PAK MKII
Testbench system

User manual for standalone operation of the PAK MKII

MÜLLER-BBM
VibroAkustik Systeme

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PAK MKII User Manual 10.3

PAK MKII G2 User Manual 1.0

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1 Goals

The independently working system monitors dynamic signals on an automated testbench in real time. This is done using data that has been analyzed in real time and is passed on to the testbench control system. At the same time, the recorded raw dataflow can be stored in the measuring device for later analysis.

A PAK MKII frontend with a controller of the latest generation is required for stand-alone operational capability. The PAK MKII configures itself automatically when it is started according to the stored channel and analysis-specific settings for the measurement tasks in question. Various functions are performed in parallel mode directly on the PAK MKII:

- Online analyses are continually calculated on the PAK MKII. In addition to the total level (RMS level detector with a definable time constant) or orders, high-pass, low-pass and band-pass filters, together with integration/differentiation, multiplication and downsampling functions are also available. The analyzed results are forwarded to the testbench control system via Modbus TCP.
- The input signals can be saved directly on the PAK MKII as ATF/XML data conformant to the ASAM ODS NVH standard. This data can be valuated later in ASAM ODS-compatible programs such as PAK or edp.
- The raw time data can be kept in a ring buffer and saved as required.
- Available in next update:
  The raw time data can also be streamed directly to the PAK analysis software via an integrated data server for more detailed and specific online analysis.
- Available in next update:
  Latency-optimized analog output of conditioned and scaled dynamic signals is made available for downstream systems such as control systems.

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2 First Steps

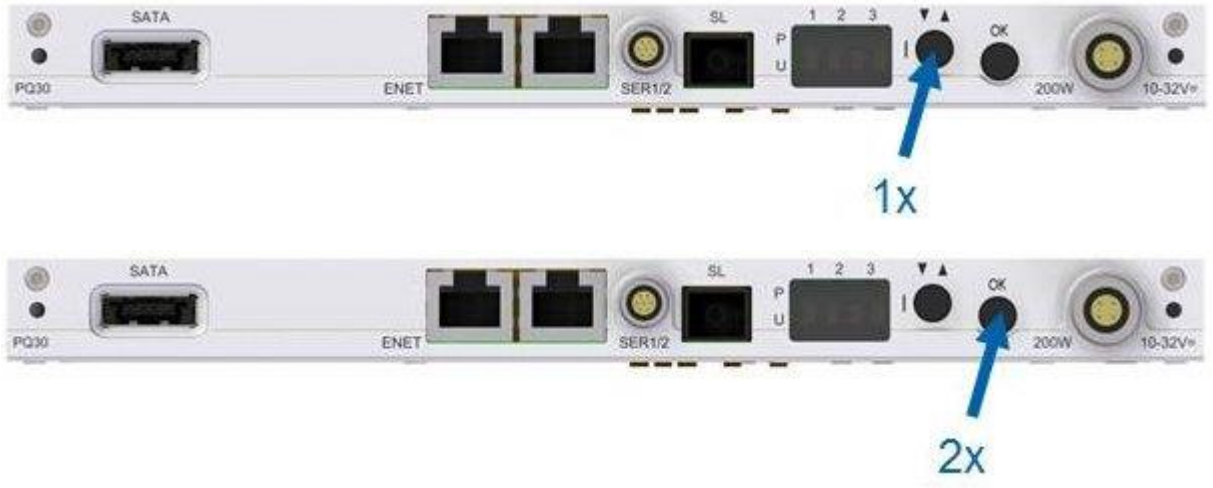
Starting up the PAK MKII

1. Connect the PAK MKII with the external power supply unit.

2. Connect the power supply unit with 220 VAC voltage supply.

3. Start the PAK MKII.

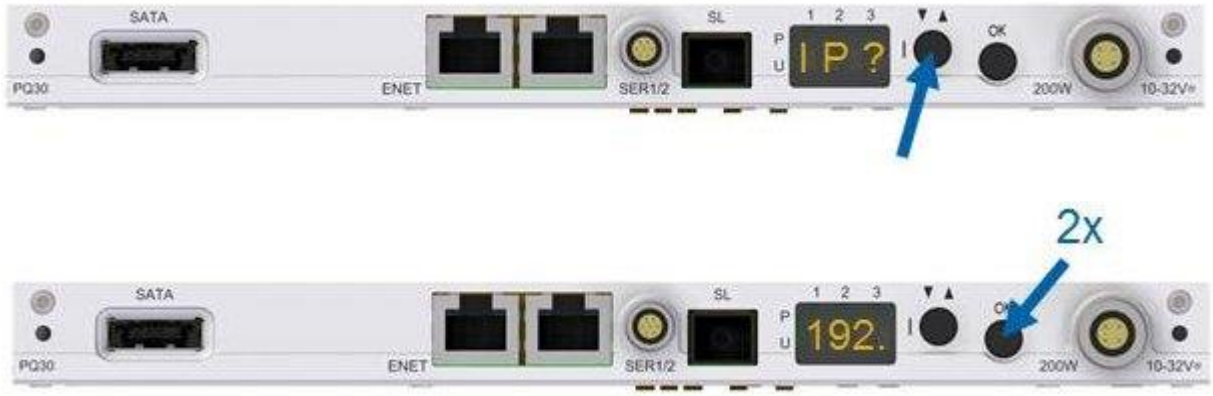
Press the left button of the PAK MKII once and the right button twice.



