Combustion Engine Analysis - CEA

APPLICATION USER MANUAL

CEA V24-1

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2. About this document

This is the users manual for Combustion Engine Analysis - CEA module.

2.1. Legend

The following symbols and formats will be used throughout the document.

Important
It gives you important information about the subject.
Please read carefully!

Hint
It gives you a hint or provides additional information about a subject.

Example
Gives you an example of a specific subject.

3. Introduction

The Combustion Engine Analyser (a.k.a. **CEA**) system from Dewesoft is used for engine research, development and optimization. Also for component development and testing – such as ignition systems, exhaust systems and valve control gear.

The system consists of our top of the notch isolated SIRIUS hardware and the well-known DEWESoft® software package for measurement and analysis.

It supports angle and time-based measurement results and uses highly sophisticated algorithms for online or offline mathematics and statistics – calculating heat release and other thermodynamic parameters.

The combustion analyser can be fully integrated within a testbed and also supports data from other sources: e.g. Video, CAN, Ethernet, XCP,...

If the powerful integrated post processing features of DEWESoft® are not enough, you can even export the data to several different file formats.

In addition to combustion analysis, the system can be expanded to handle other measurement applications such as hybrid testing on the powertrain, noise and vibration measurement together with synchronized video or GPS data.

4. System Overview

Pressure sensor(s) are used to measure the cylinder pressure of the engine. Depending on the sensor type, these can be directly connected to our SIRIUS*i* amplifier like any other input channel or through external signal conditioning amplifiers.

Additionally an angle sensor is needed for getting angle domain measurement results. Several different types are supported by the Dewesoft Combustion Engine Analyser. Additional mounted CDM (Crank Disc Marker) sensors or digital native CDM sensors (like 60-2 or 36-4,...) with TTL outputs can be connected to dedicated counter inputs.

Sensors with analogue output can

- be directly connected to analogue input channels
- or to counter inputs via the DS-TACHO1 device

In both cases, the DEWESoft® re-sampling technology gives you an angle resolution down to 0.025°.

Image 1: Analog and digital input channels on SIRIUS CEA

5. Enabling CEA module

Like many other instrument modules also Combustion Engine Analysis is an option to the standard DEWESoft® package. Simply press 

and select the Combustion engine analysis to add this instrument.

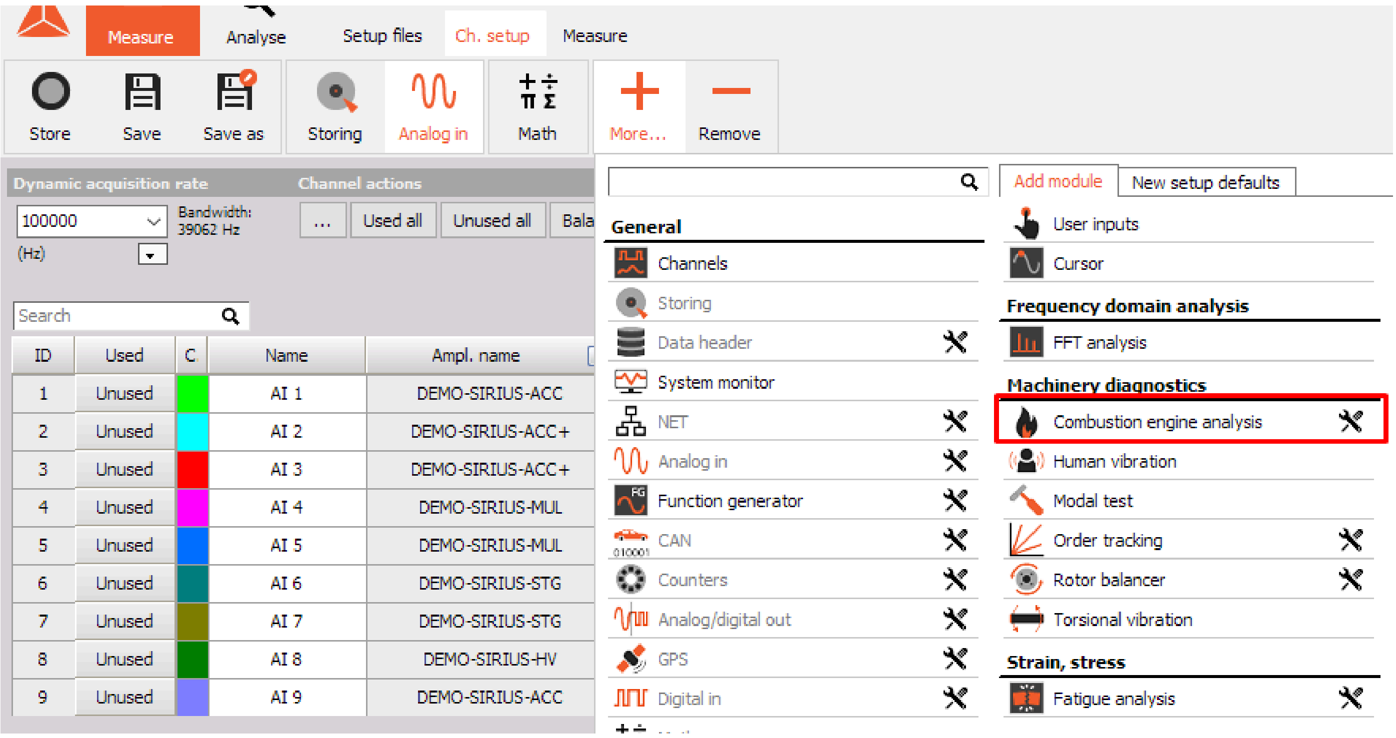


Image 2: Add CEA module in the Ch. setup

6. Basic operating concept

The combustion analyzer inside DEWESoft® is just one out of several other application modules which offer dedicated mathematics and dedicated visual controls like the pV-diagram or the CEA-scope.

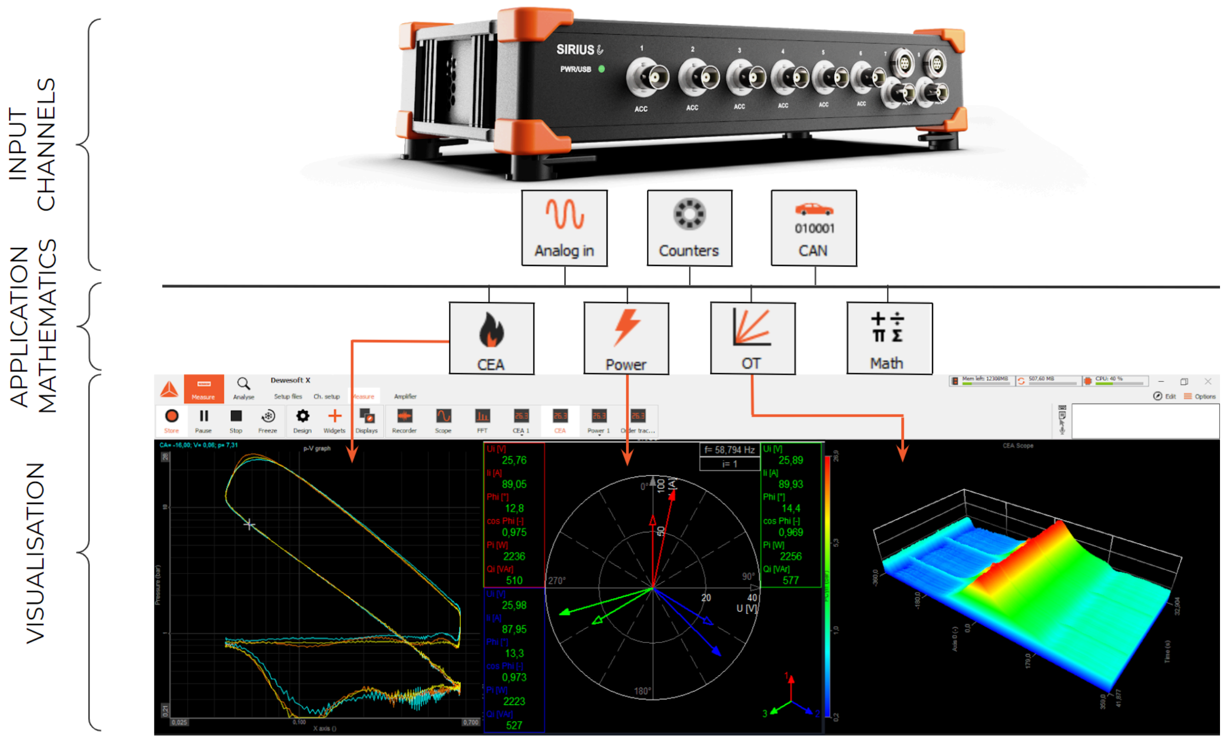


Image 3: Combustion engine analyzer is just one out of several applications modules inside DewesoftX

Since the analogue channels of the Sirius system are the input for the mathematical calculations, you must first set up the amplifier and configure the scaling of the physical unit. This is done in the Analog input section of the setup screen.

Image 4: Analog channels can be set up in the 'Analog in' section of the Ch. setup screen

When you are satisfied with the Analog configuration you can go to the next step and use those analogue channels as input for the combustion analyser module.

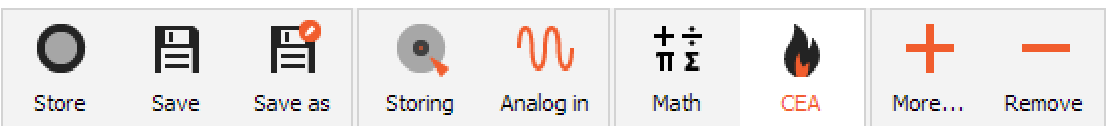


Image 5: Go to CEA and use there the channels setup in Analog in

Hint
Press F1 to enter the online help of DEWESoft® to get more information about setting up the amplifiers, using the sensor database and the TEDS (for automatic setup of amplifiers and scaling).

You can use the same analogue input channels that you have used in the Combustion Engine Analysis module for any other mathematics or applications (e.g. FFT, etc.) in parallel. This gives you a multifunctional instrument suitable for nearly any application. Output channels from one mathematics module can be used as input channels for any other module.

Example
You can use the standard mathematics result channels as combustion analyser input channels (e.g. Some special filtering or correction of the input channels).
The output of the combustion analyser module can be also used as input channel for the mathematics (e.g. advanced statistics on the cylinder pressure channels).

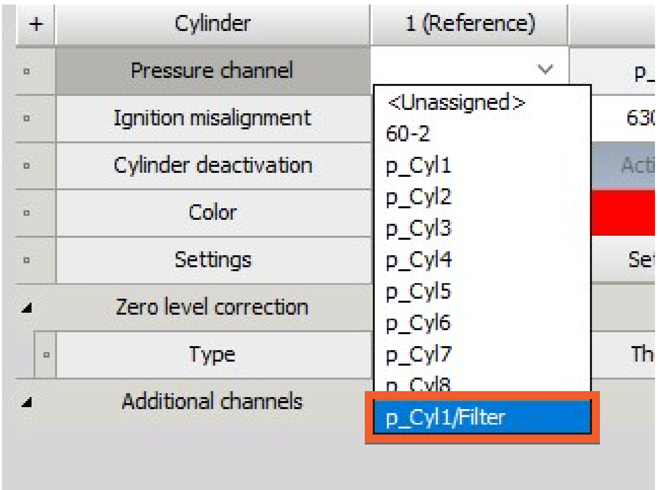


Image 6: Mathematical channels can be selected as pressure channels as well

7. Setup of the CEA module

The configuration of the CEA module is split into 3 tabs:

Engine settings: Defines the geometry and assigns the channels to the cylinders

Encoder settings: Assigns the angle sensor, sampling type and the TDC detection

Result definition: Enables/disables the output channels for the CEA module and configures all calculations

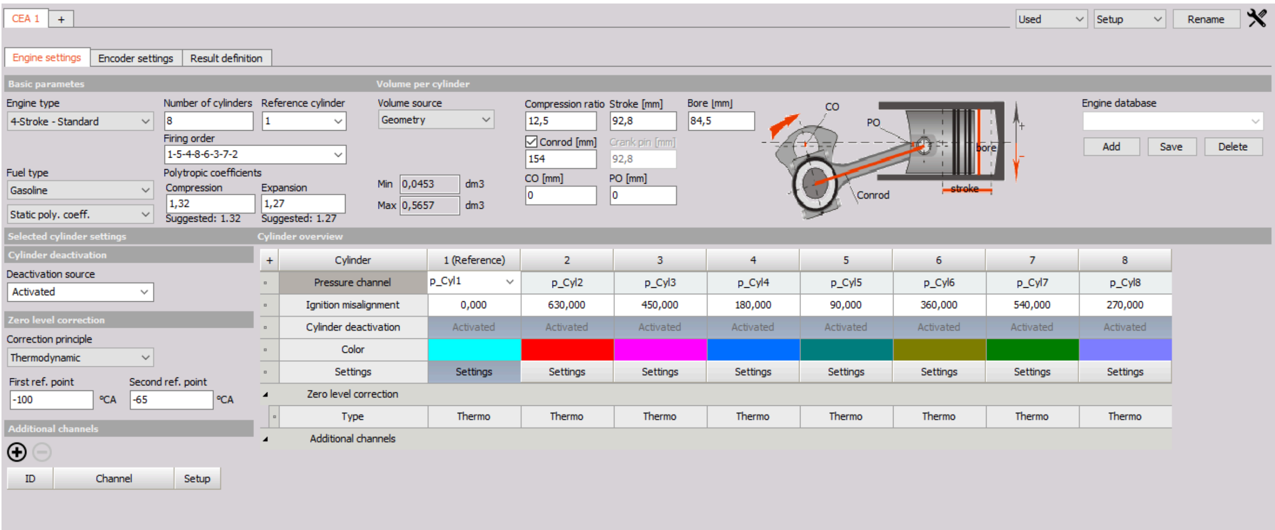


Image 7: CEA module screen

7.1 Engine Settings

Status bar below the list of CEA modules shows the current error message (red) or warning (orange). As long as there is no reference pressure channel assigned, there is an error message present.

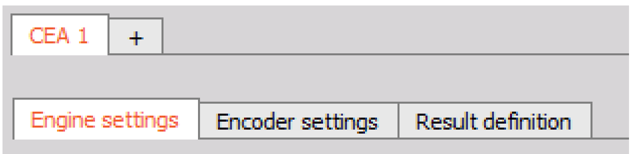


Image 8: If no reference pressure is assigned the status bar will show an error message

The default installation includes a 4-Stroke or 2-Stroke with the standard calculation method for the volume calculation. Additional templates with customized volume calculation can be added.

Pressure channel input can be assigned to each cylinder by clicking on the input and selecting it from the drop-down list or by typing-in the name, which works as a search box.

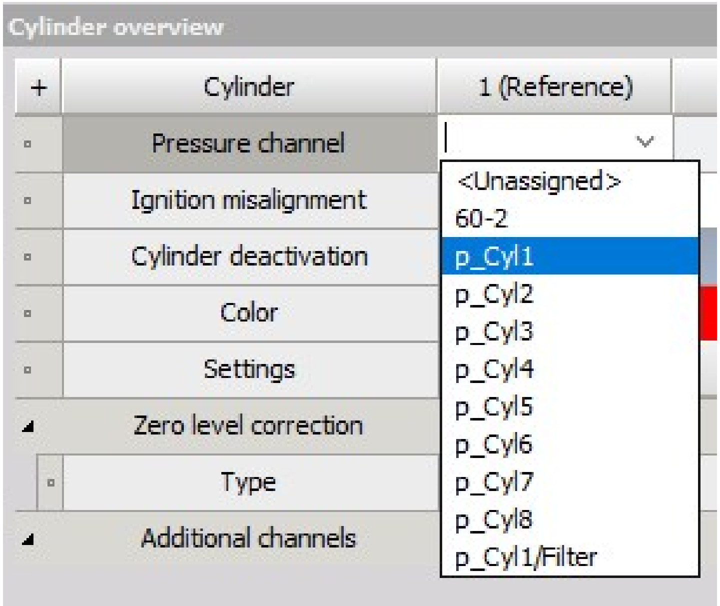


Image 9: Assigning the pressure channel

Fuel type defines the fuel of the engine. Depending on the selected fuel type, a **polytropic exponent** used for thermo-dynamic calculations is suggested. The defined value must be entered manually into the polytropic exponent field. When changing the fuel type, the value will not be changed automatically. Two polytropic exponent numbers are possible for input. The first is used for the compression stroke, where the temperature inside the cylinder is lower, the second number is used for the combustion (expansion) stroke for temperature and thermodynamics calculation where the burning process takes place. It is also possible to define a completely custom number for the polytropic exponent.

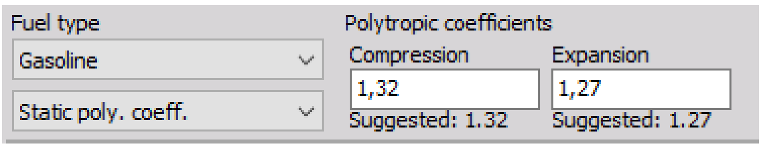


Image 10: Selecting the fuel type and its coefficients

Hint

If results need to be compared to previous versions of Dewesoft CEA where only one polytropic coefficient was used, then both numbers should have the same value and the factor will be the same. Another CEA module can also be added for control using different polytropic numbers.

Start of combustion (SOC) and end of combustion (EOC) are provided as results. EOC is defined where integrated heat release reaches 95%, which is valid for diesel and gasoline fuel types.

With gasoline, SOC is defined when the integrated heat release reaches 5%, and with diesel,SOC is defined when the integrated heat release crosses 0% (Due to the injection of diesel fuel, the integrated heat release goes negative first).

Number of cylinders defines how many pressure sensors will be connected and used for measurement and how many separate outputs will be available. **Reference cylinder** should also be selected from the list or the first used as default.

Cylinder misalignment can be entered in degrees for each cylinder separately or the **firing order** option can be used to do this automatically. If it is a straight engine then firing is usually every 720°/cylinder nr. In this case, one of the predefined firing orders can be used or a custom one defined by typing in the sequence divided by '-' signs: 1-3-2-4. Sequence starts with 1. If a custom misalignment in degrees is entered, then firing order is set automatically to custom.

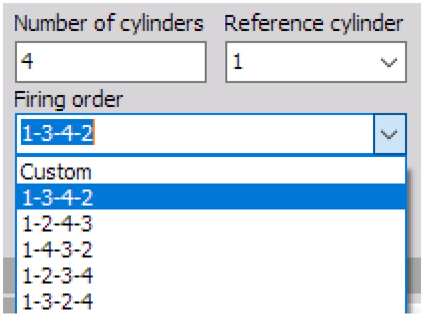
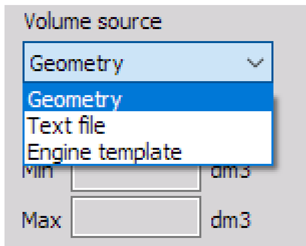


Image 11: Selecting number of cylinders and their firing order

For each cylinder the corresponding pressure channel needs to be assigned from the channel input list.

Volume source can be defined three ways:



1. Geometry: entering stroke, connecting rod length and PO or CO will define and calculate the volume curve

The **Crankshaft Offset** or the **Piston Offset** needs to be entered in the field CO or PO. It is very important to consider the running direction of the crankshaft. In the illustration above the sign('+' or '-') is shown for clockwise.

