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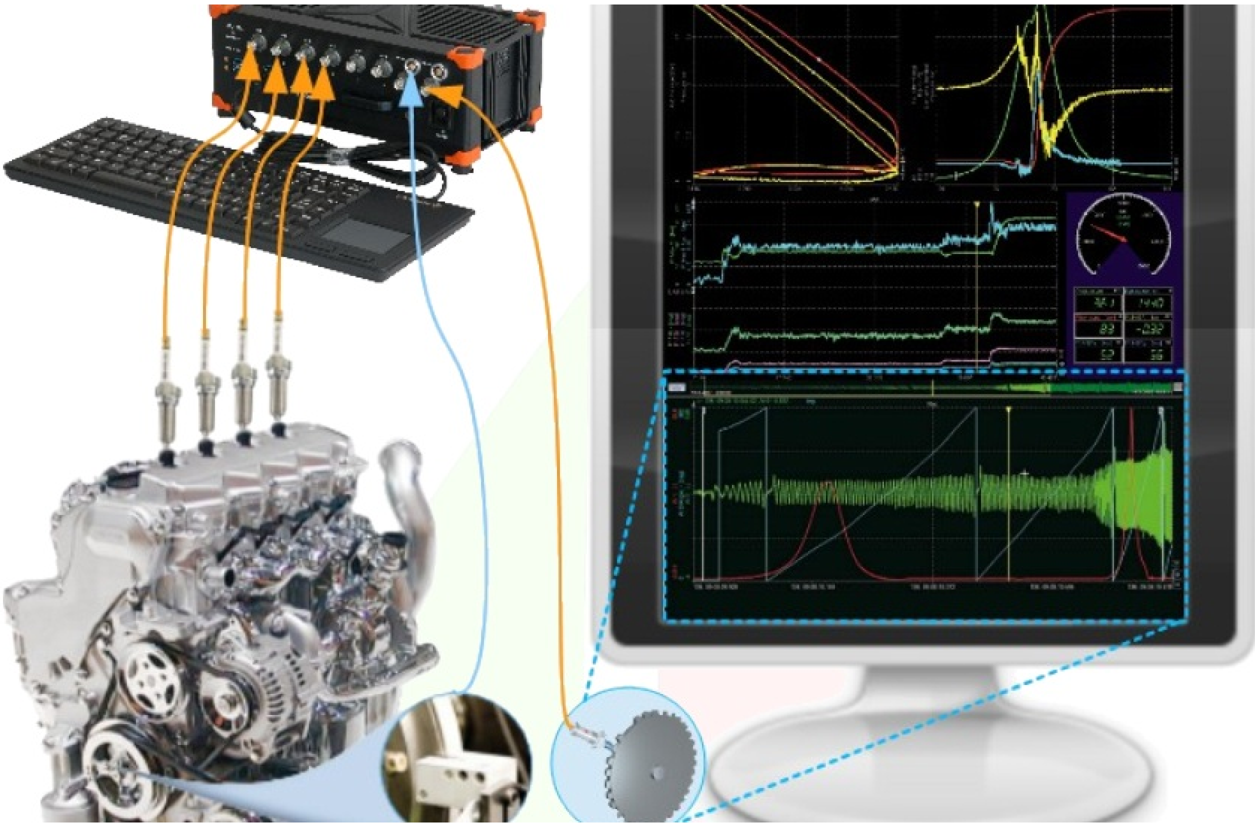
Combustion Engine Analysis



What is Combustion?

Internal combustion means just what it says: that *fuel is burned inside the engine*. In a car engine, gasoline is burned inside the engine, which ignites the fuel and releases energy that moves the car. There are also other methods of internal combustion, such as diesel engines and gas turbine engines. Internal combustion is an efficient system that requires a relatively small engine to create motion. It is also more fuel-efficient than external combustion engines, such as an old-fashioned steam engine.

Gasoline engines used to be as inefficient as steam engines. In 1876 the gasoline engine was invented and it was no more efficient than the steam engine, which used external combustion. A lot of fuel was wasted. In 1878, Rudolph Diesel decided to develop an engine with higher efficiency, and in 1892 the *diesel engine* was born. It was more efficient as an internal combustion engine, but it took many more years to develop a diesel engine that was cleaner and quieter. Early diesel engines spewed out sooty smoke and at first were only used in trucks. Today, new advancements in this method of internal combustion have improved the diesel engine. The difference between gas and diesel engines is the way fuel is converted to energy.

Turbines are another method used to create power with a spinning motion. There are wind turbines, steam turbines, water turbines, and also gas turbines. Gas turbines work on the principle of internal combustion. In a modern gas turbine engine, the engine produces its own pressurized gas by burning fuel. The engine can burn propane, natural gas, kerosene, or jet fuel. The burning fuel creates heat, the heat, in turn, expands the air, and a high-speed blast of hot air spins the turbine.

[Video available in the online version]

What is Internal Combustion Engine?

An **internal combustion engine (ICE)** is a heat engine where the *combustion of a fuel occurs with an oxidizer* (usually air) *in a combustion chamber* that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. The force is applied typically to pistons, turbine blades, rotor, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy.

The first commercially successful internal combustion engine was created by Etienne Lenoir around 1859 and the first modern internal combustion engine was created in 1876 by Nikolaus Otto.

The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar *four-stroke* and *two-stroke piston engines,* along with variants, such as the *six-stroke piston engine* and the *Wankel rotary engine*. A second class of internal combustion engines use continuous combustion: *gas turbines, jet engines* and most *rocket engines*, each of which are internal combustion engines on the same principle as previously described. *Firearms* are also a form of internal combustion engine.

In contrast, in **external combustion engines**, such as *steam or Stirling engines*, *energy is delivered to a working fluid* not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized water or even liquid sodium, heated in a boiler. ICEs are usually powered by energy-dense fuels such as gasoline or diesel, liquids derived from fossil fuels. While there are many stationary applications, most ICEs are used in mobile applications and are the dominant power supply for vehicles such as cars, aircraft, and boats.

Typically an ICE is fed with fossil fuels like natural gas or petroleum products such as gasoline, diesel fuel or fuel oil. There is a growing usage of renewable fuels like biodiesel for compression ignition engines and bioethanol or methanol for spark-ignition engines. Hydrogen is sometimes used, and can be obtained from either fossil fuels or renewable energy.

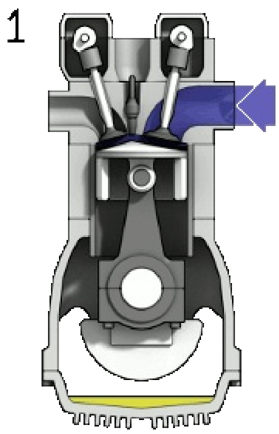


Image 1: 4-stroke spark ignited engine

Diagram showing the operation of a 4-stroke spark ignited engine. Labels:

1 Ã¢â,¬Â Induction
2 Ã¢â,¬Â Compression
3 Ã¢â,¬Â Power
4 Ã¢â,¬Â Exhaust

1.	**Intake**, **induction** or **suction**: The intake valves are open as a result of the cam lobe pressing down on the valve stem. The piston moves downward increasing the volume of the combustion chamber and allowing air to enter in the case of a compression ignited (CI) engine or an air-fuel mix in the case of spark-ignited (SI) engines that do not use direct injection. The air or air-fuel mixture is called the charge in any case.
2.	**Compression**: In this stroke, both valves are closed and the piston moves upward reducing the combustion chamber volume which reaches its minimum when the piston is at TDC. The piston performs work on the charge as it is being compressed; as a result its pressure, temperature, and density increase; an approximation to this behavior is provided by the ideal gas law. Just before the piston reaches TDC, ignition begins. In the case of a SI engine, the spark plug receives a high voltage pulse that generates the spark which gives it its name and ignites the charge. In the case of a CI engine the fuel injector quickly injects fuel into the combustion chamber as a spray; the fuel ignites due to the high temperature.
3.	**Power** or **working stroke**: The pressure of the combustion gases pushes the piston downward, generating more work than is required to compress the charge. Complementary to the compression stroke, the combustion gases expand and as a result their temperature, pressure, and density decreases. When the piston is near to BDC the exhaust valve opens. The combustion gases expand irreversibly due to the leftover pressure - in excess of back pressure, the gauge pressure on the exhaust port; this is called the blow-down.
4.	**Exhaust**: The exhaust valve remains open while the piston moves upward expelling the combustion gases. For naturally aspirated engines a small part of the combustion gases may remain in the cylinder during normal operation because the piston does not close the combustion chamber completely; these gases dissolve in the next charge. At the end of this stroke, the exhaust valve closes, the intake valve opens, and the sequence repeats in the next cycle. The intake valve may open before the exhaust valve closes to allow better scavenging.

Combustion Analysis in Dewesoft X DAQ Software

The Dewesoft X Combustion analysis math module enables the Analysis of internal combustion engines. If we measure the pressure inside the cylinder and the angle of the shaft, we can calculate the main indication values for engine development and testing, like maximum pressure, position of maximum pressure, heat release, knocking, and other important parameters.

The *combustion analysis is fully integrated inside the* **Dewesoft X** software, which means that we can use any functionality of Dewesoft including CAN bus, video, other analog signal acquisition, and more.

The video below shows how easy and fast it is to setup combustion analysis in Dewesoft and start measuring.

[Video available in the online version]

Introducton to DAQ System

SIRIUS Combustion Analyser data acquisition systems are used for engine research, development, and optimization. They are also used 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 SIRIUSi hardware and the well-known DewesoftX software package for measurement and analysis.

It supports *angle* and *time-based measurement results* and uses highly *sophisticated algorithms for online* or *offline mathematical* and *statistical* calculations of heat release and other thermodynamic parameters.

The combustion analyzer can be fully integrated within a testbed and also supports data from other sources: e.g. Video, CAN, Ethernet,... . If the powerful integrated post-processing features of DewesoftX 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 power train, noise,* and *vibration measurement together with synchronized video* or *GPS data*.

DAQ 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 SIRIUSi amplifier like any other input channel or through external signal conditioning amplifiers. Charge type sensors can be connected to *CHG amplifiers* directly.

Additionally an **angle sensor** is needed for getting angle domain measurement results. Several different types are supported by the Dewesoft Combustion Analyser. Additional mounted *CDM* (Crank Disc Marker) sensors or *digital native CDM* sensors (like 60-2 or 37-1,...) with TTL outputs can be connected to dedicated counter inputs.

Sensors with analog output can:

- be directly connected to analog input channels,
- or to counter inputs via the DS-TACHO device.

In both cases, the DewesoftX re-sampling technology gives you an angle resolution down to 0.1Â°.

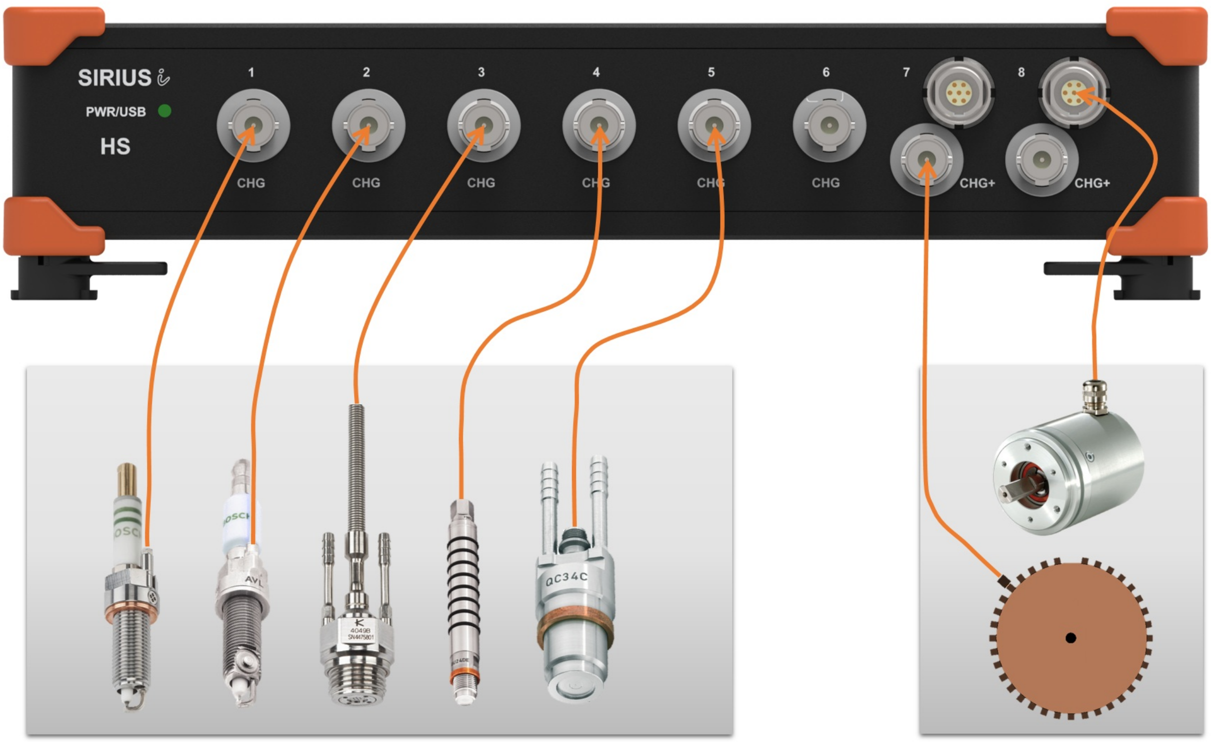


Image 3: Connecting sensors to SIRIUS DAQ device for Combustion Analysis purposes

How to Enable the Combustion Analyzer Module?

Like many other modules, Combustion Engine Analysis is also an option to the standard DewesoftX package. Simply in the *Channel setup* tab press *More* and select the *Combustion engine analysis* to add the module.

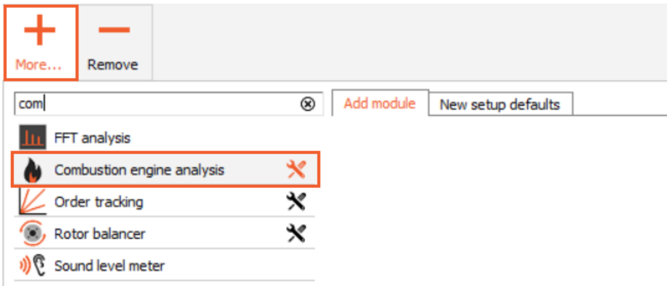


Image 4: Add a CEA module to the Channel setup inside Dewesoft X

The basic settings for the CEA module need to be done here as well. Before you add the module you can click on the screwdriver icon on the right of the Combustion engine analysis option to enter the CEA settings, or if you have already added the module, simply open the general *Settings*, select *Extensions* tab and find *CEA* module in the tree window. CEA settings are previewed on Image 5.

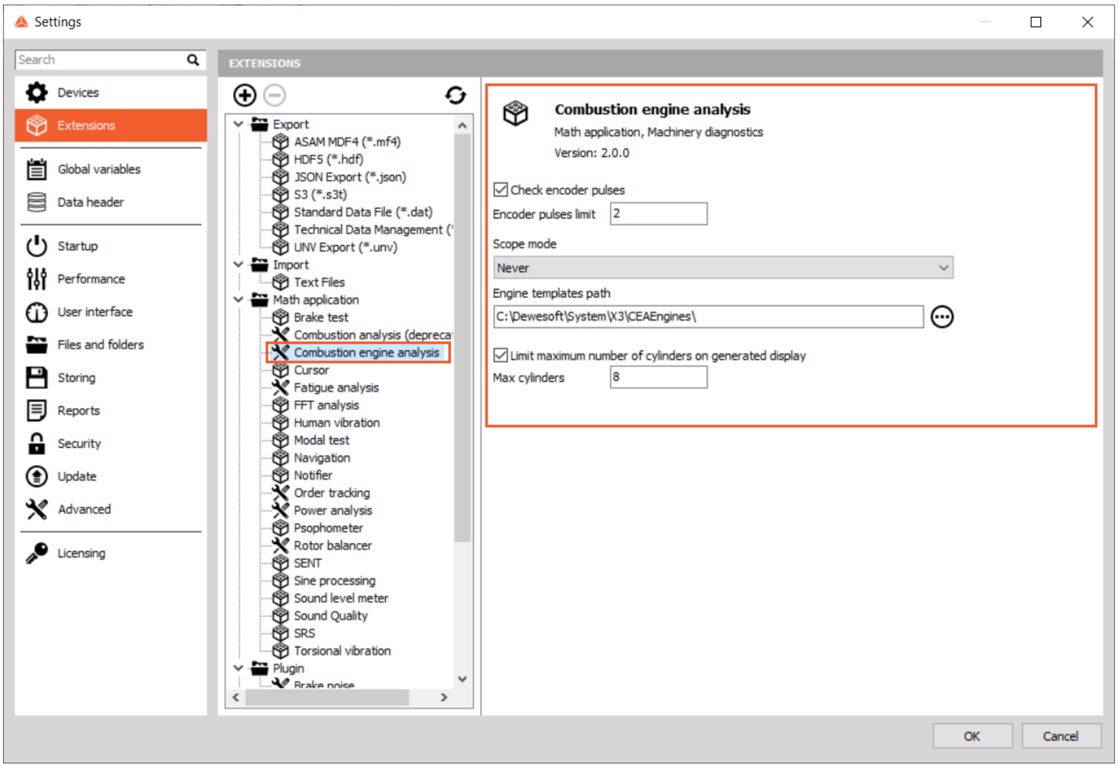


Image 5: Setting up the CEA module under Settings

CEA Settings:

- The settings for the encoder limit - **Check encoder pulses** are only used in *real angle domain acquisition* and therefore not needed for the Dewesoft's Combustion Engine Analyzer.
- If **Scope mode** is enabled, CEA *skips cycles* - in other words it does not calculate all cycles. There are several levels of scope mode available. Depending on this setting, the CEA-module also skips calculations depending on the measure mode (storing, not storing, trigger,...).
  - The default setting which should be used for CEA to calculate, store and visualize all cycles is: **never**
- Engine templates (eg. Calculation methods) are stored in the **engine templates path**.
- **Limit the maximum number of cylinders on generated display** is related only to the preview of an automatically generated measuring display.

Basic Operation Concepts

The **combustion engine analyzer** inside DewesoftX is just one out of several other applications modules that offers dedicated mathematics and dedicated *visual controls* like the *p-V diagram* or the *CEA scope*.

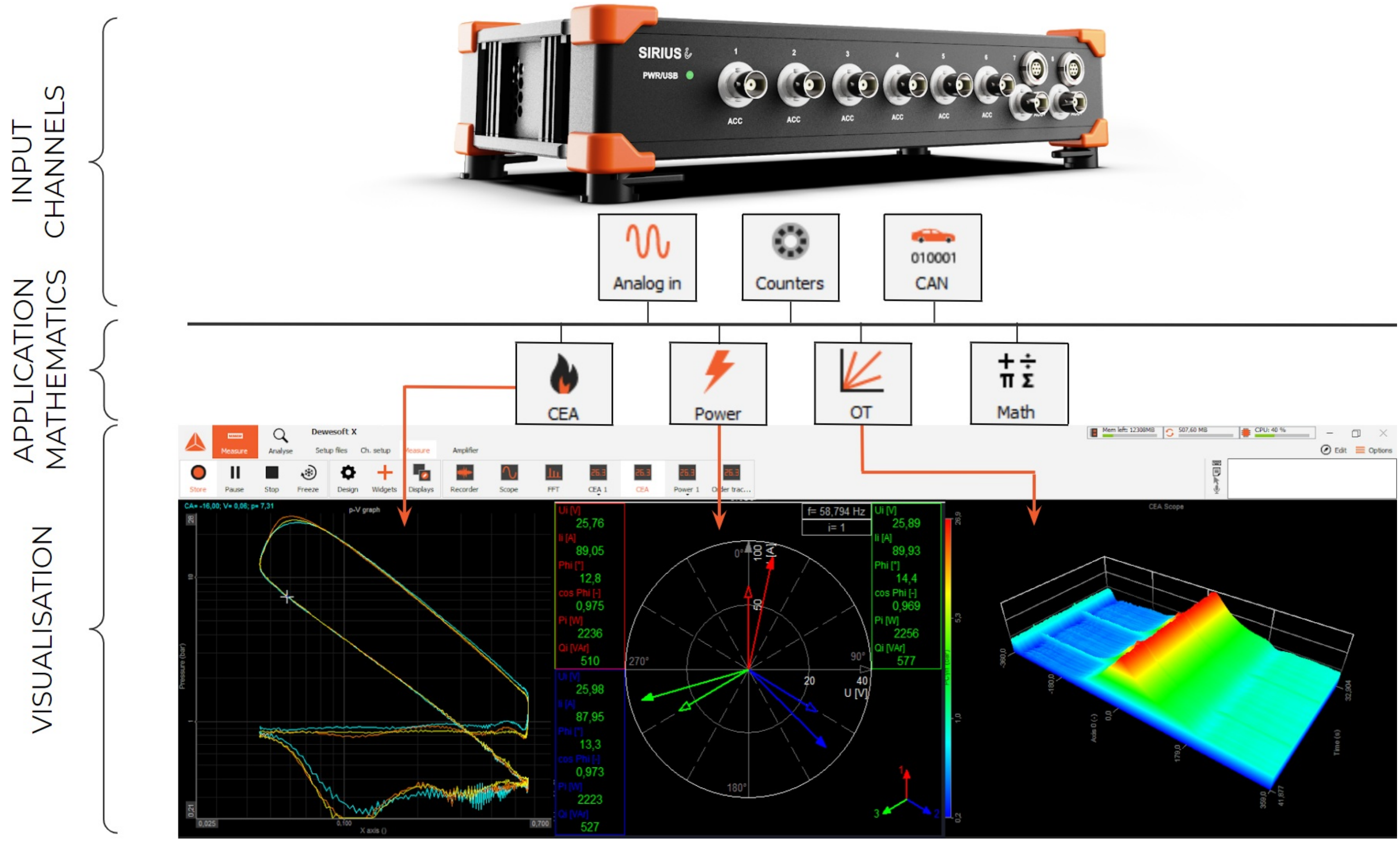


Image 6: Combustion engine analyzer is just one out of several applications modules inside Dewesoft X

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

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

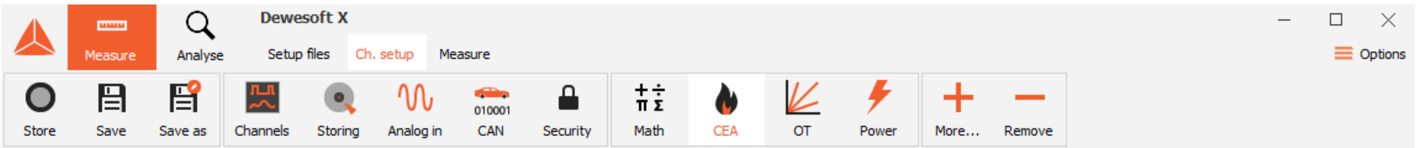


Image 7: Many applications can be combined together with Combustion Engine Analyzer

You can use the same analog input channels that you have used in the Combustion Engine Analyzer module for any other mathematics or applications (e.g. FFT, etc.) in parallel! This gives you a multi-functional instrument suitable for nearly any application. moreover, output channels from one mathematics module can be used as input channels for any other module.

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

How to setup Analog Inputs Filters?

When connecting sensors for combustion engine analysis, extreme caution should be made while *selecting the correct filters*.

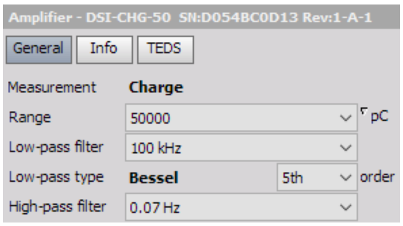


Image 8: Amplifier setup for DEWE-43 and DSI-CHG-50 adapter

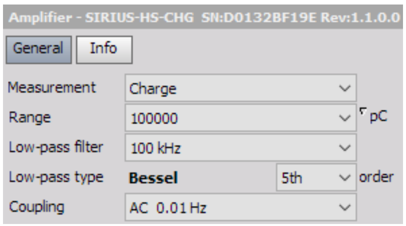


Image 9: Amplifier setup for SIRIUS with CHG inputs

Correct hardware should be selected for the type of application (engine) that will be used. If it is going to be a very low-RPM engine and charge type pressure sensors will be used, then a Sirius device with charge inputs should be used. Otherwise also DSI-CHG adapters are possible, but *they do not have the same filter settings as charge inputs*. On the images above a clear difference can be seen for the lowest High-pass filter setting on a SIRIUS with CHG inputs (Image 9) and a DEWE-43 with DSI-CHG-50 adapter (Image 8).

Signal noise should always be reduced as much as possible with quality cabling and correct mounting of the pressure sensor. If there is still unwanted noise in the pressure signal, then filtering can be used to eliminate this.

High-pass filter

For a low-RPM engine, the high-pass filter shouldn't be set too high.

