TECH NOTE #013:: QuantumX / SomatXR in Crash Testing

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Abstract

This Tech Note describes how to use HBMs QuantumX or ruggedized SomatXR and software catmanAP in crash testing.

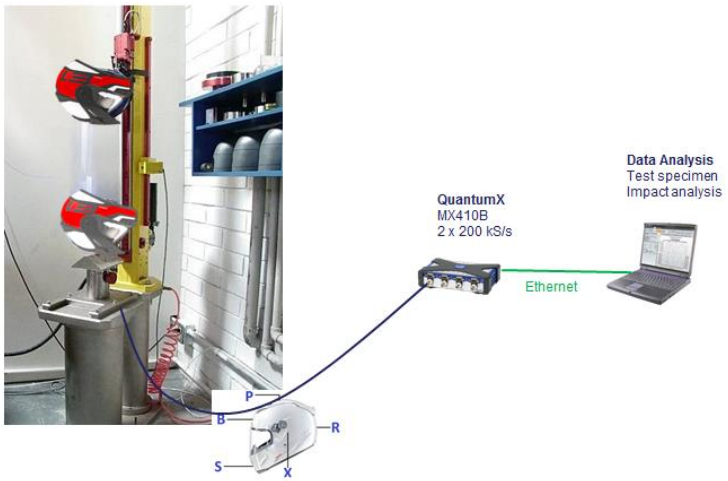


Fig. 1: helmet impact test

Intro

HBM enjoys a global reputation for state-of-the-art test & measurement solutions providing a "seamless measurement chain" – from transducers for torque, rotational speed, force, pressure, strain and displacement, to data acquisition systems and powerful software packages.

QuantumX is a modular distributable data acquisition solution from HBM for measurement and testing, solving demanding engineering tasks for quicker innovation or high quality service. The data acquisition modules offer highly accurate inputs acquiring physical quantities in the wide field of **mechanical, hydraulics, thermal, electrical, noise or mixed systems** with data rates from 0.1 to 100 kS/sec per channel. QuantumX acquires sensor or transducer inputs measuring **force, strain, torque, pressure, temperature, displacement, speed, position, acceleration, flow, voltage, current, noise and many more**. QuantumX offers superb A/D inputs supporting **voltage, current, bridge based inputs** (resistive, strain gages or inductive), **IEPE, LVDT, PT100/PT1000, thermocouple** and many more. Also highly accurate **digital timer based pulse** and **frequency** inputs or **absolute encoders (SSI)** can be acquired in parallel. Signals from bus protocols like **CAN, CCP, xCP-on-CAN** can be acquired time synchronous to all inputs. Some modules offer embedded real-time computing like **alarms, math operation, signal generator** (standard signal, arbitrary / replay) or just work as gateway to digital field busses in real-time like EtherCAT. All modules can be connected to PC software over Ethernet.

QuantumX from HBM is used in many industries for typical test & measurement tasks for mobile or lab based testing and for service or monitoring tasks. This TECH NOTE shows the possibilities and potential in using one single solution for your crash test projects acquiring all crucial quantities - mechanical, thermal, noise and camera data using QuantumX and **catman®AP** software visualizing digitally acquired data, storing it for later comparison and analysis and reporting.

catman®AP software offers CFC crash test filters in post-process mode. We developed the overall test setup together with some of our lead customers doing drop tests for certain safety critical parts.

Measure, Test, Analyze and Report with one tool!

