Micro Drivven Combustion Analysis Tool (µDCAT)
User's Manual
Version 2.90
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Introduction

The micro Drivven Combustion Analysis Tool (µDCAT) is a combustion analysis application built from the Drivven Combustion Analysis Toolkit (DCAT). While the DCAT is a toolkit for programming custom engine control and analysis applications using LabVIEW, µDCAT is derived from the toolkit, and is an installed executable which interfaces automatically to USB DAQ and CompactDAQ devices from National Instruments. Furthermore, µDCAT does not require installation of purchased LabVIEW development tools in order to run. Instead, µDCAT only requires installation of the free LabVIEW run-time engine and DAQmx device drivers. A free version of Drivven's calibration toolkit called CalVIEW is also required for the user interface and may be downloaded from Drivven's website. µDCAT is designed as a low-cost, easy-to-use, portable engine combustion analysis tool.

µDCAT was designed to work with the USB-6251/USB-6259 and CompactDAQ devices. However, it is compatible with any device that is fully compatible with the National Instruments DAQmx device driver. While monitoring combustion analysis parameters, µDCAT allows streaming of raw data or summary data to file continuously, by cycle count, time, or file size. Raw data files are stored in National Instrument's popular TDMS format and include all channel configurations, engine geometry and custom test data to allow complete reconstruction of the test environment at a later date. Cycle by cycle summaries of analysis parameters can also be logged to TDMS files for later review. TDMS files may be opened and analyzed in Excel using a free TDMS file plug-in.

DCAT Features

Channel Configuration and Engine Geometry

- Supports 1 M-Series device for multiplexed sampling of signals engine-synchronously (cylinder pressure, etc.)
- Individual channel scaling features
    - Cylinder Assignment
    - Gain
    - Gain + Offset
    - Polynomial
    - Table Lookup
- Any channel may be assigned to all cylinders as a pegging reference
- Complete set of engine geometry inputs for cylinder volume calculation
    - Optionally load volume from file
- Online motoring test assists with engine geometry verification
- Digital outputs for sample clock and active high during logging

Multiple Time Based Measurement (Requires cDAQ-9172 or cDAQ-9174)

- Engine Synchronous Measurements (Sampled at fixed crank angles)
- Engine Asynchronous Measurements (Sampled at a fixed frequency) (µDCAT Knock Calibrator Only)
- Medium Speed Data (Sampled at a fixed frequency ~1kHz or less)
    - Thermocouples
    - Slow Speed Pressures
    - Other

Pre-Processing

- Cylinder alignment of data
- Data scaling to engineering units
- Broad range of signal filtering options
- Cylinder pressure pegging options
- Data windowing option

Pressure Metrics

- Peak Pressure and Location
- Polytropic coefficients of compression and expansion
- Maximum Rate of Pressure Rise and Location
- Pressures at IVO and EVC
- Gross MEP (IMEP), Pumping MEP (PMEP), Net MEP (NMEP)

Heat Release Analysis

- Methods include
    - Single Zone
    - Single Zone Dual Transducer (for pre-chamber engines)
    - Single Zone + Heat Transfer
    - Single Zone Dual Transducer + Heat Transfer
    - Modified Rassweiler and Withrow
    - Pressure Ratio
- Locations of Mass Fraction Burned (5%MFB, 25%MFB, 50%MFB, 75%MFB, 90%MFB, Custom)
- Maximum Heat Release Rate and Location
- Variety of heat transfer correction methods
- In-cylinder temperature estimation

Engine Noise and Knock Analysis (µDCAT Knock Calibrator Only)

- Raw, time-domain-filtered and angle-domain-filtered noise indication
- Bandpass / Rectify / Integrate / Compare (BRIC) algorithm for knock signal processing
- Offline FFT analysis of knock signals for calibration of BRIC

Installing and Activating µDCAT

Recommended System

CPU:	1.6 GHz Dual Core or Greater
OS:	Windows XP, Windows Vista
Memory:	1024MB
HDD:	2 GB Free Disk Space
USB:	2.0 (for USB devices)
Software:	DAQmx 9.0.1, LabVIEW Run-Time 2009, CalVIEW 2.90
Display:	15" wide screen, 1280 x 800 dpi

DAQmx 9.0.1 (free)	http://joule.ni.com/nidu/cds/view/p/id/1444/lang/en
LabVIEW Run-Time 2009 (free)	http://joule.ni.com/nidu/cds/view/p/id/1383/lang/en
CalVIEW 2.90 (free)	http://www.drivven.com/visitor_download/Software/CalVIEW2.90.zip
µDCAT 2.90 (purchased)	http://www.drivven.com/visitor_download/Software/uDCAT2.90.zip

It is assumed that users of µDCAT are familiar with internal combustion engine concepts, common practice for acquiring combustion-related data, as well as combustion analysis methods. However, the µDCAT is designed so that users with no LabVIEW experience can run the application.

µDCAT requires a freely downloaded version of Drivven's CalVIEW (Calibration toolkit for LabVIEW) to operate. CalVIEW must be installed and licensed before µDCAT will operate. To license CalVIEW, a computer ID, found in the CalVIEW help menu under activate, must be e-mailed to license@drivven.com. An activation key will be provided. Please reference the CalVIEW User's Manual for details on setting up CalVIEW.

µDCAT must also be activated in order to enable its components. The device serial number is used for activation. It may be located in the National Instruments Measurements and Automation eXplorer (MAX). The serial numbers are typically displayed in hex (represented by a "0x" in front of the number). Please indicate if the number is in a different radix. The device serial number must be e-mailed to license@drivven.com along with your name, company name, address and telephone number. Please allow 1-3 business days to validate your account and generate a key. An activation key (32 Characters ex. 9DCJ-RN79-QBEE-TPKW-BBAB-GT3Z-RXYC-CFCW) will be generated by Drivven and sent to the customer via reply email. The key will contain only the following characters A B C D E F G H J K L M N P Q R S T W X Y Z 3 4 7 9. The activation key may expire at a specific time if generated for evaluation purposes.

The activation key must be place in a text file called "uDCAT.dat" in the "c:\ni-rt\system" directory. The directory may not exist and may need to be created by the user.

Abbreviations

Async	Asynchronous (sampled at specific time intervals)
ATDC	Crank Angle Degrees After Top Dead Center
BRIC	Bandpass, Rectify, Integrate, and Compare
BTDC	Crank Angle Degrees Before Top Dead Center
CAD	Crank Angle Degrees
cDAQ	Compact DAQ device
CPU	Central Processing Unit
DAQ	Data Acquisition
DCAT	Drivven Combustion Analysis Toolkit
DI	Direct Injection
dV	Differential Volume
EPT	Engine Position Tracking
FFT	Fast Fourier Transform
FPGA	Field Programmable Gate Array
Hz	Hertz (sec^{-1})
GMEP	Gross Mean Effective Pressure
IMEP	Gross Mean Effective Pressure
kB	Kilobyte
kHz	Kilohertz (10^3 sec^{-1})
MAX	Measurements and Automation eXplorer
MEP	Mean Effective Pressure
MFB	Mass Fraction Burned
MB	Megabyte
MHz	Megahertz (10^6 sec^{-1})
NI	National Instruments
NMEP	Net Mean Effective Pressure
OS	Operating System
PFI	Peripheral Input (DAQ)
PFI	Port Fuel Injector
PMEP	Pumping Mean Effective Pressure
PR	Pressure Ratio
PCI	Peripheral Component Interconnect
PXI	PCI eXtensions for Instrumentation
RIO	Reconfigurable I/O
RT	Real Time
TDC	Top Dead Center
uDCAT	Micro DCAT
Sycn	Synchronous (sampled at specific CAD)
V	Volume
VI	Virtual Instrument

DCAT Hardware Setup

µDCAT is configured to utilize a USB M-Series Devices (USB-6251 BNC and USB-6259 BNC) or the USB CompactDAQ chassis (with up to 4 NI-9215s and a NI-9401 or NI-9411). Any fully DAQmx compatible card may work but only the listed devices have been tested. The cDAQ-7192 or cDAQ-7194 is required to take advantage of multiple time based sampling (Medium Speed Sampling or Knock Calibration).

USB-6251 / USB-6259 (M-Series)

The USB-6251 and the USB-6259 are M-Series DAQ devices available in a BNC form-factor that provides a simple interface to many combustion and test cell sensors.

Figure 1: USB-6251 BNC

The instrumentation signals should be connected to the USB-6251 / USB-6259 according to Table 1. The crankshaft optical encoder may be optionally powered by the USB-DAQ device +5V and DGND screw terminals. The maximum current draw is 1A. If the encoder is externally powered, then the encoder Z and A signals must have their BNC connectors properly connected to the encoder ground. Shielded BNC cables are recommended. The USB DAQ device

When using the DAQ device with µDCAT, only the terminals listed in Table 1 should be used. In order to take full advantage of certain hardware features, µDCAT makes programmatic internal connections. Connecting signals to other terminals or running other programs which interact with the same DAQ device is not prohibited, but Drivven cannot guarantee compatibility between µDCAT and such programs.

The National Instruments Measurements and Automation eXplorer (MAX) should be used to discover (or change, if desired) the name of the DAQ device and its physical channels. The names of the device and physical channels will be used on the measurement configuration tab of the user interface.

Table 1: Instrumentation connections to USB-6251 / USB-6259

Instrumentation Signal	**USB-6251/USB-6259 BNC Terminals**
Encoder +5V (optional)	Externally Supplied or +5V Screw Terminal
Encoder Ground (optional)	Externally Supplied or D GND Screw Terminal
Encoder Z	PFI 1 / P1.1
Encoder A	PFI 0 / P1.0 or APFI 0
Sample Clock Out (optional)	PFI 9 / P2.1
Raw File Saving Out (optional)	P0.6
Summary File Saving Out (optional)	P0.6
Measurement 1	AI 0
Measurement 2	AI 1
Measurement 3	AI 2
Measurement 4	AI 3
Measurement 5	AI 4
Measurement 6	AI 5
Measurement 7	AI 6
Measurement 8	AI 7
Measurement 9	AI 8 (USB-6259 only)
Measurement 10	AI 9 (USB-6259 only)
Measurement 11	AI 10 (USB-6259 only)
Measurement 12	AI 11 (USB-6259 only)
Measurement 13	AI 12 (USB-6259 only)
Measurement 14	AI 13 (USB-6259 only)
Measurement 15	AI 14 (USB-6259 only)
Measurement 16	AI 15 (USB-6259 only)

cDAQ-9172 (CompactDAQ)

The CompactDAQ chassis may be used with µDCAT if the proper hardware configuration is provided. The CompactDAQ chassis should be configured with the first four slots filled with one to four NI-9215 modules and the fifth slot should have a NI-9401 or a NI-9411 digital input module, as shown in Table 2.

Figure 2: CompactDAQ System

Table 2: Module placement in the CompactDAQ chassis

CompactDAQ Slots	CompactRIO Modules
Slot 1	NI-9215 (required)
Slot 2	NI-9215 (optional)
Slot 3	NI-9215 (optional)
Slot 4	NI-9215 (optional)
Slot 5	NI-9401 or NI-9411 (required)
Slot 6	Empty
Slot 7	Empty
Slot 8	Empty

When using the NI-9401 digital I/O module, the crankshaft optical encoder must be powered externally and a ground reference from the encoder must be connected to a COM pin of the NI-9401 module. The encoder should be connected to the NI-9401 module according to Table 3. Shielded cabling is recommended.

Table 3: Crankshaft optical encoder connections to the NI-9401 module

Encoder Signal	NI-9401 DB25 Connector Pin
Encoder Ground (required)	Slot 5 NI-9401 Pin 1 (COM)
Encoder Z (required)	Slot 5 NI-9401 Pin 16 (P0.1/PFI 1)
Encoder A (required)	Slot 5 NI-9401 Pin 14 (P0.0/PFI 0)
Sample Clock Out (optional)	Slot 5 NI-9401 Pin 20 (P0.4/PFI 4)
Raw File Saving Out (optional)	Slot 5 NI-9401 Pin 23 (P0.6)
Summary File Saving Out (optional)	Slot 5 NI-9401 Pin 25 (P0.7)

When using the NI-9411 digital input module, the crankshaft optical encoder may be optionally powered by the module. If the encoder is powered from the module, power (5 to 30 VDC) must be supplied to the Vsup and COM screw terminals of the module. Vsup is internally reduced to +5V and available from the D-Sub connector. The encoder should be connected to the NI-9411 module according to Table 3. Please note that the NI-9411 module inputs are optionally

single-ended or differential pairs. Some optical encoders provide complimentary/differential signal outputs which enable greater noise immunity when connected with differential digital inputs. Table 4 shows the connections to be made for single-ended or differential operation. If single-ended operation is required, then the “b” pin of each input should be left unconnected. Shielded cabling is recommended.

Table 4: Crankshaft optical encoder connections to the NI-9411 module

Encoder Signal	NI-9411 DB15 Connector Pin
Encoder +5V (optional)	Externally Supplied or Slot 5 NI-9411 Pin 4 (+5Vout)
Encoder Ground (optional)	Externally Supplied or Slot 5 NI-9411 Pin 12 (COM)
Encoder Z (required)	Slot 5 NI-9411 Pin 2 (P0.1+/PFI 1 (DI 1a))
Encoder Z Compliment (optional)	Slot 5 NI-9411 Pin 10 (P0.1-/PFI 1 (DI 1b))
Encoder A (required)	Slot 5 NI-9411 Pin 1 (P0.0+/PFI 0 (DI 0a))
Encoder A Compliment (optional)	Slot 5 NI-9411 Pin 9 (P0.0-/PFI 0 (DI 0a))

The analog instrumentation signals should be connected to the NI-9215 analog inputs according to Table 5. The BNC version of the NI-9215 is recommended for ease of connection. Shielded BNC cables are recommended.

Table 5: Analog instrumentation connections to the NI-9215 modules

Instrumentation Signal	NI-9215 Input
Measurement 1	Slot 1 AI 0
Measurement 2	Slot 1 AI 1
Measurement 3	Slot 1 AI 2
Measurement 4	Slot 1 AI 3
Measurement 5	Slot 2 AI 0 (optional)
Measurement 6	Slot 2 AI 1 (optional)
Measurement 7	Slot 2 AI 2 (optional)
Measurement 8	Slot 2 AI 3 (optional)
Measurement 9	Slot 3 AI 0 (optional)
Measurement 10	Slot 3 AI 1 (optional)
Measurement 11	Slot 3 AI 2 (optional)
Measurement 12	Slot 3 AI 3 (optional)
Measurement 13	Slot 4 AI 0 (optional)
Measurement 14	Slot 4 AI 1 (optional)
Measurement 15	Slot 4 AI 2 (optional)
Measurement 16	Slot 4 AI 3 (optional)

When using the DAQ device with µDCAT, only the terminals described above should be used. In order to take full advantage of certain hardware features, µDCAT makes programmatic internal connections. Connecting signals to other terminals or running other programs which interact with the DAQ device may cause unexpected behavior.

The National Instruments Measurements and Automation Explorer should be used to discover or change the name of the DAQ device and its physical channels. The names of the device and physical channels will be used on the measurement configuration tab of the user interface.

cDAQ-9174 / cDAQ-9178 (CompactDAQ)

The CompactDAQ chassis may be used with µDCAT if the proper hardware configuration is provided. The cDAQ-9174 and cDAQ-9178 should have one to four NI-9215 modules installed in any slot. The cDAQ-9174 must have a NI-9401 or a NI-9411 digital input module. The cDAQ-9178 may use the chassis trigger lines, a NI-9401 or a NI-9411 digital input module. The configuration listed for the cDAQ-9172 is an acceptable configuration.

Figure 3: CompactDAQ System

When using the NI-9401 digital I/O module, the crankshaft optical encoder must be powered externally and a ground reference from the encoder must be connected to a COM pin of the NI-9401 module. The encoder should be connected to the NI-9401 module according to Table 6. Shielded cabling is recommended.

Table 6: Crankshaft optical encoder connections to the NI-9401 module

Encoder Signal	NI-9401 DB25 Connector Pin
Encoder Ground (required)	NI-9401 Pin 1 (COM)
Encoder Z (required)	NI-9401 Pin 16 (P0.1/PFI 1)
Encoder A (required)	NI-9401 Pin 14 (P0.0/PFI 0)
Sample Clock Out (optional)	NI-9401 Pin 20 (P0.4/PFI 4)
Raw File Saving Out (optional)	NI-9401 Pin 23 (P0.6)
Summary File Saving Out (optional)	NI-9401 Pin 25 (P0.7)

When using the NI-9411 digital input module, the crankshaft optical encoder may be optionally powered by the module. If the encoder is powered from the module, power (5 to 30 VDC) must be supplied to the Vsup and COM screw terminals of the module. Vsup is internally reduced to +5V and available from the D-Sub connector. The encoder should be connected to the NI-9411 module according to Table 7. Please note that the NI-9411 module inputs are optionally single-ended or differential pairs. Some optical encoders provide complimentary/differential signal outputs which enable greater noise immunity when connected with differential digital inputs. Table 7 shows the connections to be made for single-ended or differential operation. If single-ended operation is required, then the “b” pin of each input should be left unconnected. Shielded cabling is recommended.