Important settings: HPF < 0.03 Hz

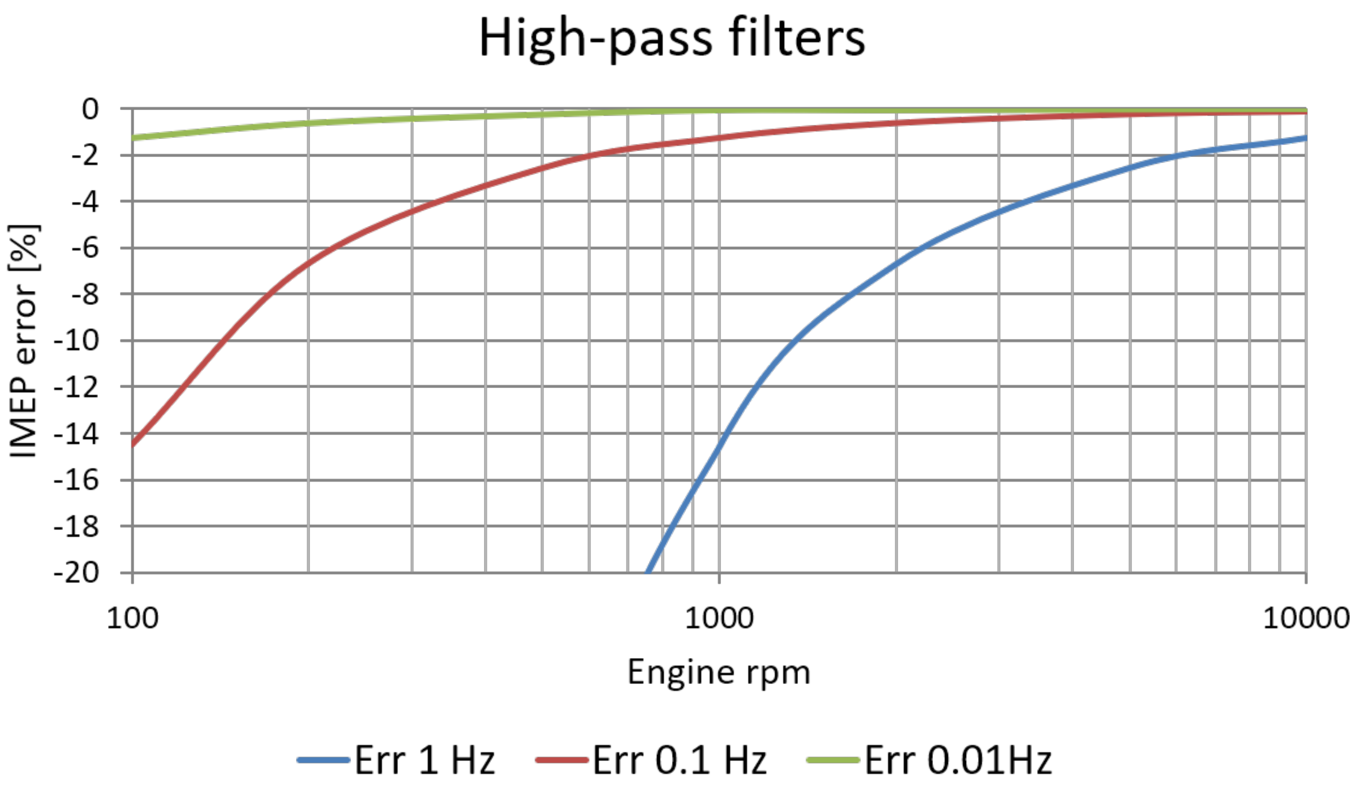


Image 10: High-pass filter diagram

Low-pass filter

For a high-RPM engine, the low-pass filter shouldn't be set too low.

Important settings: LPF > 50 kHz

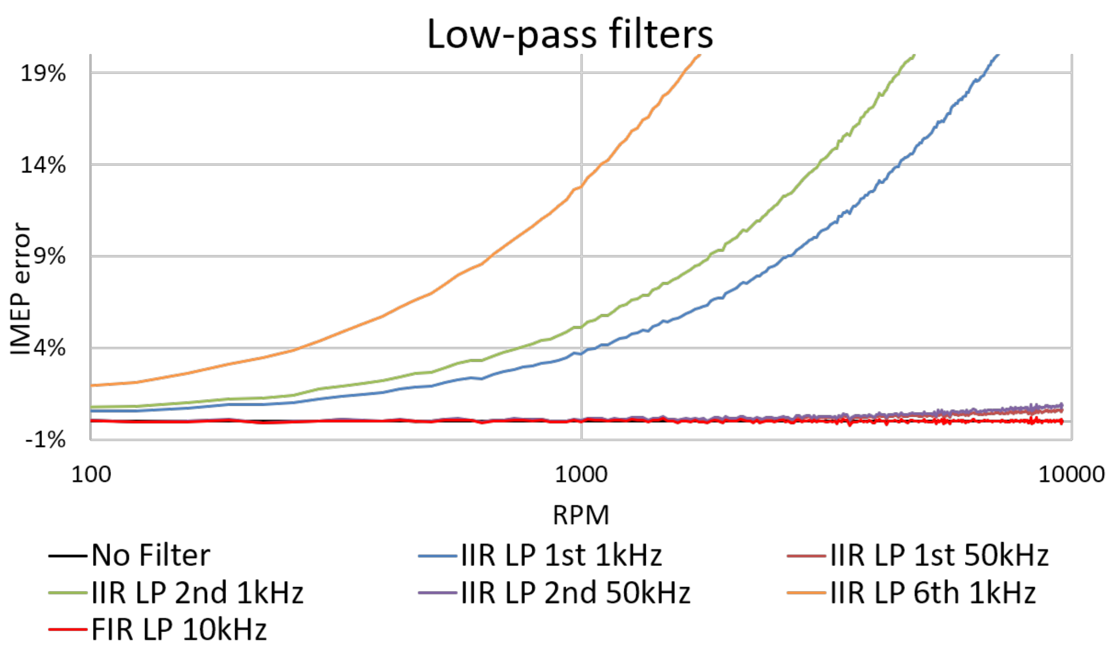


Image 11: Low-pass filters diagram

How to setup the Combustion Engine Analysis module?

You must configure the Combustion Engine Analyzer module after setting up the analog input channels.

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

- **Engine settings:** Defines the geometry of an engine and assigns the channels to the cylinders
- **Encoder settings**: Assign the encoder/angle sensor, resolution and the TDC detection
- **Result definition**: Enables/disables different possible calculations and the output channels for the CEA module

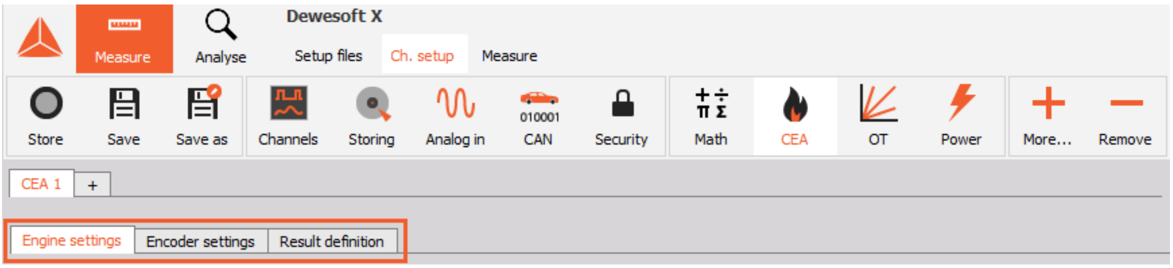


Image 12: Configuration of the CEA module

How to define the Engine Settings?

Engine settings are defined by four major fields inside the CEA module as it is shown in image 13: **Basic parameters**, **Volume per cylinder**, **Selected cylinder settings,** and **Cylinder overview**.

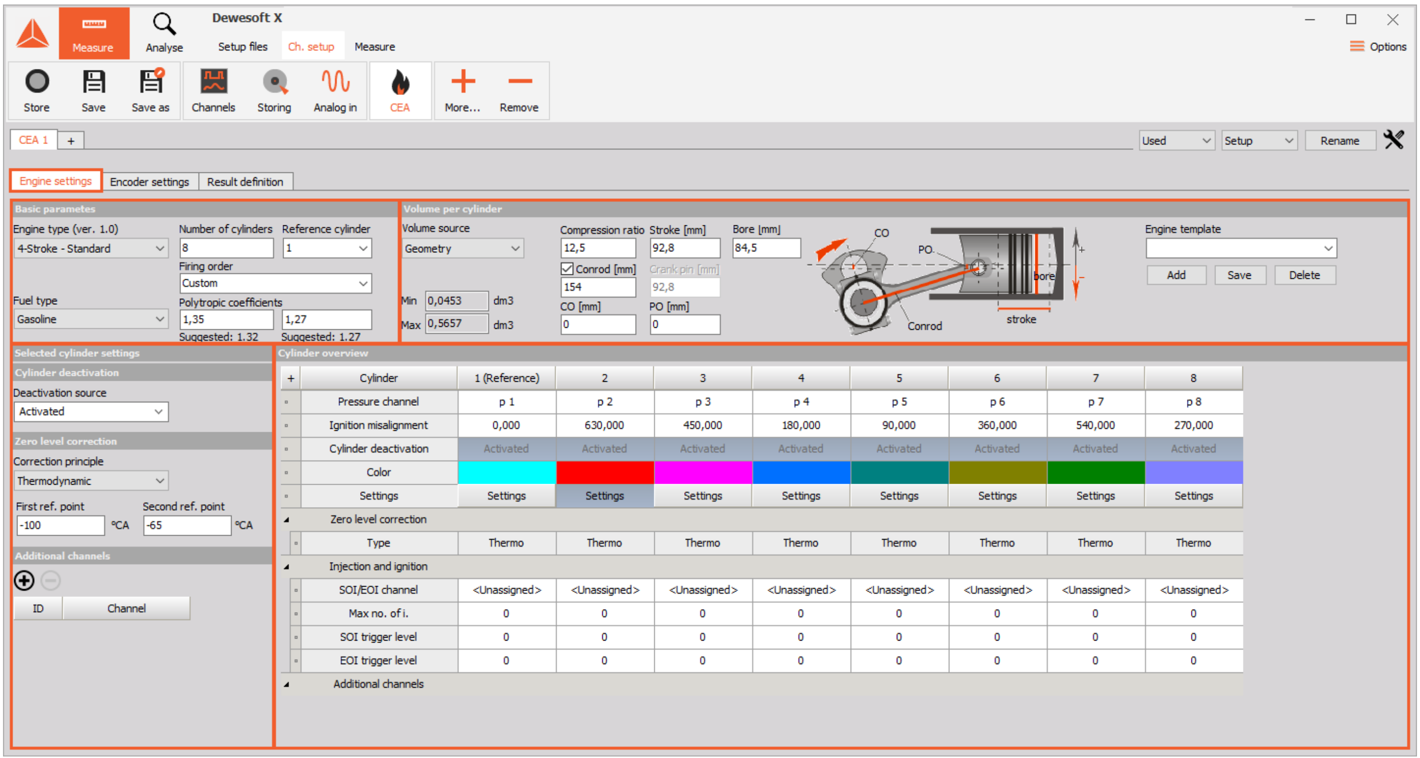


Image 13: Four mayor fields inside the CEA module define the Engine settings

Basic parameters

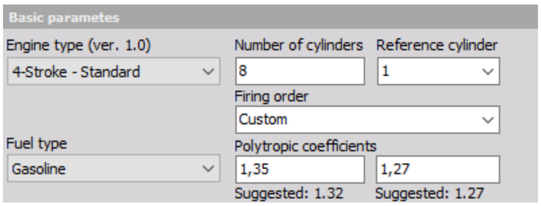
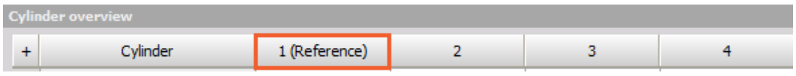


Image 14: Basic parameters definition

Engine type	The default installation includes a *2-Stroke* or *4-Stroke* with the standard calculation method for the volume calculation. Additional ***templates*** with ***customized volume calculation*** can be added.
Number of cylinders	It indicates the number of cylinders or pressure sensors that will be used in a measurement.
Reference cylinder	A reference cylinder can be selected upon setting up the number of cylinders and can be applied to any cylinder. The reference cylinder is indicated with 'Reference' written in brackets under the Cylinder overview.  Image 15: Reference cylinder preview
Firing order	Firing order can be selected according to a defined number of cylinders.
Fuel type	Defines the fuel of the engine. Depending on the selected fuel type polytropic coefficients used for thermodynamic calculations are suggested. The defined value must be entered manually into the *Polytropic coefficients* fields.

Volume per cylinder

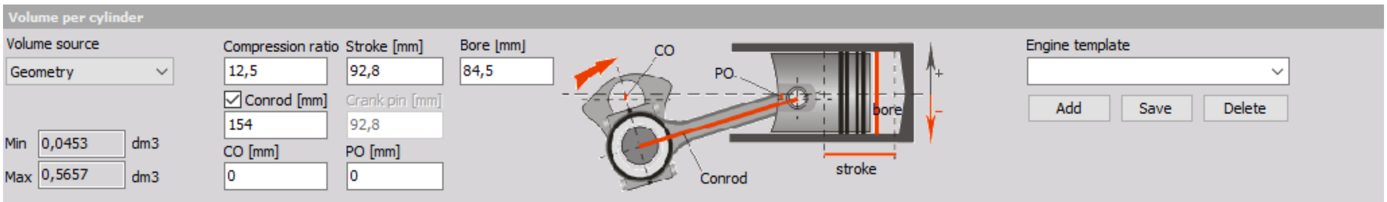


Image 16: Volume per cylinder definition

In the field Volume per cylinder the **Volume source** first needs to be defined. This will define the geometry of a cylinder which can be in fact:

- written in manually - *Geometry* option,
- imported curve as a *Text file* or
- defined within the selected *Engine template*.

Volume source	Description
Geometry	Geometry volume source is defined by the ***Compression ratio*** (defines the ratio between swept and clearance volume), **Stroke, Bore,** and **Conrod**. The **Crankshaft Offset (CO)** or the **Piston Offset (PO)** are entered in the field *CO* or *PO*. It is very important to consider the running direction of the crankshaft. The illustration on image 16 also consists of two arrows, where the signs next to the arrows '+' or '-' are shown for the counter-clockwise direction. If PO or CO is entered, stroke is not available anymore. The crankpin must be entered separately!
Text file	If for example the compression ratio of an engine is variable the cylinder curve can be imported as a 'Text file' and the calculation will be made according to changing parameters of the engine.
Engine template	*All engine settings* can be saved as an '**Enginetemplate'** for future usage. By having several templates it is *easy to switch between engines*. Several templates can be added with the Add button and saved afterward. Existing templates can then be selected from the drop-down menu. Look at the right column or at the image 17, where it is marked which information are saved in the template. When switching between templates with different numbers of cylinders, pressure channel input should be checked and corrected if necessary. Cylinder count Fuel type Polytropic exponent Compression, Stroke, Bore, Conrod, CO, PO, Crankpin Ignition misalignment (defined in Cylinder overview) SOI, EOI trigger lever (defined in Cylinder overview)

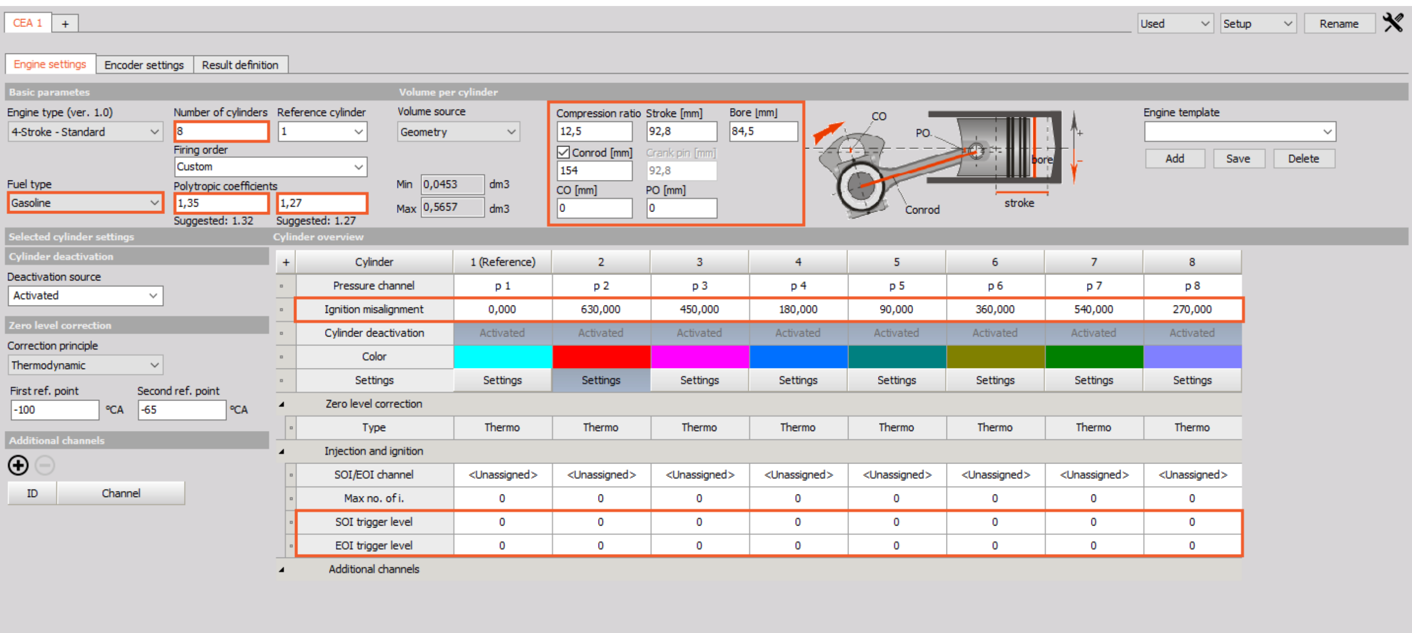


Image 17: Saved properties for the Engine template

Selected cylinder settings

For each cylinder **Selected cylinder settings** can be applied, where Cylinder deactivation, Zero level correction, and Additional channels can be set. This is done by clicking the *Settings* button in the *Cylinder overview* for the desired cylinder as it is shown in image 18.

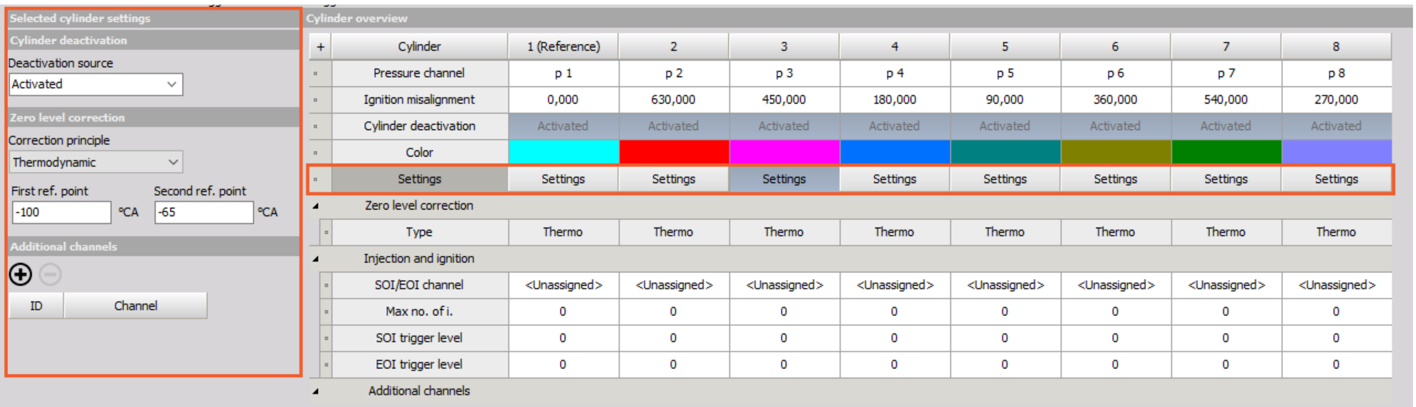
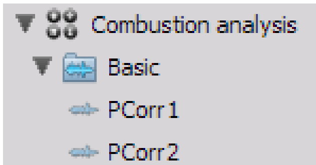


Image 18: Setting up the Selected cylinder settings in this case for cylinder 3

Zero level correction

Dewesoft CEA supports *three different correction principles*:

Correction principle	Description	
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 polytrophic coefficient, the **inlet pressure is calculated**. The *pressure curve is shifted (offset only) to get the right pressure at the bottom dead center.* Refer to the Combustion analyzer manual, chapter 11.3 Zero point correction on page 80 for getting detailed information about the calculation method.	 Image 19: The zero correction offset is also provided as a result output, for each cylinder.
Fixed value	Using this method, the pressure curve is set to a defined - fixed value. *Correction point* specifies the position related to TDC where it should be corrected.	
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 point* defines the position on which the pressure should be corrected.	
None	No zero level correction is applied. This option is used in case of working with a sensor with an inline amplifier, where correction is already made.	

Additional channels

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, and are as well as the pressure channels recalculated to an angle domain. As an example, you can also apply the *Injection signal in order to display it together with the pressure signal.*

Signals for additional channels do not need to be only the *analog signals*, but *can be also output from other modules*, for example, torsional vibration outputs can be added to CEA to view the results in the angle domain of the engine.

Cylinder overview

For each cylinder the corresponding **pressure channel** needs to be assigned from the channel input list. Also the **ignition misalignment** relative to the reference cylinder needs to be entered in degrees.

Cylinder overview

+	Cylinder	1 (Reference)	2	3	4	5	6	7	8
▫	Pressure channel	p 1	p 2	p 3	p 4	p 5	p 6	p 7	p 8
▫	Ignition misalignment	0,000	630,000	450,000	180,000	90,000	360,000	540,000	270,000
▫	Cylinder deactivation	Activated	Activated	Activated	Activated	Activated	Activated	Activated	Activated
▫	Color								
▫	Settings	Settings	Settings	Settings	Settings	Settings	Settings	Settings	Settings
◢	Zero level correction								
▫	Type	Thermo	Thermo	Thermo	Thermo	Thermo	Thermo	Thermo	Thermo
◢	Injection and ignition								
▫	SOI/EOI channel	<Unassigned>	<Unassigned>	<Unassigned>	<Unassigned>	<Unassigned>	<Unassigned>	<Unassigned>	<Unassigned>
▫	Max no. of i.	0	0	0	0	0	0	0	0
▫	SOI trigger level	0	0	0	0	0	0	0	0
▫	EOI trigger level	0	0	0	0	0	0	0	0
◢	Additional channels								

Image 20: For each cylinder, the corresponding pressure channel needs to be assigned

Start of injection (SOI) and **end of injection (EOI) channels** can also be applied to the cylinder. The setting is called **SOI/EOI channel** and can handle various signals. The *result will be the start and the stop position [deg] of the applied signal*, so the *exact position of the angle sensor when the ignition is active*. The unit of the trigger levels are related to the channel scaling on the analog input (voltage [V], current [I], ...).

For example, if an injection signal is applied and the *Number of injections* is set to 3, the *trigger level for SOI* is set to 2V, and the *EOI trigger level* is set to 1V, the each time the ignition signal crosses 2V it will return the angle position, related to the cylinder where it is applied [deg]. The same is true for EOI: if the signal crosses 1V (neg. edge) the position will be returned [deg].
In a real measurement, you can set trigger level values based on easy pre-measurement - simply start the measurement in Measure mode and observe the signal values for each injection channel. Then return to CEA set up and rewrite those values in trigger level fields.

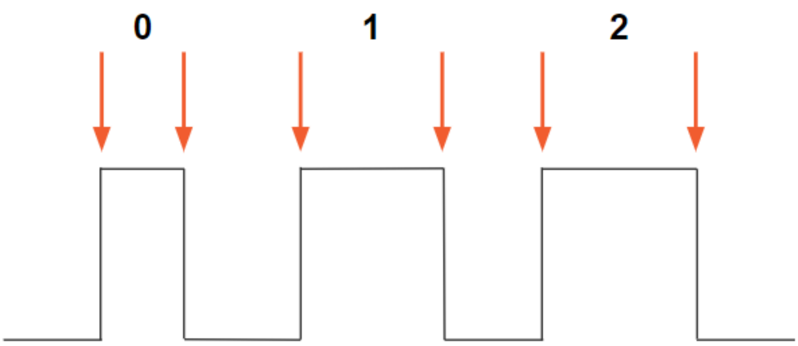


Image 21: Principle of setting up the values for trigger levels in a measure mode

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).

How to setup the Angle Sensor?

The **sampling type** of the Dewesoft CEA is always a **time domain**. This has the advantage that all time-domain related functions are not influenced by changes in the sample rate due to shaft speed, and will stay the same. For example a power calculation is only working in the time domain (fixed sampling rate). Of course **CEA is still calculated in angle domain** , so the CEA time-domain data are always 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.

