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NI Combustion Analysis System Software for LabVIEW™

User's Manual

Web : http://www.ni.com/powertrain-controls, E-mail : powertraincontrolsinfo@ni.com

Table of Contents

1. Product Introduction

The NI Combustion Analysis System Software for LabVIEW (NI CAS) is a unique LabVIEW plug-in for performing sophisticated in-cylinder combustion analysis and data logging for engine research and development targeted to a wide variety of NI Hardware. When licensed as a toolkit it can be used to develop sophisticated PXI-based combustion analysis applications with real-time feedback control capabilities. Licensed as an executable, it can be deployed to portable, low-cost cDAQ hardware.

NI CAS Software allows streaming of raw 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. The TDMS file format is an open format allowing these files to be post-processed with a variety of tools, including the NI CAS Software Post-Processing tools, NI DIAdem, or Microsoft Excel.

License Versions

Development License

The Development License of NI CAS Software enables a LabVIEW toolkit for users to integrate sophisticated combustion analysis and data logging with engine control applications. The toolkit includes many analysis functions, front panel controls, and utilities including data-streaming-to-disk, pre-processing, heat release, pressure metrics, knock analysis, noise analysis, raw data logging, summary data reporting and post-processing.

The NI CAS Software for Development leverages R Series (FPGA), S Series (simultaneous analog sampling) and M Series (Multiplexed analog sampling) PXI devices from National Instruments to supervise engine position tracking and synchronization of data collection and processing. SCXI hardware can be leveraged for medium-speed data collection which is subsequently aligned with engine-synchronous data. This software can be targeted to a wide variety of PXI real-time controllers depending on the application performance requirements.

The Development Version of NI CAS Software example application may be used stand-alone or integrated with an engine control application.

Deployment License

The Deployment License enables deployment to low-cost, easy-to-use, portable engine combustion analysis hardware bundles. NI CAS Software for Deployment is a pre-built NI LabVIEW Runtime executable for Microsoft Windows, targeting cDAQ hardware over USB and Ethernet, or Stand-Alone cDAQ chassis. Over fifty NI C Series I/O modules can be added to any available slot of an NI cDAQ chassis to meet a variety of application needs.

The Deployment Version of NI CAS Software supports three time-bases: high-speed engine-synchronous, high-speed angular-window time domain and medium-speed time domain. The Deployment License includes all of the analysis functions included in the Development Version of NI CAS Software toolkit except for Next-Cycle control and FPGA based Engine Position Tracking (EPT) functions. Engine synchronous data sampling must take place using optical shaft encoders mounted to the crankshaft.

1.1 Features By License Version

License Version

Highlighted Features	Development	Deployment
• Open source example projects for integration with real-time control applications	X	
• Next-cycle control capabilities	X	
• FPGA based high speed signal processing	X	
• Low-cost, feature rich, turnkey bundled system		X

License Version

Measurement Configuration and Engine Geometry	Development	Deployment

• Individual channel scaling features
    • Cylinder Assignment
    • Gain
    • Gain + Offset
    • Polynomial
    • Table Lookup
	X	X

• Channels can be assigned to all cylinders as references such as pegging	X	X
• Simultaneous engine-synchronous and engine-asynchronous measurements	X	X

• Medium Speed Data (Sampled at a fixed frequency ~1kHz or less)
    • Thermocouples
    • Slow Speed Pressures
    • Other
	X	X

• Supports FPGA Data (Sampled based on FPGA setup, engine synchronous and/or asynchronous)	X	
• Digital outputs for sample clock and active high during logging	X	X
• Supports multiple S Series devices for simultaneous sampling of signals in both engine-synchronous (cylinder pressure, etc.) and engine-asynchronous (knock, etc.) domains	X	
• Supports 1 M Series device for multiplexed sampling of signals engine-synchronously (cylinder pressure, etc.)	X	X

	Development	Deployment
• Supports 1 cDAQ chassis and multiple C Series devices for simultaneous sampling of signals in both engine-synchronous (cylinder pressure, etc.) and engine-asynchronous (knock, etc.) domains	X	X
Support for mapping calculated parameters to analog output channels	X	X
• Complete set of engine geometry inputs for cylinder volume calculation • Optionally load volume from file	X	X
• Online motoring test assists with engine geometry verification	X	X
• TDC probe channel configuration and analysis	X	X
• Allows online adjustment of TDC index (< +/- 2 CAD)	X	X

License Version

FPGA Based Engine Position Tracking and Sample Clock Generation	Development	Deployment
• Use traditional optical encoder setup with advanced triggering options	X	
• Flexible crankshaft encoder signal processing and filtering	X	
• Use of pressure signal for 4-stroke cam phase information	X	
• Use of cam phase signal as half cycle gate for TDC index	X	
• Use of Engine Position Tracking (EPT) block for extrapolation of lower resolution production trigger wheels for high resolution sampling and control	X	

License Version

File Saving	Development	Deployment
• Supports simultaneous streaming of raw and summary data to TDMS file continuously, by cycle count, time, or file size	X	X
• Raw data files include channel configuration, engine geometry, and test data to allow full reconstruction of the test environment in post-processing	X	X
• Supports an external hardware trigger for file saving	X	X
• Saves all non-NI CAS Software related CalPoints, e.g., engine controls	X	

License Version

Pre-Processing	Development	Deployment
• Cylinder alignment of data in both engine-synchronous and engine-asynchronous domains	X	X
• Data scaling to engineering units	X	X
• Broad range of signal filtering options	X	X
• Cylinder pressure pegging options	X	X
• Optional user developed LabVIEW VI	X	X

License Version

Pressure Metrics	Development	Deployment
• Peak Pressure and Location	X	X
• Polytropic coefficients of compression and expansion	X	X
• Maximum Rate of Pressure Rise and Location	X	X
• Pressures at IVO and EVC	X	X
• Gross IMEP, Pumping MEP (PMEP), Net IMEP	X	X

License Version

Heat Release Analysis	Development	Deployment

• 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
  • User developed LabVIEW™ VI
	X	X

• Locations of Mass Fraction Burned (5%MFB, 25%MFB, 50%MFB, 75%MFB, 90%MFB, Custom)	X	X
• Maximum heat release rate and location	X	X
• Variety of heat transfer correction methods	X	X

	Development	Deployment
• In-cylinder temperature estimation	**X**	**X**

License Version

Engine Noise and Knock Analysis	Development	Deployment
• Raw, time-domain-filtered and angle-domain-filtered noise indication	**X**	**X**
• Bandpass / Rectify / Integrate / Compare (BRIC) algorithm for knock signal processing	**X**	**X**
• Visual FFT analysis of knock signals for calibration of BRIC	**X**	**X**

License Version

Additional Calculations and Analysis	Development	Deployment
• Injection parameters of timing, duration and quantity (mg/injection)	**X**	**X**
• Cycle to cycle injection quantity (mg/cycle)	**X**	**X**
• Ignition parameters of timing and dwell	**X**	**X**
• Multi-strike analysis	**X**	**X**
• Cam phase measurement	**X**	**X**
• Optional user developed LabVIEW VI	**X**	**X**

1.2 Data Flow

The Development Version of NI CAS Software example project employs the real-time data flow structure shown below with an optional next-cycle control path. In the next-cycle control path, the DAQ alignment is stopped early to allow selected calculations to complete before the subsequent cycle begins. The example application also provides an estimated angle of completion of next-cycle calculations. The Deployment Version of NI CAS Software utilizes a similar data flow structure, however, the data processing takes place within a Microsoft Windows operating system and lacks next-cycle calculation capability.
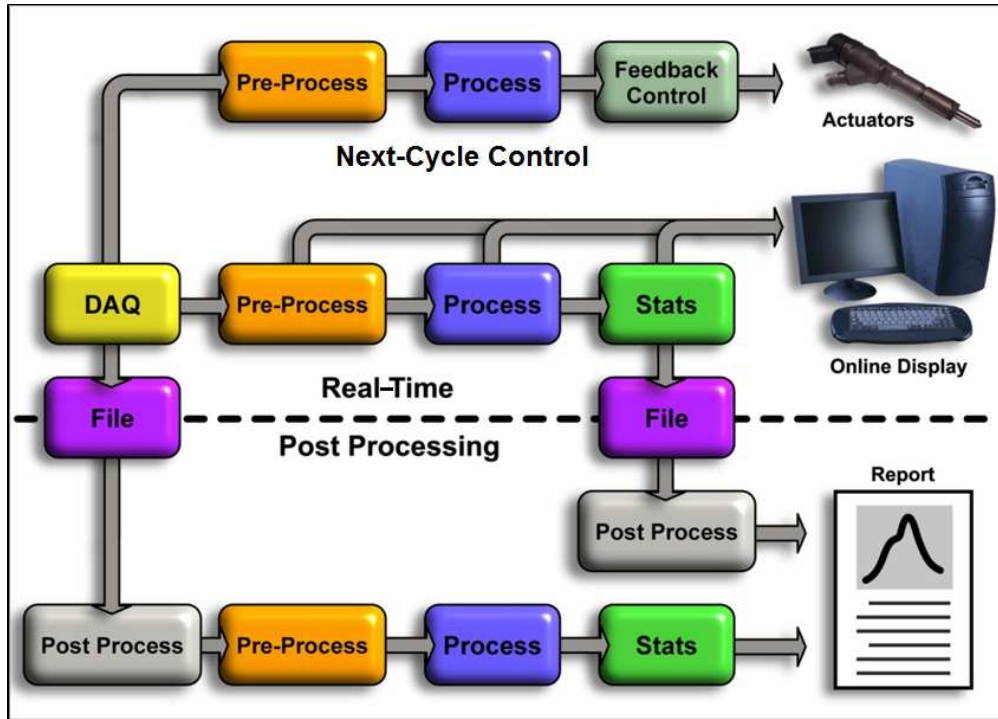
2. Getting Started

2.1 Recommended System Requirements

Note: System requirements will vary based on many factors including:

- Number of measurements
- Maximum sample rate
- Enabled real-time calculations

Development Version of NI CAS Software

Target System

Recommended Real-time System

PXI Chassis:	NI PXI-1050 PXI Chassis With Integrated SCXI--8 PXI/4 SCXI Slots
Controller:	NI PXI-8119 RT 2.3 GHz Quad-Core PXI Controller With LabVIEW Real-Time 80GB or Greater, 2.5 in SATA SSD
FPGA:	NI PXI-7853R R Series Multifunction RIO With Virtex-5 LX85 FPGA
C Series Hardware:	• NI 9151 R Series Expansion Chassis for C Series I/O • NI 9411 6-Channel, 500ns, ±5 to 24 V Digital Input Module • NI SHC68-68-RDIO Digital Cable for R Series
S Series DAQ:	2 to 4 NI PXI-6123 16-Bit, 500 kS/s/ch, Simultaneous Sampling Multifunction DAQ
M Series DAQ	NI PXI-6251 16-Bit, 1 MS/s (Multichannel), 1.25MS/s (1-Channel), 16 Analog Inputs
SCXI Modules:	• 1 or 2 NI SCXI-1102 32-Channel Thermocouple/Voltage Input Module • 1 or 2 NI SCXI-1102B 32-Channel Amplifier Module; 200Hz Bandwidth
DAQ Accessories:	• 2 to 4 NI BNC-2090A Shielded Rack-Mount BNC Connector Block • 2 to 4 SH68-68-EP (for S Series modules) • 1 or 2 TC-2095 (for NI SCXI-1102) • 1 or 2 BNC-2095 (for NI SCXI-1102B) • 2 to 4 SH96-96 (for SCXI modules)

Host System

Recommended System

CPU:	1.6 GHz Multi-Core or faster
OS:	Microsoft Windows 7/8

RAM: 4 GB or more

Hard Drive: 10 GB or more free space

Software: - NI LabVIEW Professional Development System
                    - NI LabVIEW Real-Time Module
                    - NI LabVIEW FPGA Module
                    - NI-DAQmx
                    - NI-RIO
                    - NI LabVIEW FPGA Module Xilinx Tools
                    - NI Software Calibration Management Toolkit for LabVIEW

Display resolution: ≥1920x1080

Deployment Version of NI CAS Software

Target System

> Recommended cDAQ System

> cDAQ Chassis:
>> - NI cDAQ-9139 NI CompactDAQ Stand-Alone Chassis, Core i7 1.33 GHz, 8-slot
>> - NI cDAQ-9174 NI CompactDAQ 4-Slot USB Chassis
>> - NI cDAQ-9178 NI CompactDAQ 8-Slot USB Chassis
>> - NI cDAQ-9184 NI CompactDAQ 4-Slot Ethernet Chassis
>> - NI cDAQ-9188 NI CompactDAQ 8-Slot Ethernet Chassis

> C Series Modules: See [Supported C Series Modules](#)

Host System for USB and Ethernet cDAQ Targets

> Recommended System

> CPU: 1.6 GHz Multi-core or faster

> OS: Microsoft Windows 7/8

> RAM: 4 GB or more

> Hard Drive: 10 GB or more free space

> USB: 2.0 (for USB devices)

> Software:
>> - LabVIEW Runtime Engine
>> - NI-DAQmx
>> - NI Software Calibration Management Toolkit for LabVIEW

> Display resolution: ≥1920x1080

2.1.1 Supported C Series Modules

Data Type	Supported Modules
Encoder	**NI 9401** 8 Ch, 5 V/TTL High-Speed Bidirectional Digital I/O Module **NI 9411** 6-Channel, 500 ns, ±5 to 24 V Digital Input Module (Recommended)
High-speed Engine-synchronous	**NI 9215** 4-Channel, 100 kS/s/ch, 16-bit, ±10 V Analog Input Module **NI 9220*** 16-Channel, 100 kS/s/ch, 16-Bit, ±10 V Analog Input Module **NI 9222*** 4-Channel, 500 kS/s, 16-Bit Simultaneous Analog Input Module (Recommended) **NI 9223*** 4-Channel, 1 MS/s, 16-Bit Simultaneous Analog Input Module
High-speed Engine-asynchronous	**NI 9215** 4-Channel, 100 kS/s/ch, 16-bit, ±10 V Analog Input Module **NI 9220*** 16-Channel, 100 kS/s/ch, 16-Bit, ±10 V Analog Input Module **NI 9222*** 4-Channel, 500 kS/s, 16-Bit Simultaneous Analog Input Module (Recommended) **NI 9223*** 4-Channel, 1 MS/s, 16-Bit Simultaneous Analog Input Module
Medium Speed:	**NI 9201** 8-Ch, ±10 V, 500 kS/s, 12-Bit Analog Input Module **NI 9203** 8-Ch ±20 mA, 200 kS/s, 16-Bit Analog Current Input Module (Recommended) **NI 9205** 32-Ch ±200 mV to ±10 V, 16-Bit, 250 kS/s Analog Input Module (Recommended) **NI 9211** 4-Channel, 14 S/s, 24-Bit, ±80 mV Thermocouple Input Module **NI 9213** 16-Channel Thermocouple Input Module (Recommended) **NI 9215** 4-Channel, 100 kS/s/ch, 16-bit, ±10 V Analog Input Module **NI 9220*** 16-Channel, 100 kS/s/ch, 16-Bit, ±10 V Analog Input Module **NI 9222*** 4-Channel, 500 kS/s, 16-Bit Simultaneous Analog Input Module **NI 9223*** 4-Channel, 1 MS/s, 16-Bit Simultaneous Analog Input Module **NI 9401** 8 Ch, 5 V/TTL High-Speed Bidirectional Digital I/O Module **NI 9402** 4 Ch LVTTL High-Speed Digital I/O Module **NI 9411** 6-Channel, 500 ns, ±5 to 24 V Digital Input Module
Output:	**NI 9263** 4-Channel, 100 kS/s, 16-bit, ±10 V, Analog Output Module **NI 9264** 16-Channel Analog Output Module **NI 9265** 4-Channel, 100 kS/s, 16-Bit, 0 to 20 mA Analog Output Module (Recommended) **NI 9269** Channel-to-Channel Isolated 10 V Analog Output Module (Recommended)

*If BNC connectivity is required, we recommend using L-com Item #BC55 or L-com Item #BC25.

2.2 Hardware Configuration

2.2.1 Development Version Hardware Setup

PXI Chassis Configuration

The PXI chassis should contain an NI PXI-785xR FPGA and one or more NI PXI-6123 S Series devices. The R Series devices must be inserted into PXI slot number 2 (adjacent to the controller). The FPGA is used to track the engine position and generate sample clocks. The FPGA should connect to a NI 9151 expansion chassis with a NI 9411 DI module for the encoder inputs.

S Series Accessory Configuration

The NI PXI-6123 S Series devices requires four wiring jumpers applied at each NI BNC-2090A accessory as shown in the diagrams below. For the NI BNC-2090A accessory, NI recommends that 3" of 20AWG wire with ends stripped by 0.25" should be used for each jumper.

| NI PXI-6123 Accessory Terminals ||
Source	Destination
PFI 03	P0 0
PFI 04	P0 1
PFI 08	P0 2
PFI 09	P0 3
Optional User Input	P0 4
Optional User Input	P0 5
Optional User Input	P0 6
Optional User Input	P0 7

NI 9411 Digital Input Module Connections

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 V_{sup} and COM screw terminals of the module. V_{sup} is internally reduced to +5V and available from the DSUB connector. The encoder should be connected to the NI 9411 module according to the table below. 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. The table below 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.

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 0b))
Encoder B (optional)	NI 9411 Pin 3 (P0.2+/PFI 2 (DI 2a))
Encoder B Compliment (optional)	NI 9411 Pin 11 (P0.2-/PFI 2 (DI 2b))

Expected Encoder Signals

The Deployment Version of NI CAS Software allows for a variety of encoders and triggering options by using the Engine Position Tracking (EPT) FPGA cores to synchronize the DAQ sampling. The FPGA block accepts only the encoder pattern. The encoder pattern consists of evenly spaced A and B pulses combined with a once per revolution Z pulse.

An additional signal can optionally be used to determine the phase of a 4-stroke engine. This can be any signal that has a unique pattern for the complete engine cycle, e.g., a cam pattern, cylinder pressure, spark, injector or similar.

The Development Version of NI CAS Software also has the ability to extrapolate low resolution encoder signals to increase the sample resolution greater than the encoder resolution. Similarly, the encoder signal can be divided to reduce the sample resolution.
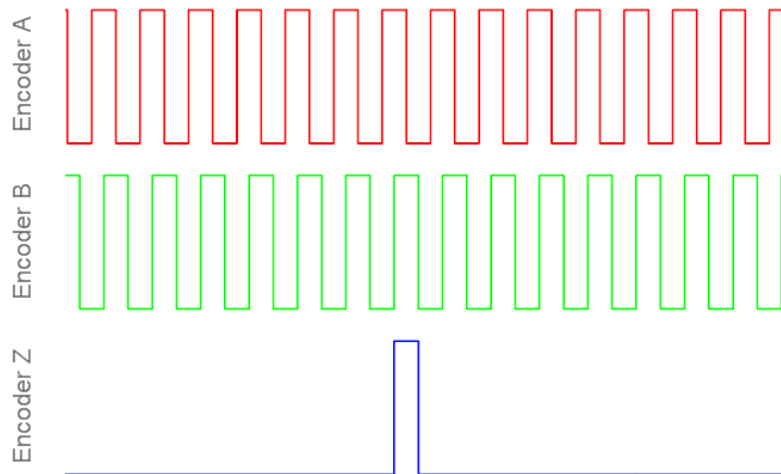
2.2.2 Deployment Version Hardware Setup

cDAQ Chassis Configuration

NI cDAQ-9139 (Stand-alone)

The NI cDAQ-9139 must utilize a NI 9411 (recommended), NI 9401, or a NI 9402 digital input module for encoder inputs. The Deployment Version of NI CAS Software is installed directly on the integrated NI cDAQ-9139 controller Microsoft Windows OS. The user interface can be displayed on a monitor attached to the cDAQ or via remote desktop over the network.

NI cDAQ-9174 / NI cDAQ-9178 (USB)

The NI cDAQ-9174 must have a NI 9411 (recommended), NI 9401, or a NI 9402 digital input module for encoder inputs. The NI cDAQ-9178 may use the chassis trigger lines, a NI 9411 (recommended), a NI 9401, or a NI 9402 digital input module.

NI cDAQ-9184 / NI cDAQ-9188 (Ethernet)

The NI cDAQ-9184 must have a NI 9411 (recommended), NI 9401, or a NI 9402 digital input module for encoder inputs. The NI cDAQ-9188 may use the chassis trigger lines, a NI 9411 (recommended), a NI 9402, or a NI 9411 digital input module.

C Series Hardware

The Deployment Version of NI CAS Software requires a 4-slot (or greater) USB, Ethernet, or stand-alone cDAQ chassis, an NI 9411 digital input module, and one or more analog input modules. The compatible C Series I/O modules are listed in the Support C Series Modules page.

Connect and install the cDAQ hardware according the recommendations found at: http://www.ni.com/gettingstarted

Encoder Connections

NI 9411 Differential Digital Input Module (recommended)

For optimum signal integrity, NI recommends using the NI 9411 Differential Digital Input Module connected to an optical encoder supporting complimentary outputs.

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 V_{sup} and COM screw terminals of the module. V_{sup} is internally reduced to +5V and available from the DSUB connector. The encoder should be connected to the NI 9411 module according to the table below. 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. The table below 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.

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 0b))

NI 9401 Digital Input Module

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 the table below. Shielded cabling is recommended.

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)

NI 9402 Digital Input Module

When using the NI 9402 digital I/O module, the crankshaft optical encoder must be powered externally. The NI 9402 should be used when BNC connectors are desired. The encoder should be connected to the NI 9402 module according to the table below.

Crankshaft optical encoder connections to the NI 9402 module

Encoder Signal	NI 9402 BNC
Encoder Z (required)	NI 9402 BNC2 (P0.1/PFI 1)
Encoder A (required)	NI 9402 BNC1 (P0.0/PFI 0)

NI cDAQ-9178 Chassis

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

Crankshaft optical encoder connections to the cDAQ-9178 chassis

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

Analog Input Module Connections

The analog instrumentation signals should be connected to the NI 9215, NI 9222, or NI 9223 analog inputs. The BNC version of the NI 9215 is recommended for ease of connection. Shielded BNC cables are recommended.

