TECH NOTE :: QuantumX and catman®AP for electrical power analysis

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Author: Christof Salcher, Product Manager Test & Measurement, HBM Germany
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Abstract

This TECH NOTE deals with data acquisition in mainly the electrical world with constant or alternating voltage and current and its calculation to electrical power. Also temperature on high electrical potential is a sub topic. When it comes to electric drives also measurement of torque and speed and its calculation to mechanical power is shown at the very end. Measurement is done by HBM's QuantumX. Power calculation and signal analysis in the time domain and frequency range is done with HBM's test & measurement software catmanAP.

Introduction

HBM is traditionally strong in the acquisition, visualization, storage and analysis of mechanical quantities in the time domain. For these purposes HBM offers first and foremost sensors for torque and rotational speed, force, pressure, displacement and strain. HBM also offers electronic measurement technology and software for data acquisition and evaluation in the area of analysis and testing for the development of components, systems and complete products with high standards of quality.

We can see the world around us becoming increasingly electrified. This is clearly evident in consumer goods, but also in public spaces, for example public transport in elevators, escalators and vehicles. Electrical actuators are rapidly replacing hydraulics, as seen in drives and valves. Physical processes of complex machines are turned on their head by electrification. It follows that the acquisition of "electrical quantities" such as voltage and current is also becoming increasingly more significant. QuantumX allows for acquisition of electrical quantities such as voltage and current as well as all other typical physical measurands in electrical, mechanical or mechatronic systems. Purely electrical quantities can be measured on electrical actuators, in energy storage devices such as batteries or in infrastructure.

The **QuantumX data acquisition series** now offers two devices covering the increasing demand to also measure and analyze the electrical world.

The **MX403B** is a 4-channel measurement module, developed especially for precise acquisition of electric voltages in the range of 10, 100 and up to 1000 V covering the highest safety standards. Also the small differential voltages of 10 V can measure at a high electrical potential. The high safety level of the MX403B is ensured by consistent development based on the latest requirements of measuring device standards IEC 61010-1:2010 + corr. 2011 and for instruments from IEC 61010-2-030:2010 + corr. 2011 and by certification and production monitoring by the VDE (German Electro technology Association).

The **MX809B** is an 8-channel measurement module, developed especially for precise acquisition of temperatures by many types of thermocouples and voltages up to 5 V at high electrical potential. The high safety level of the MX809B is ensured by the same consistent development based on the latest requirements of measuring device standards and also certified by the VDE (German Electro technology Association). Double shielded wires and a new innovative plugging ensure that no direct contact to dangerous voltages is possible.

Target Applications

The modules are suitable for applications in labs, on test benches, as a portable data acquisition system or for mobile field applications.

Typical applications can be found in the following areas:

- Testing mechatronic components with electrically powered actuators
  - Function, performance, stress and durability

  - Measuring DC voltage, 1-phase alternating voltage up to 1000 V CAT II or 600 V CAT III, measuring current via burden resistor or current probe
- Testing of energy storage devices (battery packs up to 1000 V)
  - Long-term testing / service life (charge/discharge cycles, self-discharge, fast charging, short circuit)
  - Loading / effects (temperatures, feedback, overload, short circuit, fault, overheating, application of force)
  - Single cell tests with high common-mode rejection
  - Battery management tests (overloading protection)
- Measurements in networks with transients
  - Low-voltage signals with aperiodic high peak voltages
  - Networks with induced voltage peaks (solenoid valves, relays, etc.)
- Validation of inverters / converters

In general both isolated modules MX403B and MX809B are designed for applications within measurement categories CAT II (from the socket) and CAT III (building distribution) next to non-CAT related applications like battery pack or energy storage systems.

Seamless integration into the established QuantumX series enables synchronous data acquisition of mechanical, electrical and thermal measurands and CAN bus signals. QuantumX modules can be physically distributed and set up close to the measuring point. They can also be easily integrated in any PC software and in addition to that in real time via outputs such as standardized voltage, EtherCAT or CAN.

Safety First

Measurements of hazardous voltage (AC rms > 33 V, DC > 70 V) must only be performed by persons trained to do so. The measurement categories of IEC 61010 play an important role in selecting the measuring instruments – see also the section about safety at the end of this TECH NOTE.

Voltage Measurement

The MX403B can be used in the following areas:

- 1000 V CAT II
- 600 V CAT III
- The module can also be used outside of the measurement categories (for example **Energy Storage Testing**). A precise analysis of the operating voltage, peak voltage, loop impedance, occasional overvoltage and transient overvoltage of the circuits must be determined in advance through precise analysis. Note the following characteristics in this regard:
  - Peak voltage: maximum 1250 V
  - Loop impedance: at least 100 mV
  - Occasional overvoltage: none
  - Transient overvoltage: 3000 V

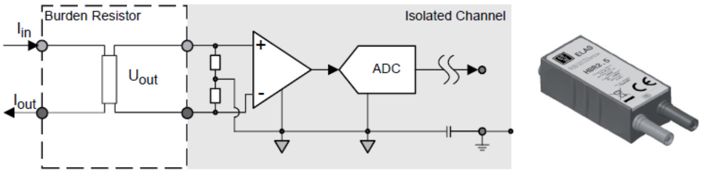
The MX403B has four isolated differential measurement channels for direct measurements of voltages up to DC 1000 V or AC 1000 V (rms). All inputs can be freely parameterized to work in the ranges of 10, 100 or 1000 V allowing data measurement and data acquisition of high voltages against reference ground as well as measurements of small differential voltages at a high potential against reference ground. Each channel is equipped with analog anti-aliasing filters, 24-bit AD converters and digital filters, and can be individually parameterized.