Angle sensor setup is done in the Encoder settings tab as it is shown on the image 22.

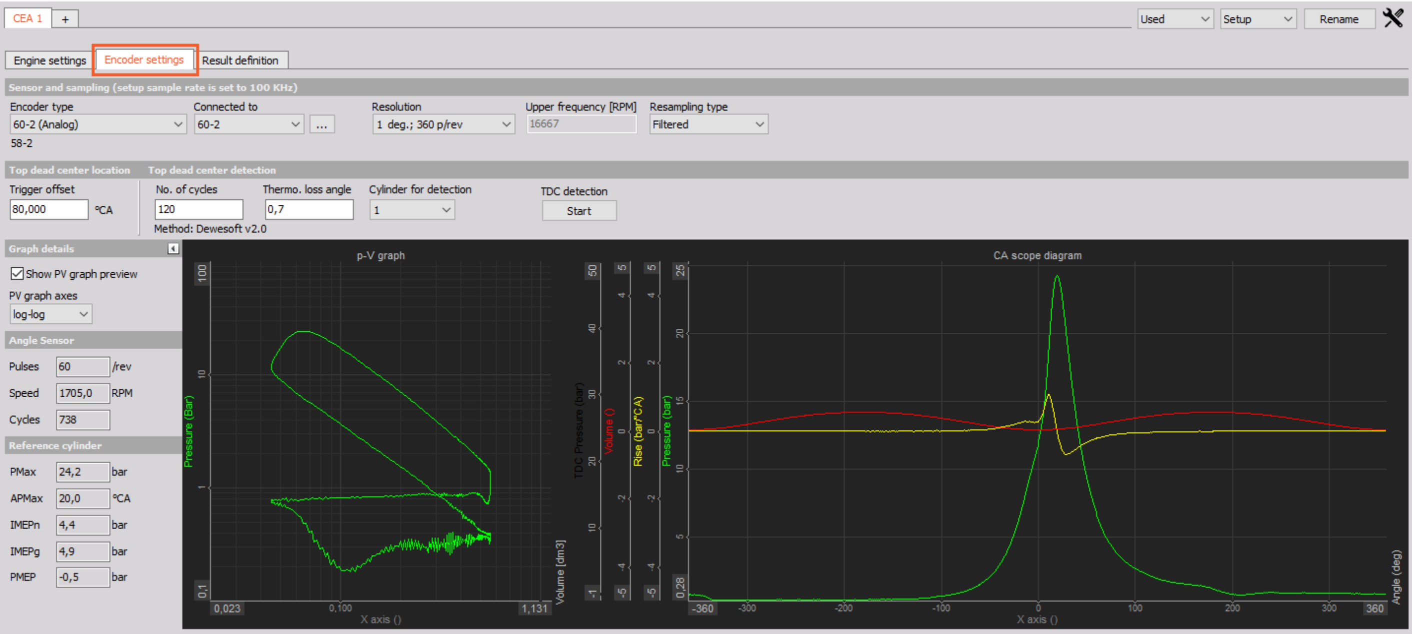


Image 22: Encoder settings

Sensor types and angle resolution

Nearly *any angle sensor type is supported*. For getting the relation to a fixed angle position the sensor must support a fixed angle mark. The drop-down list will automatically show all suitable sensor types from the counter database as it is shown in image 23.

> Encoder, Geartooth with zero (CDM+TRG), Geartooth with missing teeth, Geartooth with double teeth are the only sensors allowed for CEA. *Tacho or a gear tooth without zero cannot be used.*

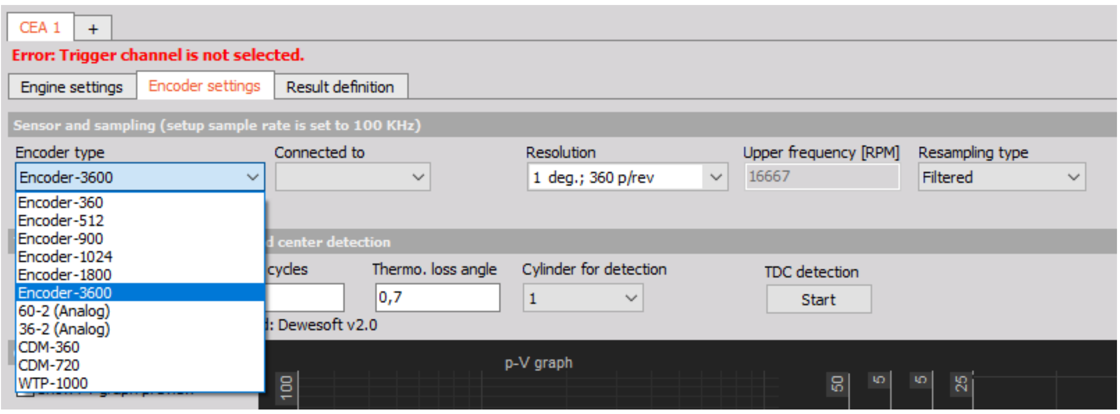


Image 23: Selecting proper encoder type from a drop-down menu

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 X software.**

To add a new counter sensor click *Options -> Editors -> Counter sensors* and you will enter the Counter sensors editor as it is shown on the image below.

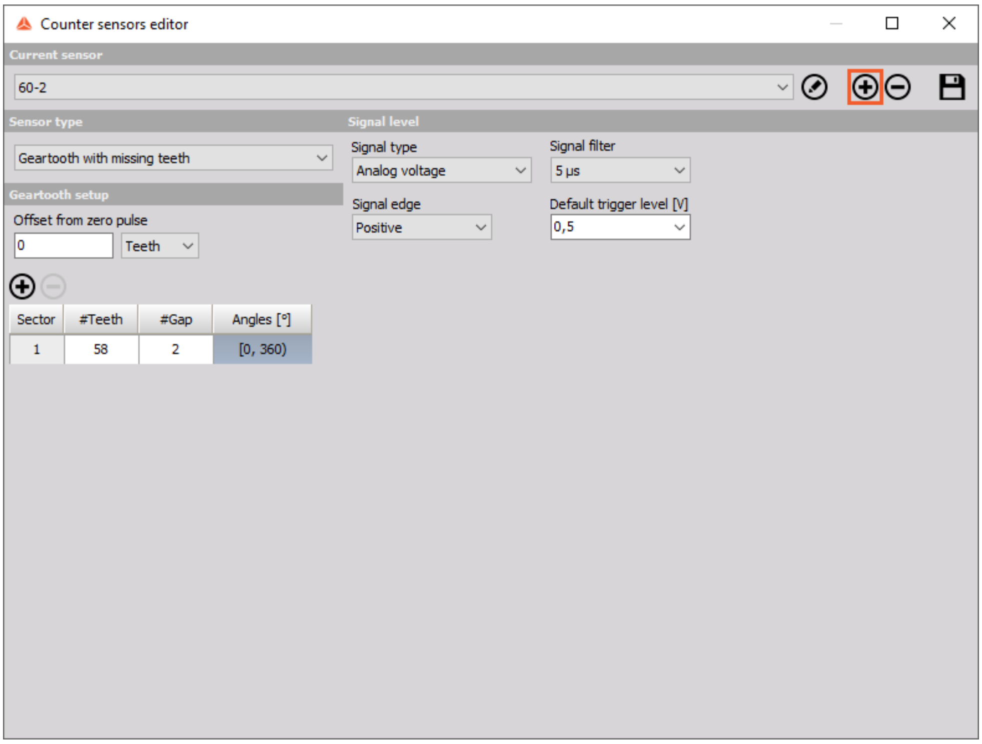


Image 24: Counter sensor editor

Press F1 after opening the Counter sensor editor to get further information ***on how to define sensors***. This will open automatically the online help.

After the sensor type is selected, we need to define where the sensor is connected to.

Only input channels which are selected as '**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***, the fine adjustment for the angle sensor must be done. In the case of analog sensor selection, the trigger levels can be precisely adjusted. First the trigger edge is defined, according to the signal. Also trigger and retrigger level is set. It is recommended to use the retrigger level to avoid false triggers. False triggers will disturb the 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.

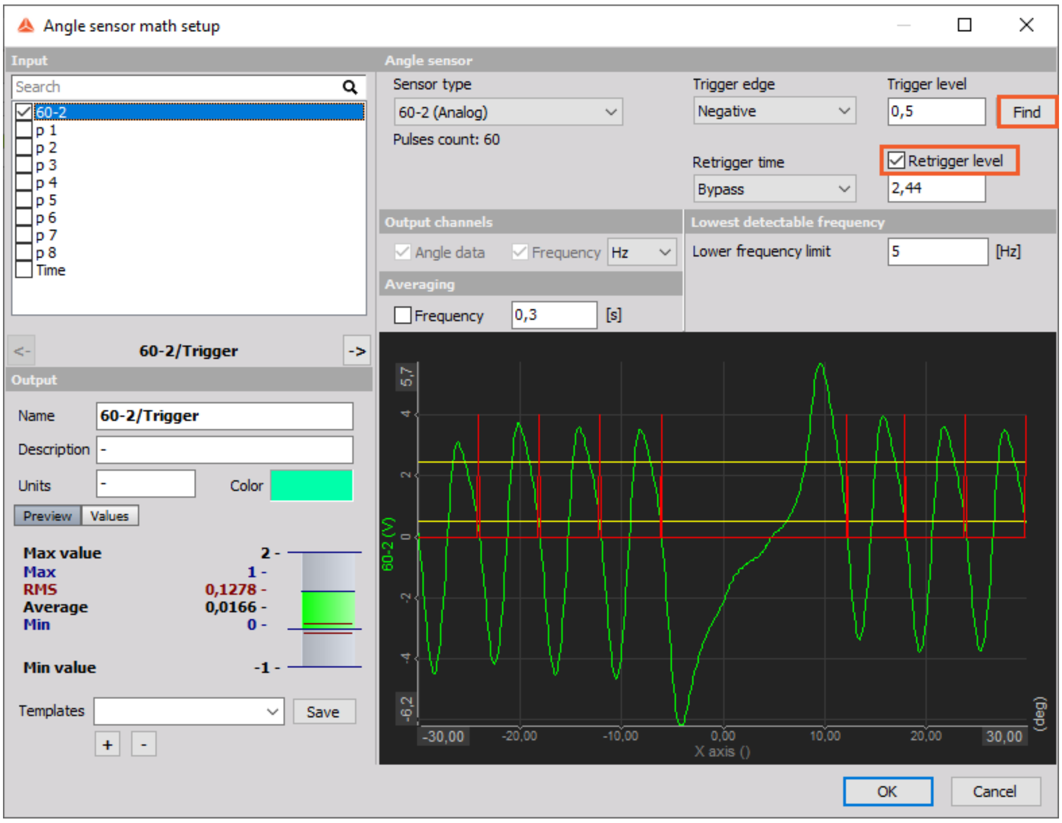


Image 25: Finding a retrigger level with Angle sensor setup located in the Math module

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

Image 26: Trigger edge determination

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.

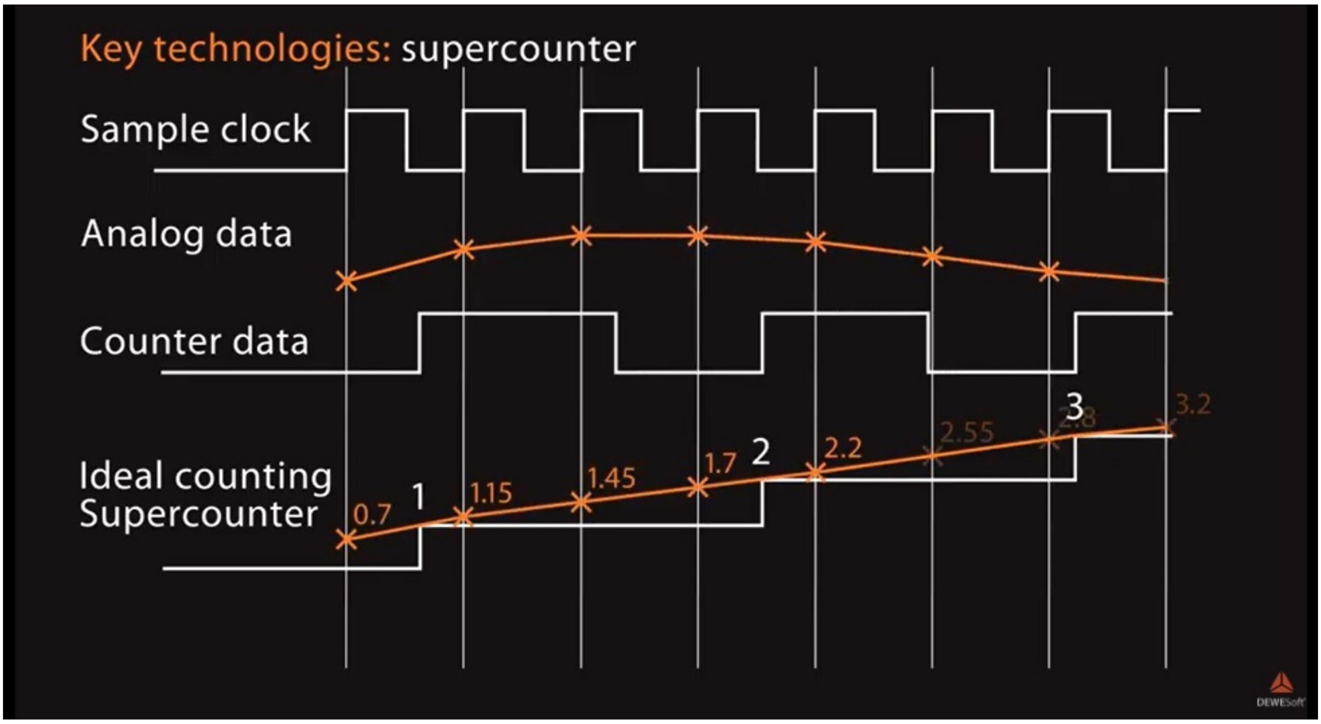


Image 27: Dewesoft Supercounter is interpolating counting values for every sample so results can be more precise

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.

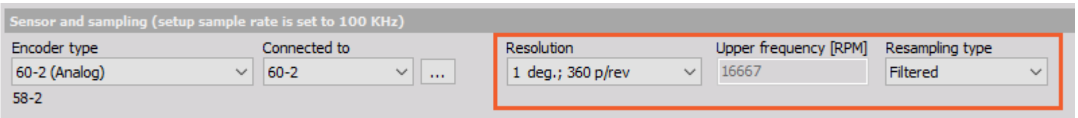


Image 28: Selecting resolution and resampling type

Take care of this limit to ***avoid aliasing*** effects by the re-sampling algorithm. As a **Resampling type**, an unfiltered method can be selected which is a linear interpolation from the time to the angle domain. The filtered type is based on an FIR polyphase decimator with a filter frequency of angle resolution * 2 to avoid aliasing effects in the angle domain data.

TDC Detection

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

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.

Image 29 shows the angle offset of a not fired engine (cranked).

For **automatic TDC detection** (Start button), the no of cycles has to be entered. CA 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.

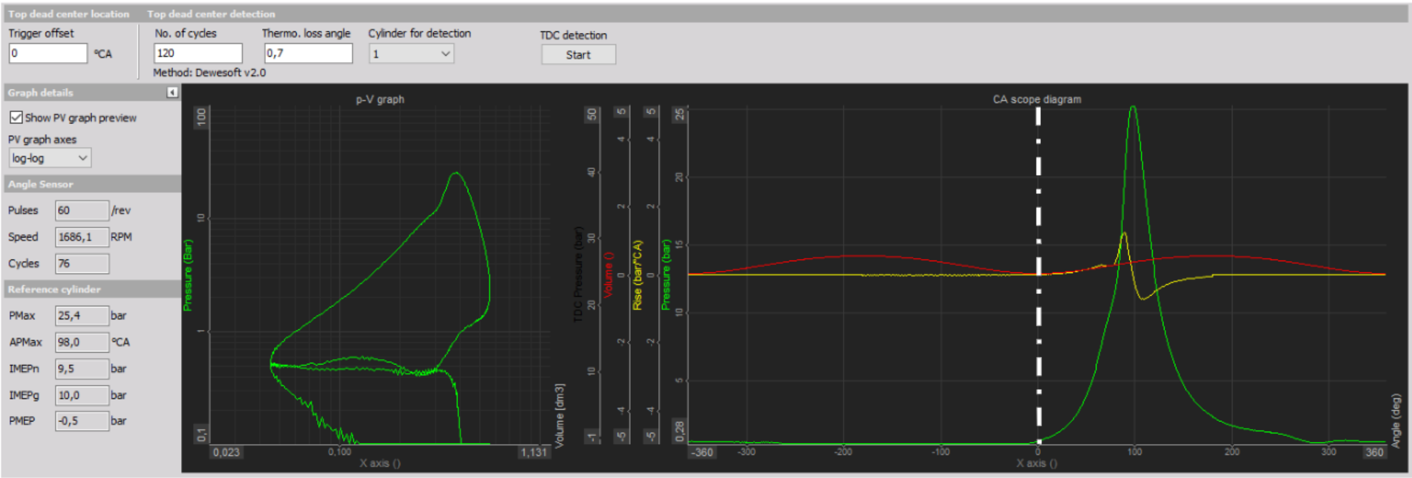


Image 29: Encoder settings without TDC detection

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

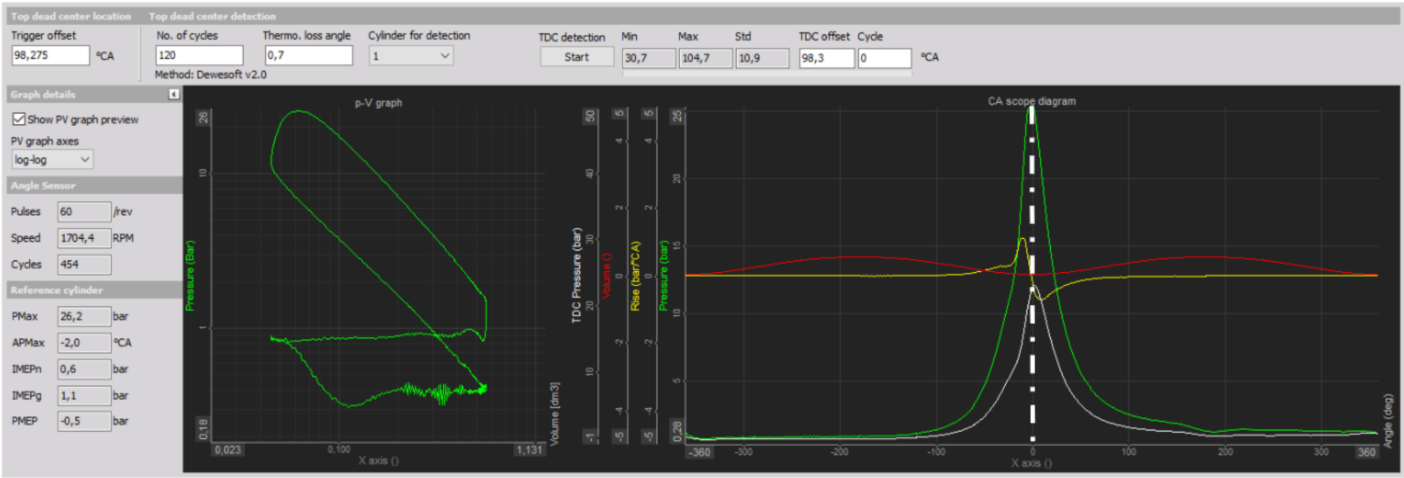


Image 30: Finished TDC detection in Encoder settings

The example above was using the ***installed pressure sensor*** to measure the TDC. This is a very convenient and fast way of doing it. The only variable is the thermodynamic loss angle.

> Basic measurement results are shown on the right side for a short check if the settings are correct.

Instead of a pressure sensor, a *TDC sensor* can be used. The TDC sensor must be connected to *an analog 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 CA setup.*

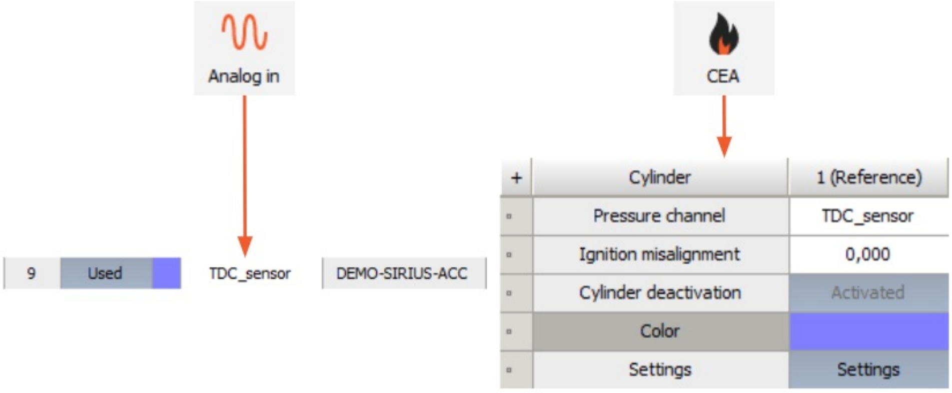
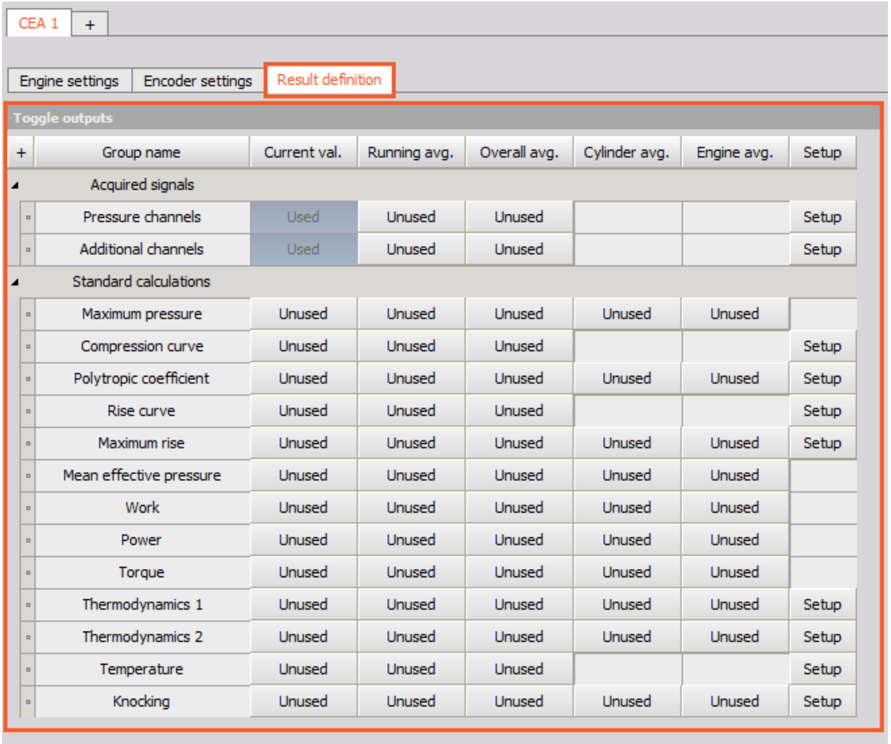


Image 31: Using a TDC sensor which has to be connected to an analog input and assigned to the reference cylinder in the CEA setup

How to define the Results?

There are plenty of options that can be used when it comes to the **Result definition** for CEA inside Dewesoft X as it is shown in image 32. Detailed channel list overview and their description is available in the Combustion analyzer manual, chapter 4.6.2 Channel overview on page 25.



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

Image 32: Result definition in Dewesoft X

For every Group name - Acquired signal and Standard calculations, different values can be used for calculation and different types of averaging can be enabled:

Calculation value type	Description
Current value	Gives the current value for each cylinder.
Running average	Calculates the mean value of the last n cycles.
Overall average	Gives one average pressure vector for the complete measurement.
Cylinder average	Gives one average vector for each cylinder separately for the complete measurement.
Engine average	Calculates the current average value of all cylinders together.

