# TECH NOTE :: The QuantumX Data Recorder CX22-W

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## Abstract

This article describes typical application examples of stand-alone data recording using the CX22-W QuantumX data recorder based on catman Easy software and provides tips and hints for optimal parameterization.

## Background

QuantumX measurement modules support many sensor technologies and thus enable almost all typical physical quantities to be acquired - a universal, powerful tool that has proved its worth for mobile use in vehicle development as well as for stationary use in long-term structural health monitoring of buildings and plants. Principal measurands typically include mechanical and thermal quantities such as strain, displacement, torque, force, pressure, temperature, oscillation, vibration, and many others.

Any number of measurands can be acquired. The distributable system architecture offers many benefits, since it enables the test equipment to be located near the measuring point and short pre-wired sensor lines to be used. The quality of measurement with specific sensor types is enhanced, installation costs are reduced and flexibility with recurring tasks is significantly increased.

Stand-alone data recording of physical measurands and digital sources makes sense in many fields of research, development, production and service. There are two different system concepts: rigid (data logger) or flexible (data recorder). Common data loggers with typically 1 to 8 inputs are in most cases intended for specific applications and are rather inflexible in terms of functionality. The QuantumX series of products offers much more scope while providing the same reliability. The rugged CX22-W QuantumX Data Recorder is a so-called box PC in a QuantumX housing. Powerful catman Easy PC software runs on the Windows Embedded 2009 operating system. The number of measuring points and the sensor or transducer types used determine the type and number of modules providing 4, 8 or 16 channels. The requirements result in a highly individual system architecture.

With mobile data recording in vehicles in particular, further parameters need to be considered. Besides analog data acquisition this also includes acquisition of the individual digital bus signals exchanged between the vehicle's electronic control units such as "current speed", "brake applied", "steering wheel angle", "brake pressure", etc. CAN bus is commonly used for this purpose in nearly all vehicles.

In road load data acquisition (RLDA)[1] in ride & handling applications with many manoeuvres like lane change or brake testing, data recorders operated via touchscreen are primarily used, since operation by the driver is limited because of the extreme conditions. Telemetric wheel force transducers (WFT) are frequently used during road load data acquisition; full digital protocol integration saves cost.

Acquiring the exact geographical position and absolute speed using GPS satellite receivers for position- and map-based analysis subsequent to measurement data acquisition is another factor.

A photo or a video sequence enables the test, the maneuver or a specific load case or failure to be recorded and subsequent data analysis to be facilitated or replayed in an impressive way.

### Integration with networks

With long-term and fleet tests or monitoring stations, however, factors such as smart data compression and Internet integration are required in addition to stand-alone, reliable data recording. Integration with the mobile network or, in general, the Internet allows, for example, automatic sending of status and alarm messages, centralized storage of data packages on a central data server (cloud) or remote access for system analysis or re-parameterization from anywhere in the world.

Load data acquisition in buildings and infrastructures means, on the one hand, upgrading inspections by means of test and measurement equipment (up to 12 months) or, on the other hand, permanent long-term analysis (monitoring over several years). System architecture and infrastructure criteria often overlap. Here again, a decentralized, distributable, Ethernet-based system with good long-term stability and easy integration with networks offer advantages. Configuring multiple data servers for automatic data and trend analyses and the possibility of web-based, worldwide access fully integrate the data acquisition task with existing IT infrastructures. *HBM's nCode GlyphWorks* software and web-based *nCode Automation* from HBM support these applications.

Network integration can be implemented in different ways. Use of globally established and standardized Ethernet technology is a main aspect of a solution ensuring full integration. Gateways help to bridge distances or obstacles - cable, optical or wireless. Different IEEE 802.11ac **WLAN standards** allow very high data throughput and configuration of private networks. WLAN enables distances up to 10 km to be bridged and can even be used for synchronous multichannel telemetry in slowly rotating parts. In **mobile communications and public networks,** transmission technologies such as EDGE, UMTS, HSDPA, LTE or 4G (LTE-Advanced) are privately owned in populated areas.

If the data recorder cannot be integrated with a network, replacement of the flash memory card is offered as an on-site service.

[1] RLDA – Road Load Data Acquisition

## The QuantumX Data Recorder

The CX22-W QuantumX data recorder is an "embedded box PC" in a QuantumX housing. The data recorder uses the *Windows Embedded 2009* operating system. The advantages are obvious - widespread use of the operating system allows convenient installation of a wide range of peripheral devices. Including, for example, USB drivers for keyboard, mouse, hard disk, touchscreen, camera, GPS, wireless connection (Bluetooth, UMTS/EDGE) and many others. It is easy to set up and parameterize services such as FTP, remote access (Teamviewer) or email. Users directly benefit from flexibility and freedom of choice, which allows for flexible upgrading; however, it means additional responsibility. It is essential that the reliability of a system set up by users themselves is checked, which certainly does not apply to the same extent to embedded systems with limited functionality and dedicated, web-based operation.

Data recording can be started using different mechanisms (trigger). This includes direct methods such as the start/stop button or also recording on power-on (auto start) or parameterization of smart triggers such as digital inputs, time, event monitoring of one or multiple measured or computed signals in the time or frequency domain. Recording can also be stopped using smart methods; in this case, the number of measuring points can be selected in addition to the time.  In addition to data recording, these mechanisms also allow use for alarms or activities. This includes digital output, LED display, sending of messages (email, sms), log entry or activation of the camera (photo, video).