Table 7: Crankshaft optical encoder connections to the NI-9411 module

Encoder Signal	NI-9411 DB15 Connector Pin
Encoder +5V (optional)	Externally Supplied or NI-9411 Pin 4 (+5Vout)
Encoder Ground (optional)	Externally Supplied or NI-9411 Pin 12 (COM)
Encoder Z (required)	NI-9411 Pin 2 (P0.1+/PFI 1 (DI 1a))
Encoder Z Compliment (optional)	NI-9411 Pin 10 (P0.1-/PFI 1 (DI 1b))
Encoder A (required)	NI-9411 Pin 1 (P0.0+/PFI 0 (DI 0a))
Encoder A Compliment (optional)	NI-9411 Pin 9 (P0.0-/PFI 0 (DI 0a))

The analog instrumentation signals should be connected to the NI-9215 analog inputs. The BNC version of the NI-9215 is recommended for ease of connection. Shielded BNC cables are recommended.

When using the cDAQ-9178 chassis external triggers, the crankshaft optical encoder must be externally powered. The encoder should be connected to the cDAQ-9178 chassis according to Table 8. Shielded cabling is recommended.

Table 8: Crankshaft optical encoder connections to the cDAQ-9178 chassis

Encoder Signal	cDAQ-9178 Chassis BNC Connector
Encoder Z (required)	cDAQ-9178 Trig 1
Encoder A (required)	cDAQ-9178 Trig 0

When using the DAQ device with µDCAT, only the terminals described above should be used. In order to take full advantage of certain hardware features, µDCAT makes programmatic internal connections. Connecting signals to other terminals or running other programs which interact with the DAQ device may cause unexpected behavior.

The National Instruments Measurements and Automation Explorer (MAX) should be used to discover or change the name of the DAQ device and its physical channels. The names of the device and physical channels will be used on the measurement configuration tab of the user interface.

Physical Channel Setup

The physical channels name is used by µDCAT to define the physical IO for each measurement. The physical channel is usually based on the device name. The device names can be found and changed in the Measurements and Automation eXplorer (MAX) as shown in Figure 4. The physical channel is in the form “Device Name”\”Channel”.

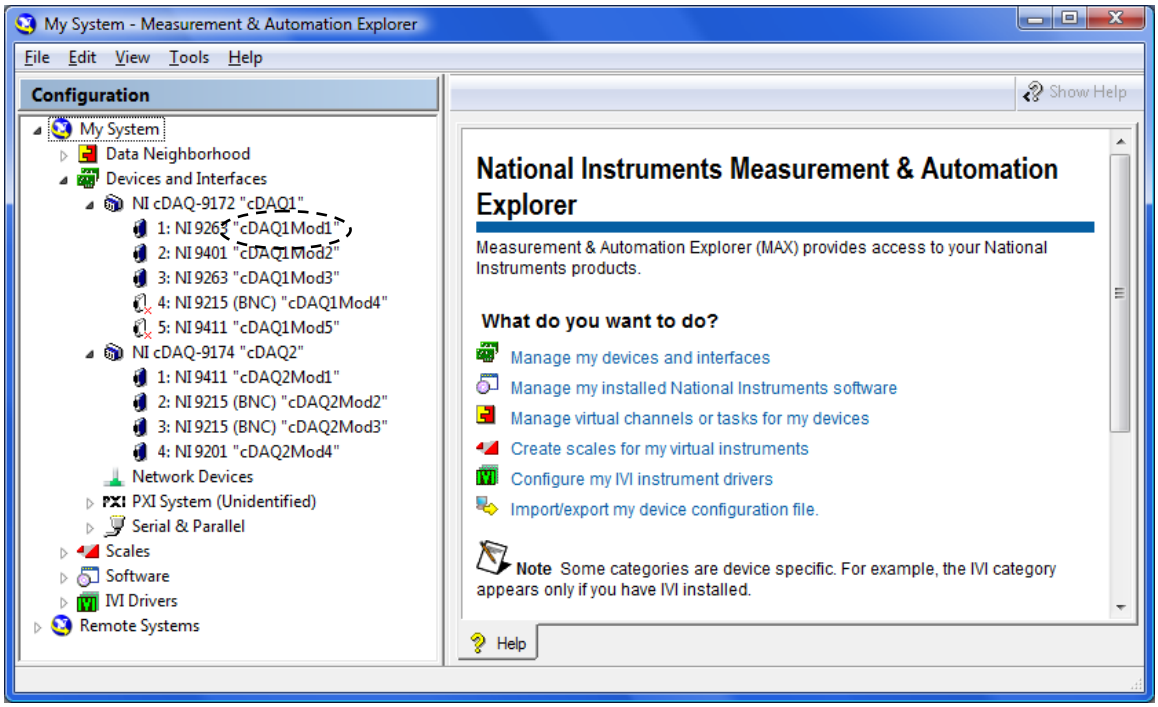


Figure 4: MAX Device Names

Running µDCAT

This section of the manual covers the basics of starting, setup, and running µDCAT. Before beginning, the latest versions CalVIEW and µDCAT should be installer and activated.

Starting µDCAT

1. Make sure CalVIEW is closed.
2. Start→Programs→Drivven→µDCAT→Launch µDCAT Target and CalVIEW
3. CalVIEW should automatically start in Mini Mode.
4. µDCAT Target application launches. This program must run in the background while using µDCAT.
5. Make sure that the **InitOK** and **Activated** lights are green on the target application.

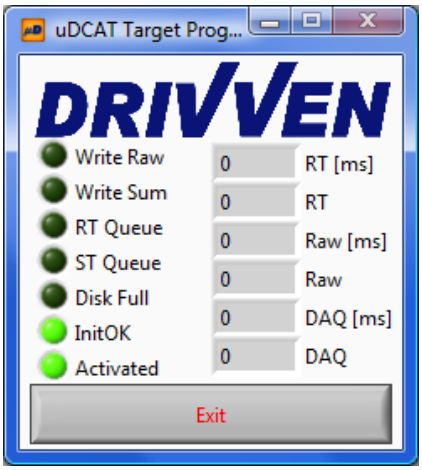


Figure 5: µDCAT Target Program

   a. If the **InitOK** light remains red, please contact Drivven.
   b. If the **Activated** light remains red, a dialog box will appear asking you to connect your hardware and retry activation. If the **activated** light continues to fail, please contact Drivven.

6. Press the **Ok** button on the CalVIEW dialog box indicating that the target application is running.

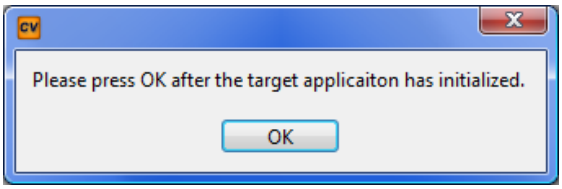


Figure 6: CalVIEW Wait Message

7. The µDCAT user interface starts running.

Measurement and Engine Setup

Before collecting and analyzing data, the Measurement Setup, the Medium Speed DAQ Setup, and the Engine Setup tabs must be configured. While on these setup tabs, no data is collected or processed. Data collection and processing will automatically begin when the user is on any of the following tabs.

To see a description of a control or indicator, hover over the parameters with the mouse cursor to see the tip strip or context-help window message. The context help window may be accessed by pressing ctl-H.

The µDCAT user interface also provides a sidebar of information to the right of the tabs that is always visible. The sidebar shows status information such as engine speed and data queue statistics that are useful at all times.

Measurement Setup

The Measurement Setup tab, shown in Figure 7, contains all of the configuration information for each measurement channel and the crankshaft encoder. The total number of measurement channels (**SyncChannelCount**) should be specified first. For each measurement, a physical channel, type, scaling, and associated cylinder should be set. The **PhysicalChannel_SyncX** is the device and channel name recognized by DAQmx. Ex. “Dev1\ai0”. The **MeasurementType_SyncX** allows the program to separate the specific measurements that are used for the calculations. A type of “undefined” should be used if the measurement type is not listed. Several options are available for the scaling of a measurement. Many of the defined measurement types require that the scaling factors be in terms of a specific engineering unit. The **AssociatedCylinder_SyncX** check boxes determine which cylinders the channel should be associated with. Some measurements, like cylinder pressure, should only be associated with a single cylinder. Others may be associated with multiple cylinders, such as manifold pressure. Please note that associating measurements with multiple cylinders may slow down the system. The **MeasurementName** is used to store the data in the file and for display. The units of undefined measurement types may be set to a text string that is used for display.

The **Filter_SyncX** refers to 1 of 16 filters that are defined on the Filtering tab. Each measurement may be set to the same filter or to its own filter.

Each measurement may be disabled with the **Disable_SyncX** button. When disabled, no data is recorded on that measurement and the configuration information for that measurement is not included in the saved files.

The **EncoderResolution** and **TDC_Offset** must be defined for the µDCAT to function properly. **TDC_Offset** must be in terms of whole encoder pulses between the Z pulse and TDC-compression of cylinder 1. Positive values mean that TDC is after the Z pulse. Please note that **TDC_Offset** is a user specified value and the **Actual_TDC_Offset** is the closest possible value. To set a partial encoder pulse TDC offset, use the **TDC_Fine_Adj** on the motoring tab.

The DAQmx device sample triggering must be setup for the Encoder A signal. The rising or falling edge of the Encoder A signal should be selected with the **A_Edge** parameter. This determines the edge of the Encoder A signal where the analog measurement is sampled. If the Encoder A signal is connected to PFI0 input, then select PFI0 for the **A_Trigger** parameter, and no further configuration is required for the Encoder A signal. If the Encoder A signal is connected to the analog APFI input, then **A_Threshold** and **A_Hysteresis** voltages must be set. **A_Threshold** is the Encoder A signal voltage at which the internal digital trigger signal goes high. **A_Hysteresis** is the Encoder A signal voltage at which the internal digital trigger signal goes low. When using a cDAQ system, the **cDAQ_DIO_Module** must specify the name of the device used to measure the encoder signals.

The combustion analysis calculation sets may be enabled and disabled depending on the specific requirements of the testing program. Please note that some of the calculations from one group may be required as inputs to another group. For example, heat release with heat transfer requires the cylinder temperature calculations.

PressureMetrics: Enables the calculations contained in the Basic tab.
MEP: Enables calculation of Mean Effective Pressures (GMEP, PMEP, NMEP). The MEP calculations are displayed on the Summary tab.
CylTemp: Enables the calculation of estimated cylinder temperature for the heat-transfer calculations. This group must be enabled if heat release is calculated with heat transfer.
HeatRelease: Enables the calculations contained on the Heat Release tab.
Misfire: Enables the calculations related to misfire detection. Misfire detection is reported on the Summary tab.

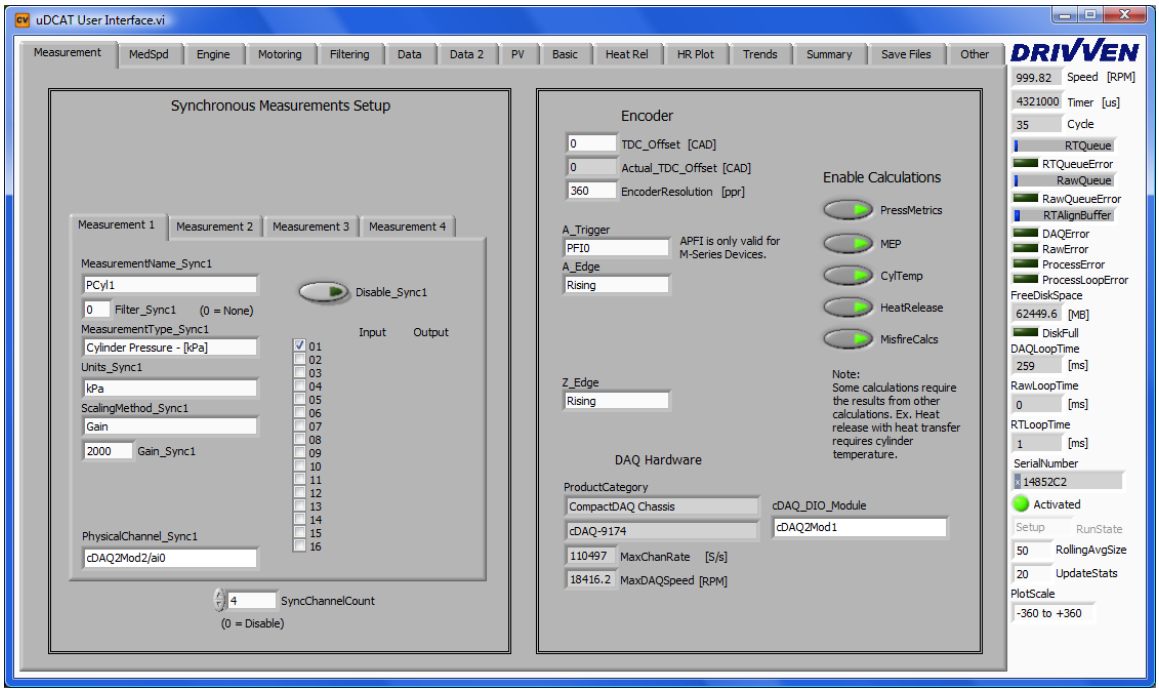


Figure 7: Measurement Setup Tab

Medium Speed DAQ Setup (cDAQ-9174 & cDAQ-9178 Only)

The Medium Speed DAQ Setup tab, shown in Figure 8, contains all the setup parameters needed to collect medium speed data. The tab control contains an easy to use XControl designed to allow the user to configure all properties. The XControl contains 3 parts: the sample rate, measurement editing, and the summary of measurements. The user may select a measurement from the summary table to edit. Once selected, the measurement configuration may be altered in the editing section. New measurements may be added using the **Insert** button. Selected measurements may be removed using the **Delete** button. The order of the measurements may be changed using the **Move Up** and **Move Down** buttons.

The Medium Speed DAQ is set up to scale measurements based on a gain and offset or a standard thermocouple calibration. Data is saved to the raw data file as a raw voltage for gain and offset scaling or as the temperature for thermocouples. The **Signal Max** and **Signal Min** values should represent the range of voltages for gain and offset scaling and the range of temperatures for thermocouples.

The **Sample Rate** of all measurements must be the same and must not exceed the sample rate of any device. Although the sample rate may be set as high as the modules will allow, large sample rates will require use more memory and CPU than modest sample rates. Each channel has the option of using a point-by-point second order Butterworth filter. The **Filter Cutoff** frequency must be less than half the sample rate. A **Filter Cutoff** frequency of 0 turns the filter off.

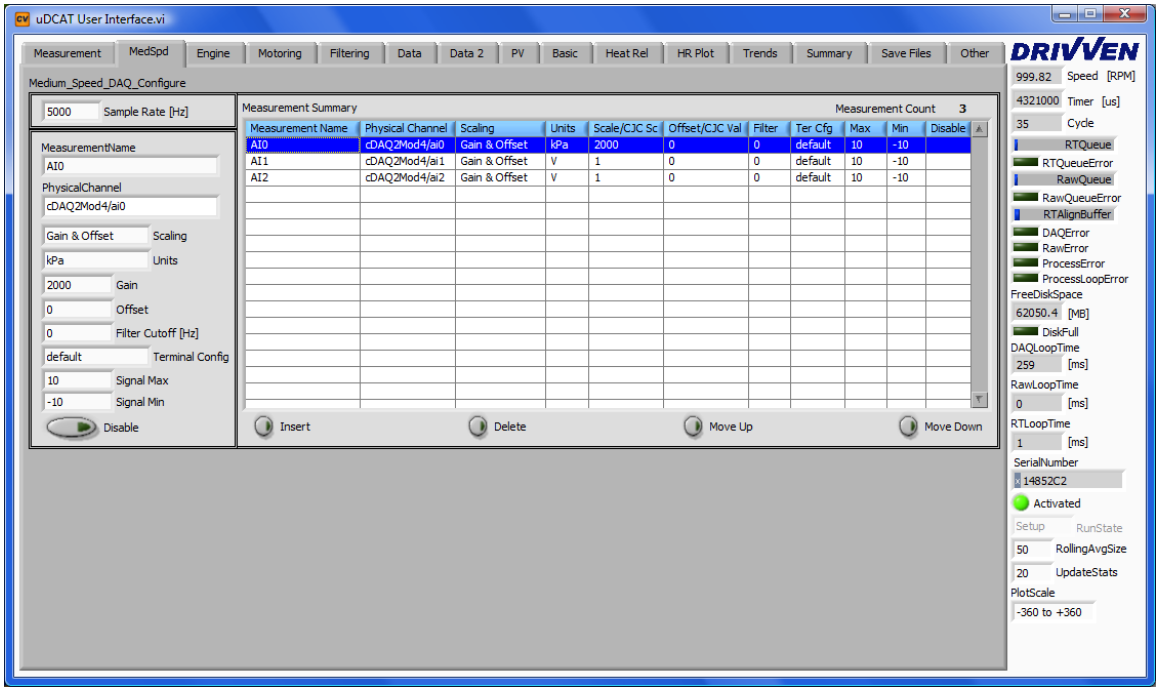


Figure 8: Medium Speed DAQ Setup Tab

Engine Setup

The Engine Setup tab, shown in Figure 9, is a collection of engine geometry parameters. The **EngineName**, **ProjectName**, and **Operator** are strings that are saved in the output file for reference. They are not use in the program.

