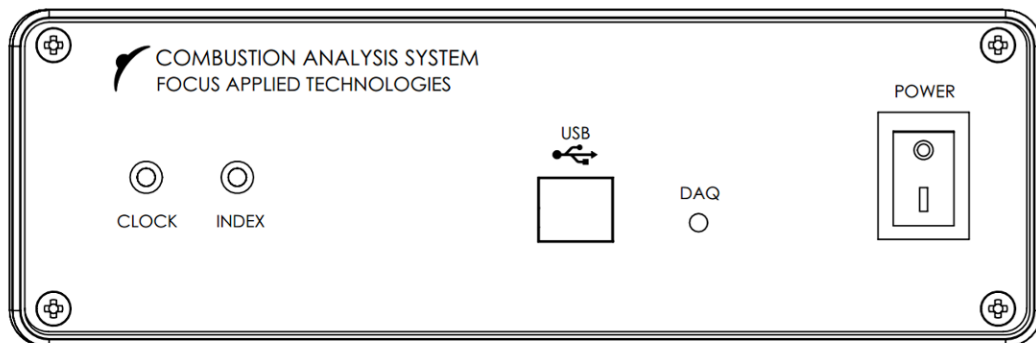
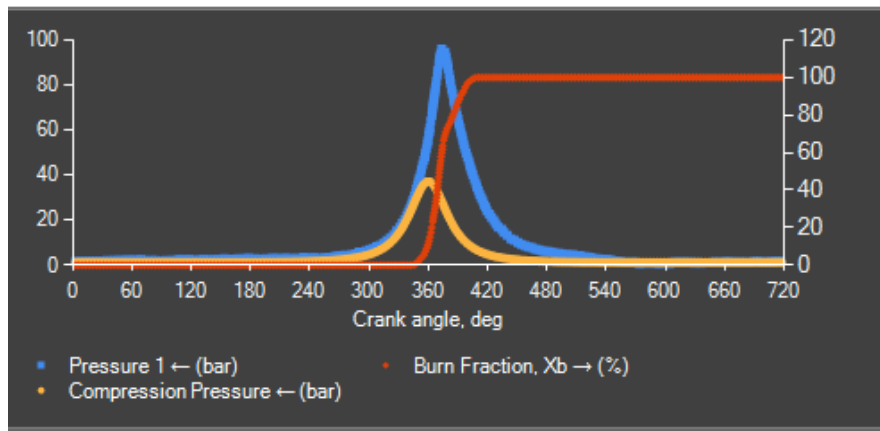




FOCUS APPLIED TECHNOLOGIES COMBUSTION ANALYSIS SYSTEM

Manual Rev. 9-0821



FOCUS APPLIED TECHNOLOGIES SDN. BHD.

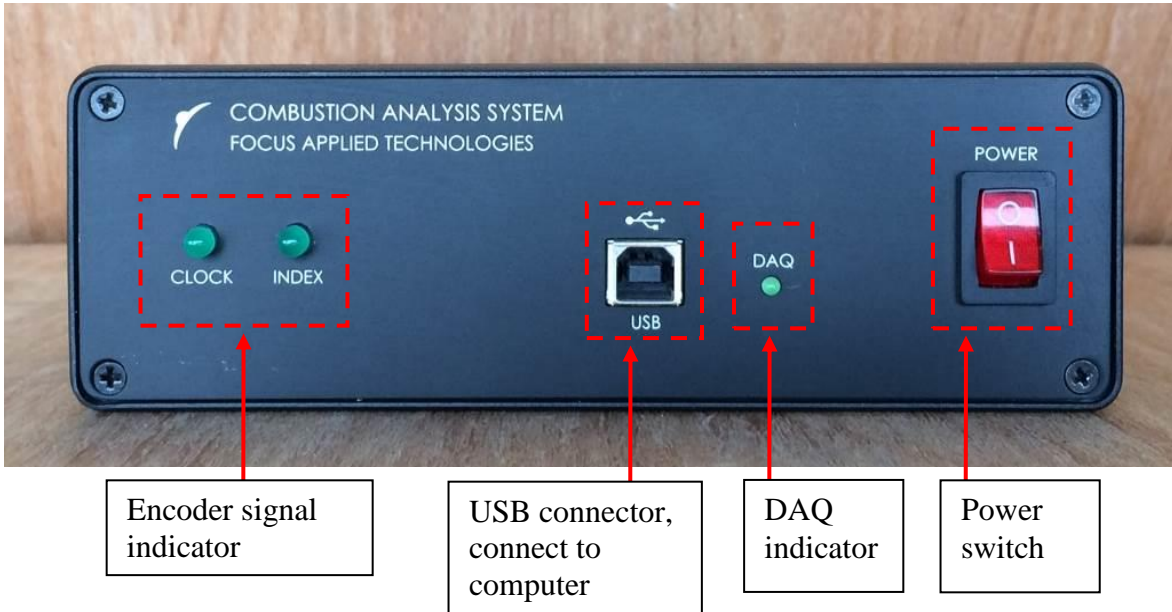
Lot 463 Jalan Relau K134, Sungai Kecil Hilir