Configuring cDAQ Chassis with NI Measurement and Automation Explorer

NI 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.

Ethernet cDAQ devices must be registered and reserved in MAX before they can be used with the Deployment Version of NI CAS Software. To add a cDAQ chassis to a system, right click on "My System > Devices and Interfaces > Network Devices" and select "Find Network NI-DAQmx Device". To reserve the cDAQ chassis on a system, right click on the discovered cDAQ chassis and select "Reserve Chassis".

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

2.3 Software Configuration

For more information on the NI Combustion Analysis System Software for NI LabVIEW, please visit http://www.ni.com/powertrain-controls/.

To download the NI Combustion Analysis System Software for LabVIEW, visit http://www.ni.com/info and enter the Info Code "CASSoftware".

After installing NI CAS Software, it will run for a 7 day full evaluation period. Any time during or after the evaluation period, NI CAS Software may be activated using the [NI License Manager](#) found in the start menu.

2.3.1 Activating Your Software

Activating Your Software

This section describes how to use the NI Activation Wizard to activate your software.

How Do I Activate My Software?
Use the NI Activation Wizard to obtain an activation code for your software. You can launch the NI Activation Wizard two ways:

> • Launch the product and choose to activate your software from the list of options presented.
> • Launch NI License Manager by selecting **Start»All Programs»National Instruments»NI License Manager**. Click the **Activate** button in the toolbar.

> **Notes**

> • If your software is a part of a Volume License Agreement (VLA), contact your VLA administrator for installation and activation instructions.
> • NI software for Mac OS X and Linux operating systems does not require activation.

What is Activation?

Activation is the process of obtaining an activation code to enable your software to run on your computer. An activation code is an alphanumeric string that verifies the software, version, and computer ID to enable features on your computer. Activation codes are unique and are valid on only one computer.

What is the NI Activation Wizard?

The NI Activation Wizard is a part of NI License Manager that steps you through the process of enabling software to run on your machine.

What Information Do I Need to Activate?

You need your product serial number, user name, and organization. The NI Activation Wizard determines the rest of the information. Certain activation methods may require additional information for delivery. This information is used only to activate your product. Complete disclosure of the National Instruments software licensing information privacy policy is available at ni.com/activate/privacy. If you optionally choose to register your software, your information is protected under the National Instruments privacy policy, available at ni.com/privacy.

How Do I Find My Product Serial Number?

Your serial number uniquely identifies your purchase of NI software. You can find your serial number on the Certificate of Ownership included in your software kit. If your software kit does not include a Certificate of Ownership, you can find your serial number on the product packing slip or on the shipping label.

If you have installed a previous version using your serial number, you can find the serial number by selecting the **Help»About** menu item within the application or by selecting your product within NI License Manager (**Start»All Programs»National Instruments»NI License Manager**). You can also contact your local National Instruments branch.

What is a Computer ID?

The computer ID contains unique information about your computer. National Instruments requires this information to enable your software. You can find your computer ID through the NI Activation Wizard or by using NI License Manager, as follows:

1. Launch NI License Manager by selecting **Start»All Programs»National Instruments»NI License Manager**.
2. Click the **Display Computer Information** button in the toolbar.

For more information about product activation and licensing, refer to ni.com/activate.

How Can I Evaluate NI Software?

You can install and run most NI application software in evaluation mode. This mode lets you use a product with certain limitations, such as reduced functionality or limited execution time. Refer to your product documentation for specific information on the product's evaluation mode.

Moving Software After Activation

To transfer your software to another computer, install and activate it on the second computer. You are not prohibited from transferring your software from one computer to another and you do not need to contact or inform NI of the transfer. Because activation codes are unique to each computer, you will need a new activation code. Refer to *How Do I Activate My Software?* to acquire a new activation code and reactivate your software.

Deactivating a Product

To deactivate a product and return the product to the state it was in before you activated it, right- click the product in the NI License Manager tree and select **Deactivate**. If the product was in evaluation mode before youactivated it, the properties of the evaluation mode may not be restored.

**Using Microsoft Windows Guest Accounts**

NI License Manager does not support Microsoft Windows Guest accounts. You must log in to a non-Guest account to run licensed NI application software.
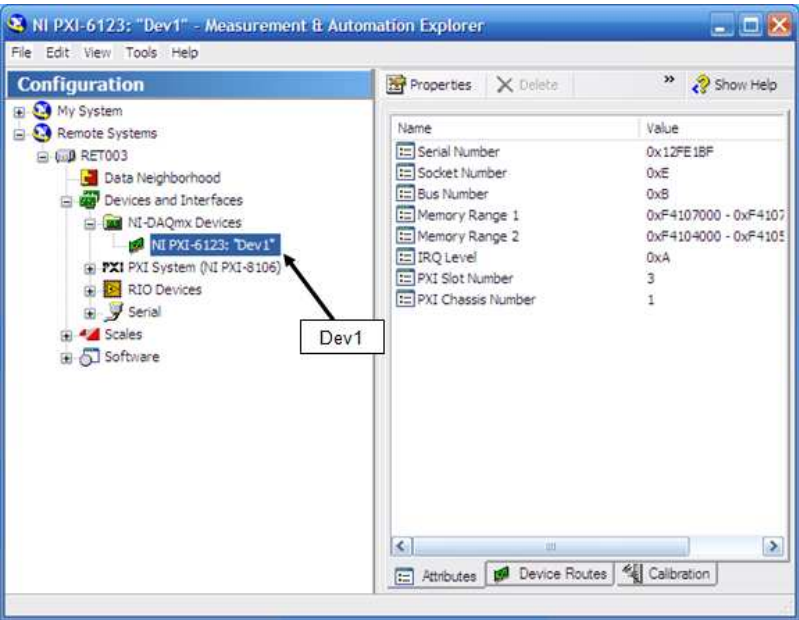
2.3.2 MAX Hardware Configuration

2.2.2.1 Development Version MAX Hardware Configuration

Using NI Measurement and Automation Explorer (MAX), configure the PXI chassis and real-time controller. Set the IP address to a desired static value. Install the current versions of NI LabVIEW Real-Time Module and the NI-DAQmx Drivers along with any other desired software. Finally, make sure the PXI system controller and PXI chassis are defined correctly in MAX, as shown in figures below MAX can also change the aliases (names) and basic configurations of the DAQ devices if desired.

The user must take note of a few configuration settings in MAX in order to work with NI CAS Software. The DAQ device aliases, as shown in the figures below, are used to identify the physical channels in the NI CAS Software measurement setup. The DAQ device can be renamed by right clicking on the device and selecting the rename option. Finally, the user must confirm that the PXI Trigger Lines are <u>not</u> reserved for other functions in MAX, as shown in the figures below. They are automatically reserved as a part of the channel configuration within the NI CAS Software.
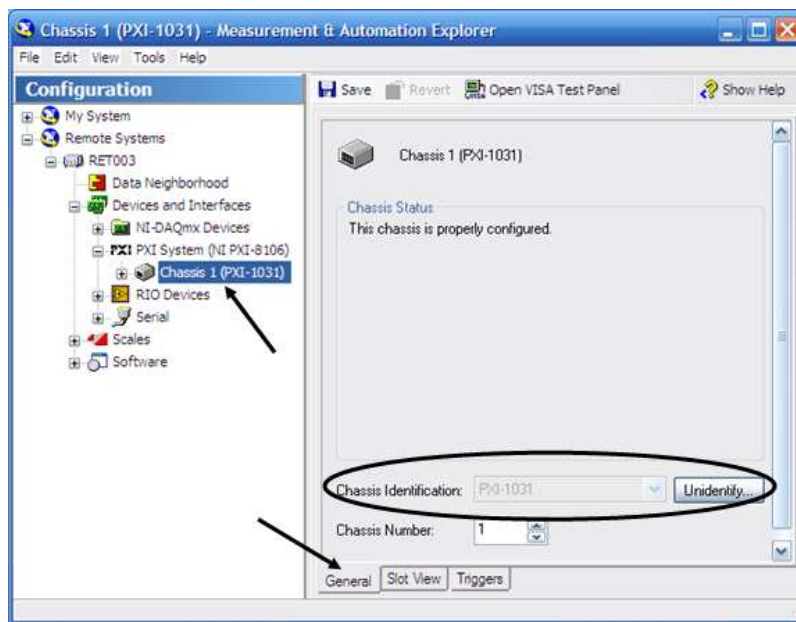
PXI Chassis Identification configuration in MAX

NI-DAQmx device names in MAX
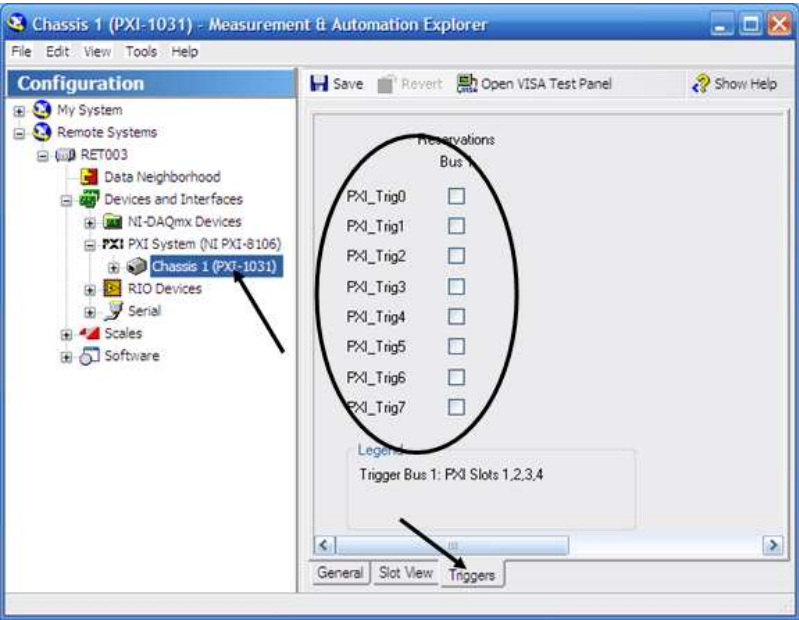
PXI Trigger Reservation options

2.2.2.2 Deployment Version MAX Hardware Configuration

The user must take note of a few configuration settings in NI Measurement and Automation Explorer (MAX) in order to work with the NI CAS Software. The DAQ device aliases, as shown below, are used to identify the physical channels in the NI CAS Software measurement setup. The DAQ device can be renamed by right clicking on the device and selecting the rename option.
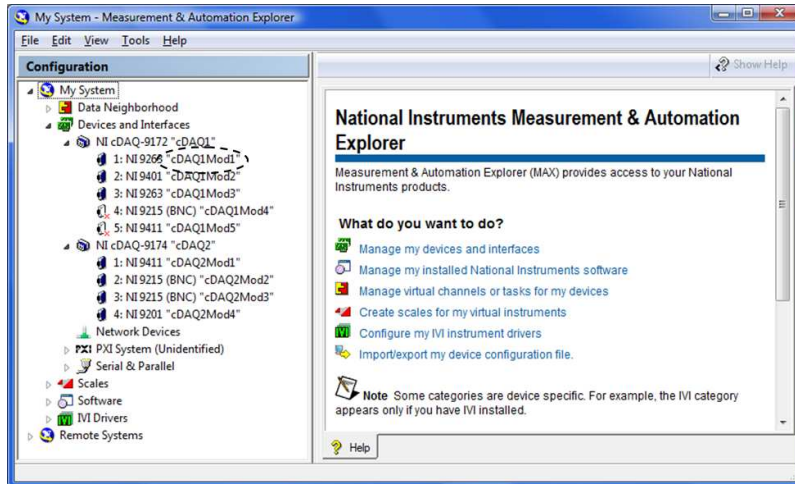
2.3.3 Development Version Example Project and System Integration

The Development Version of NI CAS Software can be run as a stand alone application using the NI CAS Software example application. The following steps are required to run the NI CAS Software example.

1. Open the CAS example project. From LabVIEW, select Help > Find Examples. Search for "Combustion Analysis"
2. Update the PXI target IP address for the user's PXI target. Right click on the PXI icon in the project and select "Properties"
3. Confirm or update the expansion chassis, C Series modules, and FPGA I/O in "CAS FPGA.vi" to match the user's hardware.
4. Open and compile "CAS FPGA.vi" in the FPGA target.
5. Open "CAS Target.vi" in the PXI target.
6. Run "SCM Init" by double clicking on the icon on the block diagram of "CAS Target.vi". It is the right most block diagram item.
7. Run "CAS Target.vi".
8. Launch NI SCM Console and point it to the PXI target IP address, "CAS Host.vi", and "CAS Host.par". The host files are located with the project in the examples folder. For more information on the SCM Console, please see the SCM user's manual.

Integrating Development Version Into An Engine Control Application

The Development Version of NI CAS Software can run as a stand alone application or as part of a larger project. A single PXI chassis can run both an engine controller and combustion analysis. Integrating the two systems into a single platform allows lowered equipment costs in addition to providing closed loop feedback to the engine controller. The following steps are required to integrate the Development Version of NI CAS Software into an engine control application.

First, open the CAS example project. From LabVIEW, select Help > Find Examples. Search for "CAS".

FPGA

1. Open "CAS FPGA.vi" under the CAS PXI\FPGA target.
2. Copy the single cycle loop from the CAS PXI\FPGA to the engine control FPGA.
3. Copy "CAS Data" and "CAS Encoder Debug" FIFOs from the CAS PXI\FPGA target to the engine control FPGA target.
4. Copy the PXI folder containing TRIG0-7 from the CAS PXI\FPGA target to the engine control FPGA target.
5. Make sure the encoder signals are connected to the appropriate sources.
6. Compile the engine control FPGA VI.

Real-Time

1. Open "CAS Target.vi" under the PXI target.
2. Copy the contents of "CAS Target.vi" into your engine control target VI.
3. Remove the SCM Init VI and FPGA Open Reference function copied from the CAS example.
4. Connect the the SCM Init VI and FPGA Open Reference function from your engine control application to the copied CAS code.

Note: The FPGA reference must be set to "Dynamic mode"

2.4 Performance

2.4.1 Development Version Performance Overview

The performance of the system depends on many factors including:

- PXI Controller Speed, Ram, & OS (Microsoft Windows or Real-Time)
- DAQ Hardware Limitations (Sampling Rate, Response Times)
- Engine Speed
- Cylinder/Measurement Count
- Asynchronous Sampling Rate
- Medium Speed Data (Number of Channels and Sample Rate)
- FPGA Data (Number of Channels and Sample Rate)
- Encoder Resolution
- Calculation Parameters
- HDD Throughput
- User Calculations

2.4.1.1 S Series Hardware

One of the key items limiting the maximum engine speed is the DAQ hardware. There are two cases where the DAQ hardware may limit the maximum engine speed. The first is the case where the DAQ equipment has a large sample rate but the encoder resolution is high. For example, a 500kS/s/ch DAQ device is limited to ~8333RPM with a 3600ppr encoder. The second case is where the DAQ hardware has a small sample rate. For example, a multiplexed sampling device at 1MS/s divided among 16 channels has a 62.5kS/s/ch sampling rate.
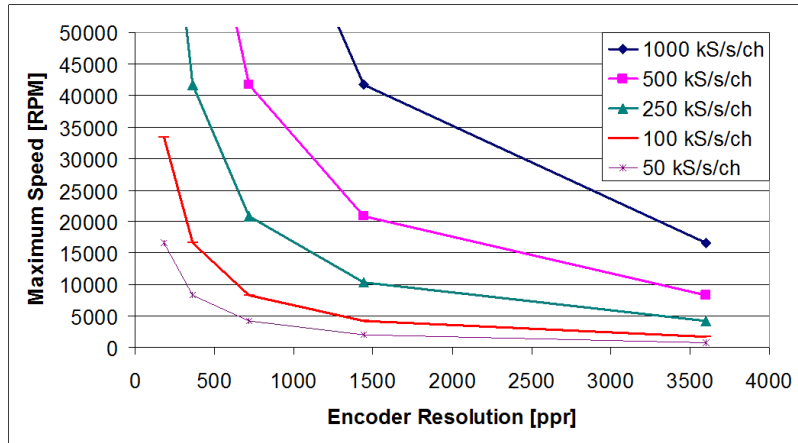
The data above was calculated using the following equation:

$$MS = \frac{60,000 * SR}{ER}$$

Where:

MS = Maximum Speed [RPM]
SR = Sample Rate [kS/s/ch]
ER = Encoder Resolution [ppr]

2.4.1.2 HDD

Streaming data to the disk requires that the speed of the hard drive is fast enough to keep up with the data waiting to write to it. Disk access is typically between 10MB/s and 70MB/s. However, due to seek times and writing header information, the actual speed at which the system can stream data to disk may be slower. The throughput of a specific HDD is dependent on many factors including the type of hard drive and the system that it is installed in. The NI CAS Software will buffer data in the RAM if the disk is not fast enough to stream all the data to disk. However, the buffers have limited space and cannot sustain continuous streaming if the disk is not fast enough.
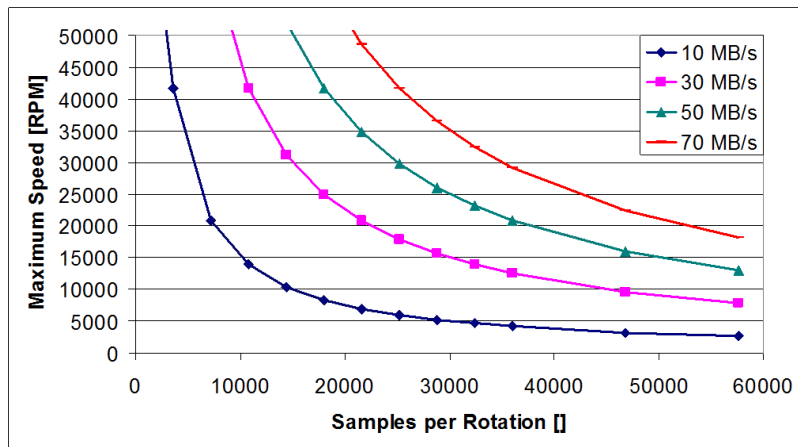
The data above was calculated using the following equation:

$$MS = \frac{60,000,000 * DS}{SR * 32 / 8}$$

Where:

      MS = Maximum Speed [RPM]
      SR = Sample per Rotation []
      DS = Disk Speed [MB/s]

2.4.2 Deployment Version Performance Overview

The performance of the system depends on many factors including:

- 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

2.4.2.1 cDAQ Hardware

The figure below shows the cDAQ hardware limitations. The cDAQ system uses simultaneous sampling device. Therefore, the DAQ hardware limitations are constant for any number of cylinders.
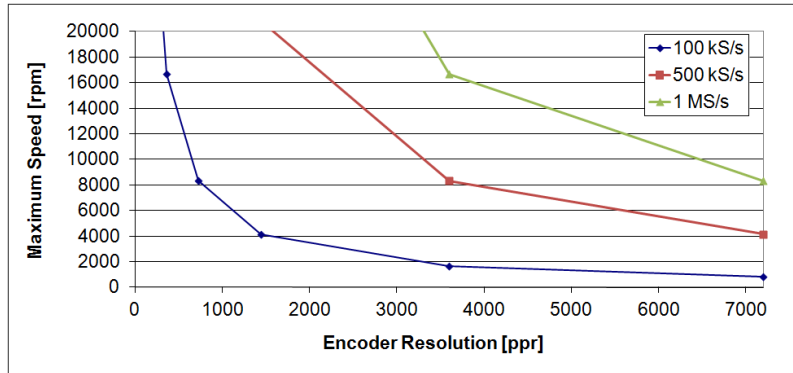
The following formula can be used to estimate the performance of a simultaneous DAQ hardware device.

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

Where:

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

2.4.2.2 NI cDAQ-1939 Benchmark

The NI cDAQ-1939 was tested under a variety of conditions in order to demonstrate the capabilities of the system while running. Each test condition was evaluated on the maximum engine speed where the system could calculate all the results without loosing data for the real-time calculation and where the system could no longer write all incoming data to disk. The maximum speed of the test engine was 8000 RPM. Therefore, the test results showing an 8000 RPM limit will probably be able to reach higher engine speeds.