The **CylinderCount** should be set for the number of cylinders that are being analyzed. The **CylinderTDC** array will show only the number of elements for the specified **CylinderCount**. Each element of the **CylinderTDC** array should be specified with the relative CAD offset of each cylinder at TDC-compression with respect to the first cylinder. Typically the first cylinder will have a CylinderTDC of 0 and the other cylinders will have positive values spaced throughout the engine cycle. Recall that the **TDC_Offset** parameter on the Measurement Setup tab specifies the global TDC offset of the first cylinder with respect to the encoder Z pulse.

The engine geometry and valve timings are used throughout the program for various calculation sets and should always be fully specified. **HeadArea** and **CrownArea** parameters are entered as percentages of the bore area. For example, **HeadArea** and **CrownArea** set to 100% assumes that the head portion of the combustion chamber and piston top are flat, and meet at TDC. **HeadArea** and **CrownArea** set to 120% assumes that those surfaces have 20% more surface area than the bore area. These parameters should only be adjusted above 100% if heat release is calculated using heat transfer. In cases where the geometry is not based on the standard slider crank calculations, **VolumeFileEnable** may be used. A comma separated spreadsheet file (*.csv) containing columns of CAD, Volume, dVolume, and Area. The data in the file will be interpolated if the data CAD values do not line up with the expected values.

An option has been added to window the data starting at a **WindowDataStart** and ends at **WindowDataEnd**. Data outside the window is replaced with the value of the window boundaries.

Misfire detection monitors the absolute peak combustion pressure or the **NMEP**. The misfire calculations must be enabled by pressing the **MisFireCalcs** button on the Measurement Setup tab. Each option for **MisfireMethod** is described below:

Peak Pressure (Absolute): Misfire is detected when the measured peak pressure falls below the specified **PressureThreshold**.
NMEP (Absolute): Misfire is detected when the calculated **NMEP** falls below the specified **PressureThreshold.**
Peak Pressure (% of Historic): Misfire is detected when the measured peak pressure falls below a **PercentThreshold** of a rolling average of the measured peak pressure. **HistoryLength** specifies the number of cycles to use for the rolling average.
NMEP (% of Historic): Misfire is detected when the calculated **NMEP** falls below a **PercentThreshold** of a rolling average of **NMEP**. **HistoryLength** specifies the number of cycles to use for the rolling average.

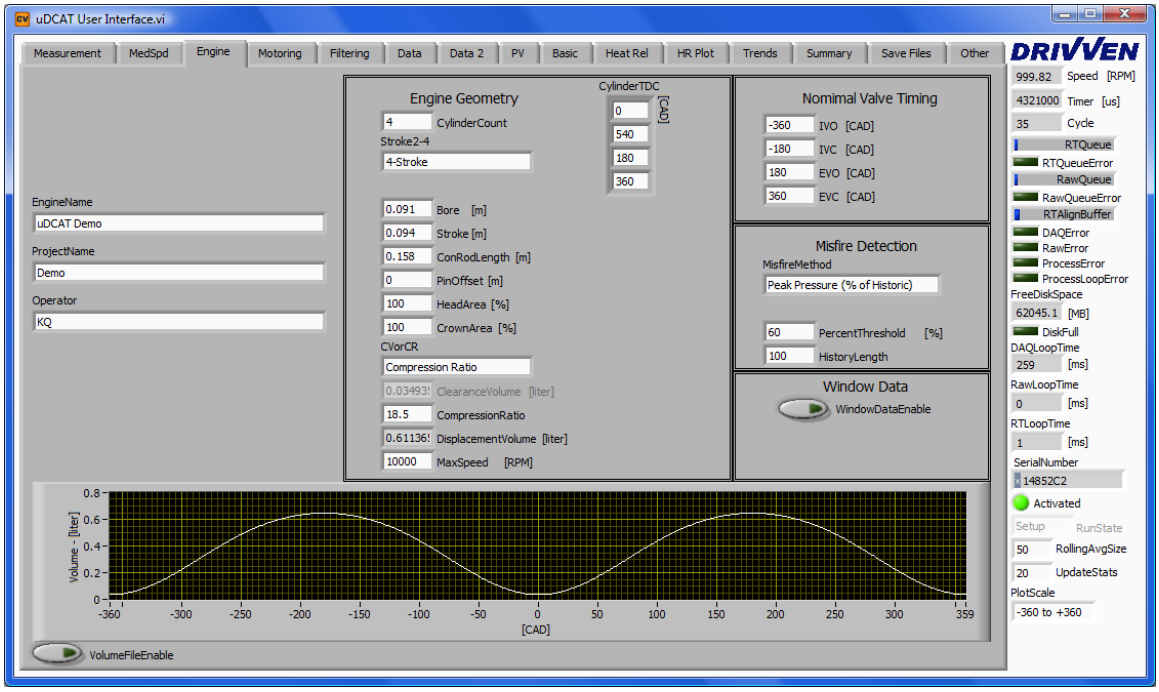


Figure 9: Engine Setup Tab

Motoring, TDC Alignment and Pegging

The motoring tab, shown in Figure 10, provides a place to check some of the key motoring parameters to ensure that the day to day variation of the engine is within acceptable ranges. Various motoring pressure metrics are displayed here. When the Motoring tab or any other tab to the right of the Engine Setup tab is selected, data acquisition begins according to the configuration of the first two tabs.

MotoringCylinder should be set to the cylinder number to be monitored. A **MotoringAverageSize** may be used to average a specified number of cycles for performing the calculations on this tab. Increasing this value will reduce the rate of updates.

The motoring polytropic coefficients of compression and expansion (**PolyC_motor** and **PolyE_motor**) are calculated here. The crank angle ranges to be used for calculating these parameters are entered on the Pressure Metrics tab. PolyC_motor and PolyE_motor are displayed graphically on the PV diagram. Tolerance ranges may be set for these parameters as a quick check of engine geometry and TDC setup.

When motoring, the **TDC_Check** method may be set to “Peak_Pressure”, “Spline Interpolation”, “Half Peak Pressure”, or Most Probable”. The **CalculatedTDCOffset** is displayed and the **TDC_Fine_Adj** parameter may be adjusted to achieve a **CalculatedTDCOffset** of zero. **TDC_Fine_Adj** may be use to correct partial encoder pulse offsets. However, setting **TDC_Fine_Adj** to a non-zero value may reduce the overall performance of the system because it causes a re-sampling of the measurement signals by linearly interpolating the arrays of data.

µDCAT provides several methods for pegging the cylinder pressure measurements. Pegging refers to dynamically adjusting the cylinder pressure offset. It is useful when using sensors that measure a dynamic pressure instead of an absolute pressure. Each selection of PeggingMethod is described below:

None: No pegging method is implemented and the measured pressure wave form, as calculated from the specified scaling parameters on the Measurement Setup tab, is used.
Constant: The average cylinder pressure (PressureAvg, not displayed) over a specified crank angle range is calculated. The center of the averaging range is specified by **PegLocation** in CAD. The PressureAvg is calculated over a range before and after **PegLocation** specified by **PegAverage** in CAD. The total angular range used to calculate PressureAvg is twice **PegAverage**. The difference between the specified **PegPressure** and PressureAvg (**PegPressure** – PressureAvg) is displayed in the **PeggingValue** table for each cylinder and is added to the entire pressure wave form for each cylinder.
Synchronous MAP: Synchronous MAP is identical to *Constant* except that a Manifold Absolute Pressure (MAP) sensor is sampled engine synchronously and averaged over the same angular range (MAPAvg, not displayed). MAPAvg is used instead of the *Constant*-mode user-specified **PegPressure**. **PegPressure** is not used. This method requires that a MAP sensor be connected to one of the measurement channels and configured on the Measurement Setup tab. It should be assigned to all relevant cylinders using the **AssociatedCylinders_SyncX** check boxes.
Polytropic: Uses the change in volume and pressure to determine the absolute pegging offset. This method calculates the pegging offset over the window specified for calculating the PolyC values on the Pressure Metrics page. The user must enter an accurate value for the polytropic coefficient of compression in **PegPolyC**. Please note that the TDC offset will effect the calculations because the cylinder volume is used.

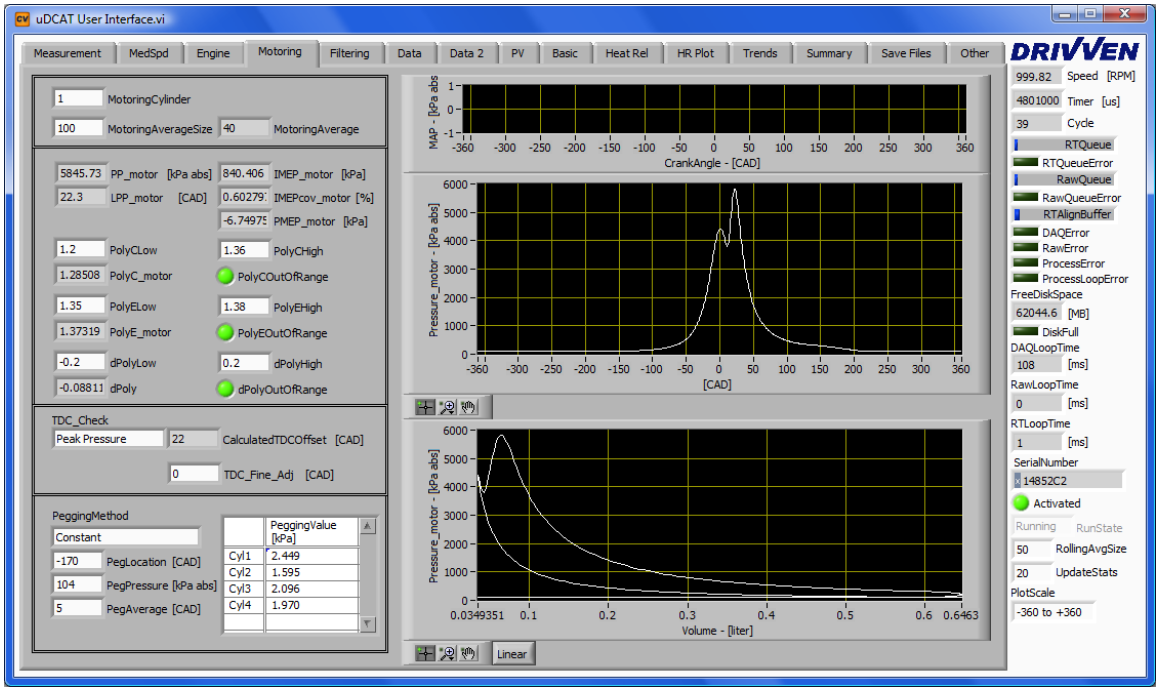


Figure 10: Motoring Tab

Filtering

The Filtering tab, shown in Figure 11, allows configuration of up to 16 filters. The filter number specified in the Measurement Setup tab for each measurement corresponds to the filter number configuration on this tab. There are several types of filters that may be selected with the **FilterMethodX** drop-down, including “Rolling N Cycles”, “Forward and Reverse IIR”, “FIR Filter with Rollback”, and “Boxcar”. A comparison of these filters is beyond the scope of this manual. When a filter type is selected, only the configuration parameters for that filter type will be shown. The filters are applied to the measurements before being displayed on all other plots.

An ensemble average of each measurement may also be used by pressing the **EnsembleEnable** button. When using the ensemble average, a specified number of cycles (**EnsembleSize**) are averaged at each crank angle and the averaged results are used in the calculations. Increasing **EnsembleSize** will reduce the rate at which the calculations are performed.

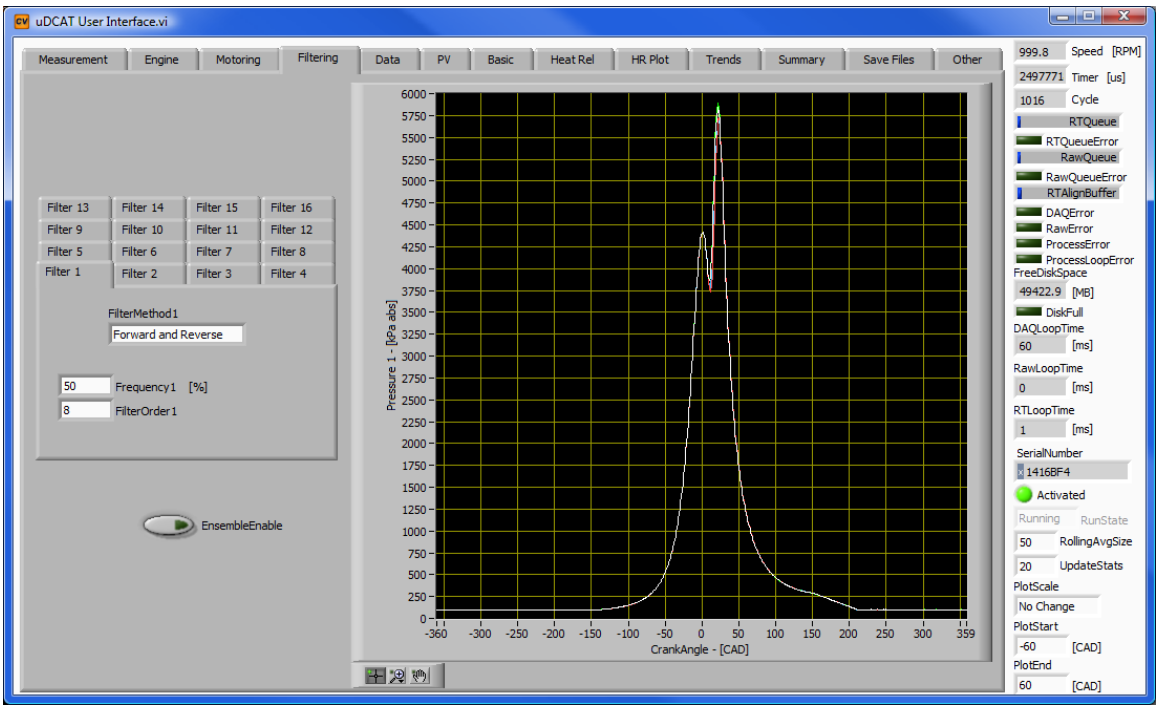


Figure 11: Filtering Tab

Viewing All Waveforms

The Data tab, shown in Figure 12 and Figure 13, displays all the measurements associated with a single cylinder specified in **DisplayCylinder**. The data is aligned with TDC, scaled, and filtered. The undefined measurement types (selected by **MeasurementType_SyncX** on the Measurement Setup tab) are displayed on this tab according to the selected associated cylinder. The sample period, instantaneous engine speed and the differential speed are displayed on the lower plot. This is the only tab where undefined measurement types are displayed. The second data tab displays all the medium speed data in the same way as the first data tab. The medium speed data is accompanied with a list of cycle averages for each measurement.