Bandar Baru 34950 Kedah

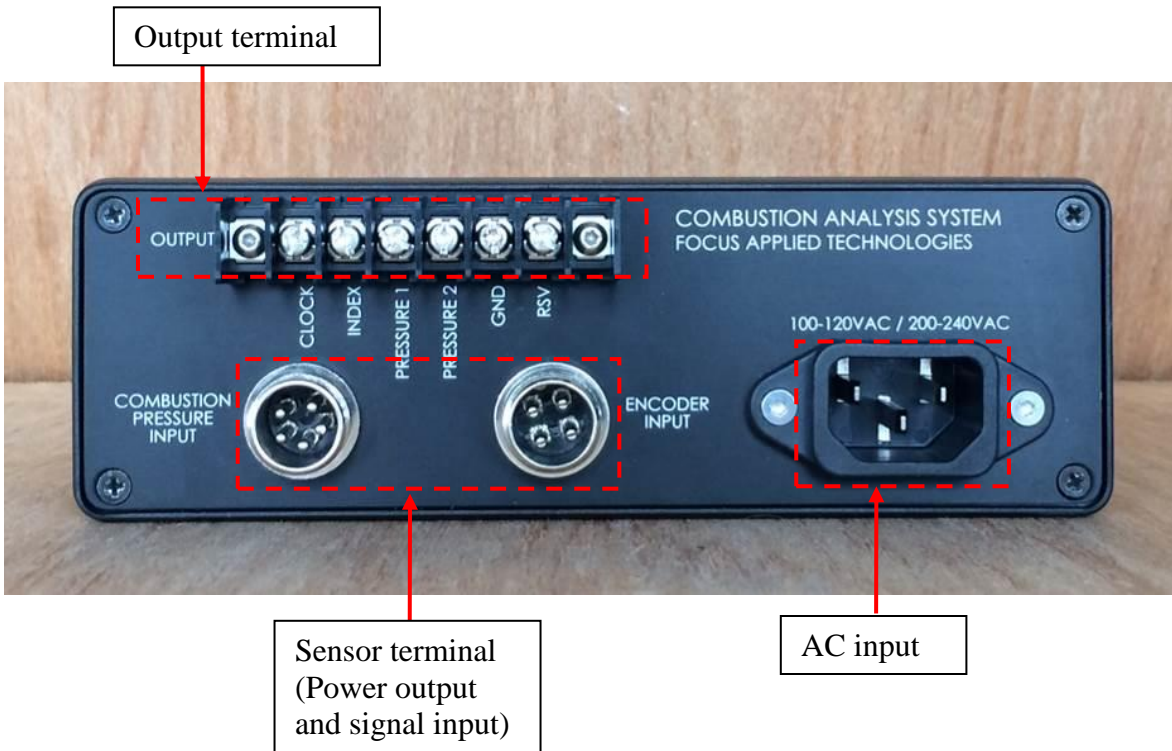
MALAYSIA

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COMBUSTION ANALYSIS SYSTEM FRONT VIEW



COMBUSTION ANALYSIS SYSTEM REAR VIEW



FEATURES

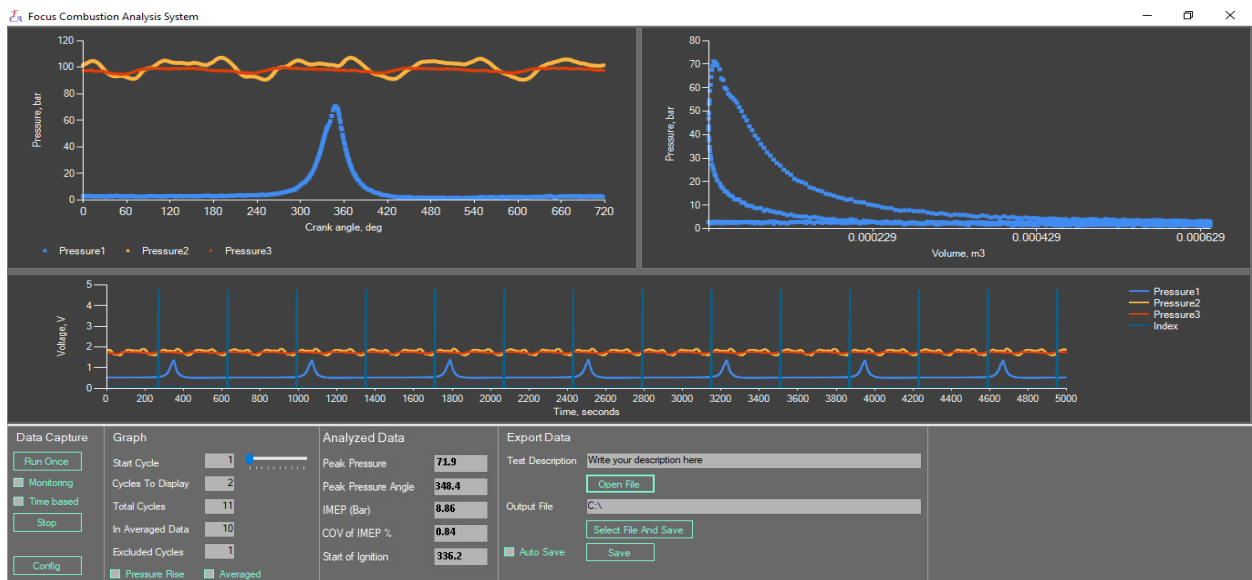
Data Acquisition Module (DAQ)

The DAQ can support 3 channels of pressure and 1 channel of TDC index mark recorded at the encoder's clock frequency, with maximum clock frequency of 200kHz. Signal output terminal for clock, index, pressure 1 and pressure 2 is provided for connection to others devices such as an oscilloscope. Connection to pressure sensors and encoder, including power, is via the quick-connector cables.

Data capture can be done in two modes: crank angle based or time based. For crank angle based acquisition data capture is driven by the encode clock signal, i.e. each clock signal will trigger capture one data point. Therefore, each data point will correspond to a fix crank angle increment. For example, with encode clock of 360 pulses per revolution (ppr), each data point will represent 1 degree of increment. Given a known crank angle of the index signal, the actual crank angle can be calculated.

For time based acquisition data are captured against time for x-axis, similar to an oscilloscope data capture. The pressure signals and index pulse will be captured with at a 50kHz sampling rate. Thus each data point is 20us apart from previous data point.

Cylinder pressure should be fed into Pressure 1, while Pressure 2 and 3 can be used for others pressure such as exhaust or intake manifold pressures, as shown below.



BLUE trace is combustion Pressure, RED is the intake manifold pressure and GOLD is the exhaust manifold pressure. Data is from a 4-cylinder automotive engine at idle.