The measurement system operates fully autonomously after configuration. The robust, removable CF card saves measurement data in the selected data format. Individual, graphic display and control levels for touch-screen connection are very easy to set up. A measurement project that has been saved can be loaded at any time. Status LEDs indicate the current operating state at any time.

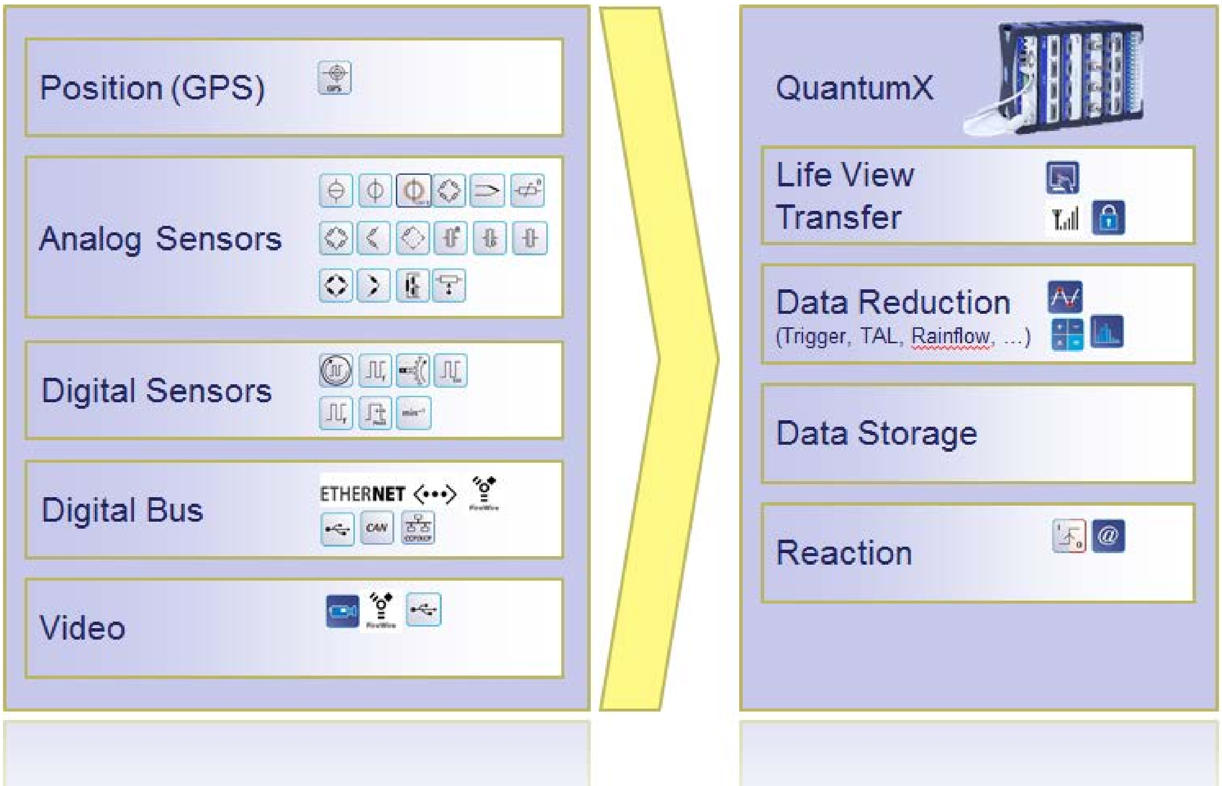
## The challenge

All sources combined can generate huge amounts of data. There are several solutions to the task of saving this synchronous data. For reasons of data integrity and simplicity, data storage on a local data recorder remains the first choice.

When designing the QuantumX data recorder, special attention was paid to providing a module with passive cooling and thus **without a fan** or rotating parts. Type Intel Atom energy-efficient microprocessors (total of 12 watts) were the first choice during the design stage in 2008. They use the x86 command set and thus running the Windows Embedded operating system, catman Easy measurement software from HBM and common drivers for peripheral devices such as mouse, keyboard, camera, touchscreen operation, GPS and many others on this platform. Unfortunately, this embedded PC architecture is not as powerful as a high-performance PC. It reaches its limits considerably faster.

**Awareness of the desired and required data throughput and knowledge of the possibilities for optimizing the data recording process can uncover potential for optimization.**

In other aspects the recorder seamlessly integrates with the specified scope of the other modules - i.e. identical electromagnetic compatibility, extended temperature and permitted humidity range and high impact and vibration resistance. This is why CX22-W is the smallest box PC with the functionality described above that is available on the market.