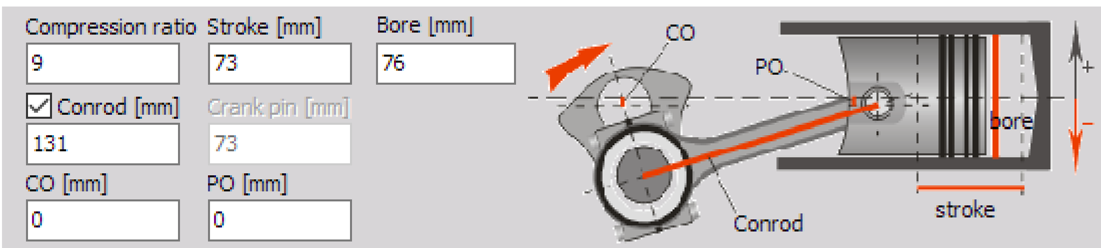


Image 12: Using geometry to define the volume source

Important
If PO or CO is entered, stroke is not available any more.
The crank pin must be entered separately!

Compression ratio defines the relation between swept volume and clearance volume.

2. Text file: Single or multiple volume curves defined in a text file. It is possible to define a variable compression ratio using predefined compression curves from a text file.

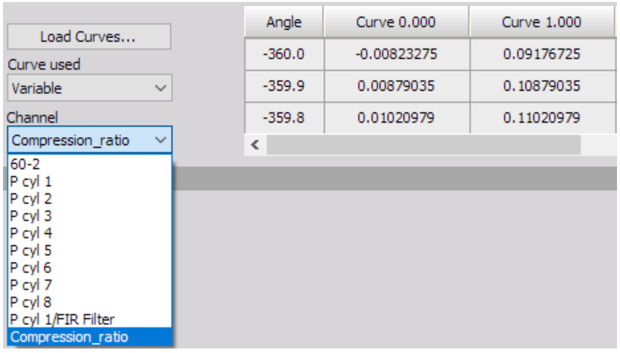


Image 13: Using text file to define the volume source

Example
By importing a text file with multiple compression curves, the current volume curve used can be defined dynamically from a synchronous channel (CAN channel from ECU needs to be put in formula and timebase set to synchronous). The volume curve will then be changed at the beginning of each new cycle if the value changes.

Important
Format for the text file is **space** delimited values.
First row is angle, all other rows are first value curve ID, all other values are volume in dm^3.
Angles must be expressed in tenths of a degree from angle -360 to 360 deg for 4-stroke and -180 to 180 for 2-stroke engines!

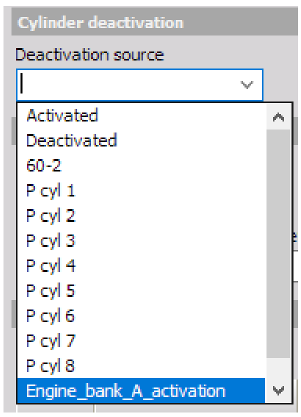
```
-360.0 -359.9 -359.8 -359.7 -359.6 -359.5 -359.4 -359.3 -359.2 -359.1 -359.0 -358.9 -358.8 -358.7 -358.6 -358.5 -358.4 -358.3 -
0 -0.008232752071578597 0.008790352417104809 0.010209792838583394 0.0060801477375084165 0.0017462596176542346 0.003417854312203
1 0.0917672479284214 0.10879035241710482 0.1102097928385834 0.10608014773750843 0.10174625961765424 0.1034178543122036 0.095776
2 0.0017672479284214036 0.01879035241710481 0.020209792838583394 0.01608014773750842 0.011746259617654235 0.013417854312203596
```

Image 14: Text file example

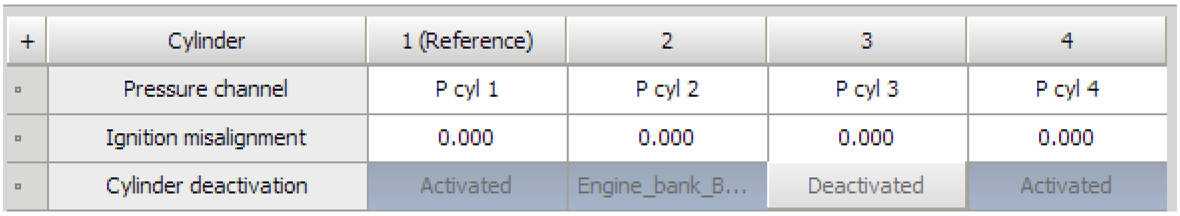
3. Engine template: Volume can also be defined by custom formula in the xml file for the engine template. Refer to the engine template chapter for definition.

Cylinder deactivation has three options:

- **Activated:** cylinder permanently activated.
- **Deactivated:** Cylinder permanently deactivated.
- **From channel:** Channel can be used to activate or deactivate a cylinder. If channel value is lower or equal than threshold value, the cylinder is deactivated.



Cylinder deactivation has two purposes - to ignore deactivated cylinder results for average value calculations (MEP, work, power, torque, thermodynamics) if a cylinder is actually not firing. It can also be used if one of the pressure sensors is faulty. That cylinder can be deactivated permanently and the setup doesn't have to be reduced by one cylinder. This can also be done offline and the file simply recalculated if one of the sensors seems to be out of range. It is possible to set activation for each cylinder separately. If a cylinder is deactivated, there is going to be an additional average output available for all deactivated cylinders combined.



+	Cylinder	1 (Reference)	2	3	4
▫	Pressure channel	P cyl 1	P cyl 2	P cyl 3	P cyl 4
▫	Ignition misalignment	0.000	0.000	0.000	0.000
▫	Cylinder deactivation	Activated	Engine_bank_B...	Deactivated	Activated

Image 15: Activated, deactivated and From channel Cylinder deactivation selections

Zero point correction is used to correct the pressure of charge pressure sensors each cycle. Dewesoft combustion analyser supports three different correction principles and it is possible to set different correction principles for each cylinder if a mixed type of pressure sensors are used.

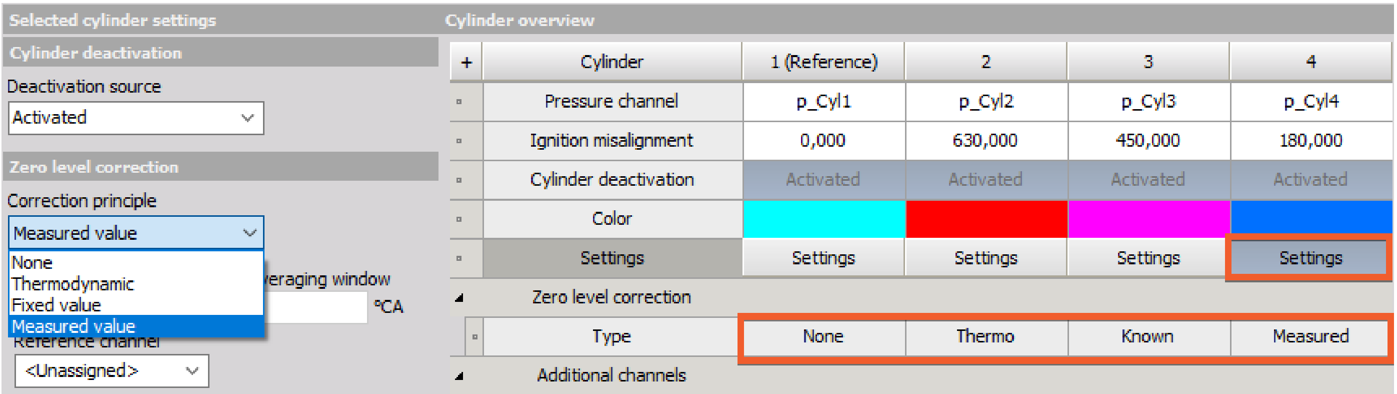


Image 16: Zero level correction principles

Thermodynamic zero:
With this method, two points (default -100, -65deg) of the pressure curve, the volume and pressure are measured. Out of the volume and pressure difference, and the entered polytropic coefficient, intake pressure is calculated. The pressure curve is shifted (offset only) to get the right pressure at First point (-100°CA).
The zero correction offset is also provided as a result output, for each cylinder as PCorrx.

From Known value:
Using this method, the pressure curve is set to a defined (static) value. "Correct" specifies the position related to TDC where it should be corrected. Usually the angle is set when the intake valve is fully opened and the piston at its bottom-most position. In case of a naturally aspirated engine, atmospheric pressure multiplied by engine efficiency is entered.

From Measured Value:
For this method a pressure sensor is used which measures the absolute pressure at the inlet manifold of the engine. From the template we can define where the inlet pressure should be measured related to TDC. So we can define a position where the inlet pressure is stable (near

bottom dead center). “Correction at”, defines the position on which the pressure should be corrected. A math formula can also be used as input.

Example
A math formula can be used as input instead of direct pressure from an intake pressure sensor to reduce the pressure and account for pumping losses. A CAN channel can also be used with pressure information directly from the ECU by making a math formula and converting the channel to synchronous.

Additional channels can be applied to each cylinder. These channels are aligned with the corresponding cylinder and will be available in the CEA-Scope diagram. As an example you can also apply the fuel pressure signal or current probe in order to display it together with the pressure signal. By clicking on the settings button for each cylinder separately, additional channels can be added on the left side by clicking on the ‘+’ button. All signals that are added as additional channels will be recalculated into the angle domain and available on the CEA scope to be compared together with cylinder pressure. Additional channels are also shifted for the ignition misalignment angle that is specified for the cylinder which has the corresponding additional channel.

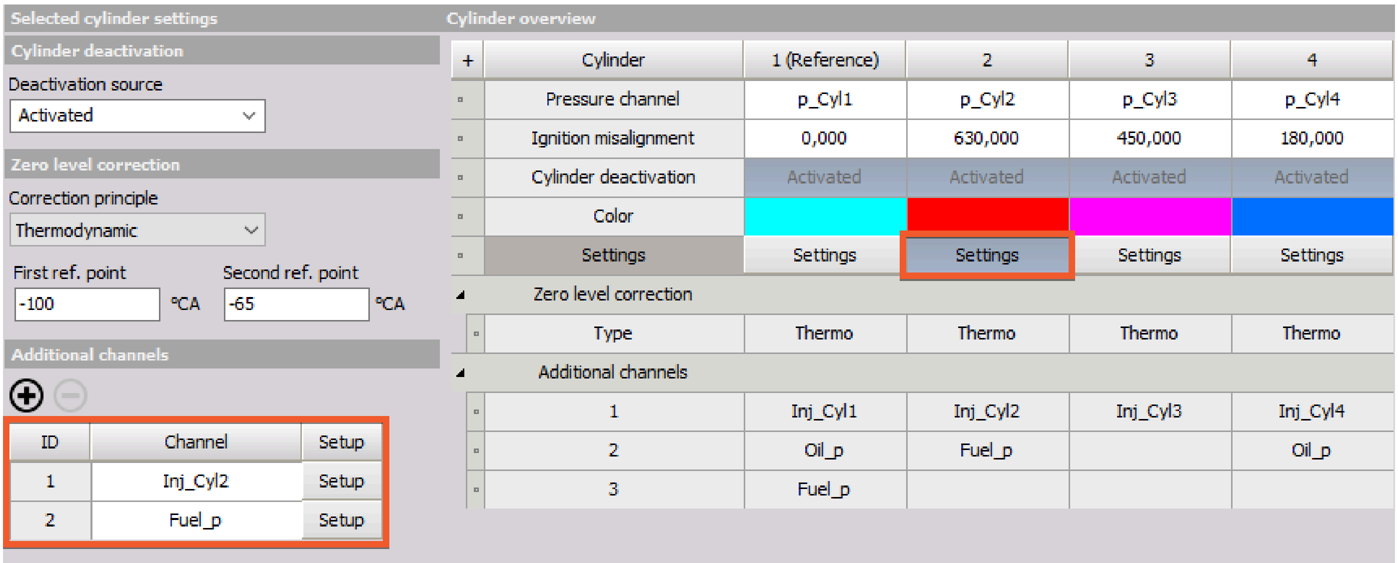


Image 17: Definition of additional channels

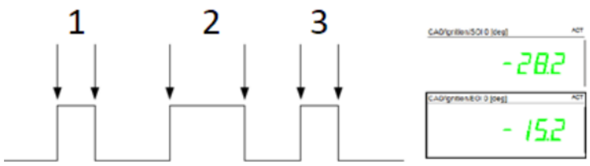
In this example below an injection signal is applied. The number of injections (events) is set to 3, and the start trigger level is set to 2V, where end trigger level is set to 1V. Each time the injection signal crosses 2V it will return the angle position, related to the cylinder where it is applied [deg]. Number of injections needs to be set to generate the output channels in advance. The result will be the start angle and the stop angle [deg] of the applied signal.

Example
Number of injections (events) needs to be set to generate the output channels in advance. If there is only one injection and max. No injections is set as 5, only the first SOI and first EOI will show an angle that is detected, all other results will be 0. Similar is also

the other way around, if there are 5 injections and there is only 1 injection set as the maximum number, only the first will be detected and all others will be ignored.

The same is true for EOI: if the signal crosses 1V (neg. edge) the position will be returned[deg].

The unit of the trigger levels are related to the channel scaling on the analogue input. In this case Ignition is scaled in voltage [V].



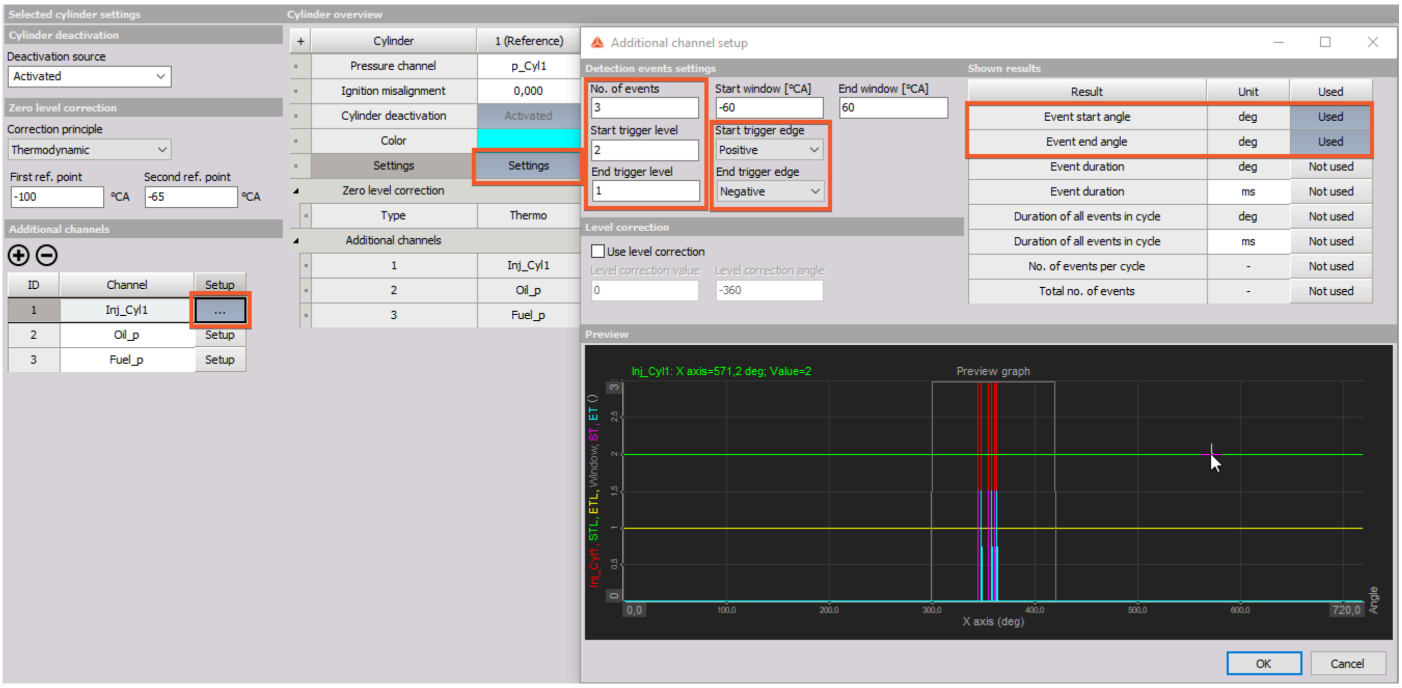


Image 18: Start and end of injection definition

The first number in the result name is the event number, the second number is the cylinder number.

Engine database (previously engine template) option is used to save the configuration made in the engine settings tab. A new template can be added with the 'add' button, renamed and then saved.

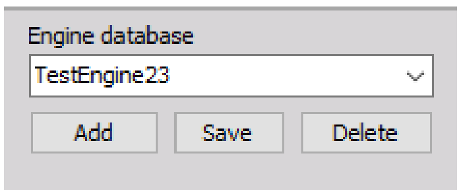


Image 19: Saving and choosing engine templates

All templates are saved in [Dewesoft installation folder]\System\CAEngines.xml

7.2 Encoder settings

The sampling type of the Dewesoft CEA is always the time domain. This has the advantage that all time domain related functions are not influenced by changes of the sample rate due to speed of the engine, and will stay the same.

For example a power calculation is only working in time domain (fixed sampling rate). Of course CEA is still calculated in the angle domain, and the CEA data will be recalculated into the angle domain. The required high calculation power for recalculating time based signals into angle based is spread over all available CPU cores of your PC.

Main advantage of time domain data acquisition is that signals acquired can also be used for noise, vibration, power and other NVH applications. Angle domain data is recalculated online and available for monitoring during measurement or to be used by other modules or mathematics. It is also possible to change any setting in the CEA module if analog data is stored and recalculate existing datafiles (even all at once by using changes made to only one of the datafiles if they are made with the same setup).

7.2.1. Sensor and sampling setting

Define the input for the angle sensor. Nearly all sensor types are supported. The main condition for CEA is that the angle sensor needs to have some reference pulse each revolution. The drop-down list will automatically show all suitable sensor-types from the counter database.

Hint
The most commonly used sensors are predefined in the angle sensor setup. But if a used sensor is not available in the list, it can be added in the counter sensor editor of DEWEsoft.

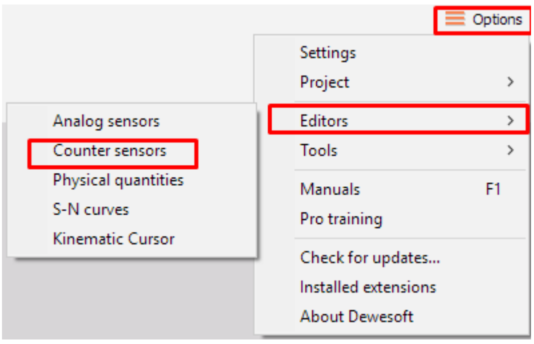


Image 20: Adding and editing counter sensors

Supported sensors are:

Encoder: Encoders can be connected to counter input and X1, X2 or X4 mode can be used.

CDM with zero pulse or gear tooth with zero pulse: Similar as the encoder but with one signal input and a one pulse per revolution signal. A gear tooth can be used if one additional sensor is installed that provides one pulse per engine revolution. Input can be connected to counter input only. For converting analog to digital, the DS-Tacho1 can be used. With an adapter cable also two of them into the same counter input to get CDM+trigger. For using an AVL optical encoder with LVDS signal, an interface box can be supplied to connect the encoder.