	NI cDAQ-1939					
Cylinder Count	4	4	4	4	4	4
Encoder Resolution [ppr]	360	360	1800	1800	3600	3600
Strokes	4	4	4	4	4	4
Manifold Pegging	x	x	x	x	x	x
Mean Effective Pressure	x	x	x	x	x	x
Single Zone Heat Release	x	x	x	x	x	x
Knock Sensors 100 kS/s	0	2	0	2	0	2
Medium Speed Channels 10 S/s	0	20	0	20	0	20
Max Speed RT Processing [RPM]	8000	8000	8000	8000	5500	5000
Max Raw File Speed [RPM]	8000	8000*	8000	8000*	8000	6000*
	NI cDAQ-1939					
Cylinder Count	8	8	8	8	8	8
Encoder Resolution [ppr]	360	360	1800	1800	3600	3600
Strokes	4	4	4	4	4	4
Manifold Pegging	x	x	x	x	x	x
Mean Effective Pressure	x	x	x	x	x	x
Single Zone Heat Release	x	x	x	x	x	x
Knock Sensors 100 kS/s	0	4	0	4	0	4
Medium Speed Channels 10 S/s	0	20	0	20	0	20
Max Speed RT Processing [RPM]	8000	8000	5500	4000	3000	2500
Max Raw File Speed [RPM]	8000	8000*	8000	8000*	6000	6000*

*Performance Optimization Settings Adjusted

3. NI CAS Software Interface

The NI CAS Software Host VI is the top level VI. It contains links to all of the NI CAS Software built in screens and provides the user with a starting place. This host always remains on top of other NI CAS Software hosts.
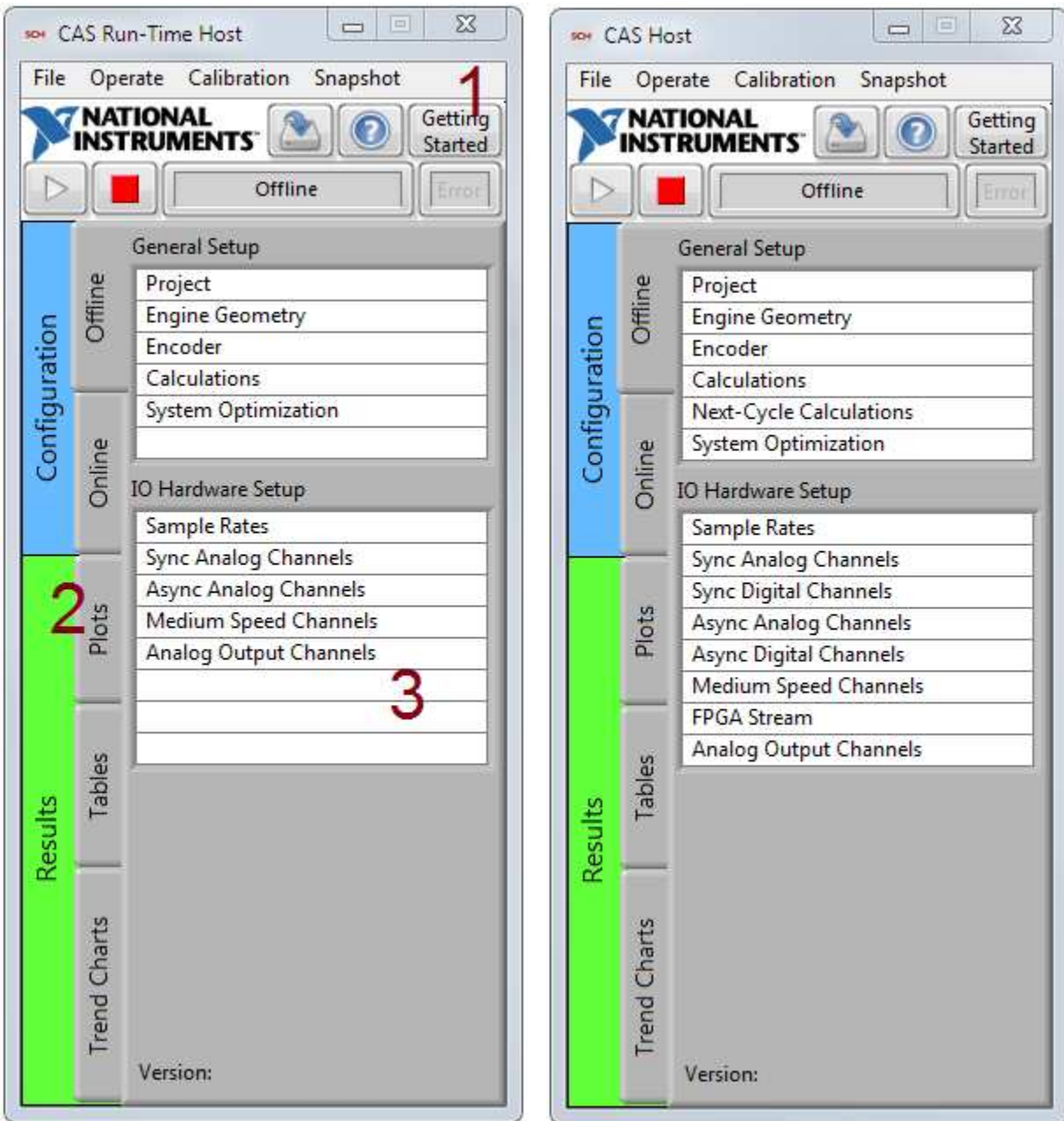
Deployment   Development

1. Information and controls that are always available. The user can switch between the setup and running modes, open this help documentation or see if any error conditions exist. There may also be menu items available for saving and loading calibrations and other useful functions.
2. Selection of different configurations and results groups.

3. SubHost list containing all the available NI CAS Software sub-hosts. Double clicking a name opens it if it is closed (normal) or closes it if open (bold). A single click on an open (bold) name brings it to the front.

3.1 Offline

3.1.1 General Setup

3.1.1.1 Project Setup

The project setup options must be configured in the offline mode. Information entered here will help identify calibration files once loaded. Internal software simulation is also enabled in this window.
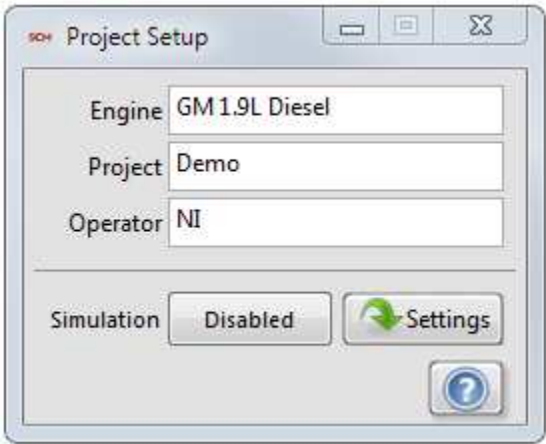
Engine	Specifies the name or description of the engine.
Operator	Specifies the engine operator.
Project	Specifies the current test project.
Simulation	Enables a simulation that doesn't require hardware.

3.1.1.2 Engine Geometry Setup

The engine geometry setup must be configured in the offline mode. Information entered should be specific to the engine and test setup as it affects all of the calculations results.

Bore	Specifies the cylinder bore.
Clearance Volume	Specifies the clearance volume of the cylinder. [Compression Ratio = (Displacement Volume + Clearance Volume) / Clearance Volume]
Compression Ratio	Indicates the calculated compression ratio. [Compression Ratio = (Displacement Volume + Clearance Volume) / Clearance Volume]
Connecting Rod Length	Specifies the connecting rod length.
Crown Area	Specifies the piston crown surface area relative to the bore area
Cylinder Count	Defines the number of cylinders in the engine.
Cylinder TDC	Defines the cylinder Top Dead Center offsets relative to the absolute encoder offset.

Displacement Volume	Indicates the calculated displacement volume. [Compression Ratio = (Displacement Volume + Clearance Volume) / Clearance Volume]
Exhaust Valve Close	Specifies the nominal exhaust valve closing angle.
Exhaust Valve Open	Specifies the nominal exhaust valve opening angle.
Head Area	Specifies the cylinder head surface area relative to the bore area.
Intake Valve Close	Specifies the nominal intake valve closing angle.
Intake Valve Open	Specifies the nominal intake valve opening angle.
Pin Offset	Specifies the pin offset.
Rotations Per Cycle	Defines the number of rotations per cycle. (2-Stroke = 1; 4-Stroke = 2)
Stroke	Specifies the piston stroke. (Stroke = 2 * Crank Radius)
Volume File Enable	Enables use of use of a volume file instead of using the volume calculations.
Volume File Path	Specifies the volume file to use instead of the calculations.

3.1.1.3 Encoder Setup

The encoder setup must be configured in the offline mode. Information entered should be specific to the engine and test setup as it affects all of the calculations results.
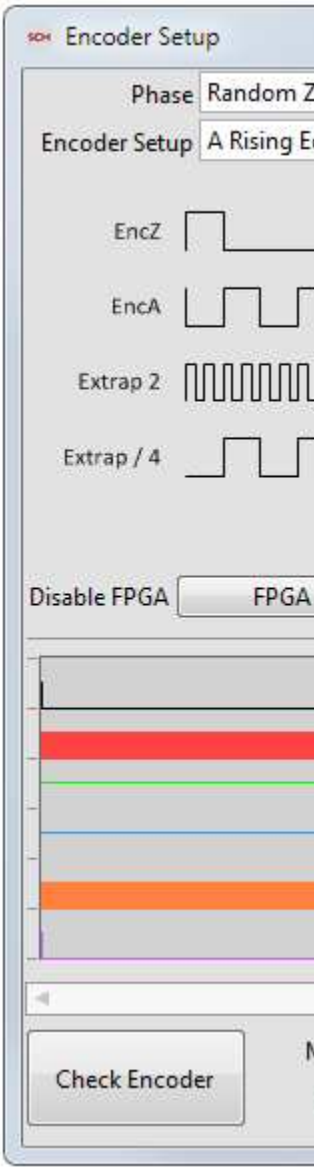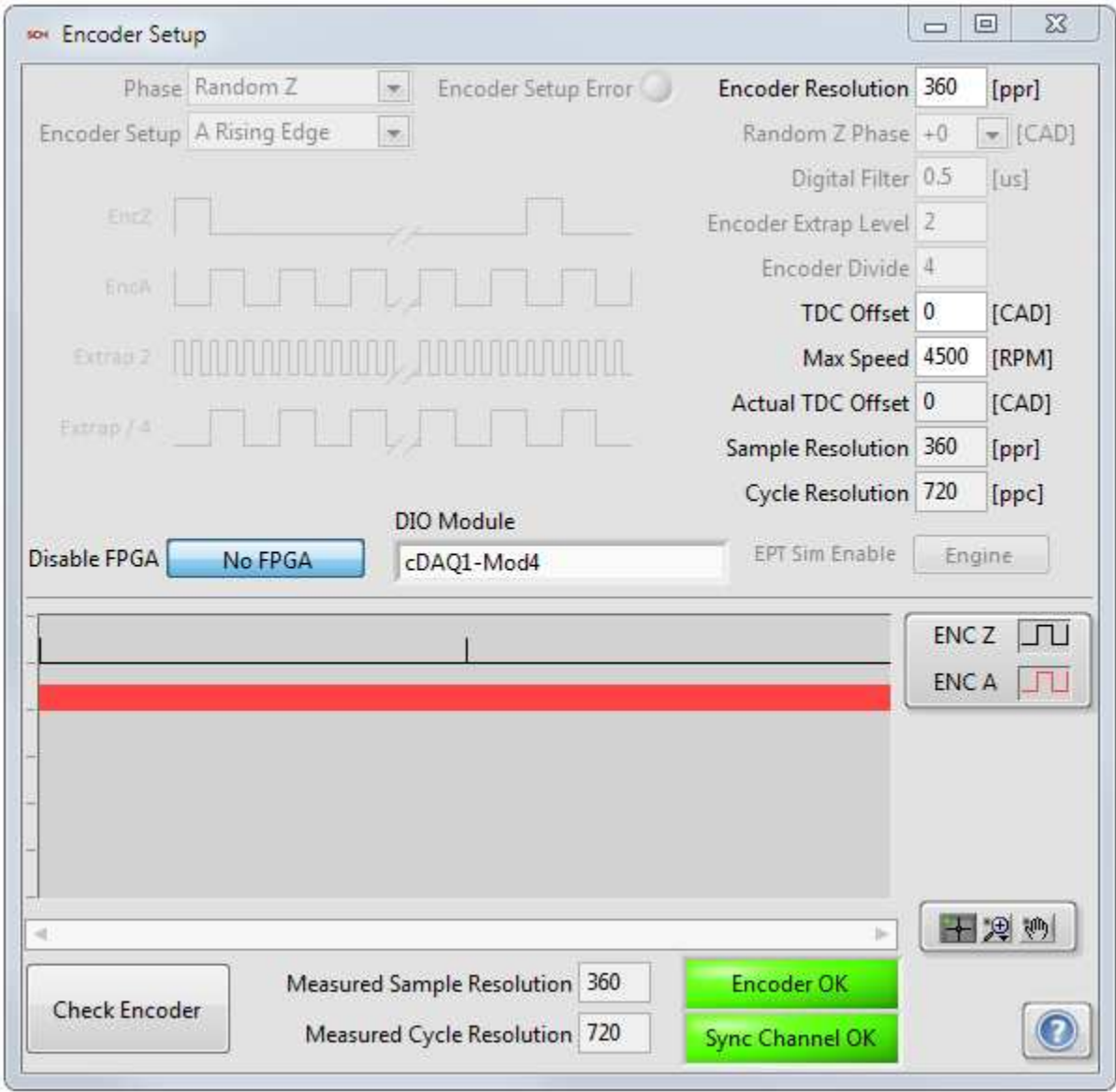
Deployment

Actual TDC Offset	Indicates the actual top dead center offset used by the engine position tracking system.
Check Encoder	Updates the encoder debug scope. (Note: Encoder must rotate at least 4 times for the scope to update once the button is pressed)
Cycle Resolution	Indicates the calculated cycle resolution.
Digital Filter	Defines the digital glitch filter used by the engine position tracking system.

Encoder Debug LED	Indicates whether the 'Measured Sample Resolution' and 'Measure Cycle Resolution' values match the 'Sample Resolution' and 'Cycle Resolution' values, respectively.
Encoder Divide	Specifies the level to divide the extrapolated resolution by in order to determine the final sample resolution (Not all combinations of encoder resolution, extrapolation level, and encoder divide are valid.)
Encoder Setup Error	Indicates an error in the engine position tracking configuration.
Encoder Extrap Level	Specifies the level of encoder extrapolation used in the engine position tracking system. (2 valid)
Encoder Resolution	Specifies the encoder resolution as it is seen by the engine position tracking.
Encoder Setup	Determines which encoder events are used by the engine position tracking system.
EPT Sim Enable	Enables EPT simulation of the engine encoder signals for offline testing.
Max Speed	Specifies the maximum speed of the engine.
Measured Sample Resolution	Displays the number of edges counted for one encoder rotation.
Measured Cycle Resolution	Displays the number of edges counted for one engine cycle.
Disable FPGA	Specifies if the system is configured for acquiring data without an FPGA engine position tracking system.
Phase	Determines the method of preprocessing the encoder signal to pass only a single index pulse per cycle to the engine position tracking system.
Random Z Phase	Defines which cycle to use when using a random z.
Sample Resolution	Indicates the calculated sample resolution based on the encoder settings.
TDC Offset	Specifies the global TDC offset. It is commonly used to easily adjust for changes in the encoder without needing to change each cylinder TDC.
cDAQ DIO Module	Specifies the encoder index signal name when using the Deployment Version of NI CAS Software and a cDAQ chassis.

3.1.1.4 Calculations

In setup mode, the user can enable or disable different groups of calculations to perform real-time calculations on the target. Each group of calculations has its own settings and results. Enabling calculation groups will increase the processor usage depending on the complexity of the calculations.

Note: Some calculations require results from another calculation group in order to work, i.e., heat release models including heat transfer simulation require the 'Gas Temp' calculation to be enabled.
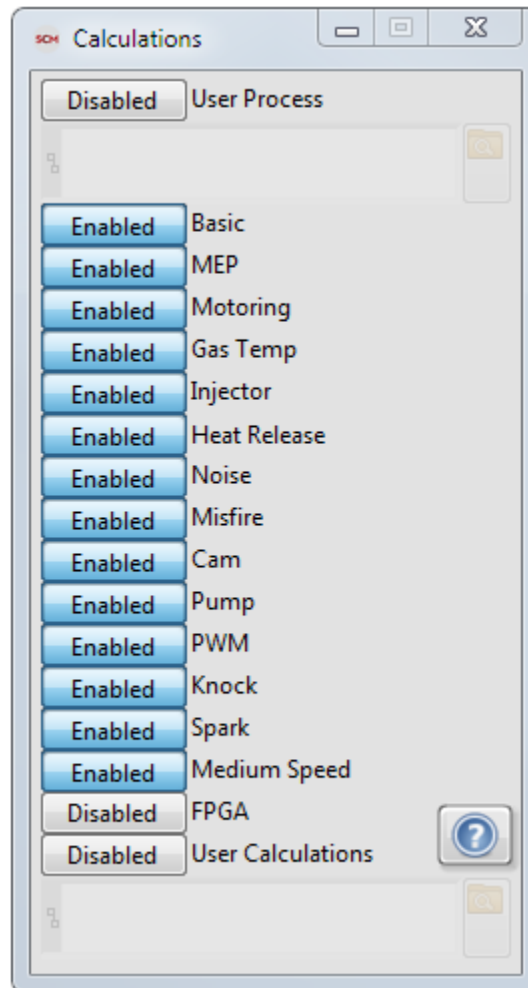
3.1.1.5 Next-Cycle Calculations

In setup mode, the user can enable or disable different groups of calculations to perform next-cycle calculations on the target. Each group of calculations has its own settings and results. Enabling calculation groups will increase the processor usage depending on the complexity of the calculations and increase the time required to provide next-cycle results.
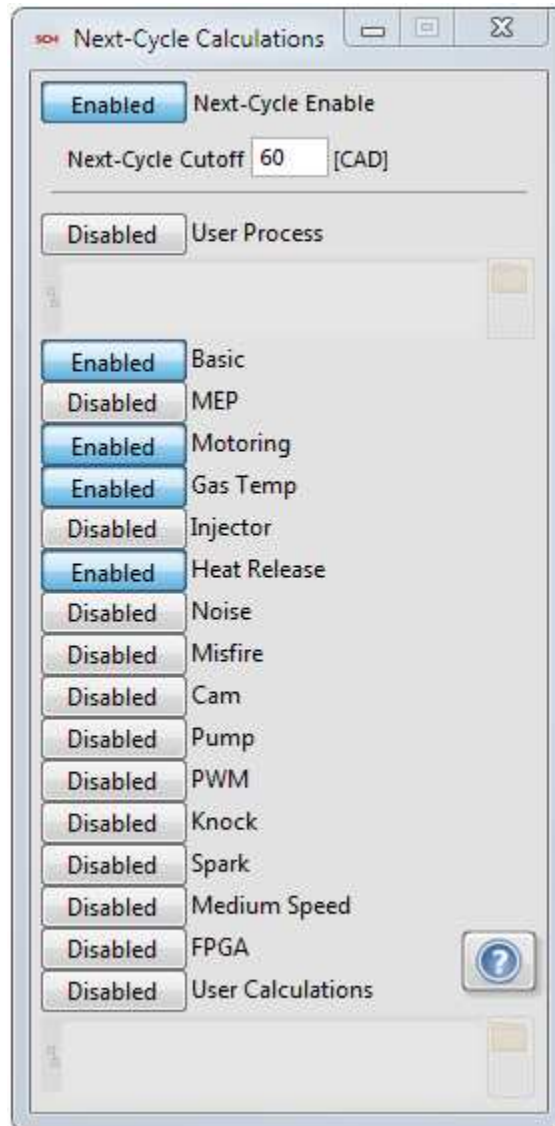
Note: Some calculations require results from another calculation group in order to work, i.e., heat release models including heat transfer simulation require the 'Gas Temp' calculation to be enabled.

*Only available with the Development License.

3.1.1.6 System Optimization

The performance dialog allow users to tune some of the NI CAS Software behavior with their system and setup. The current settings should work well for most configurations.
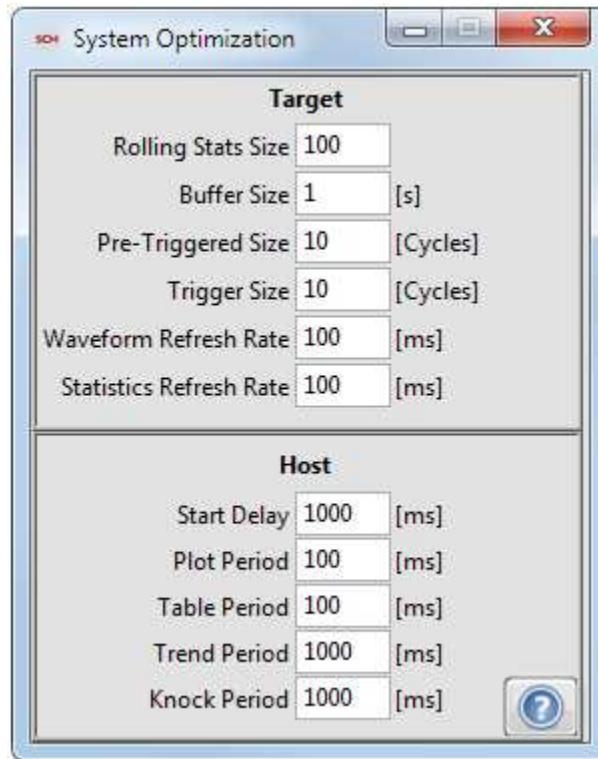

Target

Rolling Stats Size	Configures the rolling statistics buffers used in trends and tables.
Buffer Size	Determines the desired length of the alignment and raw file buffers.
Pre-Triggered Size	Determines the number of cycles the raw system will maintain before a start file event.
Trigger Size	Determines the number of cycles to save to a raw file at a time to improve disk performance.
Waveform Refresh Rate	Configures the maximum update rate of plot data.
Statistics Refresh Rate	Configures the maximum update rate of statistical data.

Host

Start Delay	Delays the start of Host VI execution to allow initialization.
Plot Period	Determines the maximum update rate of plot.
Table Period	Determines the maximum update rate of tables.
Trend Period	Determines the maximum update rate of trends.
Knock Period	Determines the maximum update rate of the knock configuration display.