The module permits measuring rates up to 100 kHz per channel and bandwidths up to 40 kHz. It can be incorporated seamlessly into the established QuantumX data acquisition system, thereby making available the advantages of that successful solution. QuantumX thus allows acquisition of all physical measurands from the mechanical, electrical and thermal worlds completely synchronously and calculates the signals, thereby establishing itself as a comprehensive complete solution and a valuable tool in research and development. QuantumX modules can be physically distributed and connected within close optical range of the measuring point (optical Ethernet or optical FireWire) to ensure maximum reliability between the measuring point and the PC or the Data Recorder CX22B-W.

Current Measurement

The traditional method measuring current is based on the principles of the ohmic resistance by adding a so called **shunt resistance** into the circuit and measure the voltage drop across it. One particular difficulty that results from this technique is the large power dissipation in the shunt. Also the active mechanical integration itself is sometimes not easy.

Current transformers provide an alternative method of measuring DC and AC currents. The low output current can be measured by a burden resistor. HBM offers them in 3 different versions: 1 or 2.5 or 10 Ω. Accuracy goes down to 0.02% with a minimal temperature drift. Connection to MX403B input is the standardized laboratory pins.



Picture: precision burden resistor from HBM

While the burden resistor allows for a precise, phase-synchronous measurement of small currents, **current probes** are especially suitable for quick current measurements without disconnecting the line. Different designs of current probes are available for different application purposes. The inductive measurement principle results in a phase shift between the current and the measured electrical signal voltage from the current probe. This phase shift must be compensated for to determine power. The easiest way to do this is to delay the measured electric voltage correspondingly. This process is described below. HBM offers also **current clamps:**

	Order no: **1-G914-2** Manufacturer: AYA M1V20 Measurement range: 20 A, 20 - 5000 Hz Connector: BNC
	Order no: **1-G913-2** Manufacturer: AEMC SR661 Measurement range: 1200 A, 10 Hz - 100 kHz Connector: BNC
	Order no: **1-G912-2** Manufacturer: Fluke i30s Measurement range: 30 A, 0 (DC) - 100 kHz Connector: BNC

Now where the most important electrical measurands have been discussed, we turn to the software.

catman®AP Data Acquisition and Analysis Software

HBM's catmanAP software is ideally suited for the following steps:

- Parameterization of channels (storage of channel settings or current probes in the sensor database)
- Optional phase compensation when using current probes
- Calculation of signals for the effective, apparent and reactive power as well as other factors
- Visualization of raw values and calculated values in individual displays
- Data storage in the desired data format
- Analyses during ongoing measurement
- Post-process analysis and creating a report

In addition to measurement acquisition, the catmanAP software also offers an integrated mathematics library. The mathematical functions extend from simple algebraic calculations to statistical and spectral analyses and also include calculation of electrical power and efficiency with simple parameterization.
The RMS value of input quantities can also be calculated in the software.

Step-by step measurement, online calculation and analysis with catmanAP

You can use the sensor database which helps you parameterizing the input channels. If the correct signal description cannot be found in the sensor database, you can create the relevant sensor or signal data sheet. Using the sensor data base makes it easier in setting up channel parameters as this process is reproducible at any time and can be copied to any other channel in a quick and easy way. Then drag and drop it to the relevant input channel.

Phase-synchronous measurement

Acquisition is synchronous for all channels of a QuantumX system. Many different sensors can be connected to QuantumX converting physical quantities such as voltage, current, temperature, torque, rotational speed, acceleration, vibration and noise into digital signals. In addition digital bus signals coming from CAN bus can be acquired as well.

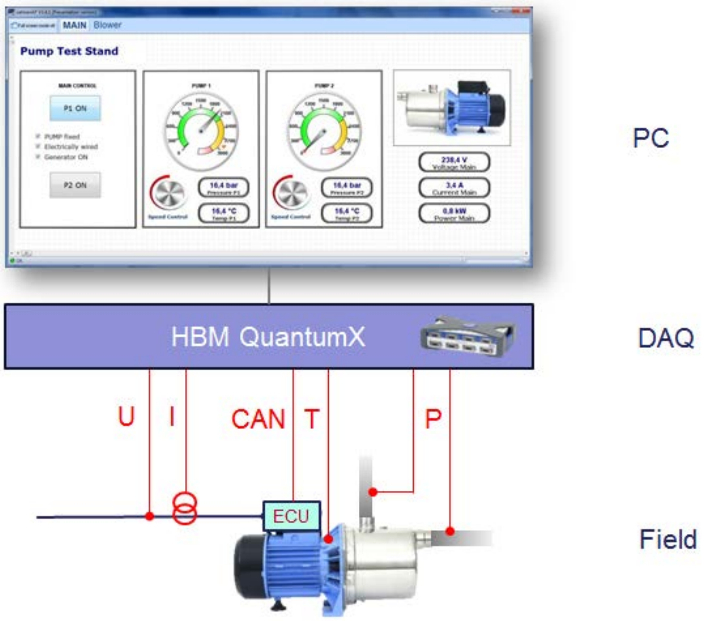
When working with alternating voltage sources we need to understand the principles of current measurement and if there is a phase delay between current and voltage. Burden resistors are often used to measure alternating and direct currents. The structure of burden resistors is purely resistive and they are therefore phase-exact or in phase with voltage. Current probes instead come with a phase delay. This means the phase of the converter's output signal is delayed relatively to the current phase.

If the phase delay of the converter is not known or need to be verified, it can be easily gauged by measuring the current and voltage on a resistive consumer, for example a filament bulb. The measured voltage can be delayed or corrected correspondingly within the catman software.