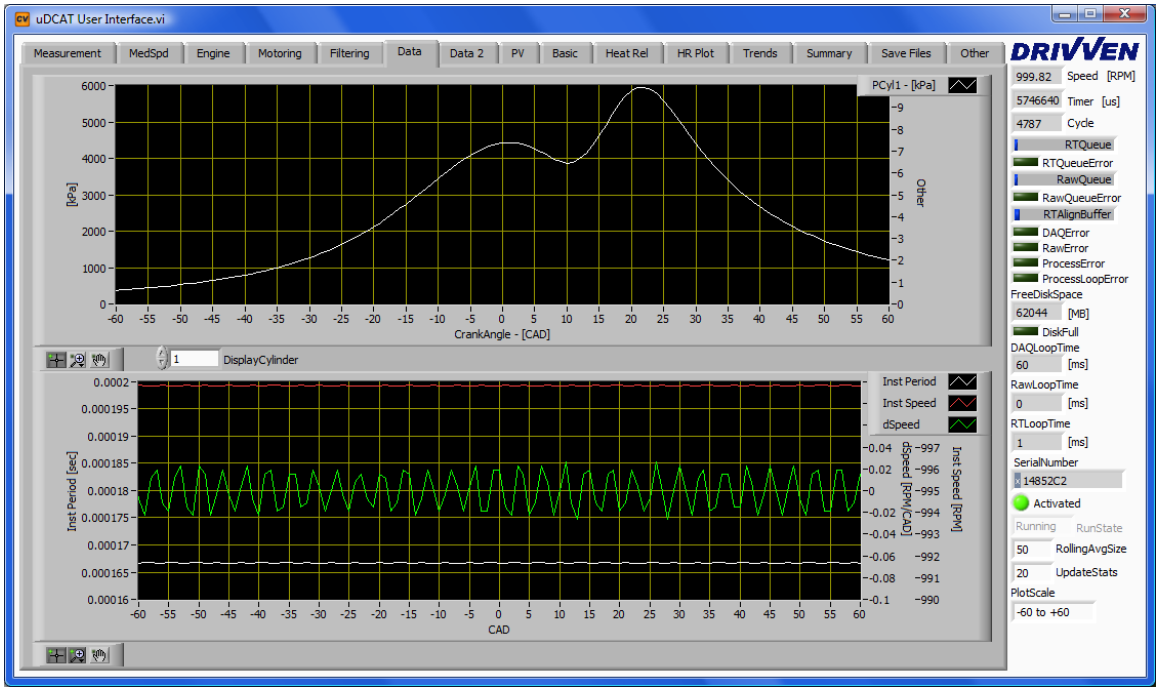


Figure 12: Data Tab

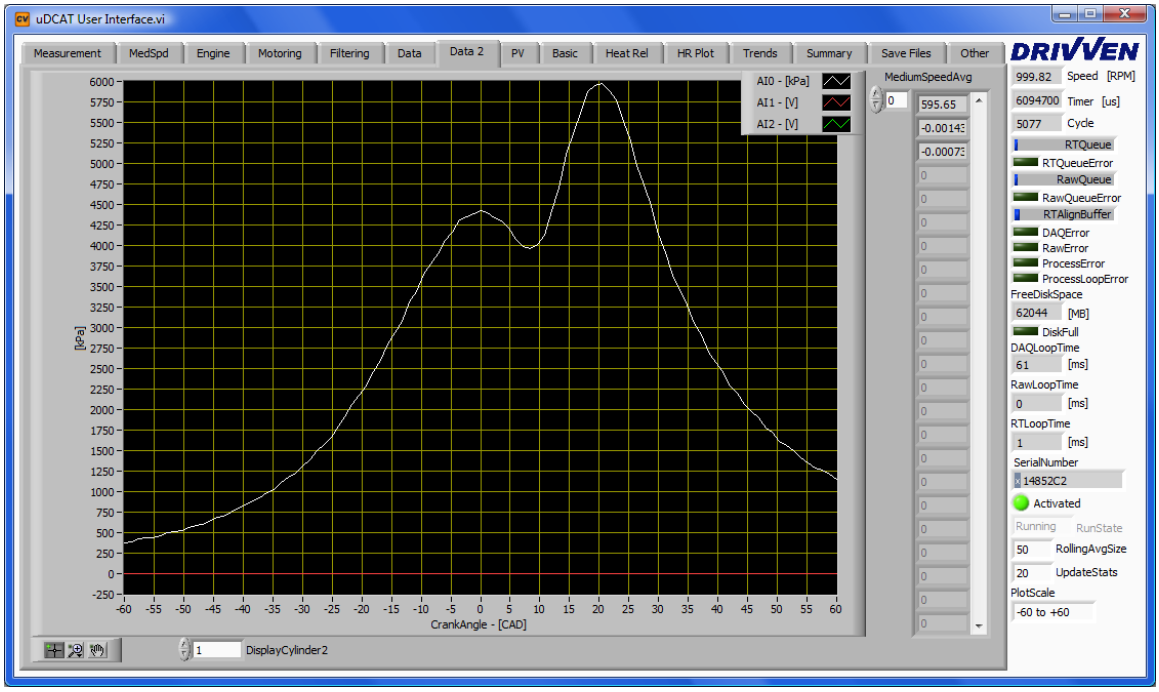


Figure 13: Data Tab 2

PV Diagram

A full screen diagram, shown in Figure 14, may be helpful in general setup and alignment. The button at the lower left of the plot may be used to switch between logP-logV view and normal axis views. In the log view, the red lines represent the straight line generated from the polyC/PolyE values. The points on the red line show the PolyC/PolyE calculation windows.

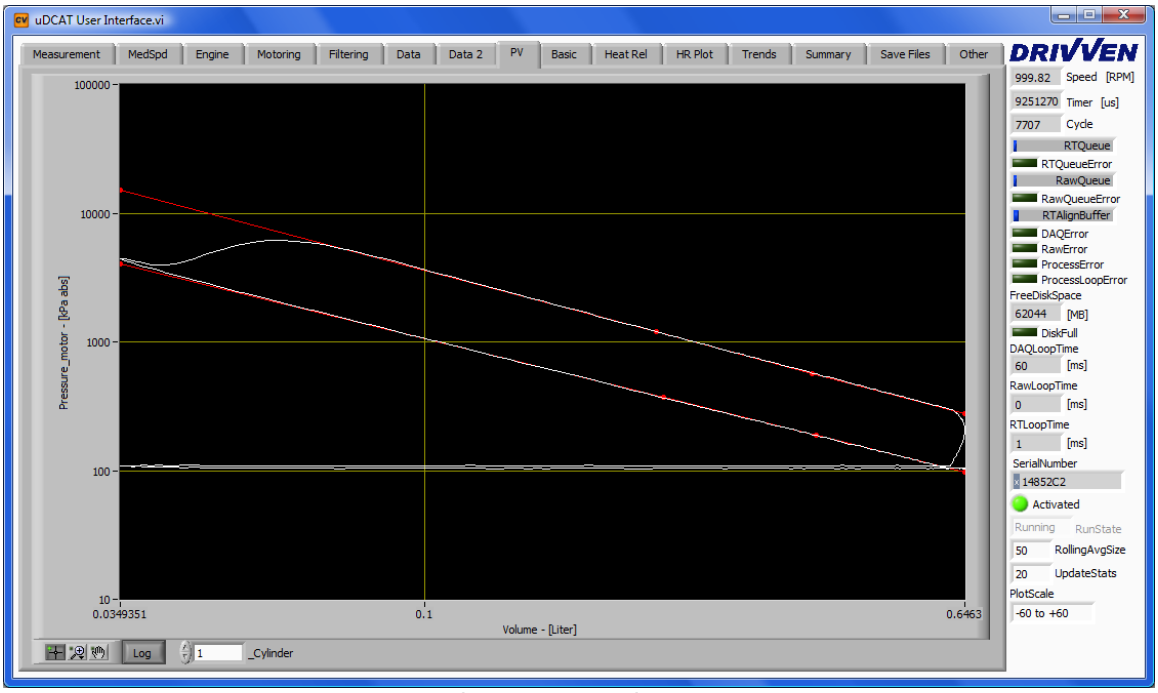


Figure 14: PV Diagram

Calculation Setup and Results

Many of the combustion analysis calculations require additional setup. The additional setup parameters may be found on the following tabs. The individual numerical results are displayed in the tables, having columns for each cylinder. The arrays of angle-based data are displayed in plots. Each calculated table value has rolling statistics associated with it. The displayed statistics may be turned off by un-checking the control next to the table. Each individual plot can be configured for auto-scaling or manual scaling of the Y axis, by right-clicking on the scale and checking or un-checking the "AutoScale" menu item. There are three parameters on the bottom right side bar for configuring the Crank Angle Degrees (CAD) scale.

Pressure Metrics (Basic)

The Pressure Metrics tab, shown in Figure 15, displays the results of basic analysis of each cylinder pressure wave form. The angle parameters at the top of the tab are required for calculating each pressure metric. The table-based calculated parameters are as follows:

PP [kPa]: Peak Pressure
LocPP [CAD]: Location of Peak Pressure
PolyC: Polytropic Coefficient of Compression
PolyE: Polytropic Coefficient of Expansion
MPR [kPa/CAD]: Maximum Pressure Rise
LocMPR [CAD]: Location of Maximum Pressure Rise
Intake [kPa]: Average pressure during intake valve opening
Exhaust [kPa]: Average pressure during exhaust valve opening

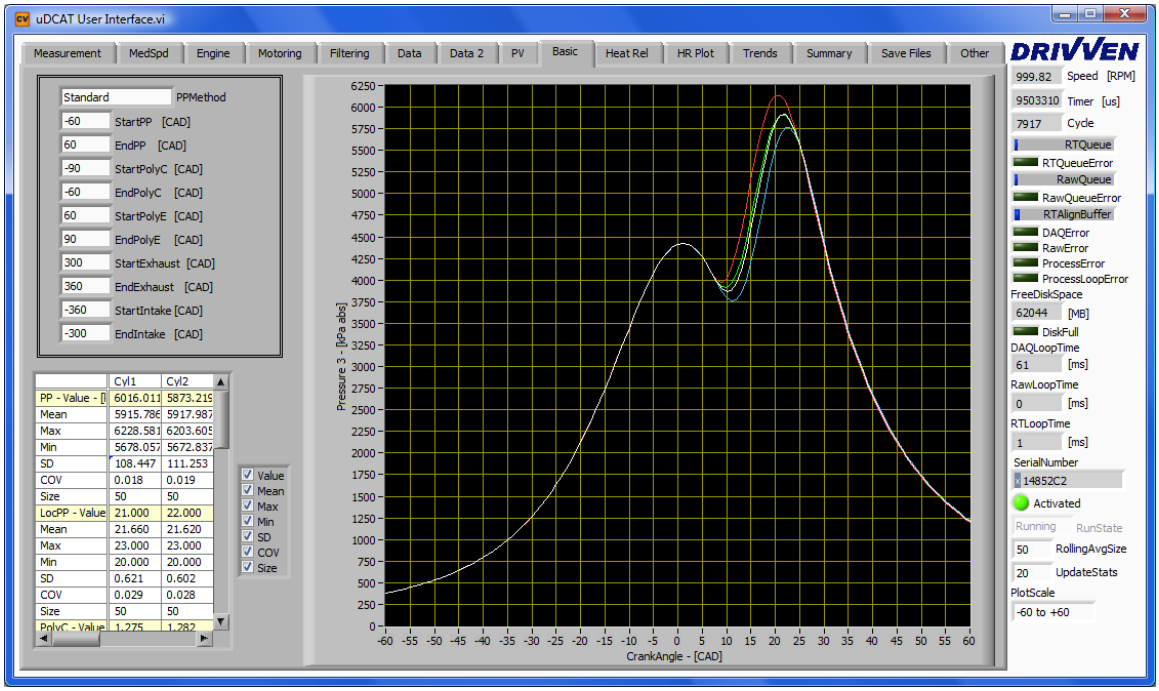


Figure 15: Pressure Metrics Tab

Heat Release

The Heat Release tab, shown in Figure 16, displays in table and plot format the Heat Release Rate (HRR) and Mass Fraction Burn (MFB) percentages. The dropdown menu **HeatReleaseMethod** selects one of several heat release methods. Different configuration parameters will be shown for each heat release method. The **StartMethod** and **EndMethod** define how the start and end of combustion are determined. The in-cylinder temperature calculation setup is also on this page. If **ResidualFraction** is zero, **IntakeTemp** and **IVC_Window** are used. The starting pressure is the average pressure ending at IVC with **IVC_Window** length. When using **ResidualFraction**, the **IntakeTemp** is adjusted depending on the **IntakePressure**, **ExhaustPressure** and **ExhaustTemperature**. For more details on the heat release calculations, please refer to the Calculations section of this manual.

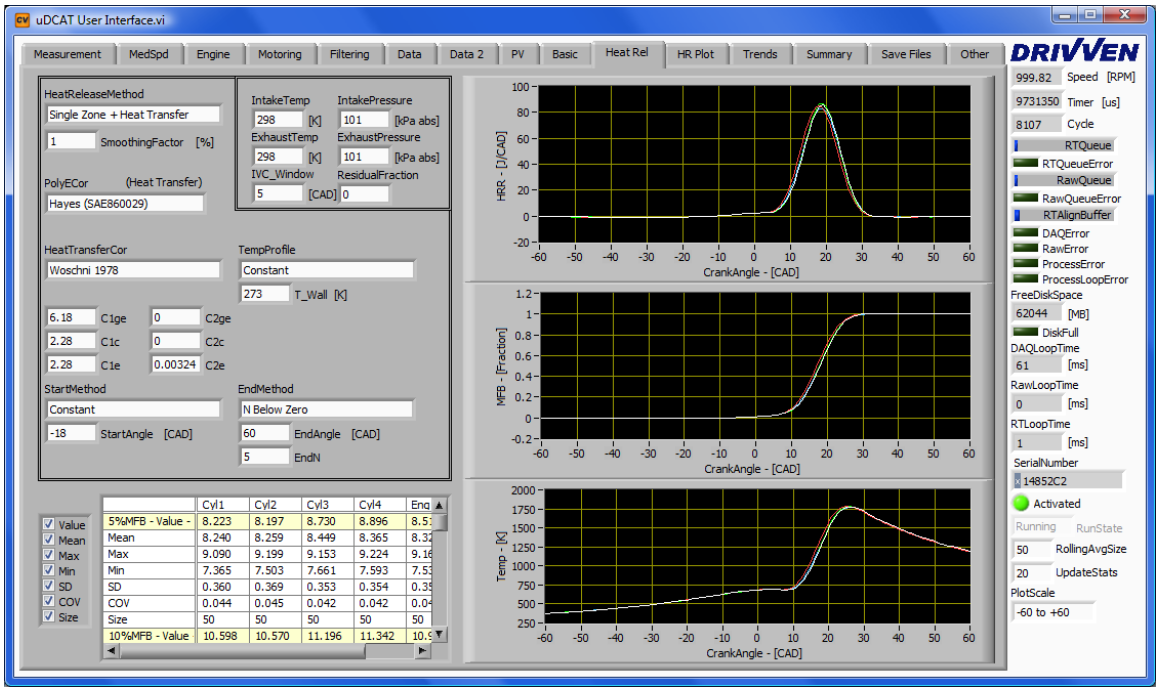


Figure 16: Heat Release Tab

Parameter	Recommended Value
C1ge	6.18
C2ge	0.0
C1c	2.28
C2c	0.0
C1e	2.28
C2e	0.00324

Heat Release Plot

The heat release plot displays a single cylinder heat release and mass fraction burned curve as shown in Figure 17.

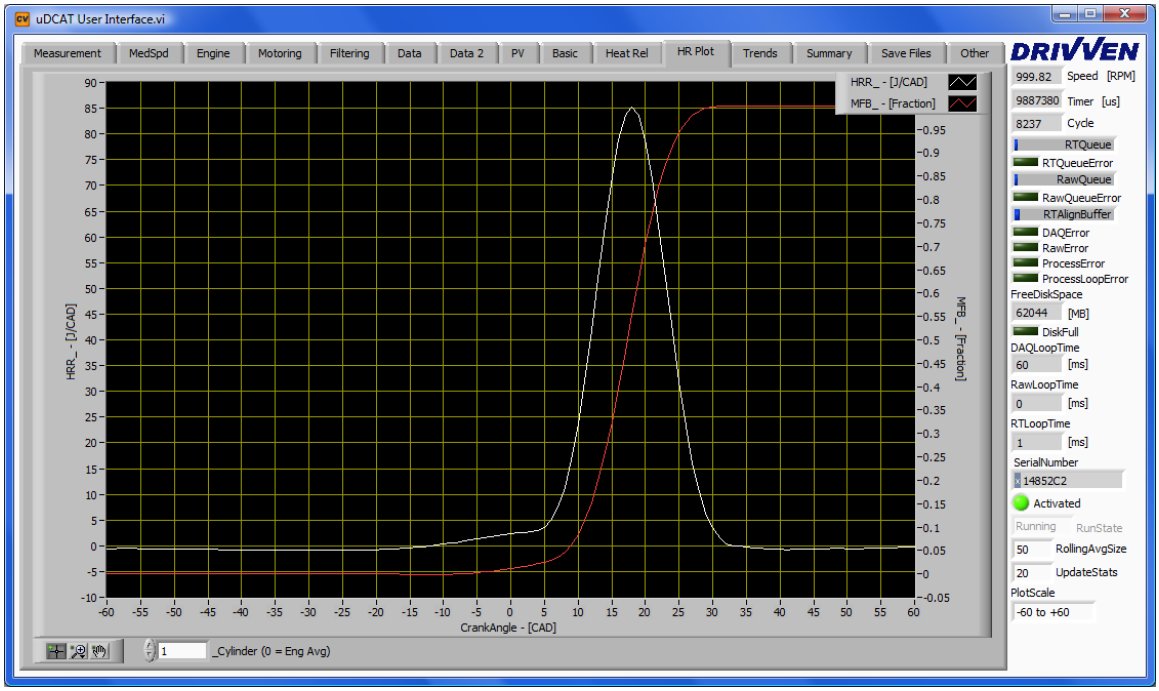


Figure 17: Heat Release Plot

Viewing Trends and Summary Data

Trends

The Trends tab, shown in Figure 18, displays charts for a quick view of the historic data. Any calculated parameter can be selected to see the historical trends. The available values are displayed in the list box to the left of the trend. Holding Shift or Ctrl allows for selecting multiple values to trend. Changing the selection will reset the trends. The listed available trends may be filtered using the controls below the list box. Please note that trends are updated periodically. Therefore, not every cycle of data will be displayed in the trend.