For details, see 4: PAK MKII User manual, Operating of the PAK MKII, Switching on the PAK MKII.

4. Retrieve the IP Address of the PAK MKII.

Press the left button several times until `IP?` is indicated on the display. Then press the right button twice. The IP address is shown on the display in 4 parts one after the other, e.g. `192.`, `168.`, `1.` and `231` to give the complete IP address 192.168.1.231.



For details, see 4: PAK MKII User manual, Operating of the PAK MKII, IP address of PAK MKII.

5. Plug an Ethernet cable into the left "ENET" connector.

6. Make sure that the configuration computer is in the same domain as the PAK MKII.

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3 VAS MKII Standalone Configuration

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Installation

Run the file VAS_Development_Standalone_Configuration.exe to install the VAS MKII Standalone Configuration tool to the PC. The tool can then be started via the corresponding shortcut on the desktop.

Operation

After running the "VAS MKII Standalone Configuration" the user interface opens for configuring the PAK MKII system and the Virtual Channels required for the evaluation.

The operating interface of the configuration is arranged in two areas. In the left window pane, the user can choose between the **Channel settings** and the **Virtual Channel Settings.** Depending upon what the user selects, the corresponding settings are shown in the right window pane. In the left pane there's also a field for the MKII's IP address, three buttons for the communication with the MKII and fields for some general settings.

Prepare MKII:

This button serves to prepare the MKII. This means that the firmware is checked and upgraded if necessary and certain boot parameters are adjusted in case the MKII has been used for other purposes before (e.g. with the PAK software). Simultaneously the actual hardware is read out. If there is no configuration file ("SetupFile.xml") on the MKII, it will be created and will also be loaded in the user interface.

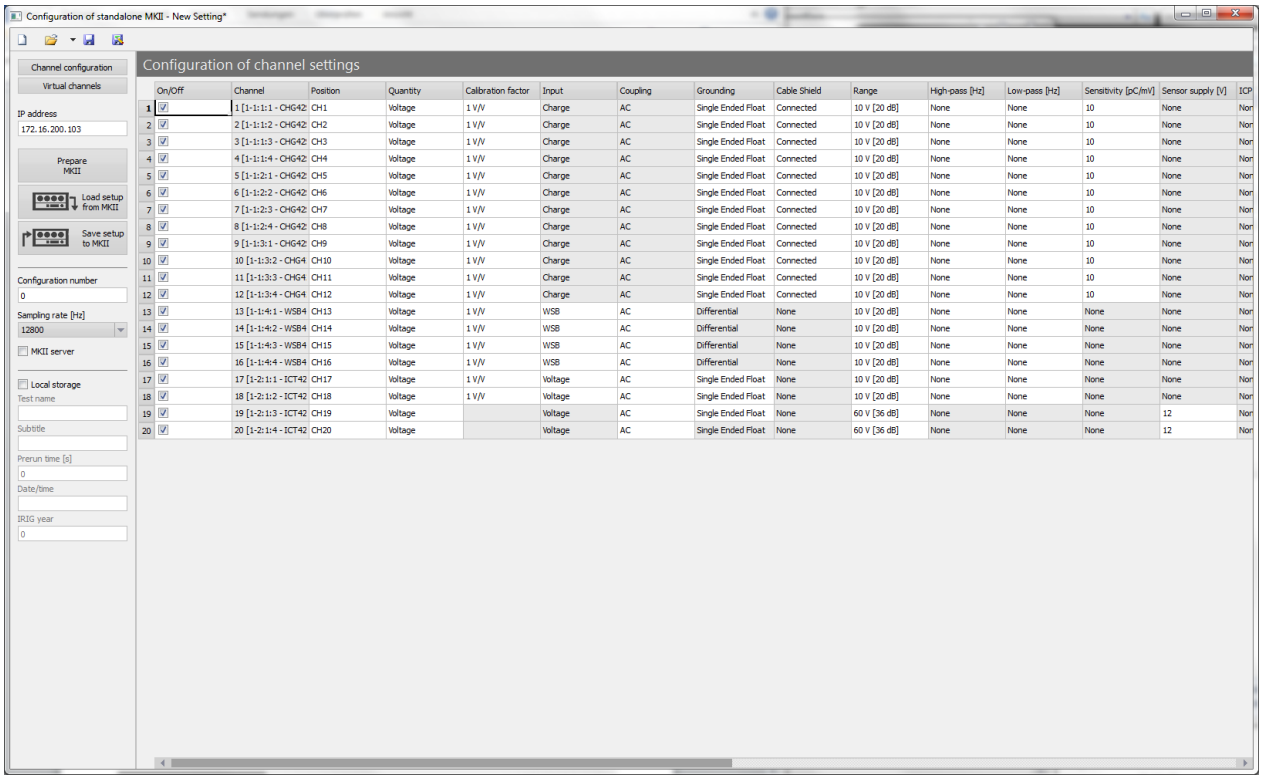
The button should also be used when some hardware component was changed (e.g. exchange of a module or insertion of an additional module). The new hardware configuration will be read out and adjustments to the existing configuration will be made. The SetupFile.xml will be updated accordingly.