Current probes often come with a single cable with BNC connector. By adding an adapter the current probe can be connected directly to the MX403B.

Picture: adapter BNC to safety banana connector (HBM article number: 1-G067-2)

1-phase Electrical Power Calculation



Picture: QuantumX Data Acquisition System in analyzing and testing a pump.

The online power calculation in catman only considers DC or harmonic signals with max 100 Hz. The process does not involve any complex integration algorithms. Only common and public formulas are used.

The power calculation in catmanAP incorporates a window-based and not a true RMS based calculation. The accuracy of the power calculation thus depends on the fundamental frequency of the signal and the width of the selected window.

Example: 1-phase AC supply, 50 Hz fundamental oscillation
-> 20 ms per period -> selected 5 times larger window with 100 ms.

The calculated power will exhibit a slight residual ripple, even in a static system.

A complete calculation of all quantities in catmanAP includes the root mean square value (RMS) and also the mean value (MEAN) over a time window. Neither one is formed in a straight forward averaging process with n values, as in the MX403B, for example. The process is a one-step Iteration.

The formulas are as follows:

RMS (n) = $\sqrt{((1-a) * measured\ value(n)^2 + a * RMS(n-1))}$

here **a =** $e^{\frac{-1}{data\ rate * time\ window}}$

The MEAN value is formed in a similar manner:

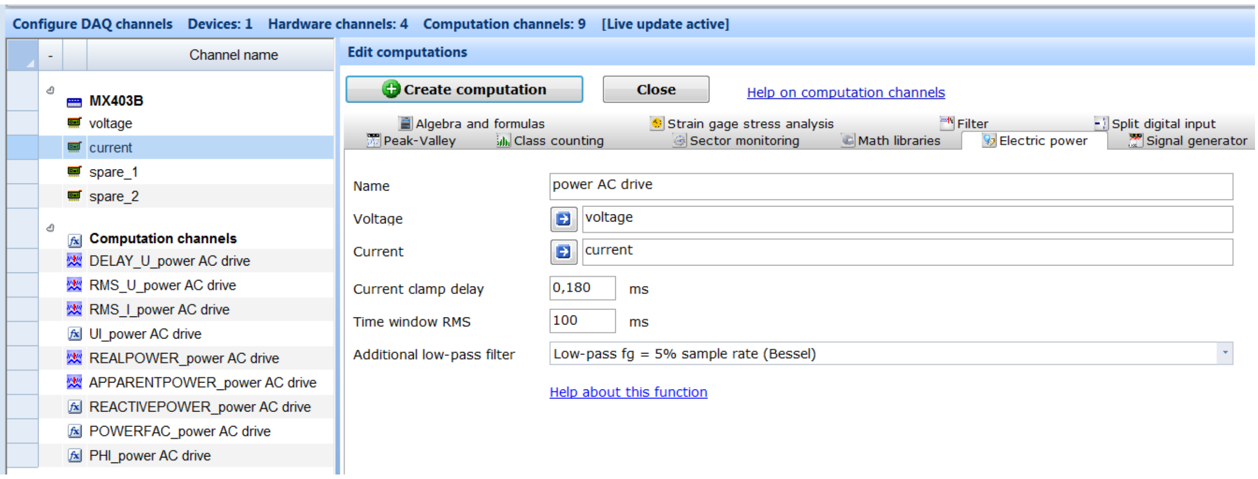
MEAN (n) = $(1-a) * \mathbf{measured\ value(n)} + a * \mathbf{MEAN(n-1)}$

The process is faster, requires practically no buffer, and can therefore implement time windows of any size. The result agrees closely with the on board calculated values of MX403B. RMS and MEAN can also be filtered for smoothing.

The other computing channels are calculated as follows:

REALPOWER = MEAN(U * I)
APPARENTPOWER = RMS(U) * RMS(I)
REACTIVEPOWER = sqrt(APPARENTPOWER*APPARENTPOWER – REALPOWER*REALPOWER)
POWERFACTOR = REALPOWER/APPARENTPOWER
PHI = acos(POWERFACTOR) * 57.29 to go from rad to °

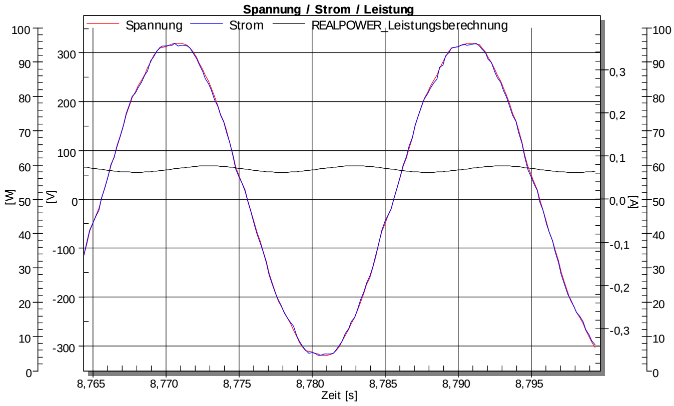
The process of parameterizing the power calculation is as follows:



Also in this dialogue you can enter the current clamp phase delay time. Here 180 µs.