SPECIFICATIONS

POWER IN

Voltage: 100-120 or 200-240 VAC
Frequency: 50Hz/60Hz

POWER OUT

To Pressure sensor: 10VDC, 300mA
To Encoder: 5VDC, 300mA

INPUTS

Pressure input: 0-5VDC
Clock input: 0-5VDC
200kHz (Maximum)
Index input: 0-5VDC
Pulses per Rev: 1440 (Varies for different systems)
Pulses within Index: 4

PRESSURE SENSOR (when provided)

Pressure: 400 Bar max
Thread: M5 x 0.5
Sensitivity: 0.8 mV/psi (Varies for different systems)
Zero Voltage: +/- 500mv

ENVIRONMENT

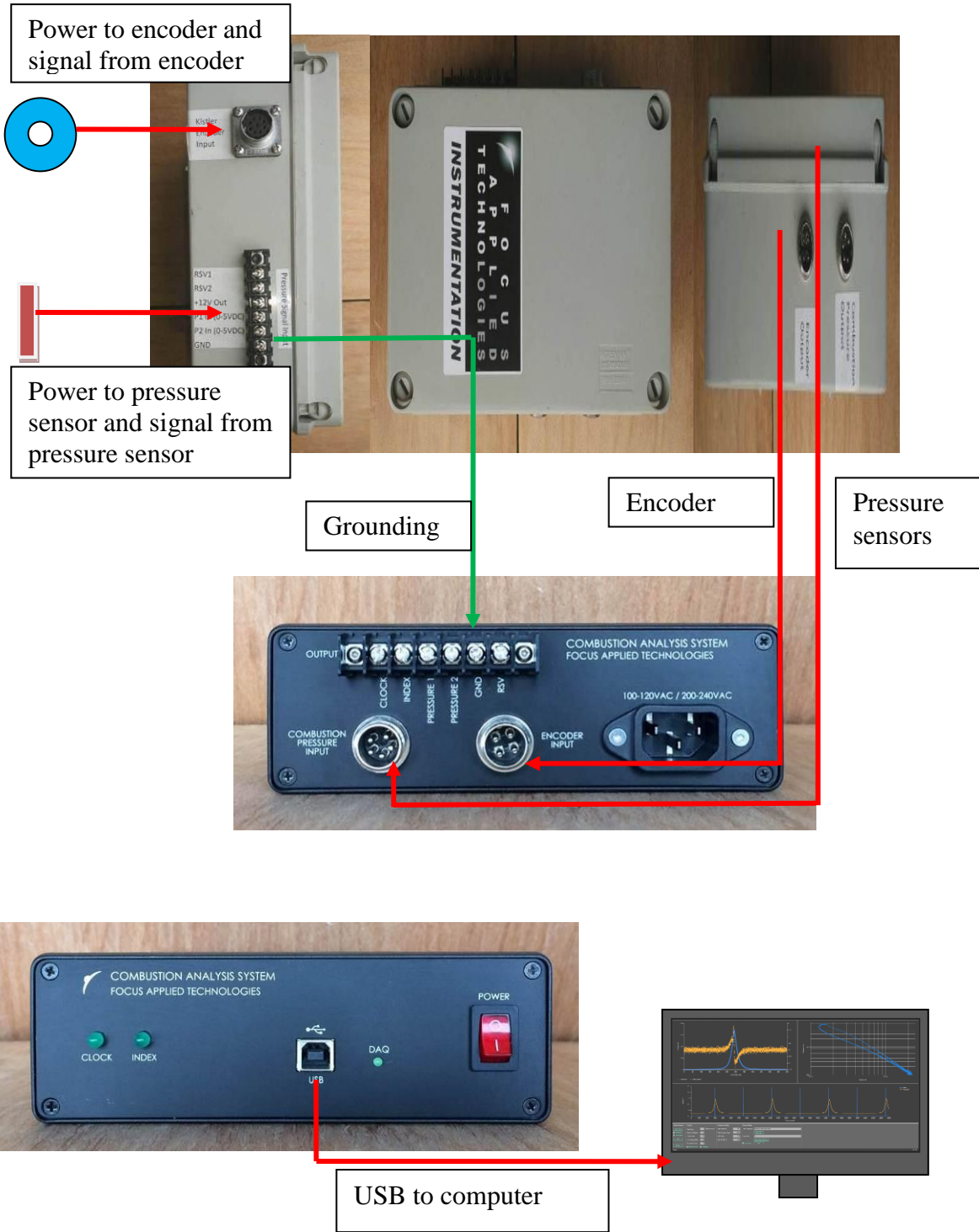
Temperature: 10 to 40°C Operational
0 to 50°C Non-Operational
Humidity: 5 to 90% Non-condensing
Shock/Vibe: <10g

SOFTWARE REQUIREMENTS

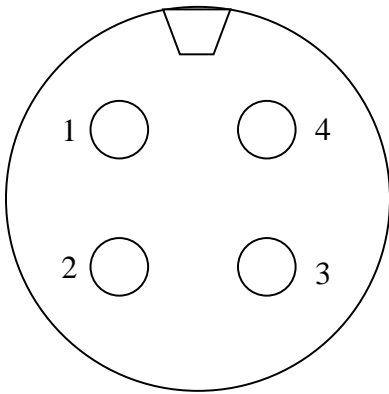
The Combustion Analysis software requires Microsoft .NET 4.0 framework and Advantech DAQNav driver for USB4716 version higher than 3.2.8.0.

