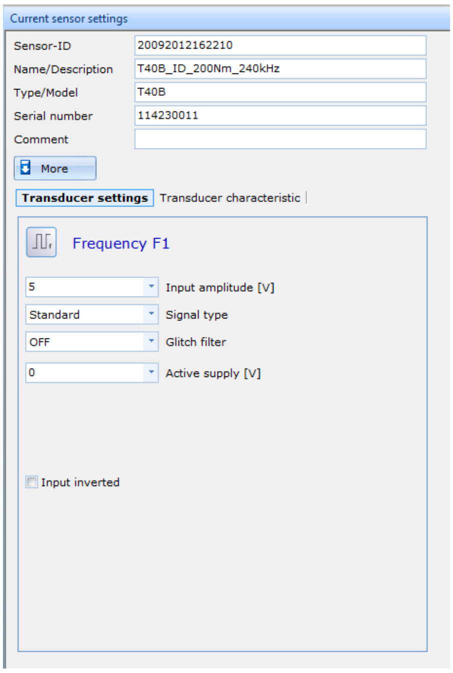
Torque Flange Datasheet:
In case you use a T40 torque flange:
Range: 200 N·m
Electrical range: mid frequency of 240 kHz, sensitivity of 120 kHz

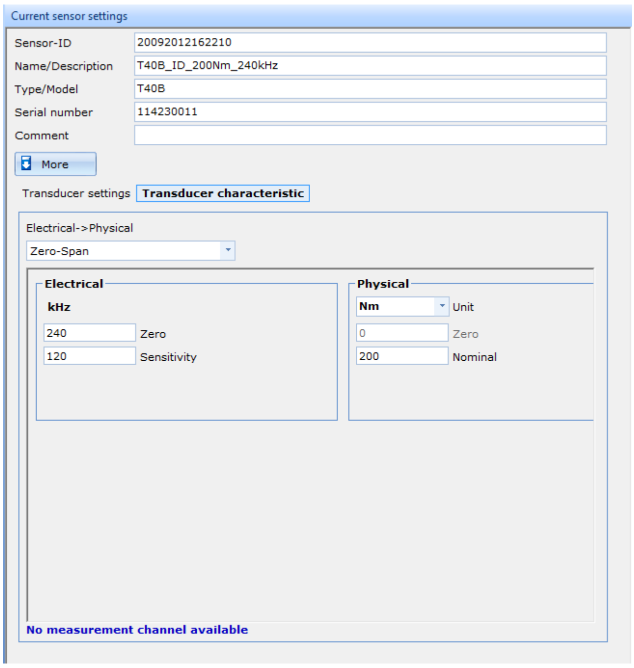
How to add the torque sensor into the Sensor Database:

Engineering units [0 N·m] = electrical signal units [240 kHz]
Sensitivity = 120 kHz
Nominal range between 120 kHz (- 200 N·m) and 360 kHz (200 N·m)

Copy the equivalent sensor from the embedded reference list of sensors to your own user sensor database:

Adapt the sensor datasheet according to your calibration data.