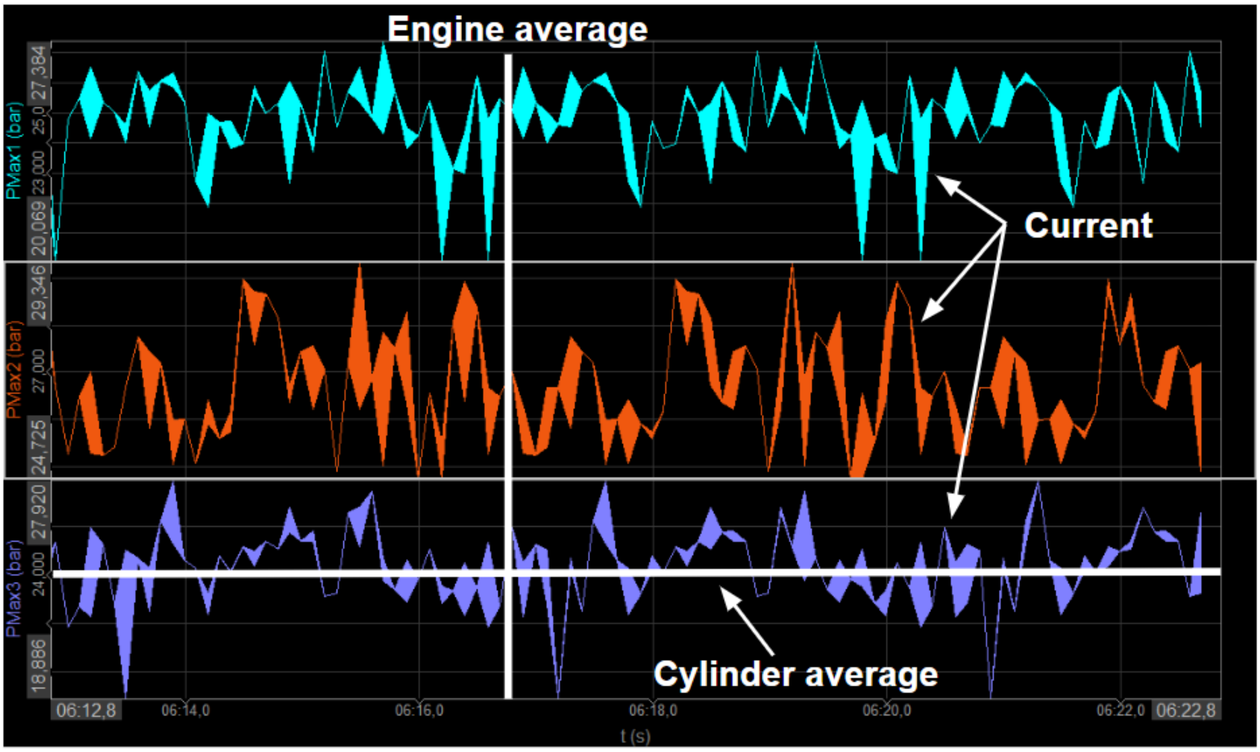


Image 33: Definition of calculation value types

Which Result Calculations can be made?

In **Result definition** from the previous chapter 'How to define the Results?' it was seen that there are *plenty of different calculations that can be applied as a result*. The following section will introduce all the calculations that can be used inside Dewesoft X.

The *Group name* column from the image 32 in *Result definition* tab is divided into two groups:

- **Acquired signals**, which are by default selected as 'used' for calculation

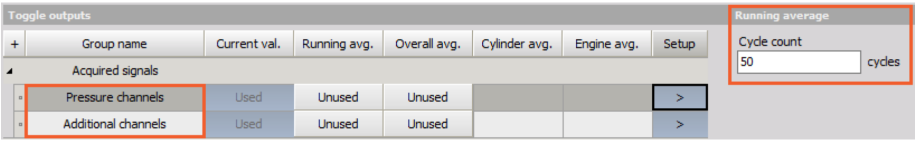


Image 34: Acquired signals in Result definition, where you can also define the Running average Cycle count for both channels

- **Standard calculations** that are totally optional for result definition.

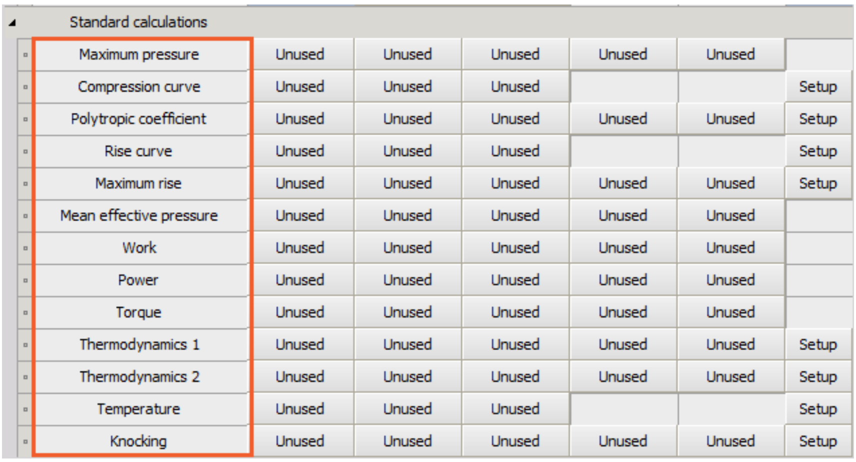


Image 35: Standard calculations options that can be used for calculation

How Thermodynamic is defined?

There are *two types* of thermodynamics calculations that can be used.

Thermodynamics 1 is the basic thermodynamic calculation that was implemented in the first CEA module and it was available in previous versions of Dewesoft X. Now it is basically only used for a relevant comparison in case you obtain some older results. While **Thermodynamics 2** is an upgraded and advanced thermodynamic calculation algorithm that is now used as a primary tool for such calculations in Dewesoft X.

Thermodynamics 2 and Temperature calculation are closely related, so when clicking on Thermodynamics 2 Setup button, the settings for temperature calculation will also pop-up as it is shown on image 36.

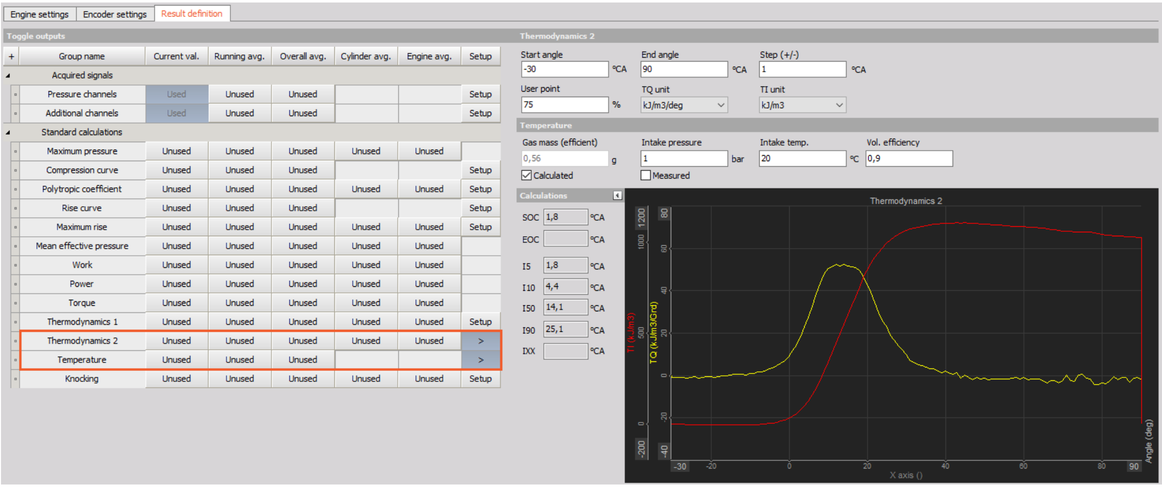


Image 36: Thermodynamics 2 and Temperature setting are related

There are a few settings that can be defined in Thermodynamics 2 and Temperature result definition:

- **Thermodynamics 2 i**s defining *pressure derivative* together with the *heat release*:

Setting	Description
Start angle [Â°CA]	For setting up the **Heat release** calculation the start and stop angle of the crank must be defined. The typical range is from -30Â° to +60Â°. An earlier injection start angle must be set according to the real injection point.
End angle [Â°CA]	
Steps [samples]	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 more information please refer to manual, chapter 11.4.1 Heat release TQ on page 80.
User point [%]	Heat release creates several output channels with angle values for certain amplitude values - 5, 10, 50, and 90% (called I5, I10, I50, and I90). Additionally, we can define one user point called IXX where the XX is the percentage value of the heat release defined here.
TQ unit	
TI unit	It is a unit for a *heat release*. We can either have the physical unit for the heat release or have it expressed in percentage: • **kJ/mÂ³/deg** - related work[kJ] to 1mÂ³ per 1deg volume is related to Vs = swept volume • **%** - scaled to sum of 100% (integrated signal =100%) • **J/deg** - related work[J] per 1deg

- **Temperature:**

Setting	Description
Gass mass	For the Temperature calculation, the gas mass is required. This can be either manually entered, or calculated. • If from Calculated is used, the intake temperature, intake pressure, and also the
Intake Pressure	
Intake Temperature	

Volume efficiency	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.

For **Pressure derivative,** the *start-angle, the stop-angle,* and also *the step size* must be defined.

Start of combustion (SOC), End of combustion (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 (refer to manual, chapter 4.1 Engine Setup on page 9):
  - Gasoline where MFB = 5%.
  - Diesel where MFB crosses 0%.

- *Burned mass fraction* is calculated out of integrated heat release TI. The maximum of the integrated heat release corresponds to 100%, and the angle positions for I5%, to I90%, are extracted.

How Knocking is defined?

How to change the default Channel names?

The channel names continuously created are default names created by the CEA math module. They can be changed afterward as well by entering the **channel** or **sub-channel list** as it is shown in image 51. Some default names can even be customized by *changing the engine template*. Please refer to the Combustion analyzer manual, chapter 10 Customizing the CA-Module on page 71 for further information.

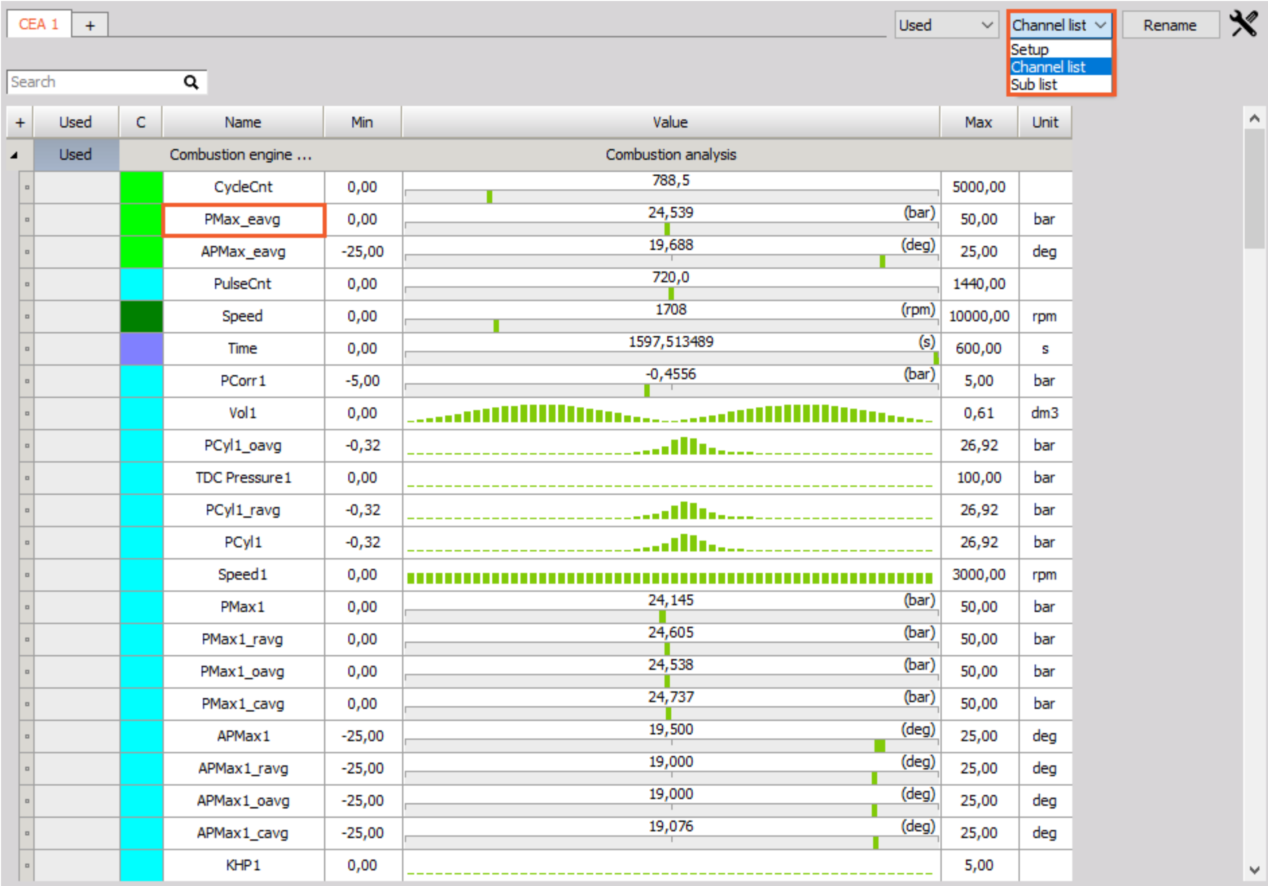


Image 51: Changing channel names in the CEA module

How to setup a channel for a Combustion Noise?

The CEA module of Dewesoft X calculates all relevant results for combustion analyzing as described. However, some applications or measurements need advanced calculations not supported directly inside the application mathematics module. For this we can use the complete mathematics toolbox of Dewesoft X to get the desired results.

This chapter will explain the Combustion Noise feature and give a short overview of the statistics.

NOTE: Those are only two of the many features that Dewesoft provides.

Theory of Combustion Noise

Combustion Noise measurement is used to calculate external noise from an internal combustion engine, using cylinder pressure. In other words, the cylinder pressure (explosion) causes an external noise.

The CEA Noise must be calculated in the time domain. First the value is scaled from bar to Pascal. This is followed by the U-filter, which simulates the transfer function of the engine (1. and 2. filter in the overview). Optionally we can use the A filter (human hearing filter) to determine the human perception of the noise produced by the engine.

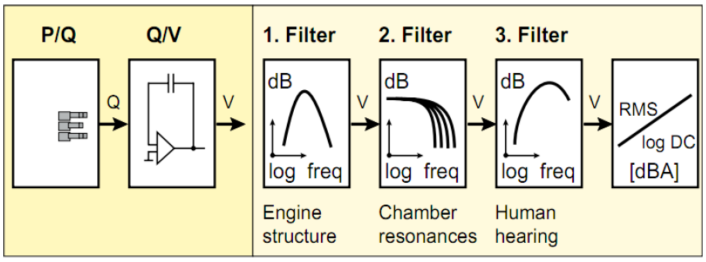


Image 52: Filters used for Combustion noise

Setup of Combustion Noise

The CEA Noise is a part of the *basic mathematics functionality* of Dewesoft X. Open the **Math module** -> **Add math** -> add **Combustion noise**. A screen similar to the one on image 53 should have opened.

Like for any other mathematics we need to select the input channels (on the left side), perform the configuration using the A filter, and finally define the output channels to be calculated and stored to the data file.

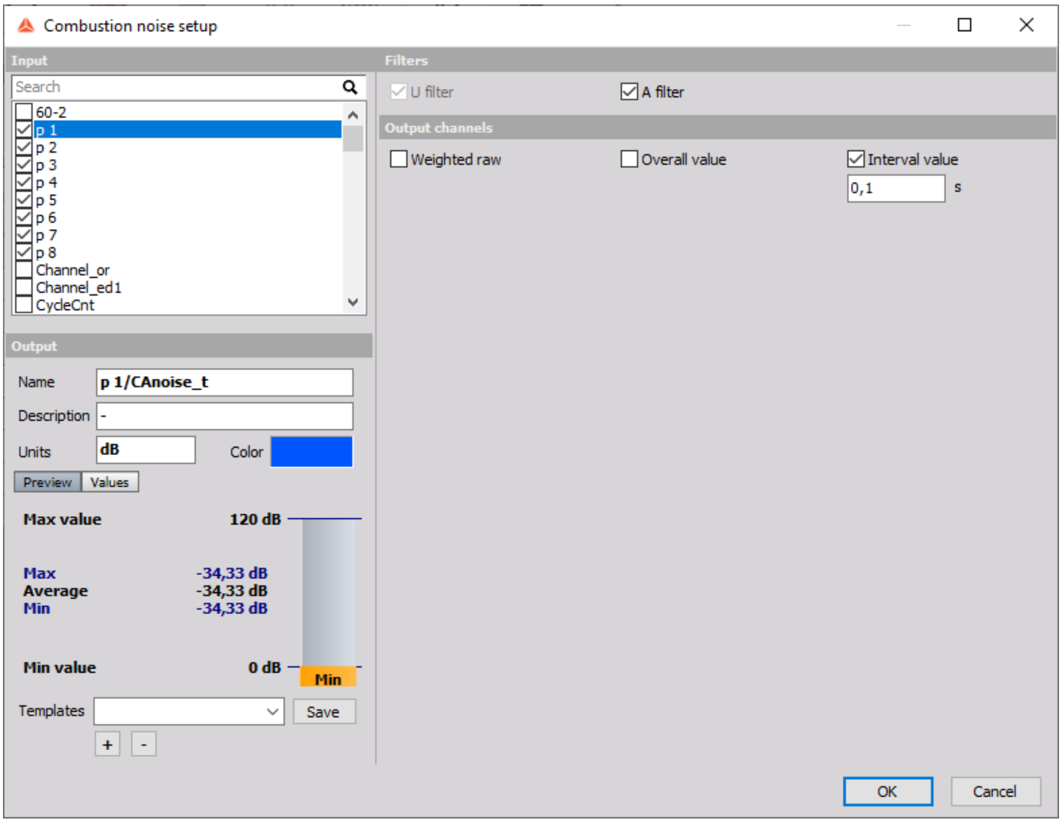


Image 53: Combustion noise setup window

The input channels have to be scaled in *bar* or *Pascal*! Unit conversation to Pascal for the **Weighted raw** channel or dB for the Overall and Interval values is automatically performed by the CA noise module.

The formula for calculation from Pascal to dB unit is:

$$SoundPressure[dB] = 20 \cdot log10 \frac{Pressure[Pa]}{2}$$

Depending on the configuration for each input channel up to three output channels are available:

- **Weighted raw:** The result is a time-domain signal with applied U- and optional A- filter and converted in Pascal, in the input unit is bar. This result can be further analyzed in the Sound Level Meter.
- **Overall value:** The result of CA noise over the whole measurement in [dB]. At the end of the measurement we will get one value, which is stored.
- **Interval value:** here the CA noise is calculated in intervals. It is recommended to set the interval so that at least 1 or 2 cycles are included. Here only the lowest rpm has to be considered. At 600rpm (= 10Hz = 100ms) at least 0.2 sec should be set for a 4 stroke engine to get stable results.

The frequency range of the U-Filter and the A-Filter is around 20 kHz. So please take care that the dynamic sample rate is set to 40 kHz or higher.

Basic statistics setup

If further statistic calculation is required, we can use the **Basic statistic function** from Dewesoft X. This is added in the *Math module -> Add Math -> add Basic statistics.* The screen similar to the one on image 54 should have opened.

Input defines the *channels where the statistics are calculated from*. Since the CA module generates many output channels, the channel filter function helps to find the needed channels.

You can define several results under the section **Output channel.** For each Input, the corresponding result is calculated. In the section Output you get a *list of all calculated channels*. You can change for example the default channel names.

There are several ways to define the time interval of the calculation and as well the time interval for the calculated result.

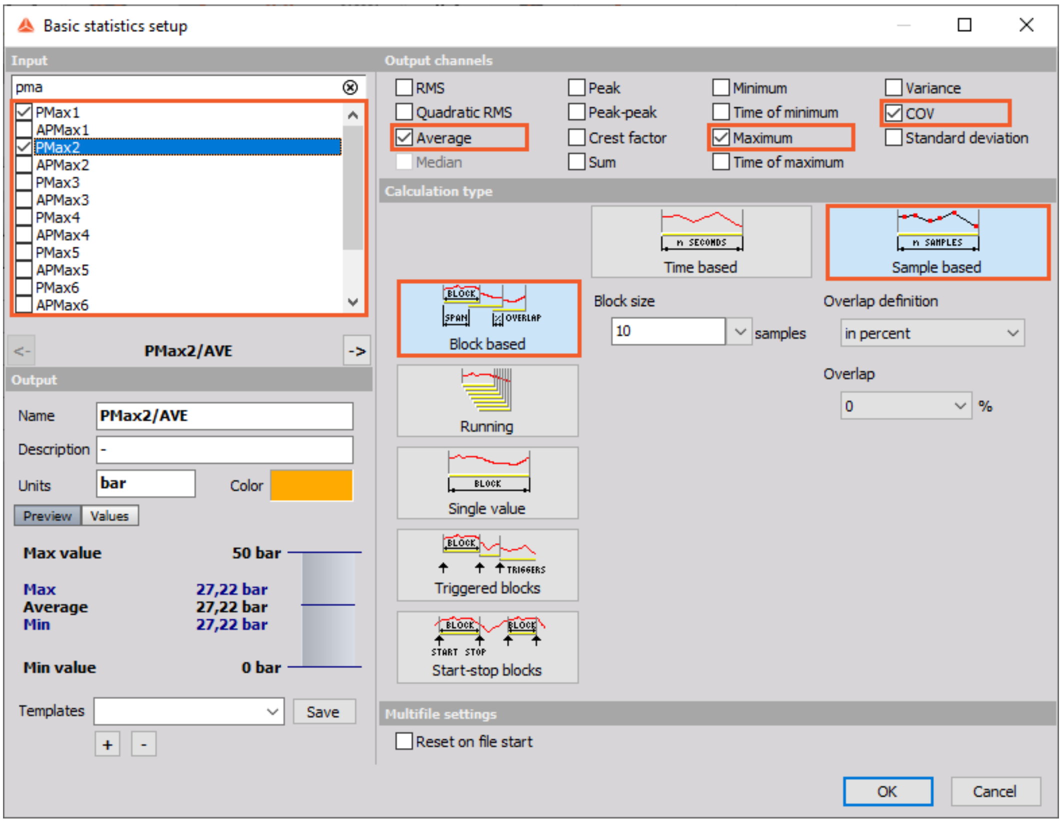


Image 54: Setting up the Basic statistics for the CEA channels

For *statistics on CEA module channels* it is strongly recommended to use **Sample based** calculation, because *1 sample corresponds to 1 cycle* (e.g. 10 cycles for the example on image 54). If we used time-based instead, the number of cycles could not be defined because it would vary according to the angular speed. Moreover the time-based calculation requires a higher CPU load.

The final step is to define how the statistic result is stored. You can choose between:

- **Block based**: One result after each block size
- **Running**: Calculation over the moving window
- **Single value**: One result of the complete measurement
- **Triggered blocks**: Calculation between the external trigger events
- **Start-Stop blocks**: The block start and the block stop can be defined based on external events.

The example on image 55 shows the settings for the statistics calculation between cycle 10 and cycle number 50. Any channel can be used as an input channel and also various trigger conditions are available.

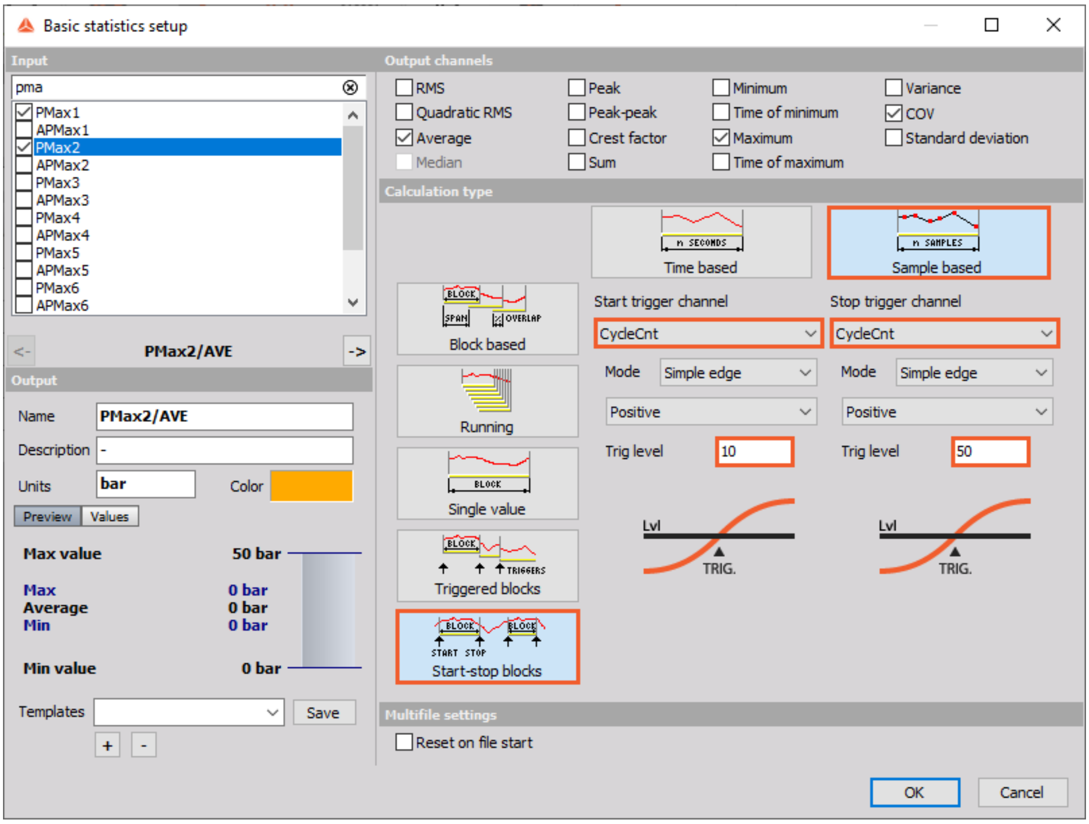


Image 55: An example of basic statistics calculation between cycle 10 and 50

Basic statistics of Angle domain data

The example settings on the image 55 are based on cycle-based data: one value per cycle. *The basic statistic can also be calculated from angle based data.* For example the maximum pressure curve over a defined number of cycles.