EXTERNAL WIRING DIAGRAM

Pressure sensors and encoder junction box
(Only used on systems which require signal conditioning)



Encoder connector (viewed facing to connector on DAQ)



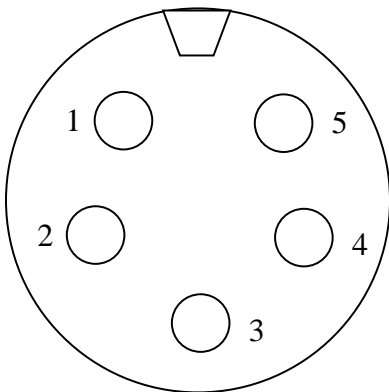
1. 5V
2. Index
3. Clock
4. GND

Encoder Wiring at Encoder:

1. 5V
2. Index
3. Clock
4. GND
5. Not Used
6. Not Used



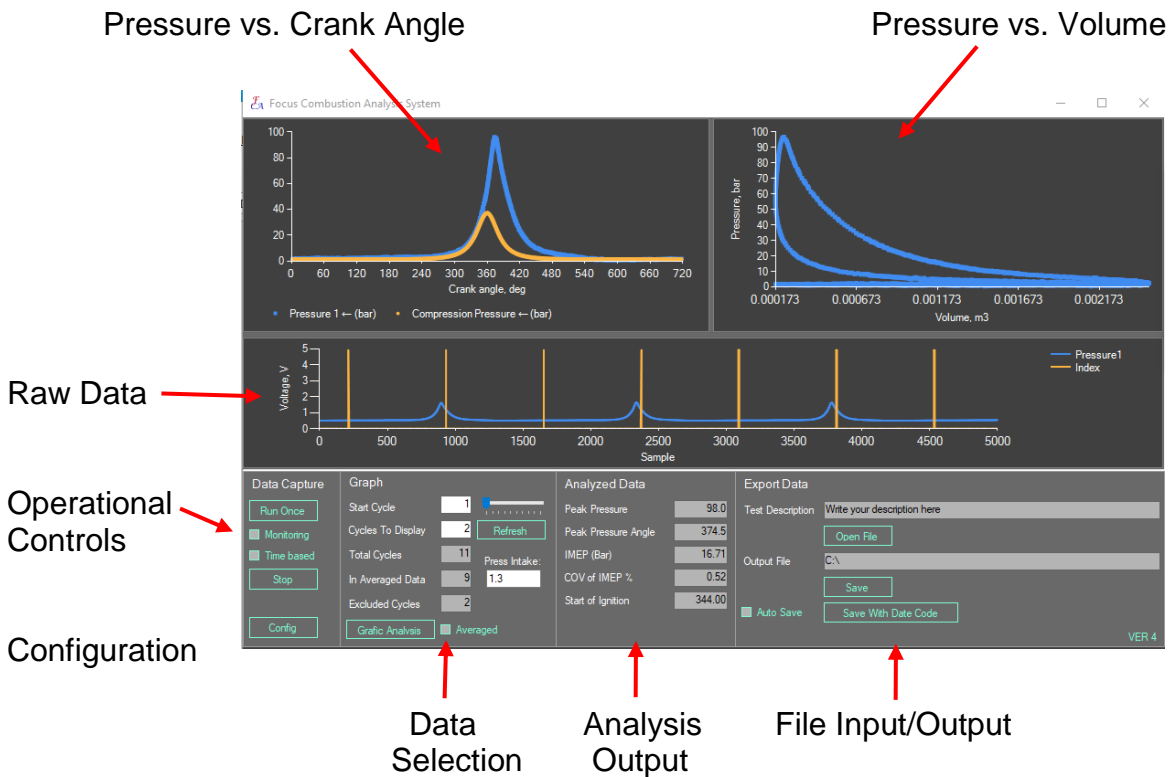
Pressure sensors connector (viewed facing to connector on DAQ)



1. 10V
2. Pressure 1
3. Pressure 2
4. GND
5. Pressure 3

FOCUS COMBUSTION ANALYSIS SOFTWARE

The Focus Combustion Analysis software provides the real-time data visualization and logging for the pressure data. Parameters for engine on test, pressure sensors and encoder can be configured, which will be used by the software to format the raw data into crank angle based and engine cycle, such as pressure vs crank angle and pressure vs volume. Averaged data over all valid cycles that were captured will be calculated. The raw data and averaged data can then be saved into two separated files for further data analysis.



There are three graphic display areas, raw data in voltage in the middle, pressure vs crank angle at the upper left and Pressure vs Volume diagram at upper right. The raw data graph can be hidden if not required by double clicking the graph splitter. Each graph size can also be resized by dragging the graph splitter.

The PV Diagram on the upper right is determined from the measured pressure and calculated displacement, assuming TDC is at 360 degrees. Make sure the engine geometry parameters are set properly to get a valid P-V Diagram.

Note: If there is a serious error in the configuration (PPR, Zero Voltage or Index Angle) the Pressure and PV diagram screens will be blank. These need to be resolved before the analyzed parameters will be correct.

Setting PPR and Index Offset (in the Config page) to AUTO and performing a single run is the easiest way to make sure they are set right, as they will be set automatically.

On the lower left are the Data Capture controls. You can select Time based acquisition, or data will be acquired on a clock-pulse basis. The Monitoring check box allows you to view the acquisition progress, handy if acquiring a large number of cycles from a slow engine. Run Once initiates pressure trace capture, and Stop halts acquisition at the next completed trace.

In the Data Selection area you can control the number of cycles to capture and display. You can also overlay a trace of Pressure Rise (the derivative of pressure) or display the Averaged pressure trace via check boxes at the bottom. The number of traces included in the average is given in the "In Averaged Data" box with any partial cycles excluded, as noted in the "Excluded Cycles" box.

Analyzed Data is displayed in the 3rd box from the left, and includes the Peak Pressure, the Angle of Peak Pressure, Indicated Mean Effective Pressure in bar, and the Coefficient Of Variation of IMEP in % Generally for stable combustion the COV of IMEP will be a few %. Also the crank angle of the start of combustion is calculated. This is the crank position at which the measured pressure deviates from the "motored" pressure. Alternatively if Injection timing is entered, then Ignition Delay is calculated.