Mechanical Power Calculation

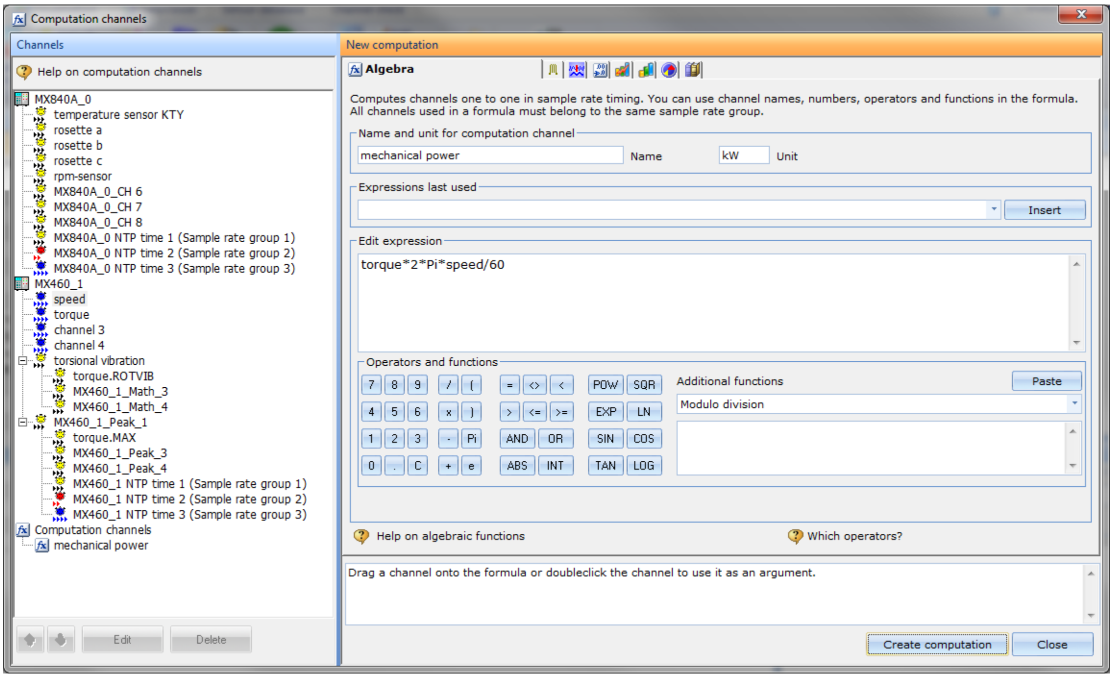
A conversion factor may be necessary when using different units of power, torque or angular speed. For example, if rotational speed (revolutions per time) is used in place of angular speed (radians per time).

$$power = torque * rotational\ speed$$

Dividing on the left by 60 seconds per minute and by 1000 watts per kilowatt gives us the following.

$$power\ (kW) = \frac{torque * 2\pi * rotational\ speed}{60}$$

How to add this formula as computation channel in catmanAP?



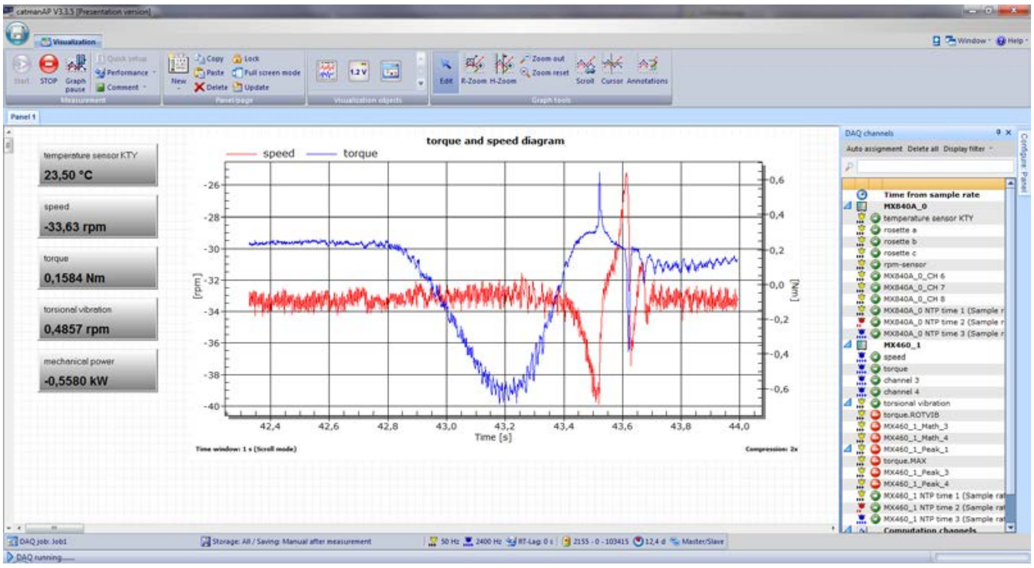
Some American automotive engineers use horsepower, foot-pounds (lbf·ft) for torque and rpm for rotational speed.