For the angle-domain data statistics and the cycle based statistics you can use the same setup. The only difference is that the **output channels of the angle based statistics are vector channels**. In the left bottom of the screen, you can see different previews according to the data-types. The cycle-based channels show a value and the angle domain-based shows a data curve (of the vector channel).

You can also mix different input channel types in one statistics module: time domain, angle domain, or cycle-based data. The statistics mathematics will always use the correct output channel types for the corresponding input data types.

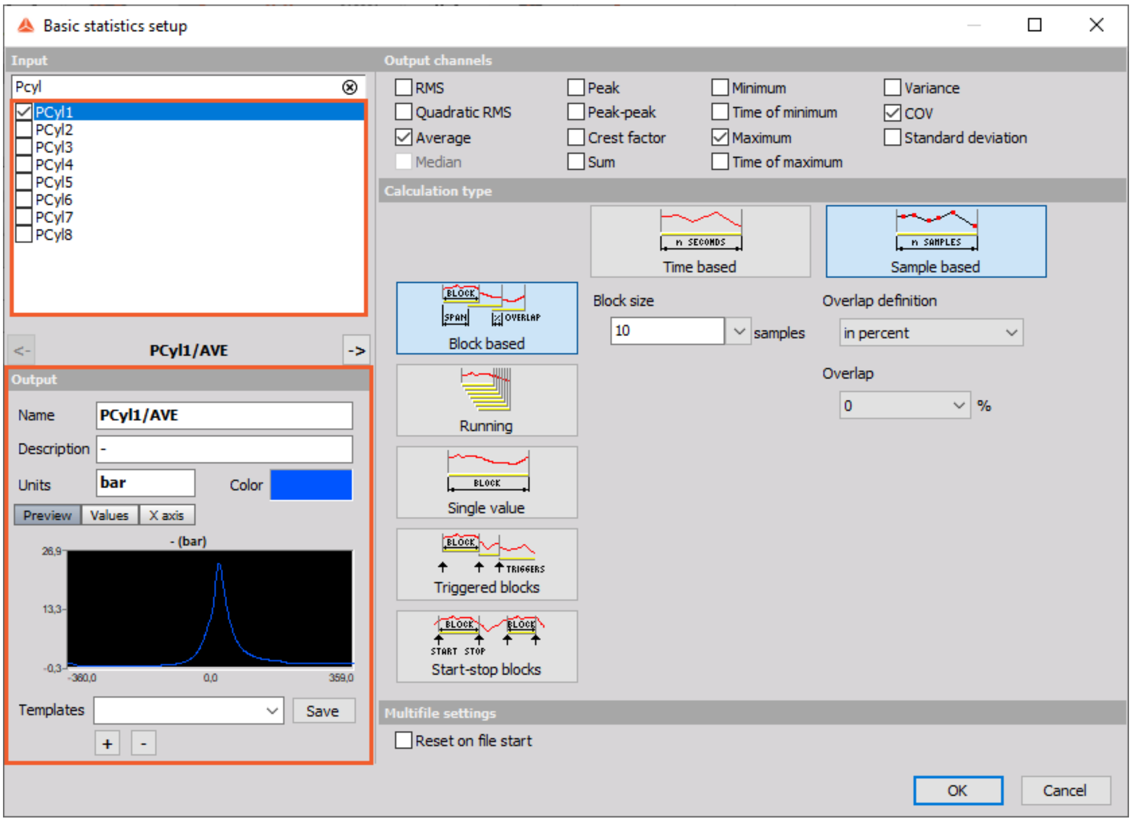


Image 56: Output channels of the angle based statistics are vector channels

Array statistics

For *analyzing angle domain data* the **array statistics** can be used. Array statistics can be added in the *Math module -> Add Math -> add Basic statistics.* The screen similar to the one on image 57 should have opened.

This module accepts only *input channels as a vector type* (angle domain data). **The output is always a single value calculated for each vector**. So using the array statistics on CEA data, the result is always a cycle based value.

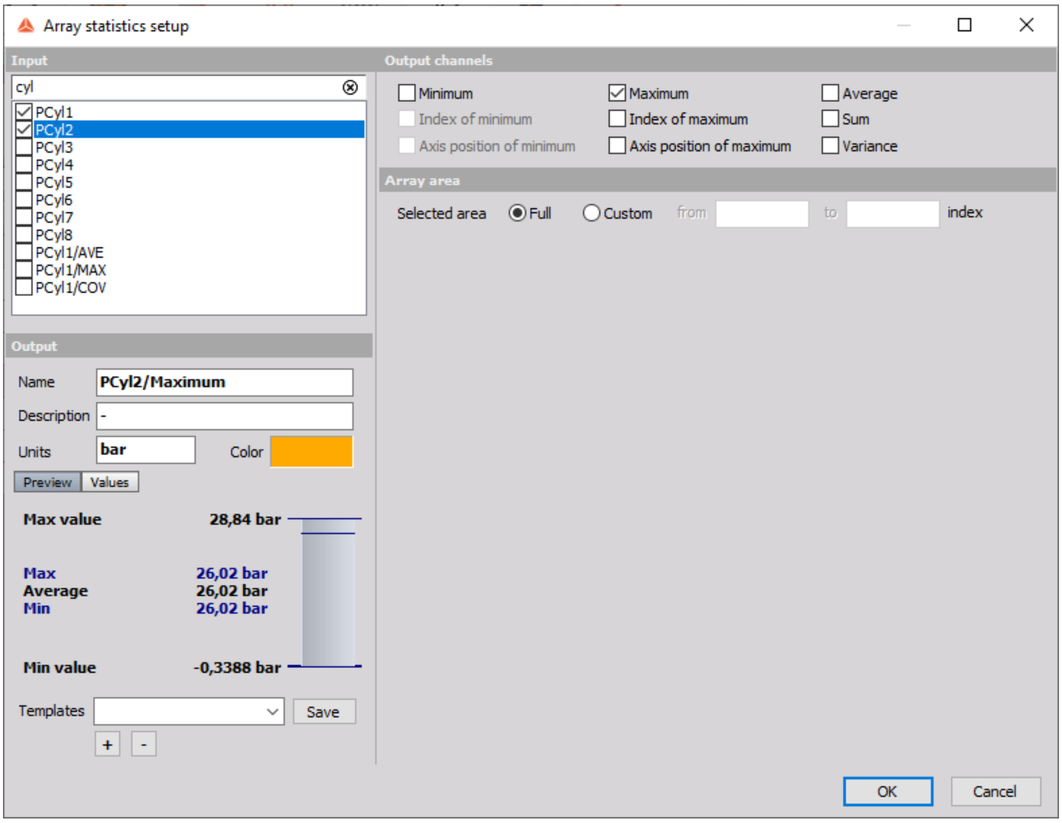


Image 57: Array statistics output is always a single value calculated for each vector

Array mathematics

Another powerful tool for manipulating data from the CEA module is the **array mathematics** inside the **Formula setup**. Only array (or vector) data are allowed as input channels. So this mathematics can be used with angle domain data from the CA Module.

This can be added in *Math module -> Add Math ->* add *Formula.*

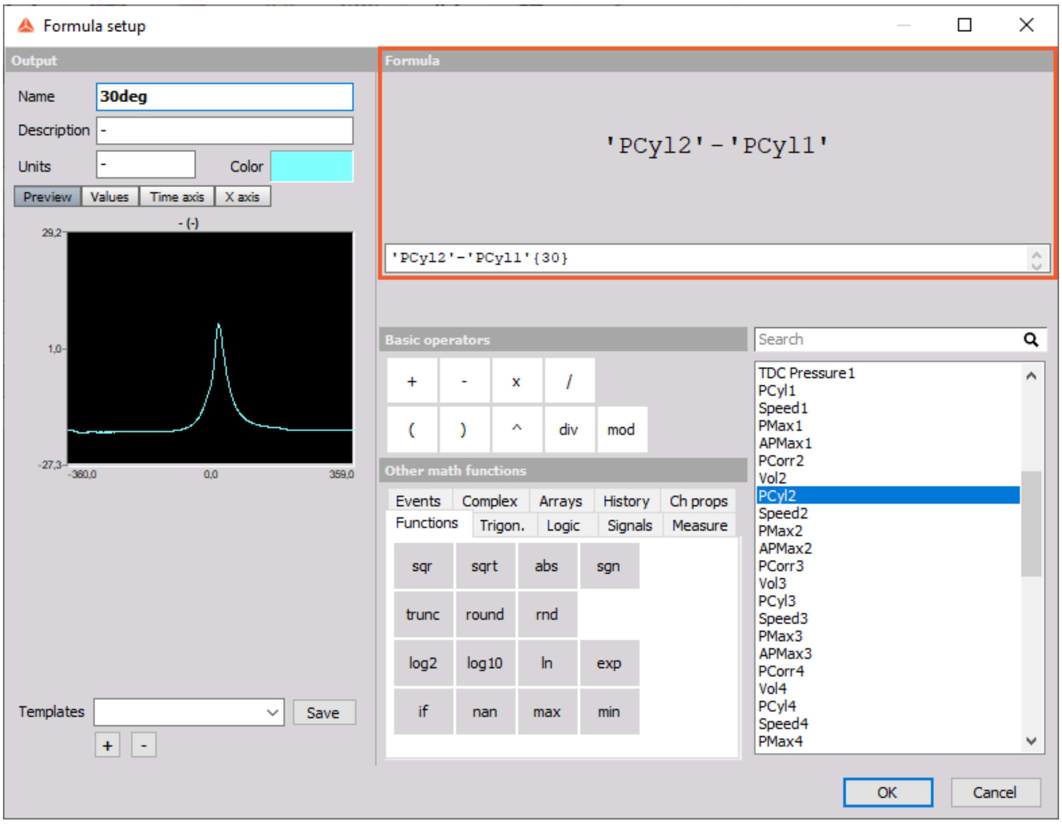


Image 58: Formula setup with the CEA channels

Below a short summary of the functions is described:

Function name	Description
[ ]	'Data'[Idx] returns one value from array channel Data at index position Idx.
{ }	'Data'{Pos} returns one value from array channel Data at position Pos in axis units.
[0:1]	'Data'[0:1] returns a cut-out array of array channel Data, from index position N to index position M, where 0 is the first value and 1 is the last possible value.
{N:M}	'Data'{N:M} returns a cut-out array of array channel Data, from position N to position M, according to axis units.
min	min('Data') returns the minimum value of array Data
max	max('Data') returns maximum value of array Data
avg	avg('Data') returns average value of array Data
sum	sum('Data') returns the sum of all values of array Data
integrate	integrate('Data') returns integrated array of array Data
minind	minind('Data') returns the index of minimum value of array Data
maxind	maxind('Data') returns the index of minimum value of array Data
minpos	minpos('Data') returns the position in axis units of minimum value of array Data
maxpos	maxpos('Data') returns the position in axis units of the maximum value of array Data

With the functions min, max, and avg we have the same functionality as the array statistics. But we have also access to a single data point of an array when using **[ ]** or **{ }**.

The formula on the image 58 ***subtracts the value at -30Â° of its vector***:

```
'PCyl2'-'PCyl1'{30}
```

Or in other words, the additional CA channel is offset compensated with the value of -30Â°.

It is also possible ***to cut data of an array***:

```
'PCyl2'{-30:60}
```

As a result we will get a new array containing the data from -30Â° to +60Â°.

Automatic display mode

When you start the measurement, DewesoftX will **automatically generate a display setup** (aka. measurement screen), named **CEA**, showing the major signals for a quick start. The tooth wheel symbol on the CEA display icon indicates that this display is generated.

On the image 59, the automatic display configuration is shown. The orange squared visual control is a 2D diagram, which can be assigned to an angle based result channel.

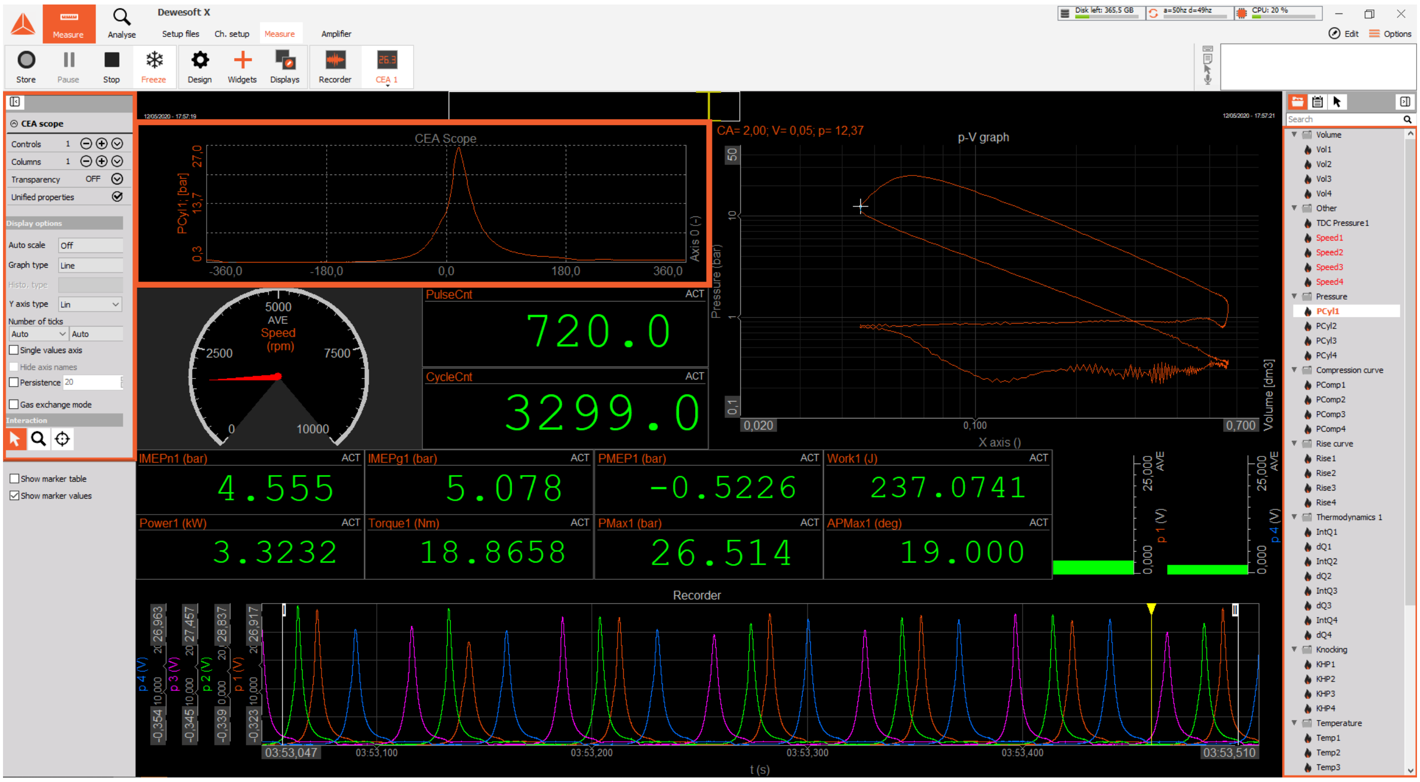


Image 59: Automatic display configuration that is generated by CEA plugin

The handling of all visual controls follows the same concept. For the selected visual control the properties are shown on the left side. The channel selector for this visual is shown on the right side. Only channel types suitable for the selected visual are shown. E.g. you can't select statistic channels for a visual control that expects angle based data. The channels that are currently selected are shown in bold.

Use the channel filter input field (at top of the channel list) to quickly filter the channel list.

Image 60: Filter channels for quick selection

Customizing displays

DewesoftX allows full customization of the measurement screens: i.e. you can ***add/remove*** and ***rearrange*** all visual controls to your specific needs. The major visual controls for combustion analyser measurement are described below.

Please refer to the Visual controls Pro Training Course for more information about visual controls.

Overview of data types

Not every display can handle every data type. ***Different input data sources generate different data types***. Different mathematic functions generate different data types as well. Moreover, the result of mathematical functions may depend on the input channel type as well.

For example: the CEA module will use the time domain data as input and generate primarily:

- angle domain data aligned to the combustion cycle, and
- cycle-based data which holds one value per cycle.

Let's make a summary of the different data types with some examples of the sources and which visual controls can be used for the different data types.

Scalar (single data points)

Scalar channels contain one single value per timeslot (i.e. in comparison to Vector or array channels, which contain multiple data values per time slot). Depending on how they are acquired (or calculated), we divide these channels into three groups:

- *Synchronous,*
- *Asynchronous, and*
- *Single value.*

The most common channels, are the **synchronous** channels which are usually analog, counter, or digital input channels as well as simple mathematical operations that depend on these channels.
Synchronous channels are time-domain data with equidistant time between the samples. The time distance is defined by the dynamic sample rate (except for external clocking).

Asynchronous channels are for instance CAN bus or GPS data. But also mathematic functions can result in asynchronous channels. For example:

- the result of block-based mathematics, like the statistics output
- all cycle-based data from the CEA module (eg. MEPx or MaxPressure)

Single value channels contain only one single value per measurement. For example:

- constants, like header variable
- the output of mathematics like:
  - *Overall statistic calculations* from the CEA module
  - basic statistics

For all of these scalar channels various visual controls are available in DewesoftX. Some examples are Digital meters, Recorder, Analog meter, Bar graphs, and so on, ... XY-recorder can also be used to visualize this data.

Only synchronous data channels can be used inside the Scope or for FFT visuals. You can use basic mathematics to convert asynchronous channels to synchronous channels but this is usually not recommended.

Vector or array channels

In contrast to the scalar data channel, **vector channels** (aka. Array channels) **contain multiple data-points for each time-slot**.

Examples:

- One FFT shot consists of multiple amplitude values - one for each frequency of the FFT resolution.
- Angle-domain pressure is stored as vector data - for each vector we get all pressure values over the defined angle resolution.

2D-Graphs are designed to display these data types. There are some special 2D-graphs dedicated to CEA:

- the Combustion scope
- the PV-Graph

3D-Graph allows you to display a history of these data channels (the time is the third dimension)

Matrix channels

Matrix channels are *multidimensional vector channels*. For example in a 2-dimensional matrix channel, each time-slot will contain an array and the elements of this array are also arrays (which contain the data in the array elements).

The output of complex sensors like a Thermo-Camera is matrix. This data can be shown in a 3D-Graph.

CEA-Scope

The CEA-Scope can be used for all angle based data from the CEA-mathematics. The results can be shown from actual data, from running or overall average, and as well from the additional channels.

Combustion PV-graph

The p-V graph (*Pressure* over *Volume*) can show actual and averaged pressure data.

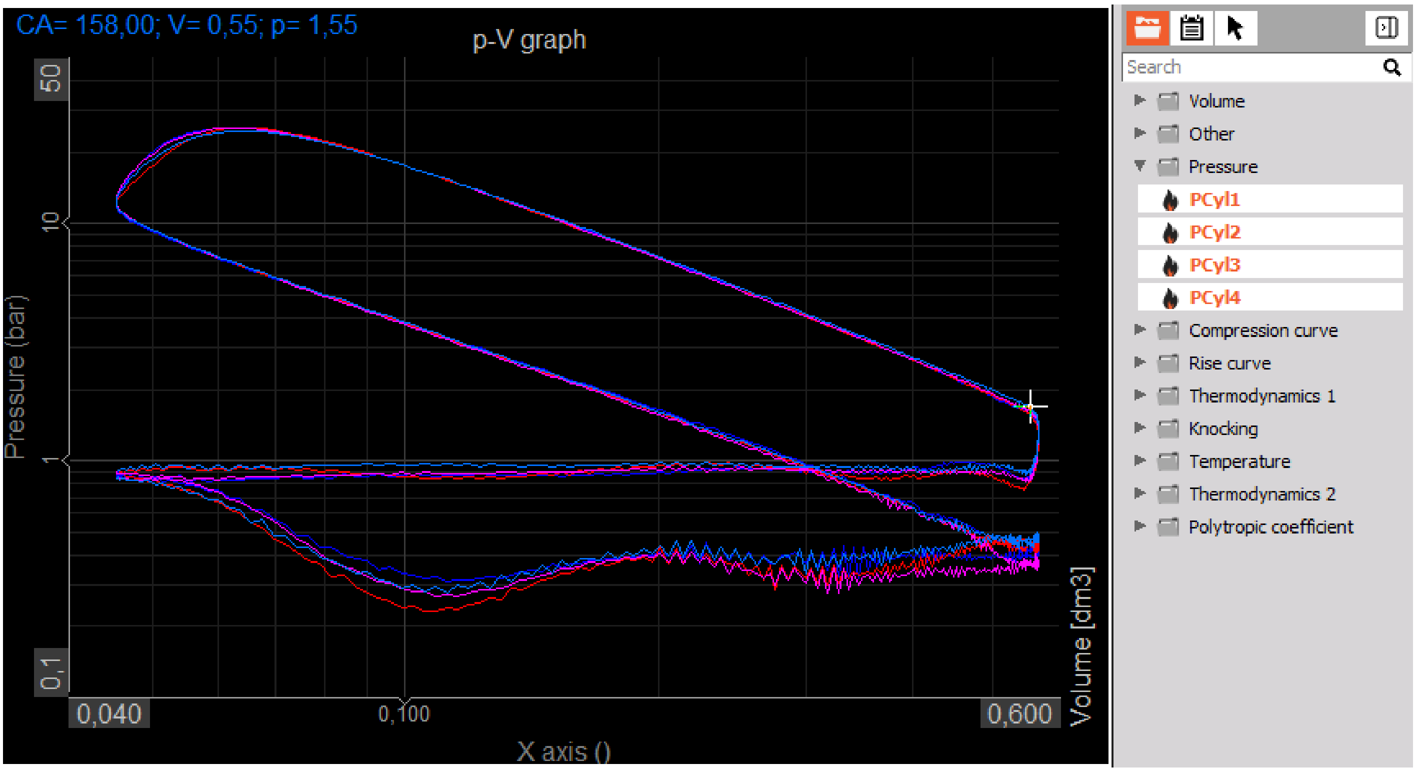


Image 62: p-V graph shows actual and averaged pressure data

Standard display types

Cycle based results such as MaxPressure are *calculated for every cycle*. We get a *single value every two revolutions for 4 stroke engines*, and *one value for every revolution in 2 stroke engines.*

Cycle based results can be shown in various displays. The common displays for cycle-based results are: **Digital, Analogue, Bar,** and **Recorder.**

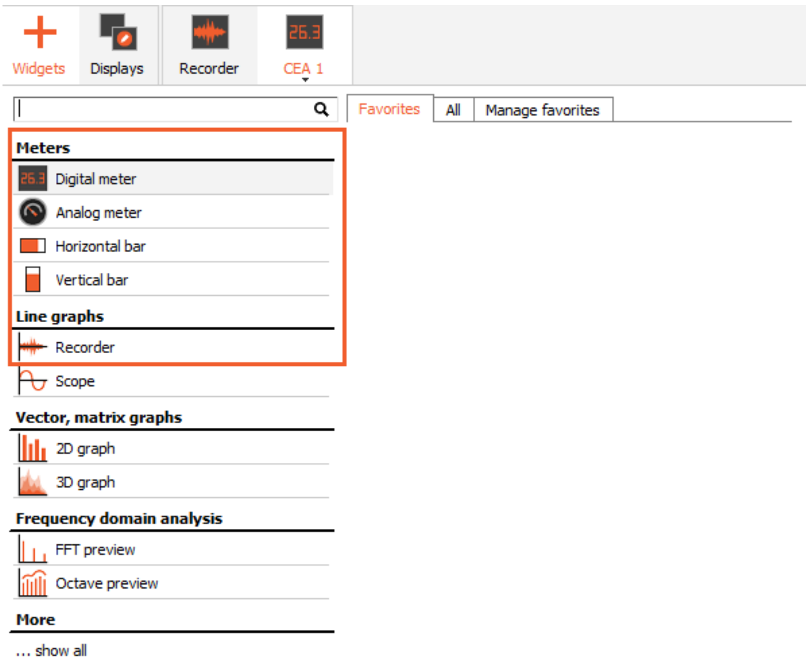


Image 63: Standard display collection

How to Store the Measurement Data?