Load setup from MKII:

The Standalone Configuration file ("SetupFile.xml") located currently on the MKII's flash storage is loaded.

Save setup to MKII:

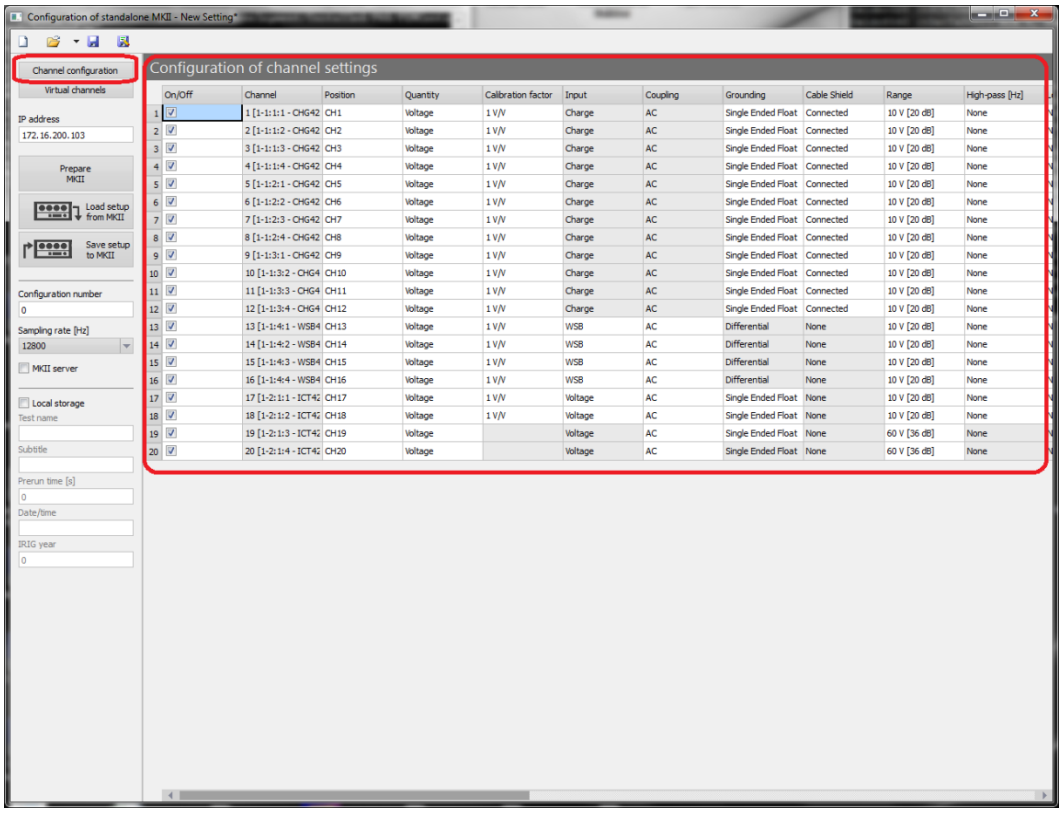
The current configuration is transferred to the MKII's flash storage.



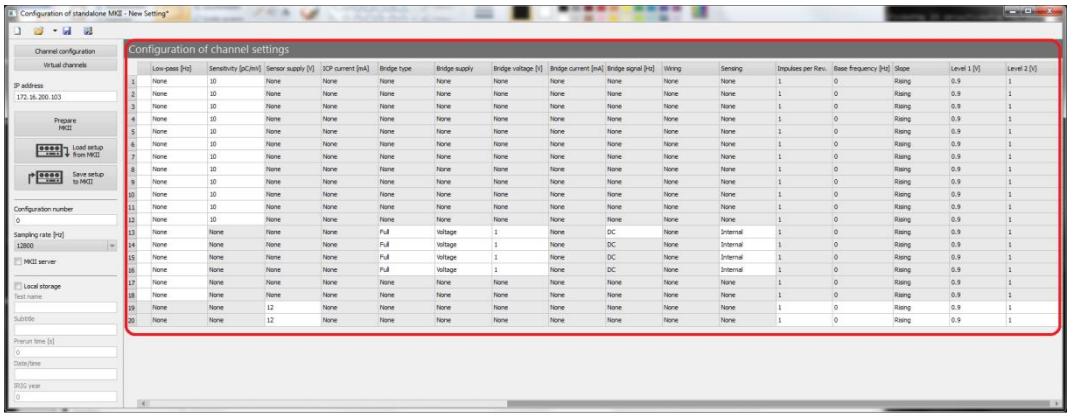
User interface of the Offline PAK MKII Configuration

Channel settings

If **Channel Settings** is selected in the left window pane, the channel settings (**Input Channel Settings** and **Alo Channel Settings**) and the general settings (**System Settings**) are displayed in the right pane for configuring the parameters of the channels.