This results in the formula changing to:

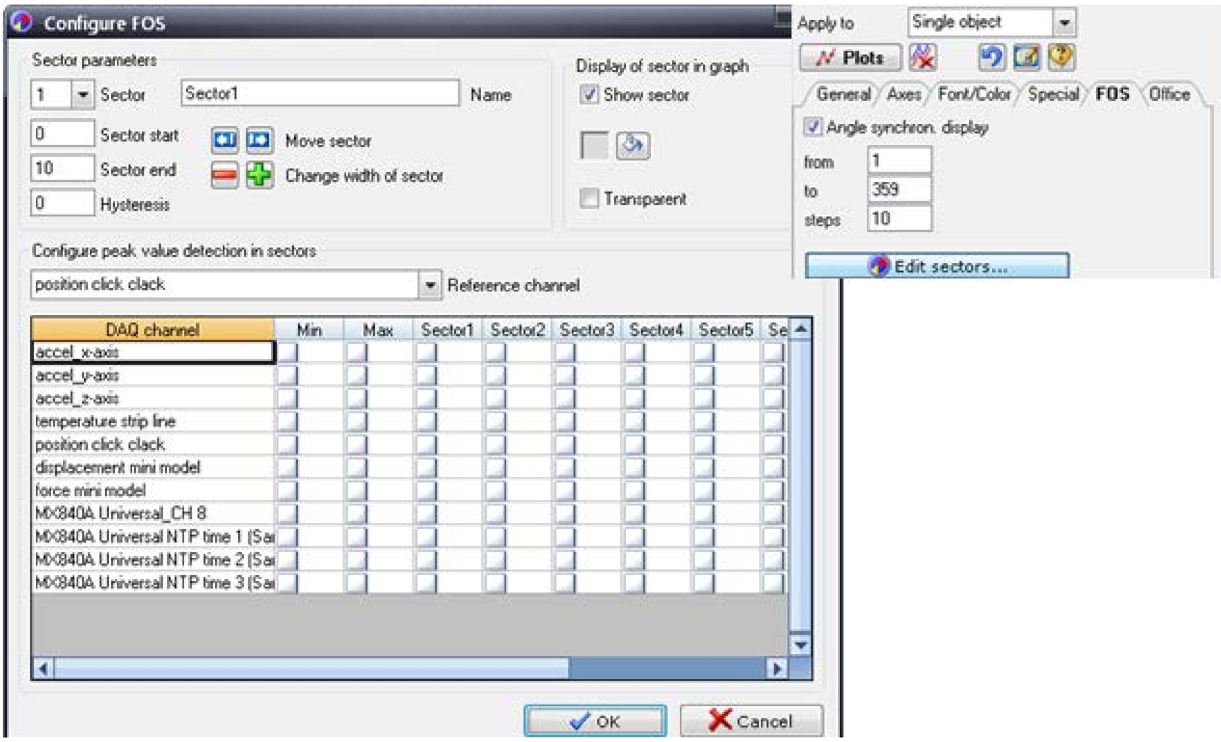
$$power\ (hp) = \frac{torque * 2\pi * rotational\ speed}{33}$$