You have several options to start and stop storing:

- **manually,** and
- **automatically** with various settings of the **trigger conditions.**

Please refer to the Storing options ProTutorial for more information about storing.

When using overall averaged data (single value results of statistic), read the information in this chapter carefully. It is important to keep in mind when the statistics calculation starts and stops! Otherwise the overall statistic results will not match the stored data!

Manual Start-Stop storing

If you want to manually start-stop storing, select the *Storing type*: *always fast*. Find the Storing settings on the location: *Measure -> Ch. setup -> Storing*. You can start storing your data directly in the setup screen by pressing '**Store**'. Or you can first go to *Measure* to first take a look at the live data and then start storing whenever you like.

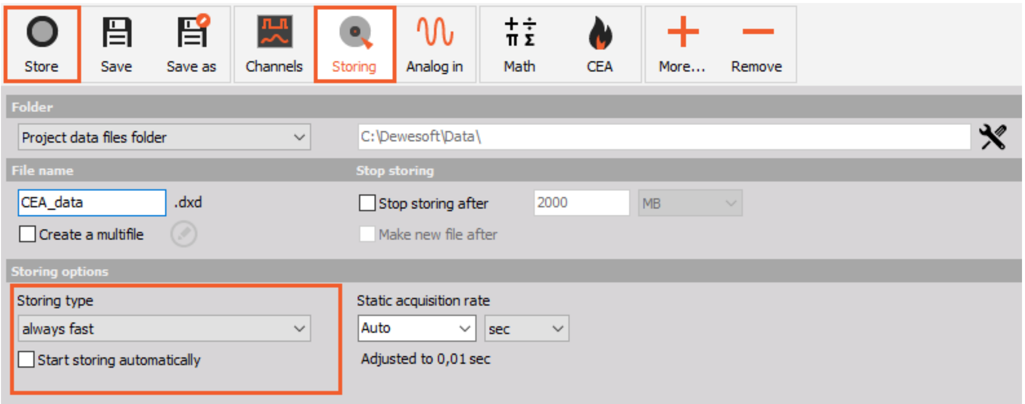


Image 64: Choose the storing type

To *stop storing*, just press the **Stop** button.

Pressing **Pause** will stop storing the data. When you are in pause mode you have 2 options:

- press **Resume** to continue storing, and
- press **Stop** to end the measurement and close the data file.

In pause mode, the overall statistics calculation is not interrupted.

When you stop the measurement, the overall statistic values are stored in the data file. The illustration below points out this difference more clearly. When you look at the graph you can see 2 marked ranges:

- The *Stored data time*: this is the time from the start of storing (when we have pressed the **Store** button) and when we have pressed the **Pause** button).
- The *Average calculation time*: this is the full time shown in the graph:
  after pressing **Pause**, the measurement still continues (and the statistics will still be calculated), but the measurement data will not be stored in the data-file. But when we press **Stop** at the end, the value of the statistics will be written to the data-file.

The overall averaged result (the green channel: *Cyl/Ave/P1/MaxP*) does not match the expected average of the data values (blue channel: *P1MaxP*) within the *Stored data time* range (because the calculation continued after pressing the **Stop** button).

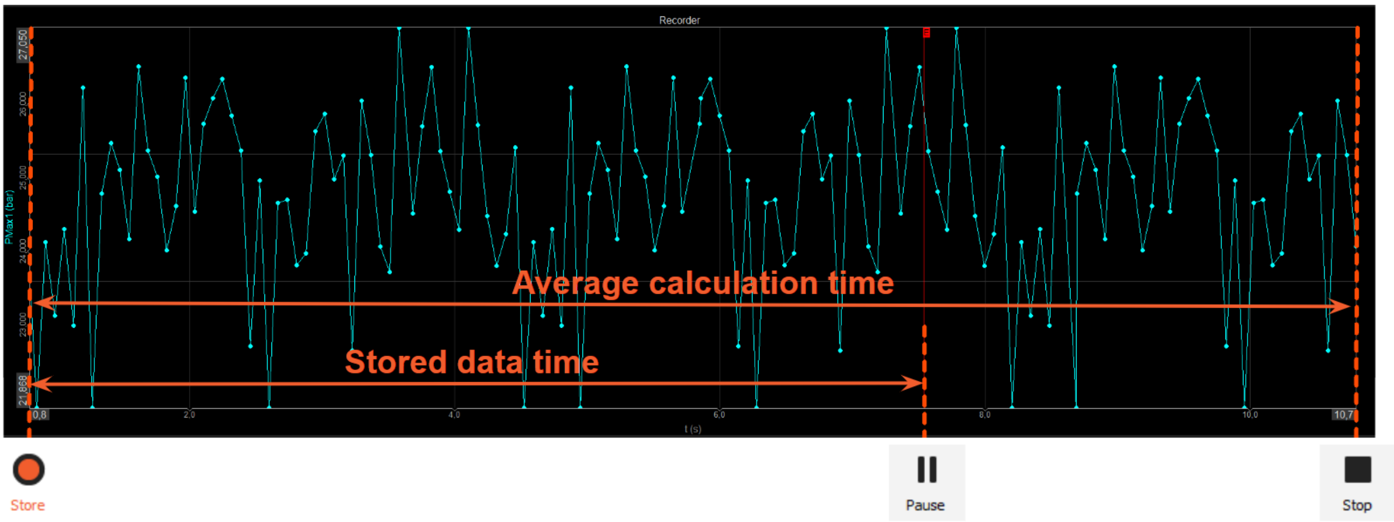


Image 65: Average calculation and stored data time

When you open the data-file in *Analyse mode*, the recorder will only contain the data of the *Stored data time* range and the average value will not match the expected value (average will be calculated from store start to stop).

Pause will stop storing the data but will not stop the overall statistic calculation. Use the Stop button to terminate your measurement, if averaged values must match the data file. Storing will always reset the overall statistic calculation!

When reloading this data file it seems now that average calculation is wrong because you can't see anymore the complete data set that was used for the average calculation. To correct this it is possible to recalculate the complete the CEA-mathematics out of the stored data file again.

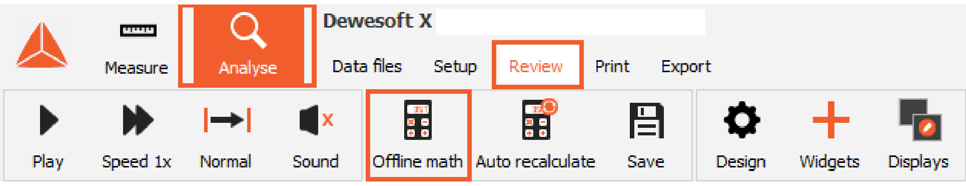


Image 66: Press Offline math

Press *Offline math*, enter the CEA module setup, and change the calculation state of the module from *Calculated* to *Offline*.

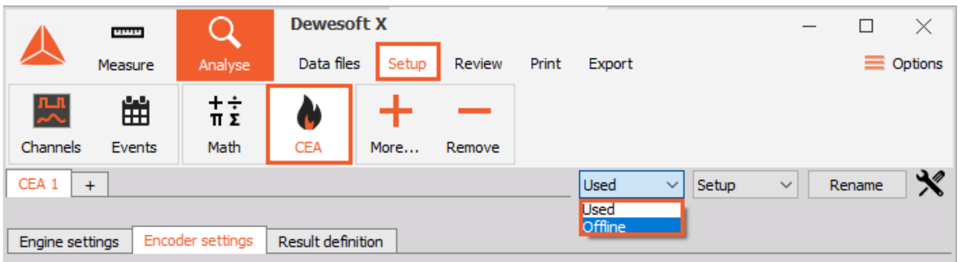


Image 67: Enter the CEA module setup

Go back to *Review* and you can *Recalculate* the CEA mathematics. The overall averaged pressure channel now matches the stored pressure data.

Press **Save** to overwrite the original stored CEA data inside this data file.

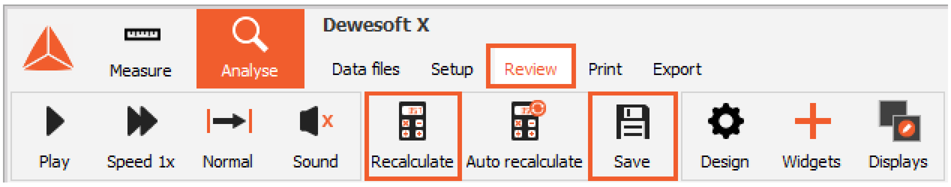


Image 68: Recalculate results

With Offline math you can modify existing Math modules and/or add new Math modules. For example inside the CA-Module you can add channels like Heat-Release which were not stored during acquisition.

Storing a defined number of cycles

DewesoftX offers various trigger conditions for starting and stopping the acquisition. When you want to store a fixed number of cycles, then you can use the Stop storing after XXX CEA cycles feature. In the example below, storing will be stopped after 100 cycles.

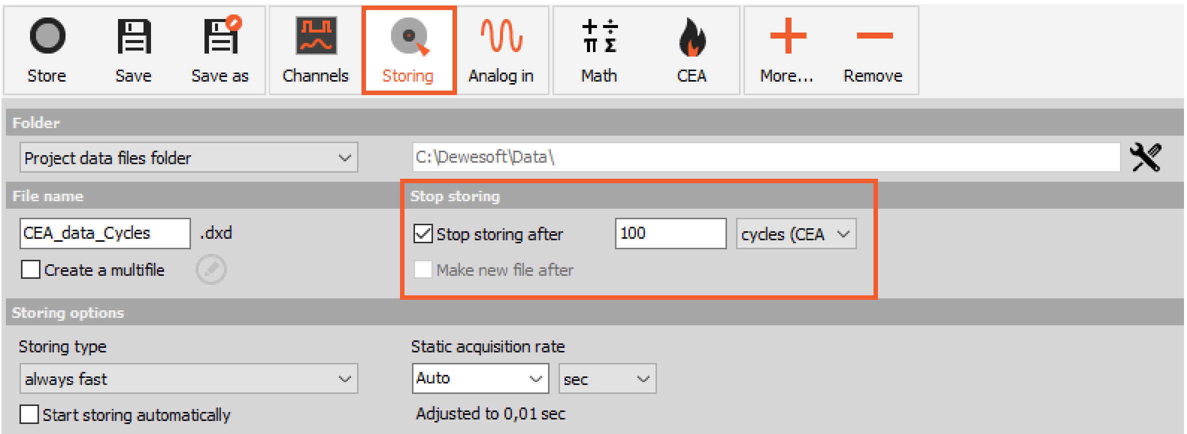


Image 69: Store a defined number of cycles

Start-Stop on channel condition

The aim of triggered storing is to store on external events. The start and the stop trigger can be any channel. Additionally pre-trigger and post-trigger time can be defined.

Dewesoft X offers various trigger conditions for starting and stopping the acquisition. As described in chapter Manual Start-Stop storing we need to take care of the calculation method of the overall statistics values to get the expected results.

For **triggered start and stop storing**, you must select the *Storing type*: *fast on trigger*. Now we have the possibilities to define *Start storing* and *Stop storing conditions*.

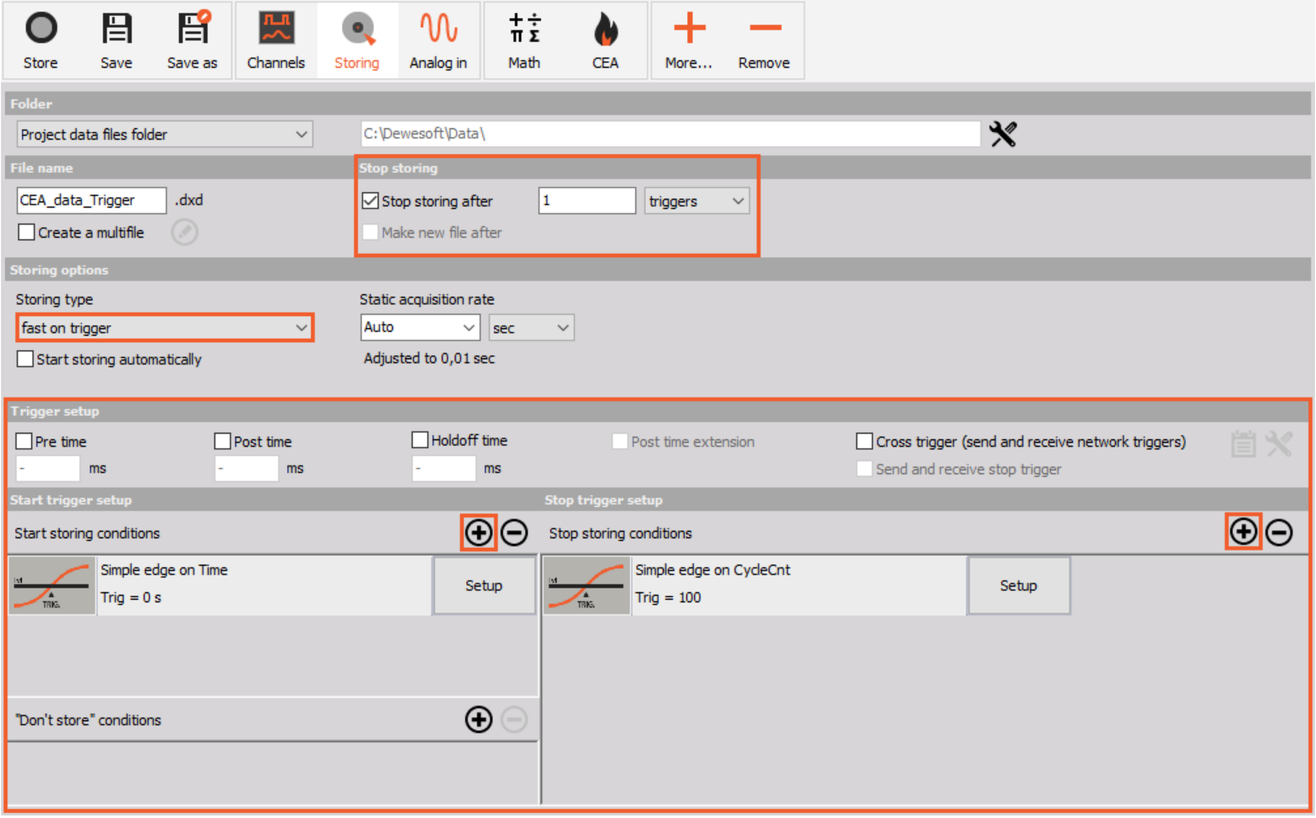


Image 70: Triggered start and stop storing

Let's make one example when storing should be started if the maximum pressure is above 100 bar and should be stopped after 100 cycles.

Start storing condition type is a simple edge on channel *P1/MaxP*.

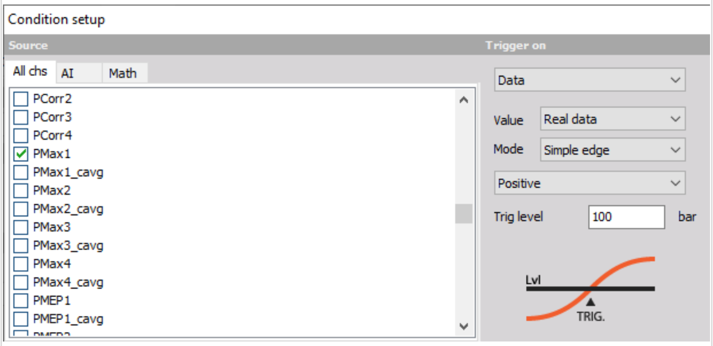


Image 71: Start trigger condition

Stop storing condition is channel *Cycle count*. As *Mode* we need *Delta amplitude* to stop after 100 cycles.

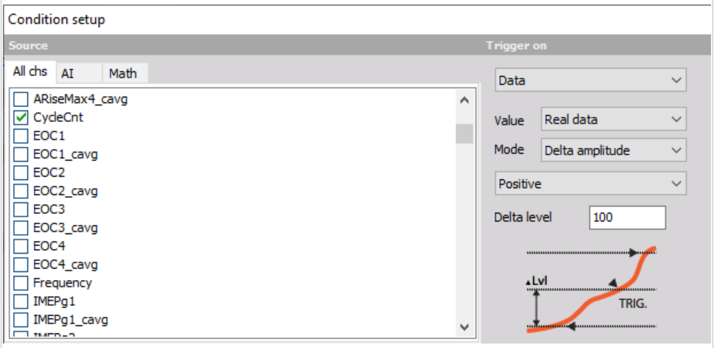


Image 72: Stop trigger condition

This will already work (e.g. it stores only the data of the 100 cycles), but we also need to take care of the overall statistics. With the current settings, the data-file will remain open after the 100 cycles and the overall statistics will remain active.

To avoid this, we can enable Stop storing after 1 trigger: This means that the storing will be stopped after 100 cycles and the DewesoftX data file will be closed (and will contain the overall statistics for the 100 cycles). When the next trigger occurs a completely new data-file will be created.

With the settings above, the ***average channels are reset at ARM of measurement***. So the Average channels will include the cycle value before the trigger event occurs as well. If average values are required for further analysis, they must be recalculated in post-processing like described before.

How to Analyze Combustion Data?

In the *Analysis* mode of Dewesoft X you can load a data file and:

- **review** the data,
- **modify** or add math modules, and
- print the complete screen to **generate a report**.

For analyzing recorded cycles the *yellow courser* can be *moved to browse through the cycles*.

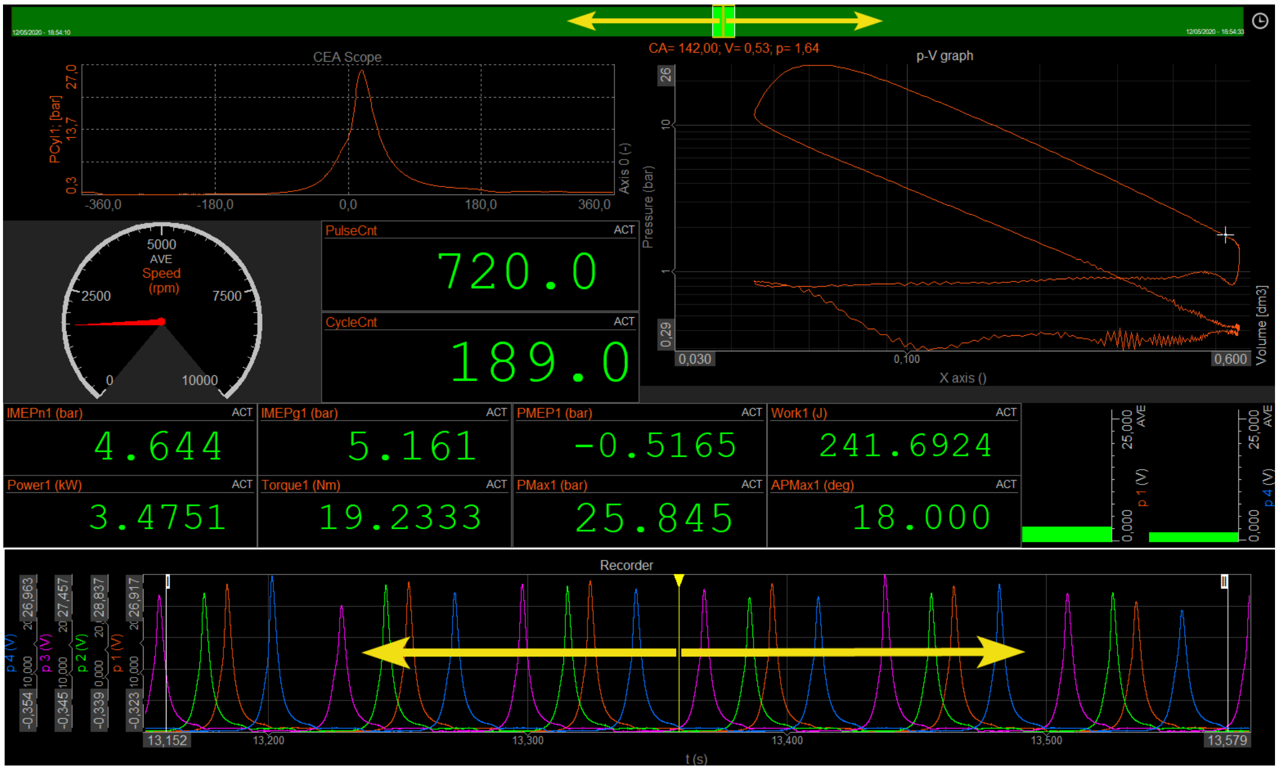


Image 73: Use the yellow cursor to move and browse through the cycles

Similar to the *Measurement mode* you can modify or add new *Visual controls* or *Displays*. All these modifications can be stored to the data file with *Save file changes*

You can also load the measurement screen layout and formulas from another data file with *Load display and offline math*.

By pressing *Edit* on the right top corner a context menu is opened which gives you the possibility to copy the image or as well the data shown on the actual display to the clipboard or to a file.

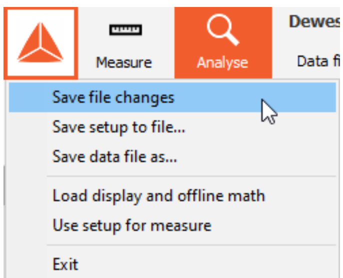


Image 74: Saving file changes

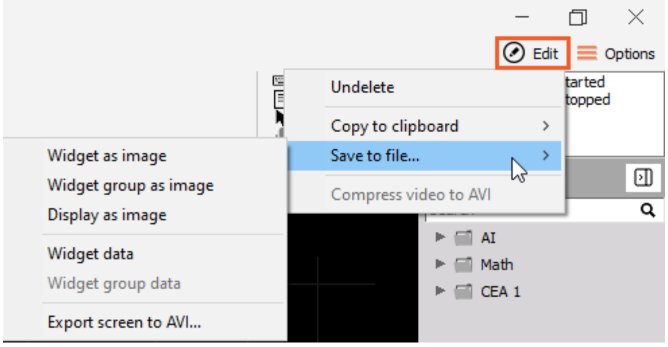


Image 75: Save to file option which allows you copying data and images

If further analysis is needed, *various export data formats* are supported.

How to Export the Combustion Data?

Time-domain data

When opening a Combustion analyzer data-file, the default ***Export Properties*** is set to Combustion ***data***. To export in time domain, export properties must be set to **Full speed data** in the ***Data presentation*** option. This means time domain data is exported. ***Angle based data from the CEA module are exported as a vector*** (if the target export format supports vectors). They are time-stamped to the end of the cycle time (the same is true for all cycle-based results).

The ***Channel list*** gives a quick overview of the channel type (***Dimension***) and update rate (values per second).

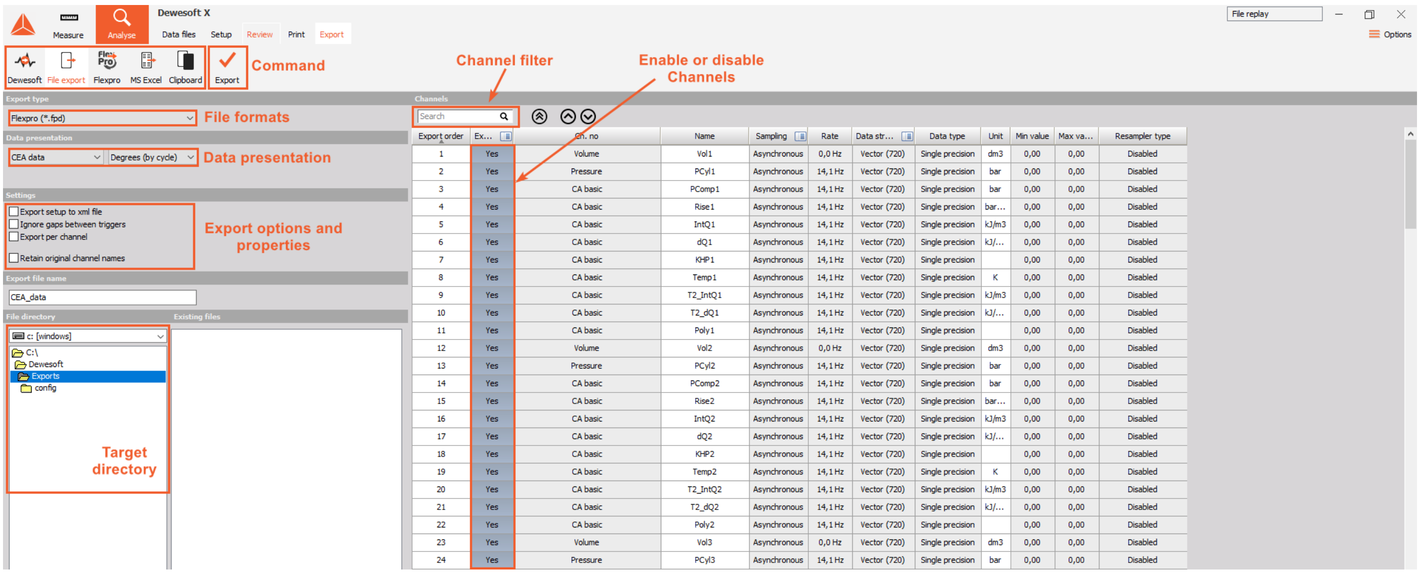


Image 76: Export window for CEA

Angle-domain data

To export angle-domain data we have to change the *Data presentation* to **CEA data**. With this setting all output channels from the CEA module can be exported as angle-domain data.