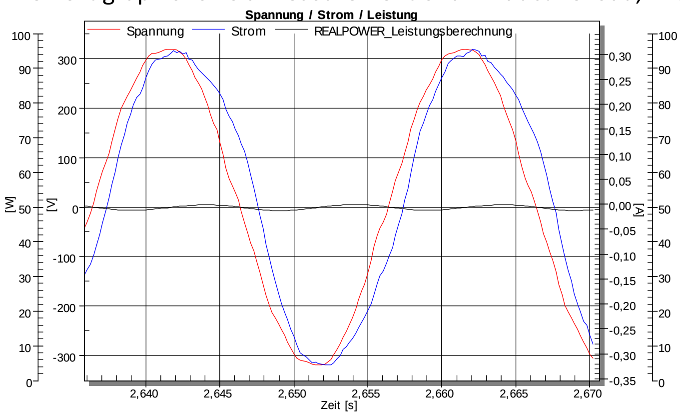
Now acquire data according to your parameterization. Here a 60-watt filament bulb is used.

The graph can exported to a measuring report in Microsoft Word with text markers (Office tab).



Frequency can be analyzed and performed in a standard 2-D FFT diagram or a 2-D colour spectrum.

The next graph shows a measurement of an inductive load, in this case a 50-watt soldering iron:



Perform a signal analysis in the frequency range. A signal analysis of this type is based on the Fast Fourier Transform (FFT). It facilitates the transition from time signals to the frequency range. catmanAP can display and also analyze the frequency distribution of one or more signals. The required parameters are the number of measurands over which the amplitude spectrum will be calculated. As a general rule is this, the more samples you use for the FFT, the higher the resolution but the more time is needed to calculate. The window function is another parameter. It determines the weighting to be applied for sampling values derived from sampling a signal within a segment (window) when they are used in the calculation. If multiple channels are assigned to the graph, the spectra of the channels can also be displayed as the vector sum.

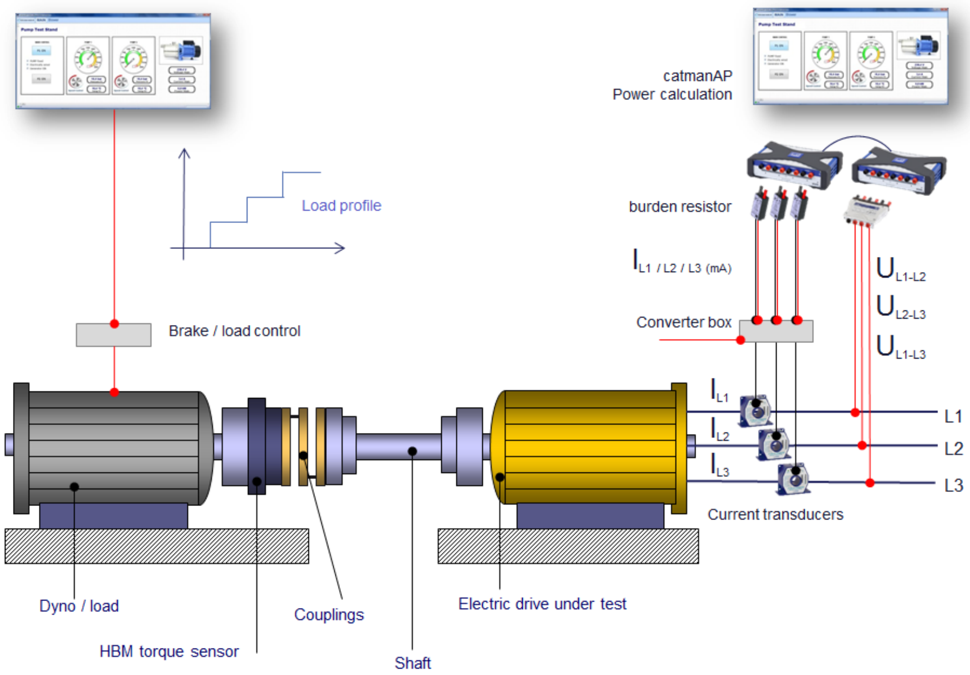
Displaying multiple spectra over time is especially important in dynamic operation. A "waterfall diagram" can be used for this purpose by successively displaying amplitude spectra tiered in three dimensions. The view can be freely rotated in all directions.

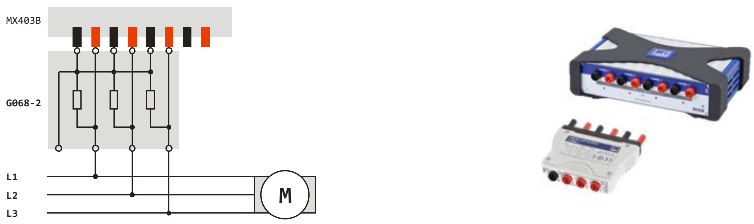
3-phase Electrical Power Calculation

The main difference between a three phase system and a single phase system is voltage level and phases of the voltages to each other. Generation of three phase power is more economical than generation of single phase power. In three phase electric power system, the three voltages and current waveforms are 120° offset in time in each cycle of power. Three phase power definition states that in an electrical system, three individual single phase powers are carried out by three separate power circuits. The voltages of these three powers are ideally 120° apart from each other in time-phase. Similarly, the currents of these three powers are also ideally 120° apart from each other. Ideal three phase power system implies balanced system. A three phase system is said to be unbalanced when either at least one of the three phase voltages is not equal to other or the phase angle between these phases is not exactly equal to 120°.

When measuring voltages we need to know to what potential we measure. In principle we differentiate between **3 and 4-wire systems**. According to this we calculate power.