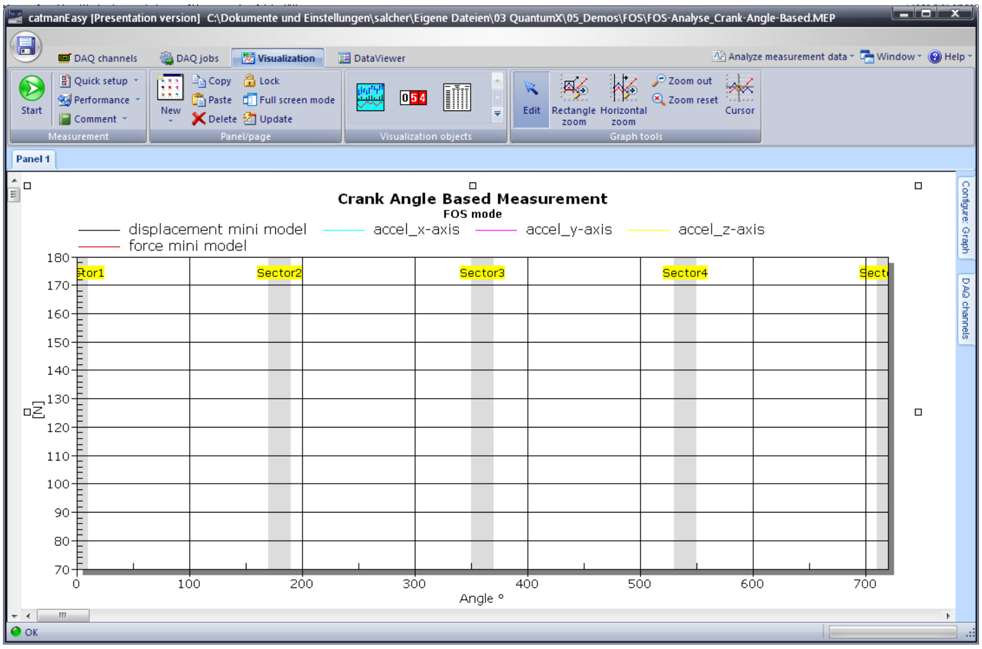
The constant below in ft·lbf/min changes with the definition of the horsepower; for example, using metric horsepower, it becomes ~32.55. Use of other units (e.g. BTU/h for power) would require a different custom conversion factor.

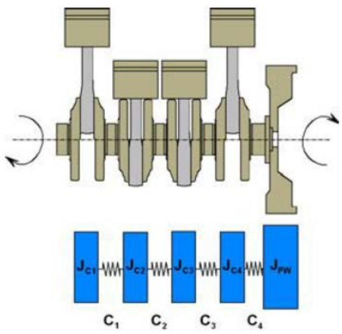
First Measurement Job



catman offers an angular based visualization (FOS mode). Easily you can set certain sectors for monitoring and evaluation purposes, i.e. peak detection or some statistics.







Real-Time Rotational and Torsional Vibration (TVA)

Rotating machines are sources of rotational and torsional vibration. Rotational vibration is a result of the change in shaft speed during one revolution and torsional vibration is due to angular twist in the shaft or drive train which may cause fatigue. Typical quantities in this field are torque, speed, mechanical power, vibration, force, strain, voltage, current, electrical power, efficiency, CAN bus data and rotational and torsional vibration with one data acquisition instrument at the same time.

Typically rotational vibration calculation is needed in combustion engine development or in general automotive powertrain engineering.

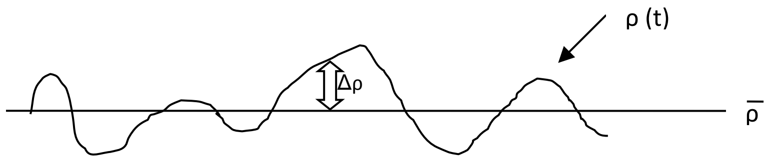
For rotational vibration measurement one rpm sensor is used to determine the rpm deviation and for torsional vibration there is one at each end of the power train. The following picture shows the crank shaft as mass damper system base for torsional vibration analysis. Encoders which can be placed to crankshaft and to camshaft can be used for Torsional Vibration Analysis.