Compared to an engineering PC or a high performance box-PC, the CX22-W data recorder provides:

- 2 integrated FireWire ports
- 3 digital inputs including start/stop button, 3 digital outputs
- 1 RS-232 interface for connecting a GPS sensor
- 1 Fast Ethernet (RJ45 socket, electrical) and 1 Ethernet WLAN (SMA socket, wireless)
- 1 digital video interface (DVI) for connecting a monitor or touch screen
- 1 CF card for integrating a non-volatile memory (incl. 8 GB, cards are available up to 128 GB)

- 3 USB 2.0 interfaces for connecting memory (USB stick or hard disk), mouse, keyboard, touch screen, GPS sensor, etc.
- Processor performance of 1.33 GHz with 512 MB L2 cache
- 1 GB RAM, 2 GB from 04-2014

### Use case – Road Load Data Acquisition (RLDA)

- Number of signals
    - 150 measurement channels + 40 CAN signals à 1200 Hz per channel
      Total rate: 228,000 measurements per second
    - 4 Kistler wheel force transducers via Ethernet: 40 signals à 1000 Hz
    - GPS via RS232: 6 signals à 10 Hz
- Data recording
    - Storage mode and data format: **FastStream**
    - Data packaging/duration of measurement: 30 min measurement result in a total data amount of approximately 7.5 GB
    - Storage location: removable CF-CARD (SAN DISC Extreme Pro with 32 GB)
- Graphic display objects
    - Table with 20 numerical values
    - 2 real-time graphics (y-t), 2 signals, 2 s
- catman Easy configuration
    - Variable write cache: 128 kB

### Use Case – Manoeuvre / Ride and Handling

- Number of signals
    - CAN channels
        - 1st channel:  62
        - 2nd channel:  102
        - 3rd channel: 0
        - 4th channel: 0
    - Analog
        - 30 channels à 9600 Hz per channel (total: 260,000 measured values per second)
- Data recording
    - Storage mode and data format: FastStream
    - Data packaging: 10 min
    - Subsequent conversion from FastStream to another data format
    - Storage location: removable CF card
- Graphic display objects
    - < 5 in live display
- catman Easy configuration
    - Variable write cache: 256 kB

### Use Case - Structural Health Monitoring

- Measurement channels
    - 6 measurement modules with a total of 36 measurement channels à 200 Hz, 6 channels à 1200 Hz and 6 channels à 5 Hz
- Data recording

- Data packaging/duration of measurement: 6-hours periodic measurement result in a total data amount of 14,430 measured values/s * 8 byte * 21,600 s = **2.32 Gbyte**
- Storage location: external USB hard disk (Solid State)
- Storage mode and data format: **BIN**
- Periodic storage can be used up to a maximum sample rate of 600 S per channel; otherwise there is the risk of measured value output buffer overflow during the export process.

### Using the Data Recorder / catman®Easy

The maximum total sample rate when using catman Easy on a high-performance PC is approximately 5 million measured values per second. The QuantumX data recorder is specified with a maximum total sample rate of 400,000 measured values per second or 3 Mbyte per second. A measured value has 4 byte data width. In general, catman Easy software saves all signals with 8 byte data width. However, it is not as simple as that to specify the performance, since it depends on many factors.

The following factors need to be considered:

- **How many measurement channels need to be saved?**
- **Are there any other signal sources such as CAN, GPS, Kistler wheel force transducers?**
- **Do you want to record video data?**
- **How and where is the data to be recorded?**
- **What is to be displayed live during the measurement?**
- **What configuration parameters are desired for catman Easy and optimal for the job?**

Let us look at these factors and their effects, before showing how to optimally parameterize the software based on specific applications.

### Inputs – Analog Inputs

QuantumX measurement modules offer sample rates from 0.1 S to 100 kS per channel. Depending on the selected type of synchronization, a maximum of several hundred signals can be synchronously acquired.

As described above, the CX22-W data recorder enables a total of 400,000 measured values per second or approximately 3 Mbyte per second to be saved.

The number of measurement modules also is essential, since up to three separate time channels are created per module to allow post-process data analysis outside catman Easy/AP. If the same sample rate is consistently used in all measurement modules, all time channels except for one can be deleted.

### Inputs - Digital bus protocols

Besides the classical input signals, the signals from buses such as RS-232, CAN or Ethernet can also be acquired. Here are some examples:

CANbus 1: Group of electronic control units in the vehicle, powertrain CAN

CANbus 2: Group of electronic control units in the vehicle, car body CAN

CANbus 3: GPS sensor with 12 signals for position, time and direction

Ethernet 1: direct connection of 4 Kistler wheel force transducers with a total of 36 signals (*EasyRoadLoad* package)

## Inputs – Video or camera

catman Easy allows integration of up to 4 camera sources in parallel with measurement data acquisition (*EasyVideoCam* package). It is also possible to take snapshots, which significantly reduces the amount of data to be recorded. The data volume depends on many factors such as frame size (pixels), frame rate (frames per second), information depth per pixel (byte), compression format, and can vary substantially.

Sample calculations

| width | height | Pixel | Data per Pixel | Frames per second | Data per second | Recording time | Raw data | Compressed by Codec | Net data | Net data per second |
|---|---|---|---|---|---|---|---|---|---|---|
| [Pixel] | [Pixel] | | [Byte] | [fps) | [MByte / sec] | [minutes] | [GByte] | [Factor] | [GByte] | [Mbyte/sec] |
| 640 | 480 | 307.200 | 2 | 15 | 8,79 | 10 | 5,150 | 5 | 1,030 | 1,758 |
| 1024 | 768 | 786.432 | 1 | 24 | 18,00 | 10 | 10,547 | 20 | 0,527 | 0,900 |
| 320 | 240 | 76.800 | 1 | 25 | 1,83 | 10 | 1,073 | 2 | 0,536 | 0,916 |
| | | | | | | | | | | |

The table shows that CX22-W is only of limited value in recording and storing video data in parallel with measurement channels and other signal sources.