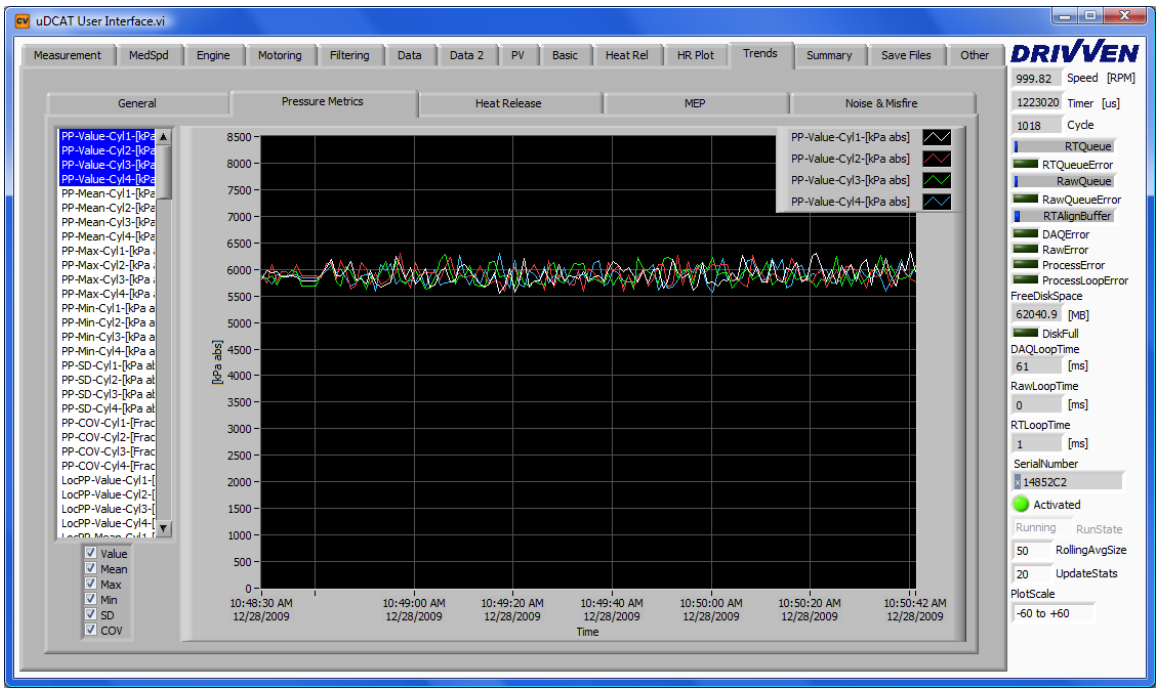
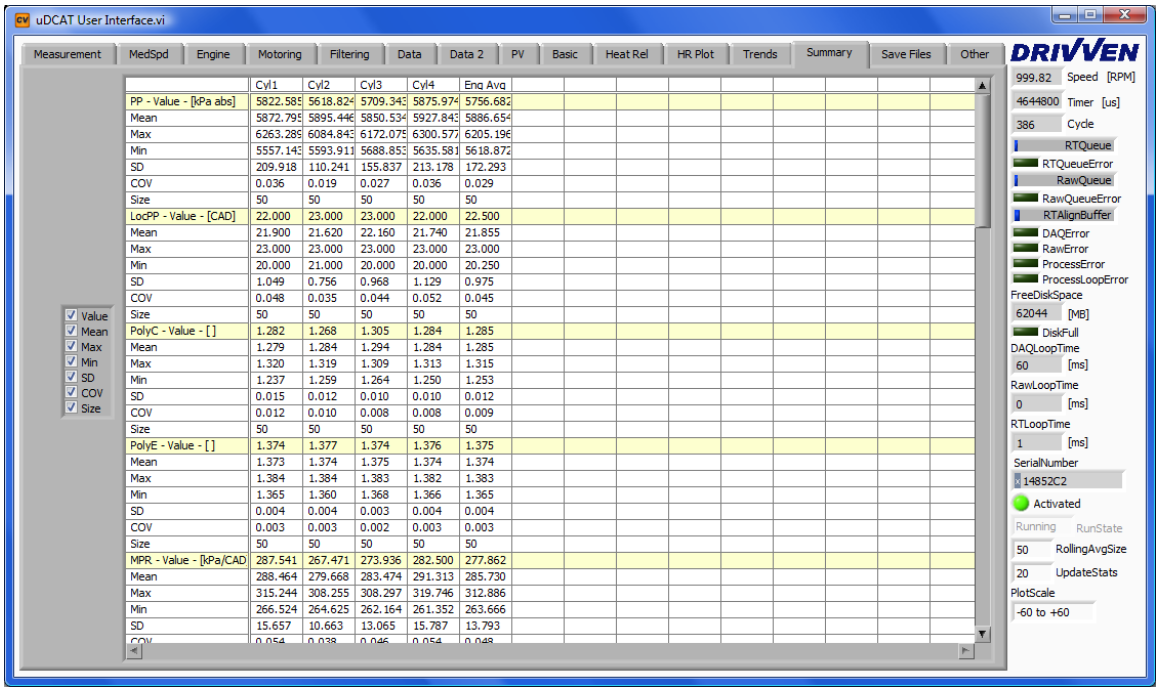


Figure 18: Trends Tab

Summary

The Summary tab, shown in Figure 19, displays a single table of all calculated values and associated rolling statistics. The values in the summary table are a collection of the same table values from the previous tabs. Please note that the Mean Effective Pressure (MEP) results and the misfire results are only displayed in the Summary tab table. Below is a definition of the MEP calculations:

IMEP: Indicated MEP over the firing portion of the cycle defined as -180 to 180 CAD.
PMEP: Pumping MEP over the portions of the cycle defined as -360 to -180 and 180 to 360 CAD. PMEP is a negative value.
NMEP: Net MEP resulting from IMEP + PMEP. NMEP is effectively over the complete cycle defined as -360 to 360 CAD.



	Cyl1	Cyl2	Cyl3	Cyl4	Eng Avg
PP - Value - [kPa abs]	5822.585	5618.824	5709.345	5875.974	5756.682
Mean	5872.795	5895.446	5850.534	5927.843	5886.654
Max	6263.289	6084.843	6172.075	6300.577	6205.196
Min	5557.143	5593.911	5688.853	5635.581	5618.872
SD	209.918	110.241	155.837	213.178	172.293
COV	0.036	0.019	0.027	0.036	0.029
Size	50	50	50	50	50
LocPP - Value - [CAD]	22.000	23.000	23.000	22.000	22.500
Mean	21.900	21.620	22.160	21.740	21.855
Max	23.000	23.000	23.000	23.000	23.000
Min	20.000	21.000	20.000	20.000	20.250
SD	1.049	0.756	0.968	1.129	0.975
COV	0.048	0.035	0.044	0.052	0.045
Size	50	50	50	50	50
PolyC - Value - [ ]	1.282	1.268	1.305	1.284	1.285
Mean	1.279	1.284	1.294	1.284	1.285
Max	1.320	1.319	1.309	1.313	1.315
Min	1.237	1.259	1.264	1.250	1.253
SD	0.015	0.012	0.010	0.010	0.012
COV	0.012	0.010	0.008	0.008	0.009
Size	50	50	50	50	50
PolyE - Value - [ ]	1.374	1.377	1.374	1.376	1.375
Mean	1.373	1.374	1.375	1.374	1.374
Max	1.384	1.384	1.383	1.382	1.383
Min	1.365	1.360	1.368	1.366	1.365
SD	0.004	0.004	0.003	0.004	0.004
COV	0.003	0.003	0.002	0.003	0.003
Size	50	50	50	50	50
MPR - Value - [kPa/CAD	287.541	267.471	273.936	282.500	277.862
Mean	288.464	279.668	283.474	291.313	285.730
Max	315.244	308.255	308.297	319.746	312.886
Min	266.524	264.625	262.164	261.352	263.666
SD	15.657	10.663	13.065	15.787	13.793

Figure 19: Summary Tab

Saving Data

The Save Files tab, shown in Figure 20, provides configuration parameters for saving two types of data sets. The left side of the tab is used for saving raw data. "Raw Data" consists of the absolute voltages measured directly from each channel. The raw data is streamed to disk without any processing. Therefore, the data is not scaled or aligned to the cylinder. However, every configuration parameter from the setup and calculation tabs is also saved to the raw data file so the test environment can be recreated in post processing.

The right side of the tab is used for saving summary data. "Summary Data" is the set of values calculated every cycle, such as pressure metrics and heat release. The statistics are also calculated and saved in the file. The ensemble average of the scaled and aligned waveforms is also saved with the summary data.

Raw data and summary data may be recorded simultaneously. The cycle number and time stamp, which is recorded in both file types, can be used to align the summary data with the raw data.

Both raw data and summary data types have identical file saving configurations. The raw data file saving parameters will be described below.

Raw_Path: Defines the full path to the directory for storing the file
Raw_Filename: Defines the name of the raw data file. A suffix of XXX tells µDCAT to append a file number to the end of the name. The file number will be assigned and incremented according to **Raw_StartCounter**, **Raw_Counter** and **Raw_ResetCounter**.
Raw_SaveMethod: Selects the method for determining the end of saving raw data to file. The options are as follows:
- **Continuous:** Continuously save data while the **Start/StopRawFile** button is pressed.
- **N-Cycles:** Saves data for number of cycles specified by **Raw_MaxCycles.**
- **Timed:** Saves data for a time specified by **Raw_MaxTime**.
- **Size:** Saves data until a file size specified by **Raw_MaxSize** is reached.

Raw_Comments: String inserted into the raw data file.
Raw_StartCounter: Specifies the starting file number to be filled in for "XXX" in the filename.
Raw_ResetCounter: Resets the file number to **Raw_StartCounter**
Start/StopRawFile: Starts and stops the file saving process.
EnableRawCMD: Enables execution of a command line when file-save finishes.
RawCMD: Command line that executes when enabled and a file-save finishes. The following variables may be used within the RawCMD text string:
- **%PATH%:** Used within the **RawCMD** text string. This variable will be replaced by Raw_Path\Raw_Filename before **RawCMD** is executed.

µDCAT includes a command line utility called FileConverter.exe. This utility opens and converts the tdms file to a cvs file. When used as a raw data file converter, the data is aligned to the cylinder TDC offset and each column is a different measurement. The flags and arguments to the utility are listed below in Table 6. A flag letter must be preceded with a – (dash) and immediately followed by = (equal). For example, –r=%PATH% defines the raw data file path using the **%PATH%** variable. Please note that the arguments should be enclosed in quotations if it contains spaces.

Table 9: FileConverter.exe Flags

Flag	Argument	Description
-p	n/a	Commands FileConverter to write raw data to cvs
-q	n/a	Commands FileConverter to write summary data to cvs
-r	Raw Data File Path	Defines the raw data file path
-s	Summary Data File Path	Defines the summary data file path

Example **RawCMD** string:
C:\Program Files\Drivven\uDCAT\FileConverter.exe -r=%PATH% -p

µDCAT also includes the LabVIEW project and source code that was used to generate FileConverter.exe. The name of the project is Custom File Converter.lvproj and can be opened from the Start->Drivven->uDCAT menu. The LabVIEW development tools are required to open and modify the project. Users may use this project as a starting point to create a custom file converter or post processing utility. Additional command line options may be added or the utility may be operated using front panel. If an .exe utility is desired, then the LabVIEW Application Builder toolkit is required as a plug-in to the LabVIEW tools.

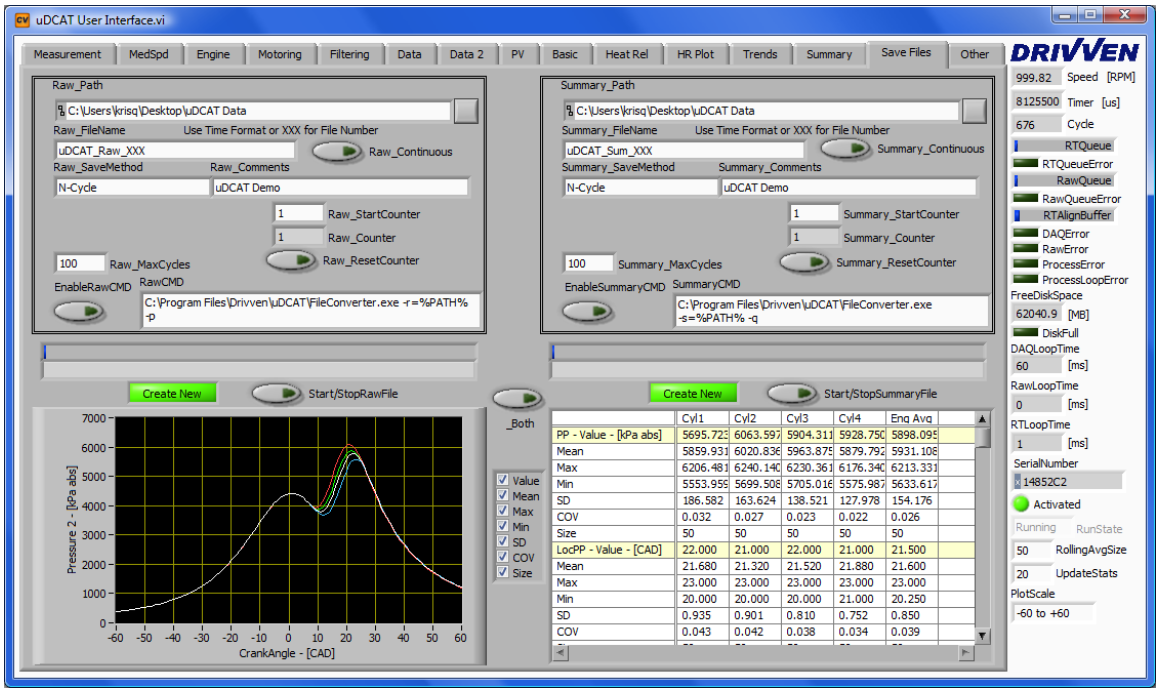


Figure 20: Saving Data Tab

Other

The other tab contains the text descriptions of errors. This tab also contains the setup controls for the CalVIEW Trends and Scopes. Please see the CalVIEW manual for more details on these features.

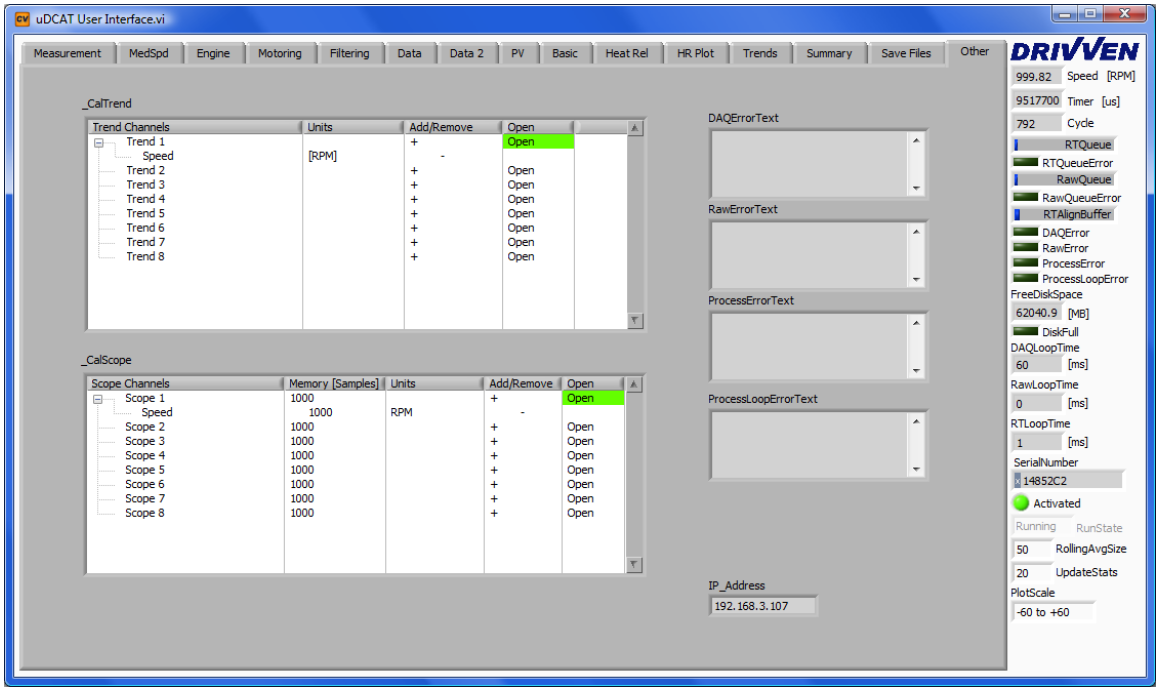


Figure 21: Other Tab

Knock Calibrator

The µDCAT Knock Calibrator is a version of µDCAT that contains asynchronous sampling and knock calibration XControl. The Knock Calibrator requires a cDAQ-9174 or a cDAQ-9178. The cDAQ chassis support multiple analog input time bases. The knock calibrator also requires different activation than the standard µDCAT version.

The Asynchronous Measurement setup is similar to the Synchronous Measurement setup as shown in Figure 22. The **MeasurementType** of the knock sensor should be set to **Acoustic**. If no acoustic sensor is found, the cylinder pressure trace will be used. At least one synchronous measurement must be used. However, asynchronous measurements are optional.