Gear Tooth with missing teeth: Completely custom sensors can be defined, not limited with the number of gaps, teeth between gaps and number of teeth between gaps.
If an asymmetric sensor with multiple gaps is defined, only digital input can be used. For sensors with one gap, analog input is also allowed.

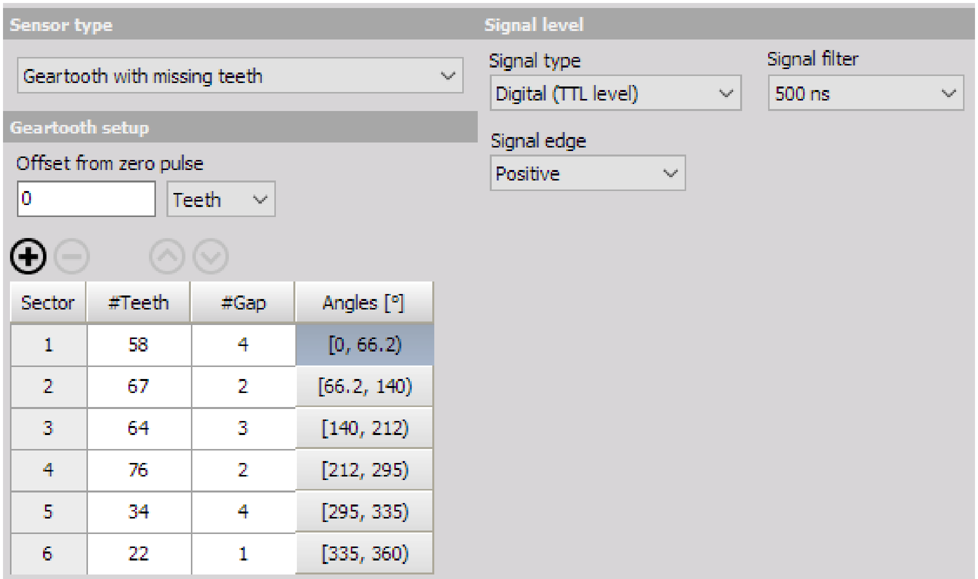


Image 21: Defining an encoder sensor

Gear Tooth with double teeth: Only one double tooth is possible. Input can be analog or digital.

Tacho: Needs to be enabled in experimental settings of Dewesoft under:
Options → Settings → Advanced → Experimental → Support for tacho in CEA (restart is required to apply changes)

Hint
Only input channels which are used (switched on) can be selected. Sensors with signal type “analog” can only be connected to analog input channels. Sensors with signal type “digital” can only be connected to counter input channels.

Under properties, fine adjustment for the angle sensor must be done. In case of **analogue sensor** selection the trigger levels can be precisely adjusted. First the trigger edge is defined, according to the signal. Also trigger and retrigger levels are set. It is recommended to use a retrigger level to avoid false triggers. False triggers will disturb CEA operation, and cause incorrect angle information.

Retrigger: After a trigger occurs, the retrigger level must be crossed, so that the trigger is armed again. Thus noise around a trigger will not cause any false triggers.

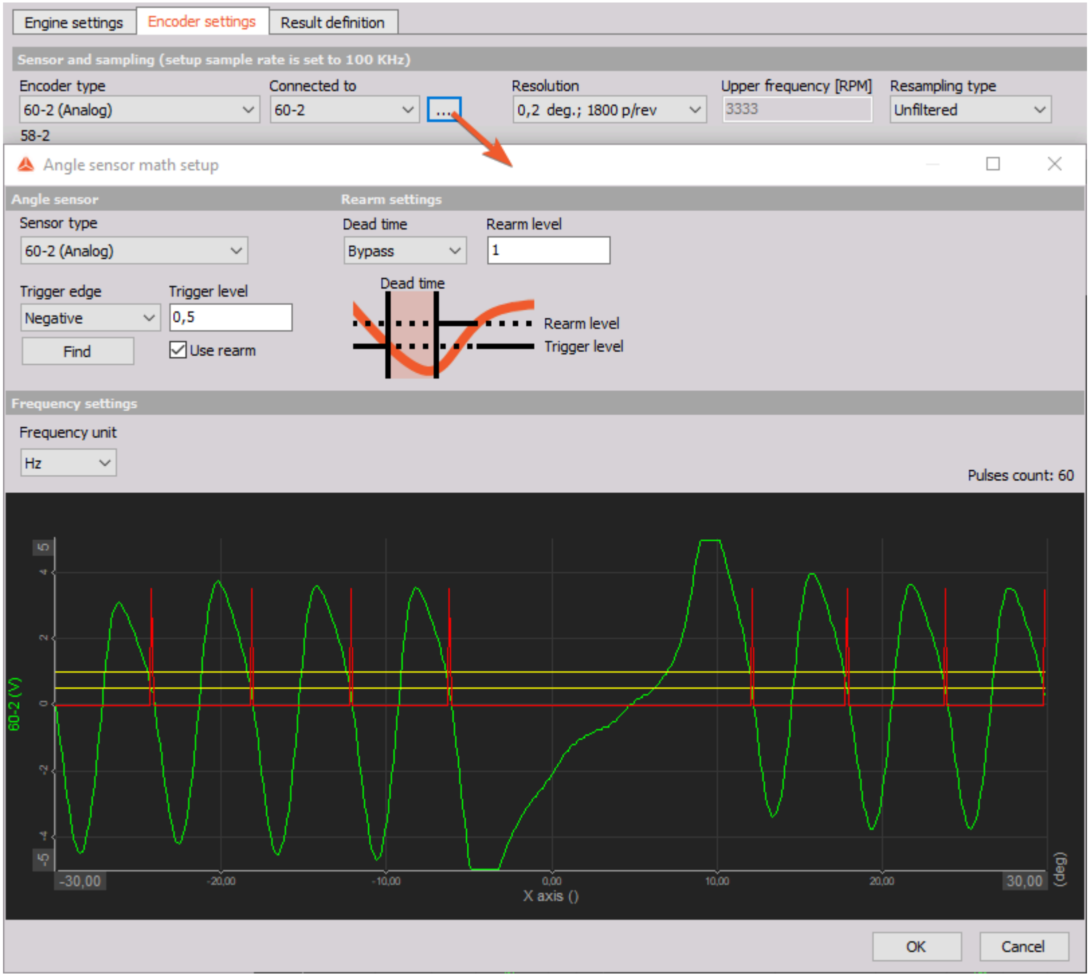


Image 22: Editing trigger levels and other parameters of selected encoder sensor in CEA module

Important
Take care about the correct trigger edge. The difference between the available options is shown below.

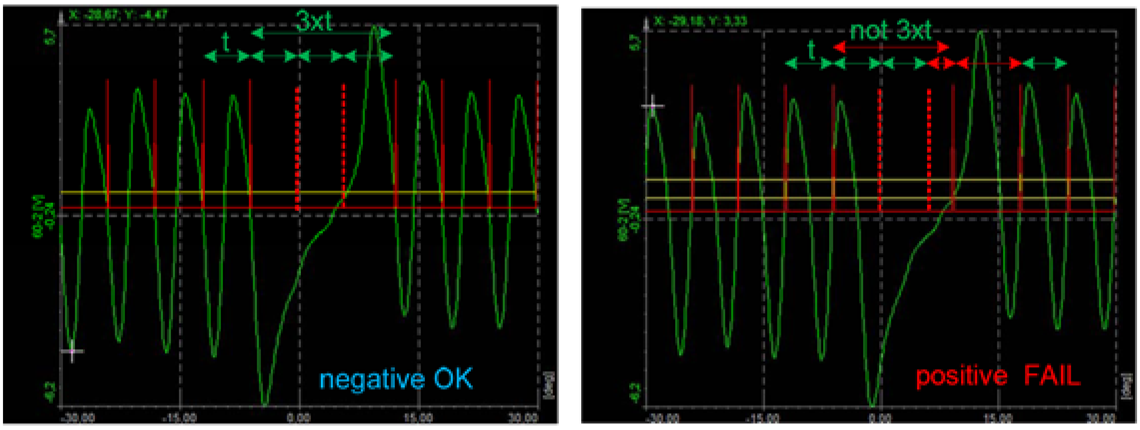


Image 23: Checking the defined triggers

If a **digital sensor** is selected, the property will open the counter channel setup of the sensor. This is convenient, because you can define the trigger: e.g. you can invert the signal input or apply an input filter to avoid double triggering.

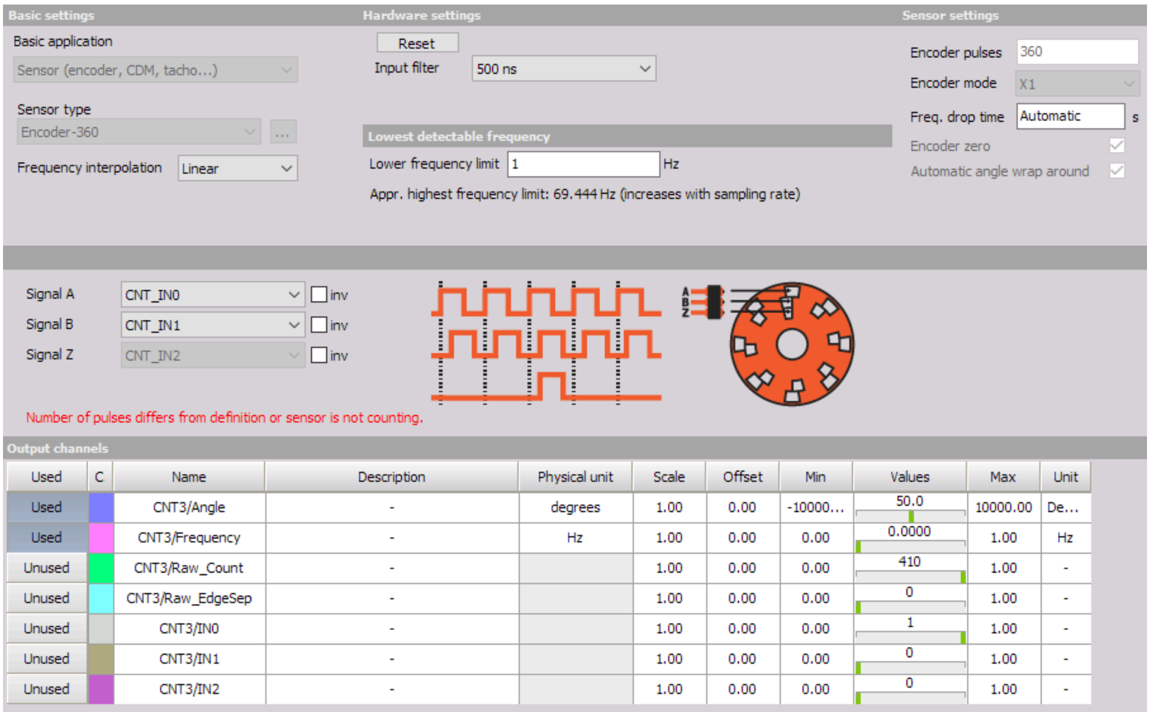
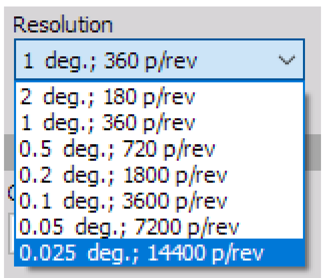


Image 24: Encoder settings view

The next step is to define the target **angle resolution** for the combustion analysis mathematics. The Upper frequency is limited by the selected resolution and the dynamic acquisition rate in the Analog channel setup.

Take care about this limit to avoid aliasing effects by the re-sampling algorithm.



As a **resampling** type an unfiltered method can be selected which is linear interpolation from the time to the angle domain. The filtered type is based on a FIR polyphase decimator with a filter frequency of angle resolution * 2 to avoid aliasing effects in the angle domain data.

Important
Use best judgment to select the angle resolution that is needed since 0.025deg angle resolution will create huge amounts of data and also require highest sampling rates.

7.3. TDC detection

Top dead center detection is used to shift the reference cylinder pressure to 0deg. The offset between angle sensor zero and TDC position of the reference cylinder is called trigger offset. This can be entered manually, or it can be measured.

Important
If you don't choose the reference-cylinder as “Cylinder for TDC” , then the ignition misalignment value in the engine setup table will be adjusted to the measurement value. This adjustment can be performed for all cylinders at once as well.

After every TDC detection measurement the date and time will be shown under Trigger offset.
This data will be also stored in the setup and data file.

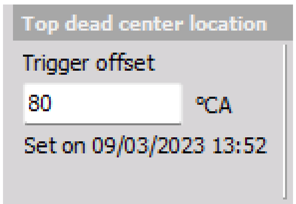


Image 25: Date and time of the last TDC detection measurement

7.3.1. TDC detection in channel setup

7.3.1.1. TDC detection with a pressure sensor

In the Illustration below you see the angle offset of a not fired engine (cranked). This offset can now be entered manually or automatically measured and applied.

For automatic measurement (Start), the no of cycles has to be entered. CEA will measure the average offset of the set of cycles automatically. The Maximum pressure will appear before the real TDC of the piston, which is caused by thermodynamic losses and blow by. That’s why the measured value is corrected with the thermodynamic loss angle.

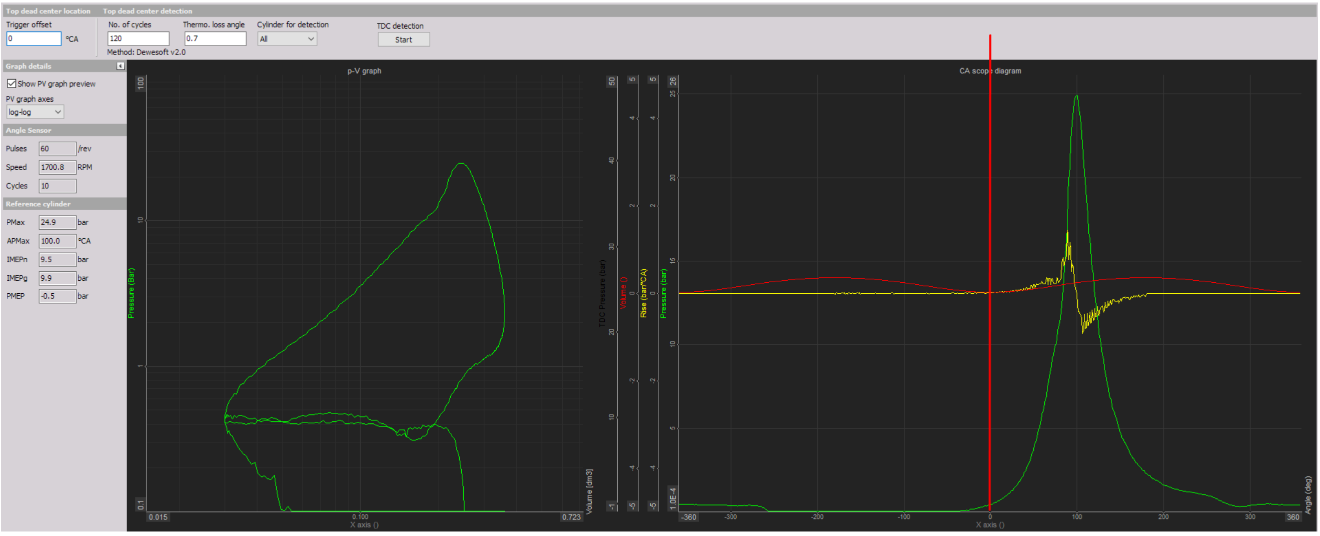


Image 26: Top dead center is not aligned, therefore TDC detection required

After TDC detection is finished, the average value (which includes the Thermodynamic Loss angle) will be set automatically for the trigger offset.

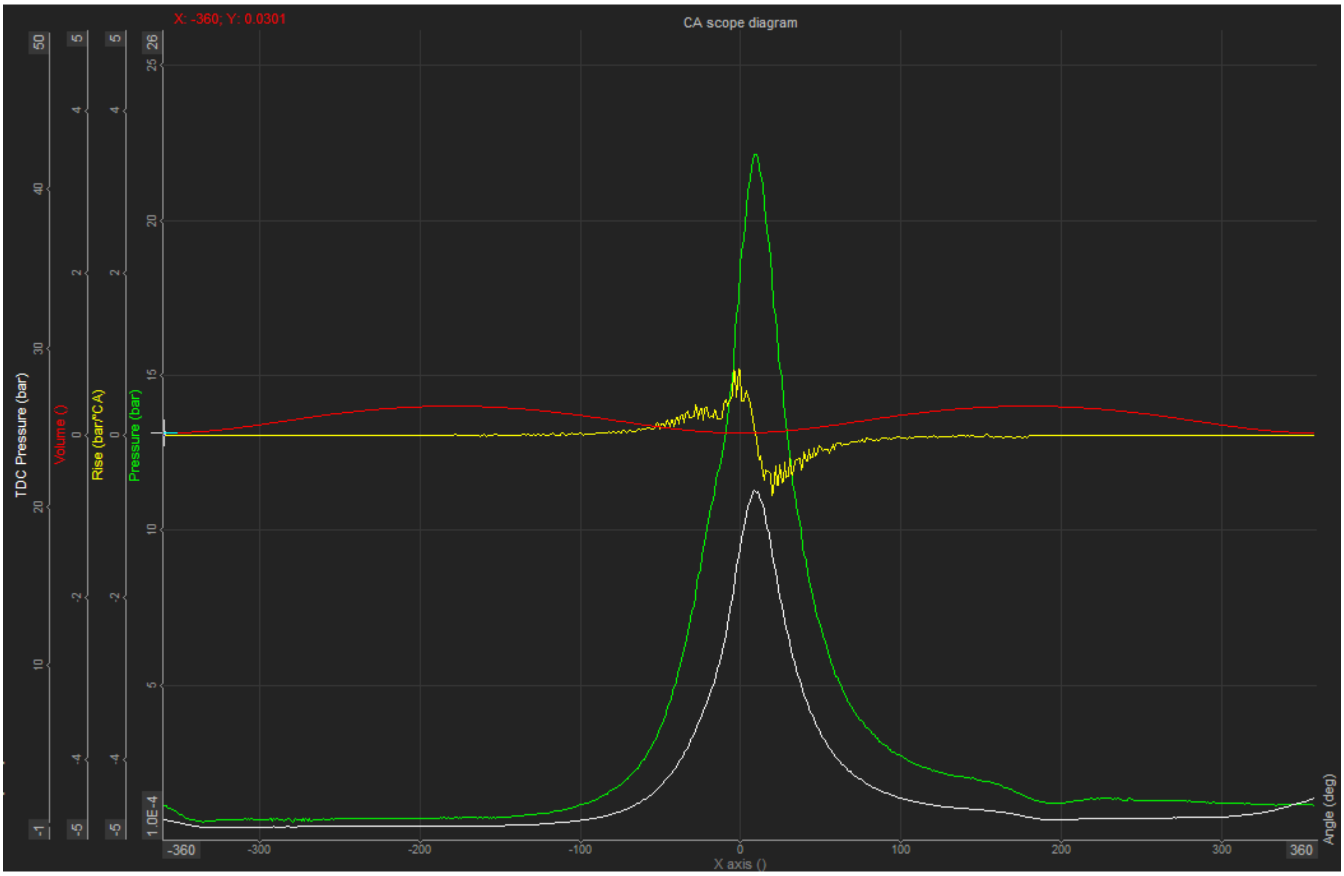


Image 27: TDC detection done properly

7.3.1.2. TDC detection with position sensor

Instead of a pressure sensor, a TDC sensor can be used. The TDC sensor must be connected to an analogue input and assigned to the reference cylinder in the CEA setup. The thermodynamic loss angle must be set to 0, and the automatic TDC detection can then be started again. After the measurement the pressure channel must be set in the CEA setup again.