It is therefore of high importance to calculate the memory capacity to be expected based on a given parameterization for a given period of time and to compare it to the desired storage location. Encoding of the video data stream requires the biggest part of the processing power.

After parameterization, the software computes the maximum possible recording time and displays it in the status bar. A separate video file is created.

Please consider the following factors to limit the data volume:

- How many cameras are required?
  - The CX22-W data recorder with 2 GB RAM allows connection of one camera
- What is the required resolution and sample rate?
  - Will 320 x 240 and 15 fps be sufficient?
- Which period of time is to be considered?
  - Will a snapshot be sufficient?
  - Would it make sense to set a trigger to reduce the recording time?
- What type of compression (Codec) can and should be used?

Note: If your requirements cannot be met, we recommend using a powerful box PC, which also supports multiple cameras in parallel.

## catman – Inside

catman can be optimally adjusted to different measurement tasks. In addition to platform performance, e.g. CX22-W data recorder, the following factors have a decisive impact:

- **Data storage**
  - Inputs: Channels/signals, modules, other information, time channels, etc.
  - Data transfer
  - Calculations: Computation, data compression (counting), scripts, etc.

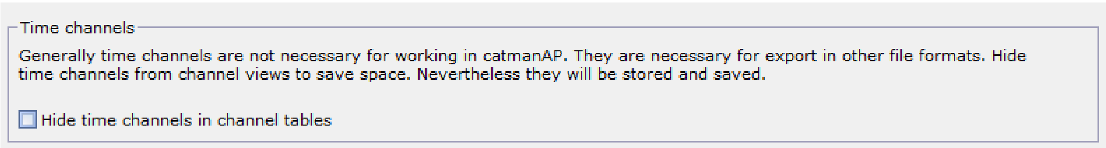
  - Data storage: mode, format, duration, storage location and performance
- **Online visualization**
  - Display: number, type, graphics
- **Post-process analysis**
  - Calculation and visualization based on temporary data

Possibilities for optimization are set out in the following chapters.

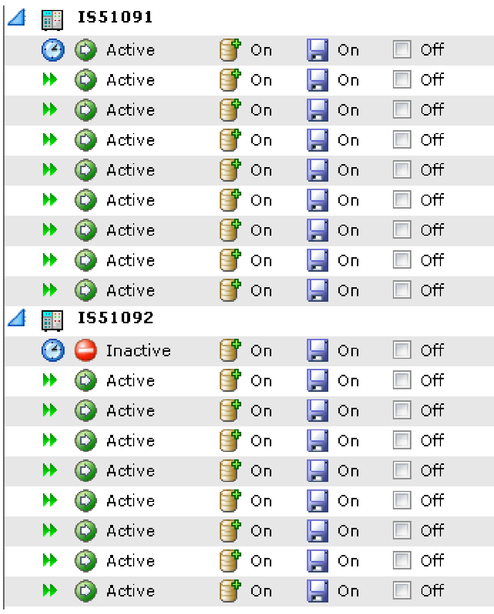
## Optimizing data storage

Data recording of time channels is necessary when tools other than catman Easy/AP are used for post-process analysis. Every module provides 3 time channels as standard. To deactivate time channels because, for example, all channels use the same sample rate and there is no additional new information per module, individual time channels can be hidden in the channel list and redundant channels deactivated in the recording of measurement data.

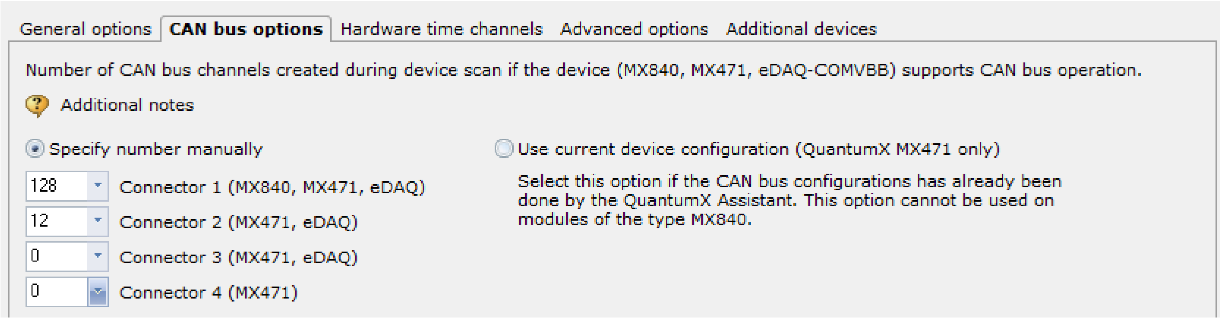
Show time channels:



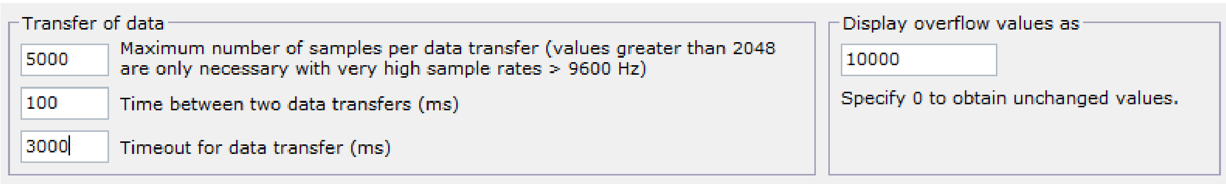

Deactivate time channel in DAQ job (no storage):