All the relevant channel settings are summarized in the table…



…and can be specified for the respective measurement task.

Channel Settings:

On/Off:

Check box for selecting the channels required for a measurement

Channel:

The grayed cells in the column **Channel** show the channel number, the location in the PAK MKII and the respective module type. The syntax for the location index in the PAK MKII is as follows:
<PAK MKII mainframe number>-<SC card number>:<module slot number>:<channel number>

Position:

Position labels can be entered for each individual channel in the cells of the **Position** column. Up to 16 characters are allowed.

Meas. Mode:

The grayed cells in the column **Meas. Mode** show the operating mode of the channel:

- **Normal** defines a channel in which the time signal is acquired that can be used for further analysis.
- **Tacho** defines a period valuation in the time signal based on trigger events and the number of pulses per rotation. This valuation is primarily used for detecting the rotational speed.

Input:

The cells in the column **Input** define the input wiring for a measuring channel:

- **Voltage**: Module input signal is an electric voltage.
- **ICP**: Voltage input with a constant power source for supplying the sensor
- **Charge**: Module input signal is an electric charge.

Coupling:

The cells in the column **Coupling** define the type of coupling being used for a measuring channel:

- **AC**: DC voltage uncoupling
- **DC**: DC voltage coupling

This cell is configurable or contains a predefined variable depending upon the input module type that is being used.

Ground:

The input wiring with respect to the ground for the PAK MKII modules is defined in the cells of the column **Grounding**.

Option	Module	Input wiring	What it means
Single-Ended Float	ICP42, ICP42S, ICT42, ICT42S	**Voltage**	Signal ground to module ground Module ground isolated from ground of measurement device (recommended)
Differential	ICP42, ICP42S, ICT42, ICT42S	**Voltage** **ICP**	Signal ground isolated from module ground Module ground isolated from ground of measurement device (recommended)
Single-Ended Ground	ICP42S, ICT42, ICT42S	**Voltage**	Signal ground to module ground Module ground to ground of measurement device (for all signal wires to the same ground)

Range [V]:

Definition of the measuring range being used for the respective input channel.

The column **Sensitivity [pC/mV]** must also be taken into account when using a special module for load sensors.

Quantity:

The cells in the column **Quantity** allow the definition of a measurement quantity for a measuring channel. The variables in the selection list for defining a measurement quantity are determined by the file “quantities.xml”, which is part of the “VAS MKII Standalone

Configuration" and is automatically uploaded to the MKII if necessary when the button "Prepare MKII" is clicked.

Calibration Factor:

A calibration factor can be entered in the cells of the **Calibration Factor** column for every measuring channel where the Meas. Mode is "Normal". Calibration factors are always given as V/ISO units.

Attention must be paid to the definitions of the basic and ISO measurement quantities that are valid in PAK, particularly when using the PAK MKII as a server for PAK clients. For example, a calibration factor given in mV/g needs to be converted to the unit V/(ms^{-2}) for an acceleration sensor.

Sensitivity [pC/mV]:

(module types CHG42 and DCH42 only)

The sensitivity of the input amplification for charge sensors can be entered in the cells of the column **Sensitivity [pC/mV]**. The cells are grayed for other input modules.

Timeconstant [s]:

(module type DCH42 only)

The cells in the column **Timeconstant** allow defining a decay constant for the selected input channel.

Pulses per Rotation:

(only if Meas. Mode = Tacho (module type ICT42 Tacho))

The number of edge triggers that occur in a rotational speed signal during one rotation can be entered in the cells of the **Impulses per Rev.** column.

Trigger 1 [V]:

(only if Meas. Mode = Tacho (module type ICT42 Tacho))

The trigger threshold within the selected measuring range is entered in volts in the cells of the **Level 1 [V]** column. A rotational speed edge is then recorded dependent upon the selected edge direction (cell **Trigger Edge**).

Trigger 2 [V]:

(only if Meas. Mode = Tacho (module type ICT42 Tacho))

A second trigger threshold within the selected measuring range in volts is available in the **Level 2 [V]** column. A rotational speed edge is then recorded dependent upon the selected edge direction (cell **Trigger Edge**).

Trigger Edge:

(only if Meas. Mode = Tacho (module type ICT42 Tacho))

Whether rising or falling edges are to be detected is entered in the cells in the column **Slope**.

If **Rising** is selected, a rotational speed edge is recorded based on the higher of the two given trigger thresholds.

If **Falling** is selected, a rotational speed edge is recorded based on the lower of the two given trigger thresholds.

The other trigger threshold in each case serves merely as the precondition for recording a rotational speed edge. A triggering at the actual trigger threshold takes place in each case only once following the fulfillment of a precondition at the other trigger threshold.

System Settings:

Sampling Rate [Hz]:

Define the sampling rate that is to be used for the measurement in the **Sampling Rate** selection list.