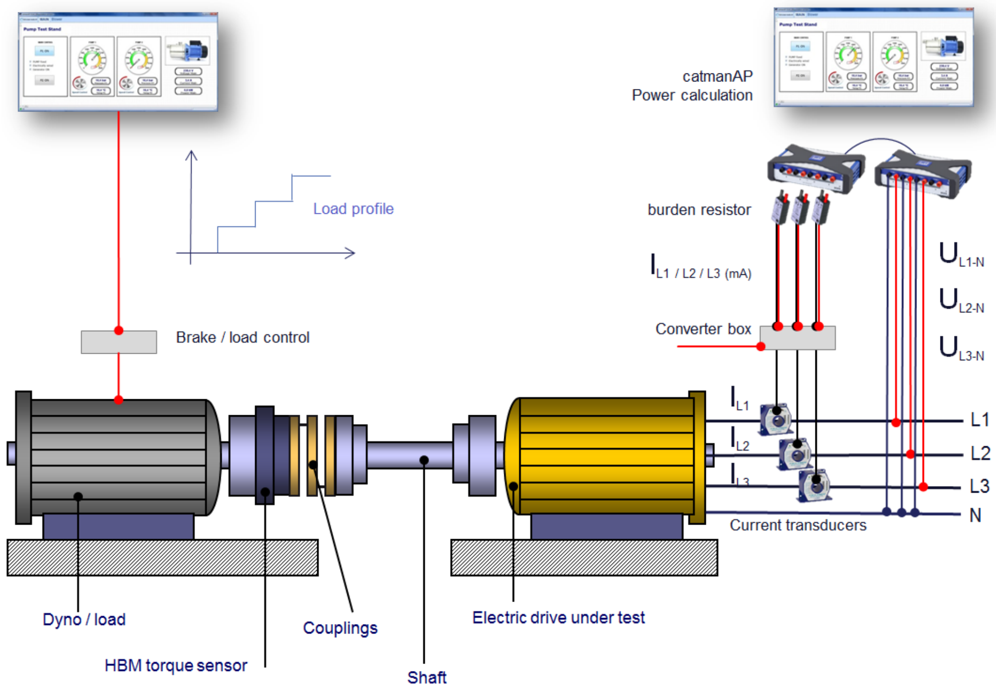
The next picture shows a classical 3-wire system of an AC drive without the possibility to access the star point. So we use the *virtual star adapter* from HBM.





picture: virtual star adapter G068-2 from HBM

The next picture shows voltage and current measurement in a 4-wire system (star with neutral wire).



Electrical power is calculated based on the 3 single power lines in a geometric way.

REAL POWER P_1 = MEAN(U_1 * I_1)

REAL POWER $P_\Sigma = P_1 + P_2 + P_3$

Calculating Apparent Power is calculated by the RMS of voltage and current.

APPARENT POWER = S_1 = RMS(U_1) * RMS(I_1)

$S_\Sigma = U_\Sigma \cdot I_\Sigma \geq |P\Sigma|$.

REACTIVE POWER = Q = $\sqrt{S^2 - P^2}$

The ratio between REAL POWER and APPARENT POWER results in the **Power Factor** which is max. 1. This number is a factor for quality of energy transmission.

All the formula above deals with balanced three phase systems. Current in each phase is the same and each phase delivers or consumes the same amount of power. This is typical of power transmission systems, electrical motors and similar types of equipment.

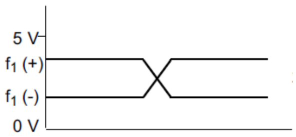
Torque and Speed Measurement

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 functionality, power efficiency, durability, noise and vibration.

There are many different types of dynos in use but in general we can say it is a dynamic load or break.

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:



There are several sensors on the market for rotational speed 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.

When using speed sensors, such as shaft encoders the easiest way to determine RPM is to monitor the pulse frequency from the sensor using a digital input and the frequency based parameterization.

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

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:

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

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.
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 20 kHz. 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.

Example: Let's say your drive goes up to 15,000 RPM and your digital encoder reads 1024 PPR.
You use T40B torque flange with 200 N·m measuring range.

<u>Speed Sensor Datasheet</u>
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]

Let's say we use a T40 for torque measurement.

<u>Torque Flange Datasheet:</u>
Range: 200 N·m
Electrical range: mid frequency of 240 kHz, sensitivity of 120 kHz
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)

After parameterizing all relevant inputs you can setup the mechanical power calculation.

Mechanical Power Calculation

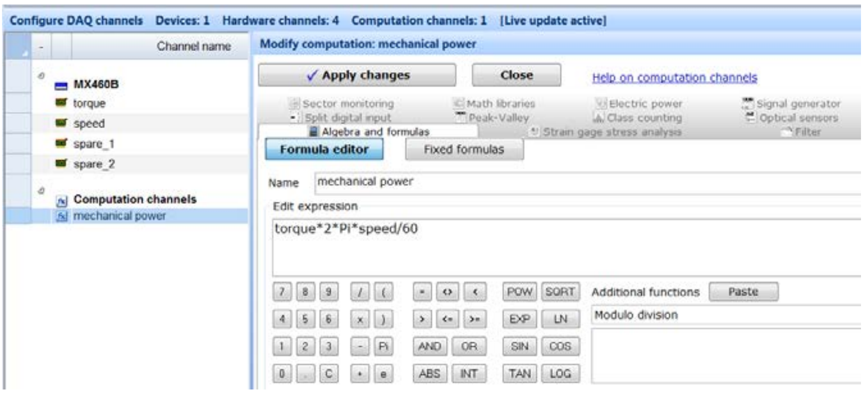
A conversion factor may be necessary when using different units of power, torque or angular speed. For example, if rotational speed (revolutions per time) is used in place of angular speed (radians per time).

$$power = torque * rotational\ speed$$

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

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

Add this formula as computation channel in catmanAP:



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

This results in the formula changing to:

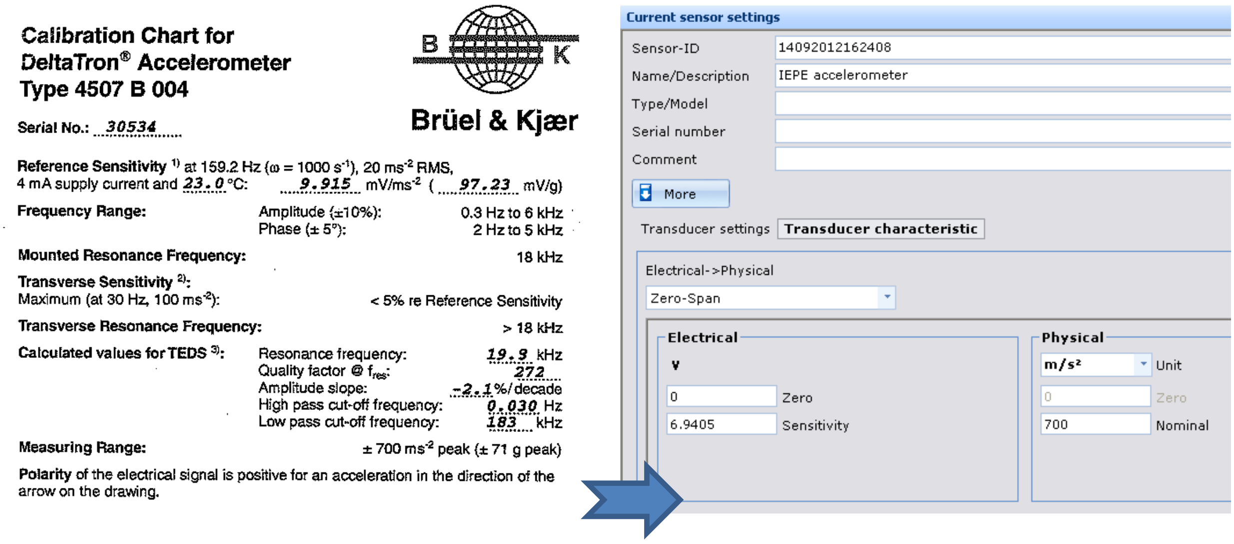
$$power\ (hp) = \frac{torque * 2\pi * rotational\ speed}{33}$$

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.

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.

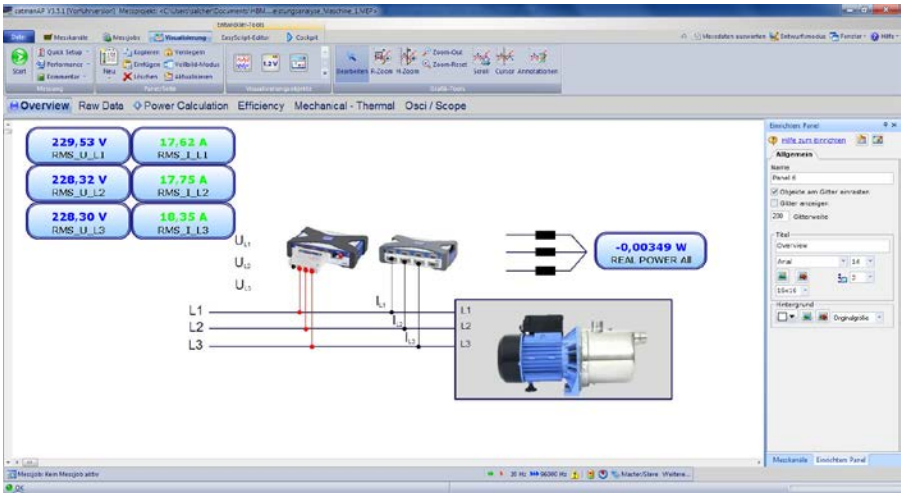
Setup and adapt the “digital sensor datasheet” according to your calibration data.

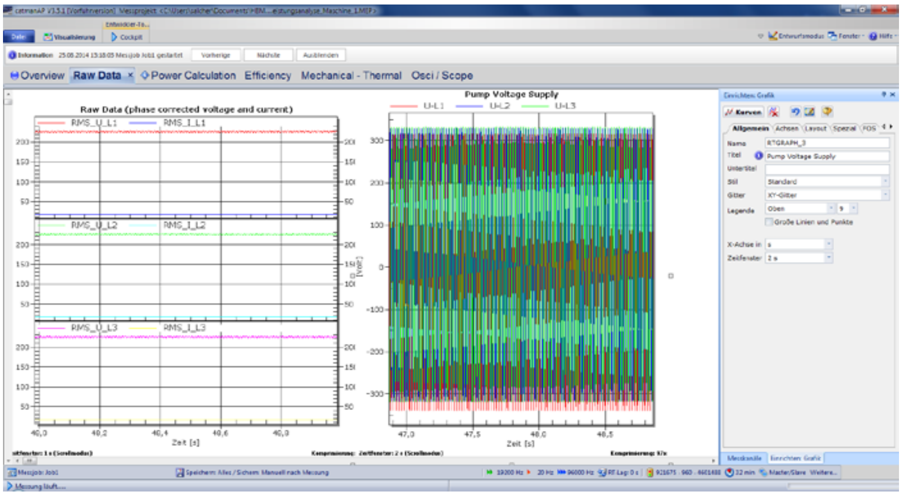


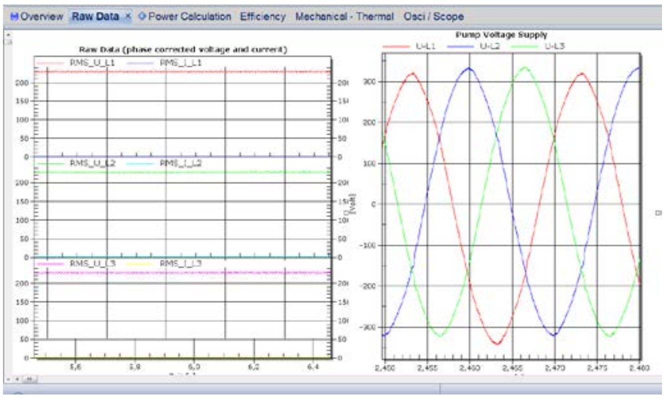
Test runs concerning rotation and frequency analysis based spectrum analysis you can find Eigen frequencies of the system under test.