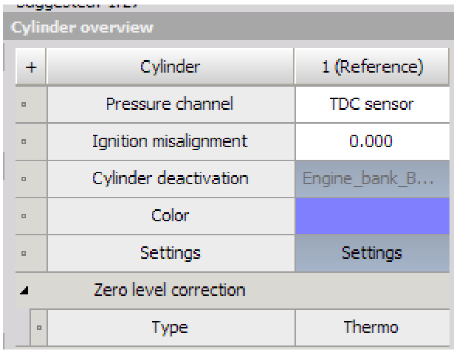


Image 28: Instead of a pressure channel, a TDC sensor can be used and must be connected to an analog input and assigned to the reference cylinder. The thermodynamic loss angle must be set to 0, and the automatic TDC detection can then be started again.

7.3.2. TDC detection in measure mode

When performing TDC detection in measure mode the “TDC mode in measure” must be checked.
The predefined display will offer 3 user input slots for: TDC start/stop, TDC cylinder index and TDC cycle count.
On the right side of the measuring screen there is a tabular values display named after the reference cylinder (usually Cyl1 (Ref) TDC info).
Below is a 2D graph showing the results of the TDC detection procedure.

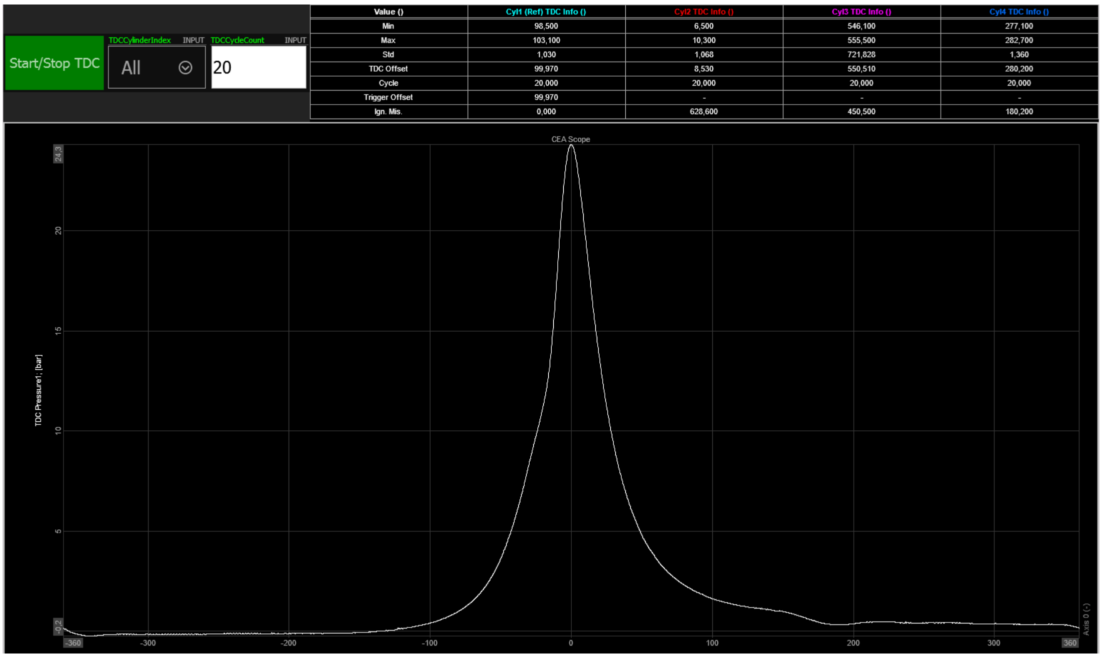


Image 29: TDC measurement in measure mode

TDC Detection in measure mode is the only way to do a TDC correction when the pressure and angle signals aren't measured with the same HW slice. (Synchronization of the devices isn't present in ch. setup mode)

7.3.3. TDC detection with combustion (industrial 2-stroke engines)

When using the 2 stroke industrial engine mode in Dewesoft CEA, the TDC can be made with delayed combustion.

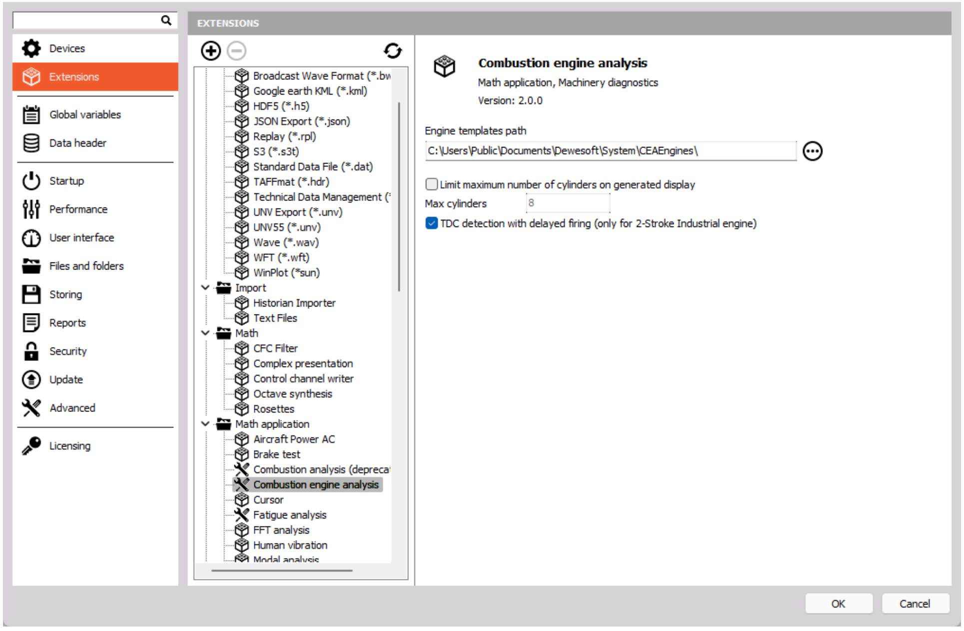


Image 30: Enabling TDC with delayed combustion

7.4. Result definition

7.4.1 Results common settings

7.4.1.1. Unified settings

From DewesoftX version 24.1 onwards the CEA module offers an unified settings.
Unified settings offer one setting for all Cycle based calculations and Step to be defined by one unified value for all dependent calculations.

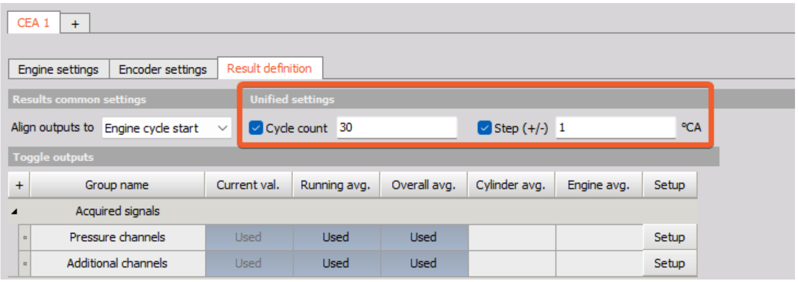


Image 31: Unified settings definition

7.4.1.2 Aligning CEA outputs to the end of the engine cycle

From DewesoftX version 24.1 onwards the CEA module has a new set of settings, called Results common settings. Outputs can now be aligned to the Engine cycle start, which will align all calculated results to the start of the engine cycle, or they can choose to align the CEA outputs to Cylinder cycle start, which will align the cylinder calculations to cylinder cycle start.

Image 32: Aligning outputs to Engine cycle start

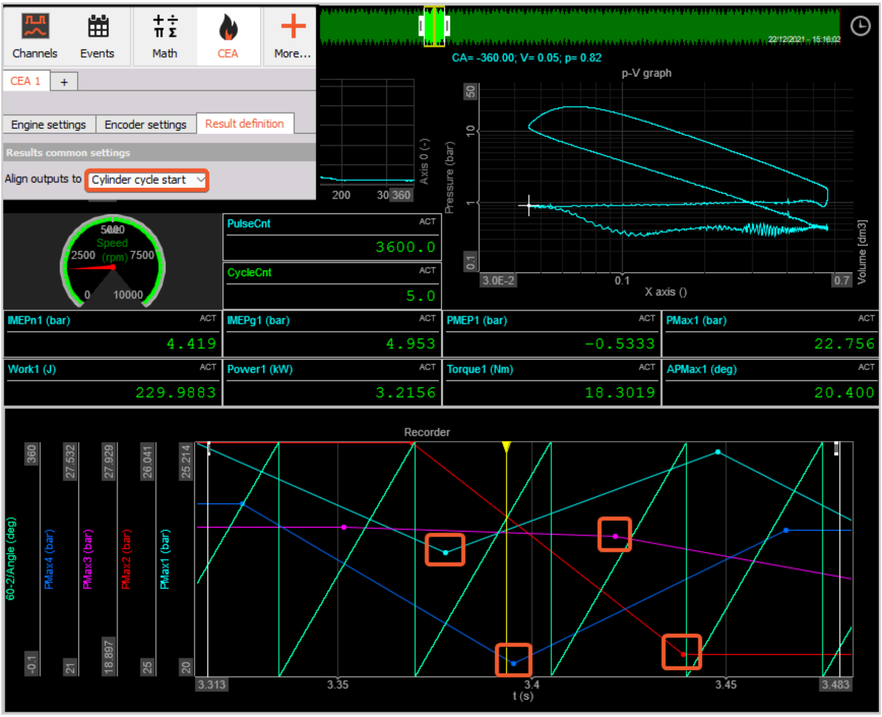
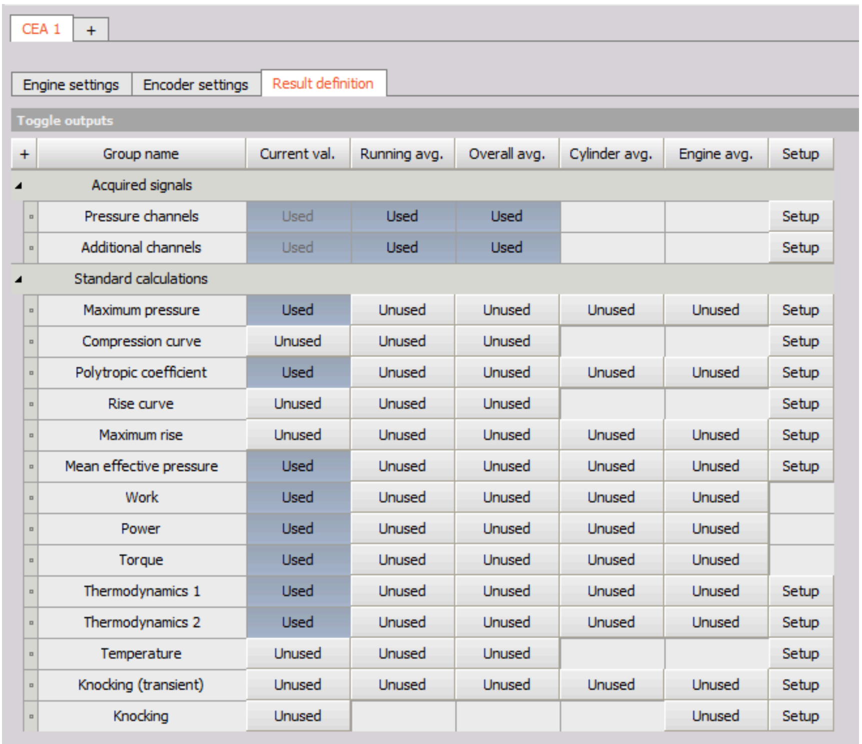


Image 33: Aligning outputs to Cylinder cycle start

7.4.1.3 Result definition table

All results and settings for outputs are grouped in a single tab and at the right side, settings can be opened for output that are configurable. As long as the analog data is stored during the measurement (default setting) then additional results can be enabled also later in analysis mode if needed.


CEA 1 | +
Engine settings | Encoder settings | Result definition
Toggle outputs

Group name	Current val.	Running avg.	Overall avg.	Cylinder avg.	Engine avg.	Setup
Acquired signals						
Pressure channels	Used	Used	Used			Setup
Additional channels	Used	Used	Used			Setup
Standard calculations						
Maximum pressure	Used	Unused	Unused	Unused	Unused	Setup
Compression curve	Unused	Unused	Unused			Setup
Polytropic coefficient	Used	Unused	Unused	Unused	Unused	Setup
Rise curve	Unused	Unused	Unused			Setup
Maximum rise	Unused	Unused	Unused	Unused	Unused	Setup
Mean effective pressure	Used	Unused	Unused	Unused	Unused	Setup
Work	Used	Unused	Unused	Unused	Unused	
Power	Used	Unused	Unused	Unused	Unused	
Torque	Used	Unused	Unused	Unused	Unused	
Thermodynamics 1	Used	Unused	Unused	Unused	Unused	Setup
Thermodynamics 2	Used	Unused	Unused	Unused	Unused	Setup
Temperature	Unused	Unused	Unused			Setup
Knocking (transient)	Unused	Unused	Unused	Unused	Unused	Setup
Knocking	Unused				Unused	Setup

Image 34: Result definition table

Depending on the group name, the column “Current” may contain angle domain or/and cycle based results. “Cylinder avg.” always has the overall average per cylinder as the result. Engine avg. are cycle based where the average of all cylinder results are calculated.

Image 35: Definition of cylinder average, engine average and current results

Two different types of averaging can be enabled. The “Overall average” gives one average vector for the complete measurement. The “Running average cycles” calculates the mean value of the last n cycles.

This basic statistics is available for the pressure and for the Additional channels of each cylinder. The result is a vector with the angle as reference.

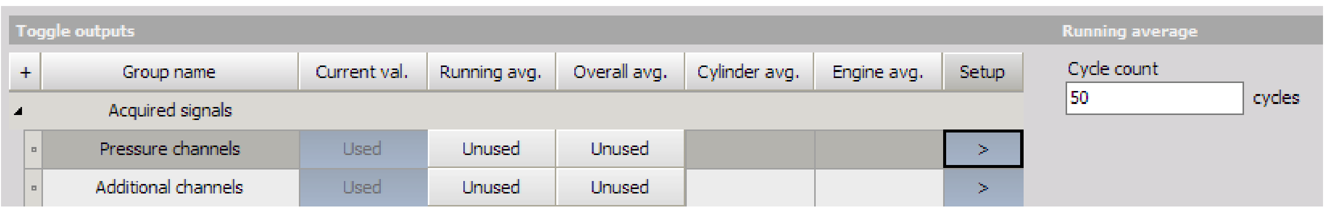


Image 36: Selecting the Cycle count for basic statistics on the pressure channels

7.4.2. Maximum pressure

Calculates the peak pressure of each cycle and angle of the peak pressure.
Output is single value once per cycle:

PMax*x* [bar] → Maximum pressure of cylinder *x*
APmax*x* [deg CA] → angle of maximum pressure of cylinder *x*

7.4.3. Compression curve

Calculates the theoretical compression curve without combustion. Reference angle needs to be set to fit the compression curve with angle set at compression, before any ignition is present.

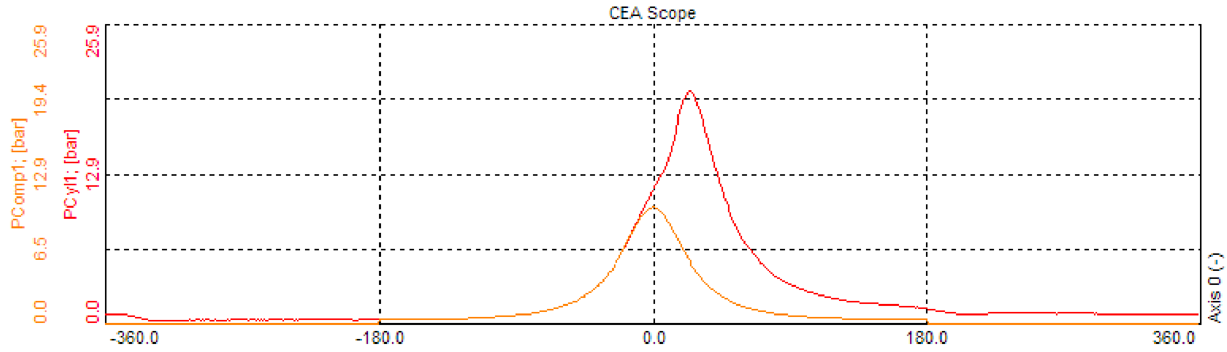


Image 37: Compression curve

Output is array channel:

PComp*x* [bar]

7.4.4. Polytropic coefficient

Polytropic coefficient can be detected as an output. Parameters for start and end of compression and combustion need to be set properly to get the correct output. It is also possible to override the manual coefficients and use the calculated output as input. This can be useful with dual-fuel engines so that the measurement doesn't have to be stopped and the exponents changed manually.

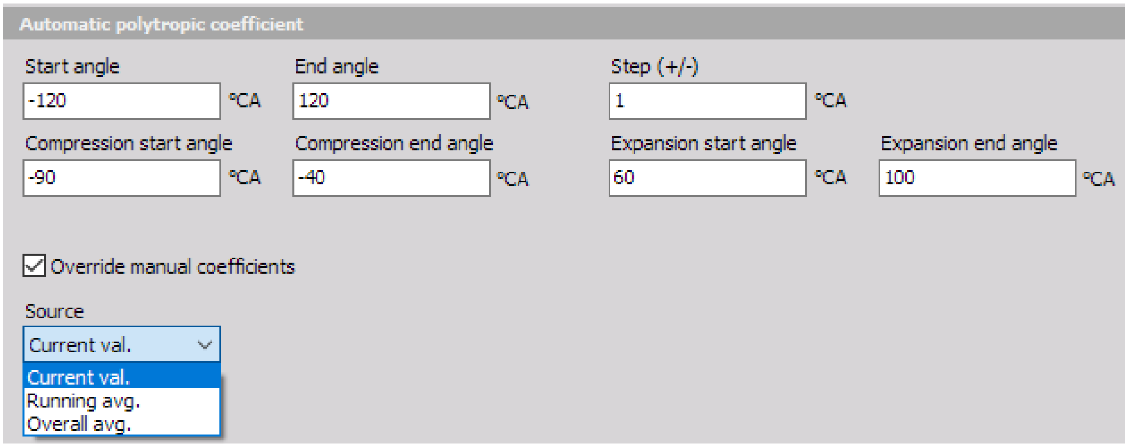


Image 38: Selecting the source of automatic polytropic coefficient definition

Output is single value once per cycle:

Polyc*x* → compression polytropic exponent of cylinder *x*
Polye*x* → expansion polytropic exponent of cylinder *x*

7.4.5. Rise curve

Rise curve is a derivative of the pressure curve.