On the right are Data File controls. Enter a description of the data in the box at the top of this section, and click Save. If you click on the Auto Save box, data will be saved after each trace acquisition.

WARNING: Running with Auto Save on will rapidly fill up your hard drive! Make sure you really want all the data you are acquiring when using Auto Save, or un-check it and only save the individual traces you really want.

When saving a trace both the raw (multiple cycle) data and the averaged data are saved into separate files. These are saved in Comma Separated Variable format for easy import and analysis in such programs as Excel.

GRPAICAL DISPLAY CONTROLS

GRAF ZOOM

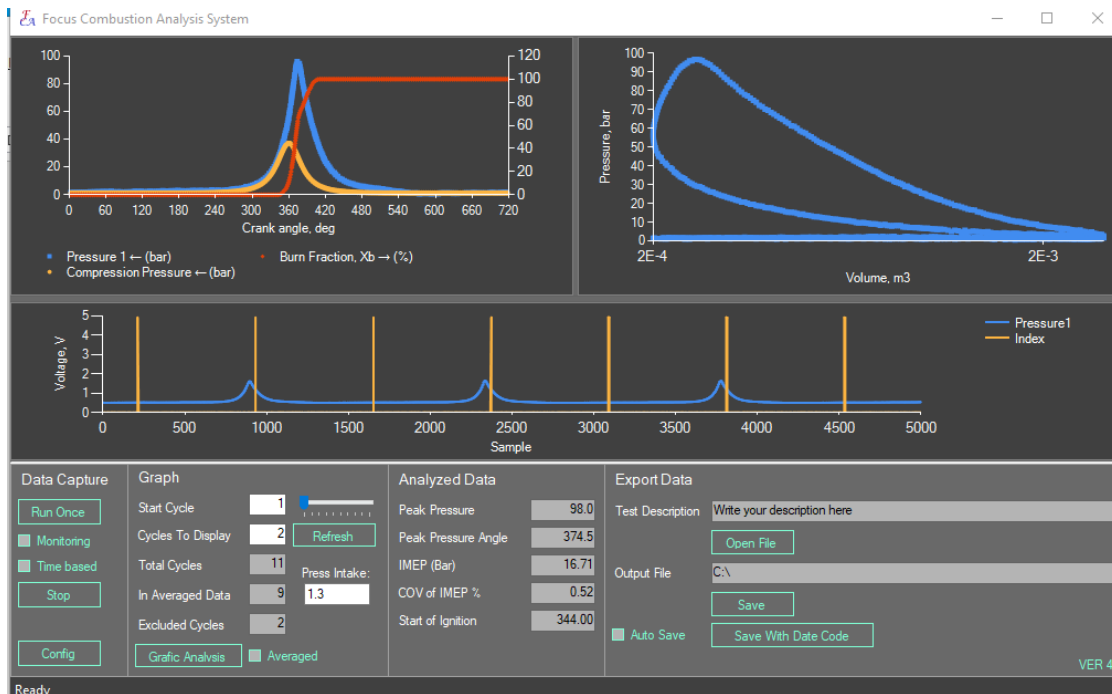
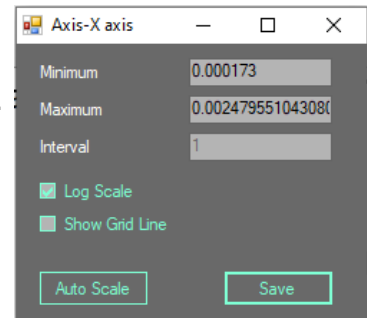
You can zoom in to see fine details of the graf's by clicking on them and dragging the cursor across the area of interest. To zoom out you can click on the side bars. Additionally the graf data can be exported to a file by right clicking the graf.

GRAF SAVE

The data displayed in the analysis graf's can be saved by Right clicking on the graf where the curves are displayed (may require 2 clicks). It will give you a button to save the file, and all displayed traces will be saved in this file.

GRAF SCALE

Double Click near the axis to set the axis scale minimum/maximum, or have them automatically calculated. Additionally the scales can be set to linear or Logarithmic (some times used in P-V Diagrams). Finally you can select whether to show Grid Lines or not.



Different analysis parameters can be added to the upper right graf by clicking the Grafic Analysis button at the bottom of the screen. These calculated curves depend on the measured pressure trace, and the various input parameters, such as Engine Geometry, Intake pressure and Temperature and polytrophic Coefficient.

The analysis parameters include:

- Pressure 1, 2 and 3
- Pressure 1 Rise
- Volume (based on engine geometry and crank angle)
- Compression Pressure (ie. motored pressure based on the engine geometry)
- Combustion Chamber Average Temperature
- Rate of Pressure 1 Rise
- Mass Fraction Burned (in %)
- Heat Release Rate, HRR (in kJ/deg)

Graph to View

| Name | View | Unit | Scale | Filter | Axis |
|-------------------------|-------------------------------------|---------|-------|--------|------|
| Pressure 1 | <input checked="" type="checkbox"/> | bar | 1 | 0 | 1 |
| Pressure 2 | <input type="checkbox"/> | bar | 1 | 0 | 1 |
| Pressure 3 | <input type="checkbox"/> | bar | 1 | 0 | 1 |
| Pressure Rise 1 | <input type="checkbox"/> | bar | 1 | 0 | 2 |
| Volume | <input type="checkbox"/> | m3 | 1 | 0 | 2 |
| Compression Pressure | <input checked="" type="checkbox"/> | bar | 1 | 0 | 1 |
| Combustion Temperature | <input type="checkbox"/> | Kelvin | 1 | 0 | 2 |
| Rate of Pressure Rise 1 | <input type="checkbox"/> | bar/deg | 1 | 0 | 1 |
| Burn Fraction, Xb | <input type="checkbox"/> | % | 1 | 0.9 | 2 |
| Heat Release Rate | <input type="checkbox"/> | kJ/deg | 1 | 0 | 2 |

Polytropic Index:

Intake Temp. (Kelvin):

Injection Angle:

For each curve you can put in a scaling factor (for eg. the HRR curve will have to be scaled based on the fuel consumption per cycle during the data capture). A filter value is provided (0 = no filter, 0.99 = heavy filtering), and a choice of Yaxis: 1 means that it will be plotted against the left axis, and 2 means that it will be plotted against the right axis.