Visualization

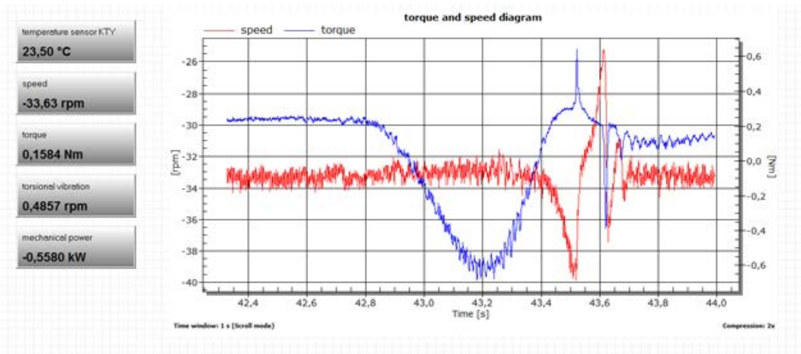
Visualization and operation in catman can be handled in a flexible way with different y-t, y-x, y-f strip charts.

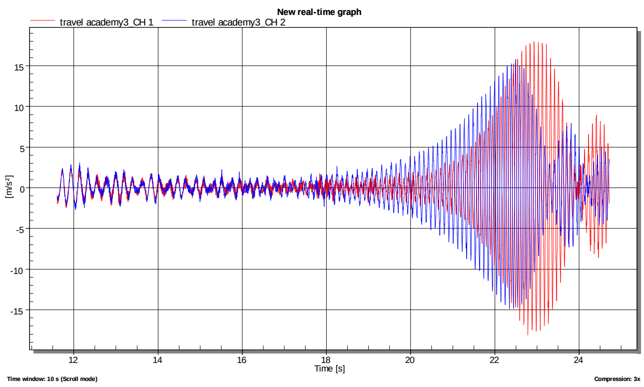


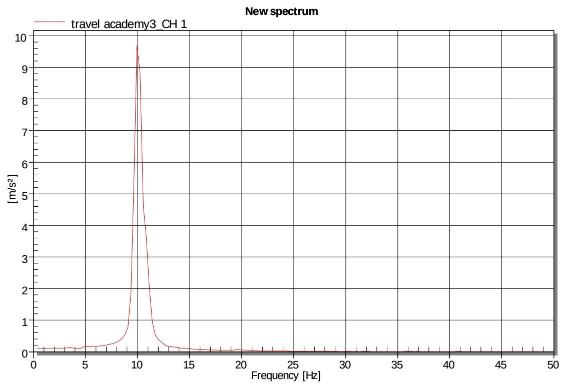




Of course also temperatures can be measured and added in this way. MX809B offers 8 channels fully isolated for temperature measurement with thermocouples.







Analysis of recorded measurement data

Switch to data analysis mode (post-process). Frequency analysis in the post-process mode uses the FFT to calculate a spectrum (an amplitude, phase or power spectrum). The calculation may be performed multiple times over a part of the measurands in some circumstances depending on the frequency resolution. The advantage of this method is that the available measurands can be analyzed best if there is not a 2n number of measurands present. For frequency resolution select the number of points from FFT and enter the number of values (points) under FFT or define the frequency resolution you want.

If you specify a frequency resolution, depending on the number of available measurands and the data rate you are using, either all measurands will be used for a calculation or several spectra may be calculated, each over part of the measurands. In this case the mean value will then be formed from all calculated spectra unless you activate the Joint Time Frequency Spectrum option.

You can activate Generate Frequency Data Set to have the frequency channel available for export as well. The channel is not needed for the display in an overview graphic.

Working on Electrical Components – Safety first !!!

Speaking generally, voltage cannot be perceived by the senses. Human beings have no way of sensing electrical current - only its effects are perceived. A flow of current requires voltage as its cause. A high voltage can quickly bridge and flow through conductive parts. Electrical current is lethal. The let-go threshold is 10 mA, while respiratory arrest can occur at 30 mA. Everything depends on the nature of the current, the duration of its effect, the frequency and perfusion.

What categories of voltage are there?

Low voltage	**≤ 1000 VAC / ≤ 1500 VDC**
Separated extra-low voltage (SELV)	≤ 25 VAC / ≤ 60 VDC
Extra-low voltage (ELV)	≤ 50 VAC / ≤ 120 VDC
Mains voltage	230 VAC, 400 VAC

The MX403B covers a range up to either 1000 V AC CAT II or 1250 V DC non CAT.

High voltage	**> 1000 VAC / > 1500 VDC**
Medium voltage	≤ 52 kV
High voltage	60 kV, 110 kV
Extra high voltage	220 kV, 380 kV, …1150 kV

The MX403B is therefore not an instrument for measuring high voltage!
Safety is a topic that encompasses many different areas in measurement and testing.

Test laboratories such as the **VDE** can certify a product and its manufacturing process. The products QuantumX MX403B and MX809B are certified by the VDE. In addition to the module design, naming conventions and instructions in the documentation, the production location and personnel were all subjected to a comprehensive audit.