There are many advantages in using a single tool for parallel, synchronized acquisition of all the interesting measurands:

- Time saving fast acquisition and analyses jobs with just a few clicks
- Saving all data in one file and export to different other formats
- Speedy comparison with earlier measurement results (trend analyses)
- Compact and portable solution for service and maintenance

This TECH NOTE puts this forward as a starter kit:

- QuantumX module MX410B with sample rates up to 100 kS/sec and a 40 kHz bandwidth per channel
  - Connecting IEPE based acceleration sensors or microphones for noise analysis
  - with resistive bridge inputs in full and half bridge configuration measuring strain, load cells, piezo-resistive acceleration, pressure
  - and also inductive full and half bridge for displacement transducers
  - and finally standardized voltage (± 10 V) and current (0/4 … 20 mA) with active transducer supply for any active sensor
- catman®AP software for powerful configuration, visualization, alarming, analysis and reporting
  - Converting crash test data via CFC filters into true results
  - FFT frequency analysis, 2D spectrogram, frequency triggers
  - Report generation, data export

Crash Standards

- FMVSS 208, S6.2
- SAE J2052, 3.2
- SAE J1727,3.6
- ISO/TC22/SC12/WG3 N 282 Issued 1990-03-16
- ADR69/00, 5.3.1
- ECE-R8O, Anlage 4, 1
- ECE-R22, 7.3.2.5
- EuroNCAP. Front Impact. 10. 10.1
- EuroNCAP. Side Impact. 10. 10.1
- EuroNCAP. Pole Side1111mm. 10. 10.1
- EuroNCAP. Assessment, Protocol. 5
- EuroNCAP. Pedestrian Testing Protocol. 10.2
- TRIAS 47. Frontal Impact. 2-6
- TRIAS 63. Pedestrian Impact. 2.4

Especially CFC filter are used in crash testing.

Inputs in Crash Testing

Acceleration and shock can be measured with different sensor types but most likely with piezo electric (charge), ICP/IEPE, piezo-resistive or MEMS type of crash sensors.

Typical manufacturer here are DYTRAN, PCB, Kistler, B&K, ASC and many others.

QuantumX MX410B or SomatXR MX411B-R – the universal amplifier with maximum signal bandwidth

The MX410B universal amplifier is the flagship of the QuantumX series.
The module has an incredibly wide range of functions. Each of the 4 channels can be individually configured, and supports:

- Resistivity in full and half bridges for SGs or piezo-resistive transducers
- Current-fed piezoelectric transducers (IEPE / ICP®)
- Normalized voltage: +/- 10 V
- Normalized current: 0 / 4 …. 20 mA

- Sample rate/filters
  - 24-bit sigma-delta AD converter
  - 100 kS/s per channel or in two-channel operation up to 200 kS/s, bandwidth to 40 kHz
  - Digital Bessel or Butterworth filters
- Can be extended with clip-on adapters:
  - 300 V CAT II: SCM-HV
  - SG quarter bridge: SCM-SG120 or -SG350
- Analog output of the universal input: +/- 10 V, optional filter, 150 µs latency
- Internal module calculations of the root mean square value (RMS) or peak value (PEAK) are possible

Virtually any system expansion is possible. Synchronization mechanisms such as PTP, FireWire, NTP, IRIG-B or EtherCAT are available for this. The channels are electrically isolated from one another for supply and communication, which allows an extremely high signal-to-noise ratio (SNR) of approx. 120 dB.

The full description of the modules can be found on our website at hbm.com.

The catman®AP Software

The powerful catman®AP software from HBM can roughly be described as follows:

- Support for HBM DAQ systems such as QuantumX or the ruggedized version, named SomatXR
- Support for additional devices such as GPS, video, odometers
- Parameterization of all channels and sources
- Offsetting input signals with one another
  - Algebra, logic, …
- Intelligent triggers for recording measurement (start/stop)
  - In the time or frequency range, e.g. sound level
- Visualization of all signals in the following domains:
  - Time (x over t)
  - Channel (x over y), e.g. displacement, angle, rotational speed, velocity
  - Frequency (x over f), e.g. acoustics, vibrations
- Data storage in the desired data format
- Data analysis, modification and storage
  - Export: UFF58, MAT, …
- Report generation (direct printing or via Microsoft Office, e.g. Word or PowerPoint)

The catman®AP software not only offers data acquisition, it also has an integrated math library for online, as well as post-process calculations. The mathematical functions extend from simple algebraic calculations, filters, statistics, classifications such as rainflow or time-at-level, to spectral analyses, to calculation of electrical power and efficiency through simple parameterization.