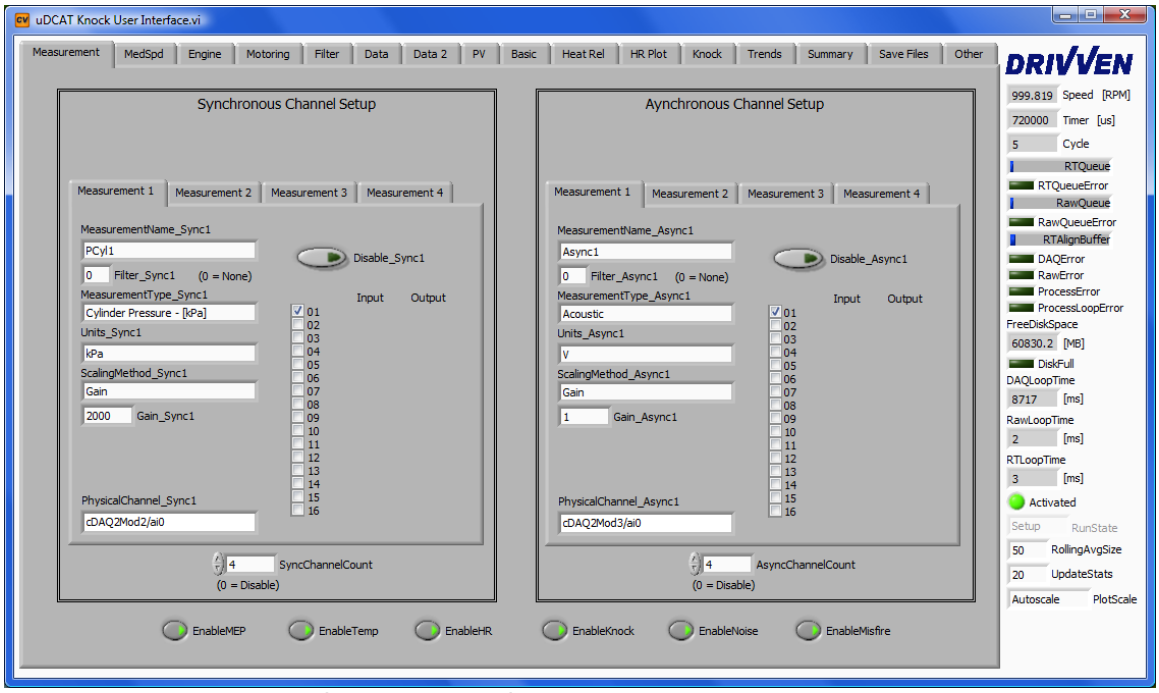


Figure 22: Asynchronous Measurement Setup

The encoder setup has been moved to the Engine Setup tab as shown in Figure 23. The inputs setup is the same as the standard µDCAT version.

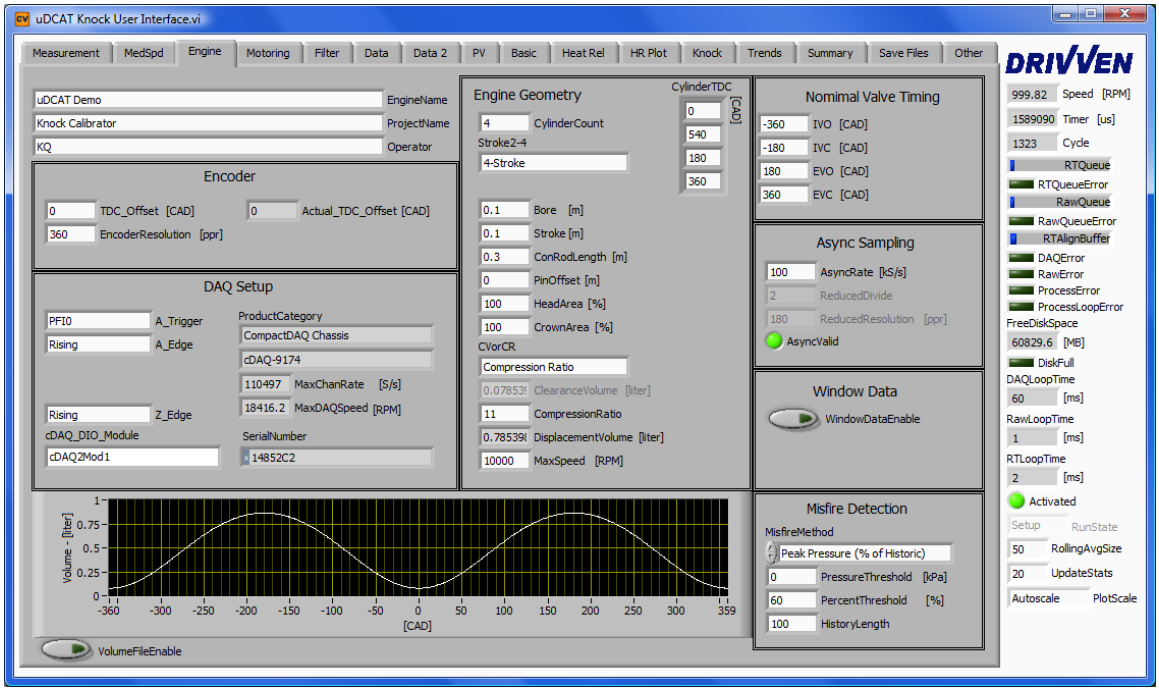


Figure 23: Engine Setup Tab

The knock tab, shown in Figure 24, may be used to calibrate and display knock. Knock is calculated using the Bandpass, Rectify, Integrate, Comair (BRIC) method.

The knock XControl is used to provide a visual display of the cylinder pressure and knock sensor signals so that the user can select a window for knock detection and a window for a reference (top left plot). An FFT of the windows is displayed so that the user may select a frequency window (top right plot). The filters are applied to the windows and another FFT is applied and the results are displayed (lower right plot). Finally, the windows are integrated and compared. The results are displayed for the user (lower left plot). The user can save and load data sets. Up to 8 data sets may be loaded and viewed. The calculated knock values are updated on each dataset when any of the windows change.

Knock [dB]: Calculated Knock
PtoPKnock []: Filtered Peak to Peak Value

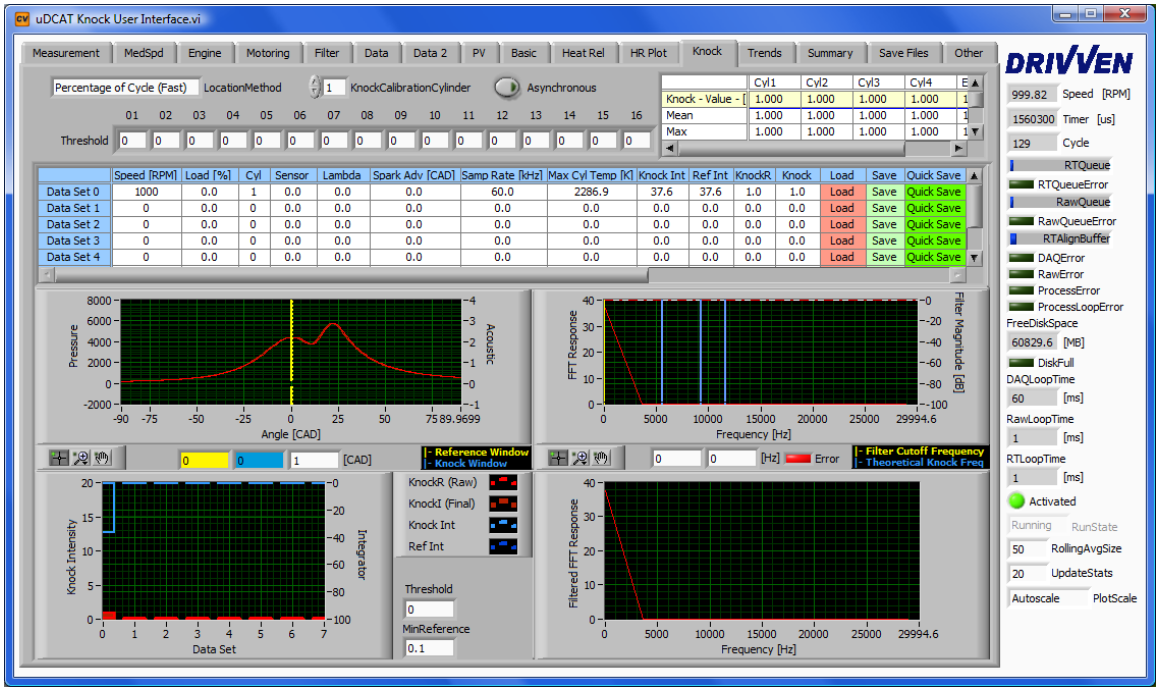


Figure 24: Knock Calibration Tab

The Knock XControl (Figure 25) is a graphical knock calibration tool. It can be used to the BRIC windows and filters coefficients. There are five parts of the tool.

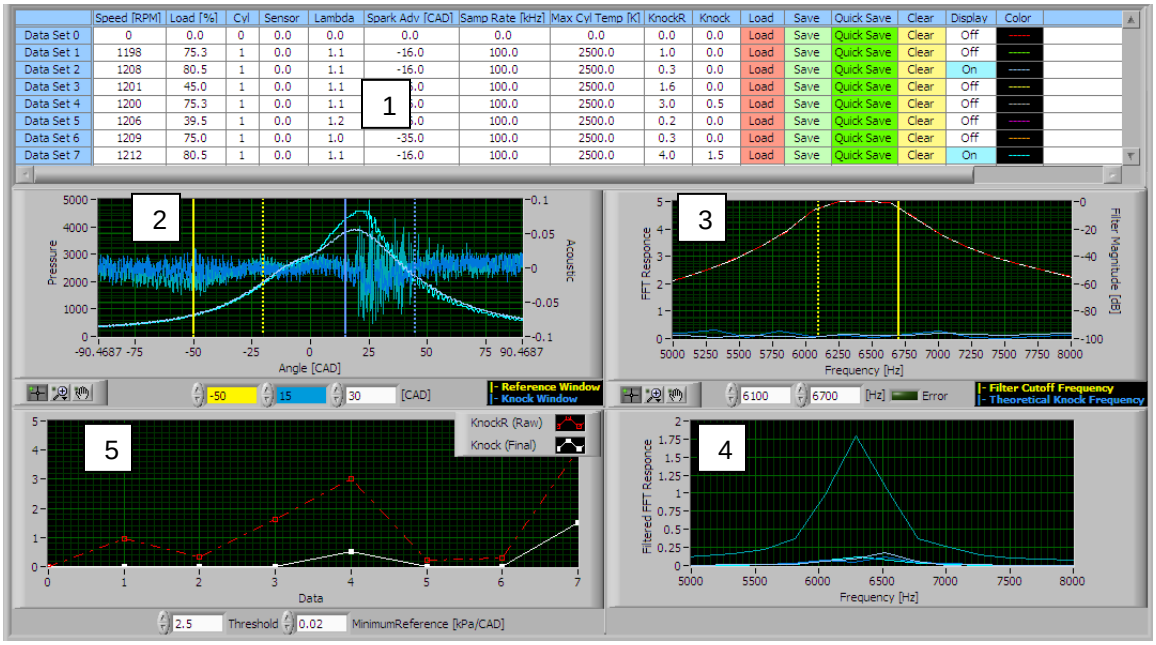


Figure 25: Knock XControl

1. The summary displays up to 8 data sets. Each data set may be saved or loaded from file. Pressing the save or load button opens a file dialog box. The clear button on the summary display clears the data set. The display button turns on an off the corresponding waveforms on the plots below. The color indicates the corresponding waveform color.

2. The window plot shows the pressure waveform overlaid with the acoustic waveform. This allows the user to view the ripple on the pressure waveform along with the corresponding acoustic signal. This also allows the user to check for other issues like valve noise and other cylinder knock events. The yellow window defines the reference window. Likewise, the blue window defines the knock window. The user may drag and drop the start cursor on both windows or enter the value in the appropriate colored box below.
3. The filter magnitude response plot displays the filter cutoff with an FFT of the knock and reference windows. The filter cutoffs are represented with cursors that the user may drag as needed.
4. The FFT of the filtered windows is displayed based on the current settings.
5. The integrated values of knock are displayed for each data set. The plots show the ratio of the integrated and filtered windows before and after the threshold is applied.

Post Processing Data Files

µDCAT saves data in National Instruments' standard TDMS file format. TDMS files provide a powerful and flexible way to store and retrieve data. National Instruments provides many resources on their website to edit and view TDMS files outside LabVIEW in programs such as MatLab and Excel. The µDCAT tool contains several VIs used to stream data from the TDMS files.

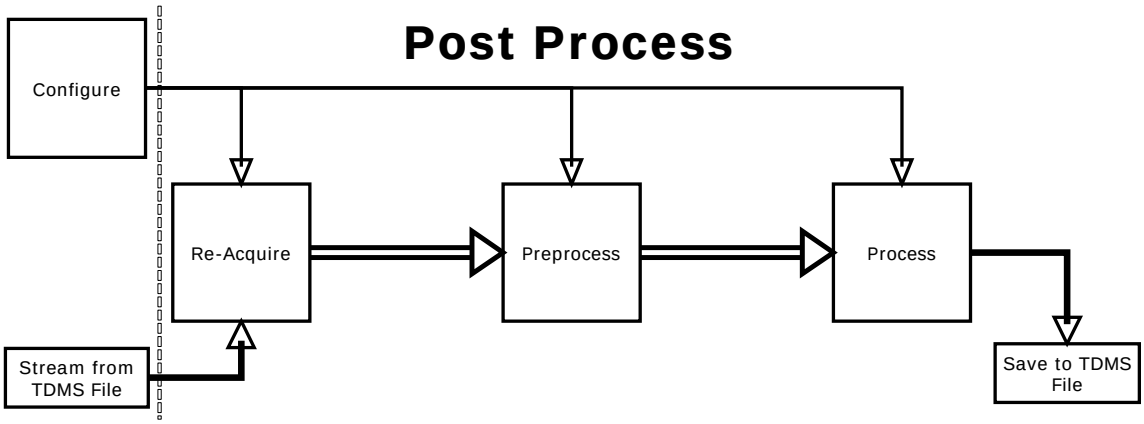
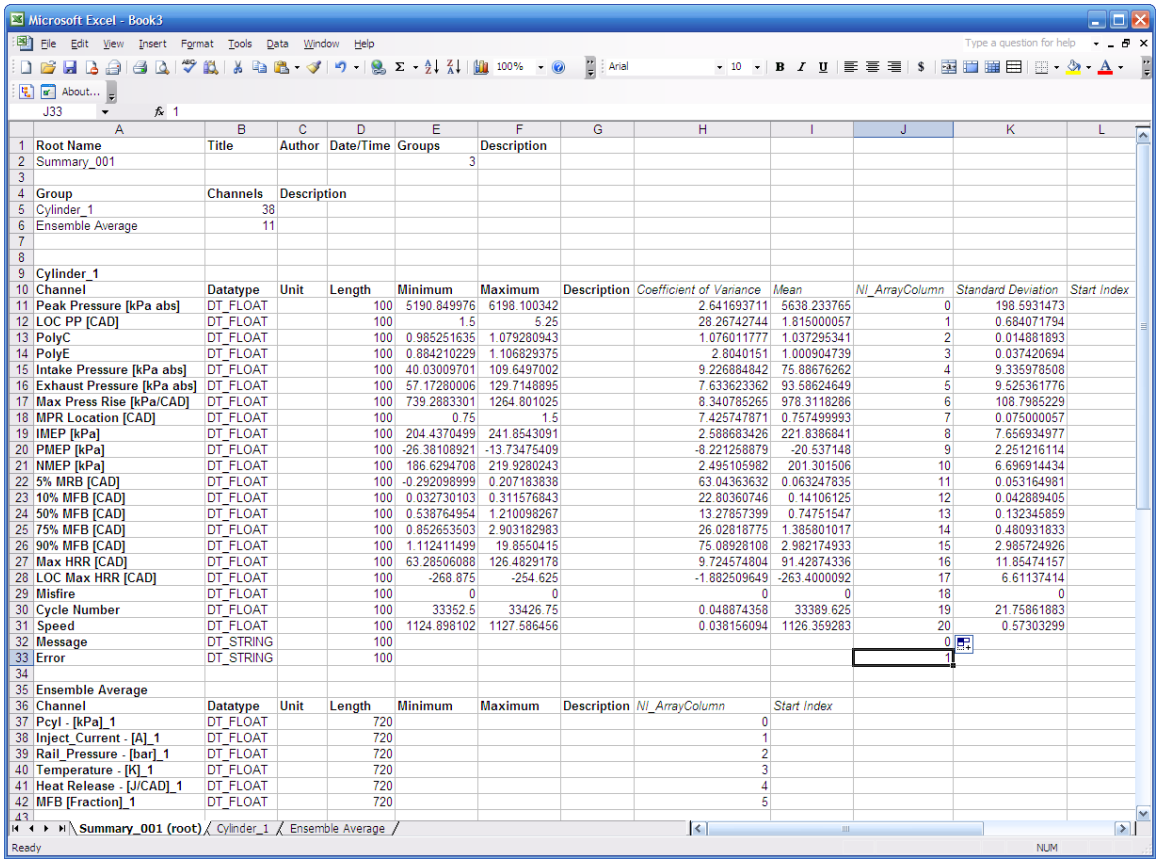


Figure 26 - Post Processing Overview

Opening TDMS Files in Excel

National Instruments provides a free excel plug-in that imports TDMS files. Importing a file creates a multi-page spreadsheet with all the data stored in the file, shown in Figure 27. The first page contains a summary of all the groups and channels. Each group has a page where each column is a channel of data. Please note that Excel 2003 is limited to 256 columns and 65536 rows. Therefore, the custom properties (displayed in the first 2 rows on the main page) which contain all the calculation configuration information may need to be turned off. Raw data channels may also be too long and will be truncated.