## Optimize number of signals per CAN port:



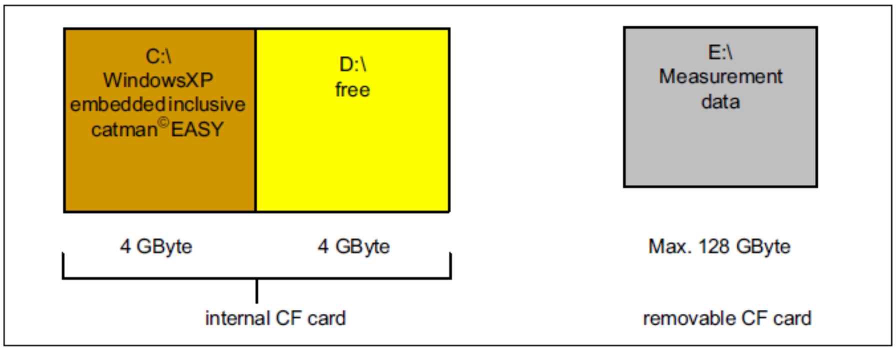

## Optimize data transfer:




## Optimize storage location and data storage device performance

The non-volatile memory's performance characteristics are essential.

The complete internal memory is structured as follows:




Operating system + application **C:**

Buffer, e.g. for project files: **D:**

Measurement data (removable FC card): **E:**

We recommend storing data on the removable CF card (drive E).

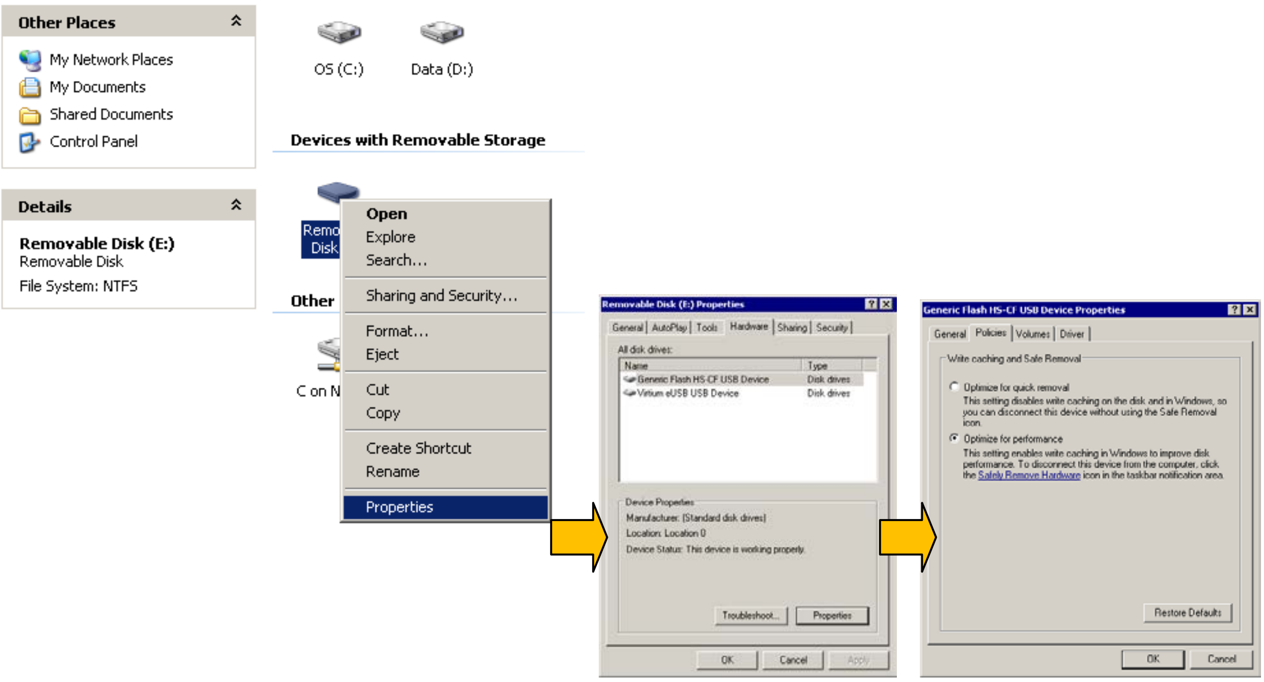
Recommended manufacturer and type: **SanDisk CF Extreme Pro** (UDMA7, max 160 MB/s)

Larger amounts of data can also be stored on an external **USB based SSD.**

It is essential that the memory is formatted in **NTFS** format.