SAE J211

SAE regulation J211 defines how to record signals recorded in crash tests. It defines different Channel Frequency Classes (CFCs) to be used depending on the signal type. The CFC is the -1 dB cut-off frequency of the filter, which is approximately 0.6 times the usual cut-off frequency (-3 dB). The CFC 60 (applied, for example, to cell accelerations) thus has a filter cut-off frequency of 100 Hz.

The SAE J211 defines a corridor in which the transfer function of the filter must run, thereby allowing filters of different order. However, it is now common to use 4th order (24dB / octave) filters. Nowadays, it is common to sample the signals higher (> 10 kHz) and then filter digitally according to the CFC. The SAE J211 recommends using an anti-aliasing filter.

If accelerations ax, ay, az are calculated as a resultant, the individual signals must first be filtered and then added in quadratic form. The SAE J211 explicitly prohibits the filtering of already filtered (and then possibly offset) signals again. This is to prevent the multiple application of an »SAE filter« from producing a higher-order filter whose frequency response would then be outside the SAE specification.

Digital filter

The SAE J211 makes the explicit suggestion to realize the digital filter by "connecting in series" two identical Butterworth filters of the second order and in the second filter to reverse the time direction to compensate for the phase shift. (Contrary to the representation in the standard, however, the successive switching of two such Butterworth filters results in no 4th order Butterworth filter.) The 2nd order Infinite Impulse Response (IIR) filter is characterized by the difference equation.

$$y_k = a_0 x_k + a_1 x_{k-1} + a_2 x_{k-2} + b_1 y_{k-1} + b_2 y_{k-2}$$

The coefficients are calculated according to

$$a_0 = \frac{\omega_a^2}{1 + \sqrt{2}\omega_a + \omega_a^2}$$
$$a_1 = 2a_0$$
$$a_2 = a_0$$
$$b_1 = \frac{2(1 - \omega_a^2)}{1 + \sqrt{2}\omega_a + \omega_a^2}$$
$$b_2 = -\frac{1 - \sqrt{2}\omega_a + \omega_a^2}{1 + \sqrt{2}\omega_a + \omega_a^2}$$

$$\omega_d = 1.25 \times 2\pi \frac{CFC}{0.6}$$
$$\omega_a = \tan\left(\frac{\omega_d T}{2}\right)$$

ωd is the limit (circle) frequency of the individual filters 2nd order. The division by 0.6 counts up from the 1 dB cut-off frequency of the CFC to the usual cut-off frequency (-3 dB). The factor of 1.25 increases the cut-off frequency of the individual filters so that their reduction at the planned cut-off frequency is only 1.5 dB. In the series connection, they then lead to the usual 3 dB cut-off frequency.

Since the filter should not amplify static signals, must be valid.

$$a_0 + a_1 + a_2 + b_1 + b_2 = 1$$

(In particular, in the case of xk = xk-1 = xk-2 = 1, yk = yk-1 = yk-2 = 1, which directly implies this condition). This summation condition is indeed the case, as easily checked, because the numerator in this case is identical to the denominator 1 + 2-√ωa + ω2a.

Frequency Response Classes

According to SAE J211 is the amount of the appropriate CFC depending on the eventual use of the data and engineering expertise. But there are a few recommendations:

- total vehicle comparison CFC-60
- collision simulation input CFC-60
- component analysis CFC-600
- integration for velocity or displacement CFC-180
- barrier face force CFC-60
- head acceleration (linear and angular) CFC-1000, for example, to calculate the HIC; Also CFC-600 applicable to ECE-R 80

Workflow

Acquire your data with QuantumX and catman and then go over to power-processing mode