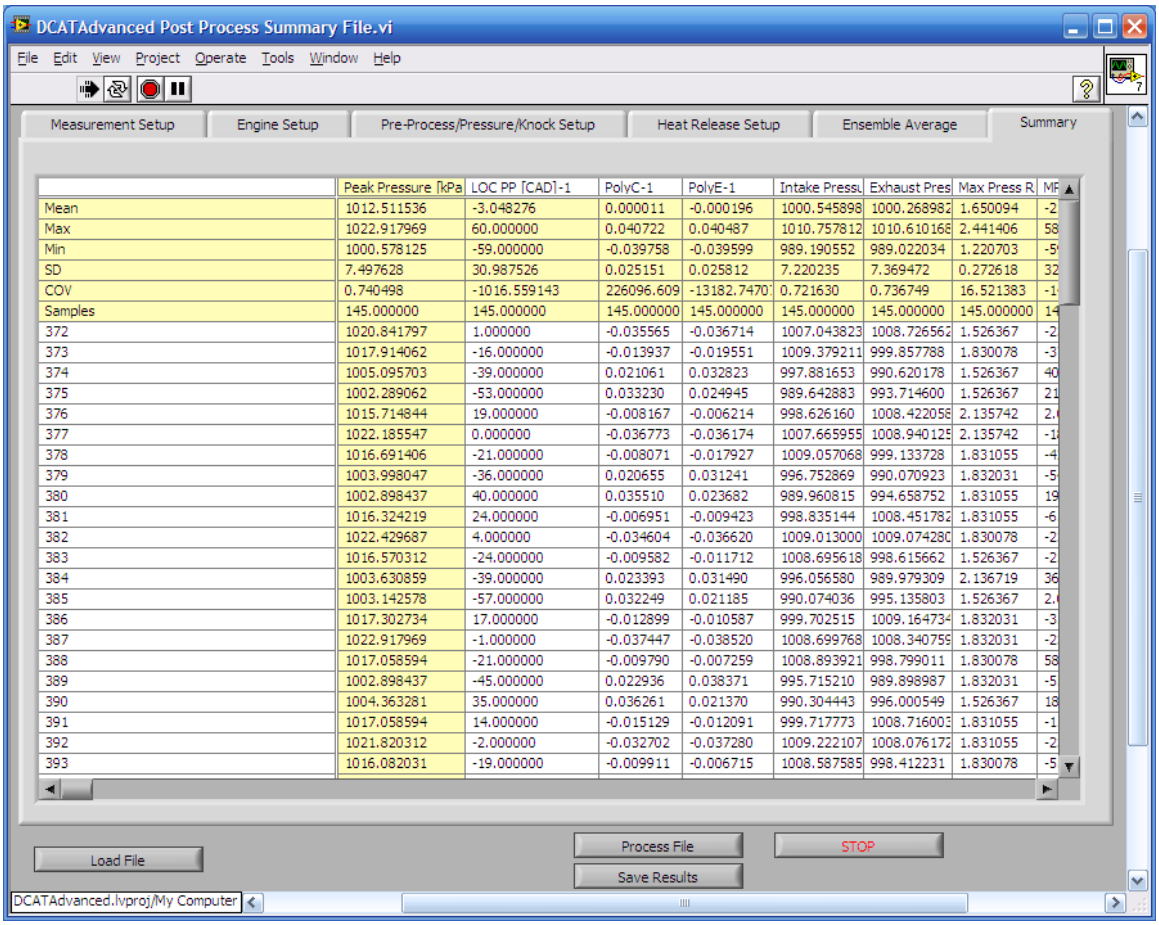


	A	B	C	D	E	F	G	H	I	J	K	L
1	**Root Name**	**Title**	**Author**	**Date/Time**	**Groups**	**Description**						
2	Summary_001				3							
3												
4	**Group**	**Channels**	**Description**									
5	Cylinder_1	38										
6	Ensemble Average	11										
7												
8												
9	**Cylinder_1**											
10	**Channel**	**Datatype**	**Unit**	**Length**	**Minimum**	**Maximum**	**Description**	*Coefficient of Variance*	*Mean*	*NI_ArrayColumn*	*Standard Deviation*	*Start Index*
11	**Peak Pressure [kPa abs]**	DT_FLOAT		100	5190.849976	6198.100342		2.641693711	5638.233765	0	198.5931473	
12	**LOC PP [CAD]**	DT_FLOAT		100	1.5	5.25		28.26742744	1.815000057	1	0.684071794	
13	**PolyC**	DT_FLOAT		100	0.985251635	1.079280943		1.076011777	1.037295341	2	0.014881893	
14	**PolyE**	DT_FLOAT		100	0.884210229	1.106829375		2.8040151	1.000904739	3	0.037420694	
15	**Intake Pressure [kPa abs]**	DT_FLOAT		100	40.03009701	109.6497002		9.226884842	75.88676262	4	9.335978508	
16	**Exhaust Pressure [kPa abs]**	DT_FLOAT		100	57.17280006	129.7148895		7.633623362	93.58624649	5	9.525361776	
17	**Max Press Rise [kPa/CAD]**	DT_FLOAT		100	739.2883301	1264.801025		8.340785265	978.3118286	6	108.7985229	
18	**MPR Location [CAD]**	DT_FLOAT		100	0.75	1.5		7.425747871	0.757499993	7	0.075000057	
19	**IMEP [kPa]**	DT_FLOAT		100	204.4370499	241.8543091		2.588683426	221.8386841	8	7.656934977	
20	**PMEP [kPa]**	DT_FLOAT		100	-26.38108921	-13.73475409		-8.221258879	-20.537148	9	2.251216114	
21	**NMEP [kPa]**	DT_FLOAT		100	186.6294708	219.9280243		2.495105982	201.301506	10	6.696914434	
22	**5% MRB [CAD]**	DT_FLOAT		100	-0.292098999	0.207183838		63.04363632	0.063247835	11	0.053164981	
23	**10% MFB [CAD]**	DT_FLOAT		100	0.032730103	0.311576843		22.80360746	0.14106125	12	0.042889405	
24	**50% MFB [CAD]**	DT_FLOAT		100	0.538764954	1.210098267		13.27857399	0.74751547	13	0.132345859	
25	**75% MFB [CAD]**	DT_FLOAT		100	0.852653503	2.903182983		26.02818775	1.385801017	14	0.480931833	
26	**90% MFB [CAD]**	DT_FLOAT		100	1.112411499	19.8550415		75.08928108	2.982174933	15	2.985724926	
27	**Max HRR [CAD]**	DT_FLOAT		100	63.28506088	126.4829178		9.724574804	91.42874336	16	11.85474157	
28	**LOC Max HRR [CAD]**	DT_FLOAT		100	-268.875	-254.625		-1.882509649	-263.4000092	17	6.61137414	
29	**Misfire**	DT_FLOAT		100	0	0		0	0	18	0	
30	**Cycle Number**	DT_FLOAT		100	33352.5	33426.75		0.048874358	33389.625	19	21.75861883	
31	**Speed**	DT_FLOAT		100	1124.898102	1127.586456		0.038156094	1126.359283	20	0.57303299	
32	**Message**	DT_STRING		100						0		
33	**Error**	DT_STRING		100						1		
34												
35	**Ensemble Average**											
36	**Channel**	**Datatype**	**Unit**	**Length**	**Minimum**	**Maximum**	**Description**	*NI_ArrayColumn*	*Start Index*			
37	**Pcyl - [kPa]_1**	DT_FLOAT		720				0				
38	**Inject_Current - [A]_1**	DT_FLOAT		720				1				
39	**Rail_Pressure - [bar]_1**	DT_FLOAT		720				2				
40	**Temperature - [K]_1**	DT_FLOAT		720				3				
41	**Heat Release - [J/CAD]_1**	DT_FLOAT		720				4				
42	**MFB [Fraction]_1**	DT_FLOAT		720				5				

Figure 27: Summary File Import to Excel

Post Processing (Summary Files)

The µDCAT Post Process Summary File example, shown in Figure 28 and Figure 29, is set up to display all of the configuration information and allow the user to easily insert their own post processing code. The front panel contains a tab control and several buttons to load and view files. The slider controls the cycle displayed in the graphs and tables. The buttons labeled for processing and saving do nothing in the example but are set up to allow the user to easily add processing and saving code for their specific needs. The example is not set up to allow the user to change the setup parameters because the properties have already been applied to all the calculated values.



	Peak Pressure [kPa	LOC PP [CAD]-1	PolyC-1	PolyE-1	Intake Pressu	Exhaust Pres	Max Press R	MF
Mean	1012.511536	-3.048276	0.000011	-0.000196	1000.545898	1000.268982	1.650094	-2
Max	1022.917969	60.000000	0.040722	0.040487	1010.757812	1010.610168	2.441406	58
Min	1000.578125	-59.000000	-0.039758	-0.039599	989.190552	989.022034	1.220703	-5
SD	7.497628	30.987526	0.025151	0.025812	7.220235	7.369472	0.272618	32
COV	0.740498	-1016.559143	226096.609	-13182.7470	0.721630	0.736749	16.521383	-1
Samples	145.000000	145.000000	145.000000	145.000000	145.000000	145.000000	145.000000	14
372	1020.841797	1.000000	-0.035565	-0.036714	1007.043823	1008.726562	1.526367	-2
373	1017.914062	-16.000000	-0.013937	-0.019551	1009.379211	999.857788	1.830078	-3
374	1005.095703	-39.000000	0.021061	0.032823	997.881653	990.620178	1.526367	40
375	1002.289062	-53.000000	0.033230	0.024945	989.642883	993.714600	1.526367	21
376	1015.714844	19.000000	-0.008167	-0.006214	998.626160	1008.422058	2.135742	2.
377	1022.185547	0.000000	-0.036773	-0.036174	1007.665955	1008.940125	2.135742	-1
378	1016.691406	-21.000000	-0.008071	-0.017927	1009.057068	999.133728	1.831055	-4
379	1003.998047	-36.000000	0.020655	0.031241	996.752869	990.070923	1.832031	-5
380	1002.898437	40.000000	0.035510	0.023682	989.960815	994.658752	1.831055	19
381	1016.324219	24.000000	-0.006951	-0.009423	998.835144	1008.451782	1.831055	-6
382	1022.429687	4.000000	-0.034604	-0.036620	1009.013000	1009.074280	1.830078	-2
383	1016.570312	-24.000000	-0.009582	-0.011712	1008.695618	998.615662	1.526367	-2
384	1003.630859	-39.000000	0.023393	0.031490	996.056580	989.979309	2.136719	36
385	1003.142578	-57.000000	0.032249	0.021185	990.074036	995.135803	1.526367	2.
386	1017.302734	17.000000	-0.012899	-0.010587	999.702515	1009.164734	1.832031	-3
387	1022.917969	-1.000000	-0.037447	-0.038520	1008.699768	1008.340759	1.832031	-2
388	1017.058594	-21.000000	-0.009790	-0.007259	1008.893921	998.799011	1.830078	58
389	1002.898437	-45.000000	0.022936	0.038371	995.715210	989.898987	1.832031	-5
390	1004.363281	35.000000	0.036261	0.021370	990.304443	996.000549	1.526367	18
391	1017.058594	14.000000	-0.015129	-0.012091	999.717773	1008.716003	1.831055	-1
392	1021.820312	-2.000000	-0.032702	-0.037280	1009.222107	1008.076172	1.831055	-2
393	1016.082031	-19.000000	-0.009911	-0.006715	1008.587585	998.412231	1.830078	-5

Figure 28: Summary Post Processor Example Front Panel

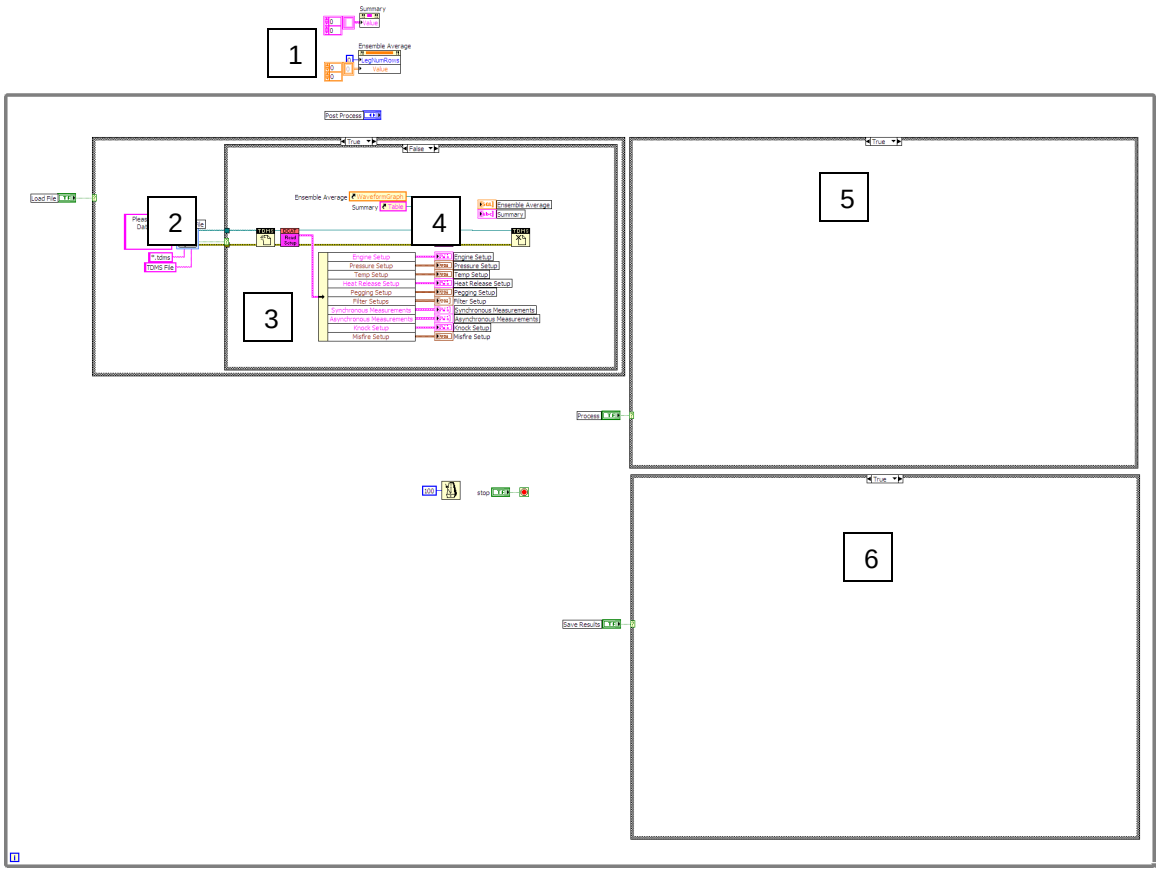


Figure 29: Summary Post Processing Example Block Diagram

1. Initialize the tables and plots.
2. Open the TDMS combustion data file.
3. Load the configuration data from the file.
4. Load the summary data from the file and populate the table and plot.
5. Area available for user-defined processes.
6. Area available for user-defined saving.

Opening a Raw Data File

The µDCAT Open Raw Data File VI, shown in Figure 30 and Figure 31, is a simple example which opens the raw data file and then allows the user to display a single cycle for a single cylinder. The plot automatically formats to show the measurement names originally saved with the data. Note that all the setup clusters are available and may be used for post processing or they may be modified before post processing.

The example can easily be modified to run all the cycles for all the cylinders in order to process an entire file. To automatically process the entire file, replace the While Loop with two For Loops that run for each cycle and for each cylinder, respectively.