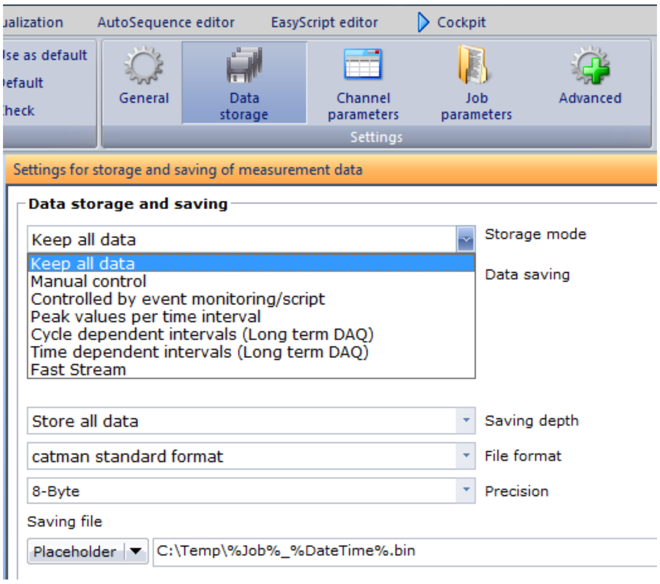
Optimize data storage

Optimize data access to drive E:\ for performance:




Storage mode and data format

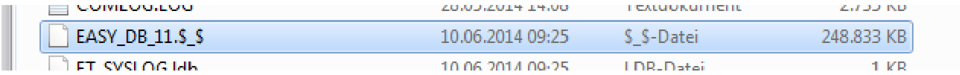
Catman®Easy allows different storage modes, data formats and packaging for data storage.




In the "standard" storage mode, incoming data flows into so-called **IO buffers**. Visualization, calculations, responses, scripts and the **temporary dynamic database** access these buffers. Graphic post-process displays access the temporary database. On completion of the measurement job the data is converted to catman binary format (BIN), MB per MB, into the final **measurement file**. Conversion to the final measurement file takes some time.

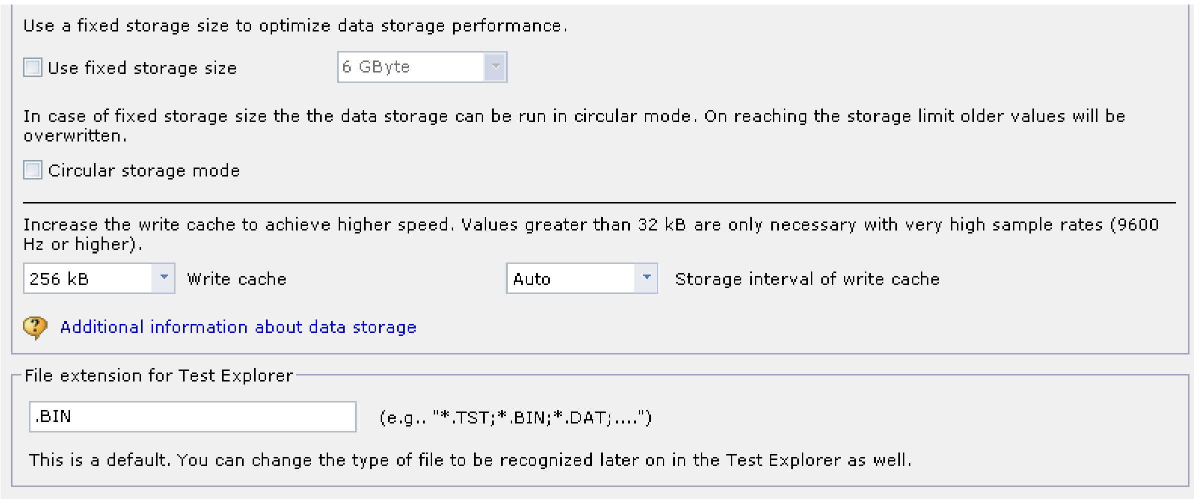
The catman Easy data acquisition core can be parameterized. In general, the software uses a temporary measurement data memory, which offers advantages, e.g. the dynamic creation of graphic displays during ongoing measurements. To go to the setup dialog for the temporary measurement data memory click File -> Options -> Data storage.

The temporary measurement data memory should be on the removable disk and looks as follows
(the name is not generally valid):




A fixed storage size in cyclic storage mode is useful for brief recordings, e.g. via trigger, transients and data storage in BIN format. This fixed storage can also be cyclically overwritten.

Options…




In the so-called "**FastStream mode**" the focus is on maximum data throughput so that data is directly streamed to a file in binary format. This mode is therefore the perfect solution for applications with high sample rates on platforms with limited resources such as the data recorder. Using this mode with the QuantumX CX22-W data recorder enables up to 100% additional performance to be achieved compared to the standard storage mode. Full data integrity is maintained. However, interruption of the power supply during write access to the flash memory is to be regarded as critical.

In general, all channels are stored in FastStream mode. To deactivate storage for individual channels go to "Measurement jobs", "Channel parameters".

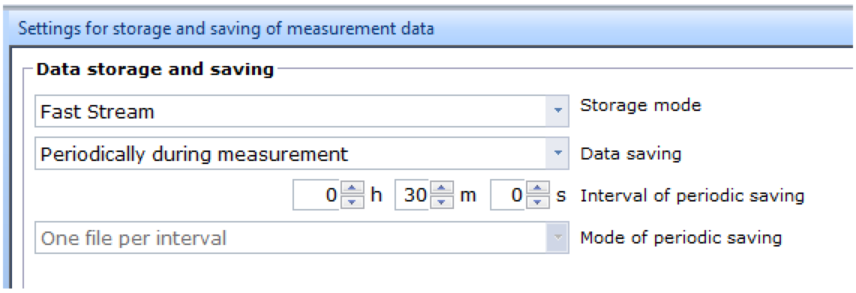
However, FastStream also has limitations compared to the standard setting:

- Recorded measurement data need to be converted for post-process analysis and fast read access. With large files, this process can take several minutes. We recommend performing the conversion on a PC with better performance.
- FastStream mode does not support pre-triggering (the software explicitly makes you aware of that)
- When adding a channel to a real-time graph in an ongoing measurement, the channel's "history" is not displayed in the time window.