<u>Definition Torsional Vibration Analysis (TVA):</u>

$\Delta\rho = \rho(t) - p0$

$\rho(t)$ = time based angle

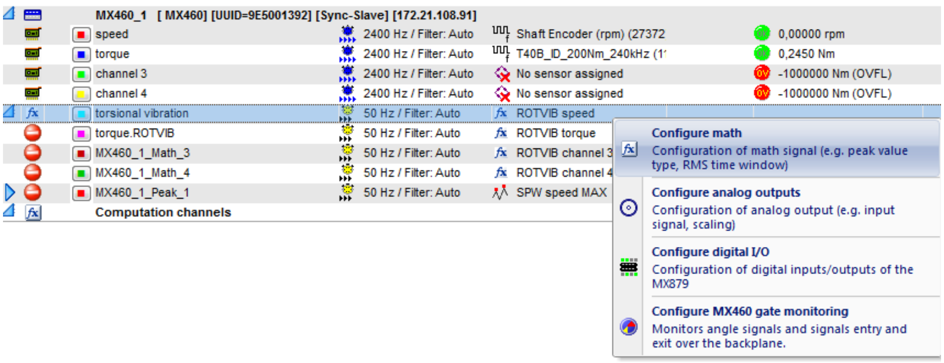
$p0 = p =$ average of angle over time

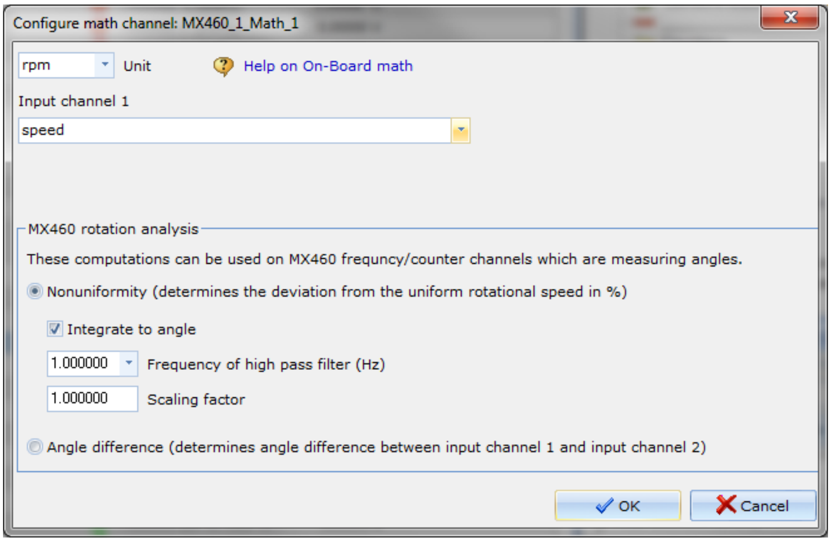


MX460B offers *Rotational Torsional Vibration Analysis* in real-time which can calculate the non-uniformity which determines the deviation from the uniform rotational speed in % of a speed measurement signal. Advantage of real-time calculation is the ability to send the calculated signal to an automation system over EtherCAT (CX27), to CAN bus (MX471) or analog out (MX878 / MX879) for control purposes. QuantumX can also be used for in-vehicle mobile testing.