Output is an array channel:

Rise*x* [bar/deg]

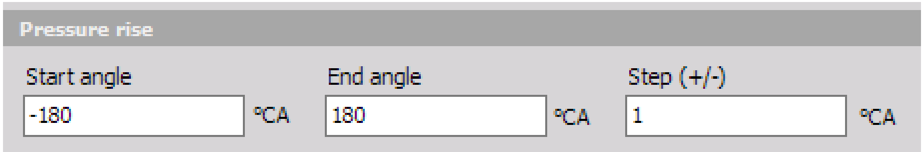


Image 39: Rise curve definition

Start and end angle can be defined for calculation and step.

7.4.6. Maximum rise

Output is single value once per cycle:

RiseMax*x* [bar/deg] → Max. pressure derivation of cylinder *x*
ARiseMax*x* [deg] → Position of max. derivation of cylinder *x*

7.4.7. Mean effective pressure

Output is single value once per cycle:

IMEPg*x* [bar] → Indicated mean effective pressure gross of cylinder *x*
IMEPn*x* [bar] → Indicated mean effective pressure net of cylinder *x*
PMEP*x* [bar] → Pump mean effective pressure of cylinder *x*

7.4.7.1. Misfire detection

DewesoftX version 24.1 and newer has a feature for detecting misfires: IMEPn / IMEPn_ravg < 0.xx e.g. 5% is 0.95 .

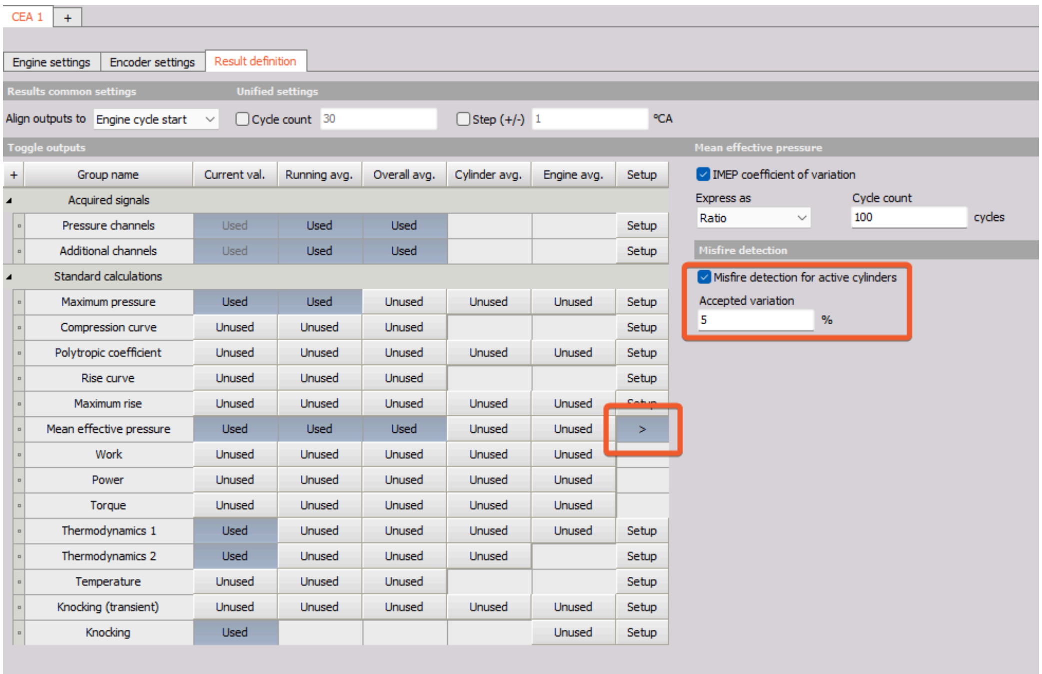


Image 40: Misfire detection setup

Misfire_detection*x* [0/1] → Detected misfire on cyl *x*

7.4.8. Work

Output is single value once per cycle:

Work*x* [J] → Work of cylinder *x*

7.4.9. Power

Output is single value once per cycle:

Power*x* [kW] → Power of cylinder *x*

7.4.10. Torque

Output is single value once per cycle:

Torque*x* [Nm] → Torque of cylinder *x*

7.4.11. Thermodynamics 1

For setting up the Heat release calculation the start and stop angle must be defined. The typical range is from -30° to +90°. An earlier injection start angle must be set according to the real injection point.

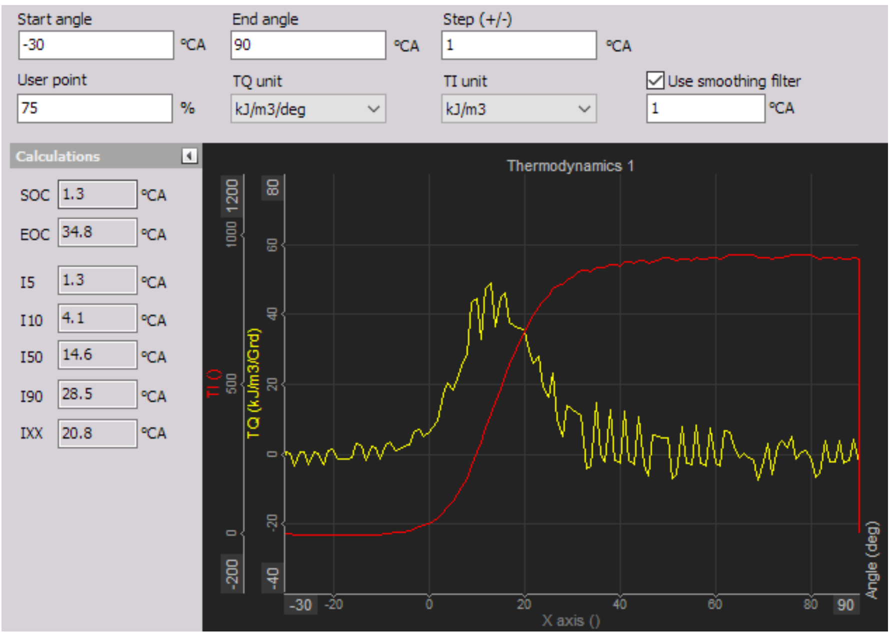


Image 41: Thermodynamics1 calculation setup

Start of combustion (SOC), End of combustions (EOC) and also the *Mass Fraction Burned (MFB)* points I5, I10, I50, I90 and Ixx (User point) are calculated if heat release is activated.

Depending on fuel type (Diesel/Gasoline) – which have been selected in the engine setup SOC is defined differently

- Gasoline where MFB =5%,
- Diesel where MFB crosses 0%.

Mass fraction burned is calculated out of integrated heat release IntQ. The maximum of the integrated heat release corresponds to 100%, and the angle positions for I5% to I90% are extracted.

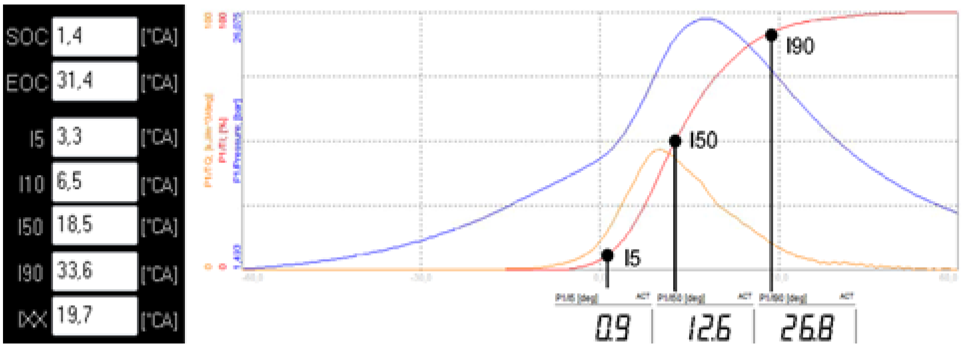


Image 42 Mass fraction burned calculation

The step input field defines the calculation width: e.g. Step 1 means the calculation is based on ±1 sample (or angle resolution value). A higher value smooths the result.

For heat release (dQ) and integrated heat release (IntQ) various units are available.

dQ: Heat release

kJ/m³/deg	related work[kJ] to 1m³ per 1 deg volume is related to Vs = swept volume
%	scaled to sum of 100% (integrated signal =100%)

IntQ: Integrated heat release

kJ/m³	work[kJ] to 1m³ volume is related to Vs = swept volume
%	scaled to maximum of integrated value = 100%

7.4.12. Thermodynamics 2

Thermodynamics2 is a combination of thermodynamics1 with a temperature calculation. It is more accurate since it has better heat prediction during the burning process. Nevertheless also more input information is needed.

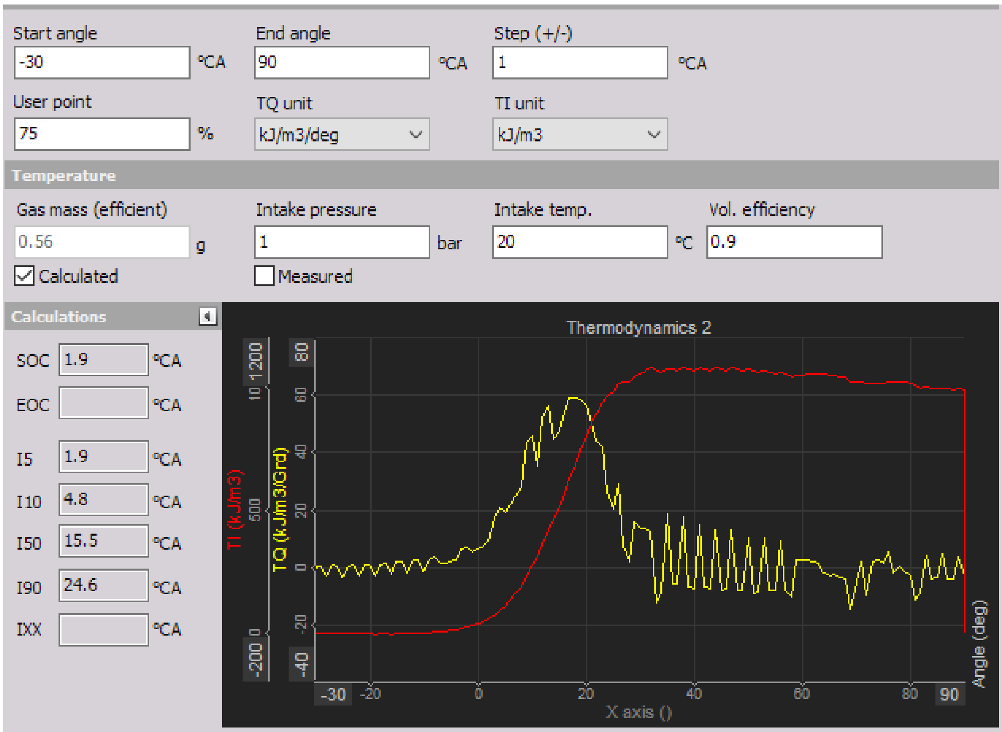


Image 43: Thermodynamics2 calculation

T2_dQ: Heat release

kJ/m³/deg	related work[kJ] to 1m³ per 1 deg volume is related to Vs = swept volume
%	scaled to sum of 100% (integrated signal =100%)

T2_IntQ: Integrated heat release

kJ/m³	work[kJ] to 1m³ volume is related to Vs = swept volume
%	scaled to maximum of integrated value = 100%

7.4.13. Temperature

For the Temperature calculation the gas mass is required. This can be either manually entered, or calculated.

If from Calculated, the intake temperature, intake pressure, and also the volumetric efficiency (0.9= 90% filled) must be entered.

If "*measured*" is selected, the intake pressure is measured from the zero point corrected high pressure curve.

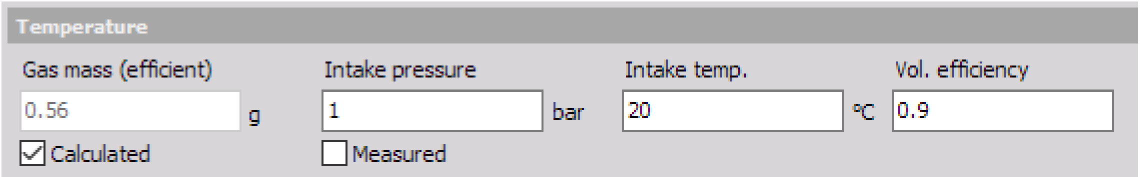


Image 44: Temperature calculation definition

Output is an array channel:

Temp*x* [K]

7.4.14. Knocking (transient)

Knocking is an uncontrolled burning of fuel in gasoline and gas engines. In normal operation, the fuel-air mixture is ignited by the spark plug and burns continuously. When the engine is knocking, a self-ignition starts causing high pressure transients, which will overload the engine mechanically and thermally. This can seriously harm the engine's parts, especially the piston. The knock detection algorithm indicates this knocking, so that the user can react to this abnormal condition.

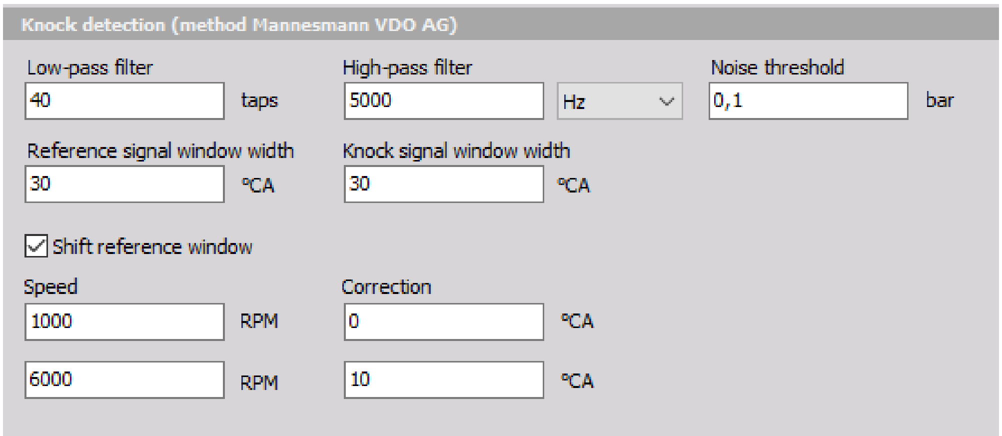


Image 45: Knocking setup definition

Knocking can be detected by extracting the high frequency component out of the cylinder pressure signal. This can be done with a high pass filter. The knocking frequencies are typically between 5 kHz – 12 kHz.

The high-pass (HP) filter and rectified (red) extracts frequency components which are above the cut-off frequency.

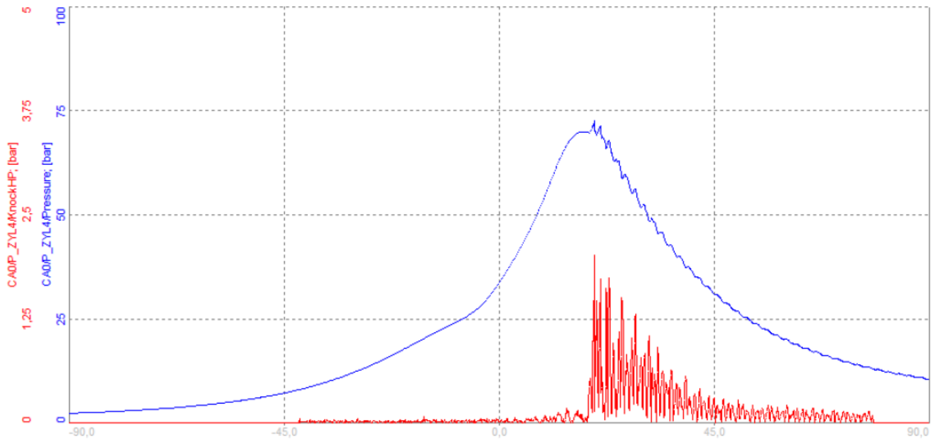


Image 46: Pressure fluctuations shown on the falling slope of the pressure curve (blue)

In comparison to the Illustration above, we can see pressure fluctuations on the falling slope of the pressure curve (blue). The combustion pressure curve can reach very high pressures >>100 bar, so sometimes it is hard to observe it on top of the main combustion pressure curve. If we only extract the high frequency components above 5000 Hz we can analyze knocking much easier. The high-pass filtered pressure signal (red line) indicates the pressure fluctuation around the maximum of the pressure curve.

Another important value is the maximum pressure of this high-pass filtered signal (red), which can be extracted and visualized in a recorder display, immediately reflecting the pressure transients of the previous cycles.

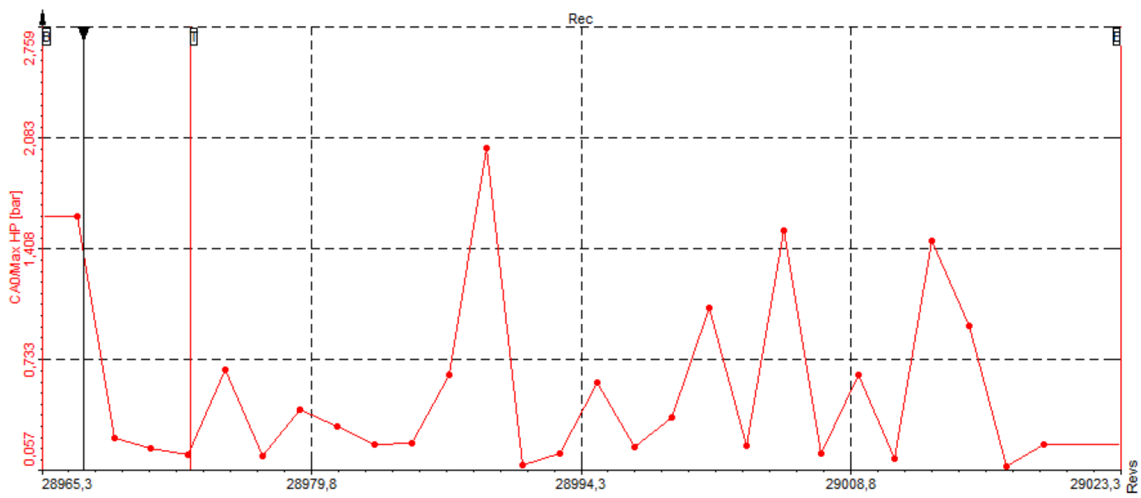


Image 47: Maximum pressure of high-pass filtered signal (red) is immediately reflecting the pressure transients of the previous cycles.

This value is a good indication of knocking, but in some circumstances it can show incorrect information. If the pressure curve is very noisy, or a spike (caused by some external electrical signal) is present, the maximum value extracted out of the high-pass filtered signal shows high values, which are not related to knocking.

Knocking typically starts at or after the pressure maximum, and continues on the falling slope of the pressure signal. So instead of taking only one value (peak), we could integrate the high-pass filtered signal of the negative part of the pressure slope.