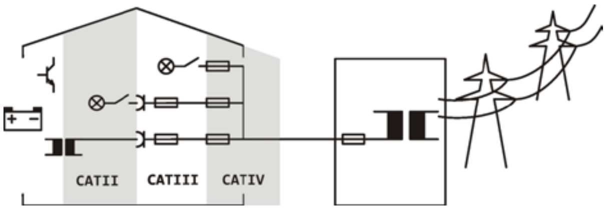
International standards such as **EN61010** play an important role in this. A standard describes the current state of the art, in other words what can reasonably be implemented in terms of design. EN61010 deals with safety requirements for electrical measurement, control, regulatory and laboratory equipment
Part 1: General requirements
Part 2: Special provisions for test and measuring circuits

The **EN61010** standard defines measures for minimizing hazards that can occur while measuring electrical quantities.

Hazards and structural countermeasures for:

- Electrical shock
  - Double insulation for conductive parts that can be touched
  - Reinforced insulation separates hazardous active circuits
  - Insulation from air and creepage distances or fixed
  - Energy and signals are transferred via certified converters
  - High-voltage quantities are energy-limited by protective impedances
- Mechanical hazards (housing)
  - No injuries
  - Stable and secure under loading
- Spreading of fire
  - A fire originating in the device must not be allowed to spread
  - No ventilation slots
  - All plastics, non-flammable

Measurement categories



Version 3 of EN 61010 has been in effect since October 2013. According to this standard measurement category I doesn't exist anymore. MX403B and MX809B have been developed in compliance with version 3.

Measurement categories describe the **energy capacity** of a measuring place. Thus the **source impedances** and the **number of safety devices** differ from one category to another. In addition, the magnitude of transients that are expected increases with higher categories.

The voltage specified in connection with the CAT figure is referred to as the **operating voltage**. It applies **against reference ground** (L-N). The following supply network applies to phase-to-phase (Lm-Ln):
300V (L-N) ⇨ 400V (Ln-Lm).

CAT I implied that CAT II was a safe measuring place. The fallacy of this has become evident, however, at least now that high battery voltages can occur in electric vehicles. **Outside of the measurement categories**, the suitability of the measuring device for peak voltages and over voltages that will occur, the loop impedance and expected transients must therefore be tested in addition to the electrical strength of the measuring device.

Operating voltage	**CAT II**	**CAT III**
300V DC / VAC	U_{TR} 2 500V, R_{LOOP} 100mΩ	U_{TR} 4 000V, R_{LOOP} 20mΩ
600V DC / VAC	U_{TR} 4 000V, R_{LOOP} 100mΩ	U_{TR} 6 000V, R_{LOOP} 20mΩ
1000V / VAC	U_{TR} 6 000V, R_{LOOP} 100mΩ	U_{TR} 8 000V, R_{LOOP} 20mΩ

Who is permitted to perform live working?

Live working refers to work carried out on energized electrical equipment with operating voltages above 50 V AC or 120 V DC. Live working requires specially trained employees (qualified electricians trained for live working) and special work equipment.
Only a qualified electrician is permitted to determine zero voltage in low voltage networks.
In Germany the term "qualified electrician" (German: Elektrofachkraft) is used to describe a person who is permitted to perform and monitor electrical engineering tasks.
EU law defines the matter in this manner: "A qualified electrician is someone whose technical training, know-how and experience, as well as knowledge of the relevant requirements, allows him/her to assess the work assigned to him/her and recognize potential risks." (Employers' Liability Insurance Regulations A 3 ; 2 Definitions of Terms No. 6)

HBM regularly qualifies selected personnel as part of training to become a qualified electrician.

To exclude the possibility of working on live parts, the following safety rules must be followed:
1. Isolate
2. Protect against being turned on again
3. Determine zero voltage on all poles
4. Ground and short-circuit
5. Cover or block off adjacent live parts

Only a qualified electrician is permitted to determine zero voltage in low voltage networks.

What else requires attention?

"Live working" presupposes "live parts that can be touched." The **correct** accessories must therefore be used. Regarding accessories pay close attention to the measurement category and the specified voltage. Incorrect accessories nullify the structural safety of measuring devices!



What's important from data sheets?

Measuring range: Important in terms of figures related to the full scale value (accuracy class, linearity deviation and drift). The measuring range is also reused in the catmanAP software, since a conventional designation (such as 1200 V) could result in prompting hazardous actions.

Measurement category (CAT): A certain maximum voltage is permitted within the specified category according to the standard. As non-sinusoidal voltages also occur with AC outside of the supply network, pay close attention to the maximum peak voltage here as well.

Transients: brief voltage peaks that occur rarely. Insulation is designed according to the various categories of transients that are expected.

Coverage: the maximum range for which acquisition is still possible. If we enter 2000 V here, for example, the measuring amplifier will return OVERFLOW at 2001 V.

No distinction is made for insulation between AC and DC. 1000 V CATII simply means that you are only permitted to apply 1000 V AC or 1000 V DC (transients up to 3000 V can occur and will be recorded up to 1200 V).

Yes, but then how high can the measurement signals be on the MX403B?
Answer: Downstream from a mains plug and therefore in the CATII area, maximum 1000 V DC or AC rms against ground potential and 1000 V AC RMS against other channels (phase-against-phase).
Upstream from a mains plug and therefore in the CATIII area, maximum 600 V DC or AC rms against ground potential and 600 V AC RMS against other channels (phase-against-phase).
Outside of the network or measurement category maximum 1250 V DC or AC RMS are OK.
Maximum additional transient overvoltages are protected up to ± 3000 V.

-- end

Literature:

- Measurement and Instrumentation principles, by Alan S. Morris