MKII Server:

This checkbox enables the PAK MKII server functionality which allows to connect with a PAK client to the MKII.

Local storage:

It is possible to write the raw data including the calibration factors and units as ATFX file to the internal Local Storage Disk. This measurement is controled by the Modbus.

Prerun [s]:

As soon as the Extra Feature **Local storage** has been selected, the **Prerun** box becomes active. A prerun time for the PAK MKII ring buffer can be specified here. If a number greater than 0 is entered, a new measurement directory with a ring buffer of the specified time is generated on the Local Storage Disk when starting the PAK MKII and after each measurement. During the start of the measurement the actual measurement is appended to the ring buffer.

Test name:

Here enter the test name. After that the PAK MKII generates a directory of the same name on the Local Storage Disk.

Subtitle:

Here enter the measurement name. In the Test name directory, a measurement with that name is generated automatically plus a consecutive number which prevents overwriting of existing measurements.

Configuration:

In this box a configuration number can be entered. As a check this number is read out via the Modbus.

Timestamp:

The timestamp is generated during a configuration of a new setup file. However, it can be modified at any time. The timestamp uses the appropriate country specific format.

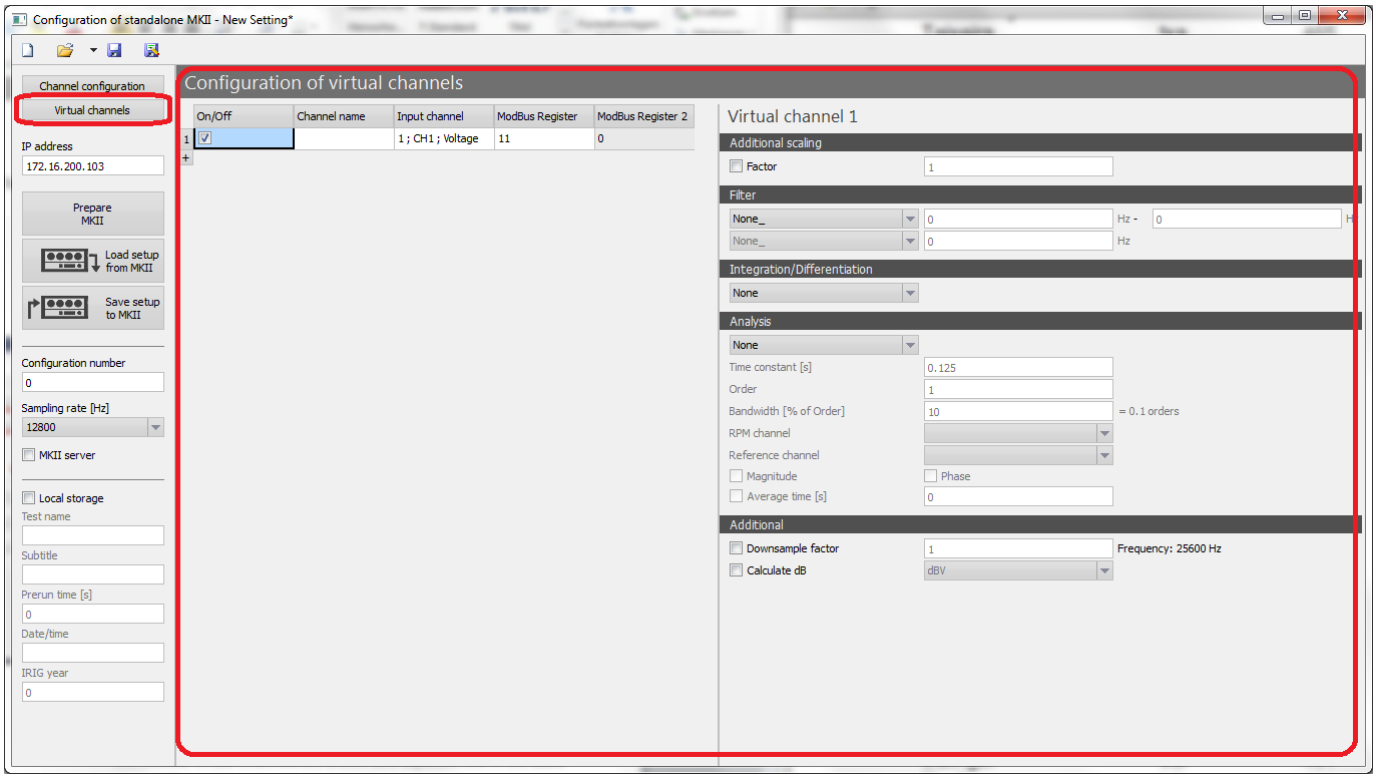
Background: The MKII device does not know the date and time, it needs some initialization of the time by an external source. The time stamp in the SetupFile.xml serves as a source of the time. When starting the measurement on the MKII, the time stamp from the SetupFile.xml will be used as the starting time, and recorded ATFX data will carry time stamps that are based on this time stamp.

IRIG year:

If you have an IRG module, the time stamp will not be taken from the fix value set in the SetupFile.xml, but from the IRIG signal. However, since IRIG only provides days since beginning of the year, you have to provide the year in the configuration file.