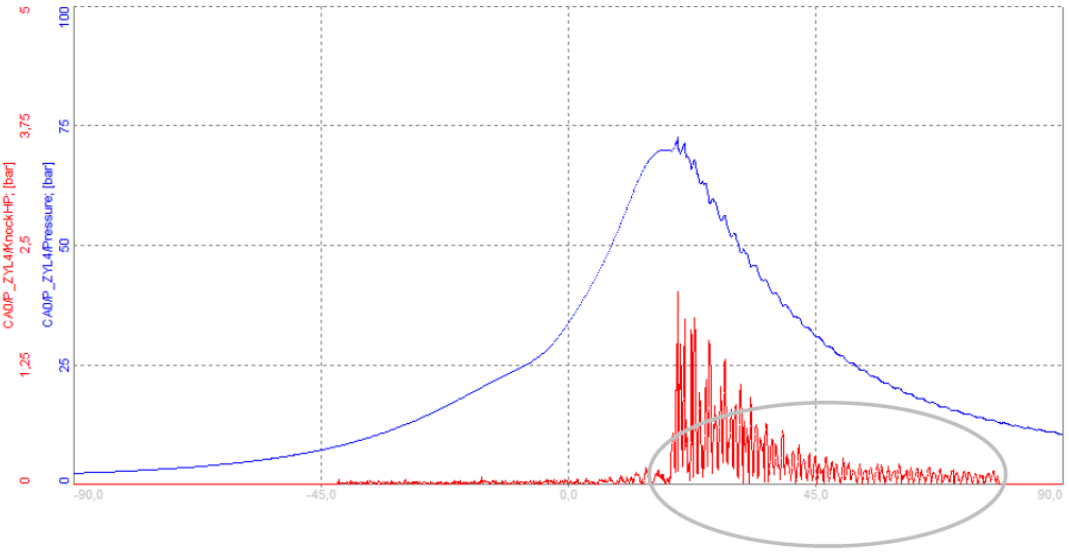


Image 48: Knocking typically starts at or after the pressure maximum, and continues on the falling slope of the pressure signal. So instead of taking only one value (peak), we could integrate the high-pass filtered signal of the negative part of the pressure slope.

This integrated value (knock integral = KI) will give a more stable value for single transient noise peaks. The high-pass filter outputs the absolute pressure (positive values only). So, if we integrate the signal, we can reject a single transient, but will also sum up the noise which may be present all the time. Depending on the engine speed, the noise will also increase which in turn will cause an increase of the integrated signal. With a single integration it will be hard to determine if it is knocking, or simply noise?

To prevent this, the integration can additionally be done before the maximum pressure, so that the results before and after the maximum can be compared.

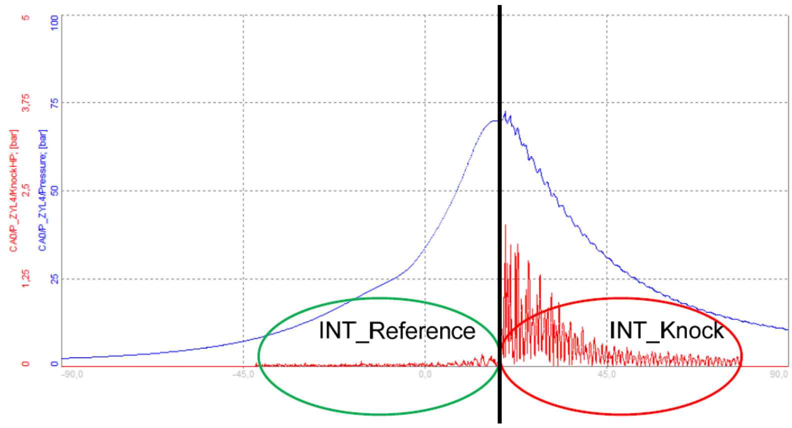


Image 49: Knock factor calculation is done directly from INT_Reference and INT_Knock

KnockFactor = INT_Knock / INT_Reference

So the KF will give a weighted result related to knocking.

Without any knocking present the KF is around 1. The integration windows (reference window; knock window) will separate at the average maximum pressure position.

The example below this paragraph shows the pressure curve (blue) and the high-pass filtered and rectified signal (red) in the diagram at the top. And then, the maximum pressure extracted from the high-pass filtered signal (red) and the calculated KF (orange).

Both maximum graphs show peaks, so knocking is present and could be detected in either way – as long as no spikes are present.

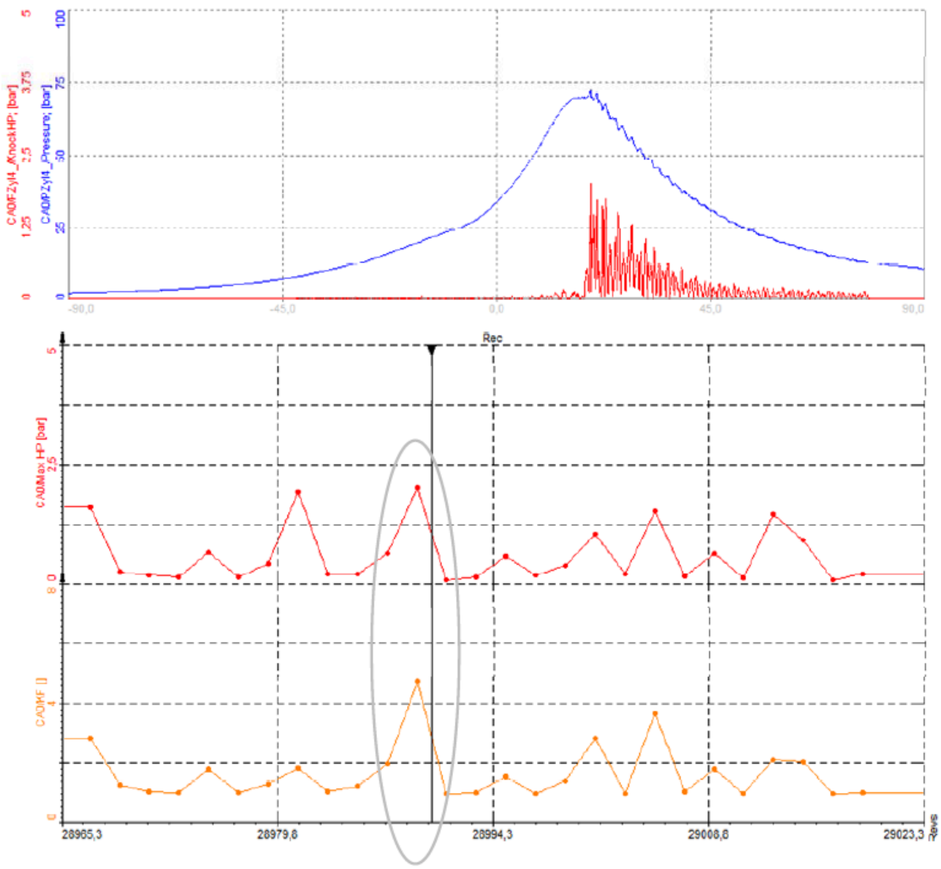


Image 50: The example shows the pressure curve (blue) and the high-pass filtered signal (red) in the diagram at the top. And then, the maximum pressure extracted from the high-pass filtered signal (red) and the calculated KF (orange).

Some cycles before we can see an error spike (red curve). While the maximum of the filtered signal still shows a peak here, the KF algorithm does not indicate knocking at all, and the value obtained is close to 1.

This way DEWESoft® can provide robust knock detection, even if there are accidental spikes in the signal.

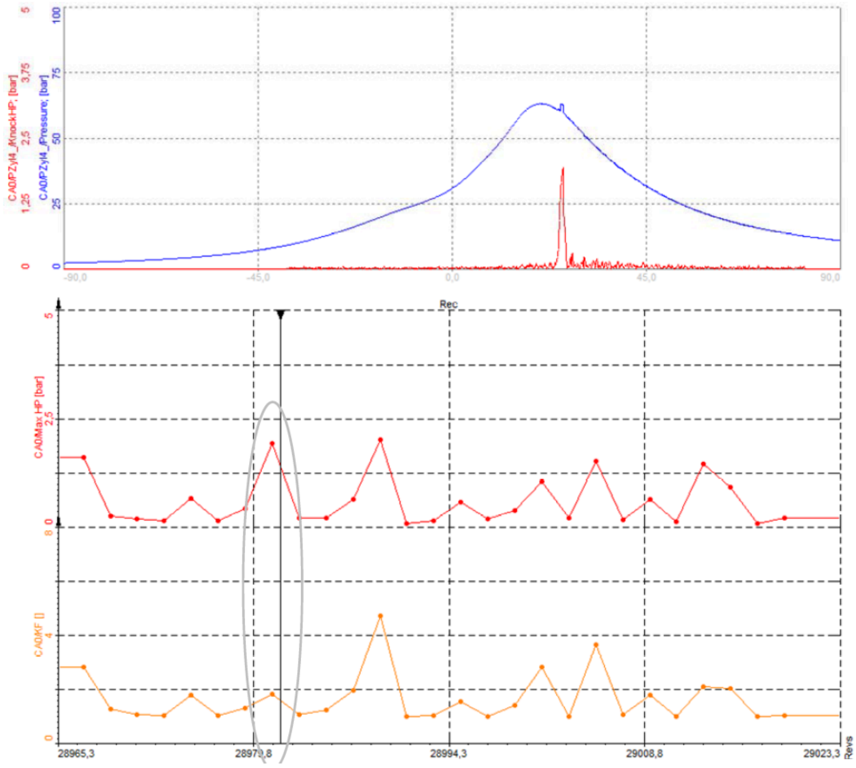


Image 51: Some cycles before we can see an error spike (red curve). While the maximum of the filtered signal still shows a peak here, the KF algorithm does not indicate knocking at all, and the value obtained is close to 1.

The next example shows a very noisy pressure signal. The KF (orange) will stay around 1, because integrated noise is similar in the reference (green) window and knock (red) window.

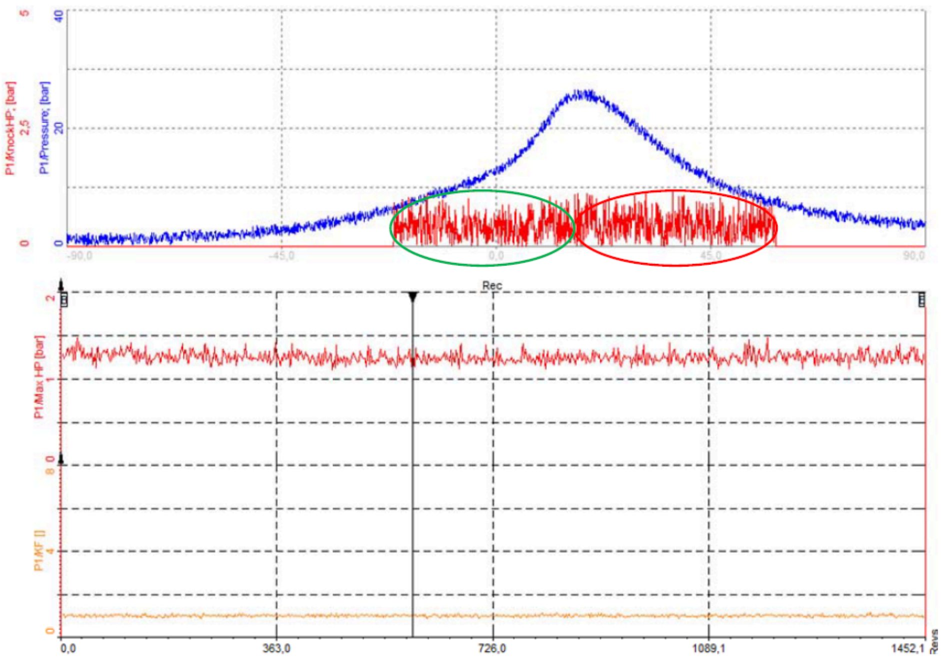


Image 52: Dewesoft X provides robust knock detection

7.4.13.1. Setup the algorithm (Mannesmann VDO AG)

The previous chapters have described which signals can be obtained from the knock detection algorithm:

- HP filtered pressure signal
- Maximum value of HP filtered pressure signal
- Knocking factor

Below you can see the settings for getting the knocking factor.

Low-pass filter: The reference window and the knocking window are separated at the maximum pressure point (red curve), without the influence of noise or already present knocking peaks. A running average filter is used here, with setup taps corresponding to the angle resolution. If the angle of the CA is set to 0.2 deg and 40 taps are used, we get a moving average window (smoothing) of 40*0.2 deg= 8 deg.

The reference window position is taken from the pressure curve maximum pressure position and angle before or after is calculated from that angle.

recommended value [deg]: 4-10 deg → Info TAPS = deg/angle resolution!

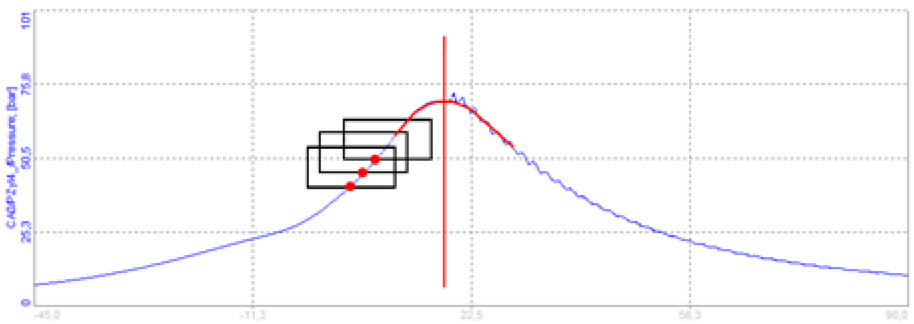


Image 53: The reference window and the knocking window are separated at the maximum pressure point (red curve), without the influence of noise or already present knocking peaks

High-pass filter: Here the high-pass filter frequency is set in Hz. The pressure curve is high-pass filtered and rectified (blue) and the result can be shown in the CEA-Scope. The channel is named CylinderChannelname/KnockHPMax.

recommended value [Hz]: 5000 Hz

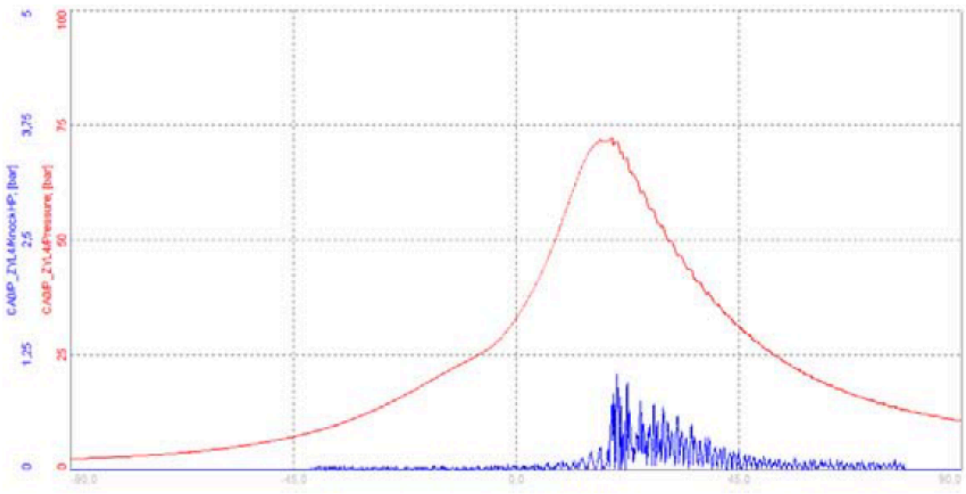


Image 54: The pressure curve is high-pass filtered (red) and the result can be shown in the CEA-Scope

Background information about high pass filter:

The cylinder pressure channel is already present as an angle domain result. So the time between the samples varies with the engine speed. Since we need to set the high pass filter cut-off frequency in Hertz, a conventional IIR would not work.

The high-pass filter is created from a moving average window with a specific width, which is subtracted from the original signal, and (as for all filters) a minimum sampling rate is required for the filter to work properly:

*minsamplerate [Hz] >= high-pass frequency [Hz] * 4.5*

With the high-pass filter set to 5000 Hz a sampling rate of at least 22,500 Hz is required. With an angle resolution of 0.1° (3600 pulses per revolution) we need 375 rpm to get to this sample rate.

*Engine speed [rpm] = Sample rate [Hz] / pulses per revolution * 60 = 22500 / 3600 * 60 = 375*

In the table below the minimum engine speed is shown depending on resolution and a set HP filter of 5000 Hz.

resolution [° CA]	HP Filter [Hz]	Min. engine speed [rpm]
0.1	5000	375
0.2	5000	750
0.4	5000	1500
0.5	5000	1875

Important
If the engine speed is lower than required, the HP filter will be set to a lower frequency until the minimum engine speed is reached!

Noise threshold: For the Knock Factor, the quotient of the integrated signal of the Knock window and the Reference window is obtained. If the pressure value is lower than the specified threshold, then the threshold value will be used for integration. This is done to reduce the influence of different base-noise levels between the reference window and knocking window.

recommended value [bar]: 0.1 – 0.5 bar

Reference, Knock signal window width: The width of the reference window and the knock window is defined here. It is recommended to set both windows to the same length. If this is done and the noise threshold is set to a reasonable level, the KF will be about 1 without knocking. If the window sizes are set differently, the base value without knocking is the quotient between the two window lengths.

reference window size [° CA]	knocking window size [° CA]	Knocking factor KF, base value
30	30	1
60	30	0.5
3	60	2

Shift reference window: At higher RPM it can happen that knocking already starts before maximum pressure. In this case, part of the knock signal will fall into the reference window area, which reduces the knocking factor value. To avoid this, the knocking window and the reference window can be shifted according to the actual engine speed.

With the above settings (setup screen) the window is shifted at 6000 rpm by 10° CA (or 5° CA at 3500 rpm). If any knocking before the maximum pressure point occurs now, we don't get an increased KF reading, as no knocking leaks into the reference window when shifted correctly.

7.4.15. Knocking (non-transient or stationary)

Knocking module will compare multiple engine cycles and make a decision, based on knocking event criteria, if there was a knocking event in the previous cycle. Results will be available right after the last cycle was finished.

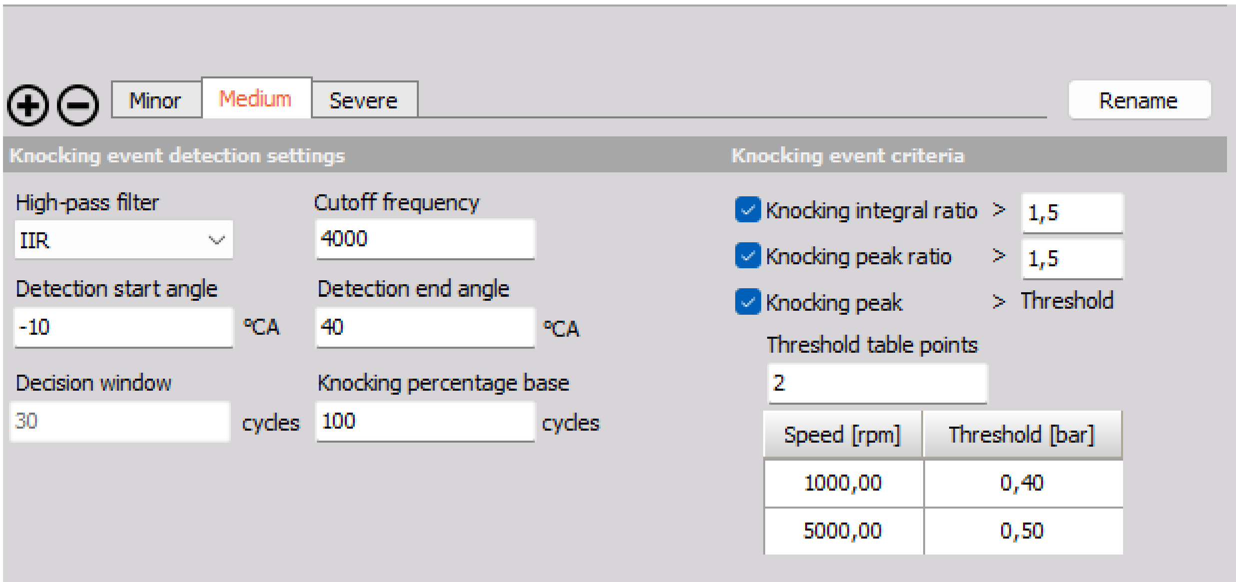


Image 55: Knocking event detection setup

Multiple knocking modules can be added or removed with +/- buttons on the top left corner.