CONFIGURATIONS

Before using the software, ensure that all parameters required are properly configured. Click the “Config” button to open then configuration windows.

In the Configuration screen you must set up the engine’s geometry (bore, stroke, connecting rod length and clearance volume) for calculation of the motored pressure, and other graphical analysis curves.

Each channel (pressures or other curves) can be setup with individual offsets (Zero Voltage) and Gain (Sensitivity).

The Encoder requires the proper pulse per revolution setting, as well as the Index pulse width (in encoder pulses) and the location of Index mark. The Index need not be exactly at TDC as long as you enter the actual crank angle position of the index pulse. The Index is set up assuming Top Dead Center (TDC) is at 360°, and the value to be entered is the *offset of the index*: if the index happens 10° after TDC, then the index offset is 10. If the index occurs 45° before TDC, then the index offset will be -45. If you are unsure, click AUTO next to the Pulse Per Revolution and Index Offset. These parameters will automatically be set for you on the next run.

The screenshot shows the 'Configurations - UTM-CASConfig' window. On the left is a diagram of an engine cylinder with labels for Bore (B), Stroke (S), Clearance Volume (Vd), Connecting Rod (L), Crank Angle, TDC, and BDC. The main area contains several configuration panels:

- Sensor:** Three channels are configured. Channel 1: Identifier D522-94-R41, Zero Voltage 520 mV, Sensitivity 0.8 mVPerPsi. Channel 2: Identifier Default2, Zero Voltage 500 mV, Sensitivity 1.44 mVPerBar. Channel 3: Identifier Default3, Zero Voltage 500 mV, Sensitivity 1.44 mVPerBar.
- Engine:** Bore, B: 139 mm; Stroke, S: 152 mm; Connecting Rod, L: 250 mm; Clearance Volume, Vd: 173 cc; Number of Stroke: FourStroke.
- Timebase:** Sample Rate: 10000 Hz; Sample Size: 20000 sample; Monitor Interval: 1000 ms.
- Encoder:** Pulse Per Revolution: 1440 (Auto); Index Offset (°): 32 (Auto); Pulses Within Index: 4.
- DAQ:** Number Of Cycle: 20; Number Of Sample: 60480; Device Number: 0; Start Channel: 0. A green message 'DAQ not found' is displayed.

Buttons for 'Open', 'Save', 'Ok', and 'Cancel' are at the bottom.

For Time-based measurements (ie. for running without an encoder or to look at things like engine speed stability) the Sampling rate, Sample size (total number of samples to take) and Monitor Interval can be entered.

Finally there are some setup parameters for the Data Acquisition board in the Combustion Analysis System. Device number is generally 0 or 1. Start Channel is generally set to 0 unless otherwise specified. The number of cycles is set for how many full engine cycles to record.

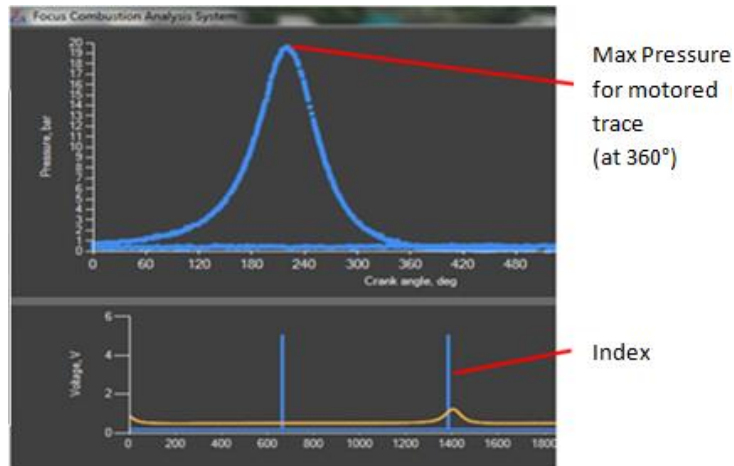
Configurations can be saved and be recalled later, just click “Save” in configurations windows and “Open”

to reuse previously saved configurations. The current configurations file name is displayed on the windows title.

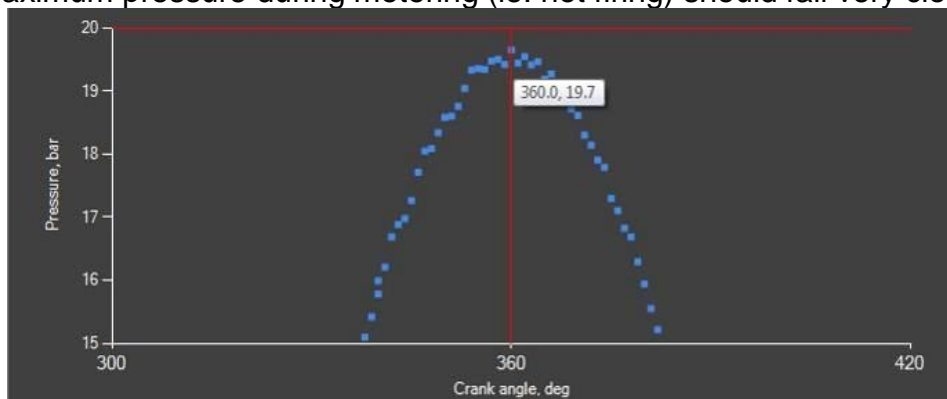
ALIGNMENT OF PRESSURE TRACE

Get motored trace using combustion analysis software, this can be done by cranking the starter without ignite the engine, or running the engine, then cutting off spark or injection, and gathering the pressure trace during spin down.