Virtual Channel settings

If the option **Virtual Channel Settings** is selected in the left window pane, these settings are displayed in the right pane. They are used for creating and configuring the parameters of the Virtual Channels for storage and calculation of other analyses (e.g. filtering, RMS detector, Kalman filters).



Virtual Channels can be defined for calculating other analyses.

Virtual Channels can be created and deleted for analyses by clicking the small "+" or "-" respectively on the left of the table "Configuration of virtual channels". Each created Virtual Channels is shown as a separate row in the table **Virtual Channels**.

Virtual Channels table:

Virtual Channel:

A position label can be entered for each individual virtual channel in the cells of the **Virtual Channel** column. A default name is automatically assigned to a Virtual Channel when it is created (Virtual Channel 1 … n).

Meas. Channel:

A physical measuring channel is selected here as the basis for calculating the Virtual Channels. The **Meas. Channel** selection list contains all the activated measuring channels from the channel settings. The possible analysis settings for normal or tacho channels are displayed under **Analysis Stack** in the right window pane dependent upon the selected channel (the marked table row).

Modbus 1:

If a Virtual Channel is to be output via Modbus, a Modbus register number can be entered in the cells in the column **Modbus Register**.

A Modbus register number cannot be assigned more than once and must be equal to or greater than 2.

The Modbus register number 1 is reserved for the start/stop instruction sent to the PAK MKII in measuring mode.

Modbus 2:

If the Kalman filter has been selected as an analysis for a Virtual Channel, both the amplitude values and the order phase can be calculated. These are then written separately to two different Modbus registers. The respective Modbus register number is entered for the amplitude values in the cells of the **Modbus Register** column and for the phase values in the cells of the **Modbus Register 2** column. The column **Modbus Register 2** is grayed for Virtual Channels with a deselected Kalman filter.

Analysis Stack – normal channels:

Multiplicator:

An additional multiplication factor for applying on the measuring signal can be entered in the appropriate text box by enabling the option **Additional multiplication factor**.

This option is particularly interesting in cases where the values to be output at the Modbus are suitably output in a specific unit of measurement that is not directly composed from the base/ISO measurement quantities.

Example: An acceleration signal, which is given with values in m/s^2 if it was correctly calibrated, is acquired at a channel. The calculation stated in the analysis stack runs an integration (i.e. a conversion into vibration velocity) together with an RMS detector calculation.

However, a signal level is to be output at the Modbus in inch/s as a peak-peak value.

The values provided as m/s^2 by the measuring channel are automatically converted into m/s by the integration in this calculation. To acquire the unit inch/s from m/s, a value of 39.37 has to be given as the factor (calculated from 1/0.0254). To then convert the output RMS values from the RMS detector calculation into peak-peak, they have to be multiplied by $2 * \sqrt{2}$. The total output factor to be given in this example is therefore 111.355.

Filter:

A high-pass, low-pass or band-pass filter can be chosen from the **Filter** selection list. The filter frequencies to be used can be defined in the appropriate text boxes for the minimum and maximum limit frequency.

Integration / Differentiation:

A single or double integration, or differentiation, of the time signal from the measuring channel being used can be selected.

- **1x Integration**
- **2x Integration**
- **1x Differentiation**
- **2x Differentiation**

For the integration it is advisable to first activate a high-pass filter to suppress the constant component. Otherwise, the result value can permanently increase with the potential risk of inaccurate values.

Regarding differentiation and integration the following general considerations apply (excerpt from the PAK Documentation):

"As it is a matter of common knowledge within analytical investigation, especially differentiation but also integration of time domain data includes methodical difficulties, which might cause inconsistency in the result. The differentiation and integration of time domain data, e.g. during online data acquisition or graphic output, are based on the direct computation of the samples of the time signal. Doing so might result in principle caused variation of the resulting amplitudes compared to the differentiation and integration in the spectral domain. When using differentiation in the time domain, there might be a spectral attenuation up to 12 dB at the top of the analysis range compared to the spectral differentiation. When using integration, there might be an increase up to 2 dB at the top of the analysis range.

Besides these differences, also significant variation of the differentiation is possible, which is caused by the gradient changes within the noise signal in the high frequency ratio of the time signal.

Depending on the application and the kind of signal, no calculation method (neither in the time domain nor in the spectral domain) can be clearly determined in advance, which leads to a meaningful or correct result. That is why it is recommended to stick to an obvious distance between the interesting wanted signal range and the top of the analysis range by selection of a respectively high sampling rate ("Guardband")."

Analysis:

Selection list for further analyses such as the **RMS detector** or **Kalman filter**.