7.4.15.1. Input variables

Event detection settings:
- High-pass filter type with cutoff frequency or order:
This setting will extract the high frequencies, the knocking frequencies are typically between 5 kHz – 12 kHz.
- Detection window in crank angle degrees:
Detection window will limit the area of filtering, calculation and knocking event detection.
- Decision window for the knock detection base level definition:
Number of cycles used for comparison to current event detection cycle.
Decision window for knocking cycles percentage calculation:
Will define the base number for calculating the frequency of knocking event in percentage.

Knocking event criteria:
- Knocking integral ratio (is bigger than a value)
Current value of the knocking integral ratio must be greater than factor “n” when compared to averaged cycles from the decision window .
- Knocking peak ratio (is bigger than a value)
Current value of knocking peak ratio from knocking integral must be greater than factor “n” when compared to averaged cycles from the decision window.
- Knocking peak (is bigger than a value table)

Current value of knocking peak from knocking integral must be greater than “n” (value in Bar) when comparing to averaged cycles from decision window, the table allows defining different thresholds for different engine RPMs.

7.4.15.2. Output channels:

- **Knocking filtered** - Gives component of knocking signal without pressure in array form (possible to show with CEA scope)
- **Knocking filtered pressure** - Gives component of pressure signal without knocking in array form
- **Knocking integral** - Delivers the integral of the superimposed, rectified knock oscillation.
- **Knocking peak** - Delivers the absolute maximum of the rectified knock oscillation superimposed on the cylinder pressure.
- **Knocking event** - Binary value (1/0) which indicates whether the current cycle was classed as knocking or not.
- **Knocking frequency** - Specifies the number of detected knocking cycles within the last 'n' cycles ('n' is predefined by the user).
- **Knocking event percentage** - compares the knocking cycles number to the base for knocking percentage. (If 100 cycles is base and 1 cycle knocks you have 1% of cycles knocking.)

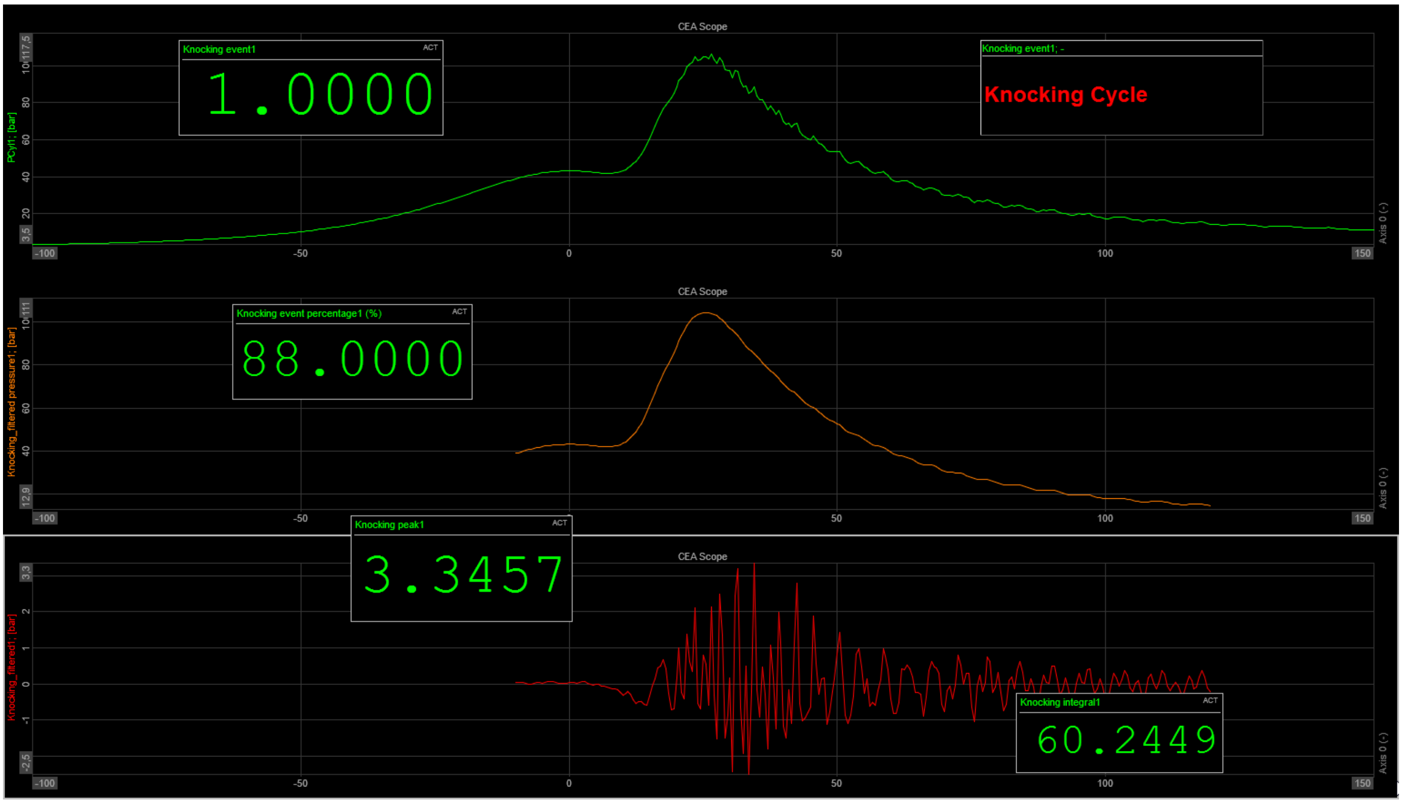
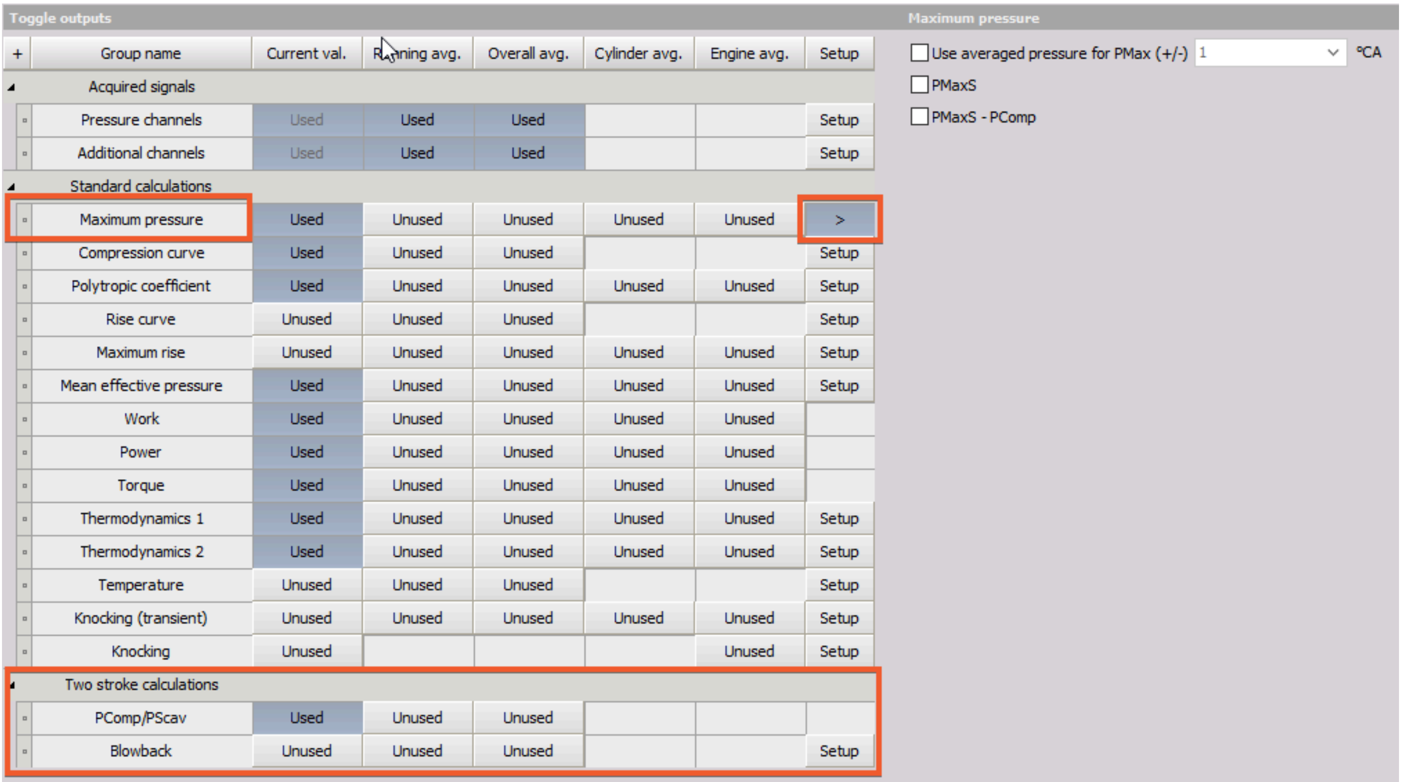


Image 56: Knocking non-transient automatically generated display

7.5. Two stroke additional calculation results

When a two stroke engine type is selected, some additional calculations are available. Maximum pressure calculation offers Maximum pressure Stroke and Compression pressure subtracted from maximum pressure Stroke.



Toggle outputs

Group name	Current val.	Running avg.	Overall avg.	Cylinder avg.	Engine avg.	Setup
Acquired signals						
Pressure channels	Used	Used	Used			Setup
Additional channels	Used	Used	Used			Setup
Standard calculations						
Maximum pressure	Used	Unused	Unused	Unused	Unused	>
Compression curve	Used	Unused	Unused			Setup
Polytropic coefficient	Used	Unused	Unused	Unused	Unused	Setup
Rise curve	Unused	Unused	Unused			Setup
Maximum rise	Unused	Unused	Unused	Unused	Unused	Setup
Mean effective pressure	Used	Unused	Unused	Unused	Unused	Setup
Work	Used	Unused	Unused	Unused	Unused	
Power	Used	Unused	Unused	Unused	Unused	
Torque	Used	Unused	Unused	Unused	Unused	
Thermodynamics 1	Used	Unused	Unused	Unused	Unused	Setup
Thermodynamics 2	Used	Unused	Unused	Unused	Unused	Setup
Temperature	Unused	Unused	Unused			Setup
Knocking (transient)	Unused	Unused	Unused	Unused	Unused	Setup
Knocking	Unused				Unused	Setup
Two stroke calculations						
PComp/PScav	Used	Unused	Unused			
Blowback	Unused	Unused	Unused			Setup

Image 57: Two stroke engine calculations and results

7.5.1. PMaxS and PMaxS – Pcomp

PMaxS is the average of +/-5 samples from the maximum pressure +- 0.1 deg angle resolution.

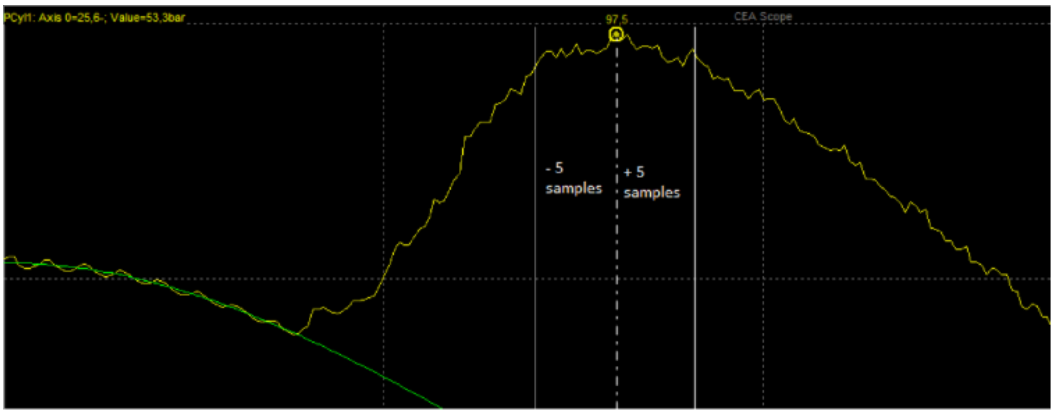


Image 58: PMaxS calculation

PMaxS – PComp presents the difference between PMaxS and the compression pressure. PComp is calculated from the compression curve function.

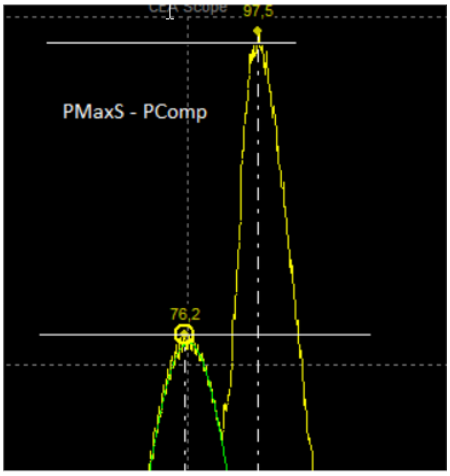


Image 59: PMaxS - PComp

7.5.1. PComp/PScav

The calculation is dividing the PComp with the average scavenging pressure (PScav).

PScav = Average at bottom dead center (-180deg) +/-20deg of all cylinders combined.

7.5.2. BlowBack

Blow-back is the pressure difference when the piston top passes the scavenging port and the average scavenging pressure (E.g. +/-20° from BDC). The piston passes the scavenging port at the nominal blow back angle (NBA) with no shims. The apparent blow back angle (ABA) is the NBA + angle (considering the shims length).

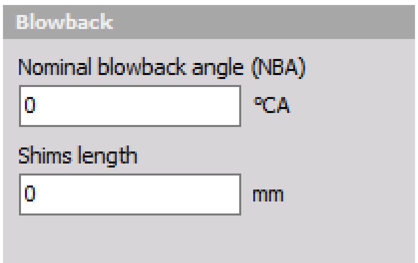


Image 60: Blowback user input values

Blowback = Pressure(@ABA) - Pscav(+/-20° from BDC)

8. Customizing the CEA-Module

8.1. Overview

All the XML templates which are added to the above folder will be shown in the CEA module under Engine type. When you select a new engine type, the formulas in CEA are rebuilt according to the XML script.

8.2. Engine Database

8.2.1. Basic structure

The Xml structure of the CEA engine template is shown below. Every template you create must follow this structure!

With "//" the description for each line starts.

Mandatory items are written in bold

Fields that can be repeated multiple times with different parameters are marked with (*). Please compare as well a complete engine template xml as a reference.

<Engine>	Mark of start of xml file node
<Version>1.0</Version>	You can write here a revision of the engine template (just to keep track).
<EngineType>4-stroke</EngineType>	**This field for now allows: 4-stroke or 2-stroke - CEA data collection and graphs are set according to this setting**
<EngineName>4-Stroke Standard</EngineName>	**Template name which will be used in drop down of the engine typ list**
<UserInterface>Standard</UserInterface>	User interface can be: Standard, non-standard –
<EngineParameters>	Start of engine parameters like bore, stroke, polytropic exponent..

<Parameter>	(*) Each parameter stars with this node word
<Id>#Bore#</Id>	**Id of parameter, which MUST be unique otherwise Dewesoft will not be able to handle it correctly. Id must start and end with "#" character**
<Name>Bore</Name>	**Parameter name, used for display in Dewesoft graphs and CEA settings**
<DefaultValue>500</DefaultValue>	**Default value will be set when template is selected**
<Unit>mm</Unit>	Unit for parameter
</Parameter>	End of parameter section
</EngineParameters>	End of engine parameter section
<CylinderParameters>	Cylinder parameters are displayed under each cylinder and can be different for each
<Parameter>	(*) Each parameter stars with this node word
<Id>#P10#</Id>	Unique Id of parameter, Id must start and end with "#" character
<Name>P10</Name>	Parameter name, used for display in Dewesoft graphs and CEA settings
</Parameter>	End of parameter section
</CylinderParameters>	End of cylinder parameter section
<Formula>	(*) Start of formula section
<Id>#MaxP#</Id>	Id of formula, which MUST be unique or Dewesoft will not be able to handle it correctly. Id must start and end with "#" character
<Name>MaxP</Name>	Formula name, used for display in Dewesoft graphs and CA settings

<Unit>bar</Unit>	Unit for formula. For using the same unit like for the input channel, use the expression <CopyUnitFromInput>True</CopyUnitFromInput>
<GroupName>Max pressures</GroupName>	Group name is used for organizing formulas into groups. If you set the same name for different formulas they will be grouped together in CEA setup screen and graphs
<CalcFormula>Max(#P_x_cur#)</CalcFormula>	Actual formula (for further explanation refer to 10.2.3 Formulas)
</Formula>	End of formula section
<VolumeFormula/>	Here the custom volume equation can be entered. If you don't need custom volume than you should leave this node out. Please refer to 10.4.1 Customized volume formula on page 75 for further information.
</Engine>	End of base xml node

8.2.2. Reserved expressions

Reserved words are words which can be used inside your formulas like normal variables. The combustion analyser formula parser will recognize them and exchange them for correct Dewesoft channels or constant values. If reserved words include the symbol "_x_", the formula will be repeated for each cylinder and taking the input channel of that cylinder for calculation (pressure or additional channel). Each reserved word must start and end with "#" symbol.

Reserved words can be used inside: <Formula><CalcFormula>...</CalcFormula></Formula> tag in xml.

#P_x_cur# - current pressure channel

#P_x_ovl# - overall averaged pressure (whole measurement)

#P_x_run# - running averaged pressure (running averages for X last cycles)

#Ax_x_cur# - current additional channel

#Ax_x_ovl# - overall averaged additional (whole measurement)

#Ax_x_run# - running averaged additional (running averages for X last cycles)

#Phi# - this is only useful for volume formulas. We must iterate through each channel and generate the right value for that position of piston

#Speed# - speed channel

#R# - resolution of CA measurement

#V_x# - volume for each cylinder

#Tdc_x# - TDC curve for each cylinder (if TDC detection was done in setup)

#TotalVolume# - Total volume calculated out of volume. This comes in handy when calculating MEP values,...

8.2.3. Formulas

These are standard formulas which can be used inside an Xml script or inside a standard Dewesoft formula.

Formulas allow only one level of recursion depth. If you have more levels you will get an error, because checking is not done on this level. In the xml script also all other formulas from Dewesoft can be used.

#PressureChannel# changes with one of the following: #P_x_cur#, #P_x_ovl#, #P_x_run#, #Ax_x_cur#, #Ax_x_ovl#, #Ax_x_run#

#Volume# with #V_x#

#TIChannel# recursively uses channel from TD_HeatRelease - integrated heat release

#MEPChannel# is used for work, power and torque calculation

Formulas for maximum and position of maximum

Max(#PressureChannel#)

MaxPos(#PressureChannel#))

Derivative, max and position of maximum derivative

TD_Derivate(#PressureChannel#, #DerivativeStep#, #R#, #StartDerivAngle#, #EndDerivAngle#)

DerivativeStep - step of derivation in degrees

StartDerivAngle, EndDerivAngle - range for derivation, from -360 to +360 (deg.)