3.1.2 IO Hardware Setup

3.1.2.1 Sample Rates Setup

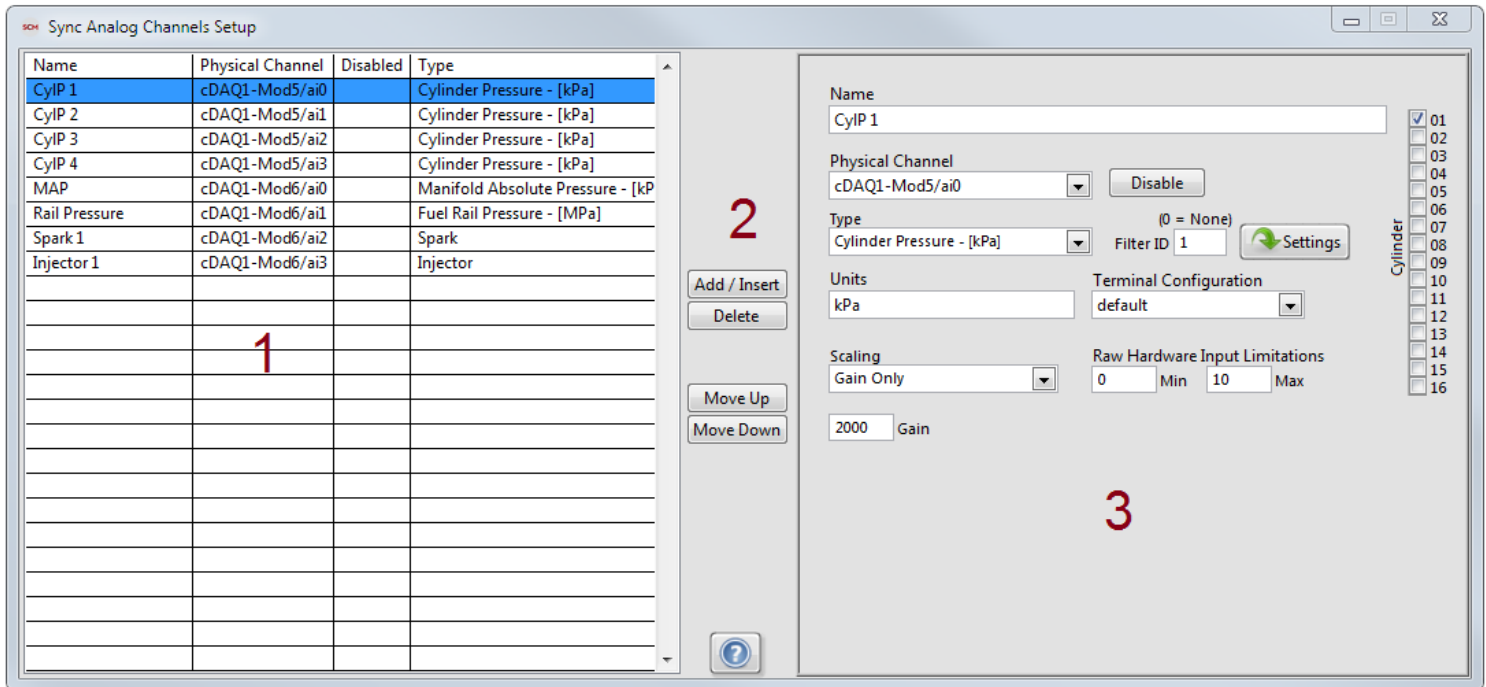The sample rates setup must be configured in the offline mode. Information entered should be specific to the data acquisition hardware used as invalid inputs will cause DAQ errors.
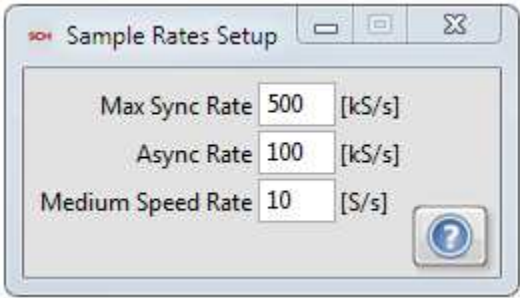
Async Rate	Specifies the sample rate of the asynchronous data.
Max Sync Rate	Specifies the maximum sample rate of the synchronous measurement DAQ device.
Medium Speed Rate	Specifies the sample rate of the medium speed DAQ.

3.1.2.2 Sync Analog Channels Setup

The engine synchronous measurement setup is used to define all the physical channels. These measurements are sampled at even crank angle increments with respect to the engine.
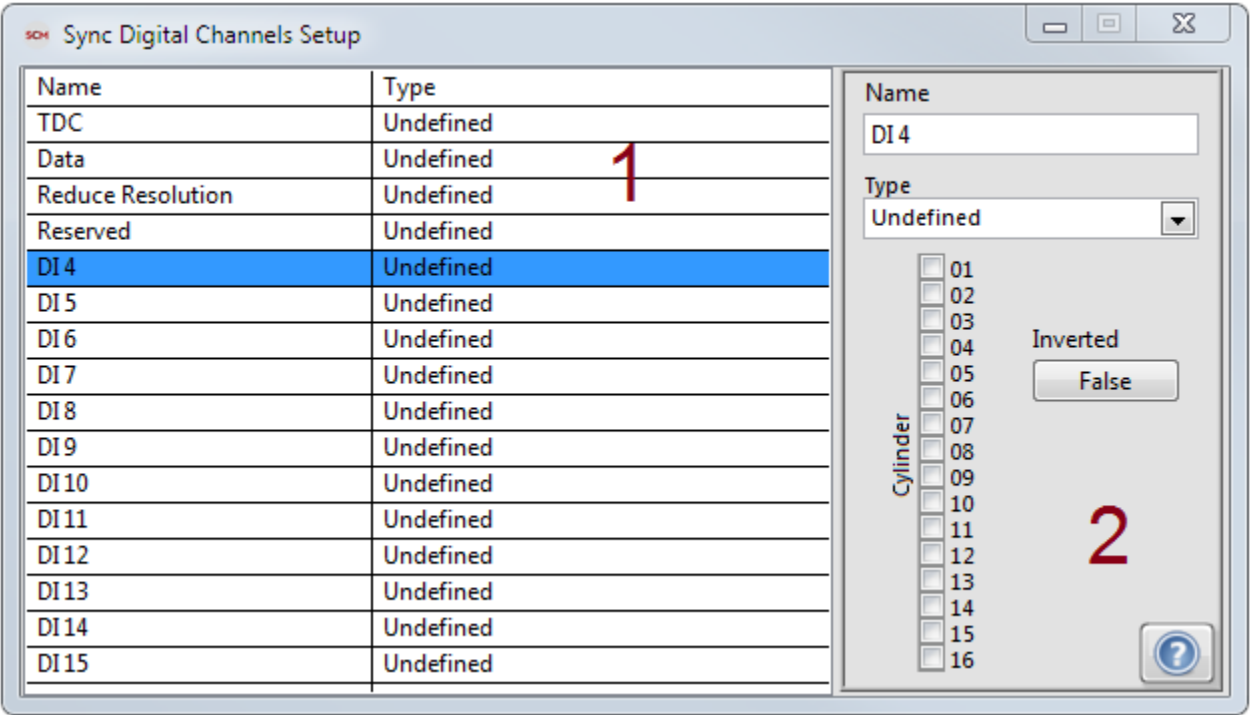

1. Summary of all defined measurements.
2. Controls for manipulating the list of measurements.
3. Detailed setup of the selected measurement.

Cylinder	Cylinders associated with each measurement in a bitfield.
Disable	Disables data acquisition and calculations associated with each measurement.
Filter	Filter resource number associated with each measurement. (0 = No Filter)
Gain	Gain associated with each measurement when using the gain only or gain and offset scaling methods.
Max	Maximum channel voltage range associated with each measurement.
Min	Minimum channel voltage range associated with each measurement.
Name	Name or description associated with each measurement.
Offset	Offset associated with each measurement when using the gain and offset scaling method.
Physical Channel	Physical channel associated with each measurement.
Polynomial Coefficients	Polynomial Coefficients associated with each measurement when using the polynomial scaling method.
Scaling	Scaling method associated with each measurement.
Table X	Table X array associated with each measurement when using the table scaling method.
Table Y	Table Y array associated with each measurement when using the table scaling method.

Terminal Configuration	Terminal Configuration array associated with each measurement.
Type	Measurement Type associated with each measurement.
Units	Units associated with each measurement.

3.1.2.3 Sync Digital Channels Setup

The engine synchronous digital measurement setup is used to define hardware timed digital IO associated with the engine synchronous analog inputs. These measurements are sampled at even crank angle increments with respect to the engine.

1. Summary of all defined measurements.
2. Detailed setup of the selected measurement.

Cylinder	Cylinders associated with each measurement in a bitfield.
Inverted	Invert the digital signals associated with each measurement.
Name	Name associated with each measurement.
Type	Measurement Type associated with each measurement.

*Only available with the Development License.

3.1.2.4 Async Analog Channels Setup

The time-based asynchronous measurement setup is used to define all the physical channels. These measurements are sampled at a fixed frequency.

1. Summary of all defined measurements.
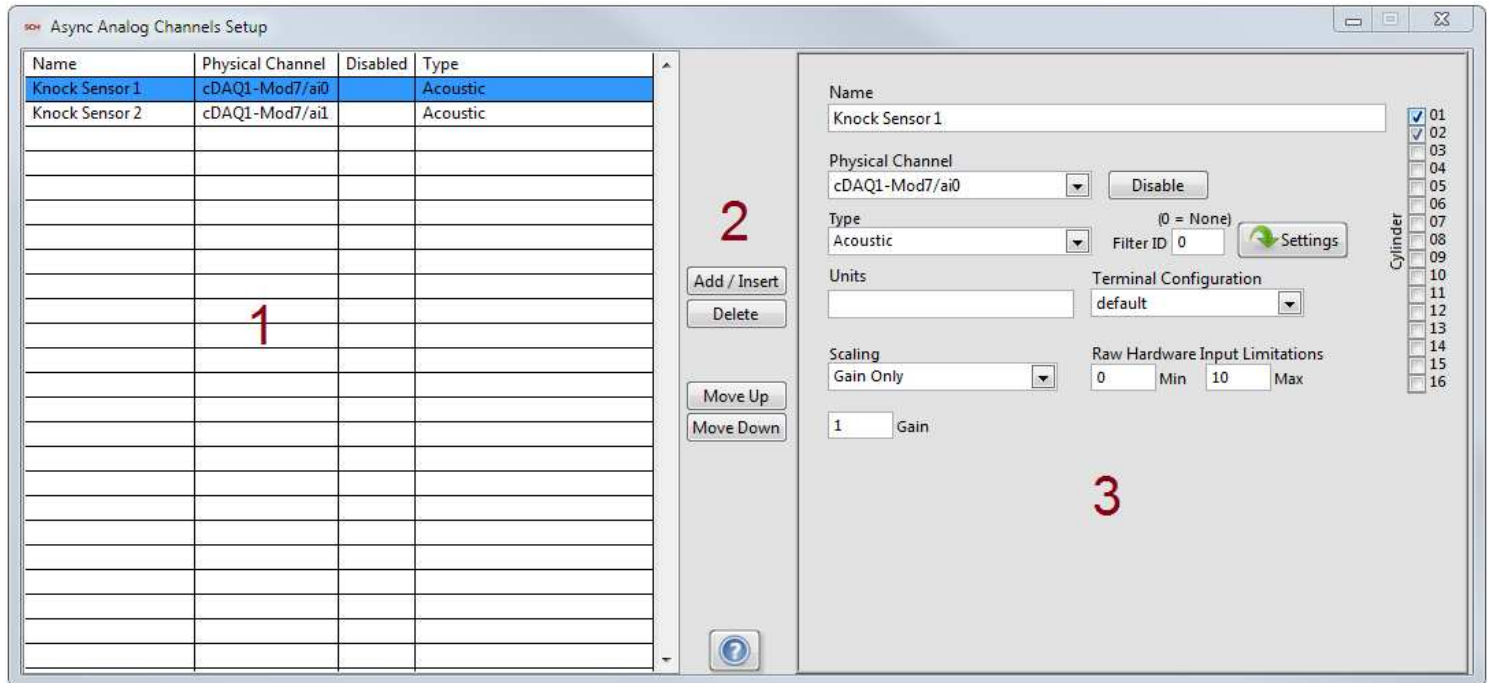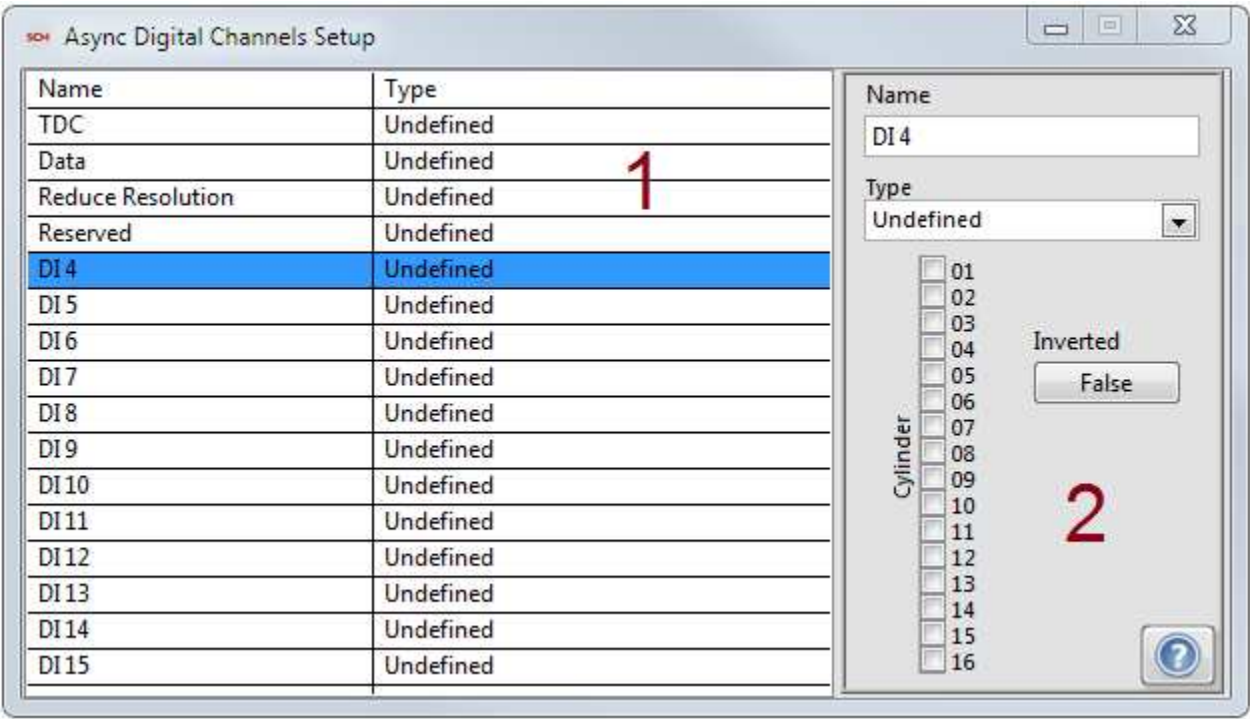2. Controls for manipulating the list of measurements.
3. Detailed setup of the selected measurement.

Cylinder	Cylinders associated with each measurement in a bitfield.
Disable	Disables data acquisition and calculations associated with each measurement.
Filter	Filter resource number associated with each measurement. (0 = No Filter)
Gain	Gain associated with each measurement when using the gain only or gain and offset scaling methods.
Max	Maximum channel voltage range associated with each measurement.
Min	Minimum channel voltage range associated with each measurement.
Name	Name or description associated with each measurement.
Offset	Offset associated with each measurement when using the gain and offset scaling method.
Physical Channel	Physical channel associated with each measurement.
Polynomial Coefficients	Polynomial Coefficients associated with each measurement when using the polynomial scaling method.
Scaling	Scaling method associated with each measurement.
Table X	Table X array associated with each measurement when using the table scaling method.
Table Y	Table Y array associated with each measurement when using the table scaling method.

Terminal Configuration	Terminal Configuration array associated with each measurement.
Type	Measurement Type associated with each measurement.
Units	Units associated with each measurement.

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3.1.2.5 Async Digital Channels Setup

The time-based asynchronous digital measurement setup is used to define hardware timed digital IO associated with the asynchronous analog inputs. These measurements are sampled at a fixed frequency.

1. Summary of all defined measurements.
2. Detailed setup of the selected measurement.

Cylinder	Cylinders associated with each measurement in a bitfield.
Inverted	Invert the digital signals associated with each measurement.
Name	Name associated with each measurement.
Type	Measurement Type associated with each measurement.

*Only available with the Development License.

3.1.2.6 Medium Speed Channels Setup

The time-based medium speed measurement setup is used to define all the physical channels. Medium speed are intended for sampling test cell and other auxiliary signals. These measurements are sampled at a fixed frequency.
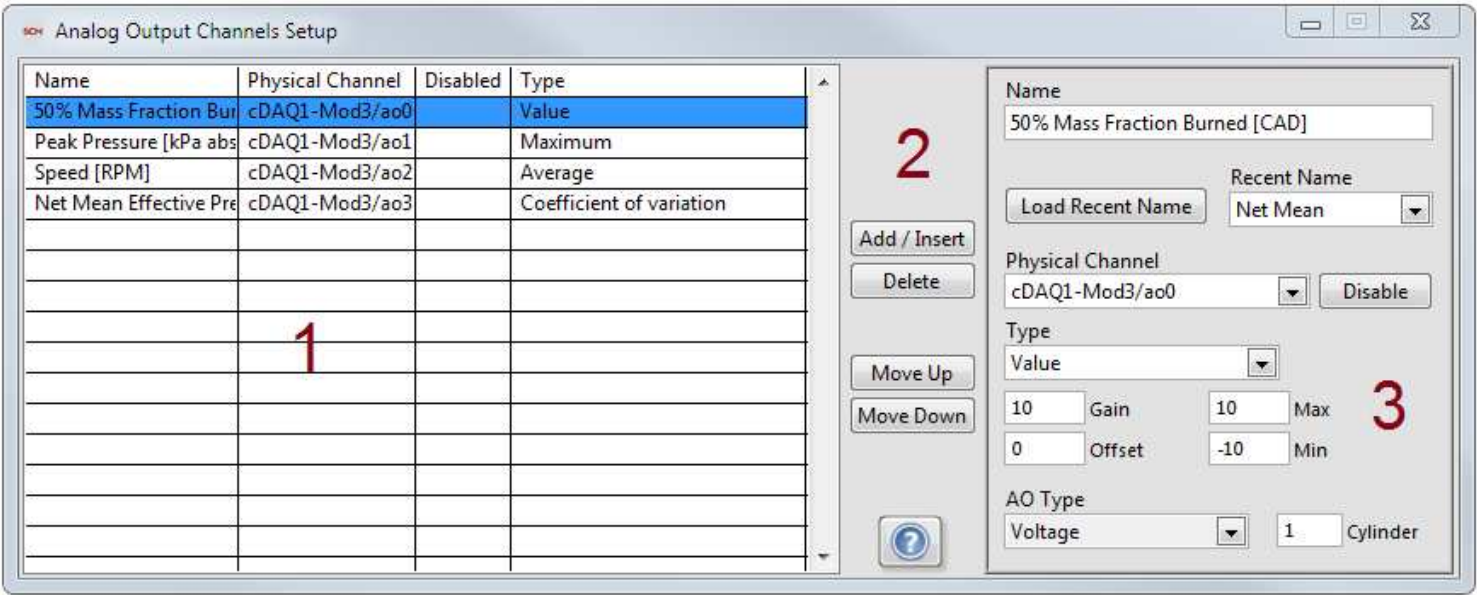

1. Summary of all defined measurements.
2. Controls for manipulating the list of measurements. Enable/Disable engine cycle averages and statistic calculations.
3. Detailed setup of the selected measurement.

CJC Channel	Cold junction compensation channel associated with each measurement when using a channel cold junction compensation source.
CJC Source	Cold junction compensation source associated with each measurement.
CJC Value	Cold junction compensation value associated with each measurement when using a constant cold junction compensation source.
Disable	Disables data acquisition and calculations associated with each measurement.
Filter Cutoff	Knock Threshold for Each Cylinder
Gain	Gain associated with each measurement.
Max	Maximum voltage, current, or temperature associated with each measurement.
Min	Minimum voltage, current, or temperature associated with each measurement.
Name	Name or description associated with each measurement.
Offset	Offset associated with each measurement.
Physical Channel	Physical channel associated with each measurement.

Save Trigger	Enables the channel to be used to trigger the start of a file save. Each index is associated with each measurement.
Scaling	Scaling method associated with each measurement.
Terminal Configuration	Terminal configuration associated with each measurement.
Thermocouple Type	Thermocouple type associated with each measurement.
Units	Units associated with each measurement.

3.1.2.7 FPGA Stream Setup

The FPGA setup is used to define data streamed from the FPGA. The measurements are defined in the FPGA when using an FPGA with the Development Version of NI CAS Software. Defining them in the FPGA setup allows the Development Version of NI CAS Software to calculate cycle averages and statistics for the display and summary files.
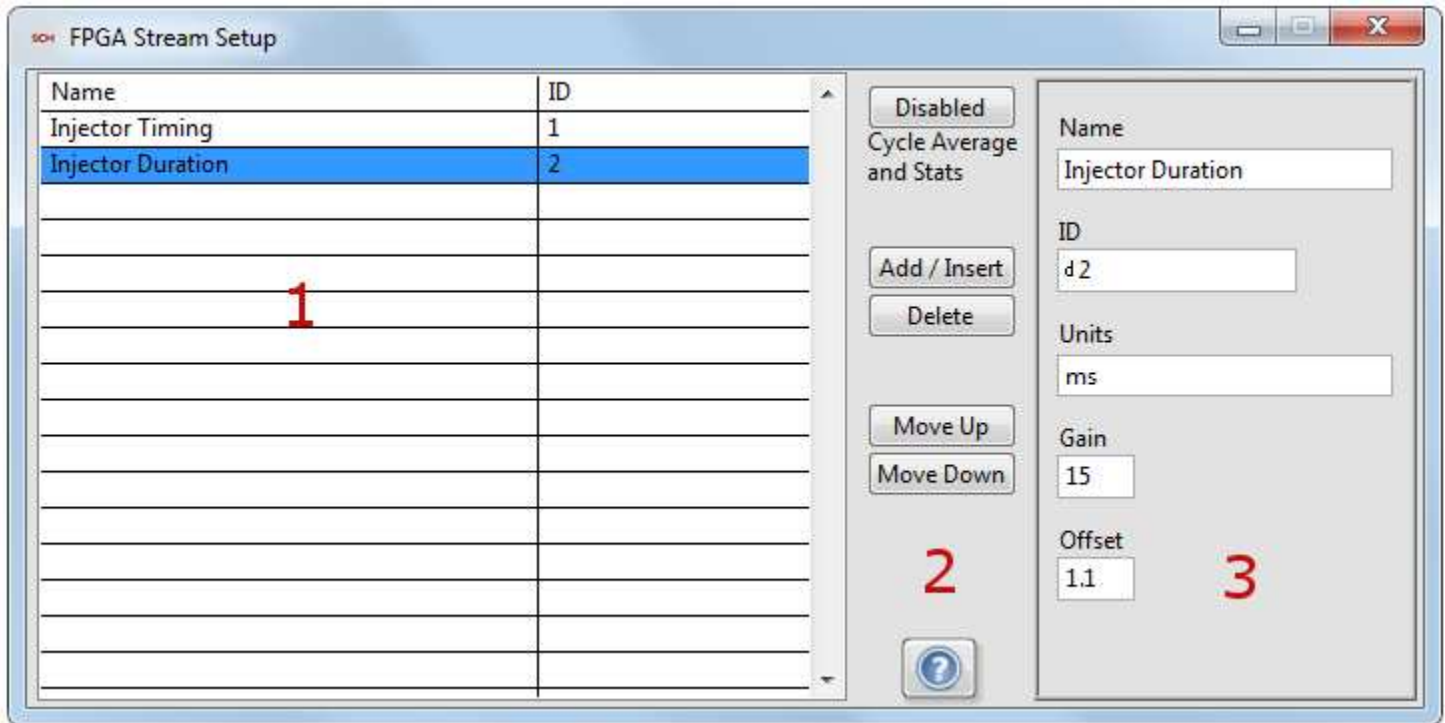
1. Summary of all defined measurements.
2. Controls for manipulating the list of measurements. Enable/Disable engine cycle averages and statistic calculations.
3. Detailed setup of the selected measurement.