Initially the index should be within +/-100° of TDC. The maximum pressure for motored trace should be very close to 360°. This indicates that the index pulse offset is properly set. If the maximum pressure is not in 360°, as shown in figure below, we can adjust the index to 360° by change the “crank angle of index” in program configuration, “Config”.



The maximum pressure during motoring (ie. not firing) should fall very close to 360°.



PRESSURE CALIBRATION

You can adjust the sensors “Zero” voltage to give the proper pressure at the beginning of the intake stroke (typically 0.9 – 0.95 for diesel engines and 0.85-0.9 for petrol engine at mid rpms).

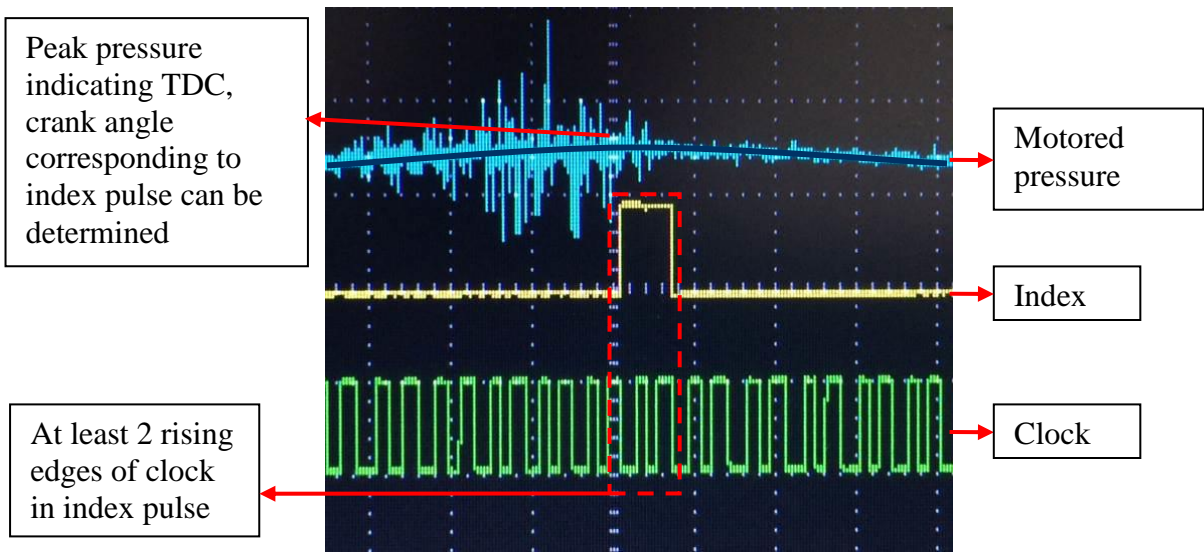
If you have the proper engine geometry, you should be able to closely match the “motored” pressure curve by adjusting the sensor’s sensitivity. To get a good motored pressure trace operate the engine until warm, then cut power (injection and/or ignition) and record the pressure just as the engine begins to spin down. As there is no combustion taking place the pressure in the combustion chamber is almost exclusively compression pressure, and should match the “Motored” pressure trace.

Checking the Index Pulse Alignment on an Oscilloscope

You can check the alignment of the encoder using an oscilloscope. Rotate the engine (with out firing) and record the Pressure, Clock and Index signals simultaneously. A good way to do this is to operate the engine at normal speeds and temperatures, then cut off the ignition and/or injection of fuel, and immediately grab the signals on the oscilloscope. This guarantees that the motored pressure trace is representative of the nominal engine temperatures and speeds.

The Index pulse should correspond to the maximum pressure of the motored pressure trace. Also the index pulse should cover at least 2 clock pulses.

If the index and peak pressure do not align, loosen the indexer, rotate it in the appropriate direction, and re-tighten it. Recheck until the index pulse is within a few degrees of TDC (peak pressure of the motored trace). You can correct for a deviation of 10's of degrees in the Combustion Analysis Software, "Crank Angle of Index" calibration as shown above.



ELECTRICAL HAZARDS

This equipment is powered by potentially dangerous AC voltage, and normal precautions pertaining to electrical appliances apply. Do not operate the equipment if there is water present in, on, or around the equipment. Make sure all electrical wiring is properly installed and grounded, and has a fast-acting Ground Fault Interrupter in the circuit.

MECHANICAL DETAILS

This Combustion Analysis System can be used with any combustion pressure sensor and encoder. When provided, the standard sensor is a 400 bar, M5 x 0.5 threaded optical type sensor. As this is an optical sensor great care must be taken when inserting or removing it from the engine, as any twisting of the cable can destroy the probe.



For some systems adapters may be required to fit the combustion sensor into an existing combustion pressure port. Alternatively the pressure sensor may be mounted in wither a spark plug or a glow plug to avoid having to machine a hole in the head of the engine.

WARNING: Use care when inserting or removing the pressure probe. Twisting the cable may damage the sensor as it is an optical cable.

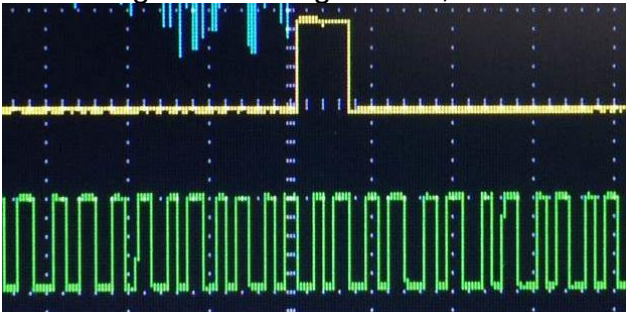
TROUBLE SHOOTING

The Combustion Analysis system depends on only two input devices: the Encoder and the Pressure Sensor. Each of these can be investigated as follows in the event of problems with the system.