Heat-release calculation

TD_HeatRelease(#PressureChannel#, #Volume#, #TotalVolume#, #PolyExp#, #R#, #HeatReleaseStep#, #StartHeatAngle#, #EndHeatAngle#, #TQUnitType#)

PolyExp - polytropic exponent defined in engine parameters section of xml

StartHeatAngle, EndHeatAngle - range for heat release calculation, from -360 to +360 (deg.)

HeatReleaseStep - step of heat release calculation in degrees

TQUnitType - unit of result from HR calculation:

0: kJ/m^3/deg

1: %

2: J/deg

Integrated heat-release calculation

TD_IntHR(#PressureChannel#, #Volume#, #TotalVolume#, #PolyExp#, #R#, #StartHeatAngle#, #EndHeatAngle#, #TIUnitType#)

PolyExp - polytropic exponent defined in engine parameters section of xml

StartHeatAngle, EndHeatAngle - range for heat release calculation, from -360 to +360 (deg.)

TIUnitType - unit of result from integrated HR calculation:

0: kJ/m^3

1: %

2: J

Power points out of heat release

TD_GetHRIVal(#TIChannel#, #Perc#, #R#, #FuelType#)

Perc - at which percent to calculate power value from heat release:

0 to 100: power points

-1: start of injection

-2: end of injection

FuelType:

0: Gasoline

1: Gasoline - direct injection

2: Diesel

I, P and N- mean effective pressure

TD_MEP(#PressureChannel#, #Volume#, #TotalVolume#, #MepType#)

MepType:

0: iMEPn

1: pMEP

2: iMEPg

Work, power and torque

TD_Work(#MEPChannel#, #TotalVolume#)

TD_Power(#MEPChannel#, #TotalVolume#, #Speed#, #EngineType#)

TD_Torque(#MEPChannel#, #TotalVolume#, #EngineType#)

EngineType:

0: 2-stroke

1: 4-stroke

Temperature

TD_Temperature(#PressureChannel#, #Volume#, (#IntakePressureChannel#, #CalcGassMass#, #TotalVolume#, #IP#, #VE#, #GM#, #T#, #R#, #EngineType#)

CalcGassMass - intake pressure from channel:

0: True

1: false

IP - intake pressure value

VE- efficiency (0.9 is standard)

GM - gass mass

T - intake temperature

Knock detection

TD_KnockDetection(#PressureChannel#, #KF_LowPass#, #KF_HPCuttoff#, #KF_HPType#, #KF_NoiseTreshold#, #KF_RefWinWidth#,#KF_KnockWinWidth#, #KF_UseSpeedCorr#, #KF_StartSpeed#, #KF_StartSpeedCorr#,

#KF_EndSpeed#, #KF_EndSpeedCorr#, #Speed#, #R#, #EngineType#)

KF_LowPass - low pass filter cutoff

KF_HPCuttoff - high pass filter cutoff

KF_HPType - type of high pass filter (taps or Hz)

KF_NoiseTreshold - noise threshold level

KF_RefWinWidth - width of reference window

KF_KnockWinWidth - width of knock window

KF_UseSpeedCorr - speed correction

0: use

1: don't use

KF_StartSpeed - start speed for correction

KF_StartSpeedCorr - correction in degrees for start

KF_EndSpeed - end speed for correction

KF_EndSpeedCorr - correction in degrees for end

High pass filter pressure channel

TD_KnockHighPass(#PressureChannel#, #KF_HPCuttoff#, #KF_HPType#, #Speed#, #R#, #KF_RefWinWidth#,

#KF_KnockWinWidth#, #EngineType#)

Parameters are the same as for TD_KnockDetection

8.2.4. Custom user interface

The user interface can be: standard or non-standard. If you use a standard UI than the basic formulas should not be changed. Only some minor things can be added, because edit fields are tied to exactly those formulas.

If you define a completely new custom script, then use non-standard and all the properties will be put into the grid on the screen.

The engine geometry is not visible. These settings are combined together with the settings for Thermodynamics and Knock detection in a flat list under Engine parameters.

Independent of the user-interface (Standard or non-standard), the channel list at the Output only displays the formulas defined in the engine temple. In the example below only maximum pressure channels are available.

8.2.5. Examples

8.2.5.1 Customized volume formula

If the XML node <VolumeFormula> is missing, the default calculation is used.

Below the XML entry for this standard formula is shown as a base for your needed modifications.

```
<VolumeFormula>

        ((Sqr(#Bore#) * Pi/4) * ((#Stroke# / 2) * (1-Cos(#Phi#)) +

        #Rod# * (1 - Sqrt(1 - Sqr((#Stroke# / 2) / #Rod# * Sin(#Phi#)))))) * 1E-6 +

        ((Sqr(#Bore#/100) * Pi/4 * (#Stroke#/100)) / (#Compression# - 1))

</VolumeFormula>
```

8.2.5.2. Changing default channel names

In addition to the calculation itself, also the default channel names are defined inside the Engine templates. For example, the formula node for the calculation of the Max pressure can be defined like this:

```
        <Formula>

        <ID>#MaxP#</ID>

        <Name>PMax</Name>

        <GroupName>Max pressures</GroupName>
```

```
    <Unit>bar</Unit>

  <CalcFormula>Max(#P_x_cur#)</CalcFormula>

    </Formula>
```

As a result, the channel name for each cylinder would be: PMax1, PMax2, PMax3 and so on.

To change this default names for example to MaxPressure1, MaxPressure2..., modify the node <Name>:

```
    <Formula>

    <ID>#MaxP#</ID>

    <Name>MaxPressure</Name>

    ...
```

8.2.5.3. Max pressure out of running average pressure

At first the entries for the standard calculation are shown. For changing the calculation to the running average values only the exchange of the formula “Max(#P_x_cur#) to Max(#P_x_run#) inside <CalcFormula> would be needed.

```
    <Formula>

    <ID>#MaxP#</ID>

    <Name>PMax</Name>

    <GroupName>Max pressures</GroupName>

    <Unit>bar</Unit>

  <CalcFormula>Max(#P_x_cur#)</CalcFormula>

    </Formula>

    <Formula>

    <ID>#MaxPPos#</ID>

    <Name>APMax</Name>

    <GroupName>Max pressures</GroupName>

    <Unit>deg</Unit>
```

```
<CalcFormula>MaxPos(#P_x_cur#)</CalcFormula>

</Formula>
```

When additional channels are needed, a new complete section needs to be added.

```
<Formula>

<ID>#MaxAvP#</ID>

<Name>AvPMax</Name>

<GroupName>Max AvePressure</GroupName>

<Unit>bar</Unit>

<CalcFormula>Max(#P_x_run#)</CalcFormula>

</Formula>

<Formula>

<ID>#MaxAvPPos#</ID>

<Name>AAvPMax</Name>

<GroupName>Max AvePressure</GroupName>

<Unit>deg</Unit>

<CalcFormula>MaxPos(#P_x_run#)</CalcFormula>

</Formula>
```

8.2.5.4. MEP values based on running average pressure

Similar to the example above, only the variable #P_x_cur# must be exchanged inside the <CalcFormula> to #P_x_run#.

Standard formula inside the node <Formula>:

```
<CalcFormula>TD_MEP(#P_x_cur#, #V_x#, #TotalVolume#, 0)</CalcFormula>

<CalcFormula>TD_MEP(#P_x_cur#, #V_x#, #TotalVolume#, 1)</CalcFormula>

<CalcFormula>TD_MEP(#P_x_cur#, #V_x#, #TotalVolume#, 2)</CalcFormula>
```

Formula based on running average:

```
<CalcFormula>TD_MEP(#P_x_run#, #V_x#, #TotalVolume#, 0)</CalcFormula>
<CalcFormula>TD_MEP(#P_x_run#, #V_x#, #TotalVolume#, 1)</CalcFormula>
<CalcFormula>TD_MEP(#P_x_run#, #V_x#, #TotalVolume#, 2)</CalcFormula>
```

If both MEP calculation methods are needed, the complete <Formula> section must be added.

8.2.5.5. Max Value and position of additional channels

Similar to the max pressure values, the calculation can be defined alos for the additional channels.

```
<Formula>
<ID>#MaxAdd#</ID>
<Name>MX</Name>
<GroupName>Max Additional</GroupName>
<CopyUnitFromInput>True</CopyUnitFromInput>
<CalcFormula>Max(#Ax_x_cur#)</CalcFormula>
</Formula>
<Formula>
<ID>#MaxAddPos#</ID>
<Name>AMX</Name>
<GroupName>Max Additional</GroupName>
<Unit>deg</Unit>
<CalcFormula>MaxPos(#Ax_x_cur#)</CalcFormula>
</Formula>
```

8.2.5.6. Value at defined angle position of additional channels

The two formulas below are adding the new group “Pos Additional” and calculates the value at -20° and 90°

```
<Formula>
<ID>#Add-20#</ID>
<Name>-20_</Name>
<GroupName>Pos Additional</GroupName>
<CopyUnitFromInput>True</CopyUnitFromInput>
<CalcFormula>#Ax_x_cur#{-20}</CalcFormula>
</Formula>
<Formula>
<ID>#Add90#</ID>
<Name>A90_</Name>
<GroupName>Pos Additional</GroupName>
<CopyUnitFromInput>True</CopyUnitFromInput>
<CalcFormula>#Ax_x_cur#{90}</CalcFormula>
</Formula>
```

9. Warranty information

Notice
The information contained in this document is subject to change without notice.

Note:
Dewesoft d.o.o. shall not be liable for any errors contained in this document. Dewesoft MAKES NO WARRANTIES OF ANY KIND WITH REGARD TO THIS DOCUMENT, WHETHER EXPRESS OR IMPLIED. DEWESOFT SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Dewesoft shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory, in connection with the furnishing of this document or the use of the information in this document.

The copy of the specific warranty terms applicable to your Dewesoft product and replacement parts can be obtained from your local sales and service office. To find a local dealer for your country, please visit https://dewesoft.com/support/distributors.

9.1. Calibration

Every instrument needs to be calibrated at regular intervals. The standard norm across nearly every industry is annual calibration. Before your Dewesoft data acquisition system is delivered, it is calibrated. Detailed calibration reports for your Dewesoft system can be requested. We retain them for at least one year, after system delivery.

9.2. Support

Dewesoft has a team of people ready to assist you if you have any questions or any technical difficulties regarding the system. For any support please contact your local distributor first or Dewesoft directly.

Dewesoft d.o.o.
Gabrsko 11a
1420 Trbovlje Slovenia

Europe Tel.: +386 356 25 300
Web: http://www.dewesoft.com
Email: Support@dewesoft.com
The telephone hotline is available Monday to Friday from 07:00 to 16:00 CET (GMT +1:00)

9.3. Service/repair

The team of Dewesoft also performs any kinds of repairs to your system to assure a safe and proper operation in the future. For information regarding service and repairs please contact your local distributor first or Dewesoft directly on https://dewesoft.com/support/rma-service.

9.4. Restricted Rights

Use Slovenian law for duplication or disclosure. Dewesoft d.o.o. Gabrsko 11a, 1420 Trbovlje, Slovenia / Europe.

9.5. Printing History

Version 2.0.0, Revision 217 Released 2015 Last changed: 23. July 2018 at 16:54.

9.6. Copyright

9.7. Trademarks

We take pride in our products and we take care that all key products and technologies are registered as trademarks all over the world. The Dewesoft name is a registered trademark. Product families (KRYPTON, SIRIUS, DSI, DS-NET) and technologies (DualCoreADC, SuperCounter, GrandView) are registered trademarks as well. When used as the logo or as part of any graphic material, the registered trademark sign is used as a part of the logo. When used in text representing the company, product or technology name, the ® sign is not used. The Dewesoft triangle logo is a registered trademark but the ® sign is not used in the visual representation of the triangle logo.

10. Safety instructions

Your safety is our primary concern! Please be safe!

10.1. Safety symbols in the manual

Warning

Calls attention to a procedure, practice, or condition that could cause the body injury or death

Caution

Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.

10.2. General Safety Instructions

Warning

The following general safety precautions must be observed during all phases of operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the product. Dewesoft d.o.o. assumes no liability for the customer's failure to comply with these requirements.

All accessories shown in this document are available as an option and will not be shipped as standard parts.

10.2.1. Environmental Considerations

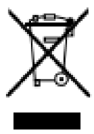
Information about the environmental impact of the product.

10.2.2. Product End-of-Life Handling

Observe the following guidelines when recycling a Dewesoft system:

10.2.3. System and Components Recycling

Production of these components required the extraction and use of natural resources. The substances contained in the system could be harmful to your health and to the environment if the system is improperly handled at its end of life! Please recycle this product in an appropriate way to avoid unnecessary pollution of the environment and to keep natural resources.



This symbol indicates that this system complies with the European Union's requirements according to Directive 2002/96/EC on waste electrical and electronic equipment (WEEE). Please find further information about recycling on the Dewesoft web site www.dewesoft.com

Restriction of Hazardous Substances

This product has been classified as Monitoring and Control equipment and is outside the scope of the 2002/95/EC RoHS Directive. However, we take care of our environment and the product is lead-free.

10.2.4. General safety and hazard warnings for all Dewesoft systems

Safety of the operator and the unit depend on following these rules.

- Use this system under the terms of the specifications only to avoid any possible danger.
- Read your manual before operating the system.
- Observe local laws when using the instrument.
- DO NOT touch internal wiring!
- DO NOT use higher supply voltage than specified!
- Use only original plugs and cables for harnessing.
- You may not connect higher voltages than rated to any connectors.
- The power cable and connector serve as Power-Breaker. The cable must not exceed 3 meters, the disconnect function must be possible without tools.
- Maintenance must be executed by qualified staff only.
- During the use of the system, it might be possible to access other parts of a more comprehensive system. Please read and follow the safety instructions provided in the manuals of all other components regarding warning and security advice for using the system.
- With this product, only use the power cable delivered or defined for the host country.
- DO NOT connect or disconnect sensors, probes or test leads, as these parts are connected to a voltage supply unit.
- Ground the equipment: For Safety Class 1 equipment (equipment having a protective earth terminal), a non-interruptible safety earth ground must be provided from the mains power source to the product input wiring terminals.
- Please note the characteristics and indicators on the system to avoid fire or electric shocks. Before connecting the system, please read the corresponding specifications in the product manual carefully.

- The inputs must not, unless otherwise noted (CATx identification), be connected to the main circuit of category II, III and IV.
- The power cord separates the system from the power supply. Do not block the power cord, since it has to be accessible for the users.
- DO NOT use the system if equipment covers or shields are removed.
- If you assume the system is damaged, get it examined by authorized personnel only.
- Adverse environmental conditions are Moisture or high humidity Dust, flammable gases, fumes or dissolver Thunderstorm or thunderstorm conditions (except assembly PNA) Electrostatic fields, etc.
- The measurement category can be adjusted depending on module configuration.
- Any other use than described above may damage your system and is attended with dangers like short-circuiting, fire or electric shocks.
- The whole system must not be changed, rebuilt or opened.
- DO NOT operate damaged equipment: Whenever it is possible that the safety protection features built into this product have been impaired, either through physical damage, excessive moisture, or any other reason, REMOVE POWER and do not use the product until the safe operation can be verified by service-trained personnel. If necessary, return the product to Dewesoft sales and service office for service and repair to ensure that safety features are maintained.
- If you assume a more riskless use is not provided anymore, the system has to be rendered inoperative and should be protected against inadvertent operation. It is assumed that a more riskless operation is not possible anymore if the system is damaged obviously or causes strange noises. The system does not work anymore. The system has been exposed to long storage in adverse environments. The system has been exposed to heavy shipment strain.
- Warranty void if damages caused by disregarding this manual. For consequential damages, NO liability will be assumed!
- Warranty void if damage to property or persons caused by improper use or disregarding the safety instructions.
- Unauthorized changing or rebuilding the system is prohibited due to safety and permission reasons (CE).
- Be careful with voltages >25 VAC or >35 VDC! These voltages are already high enough in order to get a perilous electric shock by touching the wiring.
- The product heats during operation. Make sure there is adequate ventilation. Ventilation slots must not be covered!
- Only fuses of the specified type and nominal current may be used. The use of patched fuses is prohibited.
- Prevent using metal bare wires! Risk of short circuit and fire hazard!
- DO NOT use the system before, during or shortly after a thunderstorm (risk of lightning and high energy over-voltage). An advanced range of application under certain conditions is allowed with therefore designed products only. For details please refer to the specifications.
- Make sure that your hands, shoes, clothes, the floor, the system or measuring leads, integrated circuits and so on, are dry.
- DO NOT use the system in rooms with flammable gases, fumes or dust or in adverse environmental conditions.
- Avoid operation in the immediate vicinity of high magnetic or electromagnetic fields, transmitting antennas or high-frequency generators, for exact values please refer to enclosed specifications.
- Use measurement leads or measurement accessories aligned with the specification of the system only. Fire hazard in case of overload!

- Do not switch on the system after transporting it from a cold into a warm room and vice versa. The thereby created condensation may damage your system. Acclimatise the system unpowered to room temperature.
- Do not disassemble the system! There is a high risk of getting a perilous electric shock. Capacitors still might be charged, even if the system has been removed from the power supply.
- The electrical installations and equipment in industrial facilities must be observed by the security regulations and insurance institutions.
- The use of the measuring system in schools and other training facilities must be observed by skilled personnel.
- The measuring systems are not designed for use in humans and animals.
- Please contact a professional if you have doubts about the method of operation, safety or the connection of the system.
- Please be careful with the product. Shocks, hits and dropping it from already- lower level may damage your system.
- Please also consider the detailed technical reference manual as well as the security advice of the connected systems.
- This product has left the factory in safety-related flawlessness and in proper condition. In order to maintain this condition and guarantee safety use, the user has to consider the security advice and warnings in this manual.

EN 61326-3-1:2008
IEC 61326-1 applies to this part of IEC 61326 but is limited to systems and equipment for industrial applications intended to perform safety functions as defined in IEC 61508 with SIL 1-3.

The electromagnetic environments encompassed by this product family standard are industrial, both indoor and outdoor, as described for industrial locations in IEC 61000-6-2 or defined in 3.7 of IEC 61326-1.

Equipment and systems intended for use in other electromagnetic environments, for example, in the process industry or in environments with potentially explosive atmospheres, are excluded from the scope of this product family standard, IEC 61326-3-1.

Devices and systems according to IEC 61508 or IEC 61511 which are considered as “operationally well-tried”, are excluded from the scope of IEC 61326-3-1.

Fire-alarm and safety-alarm systems, intended for the protection of buildings, are excluded from the scope of IEC 61326-3-1.

11. Documentation version history

Version	Date	Notes
1.0.0.	01-06-2013	Initial version of CA manual
1.1.1.	01-11-2016	Last update of CA manual
V21-1	16-02-2021	Initial version of CEA manual
V21-2	23-02-2021	Updated template
V21-3	22-12-2021	Updated screenshots
V23-1	06-02-2023	Added 2-stroke calculations explanations
V23-2	15–05-2023	Added Knocking stationary TDC detection updated
V24-1	13-02-2024	- Added Unified settings - Results alignment - Knocking non-transient displays - Misfire detection added