Gain	Gain associated with each measurement.
ID	ID associated with each FPGA measurement.
Name	Name or description associated with each measurement.
Offset	Offset associated with each measurement.
Units	Units associated with each measurement.

*Only available with the Development Version of NI CAS Software

3.1.2.8 Analog Output Channels Setup

The analog output setup defines analog outputs channels. These channels link to calculated results in NI CAS Software based on name. The recent names contain a list of available results from the last time the system ran.

1. Summary of all defined outputs.
2. Controls for manipulating the list of outputs.
3. Detailed setup of the selected outputs.

AO Type	Analog output type associate with the measurement.
Cylinder	Cylinder associated with each measurement.
Disable	Disables data acquisition and calculations associated with each measurement.
Gain	Gain associated with each measurement.
Max	Maximum voltage range associate with the measurement.
Min	Minimum voltage range associate with the measurement.
Name	Name or description associated with each measurement.
Offset	Offset associated with each measurement.
Physical Channel	Physical channel associated with each measurement.
Type	Measurement Type associated with each measurement.

3.2 Online

3.2.1 Settings

3.2.1.1 Motoring and TDC Offset Settings

The Motoring / TDC Offset window is a tool to assist the user in correctly phasing sampled engine-synchronous data with calculated volume data. In general, this window should only be utilized while the engine is 'motoring,' or spinning without firing. Several methods for finding the TDC Offset include positioning the peak pressure with the use of a thermodynamic loss angle, positioning a TDC probe signal, and manual input.
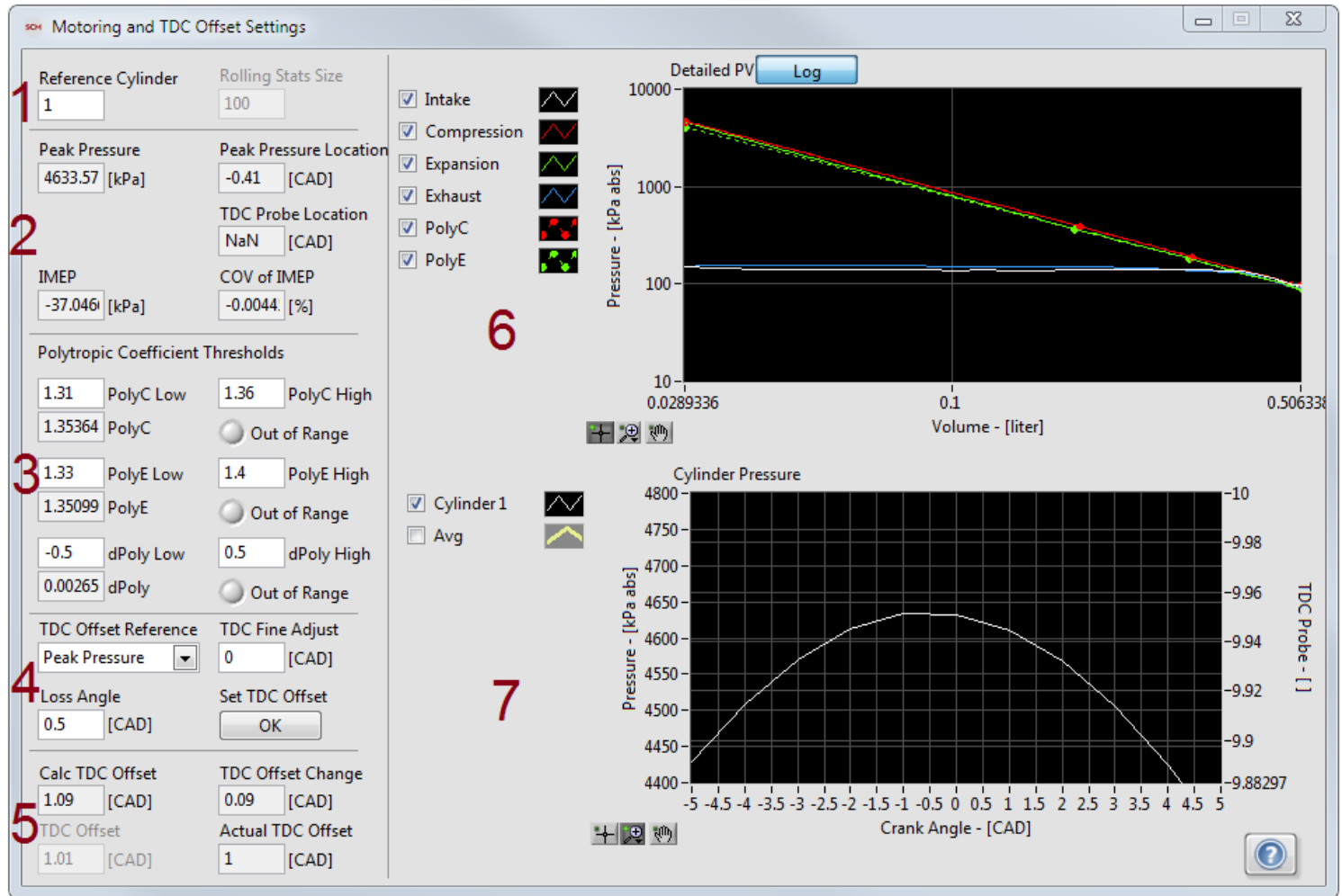
1. Selection of the reference cylinder to be used for calculating a TDC Offset.
2. Relevant motoring values based on the statistical mean.
3. Calculated polytropic coefficients for reference.
4. New TDC Offset settings using Peak Pressure or a TDC Probe.
5. Current and calculated TDC Offset values.
6. Detailed P-V diagram, including the calculated compression and expansion polytropic coefficient lines.
7. Plot of cylinder pressure and TDC probe (if selected) vs. engine position.

Actual TDC Offset	Indicates the actual top dead center offset used by the engine position tracking system.
Calc TDC Offset	Indicates the calculated (new) TDC offset based on the TDC Offset reference and associated parameters.

COV of IMEP	Indicates the statistical coefficient of variation of the indicated mean effective pressure (net) of the reference cylinder.
dPoly	Indicates the difference between the statistical mean of calculated compression and expansion polytropic coefficients.
dPoly High	Specifies the maximum threshold for the difference between compression and expansion polytropic coefficients.
dPoly Low	Specifies the minimum threshold for the difference between compression and expansion polytropic coefficients.
IMEP	Indicates the statistical mean of indicated mean effective pressure (net) of the reference cylinder.
Loss Angle	Specifies the difference between peak cylinder pressure and cylinder TDC due to heat transfer losses; commonly referred to as the thermodynamic loss angle.
Out of Range	Indicates whether the associated polytropic coefficient is within the stated maximum and minimum threshold values.
Peak Pressure	Indicates the statistical mean of peak pressure of the reference cylinder.
Peak Pressure Location	Indicates the statistical mean of location of peak pressure of the reference cylinder.
PolyC	Indicates the statistical mean of calculated polytropic coefficient of the compression stroke (based on the logarithmic P-V diagram)
PolyC High	Specifies the maximum threshold for the calculated polytropic coefficient of the compression stroke.
PolyC Low	Specifies the minimum threshold for the calculated polytropic coefficient of the compression stroke.
PolyE	Indicates the statistical mean of calculated polytropic coefficient of the expansion stroke (based on the logarithmic P-V diagram)
PolyE High	Specifies the maximum threshold for the calculated polytropic coefficient of the expansion stroke.
PolyE Low	Specifies the minimum threshold for the calculated polytropic coefficient of the expansion stroke.
Reference Cylinder	Specifies the cylinder used as a reference for TDC offset settings.
Rolling Stats Size	Specifies the size of rolling statistics buffers.
Set TDC Offset	Sets a new TDC Offset value (indicated by the Calc TDC Offset). Because the TDC Offset must be configured in the Offline mode, the DAQ software must be reinitialized.
TDC Fine Adjust	Specifies the TDC fine adjustment. A TDC offset may force resampling data which can be slow.
TDC Offset	Specifies the global TDC Offset. It is commonly used to easily adjust for changes in the encoder without needing to change each cylinder TDC.
TDC Offset Change	Indicates the difference between the current TDC offset and the new Calc TDC Offset.
TDC Offset Reference	Specifies the method used to calculate a new TDC Offset.

# 3.2.1.2 Async Conversion Settings

The async conversion settings define the method of converting signals to synchronous or asynchronous types depending on what types of signals are available.
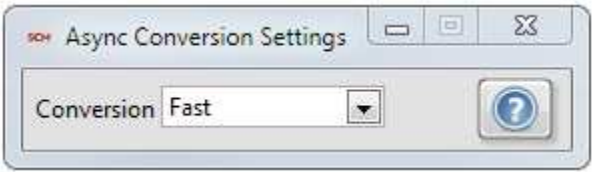
Conversion	Specifies the method used to convert synchronous data to asynchronous data.

3.2.1.3 Pegging Settings

Many of the sensors used for in-cylinder applications are relative or dynamic measurements. They are accurate in representing the change in pressure over a short period but do not represent an absolute vale. To compensate, pegging (calculating a dynamic offset) is used.
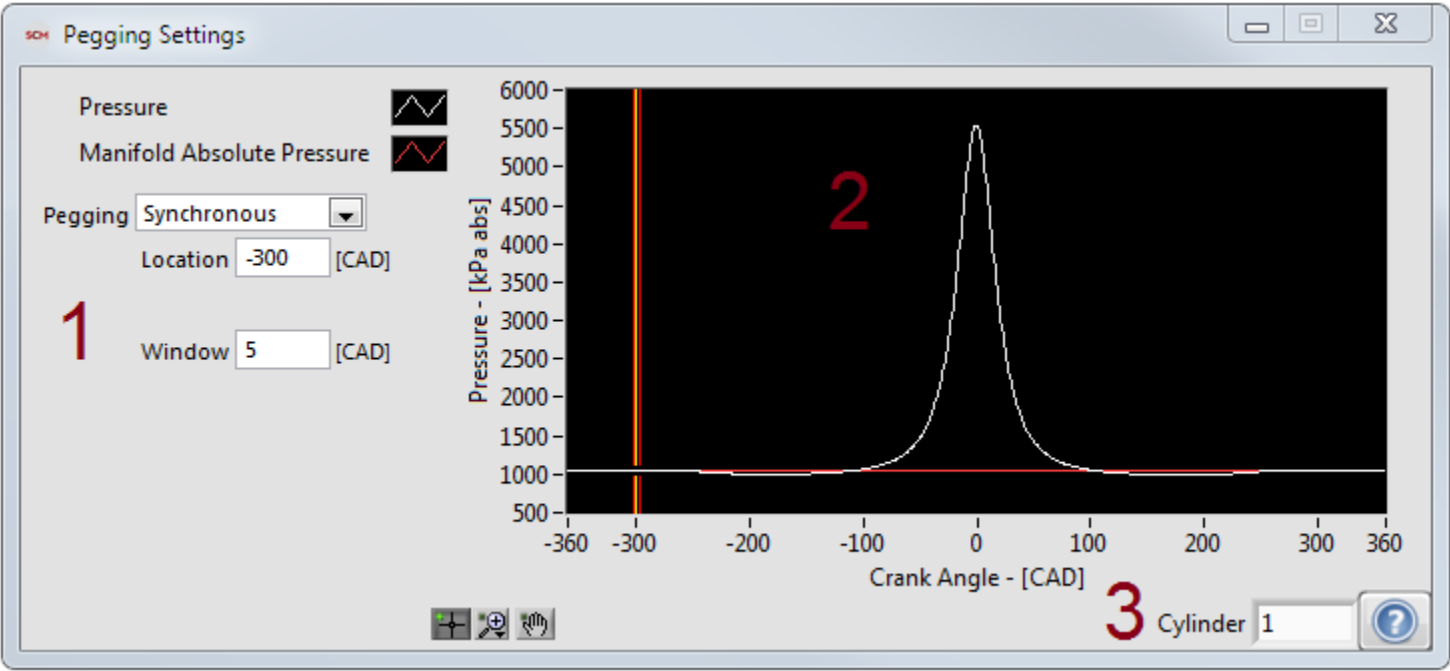
1. Detailed setup of the selected measurement.
2. Plot of current signals and windows.
3. Selection of cylinder to display.

Location	Specifies the location used to peg cylinder pressure when using constant and synchronous MAP pegging.
Pegging	Specifies the method used to peg cylinder pressure.
Pegging Pressure	Specifies the pressure used to peg cylinder pressure when using constant pegging.
Polytropic Exponent	Specifies the polytropic exponent used for polytropic pegging.
Window	The crank angle window size used to average noise in synchronous waveform measurements.

3.2.1.4 Filter Settings

The filter settings define all the filters for engine synchronous and time-based asynchronous measurements. Each measurement can be configured to a filter resource. The filter resources can be attached to a one or more measurements.
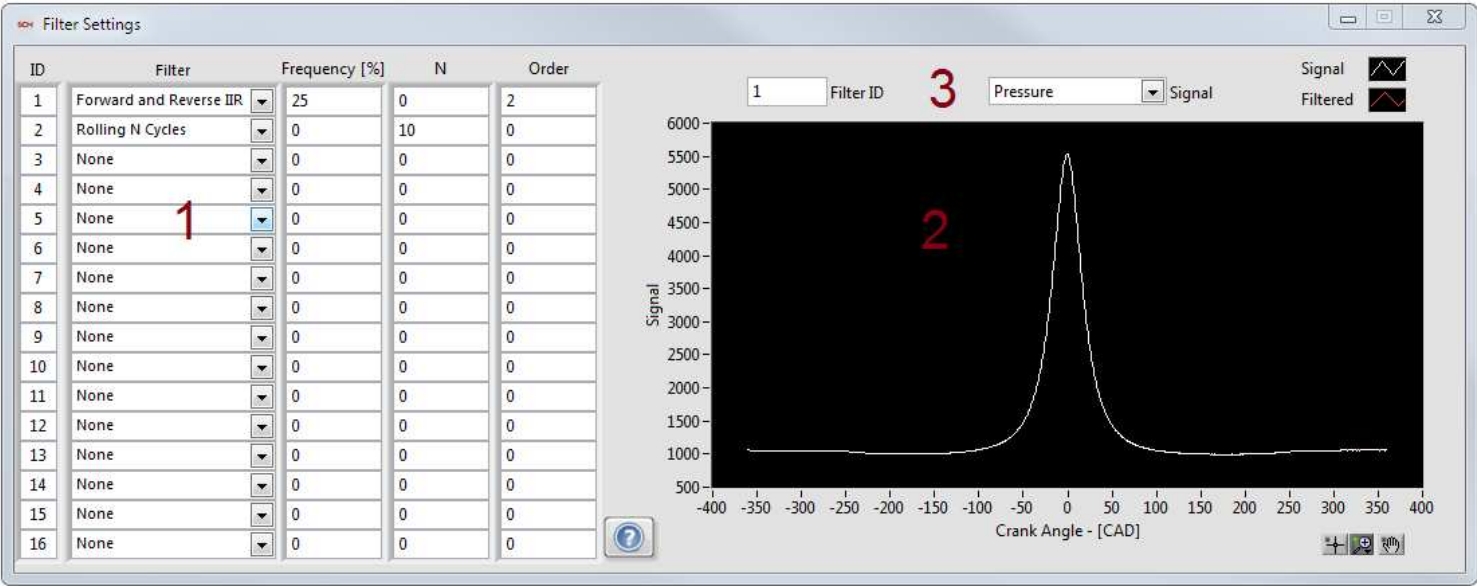
1. Detailed settings for each filter resource.
2. Plot of current signals and windows.
3. Selection of filter resource and signal to plot.

Filter	Defines the type of filter used.
Frequency	Defines the filter frequency as a percent of the nyquist frequency. This value is only valid when using FIR and IIR filters.
N	Defines the number of cycles to include in the rolling average or the number of samples to include in the boxcar average.
Order	Defines the order of the filter when using the FIR and IIR filters.

3.2.1.5 Pressure Metrics Settings

The pressure metrics settings define parameters for the pressure metrics calculation group.
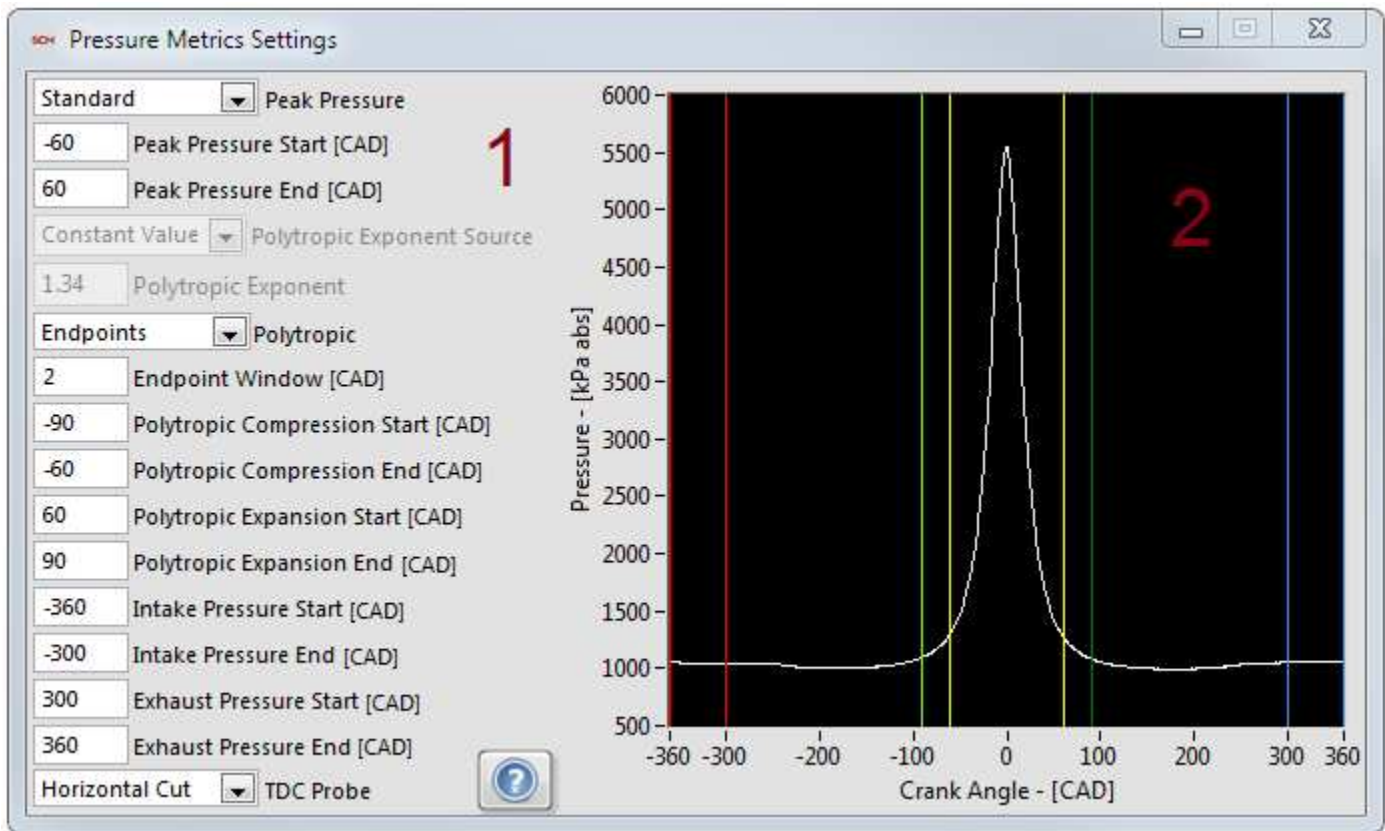
1. Detailed settings for the basic calculation group.
2. Plot of current signals and windows.

Endpoint Window	Specifies the size of the window used to average the endpoints when calculating the polytropic exponents.
Exhaust Pressure End	Specifies the end of the exhaust pressure calculation.
Exhaust Pressure Start	Specifies the start of the exhaust pressure calculation.
Intake Pressure End	Specifies the end of the intake pressure calculation.
Intake Pressure Start	Specifies the start of the intake pressure calculation.
Peak Pressure	Specifies the method used to calculate the peak pressure.
Peak Pressure End	Specifies the end of the peak pressure window.
Peak Pressure Start	Specifies the start of the peak pressure window.
Polytropic	Specifies the method used to calculate the polytropic exponents.
Polytropic Compression End	Specifies the end of the polytropic compression calculation.
Polytropic Compression Start	Specifies the start of the polytropic compression calculation.
Polytropic Expansion End	Specifies the end of the polytropic expansion calculation.