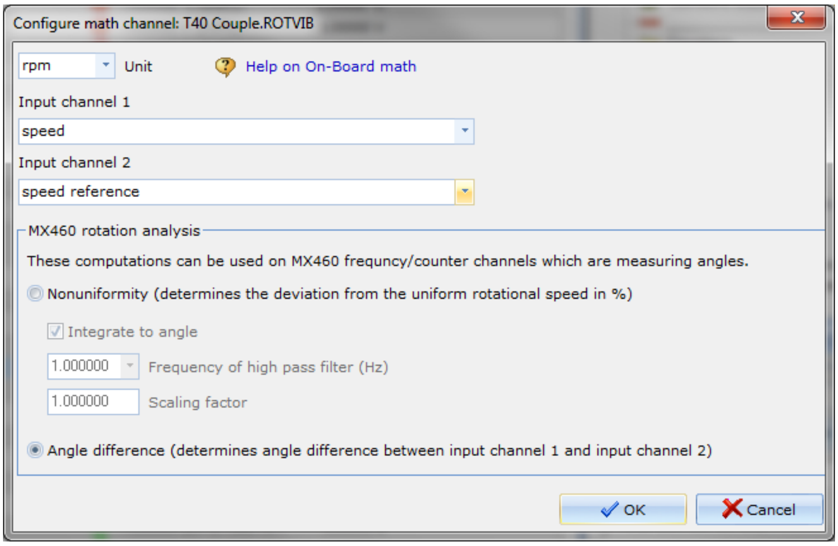
catman can calculate various calculation channels like reference angle [deg], rotational angle [deg], rotational velocity [deg/s], rotational acceleration [w/s], torsional angle [deg], torsional velocity.

Start catman and parameterize the real-time math signals accordingly:





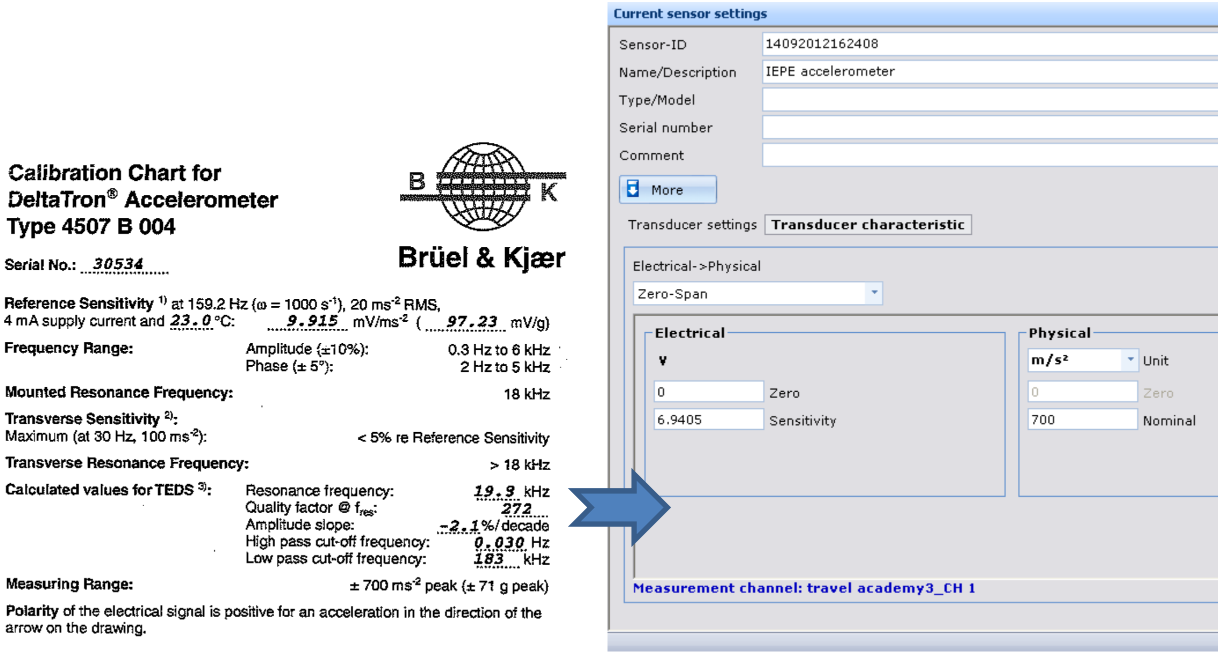
MX460B Rotational Analysis calculating the angle difference of a speed sensor in relation to reference speed:



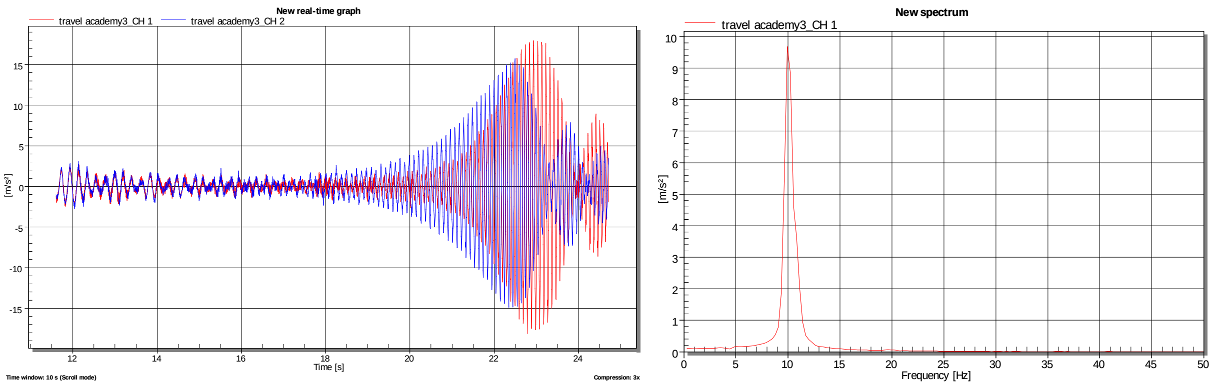
Analysing Noise and Vibration

When it comes to shaft based analysis of rotating parts, noise and vibration of the system under test needs be analysed as well. Using acceleration sensors and microphones is usual for that purpose. For highly dynamic applications integrated electronics piezoelectric sensors (IEPE) are used. The piezo based sensor has got an integrated amplifier which is supplied with a constant current from the DAQ device and delivers a bias voltage signal standing for acceleration. IEPEs can be directly measured with MX840B, MX410B or MX1601B. MX410B offers the highest data rate with 100 kS/sec and the highest bandwidth of 40 kHz. Also other sensor types are in use. IEPE microphones enable sound analysis in dBA or in a frequency spectrum.

Setup and adapt the “digital sensor datasheet” according to your calibration data.



Test runs concerning rotation and frequency analysis based spectrum analysis you can find Eigen frequencies of the system under test.



Software Analysis

Typical Requirements concerning data analysis in software:

Inputs

- Filter set: high pass, band pass
- Support of different crank wheels 60:2, 36:2, 30:3 for combustion engine analysis

Data Analysis / Math

- Graphs displaying data over time, angle and in frequency range
- Shift of angle based analysis to TDC (Top Dead Center)
- Torsional Vibration Analysis (TVA) for online or post-process analysis (same function like MX460)
- Frequency analysis in Campbell diagram showing amplitude, frequency or orders over time / rpm
- dBA weighing filter for noise analysis

Data Storage

- Save FFT data for further analysis in binary or other format (*xls,*.csv)

Conclusion

Measurement and analysis are central tasks in dyno testing or in general lab or bench testing!

QuantumX and catman bring maximum flexibility increasing testing time and depth resulting in higher functional and quality assurance. The major advantage is to gain efficiency in replacing existing DAQ by the modern QuantumX and you get:

- Universal inputs for daily changes of different sensor types
- Modular, fully scalable and easy extendible solution
  (no service or system integrator needed, no central head unit)
- Dramatic reduction of setup time (distributable, automatic channel setup using TEDS in sensor or plug)
- Powerful software package: catman, integration into CANape, LabVIEW or Visual Studio .NET

QuantumX brings best of class measurement - results you can rely on. All analog input channels with 24 bit, maximum noise suppression and galvanic isolation.

QuantumX reduces “total cost of ownership”:

- Reduced service tasks
- Reduced maintenance over years
- Extended testing time
- Higher flexibility and future proof concept

--end