Data packaging

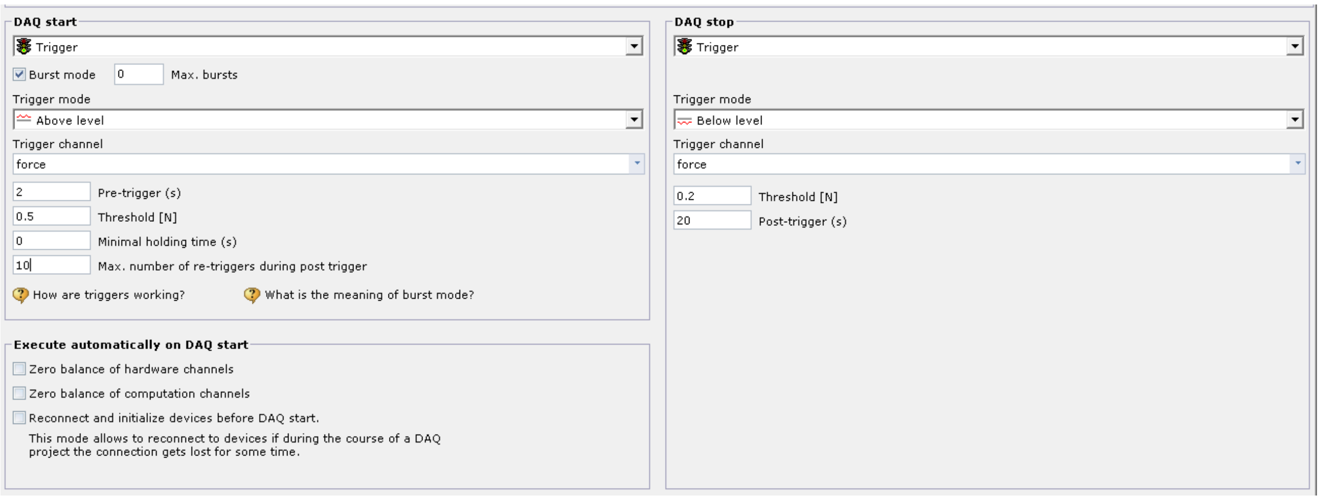
The measurement data can be stored in periodic intervals. The data packages can be easily accessed, converted and merged again later.

For long-term recording, store incoming data in meaningful packages of 6, 12 or 24 hours or 7 days to facilitate post-processing of data and enhance data integrity in the event of a power failure.



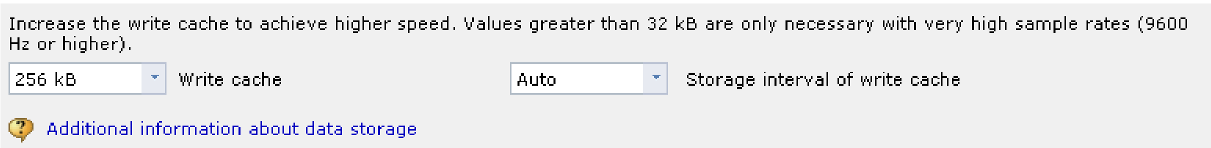
## General data compression

Smart trigger mechanisms and data counting such as time-at-level or Rainflow enable measured and displayed data to be compressed and stored at runtime.




## Write cache

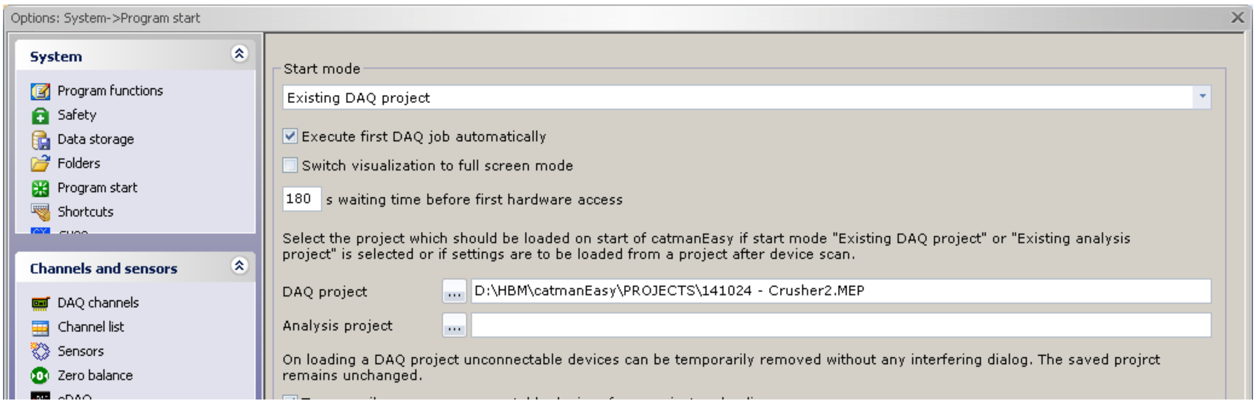
When using a large write cache and, at the same time, a low sample rate, in the event of a sudden interruption of the measurement, the last block of measurement data would be lost, because the data is written to the temporary data memory less frequently. The write cache reduces the RAM available.