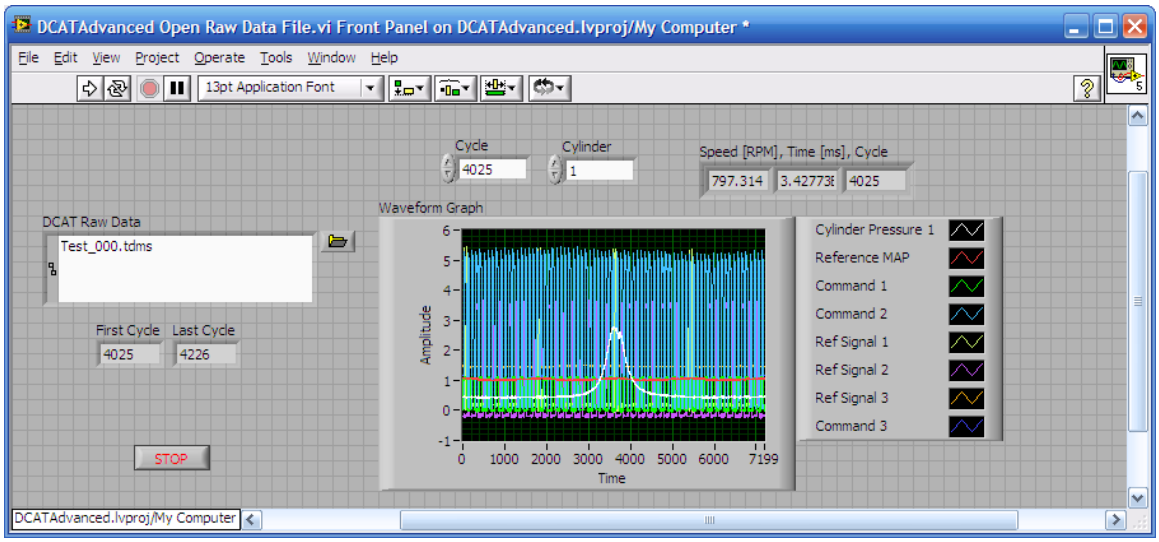


Figure 30: Open Raw Data File Front Panel

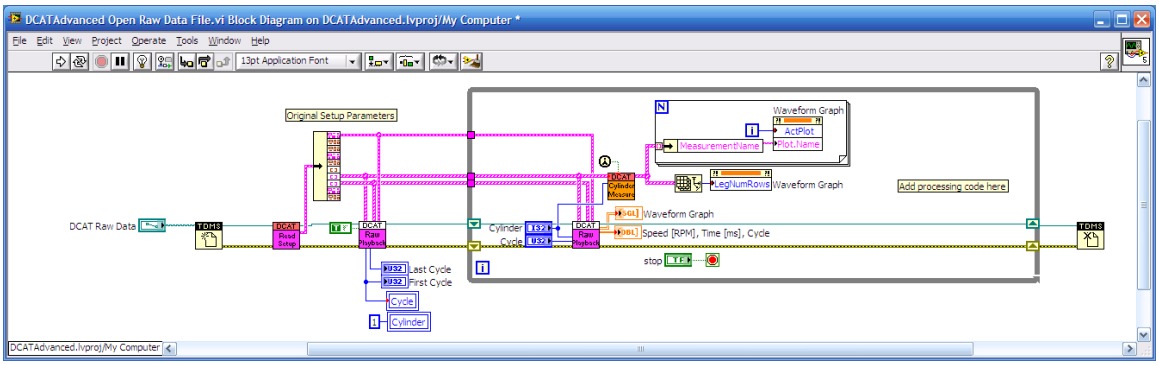


Figure 31: Open Raw Data File Block Diagram

Post Processing (Raw Files)

The µDCAT Post Process Raw File program, shown in Figure 32, displays and processes the raw TDMS data file into a new summary TDMS data file. The configuration settings can be changed and the statistics recalculated. The front panel has a similar look as that of the µDCAT user interface. It also contains several controls related to loading files, scrolling through cycles of data and processing the data to a new summary TDMS file.

To begin, load a raw data file using the **Load File** button in the lower left corner. After loading, all setup information is placed into the appropriate controls and indicators and a single cycle may be viewed along with the calculated values for that cycle, based on the setup information originally provided. Ay setup parameter may be changed to see the resulting calculation updates. The slider at the bottom of the screen determines which cycle is displayed and processed. Keep in mind that the cycle number does not necessarily start from 0, but is referenced to the start of data collection within µDCAT. Therefore, the first cycle within the raw data file may be much larger than 0.

To process a range of cycles, select the Process File tab and set the two sliders on the **Process Range** control to specify the range of cycles to be included in the results. Then press the **Process File** button to begin processing and visualize the results in table and chart formats. The user may save the summary data by specifying a file name in the **Results File Path** control and pressing the **Save Results** button.

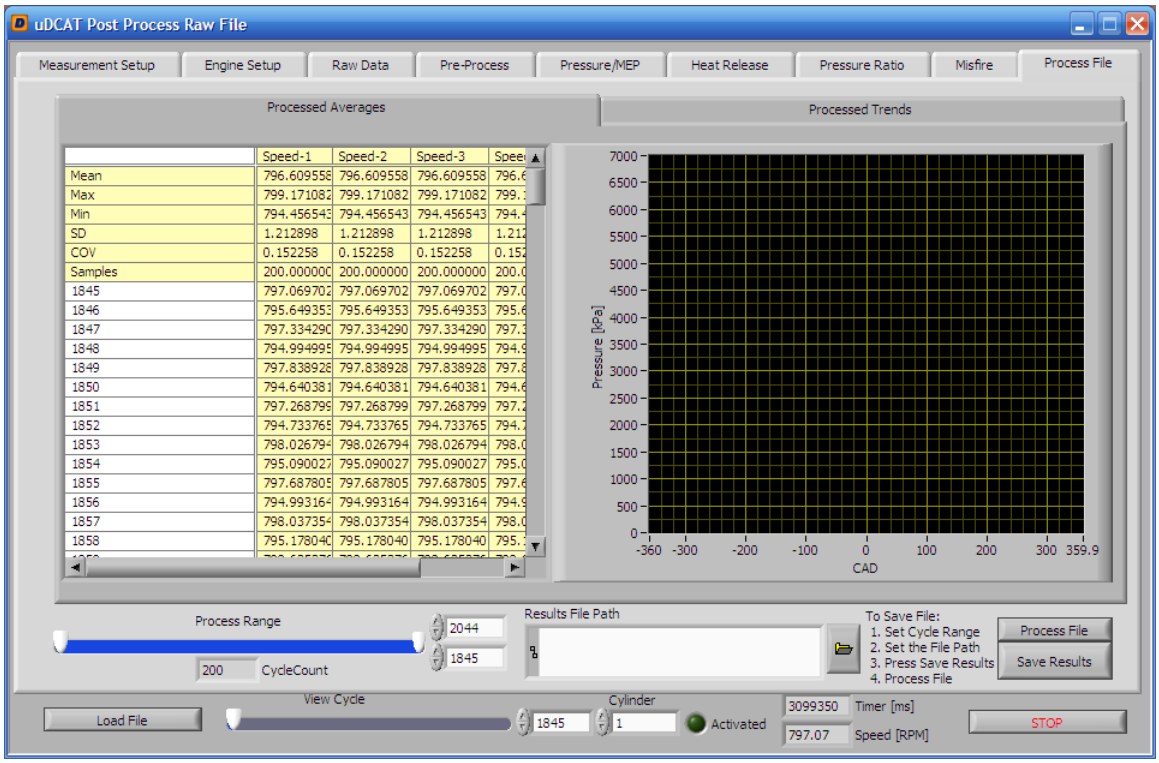


Figure 32: µDCAT Post Process Raw File Front Panel

Expected Performance

The data processing performance of µDCAT will vary depending on the following factors:

- CPU speed
- RAM size and speed
- Hard drive speed
- Operating system and additional running applications
- DAQ hardware limitations (sampling rate, response times)
- Medium Speed Data (Number of Channels and Sample Rate)
- Engine speed
- Encoder resolution
- Cylinder and measurement channel count
- Calculation configurations

Figure 33 shows the limitations of the USB-6251 and USB-6259 DAQ hardware. These devices use a multiplexed analog to digital converter and therefore share the maximum sample rate among the enabled measurements. Therefore, the number of cylinders (measurements) reduces the maximum engine speed that can be recorded. The resolution of the encoder also affects the maximum engine speed. The following charts only account for the DAQ hardware and not the computer processing capability. Actual performance will vary based on the computer hardware used to calculate the results and stream data to disk.

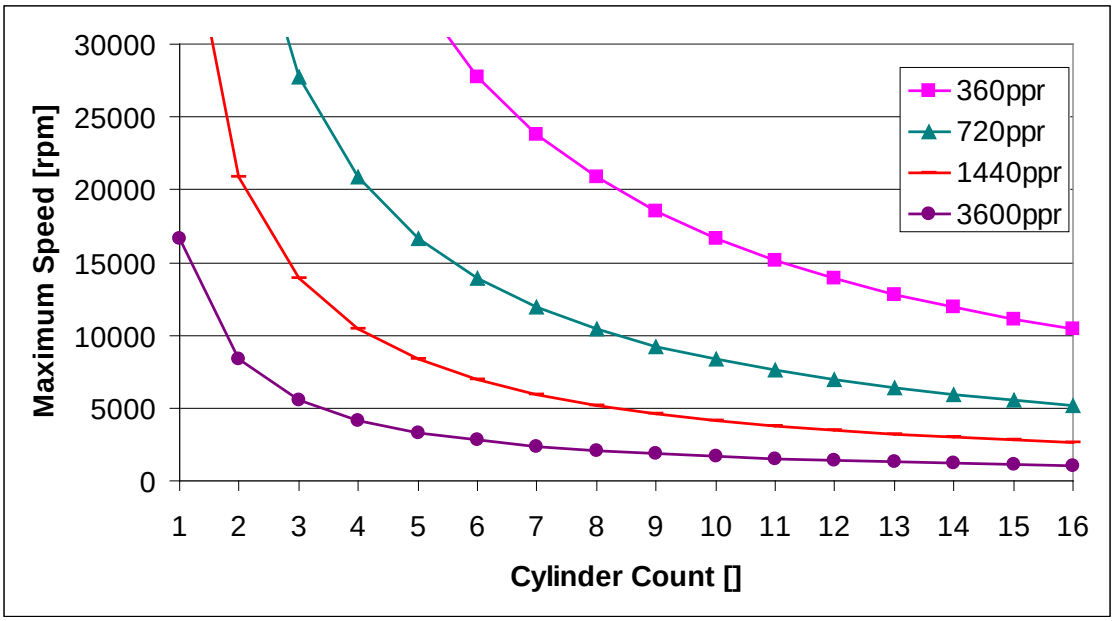


Figure 33: Maximum Engine Speed (USB-6251 & USB-6259)

The following formula can be used to estimate the performance of a multiplexing DAQ hardware device.

$$Speed = \frac{60{,}000 * MSR}{N * ER}$$

Where:

Speed = Maximum Engine Speed [rpm]
MSR = Maximum Sample Rate of DAQ device (aggregate kS/s)
N = Number of Measurements
ER = Encoder Resolution [ppr]

Figure 34 shows the CompactDAQ hardware limitations. The CompactDAQ system uses simultaneous sampling cards. Therefore, the DAQ hardware limitations are constant for any number of cylinders.

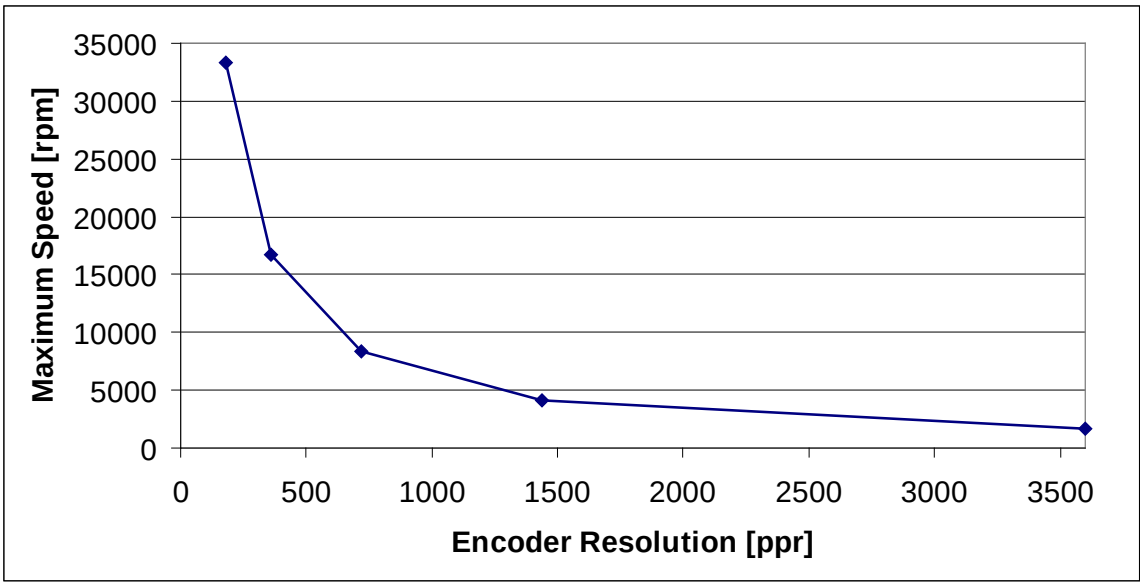


Figure 34: Maximum Engine Speed (CompactDAQ)

The following formula can be used to estimate the performance of a simultaneous DAQ hardware device.

$$Speed = \frac{60{,}000 * MSR}{ER}$$

Where:

Speed = Maximum Engine Speed [rpm]
MSR = Maximum Sample Rate of DAQ device (kS/s)
ER = Encoder Resolution [ppr]

Calculations

The µDCAT calculations are described in detail in the DCAT User's Manual. The manual may be downloaded from the Drivven website at:

http://www.drivven.com/visitor_download/Manuals/DCAT%20User's%20Manual.pdf

Frequently Asked Questions

How do I add my own calculations to µDCAT?

- µDCAT is a fixed application. However, the open-source post-processing examples can be used to build a custom post processing program which implement custom calculations. This requires LabVIEW development tools and custom programming.
- Please contact Drivven about the Drivven Combustion Analysis Toolkit which provides full-featured open-source LabVIEW example implementations of the toolkit. The toolkit allows a customized combustion analysis application to be built from scratch, or integrated with full-authority engine control applications using National Instruments PXI controllers and DAQ cards.

How do I add a diesel injector current probe trace (or any other signal) to my display?

- To display and save any signal, simply add it to the measurement setup and associate it with the appropriate cylinder. It will be displayed on the data tab and saved in the raw data file. The Measurement Type should be set to undefined. The signal will be sampled engine-synchronously according to the encoder resolution.

How do I save the current configuration of µDCAT?

- To save the current µDCAT settings, use the CalVIEW "Save Current Calibration as Default" (purple) or the "Save Calibration As…" (blue) buttons on the CalVIEW interface. This saves a file to the LabVIEW default data directory. (This is typically under ".\My Documents\LabVIEW Data") Calibration files have a .cdl extension.
- To load a previous µDCAT calibration which was given a unique name and path, copy the desired calibration file into the LabVIEW default data directory and rename it to µDCAT.cdl. Then start the µDCAT target application. Please note that the calibration file is only read when the µDCAT Target Program starts.

Why does Excel fail to open a TDMS files?

- The TDMS Excel plug-in opens each property in a new column across the top of the spreadsheet. Property fields are used to store all (>255) of the configuration parameters. However, Excel 2003 is limited to 255 columns. Open the TDMS plug-in properties and turn off custom property imports.

How do I customize the user interface?

- The user interface is a standard LabVIEW VI. It may be modified with LabVIEW development tools to meet user requirements. The file should be saved in a new location so that updating µDCAT installation does not overwrite the changes. A new CalVIEW .cvsf may be created to automatically start µDCAT with the new user interface. Please see the CalVIEW user's manual for details about the .cvsf file.

What font is used in the example applications?

- The example applications use Tahoma size 13pt as the default font. In some circumstances, a different size is used.

Why doesn't µDCAT start correctly?

- Verify that the appropriate version of DAQmx and LabVIEW Run-Time are installed. The installers are available on National Instruments website and listed at the beginning of this manual.
- Verify that CalVIEW is installed and activated. Please see the CalVIEW user's manual for details on installation and activation of CalVIEW.
- Verify that µDCAT is activated. Check the µDCAT Target Program front panel to verify that it is activated correctly.
- Manually start the application. Please see the CalVIEW user's manual for more details.
    1. Launch the µDCAT Target Program. It cam be started from the start menu or found at "C:\Program Files\Drivven\µDCAT\µDCAT.exe"
    2. Open CalVIEW
    3. Within CalVIEW, define the Target IP address as "127.0.01" or your computer IP address.
    4. Within CalVIEW, set the Host VI to "C:\Program Files\Drivven\µDCAT\User Interface\µDCAT User Interface.vi".
    5. Within CalVIEW, set the pairing file to "C:\Program Files\Drivven\µDCAT\µDCAT Pairing.par".
    6. Within CalVIEW, start the Host VI.

Why am I getting DAQ errors?

- Make sure that the hardware is set up properly in the Measurements and Automation Explorer and that the Measurement Setup tab has the proper physical channel names.
- Verify that the device is not being used for other DAQ tasks.
- Check the error text message on the other tab for details on the error.

Why is the top of the pressure signal clipped (flat)?

- The signals will appear flat when the charge amplifier is outputting a value greater than the DAQ card or the charge amplifier output is at its maximum.
- Reset the charge amplifier to set the zero offset pressure.
- Adjust the output gain of the charge amplifier.

Why are the buffers or queues overflowing?

- The buffers fill when the computer system hardware is not able to keep up with the program demands. A combination of faster CPU, faster hard drive or additional RAM will alleviate the problem.
- Raw Queue: This buffer fills when data cannot be streamed to file as fast as the DAQ Loop rate. Try saving less data or allow the queue to empty before saving more data. Removing old data from a hard drive may also increase performance.
- RT Queue or NC Queue: These buffers fill when the combustion analysis calculations cannot be completed as fast as the DAQ Loop rate. Try disabling some of the calculations or reducing the encoder resolution.
- RT Align Buffer or NC Align Buffer: These buffers will fill when the combustion analysis calculations cannot be completed as fast as the combustion events. The calculation time must be less than (60 * N) / (RPM * Ncyl) seconds. (N=Strokes per Cycle, RPM = Engine Speed in RPM, Ncyl = Number of Cylinders) Ex. 4-storke @ 10000RPM and 16 cylinders = 750us. Try disabling some of the calculations or reducing the encoder resolution.
- Defragment the hard drive. Hard drive performance decreases as the drive becomes fragmented.
- Remove data from the hard drive. Traditional hard drives read/write operations are slower in the center of the disk.