Polytropic Expansion Start   Specifies the start of the polytropic expansion calculation.
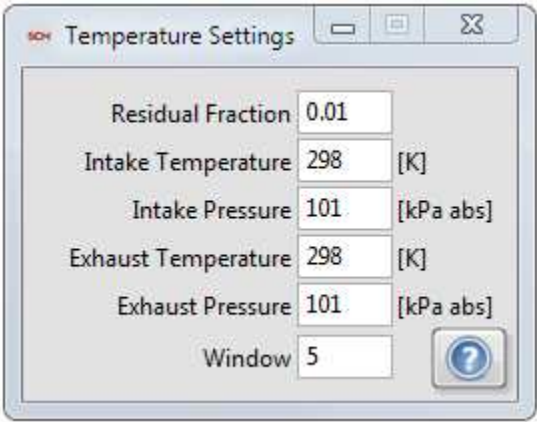
3.2.1.6 Unit Conversions Settings

The unit conversion dialog allows the user to define a set of unit conversion rules. The rules affect the tables, trends, and plots. They do not change the units of settings or results in a file.
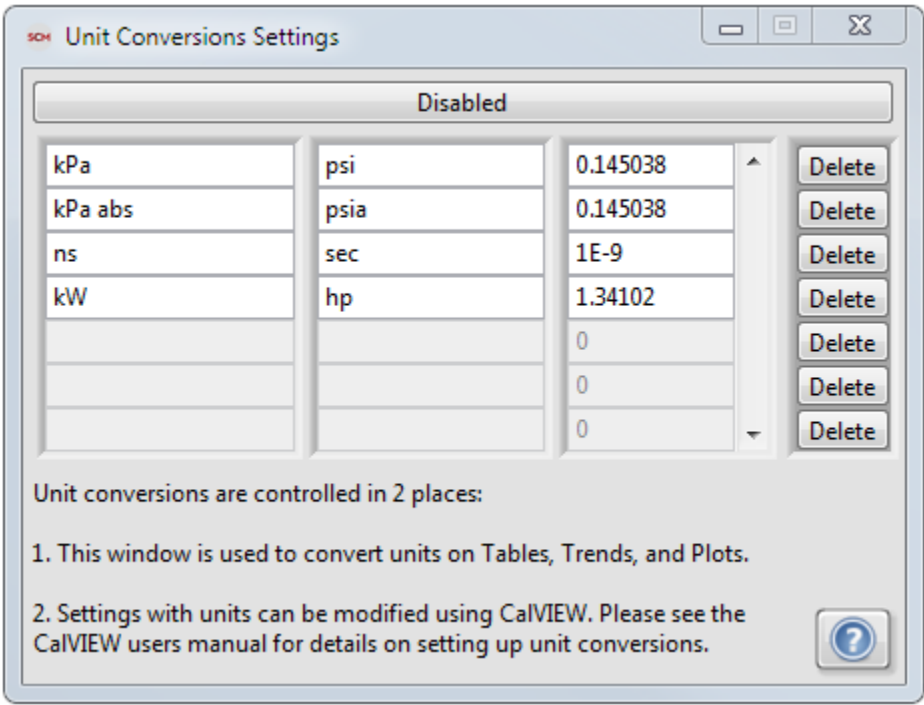
3.2.1.7 Temperature Settings

The temperature settings define how the in-cylinder temperature estimation is calculated.

Exhaust Pressure	Pressure of the intake gas at the intake valve.
Exhaust Temperature	Temperature of the exhaust gas at the exhaust valve.
Intake Pressure	Pressure of the exhaust gas at the exhaust valve.
Intake Temperature	Temperature of the intake gas at the intake valve.
Residual Fraction	Fraction of exhaust gas remaining in the combustion chamber after the exhaust event.
Window	The crank angle window size used to average noise in synchronous waveform measurements.

3.2.1.8 Heat Release Settings

The heat release settings define what settings are used for the various methods of calculating heat release.

C1c	Woschni Coefficient 1 for Compression (Default = 2.28).
C1e	Woschni Coefficient 1 for Combustion and Expansion (Default = 2.28).
C1ge	Woschni Coefficient 1 for Gas Exchange (Default = 6.18).
C2c	Woschni Coefficient 2 for Compression (Default = 0.0).
C2e	Woschni Coefficient 2 for Combustion and Expansion (Default = 0.00324).
C2ge	Woschni Coefficient 2 for Gas Exchange (Default = 0.0).
End Angle	Specifies the angle to end looking for the end of combustion.
End of Combustion	Specifies the method used to determine the end of combustion.
Heat Release	Specifies the method used to calculate heat release.
Heat Transfer	Defines the heat transfer when using the constant Heat Transfer Correlation method.
Heat Transfer Correlation	Specifies the method used to calculate the Heat Transfer Correlation.
N End	Specifies the number of samples to use when determining the end of combustion.
N Start	Specifies the number of samples to use when determining the start of combustion.
Polytropic Correlation	Specifies the method use to calculate the polytropic exponent.
PreChamber Volume	Specifies the volume of the prechamber used in dual transducer calculations.
Smoothing	Pressure waveform smoothing factor as a percent of one engine cycle.

Start Angle	Specifies the angle to start looking for the start of combustion.
Start of Combustion	Specifies the method used to determine the start of combustion.
User Heat Release VI	Specifies the file location of the user heat release VI, if used.
Wall Temperature	Specifies the Wall Temperature when using the constant Wall Temperature Profile.
Wall Temperature BDC	Specifies the Bottom Dead Center Wall Temperature when using the linear Wall Temperature Profile
Wall Temperature Profile	Specifies the method used to calculate the cylinder Wall Temperature Profile.
Wall Temperature TDC	Specifies the Top Dead Center Wall Temperature when using the linear Wall Temperature Profile
a	Defines the Polytropic Exponent Correlation "a" Value when using custom Polytropic Correlation.
b	Defines the Polytropic Exponent Correlation "b" Value when using custom Polytropic Correlation.

3.2.1.9 Knock Settings

The knock settings determine how knock is detected. The knock settings dialog provides information and displays that are helpful for calibrating the knock settings.
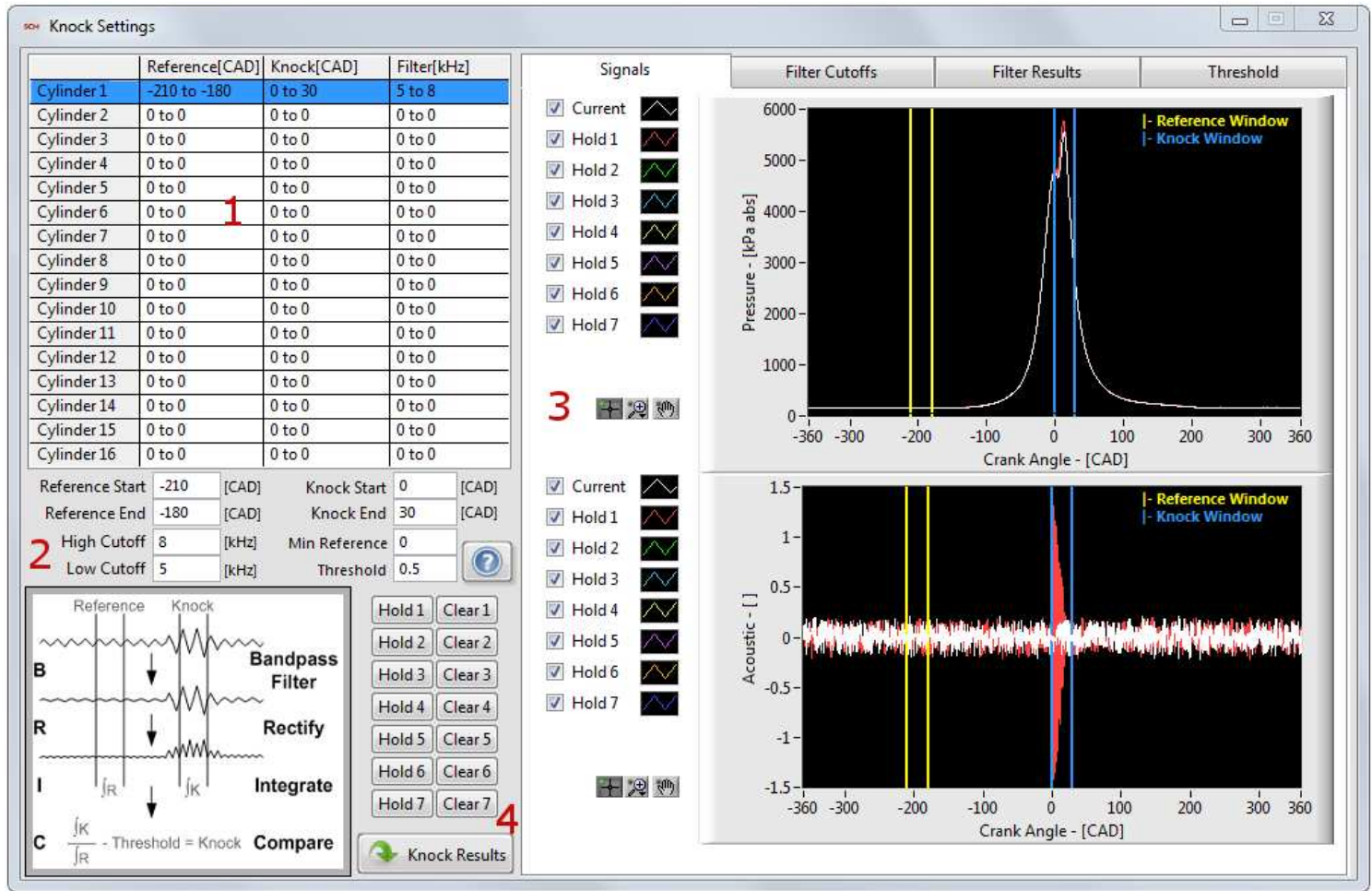
1. Summary of settings for each cylinder.
2. Detailed setup of the selected measurement.
3. Calibration setup displays.
4. Hold and clear for up to 7 cycles. Pressing the buttons captures the current waveforms for comparison.

High Cutoff Frequency	Specifies the High Cutoff Frequency of the knock filter for each cylinder.
Knock End	Specifies the crank angle to end the knock window for each cylinder.
Knock Start	Specifies the crank angle to start the knock window for each cylinder.
Low Cutoff Frequency	Specifies the Low Cutoff Frequency of the knock filter for each cylinder.
Minimum Reference	Specifies the Minimum Reference Value used to remove noise for each cylinder.
Reference End	Specifies the crank angle to end the reference window for each cylinder.
Reference Start	Specifies the crank angle to start the reference window for each cylinder.
Threshold	Specifies the knock threshold for each cylinder.

Calibrating knock is a delicate process of capturing various degrees of knock and comparing them to determine where the unacceptable level of knock occurs. Changing settings will reprocess all the held data so the new settings can be evaluated over the range of operating conditions. The process of calibrating knock starts with setting up windows for checking for knock and reference noise. The Signal page shows the current cycle of pressure data and the acoustic waveform. The knock window should be located around TDC. The reference window should be located away from noise caused by valve closings and other noisy events.
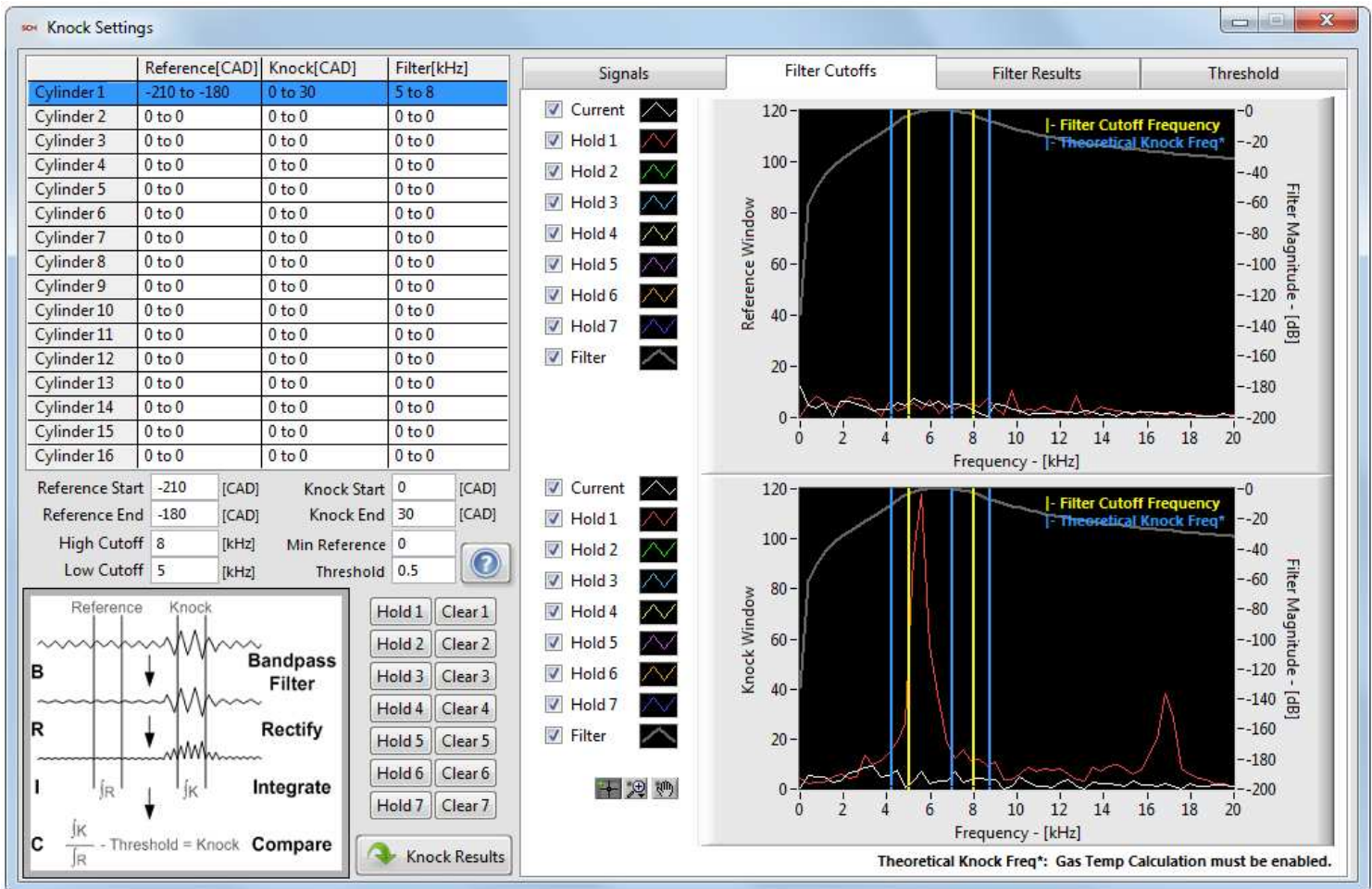
The next step in calibrating knock is to determine the knocking frequency. The frequency magnitude should be reality stable unless knocking. Therefore, the filter frequencies should include the knocking event but not other events. The filter cutoffs page displays the FFT of the for the knock and reference windows. The first three theoretical fundamental frequencies (based on cylinder bore) are calculated and displayed for reference.
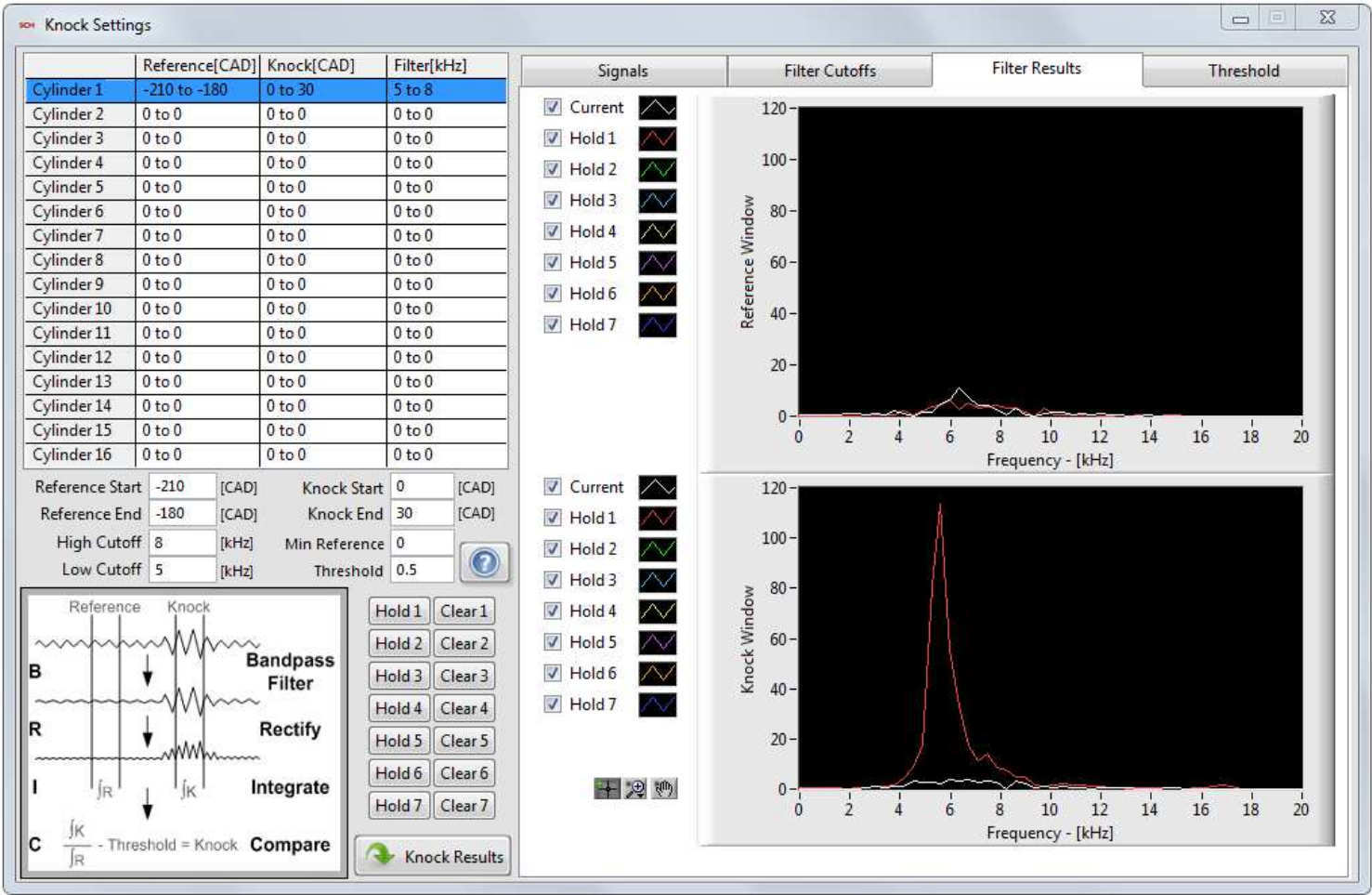
Next, the filter results for the knock and reference window are displayed on the filter results page.
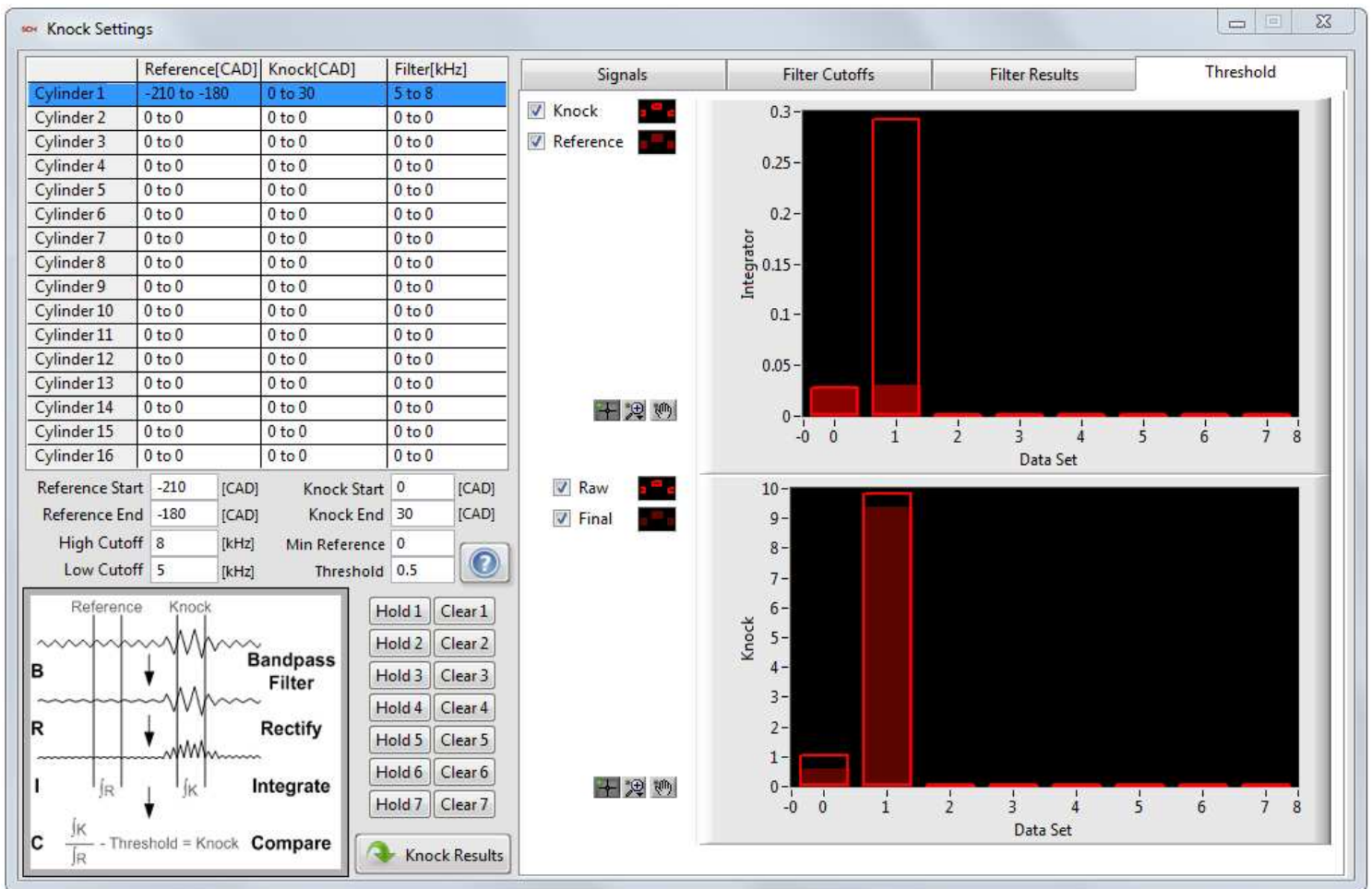
Last, the filtered window results are integrated and compared. The threshold should be set to determine where knock starts. The threshold is removed to get the final knock value. Any value above zero is considered knock. Greater knock values indicate greater levels of knock. The threshold page shows the results of the integration and the raw and final results of the comparison.