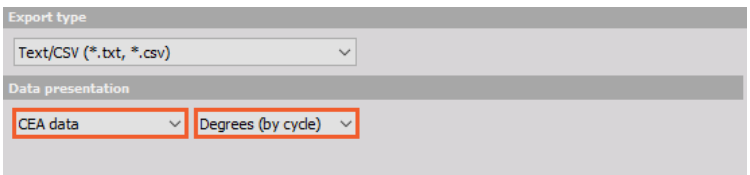


Image 77: For exporting the angle-domain data, set the Data presentation on CEA data

The results can be categorized into 4 groups:

- *Cycle* data as *Vector*: Angle domain data like pressure, integrated heat-release, additional channels...
- *Averaged Cycle* data as *Vector*: One angle vector for the complete measurement like the average pressure.
- *Once per Cycle* data as *Scalar*: Cycle based data like max. Pressure (value and position), I50, MEP values...
- *Averaged Cycle* data as *Scalar*: One value for the complete measurement like average of max. Pressure.

Some target file formats do not support multiple data types. That's why Dewesoft reports a message to select only one result type.

Before exporting the data we have to define the x-axis base.

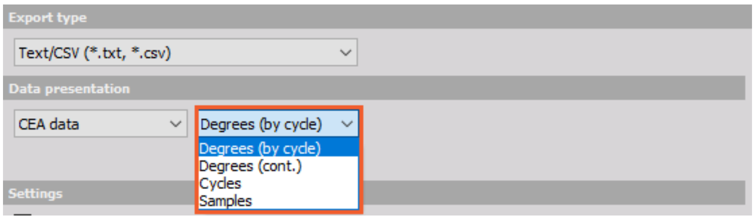


Image 78: Defining the x-axis base for CEA export

The table below gives an overview of the difference in *x-scaling using the different export types:*

Export type	Data type	Cycle 1	Cycle 2	Cycle 3
Degrees (by cycle)	Vector	-360 ... +360	-360 ... +360	-360 ... +360
	Scalar	0	720	1440
Degrees (cont.)	Vector	-360 ... +360	360 ... 1080	1080 ... 1800
	Scalar	0	720	1440
Cycles	Vector	0 ... 1	1 ... 2	2 ... 3
	Scalar	1	2	3
Samples (e.g. 360 p/rev)	Vector	0 ... 720	720 ... 1440	1440 ... 2160
	Scalar	0	720	1440

CEA data only export channels which are calculated in the CA-Plugin. If export from other Math-modules like Basic statistics is required, data must be additionally exported with the Export property Full speed data.

File replay

It is possible to export analog channels into a file that can later be used to ***simulate analog channels***, without having any hardware connected. If we have an analog angle sensor signal recorded, we can export that together with the pressure signal channel(s) and simulate a running engine.

First, the extension for replay file export must be added. This can be found in the download area.

After that, extract the file into: <Dewesoft_installation_path>\Bin\X3\Addons\

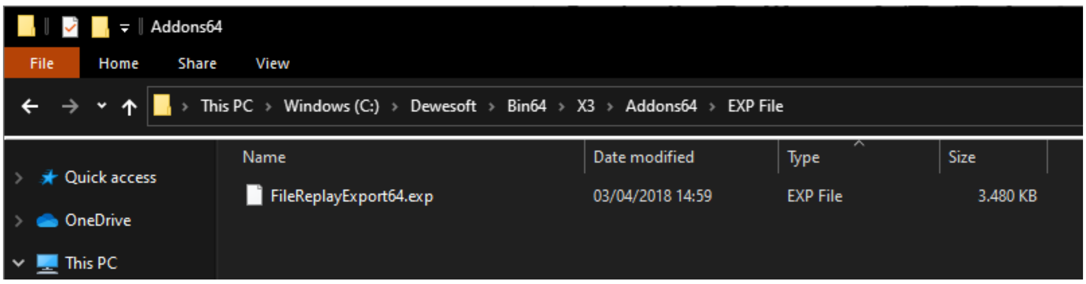


Image 79: File location for FileReplayExport file

The next step is to run Dewesoft as an administrator to register the extension.

We can export any recorded data file, where we stored the analog inputs.

In the file export, we must first select the *Data presentation* option and choose the **Full speed data** type. Then we can select **Replay (*.rpl)** export format. We can use the channel filter to find and export all Analogue (AI) channels. We can export also synchronous mathematics channels, which will act like analog channels in file replay.

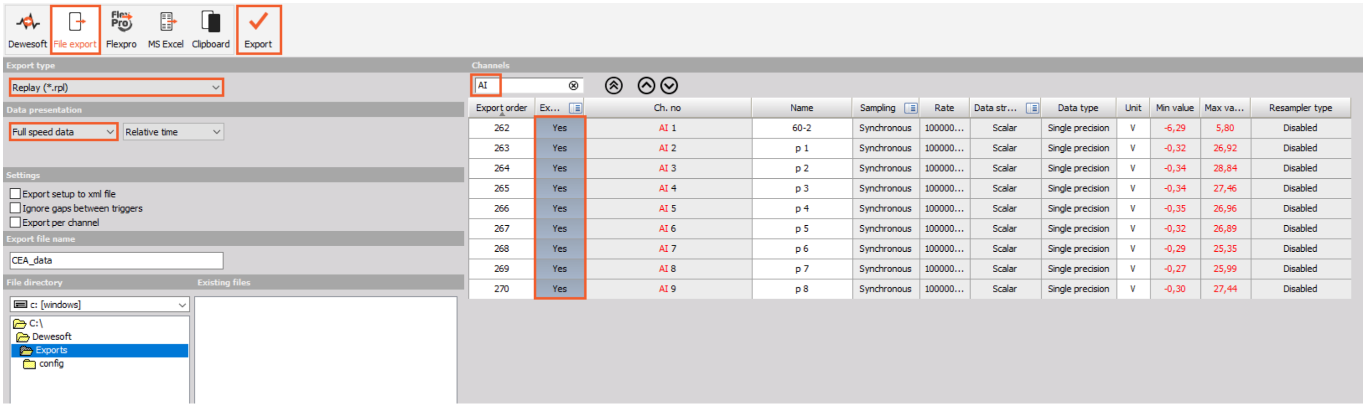


Image 80: Export the replay file

How to Transmit CEA data to ECU or Testbed?

CAN interface

The Dewesoft combustion engine analyzer can acquire and transmit CAN messages. When transmitting is used, any measurement result can be sent to any other host system (for example INCA).

1. Add a transmit channel by pressing **+Tx** button in the CAN tab.

[Video available in the online version]

CEA Example: File Replay

In Dewesoft we can use the file replay option to simulate analog input channels and create a CA setup and also test the functionality of CA.

First, the extension for replay file export must be added. This can be found in the download area.

After that, extract the file into: <Dewesoft_installation_path>\Bin\X3\Addons\

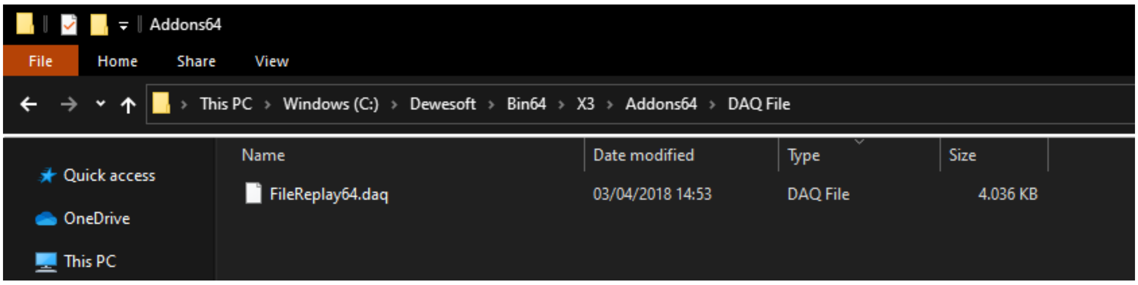


Image 84: Download and place FileReplay file in the proper folder

The next step is to run Dewesoft as an administrator to register the extension. When Dewesoft starts, open S*ettings* to configure file replay and switch Dewesoft X operation in **Simulation mode**. Then click on the Simulated devices and set the ***Simulated channels mode*** to **File replay**. See the image 85.

Exported *.rpl file can be used or you can download a test file. When the file is selected there will be information on how many channels are simulated, what was the sample rate and the total length of the file. The replay file is always in the time domain. Select also the option repeat, to loop the file, otherwise it will be played only once. Only analog synchronous channels will be replayed.

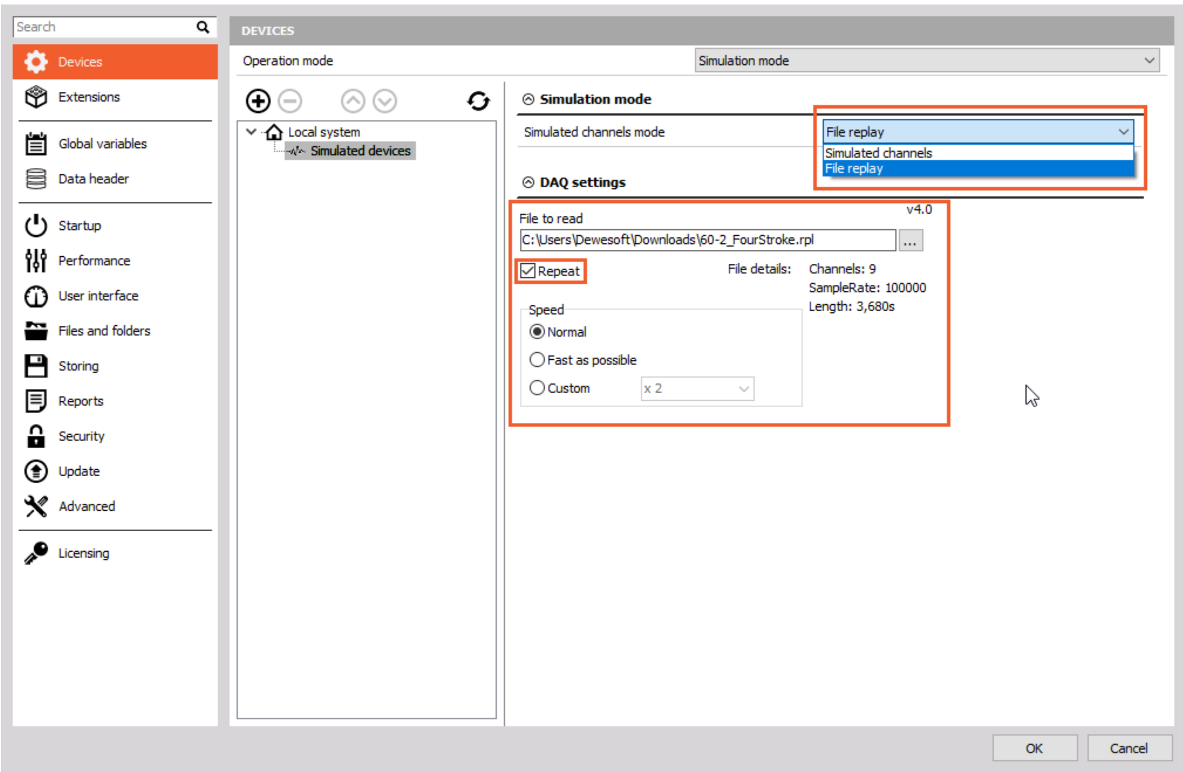


Image 85: Put Dewesoft X on Simulation mode, choose File replay for Simulated channels mode and select proper file replay

After that, close settings and ***create a new setup.***

If we go to ***channel setup*** we see that we have 9 simulated analog channels. We need to find out what these channels are and we can do this by simply enabling all channels and going to measure.

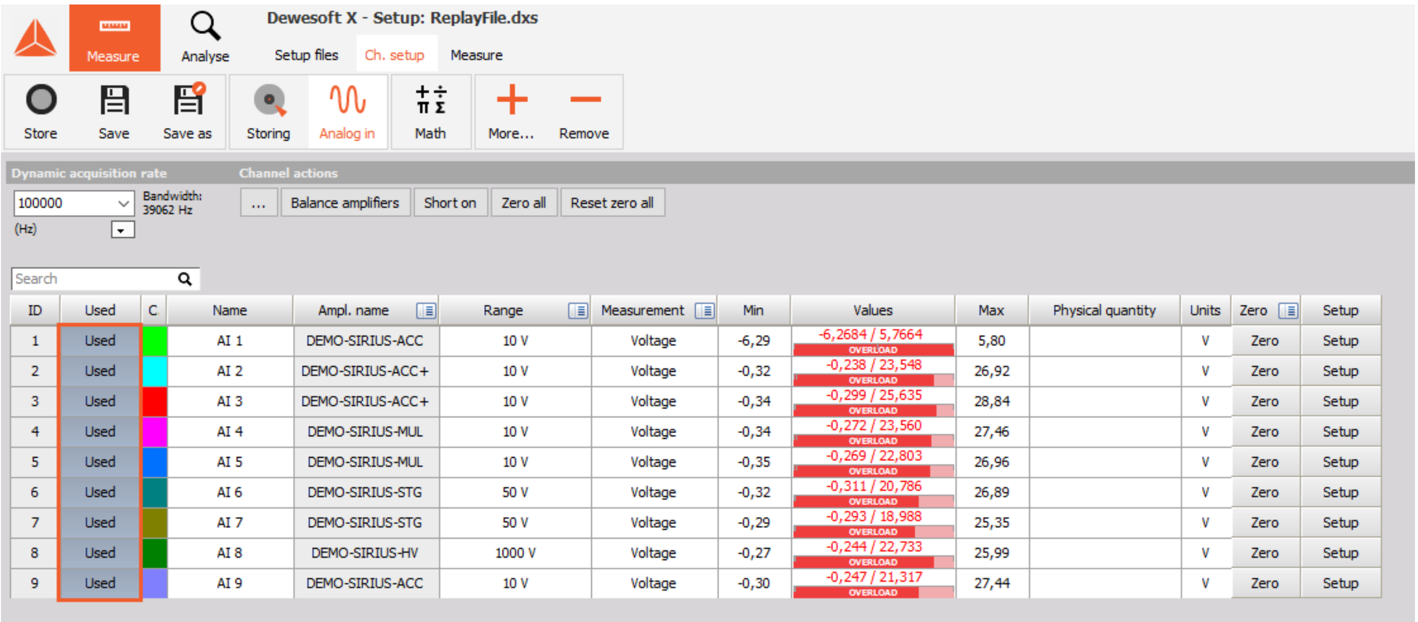


Image 86: Mark all the analog channels as 'Used'

On the recorder display we can see all 9 channels at once and can also freeze the data and zoom in to one part of the data. From this we can quickly see that the first channel is the angle sensor and the other 8 channels are pressure signals. The angle sensor in this case is a 60-2 sensor.

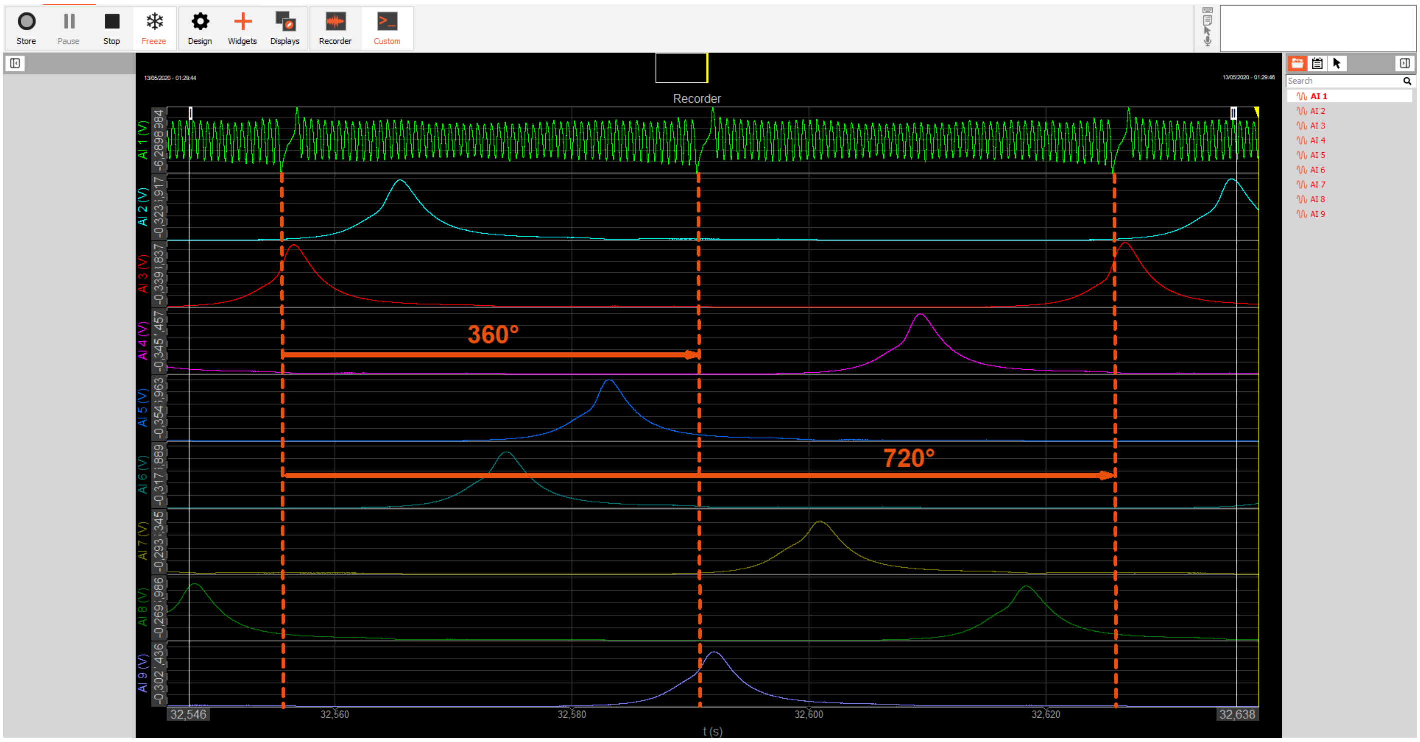


Image 87: The first channel represents the angle sensor and the other 8 channels are pressure signals

We can rename the channels for easier setup, select physical quantities, and set the scaling. We will create a 4 cylinder CEA setup.

ID	Used	C	Name	Ampl. name	Range	Measurement
1	Used		60-2	DEMO-SIRIUS-ACC	10 V	Voltage
2	Used		p 1	DEMO-SIRIUS-ACC+	10 V	Voltage
3	Used		p 2	DEMO-SIRIUS-ACC+	10 V	Voltage
4	Used		p 3	DEMO-SIRIUS-MUL	10 V	Voltage
5	Used		p 4	DEMO-SIRIUS-MUL	10 V	Voltage
6	Used		p 5	DEMO-SIRIUS-STG	50 V	Voltage
7	Used		p 6	DEMO-SIRIUS-STG	50 V	Voltage
8	Used		p 7	DEMO-SIRIUS-HV	1000 V	Voltage
9	Used		p 8	DEMO-SIRIUS-ACC	10 V	Voltage

Image 88: Rename channels

Now we need to **add the CEA module**.

In the Engine settings of the CEA module we first define ***the cylinder count, enter the geometrical data of the engine, fuel type, select the appropriate pressure signal for each cylinder and input the ignition misalignment***. After we have entered all the information we can save then engine as a new template. The only thing we need to do next is to define the angle sensor setup.

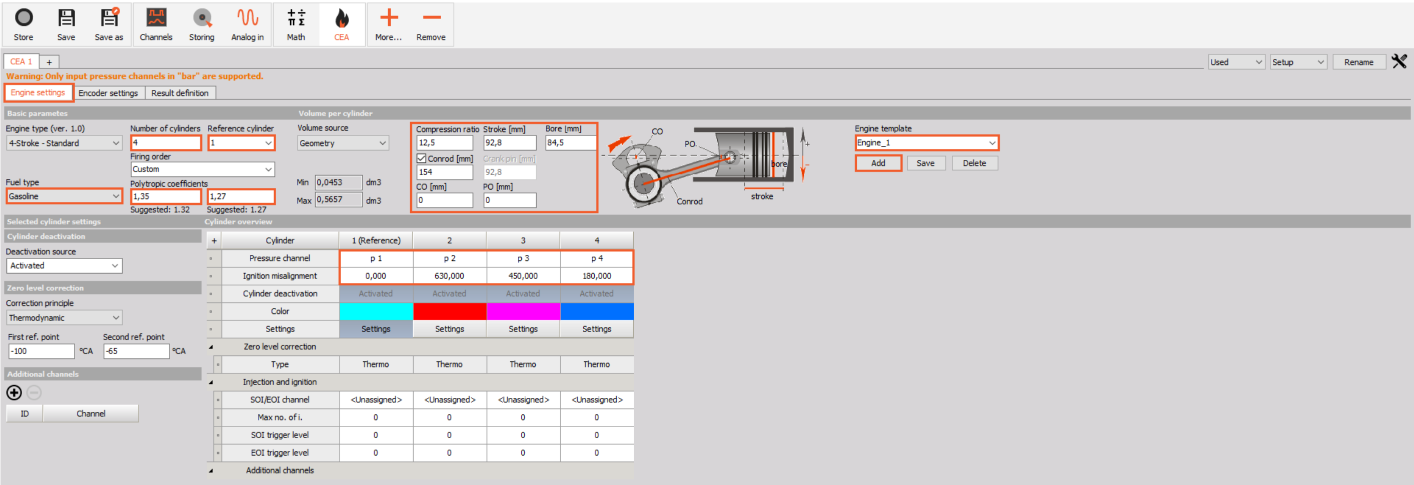


Image 89: Add the CEA module and define properties

In the next tab of the CEA setup, we select the type of angle sensor as a 60-2 and also the channel this is connected to. We should immediately see something on the p-V preview diagram (left) and also the pressure signal in the angle domain (right). If the angle sensor was defined correctly we should see stable and correct RPM on output on the right and also 60 pulses per revolution.

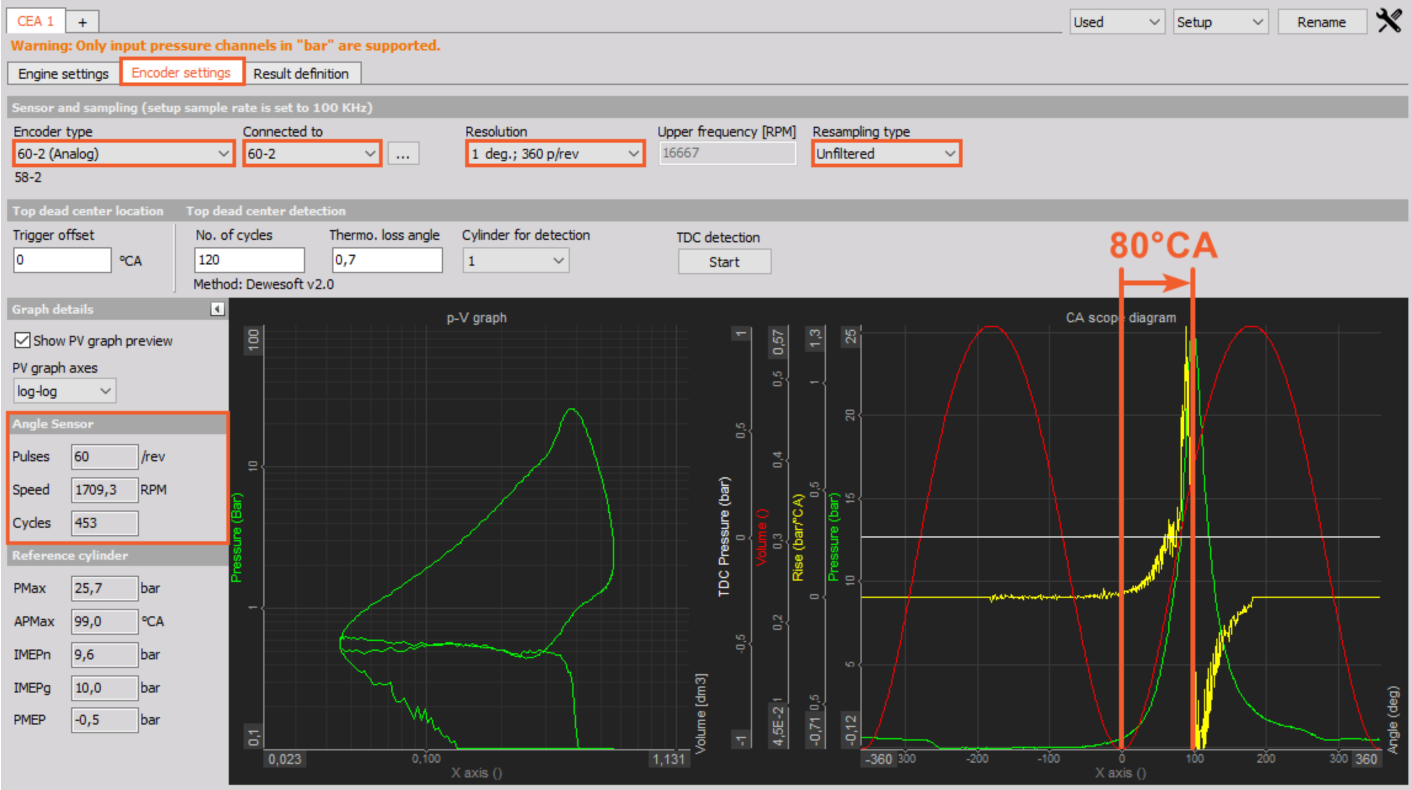


Image 90: Encoder settings without trigger offset

We can see that the peak pressure on cylinder 1 is around 100degCA. This means that we have an offset of the angle sensor. If we would have a replay file from a non-fire engine, we could do TDC detection, but since this a file with combustion, we have to enter the offset manually. In this case we know that the offset is 80deg.