- **RMS detector**: Calculation of an RMS detector with variable time constants
- **Kalman filter**: Calculation of the amplitude and/or phase progression of an order using the Kalman filter
  - **Order**: The order to be calculated
  - **Bandwidth based on**: Bandwidth should be based on "Order" or "Frequency" (fixed frequency bandwidth).
  - **Bandwidth [% of Order]**: States the order bandwidth in % (if bandwidth based on "Order" is selected).
  - **Bandwidth [Hz]**: States the bandwidth in Hz (if bandwidth based on "Frequency" is selected).
  - **RPM channel**: Rotational speed channel for calculating the order analysis (The rotational speed or tacho channel must exist as a Virtual Channel with the function **Missing Tooth Tracker**).
  - **Reference channel**: Rotational speed channel as a phase reference (The rotational speed or tacho channel must exist as a Virtual Channel with the function **Missing Tooth Tracker**).
  - **Magnitude**: Calculation and output of the amplitude progression for the selected order. The value for the magnitude is output in the Modbus register number for the field **Modbus Register**.
  - **Phase**: Calculation and output of the phase progression for the selected order. If both the magnitude as well as the phase are calculated, the Modbus register number from the **Modbus Register 2** box is used to output the phase value, otherwise the number from the box **Modbus Register**.
  - **Average Time**: Average time for the Kalman filtering in seconds.

Additional:

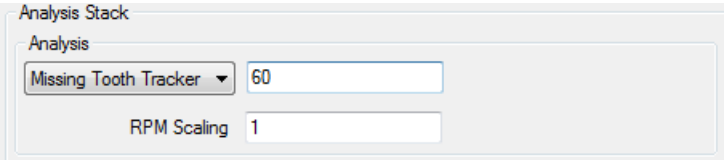
Selection of additional functions such as downsampling and level calculation in dB.

- **Downsample**: Downsampling by entering the "Downsample" factor and display of the resultant sampling rate.
- **Calculate dB**: Calculation of the level of a signal in dB stating the dB reference value.

The individual functions of the **Analysis Stack** for normal channels are run in the following order:

1. Additional multiplicator
2. Filter (high-pass, low-pass and band-pass filter)
3. Integration / differentiation
4. Analyses (RMS detector or Kalman filter)
5. Downsampling
6. Level calculation in dB

Analysis Stack – tacho channels:



Analysis Stack section

Analysis:

The **Calculation Frequency** and **Missing Tooth Tracker** analyses can be activated from the **Analysis** selection list.

- **Calculation Frequency**: Calculation of a frequency or rotational speed from the pulse signal of the tacho input taking into account a multiplication factor that can be entered in the text field (e.g. a multiplication factor of 60 for calculating the rotational speed from the frequency values). Here it must be noted that the value entered in the field **Impulses per Rev.** in the channel settings is ignored when this frequency is calculated. The calculated frequency with a multiplication factor of 1 is the pulse frequency of the received pulse signal.
  To calculate the rotational speed, it is therefore necessary to set the number of pulses per rotation as well as the factor 60 for converting hertz into rpm as the multiplication factor. For example, 30 pulses per rotation gives a multiplication factor of 30/60=0.5.
  Via **Average Time** an additional average time can be given for the calculation. The default value is 0.1 seconds.

- **Fill pulse gaps**: Calculation of a pulse sequence with a single pulse per rotation from a pulse signal from the tacho input with a defined pulse gap per rotation. The number of pulses per rotation given in the channel configuration for the tacho channel is entered as the default value by the program when the Virtual Channel is created. Virtual Channels with an activated **Fill pulse gaps** analysis can be used as the rotational speed or reference channel for the Kalman filter analysis for normal channels. The rotational speed for the order analysis can be scaled using the text box **RPM Scaling** to take any gear ratios into consideration.

Upload to the PAK MKII system

Via the button **Save setup to MKII** the complete current configuration can be uploaded to a PAK MKII system. To do this, the respective IP address of the PAK MKII system must be entered in the text box **IP Address** as follows: $$$.$$$.$$$.$$$.

Any active measurements must be restarted or the PAK MKII has to be rebooted before the uploaded new setting can be used by the PAK MKII.

General operation

An XML configuration can be reset, loaded or saved from the menu bar of the VAS MKII Standalone configuration.

- Reset XML configuration 
- Load configuration from XML file 
- Save configuration as XML file 

Modbus parameters

The following parameters have to be configured for data communication via Modbus:

- sign: unsigned shorts for messages
- endian: big endian on MKII
- datatype: floats are presented by grouping two shorts
- float channel group: holding registers
- TCP implementation: OpenMODBUS
- Protocol: TCP