A smart write interval helps to mitigate this effect. When using suitable intervals, data is written to the temporary data memory more often.

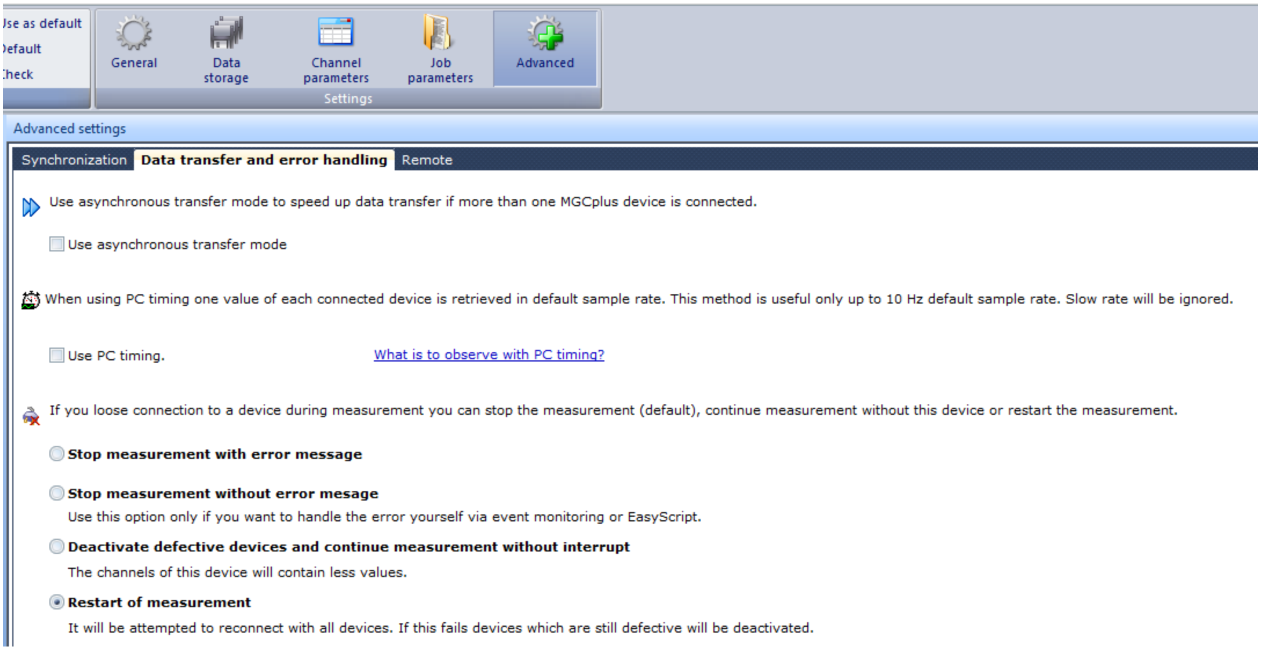
## Auto Start and Data integrity

You can parameterize catman to execute a certain DAQ job automatically. Set up your project and finally go to: Options -> Program start, and enter all details.

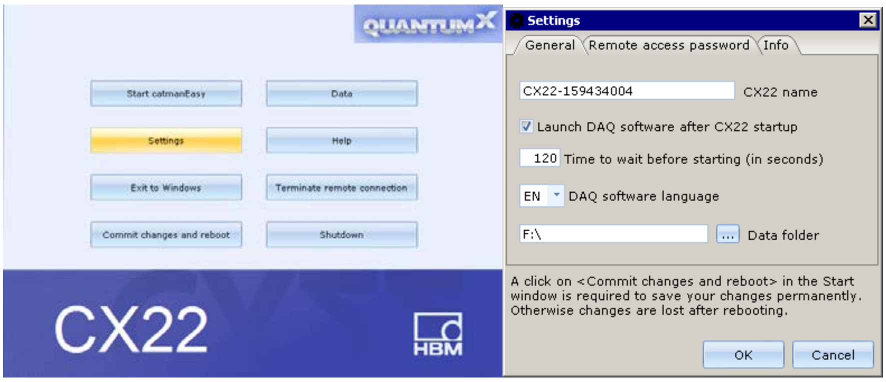



Fault Handling: In case of power loss you can also parameterize catman restarting the measurement.

In a widely distributed DAQ system (train, bridge, etc.) it may happen that some DAQ modules are disconnected during a DAQ job or after power loss. You can parameterize catman in this way that the measurement will start again with all modules found in the network scan.




For this purpose you need to go to the CX22 shell -> Settings -> Launch DAQ software at start up.With the timing parameter you are able to tune the waiting time before the DAQ job starts in case your modules are powered up step by step.




IMPORTANT: In case you modified parameters the CX22 shell you need to “commit changes and reboot” the unit to save all settings permanently.

## Optimizing visualization

On principle: the fewer visualization the better. If you still need to numerically display many channels, we recommend that you use table-based visualization.

-- end