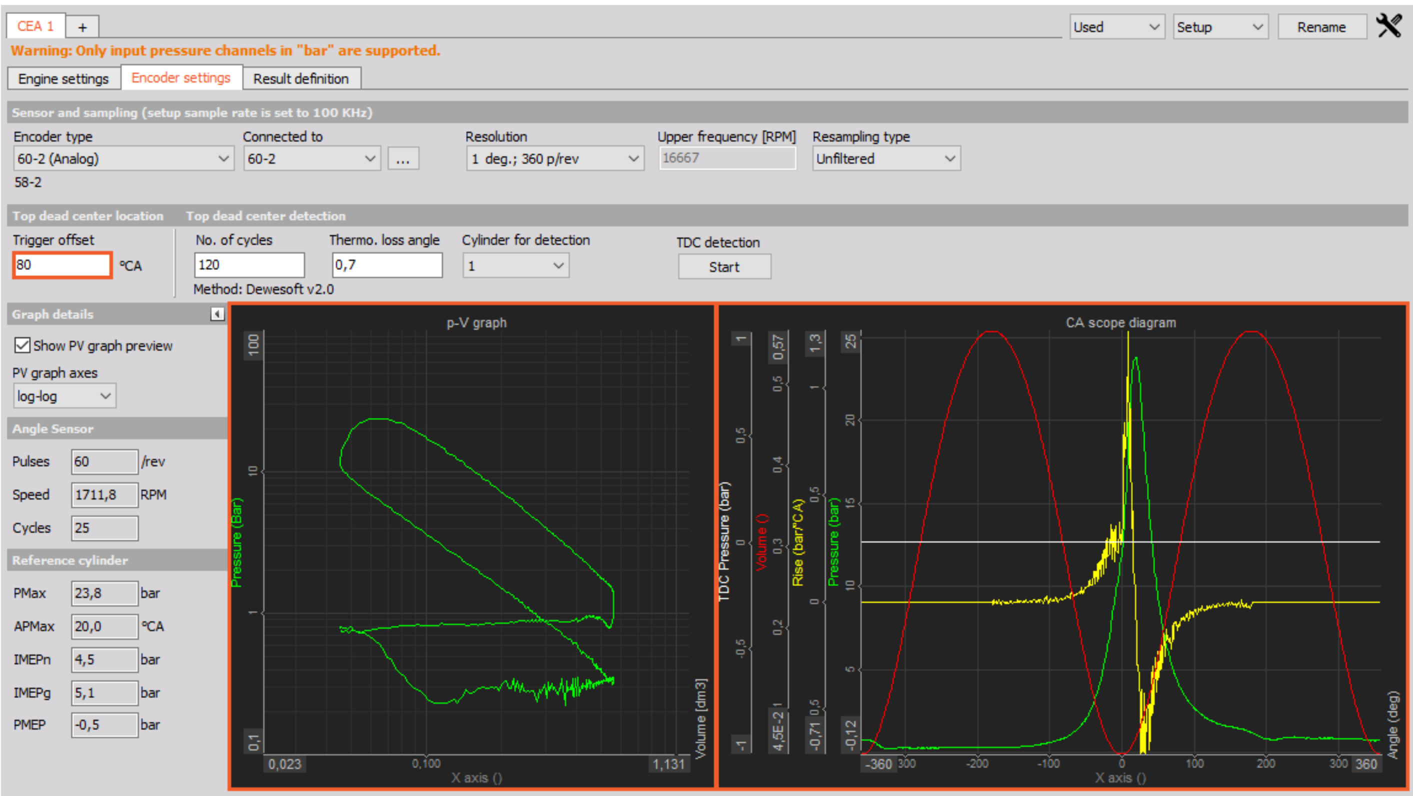


Image 91: Trigger offset set on 80 degrees

When the trigger offset is correct, we can see that the pressure curve is shifted to the correct position, and also the p-V diagram shows a correct

output.
If we switch to the **Result definition** tab we can also immediately see the rate of heat release output and accumulated heat release.

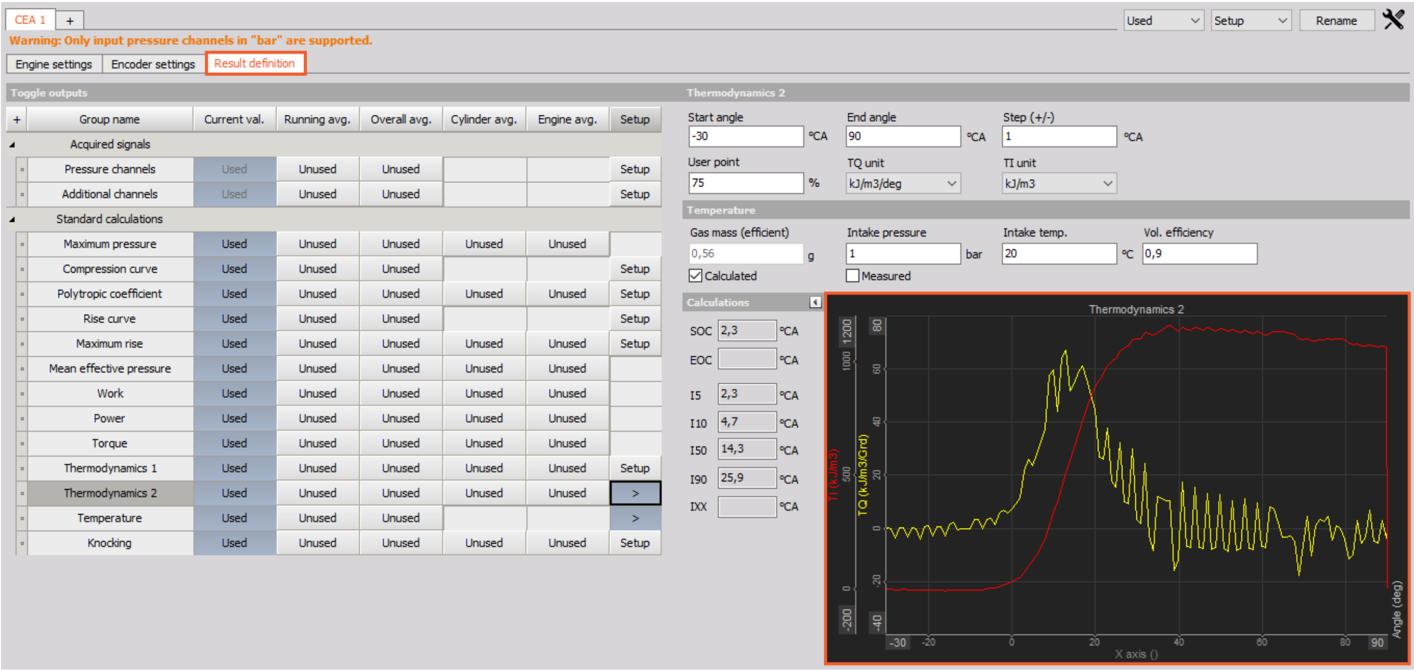


Image 92: Result definition

Now we can go to *measure*, and on the predefined CEA measure screen, we will already have all the basic combustion analysis information as it is shown on image 93.

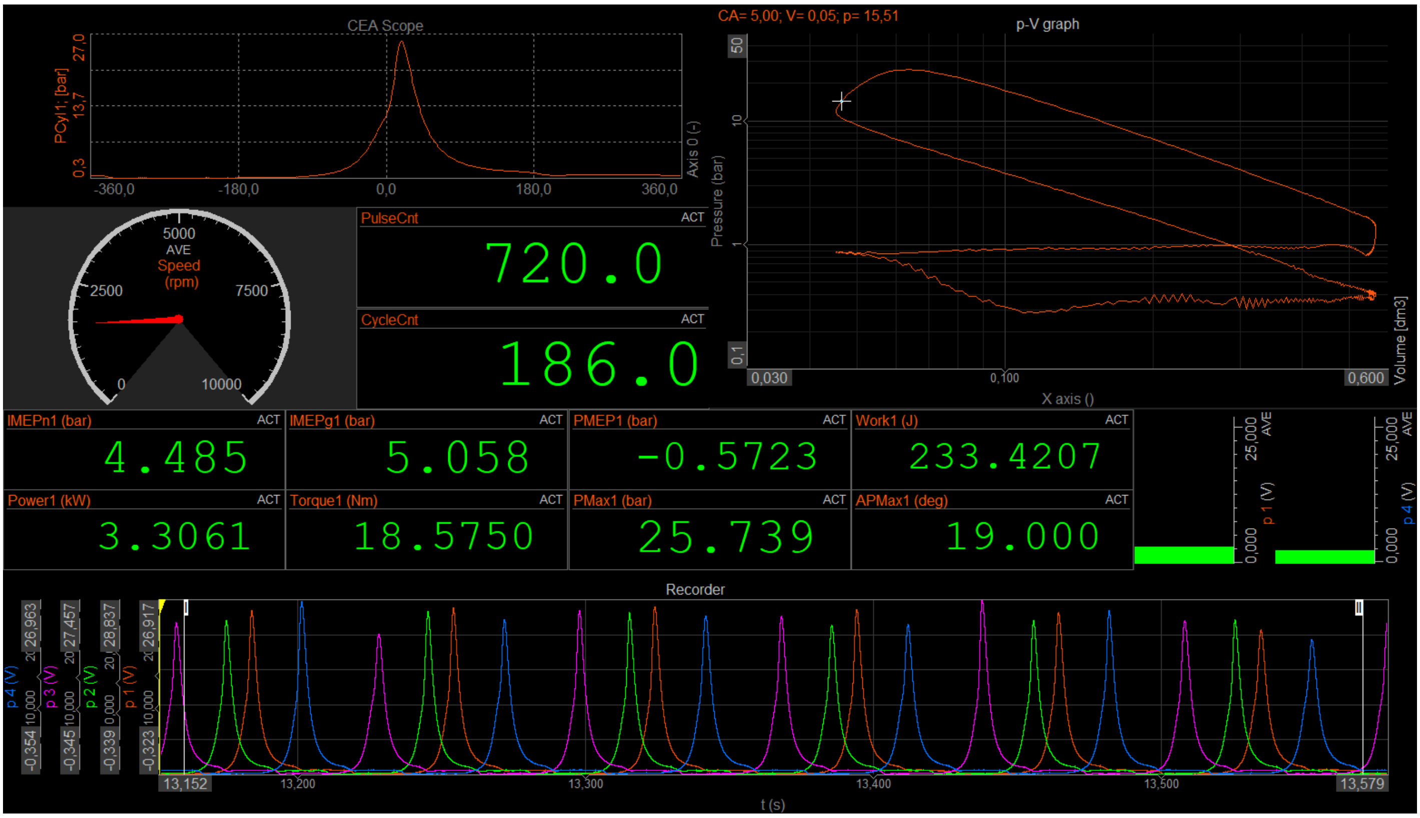


Image 93: Default CEA display will be seen after you assign channels to the diagrams

How to Combine the CEA with Other Modules?

CEA can also be used in combination with other modules. When using it for a 4-stroke engine, we get a possibility to review data in the angle domain for a complete engine cycle - 720deg.

This can be very useful to analyze vibration data for a 4-stroke engine, otherwise, we see the data only in a 360deg cycle, as shown in the image 94.

[Video available in the online version]

Torsional Vibration & Combustion Engine Analysis

Please refer to the ProTraining for detailed explanation about the Rotational and torsional vibration module.

To use the vibration analysis module together with CAA, only one angle sensor is needed. First we add the Torsional vibration module.

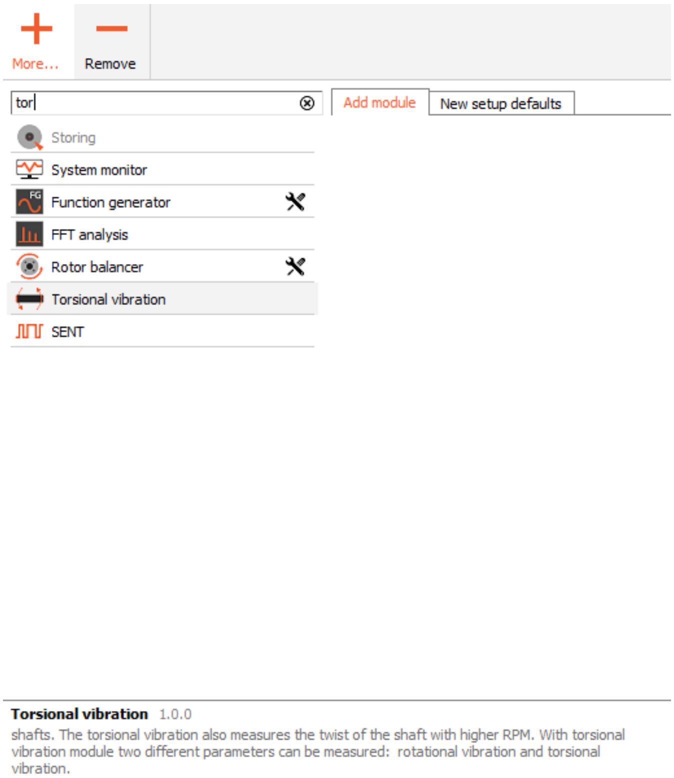


Image 95: Add Torsional vibration in Dewesoft X

Sensor input and sensor type must be selected. The rotational angle must also be selected for output.

Only counter inputs can be used for torsional vibration.

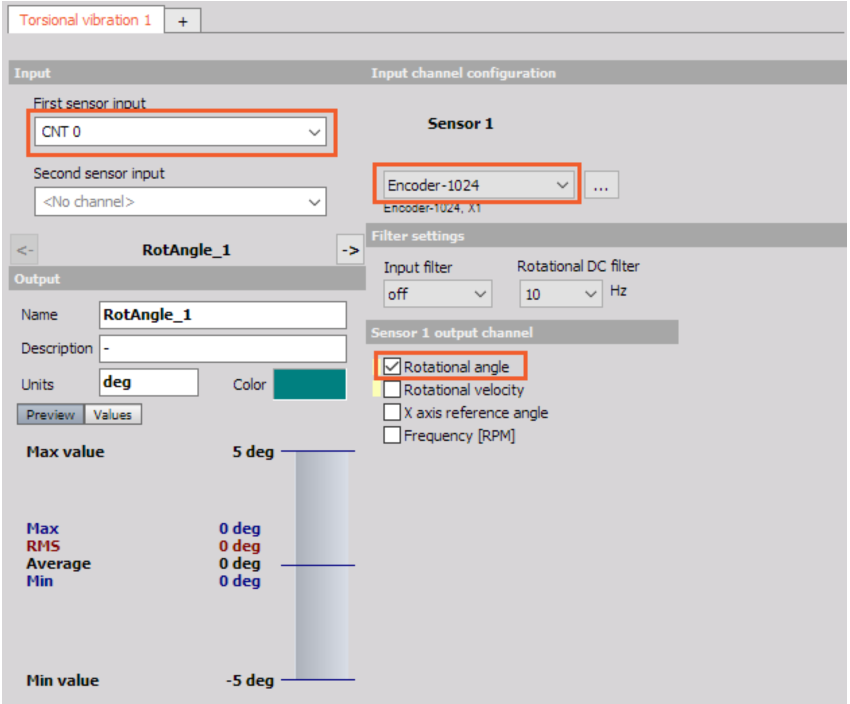


Image 96: Select sensor location, sensor type and enable the Rotation angle option

If there is another sensor mounted on the other side of the engine shaft, then we can select also the other sensor and activate the output calculation for the torsional vibration angle.

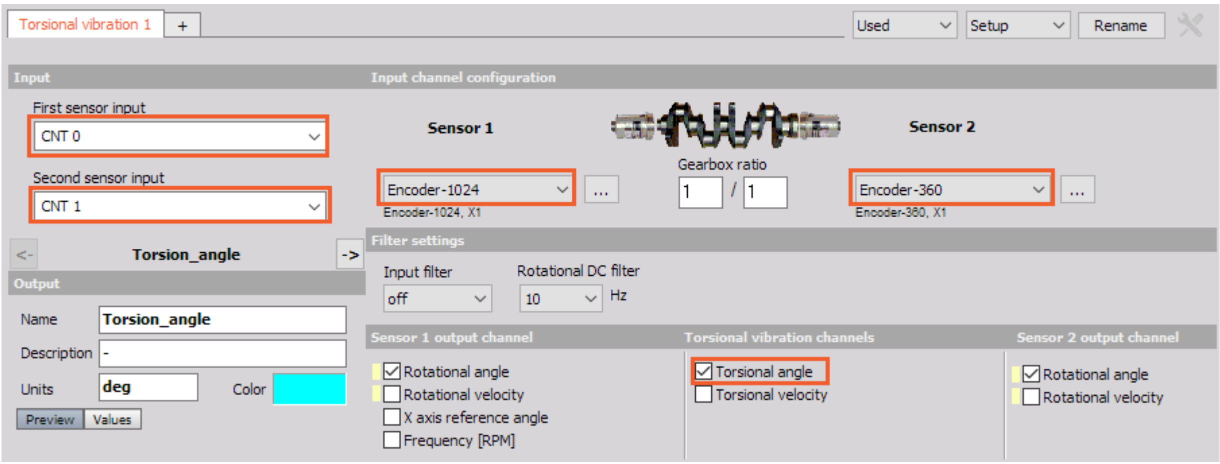


Image 97: Select also the other sensor and enable Torsional angle option

We must also add the **CEA module** and configure the angle sensor input.

For the **Encoder settings** we only need to select a *pressure sensor* - in this case, Encoder-1024 and the counter location to which the encoder is connected to.

Under *additional channels* in **Engine settings**, select the output from the torsional vibration module. All additional channels will be shown in the angle domain. If we also have an encoder on the other side of the shaft, and have torsional vibration results, *we can also add additional channels*. We can select all three outputs for conversion into the angle domain. See the image 98.

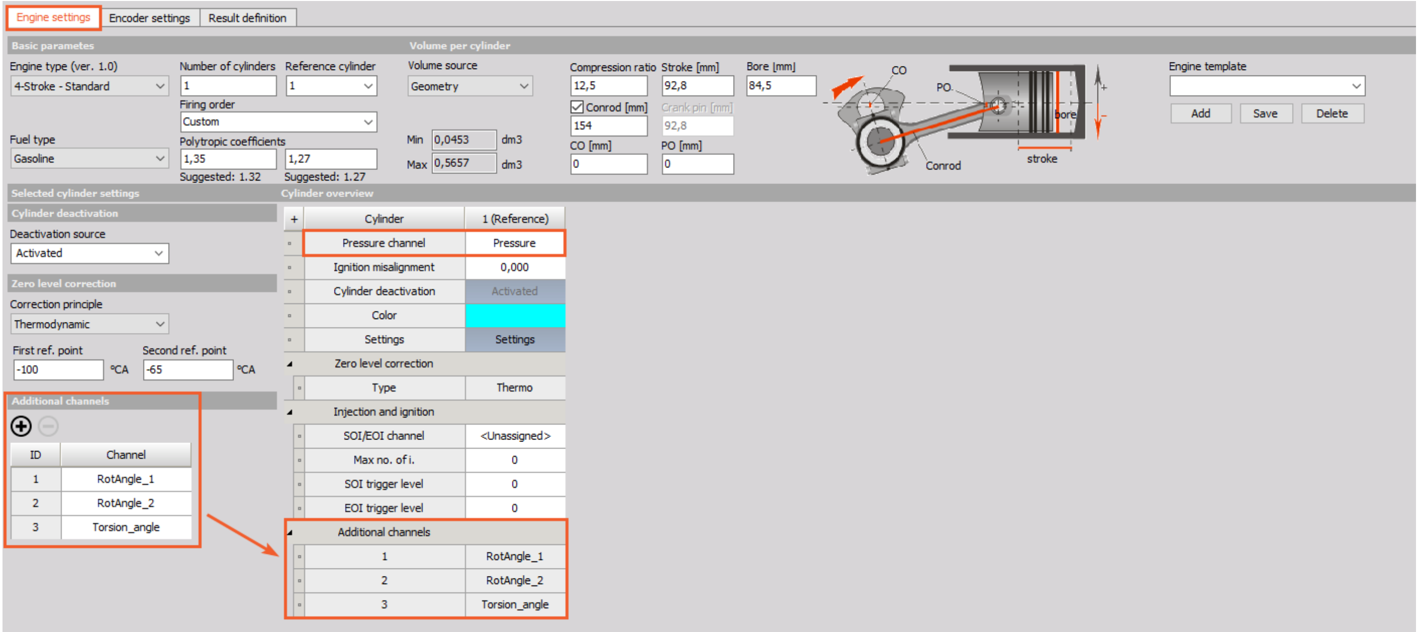


Image 98: Assign all additional channels to the cylinder

When we go into the *Measure mode* and enable the Design mode, we have two additional display types available from CAA. We add a **Combustion scope** to display the data in the angle domain for a complete engine cycle.

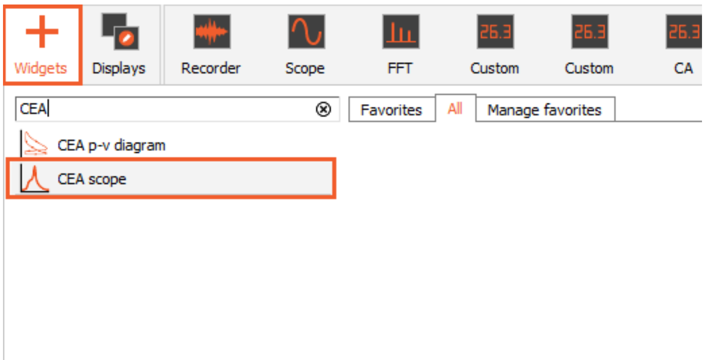


Image 99: Add the CEA scope

We can *display all three vibration channels at once on the graph*. Pressure or other channels can also be added.

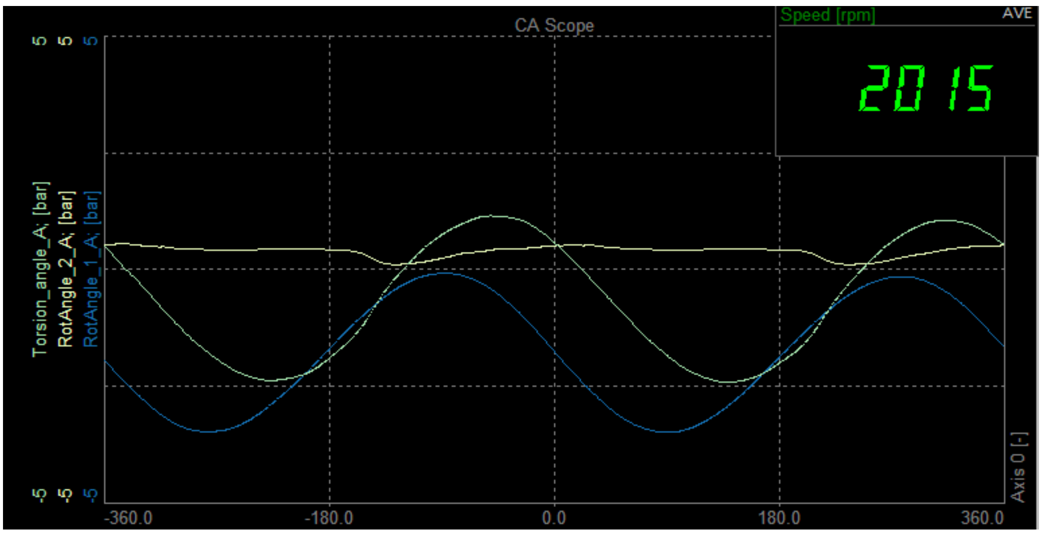


Image 100: All additional channels displayed on CEA scope