3.2.1.10 Cam Settings

The cam settings are used to calculate cam phasing. The system should be set up for each cylinder separately. The setup button analyzes the cam signal and generates an array of angles for rising and falling edges to compare to calculate the phasing. The baseline settings should be set when the phaser control is turned off or disconnected.
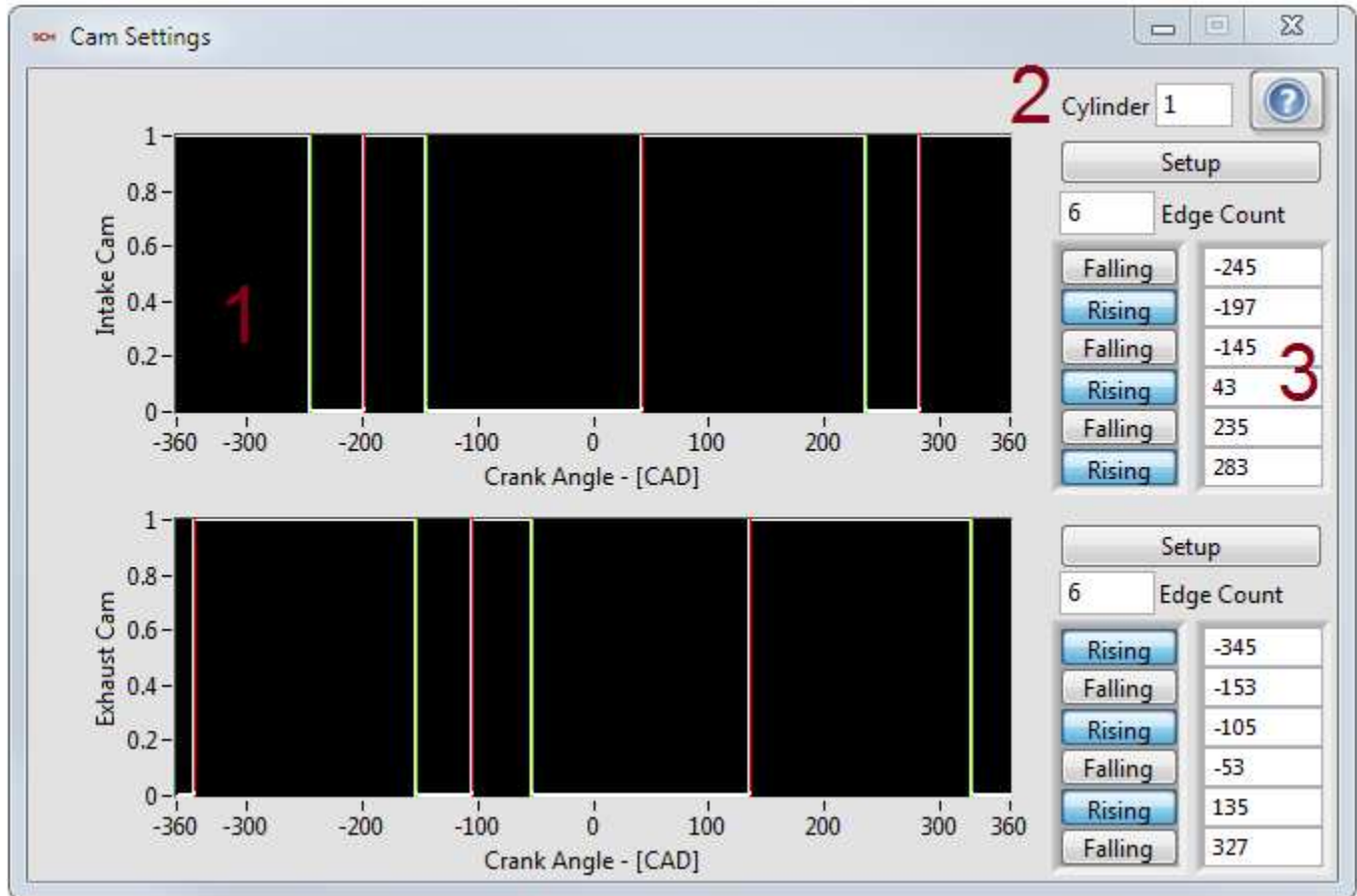
1. Plot of current signals and rising and falling edges.
2. Selection of cylinder to display.
3. Detailed setup of the selected cylinder.

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Exhaust Cam Edge Angles	Specifies the angle for each exhaust cam pulse of each cylinder.
Exhaust Cam Edge Count	Specifies the number of exhaust cam pulses for each cylinder.
Exhaust Cam Edge Directions	Specifies the direction of exhaust cam pulse for each cylinder. Each cylinders data is stored in a bit field corresponding to each pulse.
Intake Cam Edge Angles	Specifies the angle for each input cam pulse of each cylinder.
Intake Cam Edge Count	Specifies the number of intake cam pulses for each cylinder.
Intake Cam Edge Directions	Specifies the direction of intake cam pulse for each cylinder. Each cylinders data is stored in a bit field corresponding to each pulse.

3.2.1.11 Injection Settings

The injection settings define how injection waveforms are processed. The injection calculations measure starting angle, duration, and fuel flow for each injection.
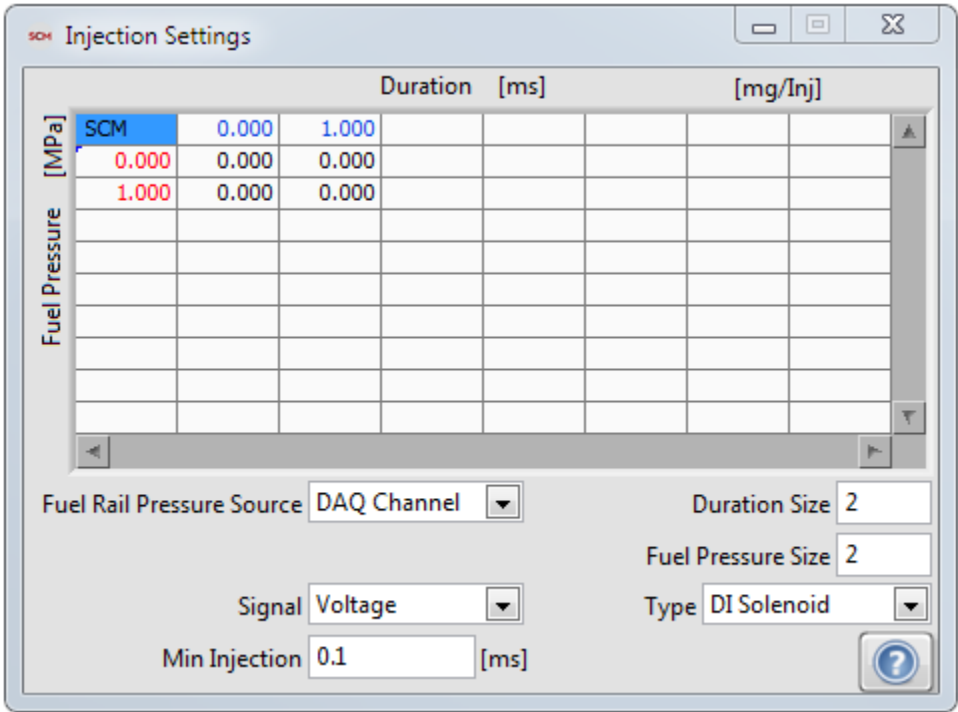
Fuel Rail Pressure	Defines the fuel rail pressure of the injectors.
Fuel Rail Pressure Source	Determines the source of the fuel rail pressure used in determining fuel flow.
Min Injection	Defines the minimum injection width.
Signal	Defines the injector signal type.
Type	Defines the injector type.
X-Fuel Pressure	Defines the X-Axis (Fuel Pressure) of the 2d injector calibration table.
Y-Duration	Defines the Y-Axis (Duration) of the 2d injector calibration table.
Z-Fuel Flow	Defines the Z-Axis (Fuel Flow) of the 2d injector calibration table.

3.2.1.12 Spark Settings

The spark setting determine how spark signals are processed. The spark calculations determine the spark angel and dwell for each spark.
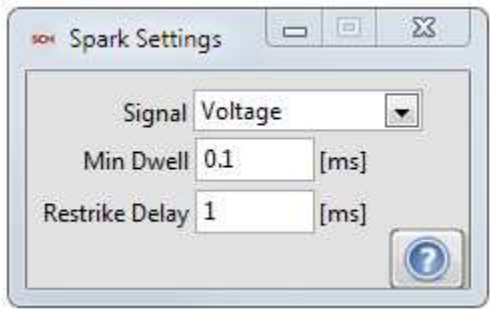
Min Dwell	Defines the minimum dwell width.
Restrike Delay	Defines the maximum restrike delay.
Signal	Defines the spark signal type.

3.2.1.13 Misfire Settings

The misfire settings determine how a misfire event is determined.
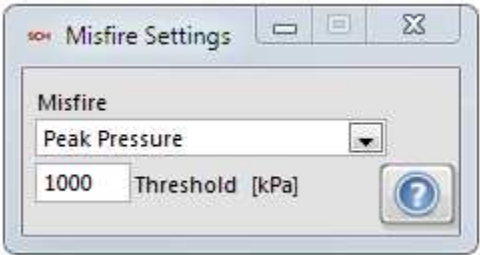
Misfire	Specifies the method to use for Misfire detection.
Threshold	Specifies the threshold used to detect a misfire. The use of the value depends on the misfire method used.

3.2.1.14 Simulation Settings

The simulation settings allow the user to control how simulated waveforms are generated. The simulation is enabled on the engine setup page.
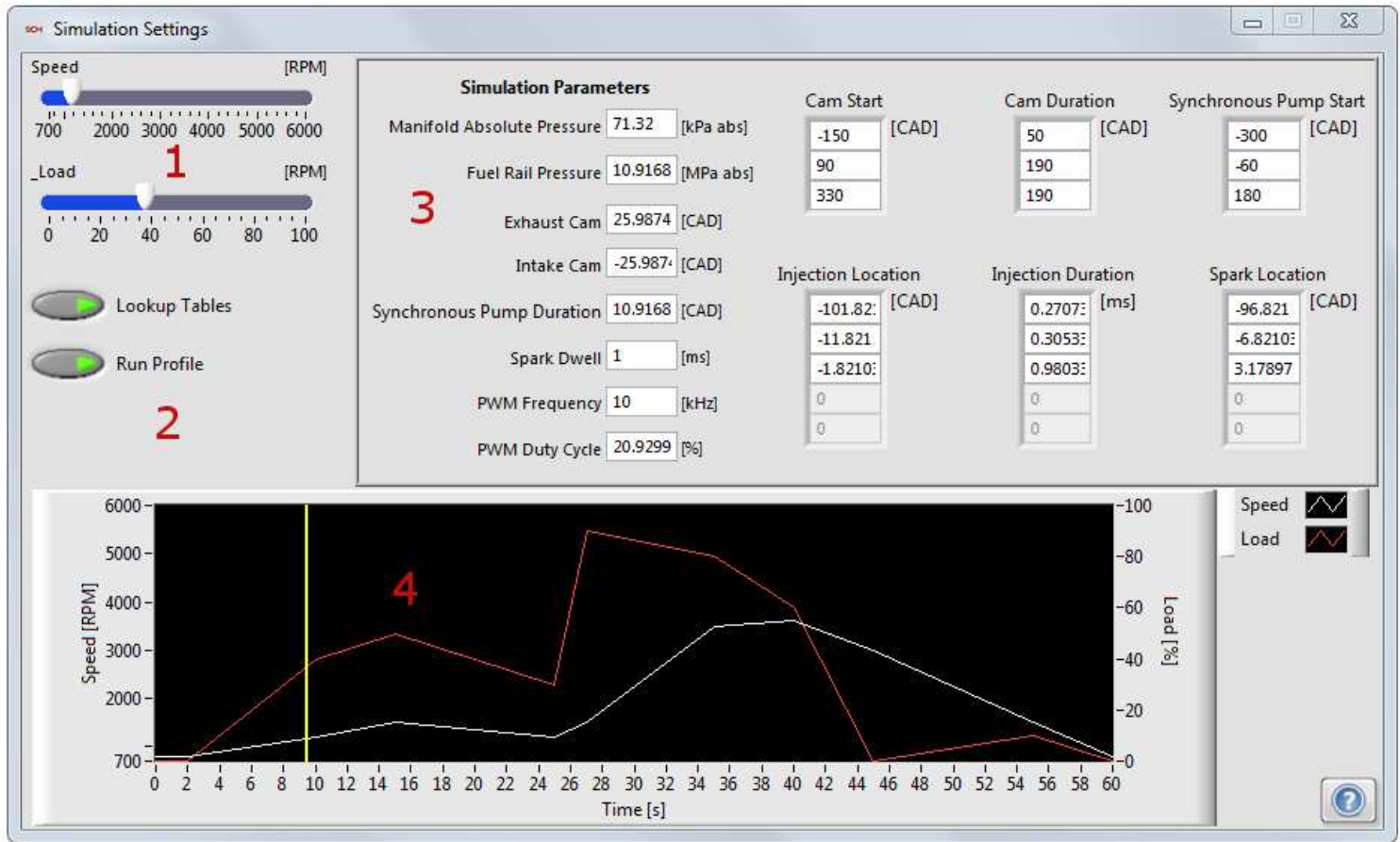
1. Speed and load settings.
2. Simulated settings mode. Lookup tables adjust detailed settings based on speed and load. Run profile runs the pre-defined profile.
3. Detailed simulation settings.
4. Pre-defined profile.

Cam Start	Specifies the simulated cam start.
Exhaust Cam	Specifies the simulated exhaust cam offset.
Fuel Rail Pressure	Specifies the simulated fuel rail pressure.
Injection Duration	Specifies the simulated injection duration.
Injection Location	Specifies the simulated injection locations
Intake Cam	Specifies the simulated intake cam offset.
Manifold Absolute Pressure	Specifies the simulated manifold absolute pressure.
PWM Duty Cycle	Specifies the simulated pulse width width measurement duty cycle.

PWM Frequency	Specifies the simulated pulse width width measurement frequency.
Spark Dwell	Specifies the simulated spark dwell.
Spark Location	Specifies the simulated spark location.
Speed	Specifies the simulated engine speed.
Synchronous Pump Duration	Specifies the simulated synchronous pump duration.
Synchronous Pump Start	Specifies the simulated synchronous pump start.

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3.2.2 File Save

3.2.2.1 Raw File Save

NI CAS Software raw files contain all of the data as it comes from the DAQ system and all of the settings entered by the user. This data can be used to generate summary data. Because all of the data is saved in a raw format, calibrations and other settings can be modified and applied the calculations when reprocessing. However, the data in the file need some processing before it is useful in most user applications. NI CAS Software contains several applications, examples, and an API for using raw data files.

Start-Stop File	Starts saving a file if currently stopped or stops saving a file if currently stopped.
Standby / Writing	Displays the state of the file writing process.
New File / Overwrite	Indicates if a new file will be written or an old file will be overwritten.
Sum + Raw	Presses the "Start-Stop File" buttons on "Raw File" and "Sum File" dialogs at the same time.
File Path	Current files path and name when saving.
Path	Location on the target system where data will be saved.
File Name	Name of saved files. "XXX" is replaced by the "File Counter" and standard data/time formats (%c) are applied to the name.
Comments	User comments added to the file.
Single / Continuous	Single - One file is written and saving stops. / Continuous - A new file is started when the previous one finishes. File Part increments by on for each file. The saving process must be stopped manually.

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File Part	Indicates the current part of a continuous multi-part save.
Size Limit	Enables a size limit on file saving and defines the maximum file size.
Time Limit	Enables a time limit on file saving and defines the maximum time.
Cycle Limit	Enables a cycle limit on file saving and defines the maximum number of cycle.
File Counter	Indicates the current file count.
Reset Counter Value	Desired value to set "File Counter" to when "Reset Counter" button is pressed.
Reset Counter	Resets the file counter to the "Reset Counter Value".
File Progress	Indicates the approximate status of the file save compared with the file limit conditions.
Process File	Contains a path to a VI on the target system that will be used to process the files after a save operation. Leave it blank to disable file processing.
File	Indicates the current file that is processing and any files waiting to be processed.
Error	Indicates any error associated with file processing.

Data/Time Format:
%X (locale-specific time)
%H (hour, 24-hour clock)
%I (hour, 12-hour clock)
%M (minute)
%S (second)
%<digit>u (fractional seconds with <digit> precision)
%p (a.m./p.m. flag)
%x (locale-specific date)
%y (year within century)
%Y (year including century)
%m (month number)
%b (abbreviated month name)
%d (day of month)
%a (abbreviated weekday name)

3.2.2.2 Summary File Save

NI CAS Software summary files contain all of the calculated results all of the settings entered by the user. The file also contains statistics on all the results. Ensemble averages are included for user reference.

Start-Stop File	Starts saving a file if currently stopped or stops saving a file if currently stopped.
Standby / Writing	Displays the state of the file writing process.
New File / Overwrite	Indicates if a new file will be written or an old file will be overwritten.
Sum + Raw	Presses the "Start-Stop File" buttons on "Raw File" and "Sum File" dialogs at the same time.
File Path	Current files path and name when saving.
Path	Location on the target system where data will be saved.
File Name	Name of saved files. "XXX" is replaced by the "File Counter" and standard data/time formats (%c) are applied to the name.
Comments	User comments added to the file.
Single / Continuous	Single - One file is written and saving stops. / Continuous - A new file is started when the previous one finishes. File Part increments by on for each file. The saving process must be stopped manually.
File Part	Indicates the current part of a continuous multi-part save.
Size Limit	Enables a size limit on file saving and defines the maximum file size.

Time Limit	Enables a time limit on file saving and defines the maximum time.
Cycle Limit	Enables a cycle limit on file saving and defines the maximum number of cycle.
File Counter	Indicates the current file count.
Reset Counter Value	Desired value to set "File Counter" to when "Reset Counter" button is pressed.
Reset Counter	Resets the file counter to the "Reset Counter Value".
File Progress	Indicates the approximate status of the file save compared with the file limit conditions.
Process File	Contains a path to a VI on the target system that will be used to process the files after a save operation. Leave it blank to disable file processing.
File	Indicates the current file that is processing and any files waiting to be processed.
Error	Indicates any error associated with file processing.

Data/Time Format:
%X (locale-specific time)
%H (hour, 24-hour clock)
%I (hour, 12-hour clock)
%M (minute)
%S (second)
%<digit>u (fractional seconds with <digit> precision)
%p (a.m./p.m. flag)
%x (locale-specific date)
%y (year within century)
%Y (year including century)
%m (month number)
%b (abbreviated month name)
%d (day of month)
%a (abbreviated weekday name)

3.2.3 Status

3.2.3.1 Engine

The engine status display shows the current speed of the engine. It also shows the running time and engine cycle.
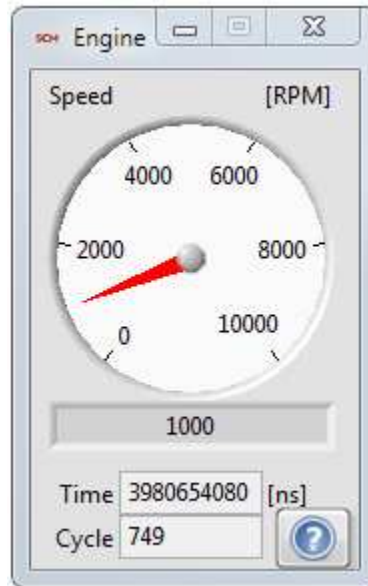
3.2.3.2 Resources

The resources display shows the status of the system hardware resources.
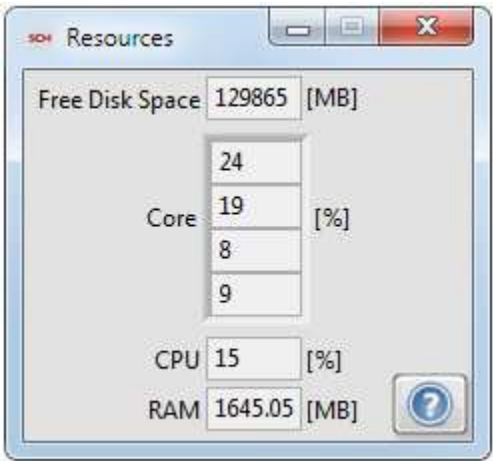
Free Disk Space	Free Space on the C Drive
Core	CPU use for each CPU core (RT only)
CPU	Average system CPU use (RT only)
RAM	Available system RAM (RT only).

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3.2.3.3 EPT

The EPT (engine position tracking) status display indicates the state of the encoder tracking. This function is only available when using an FPGA.
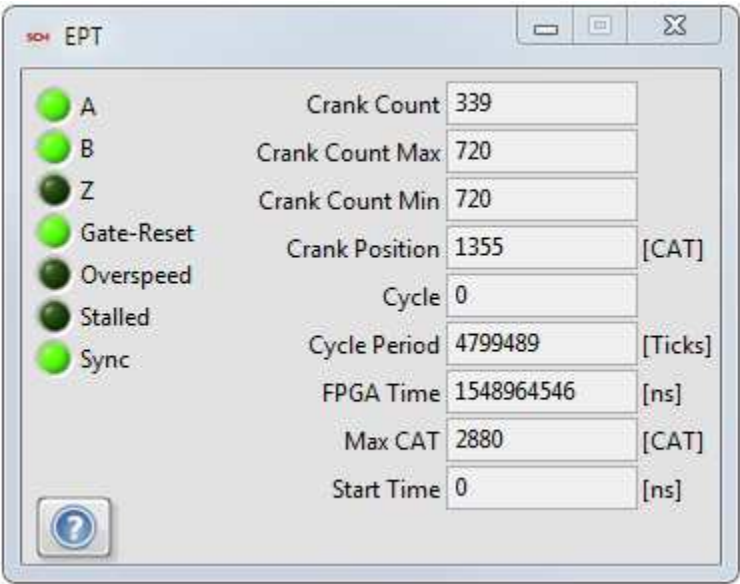
A	Indicates the state of the encoder A signal.
B	Indicates the state of the encoder B signal.
Crank Count	Indicates the current crank count of the engine position tracking system.
Crank Count Max	Indicates the maximum crank count observed after starting the engine position tracking system.
Crank Count Min	Indicates the minimum crank count observed after starting the engine position tracking system.
Crank Position	Indicates the current position of the engine position tracking system.
Cycle	Indicates the current cycle after starting the engine position tracking system.
Cycle Period	Indicates the current cycle period measured by the engine position tracking system.
FPGA Time	Indicates the current FPGA timestamp.
Gate-Reset	Indicates the state of the encoder Gate/Reset signal.
Max CAT	Indicates the maximum crank angle ticks of the engine position tracking system.
Overspeed	Indicates an overspeed state of the engine position tracking system.
Stalled	Indicates a stalled state of the engine position tracking system.
Start Time	Indicates the start time of the current DAQ sampling task according to the FPGA timestamp.
Sync	Indicates a synchronized state of the engine position tracking system.
Z	Indicates the state of the encoder Z signal.