ENCODER

The encoder is powered by a 5V signal. If it is not reading, first incur that it has a good 5V DC on the Vcc input with respect to ground (labeled 0V). When slowly rotated (*very* slowly) you should see the Clock LED blink on the front panel of the controller. Once per revolution the Index LED will blink briefly (for a few clock pulses). If the LEDs are not blinking appropriately, then either the controller is not powered on (the LEDs require power from the internal power supply), there is a disconnection of the encoder, or possibly the encoder is broken.

The Clock and Index pulses can also be displayed on an oscilloscope. You should see something like the image below, with the Index pulse in Yellow, and the Clock in Green:



If you have verified the power going into the encoder, and still are not getting the proper output, then either a wire is disconnected, or the encoder is broken. Contact Focus for further assistance.

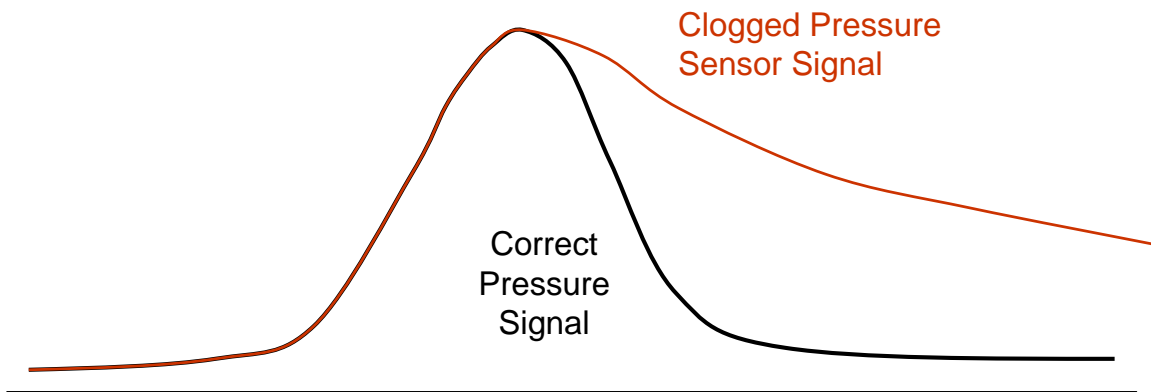
PRESSURE SENSOR

Pressure sensors can be damaged by incorrect wiring, overheating, over pressure (especially associated with knocking or detonation) and can become clogged by soot.

One quick check you can perform is to measure the voltage on the “Diagnostic” wire (the Green wire). Measuring between the Diagnostic wire and ground you should get a voltage between 1 and 2 volts. If it is out of this range, then the unit has been damaged and requires replacement.

When the sensor becomes clogged (generally as the result of running dirty/sooty fuels, or large amounts of EGR {recirculated exhaust gas}) the pressure sensing diaphragm may become “jammed” by the soot. Initially this may give a pressure signal which is slow to drop after the combustion event, and eventually will result in abnormally high pressure readings even when the engine is not operating. If the sooting is not too bad, the sensor can be carefully removed, and cleaned in an ultrasonic bath of ammonia.

The pressure trace below shows what a partially sooted up sensor signal looks like.



If the pressure sensor diagnostic voltage is out of range, or the sensor can not be cleaned, please contact Focus for further assistance.

A sample Test Datasheet is provided on the following page as a reference for data tracking during testing using the Combustion Analysis System. Be sure to take advantage of the "Test Description" field and name data files appropriately (eg. TEST-RPM-TORQUE-RUN: B20-3500rpm-100Nm-1.CSV).

TEST DATASHEET**TEST:**

OPERATOR: _____ DATE: _____ ENGINE: _____ FUEL: _____

BORE: _____ STROKE: _____ CON ROD: _____ CLEARANCE: _____

ENCODER PPR: _____ INDEX OFFSET: _____ PULSES IN INDEX: _____

SENSOR MODEL: _____ ZREO OFFSET (mV): _____

OTHER: _____

| OPERATING CONDITIONS | |
|---------------------------|----------------------------|
| FILE NAME: | Polytrophic Coefficient: |
| RPM: | TORQUE: |
| Intake Pressure: | Intake Temp: |
| RESULTS | |
| Peak Pressure: | Location of Peak Pressure: |
| IMEP: | COV(IMEP): |
| Injection/Ignition Angle: | SOI/Ignition Delay: |

| OPERATING CONDITIONS | |
|---------------------------|----------------------------|
| FILE NAME: | Polytrophic Coefficient: |
| RPM: | TORQUE: |
| Intake Pressure: | Intake Temp: |
| RESULTS | |
| Peak Pressure: | Location of Peak Pressure: |
| IMEP: | COV(IMEP): |
| Injection/Ignition Angle: | SOI/Ignition Delay: |

| OPERATING CONDITIONS | |
|---------------------------|----------------------------|
| FILE NAME: | Polytrophic Coefficient: |
| RPM: | TORQUE: |
| Intake Pressure: | Intake Temp: |
| RESULTS | |
| Peak Pressure: | Location of Peak Pressure: |
| IMEP: | COV(IMEP): |
| Injection/Ignition Angle: | SOI/Ignition Delay: |

CONTACT INFORMATION

As there are so many factors outside of our direct control, Focus Applied Technologies does not assume any liability for accidents caused by the use of this equipment. Use of this equipment is at the users own risk. If any problems or accidents occur, we wish to be informed so that we may improve our products, and fix any issues they may have. Please send back to us any feed back you have regarding the use of this equipment.

This system is covered by a one year limited warranty. If you experience any problems with the system, please contact us to determine how to resolve the problem, and if necessary, repair or replace any defective components.

For further information on this or other products please contact us via the following:

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Email: Sales@FocusAppliedTechnologies.com

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