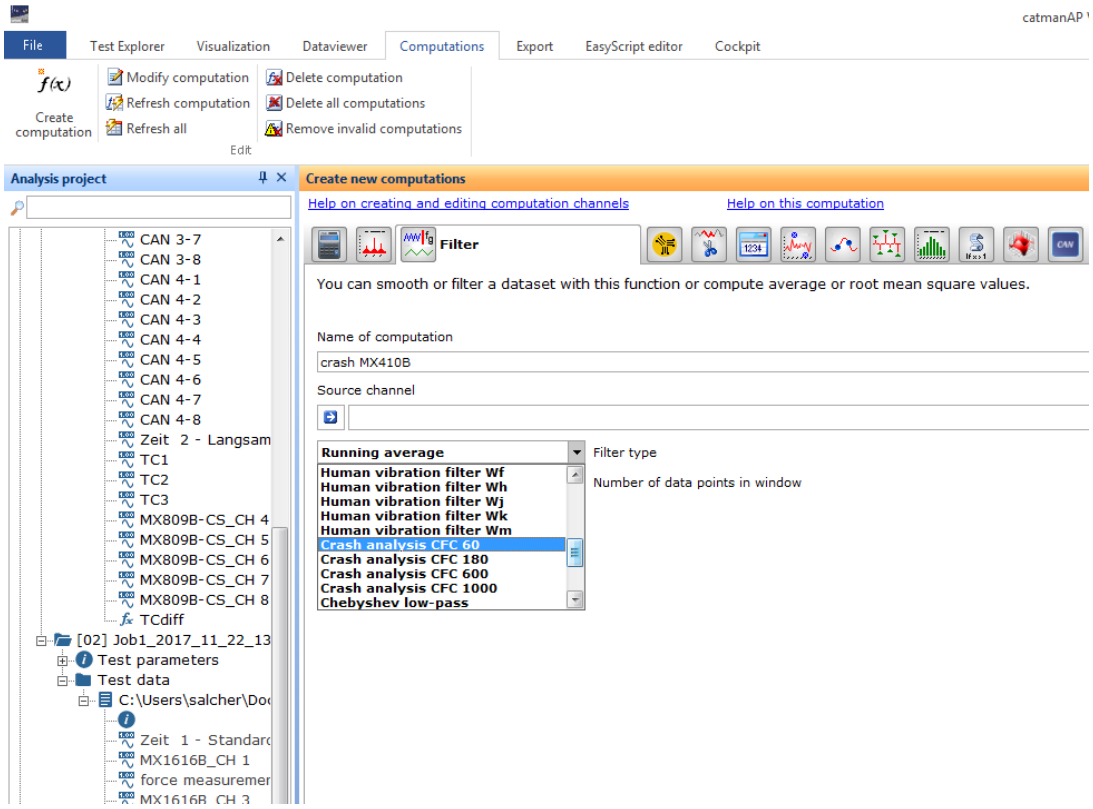


Fig. 2: Generate a crash report with catman.

Test report

There is much freedom of expression for report generation in Microsoft Word or PPT. The graphic displays of a measurement or analysis project in catman®AP can automatically be copied to a test report in Word format at a pre-defined bookmark (e.g. tt1 in the Office tab). Right-click on a display and follow the "Export/Print" dialog.
Example: Hammer impact