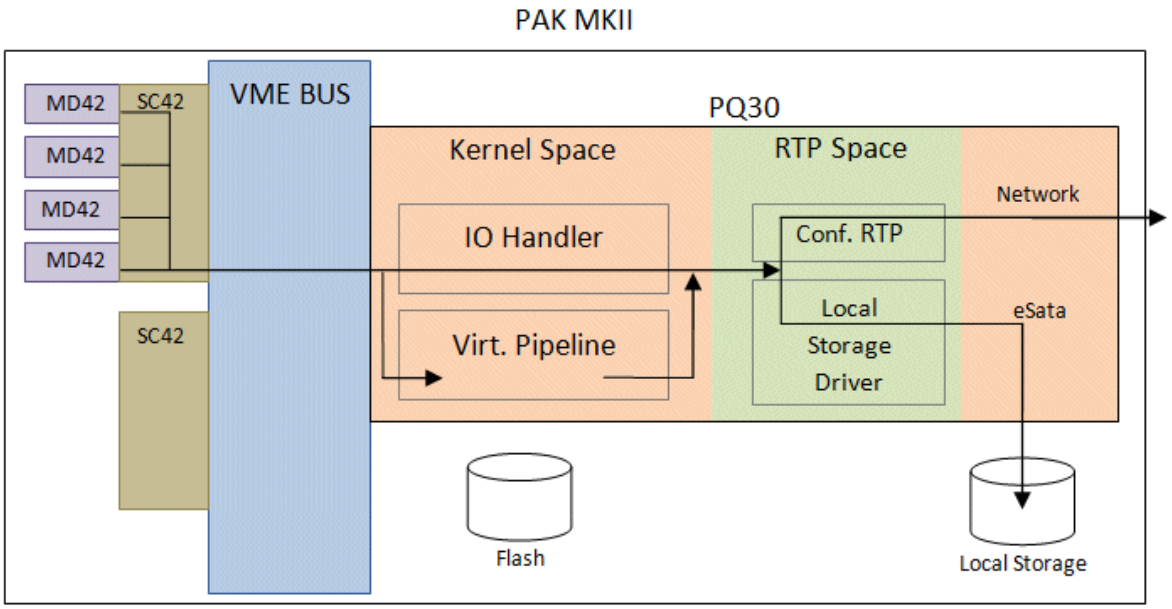
Modbus Actions and Status register

Modbus register	Type	Command/ Status	Description
1	Action 1)	1	Start test (changes status from 0 to 1 or 2)
		2	Stop test (changes status from any value to 0)
		3	Reset PAK MKII
		4	Start recording (changes status from 1 or 2 to 3)
		5	Stop recording (changes status from 3 to 1 or 2), takes 5 to 10 seconds to complete
		6	Disable prerun (changes status from 2 to 1)
		7	Enable prerun (changes status from 1 to 2 if prerun time is set to a value above zero)
		8	Start autozero (changes status from 1 to 99, returns to 1 after a few seconds)
		9	Start WSB balance (changes status from 1 to 99, returns to 1 after a few seconds)
2	Status	0	Stopped (test not running)
		1	Started (test running, prerun disabled, no recording)
		2	Prerun (test running, prerun enabled)
		3	Recording (test running, recording)
		99	Autozero (blocks all other commands while running)
		100	Error (for details, see Modbus register 10)
3	Status	0..1..0..1	Heartbeat (toggles each second)
4	Status	number	Configuration number as specified in setup
5	Status	number	Number of measurements (number of measurements corresponding to the current configuration which are already available on the harddisk)
6	Status	number	Remaining measurement time in seconds (an estimated value is indicated)
7	Status	number	Measurement duration in seconds During the prerun the ring buffer fill level is indicated. During recording the entire measurement duration is indicated (prerun + measurement time).
8	free		
9	free		
10	Status	0	No error
		1	Error: The file SetupFile.xml is invalid or missing.
		2	Error: The disc is full. No recording possible. 2)
		other	Internal error code

1) The Register value will be reset to zero once the indicated command has been completed. If no reset occurs, the desired command is illegal for the current Status. No error will be indicated in this case, but the command is silently ignored.

2) If the disc is full, the current recording will be stopped automatically, and the error state will be set. The test run does not stop, so that the values on Modbus will be updated continuously. The command for starting a new recording will be ignored. When data has been deleted from the disc, the MKII needs to be restarted (e.g. using command 3 Reset MKII) before a new recording can be started.

Structure chart



Download of the ATFX Measurements

The ATFX measurements can be downloaded from the PAK MKII by every FTP program. Make the following settings:

IP address	IP address of the PAK MKII
User	pq30
Password	password
Data transport	binary
Harddisk name	s0p0:1

It is recommended to avoid downloading ATFX measurements while a test is running, especially if a prerun is active. It might have an influence on the performance of the system and could lead to an abort of the test running on the MKII, including update of values to the Modbus. The test should always be stopped via Modbus (command 2) before you download the data.

Note on license:

The user interface for configuring the PAK MKII system uses a program library “libmodbus” which is used under the terms of the GNU Lesser Public License (LGPL). This means that there is the possibility to compile and link the program library, e.g. to make changes in the implementation. This event is not expected to occur, but it is a requirement of the license.

Due to that reason the library is delivered as a DLL (dynamic link library). The name of the DLL is libmodbus.dll, and it can be found in the installation directory (usually in C:\Users\<User>\AppData\Local\MuellerBBM-VAS\MKIIStandaloneConfiguration\bin\x86\release\). In order to be able to make changes and build the library, the following files are provided additionally:
the source code of the library, a Microsoft Visual Studio project file, and some additional information, e.g. regarding the license terms, which also can be found in the installation directory (usually in C:\Users\<User>\AppData\Local\MuellerBBM-VAS\MKIIStandaloneConfiguration\libmodbus).

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