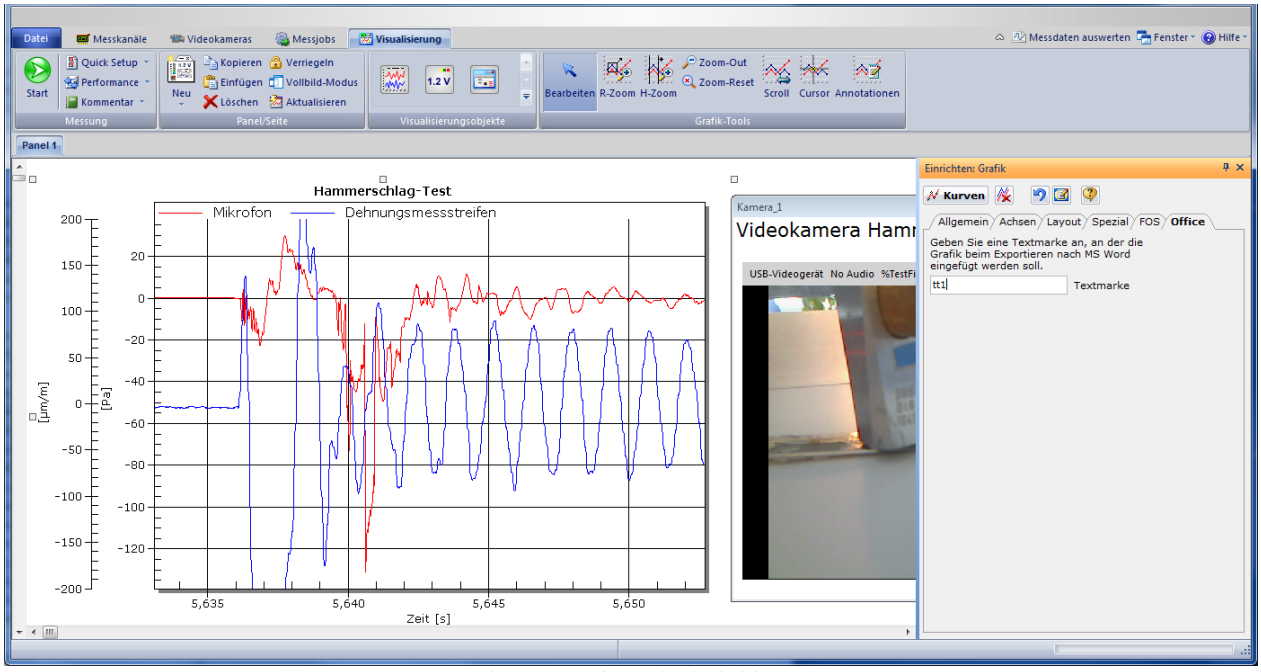
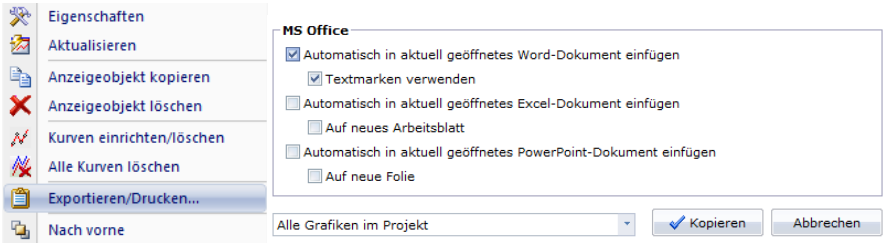


Fig. 3: Bookmark definition



Transfer display object from catman to Word:

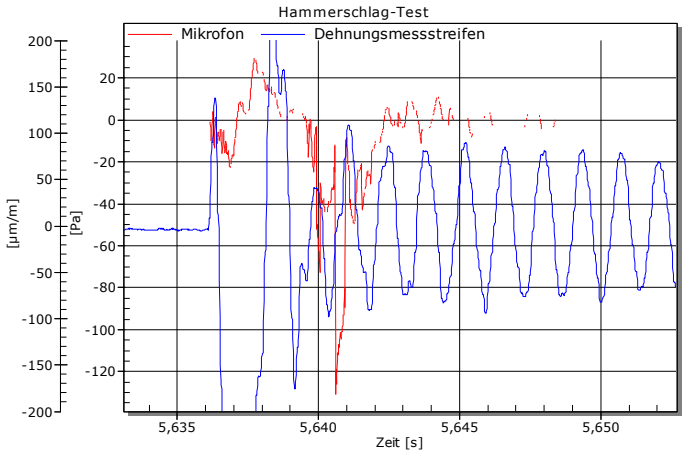


Fig. 4: Display object automatically copied to Word

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