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3.2.3.4 Execution

The execution status display indicates execution time of each processing and calculation step. The calculations can be enabled or disabled using Calculations.vi.
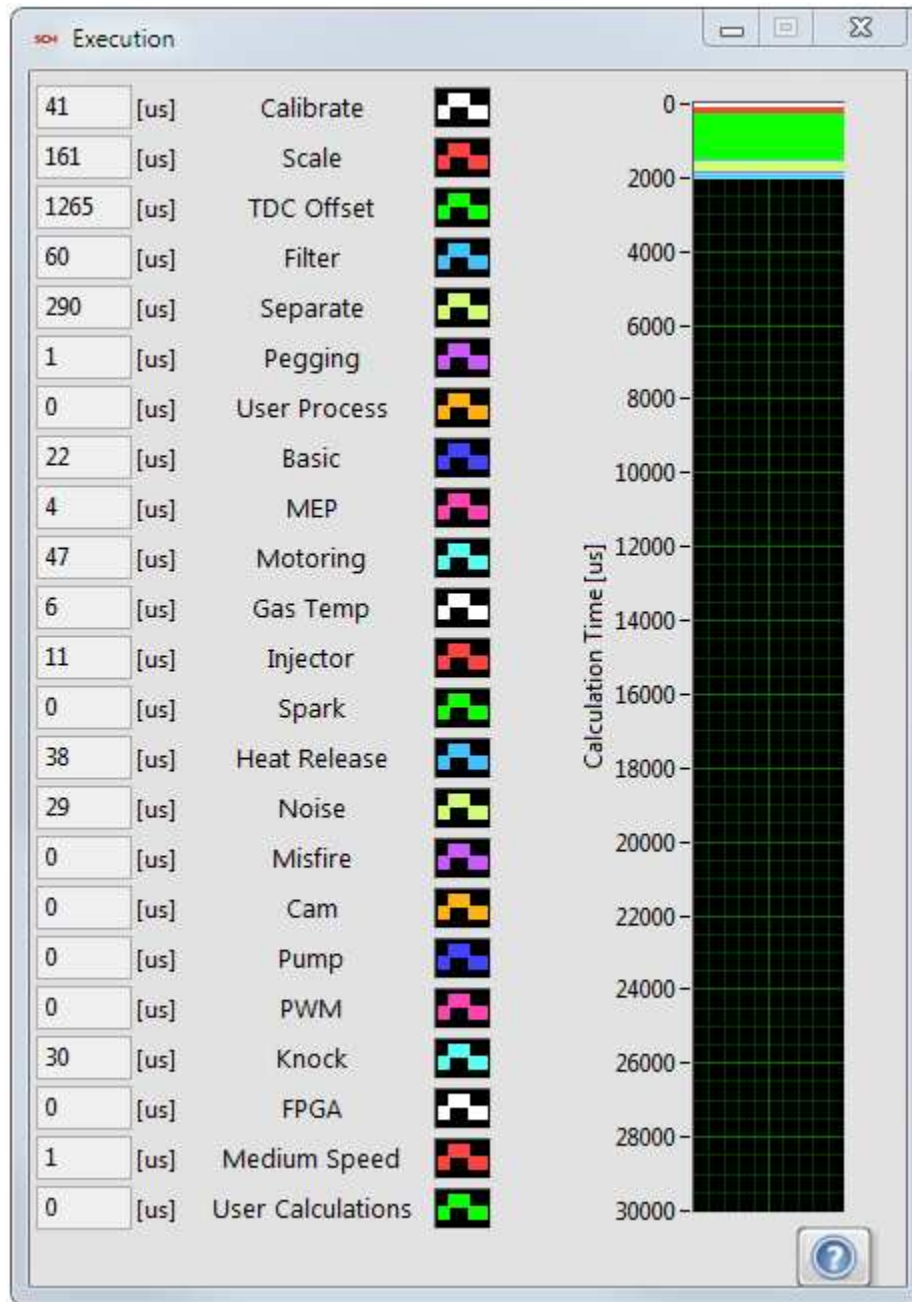
1. Calculation Time - Calculation time for each processing or calculation step.
2. Name and Color - Name and color of the processing or calculation step.
3. Calculation Time - Graphical representation of calculation time. The plot maximum is the maximum allotted time available to finish the calculations.

3.2.3.5 Buffer

The buffer status display indicates the state of the NI CAS Software buffers. The NI CAS Software buffers should not overflow under normal operation. Each buffer is used in a different part of the system.
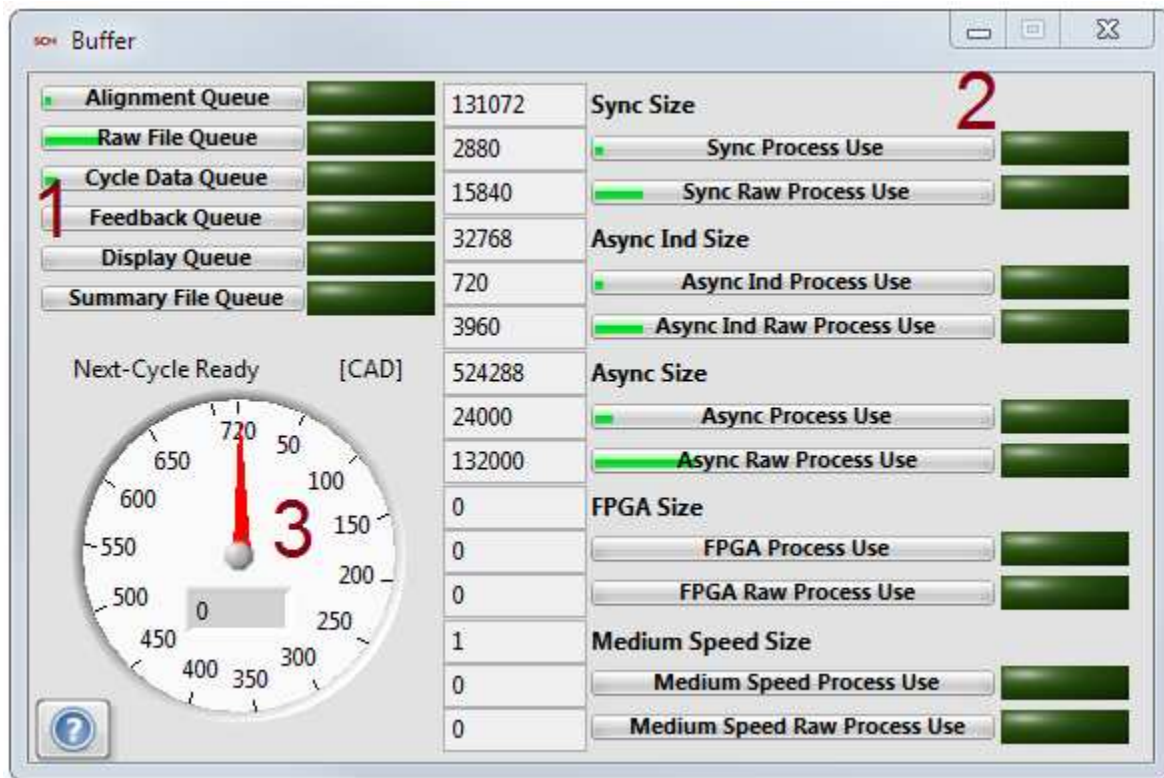
1. Buffer Summary - Each buffer holds and delivers data to a different part of the NI CAS Software.
2. Alignment and Raw Summary - The alignment and raw file buffers are many smaller buffers to hold data from different sources.
3. Next-Cycle Control Data Ready Angle - The estimated angle where next cycle results are available.

The Alignment and Raw buffers gather and hold data from the DAQ system and waits for the desired number of cycles or data to become available. The data is then distributed to other functions waiting on it. Each source of data writes the data to its own smaller buffer. The sizes of these buffers is determined by the maximum sample rate calculated from the engine speed and sample resolution or the sample frequency.

Next-Cycle control data is handed off to the user program where it can be used for whatever control strategy needs it. Data for processing real-time results is passed to the processing code where it performs all the required calculations and hands the results to the display and summary file functions.

The raw data streaming has direct access to the alignment buffers and and pulls the buffers directly to disk.
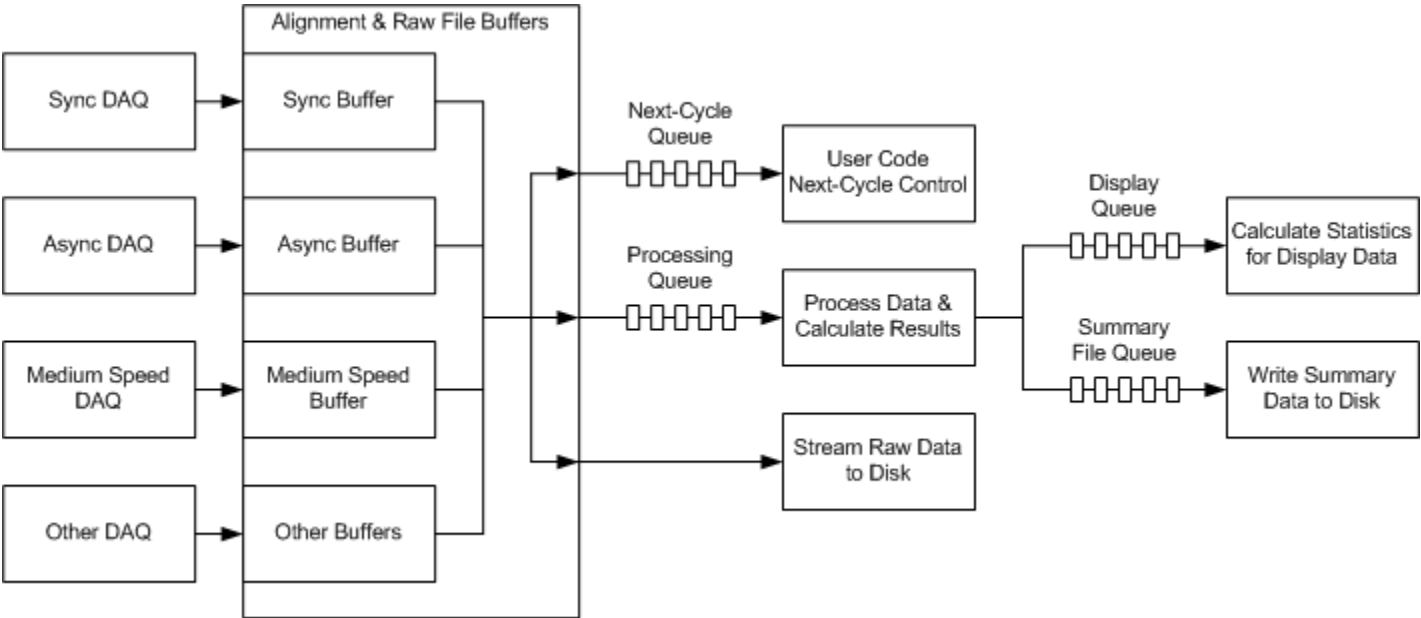
3.2.3.6 Loop

The loop status display indicates execution status of each NI CAS Software loop.

1. Loop Count - Shows the current iteration of the specified loop.
2. Loop Period - Shows the current period of the specified loop.
3. Loop Time - Shows the current execution time of the specified loop.

3.2.3.7 Error

The error status display shows an error and warning message for each loop in the NI CAS Software. The errors are accompanied with an error number and an error message. An new error state will cause the window to open.
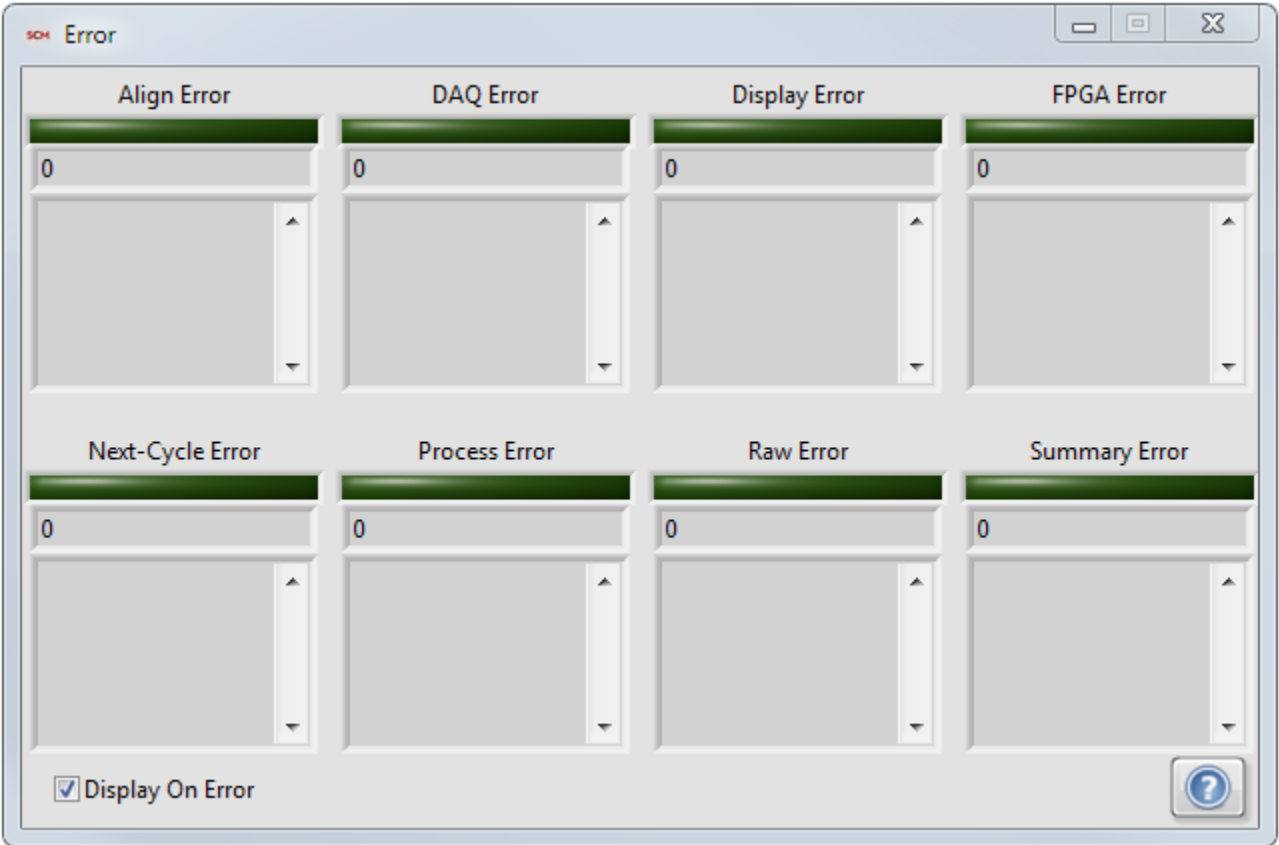
3.3 Results

3.3.1 X-Axis

All plots using "Crank Angle" as the X-axis can be modified collectively by using the plot scaling tool at the top of the "Plots" tab. The plot scaling tool contains several preset values that are commonly used to look at data, as well as a custom setting which can be used to enter values not included in the presets.
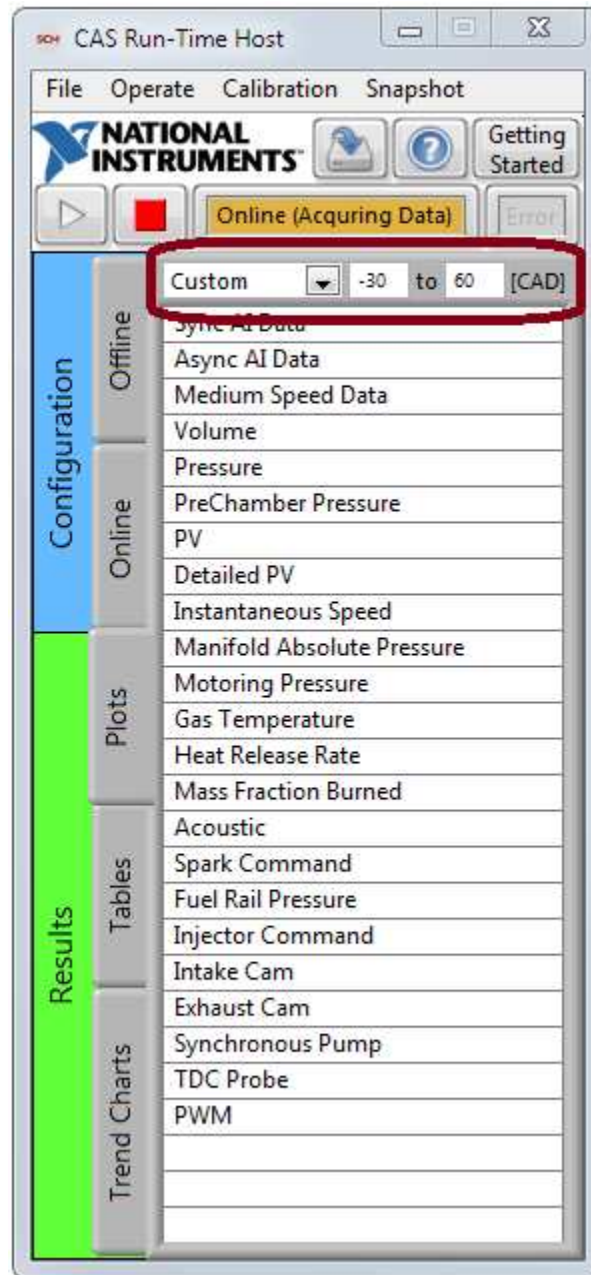
3.3.2 Plots

Plots display data in array form. The NI CAS Software contains several different typed of plots that are used for different kinds of data. Plots using "Crank Angle" as the x-axis have global settings using the X-Axis controls. Most plots are resizable by dragging the corner or side of the window.
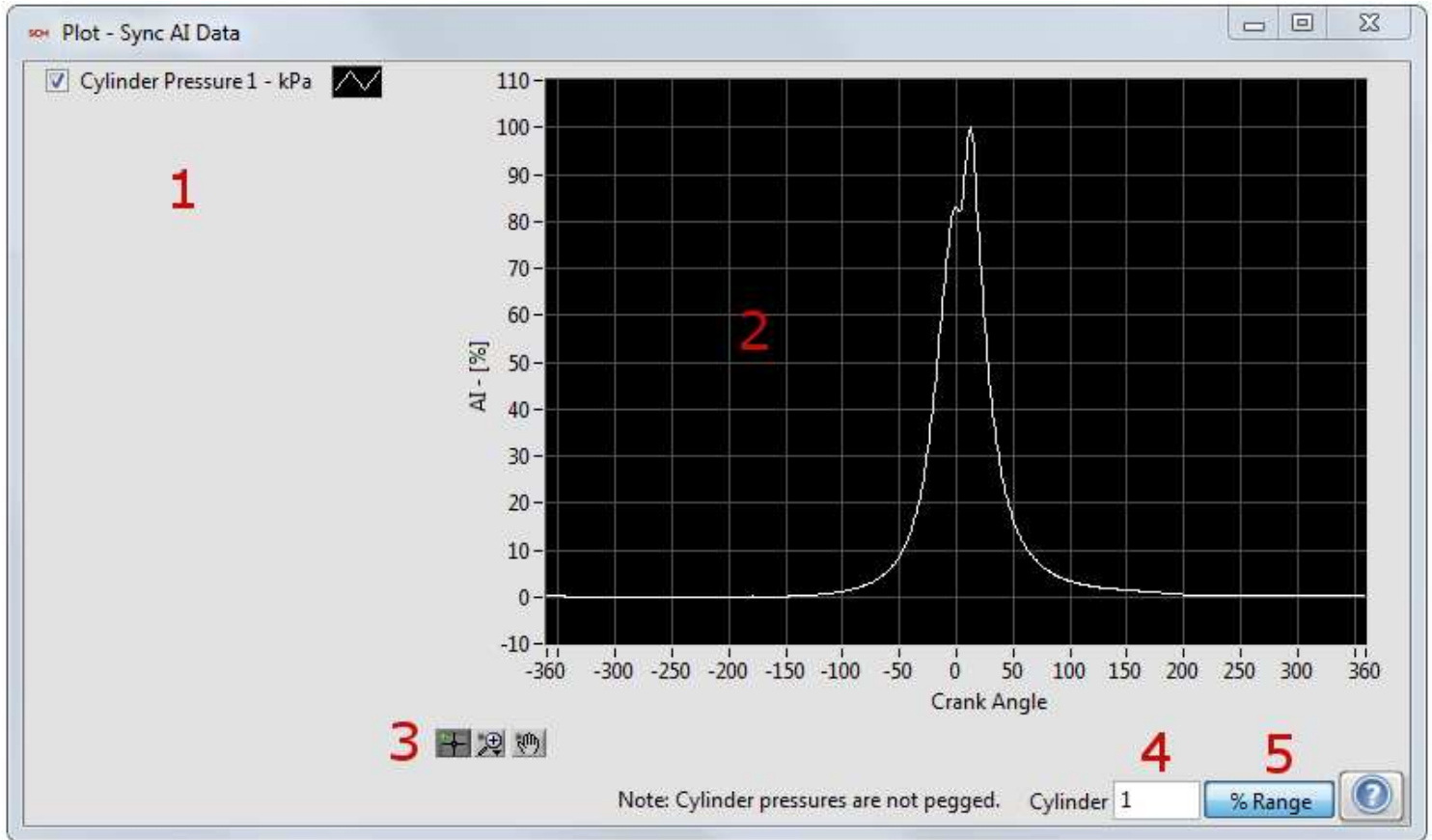
This type of plot displays analog results for a single cylinder and a single cycle of data at a time.
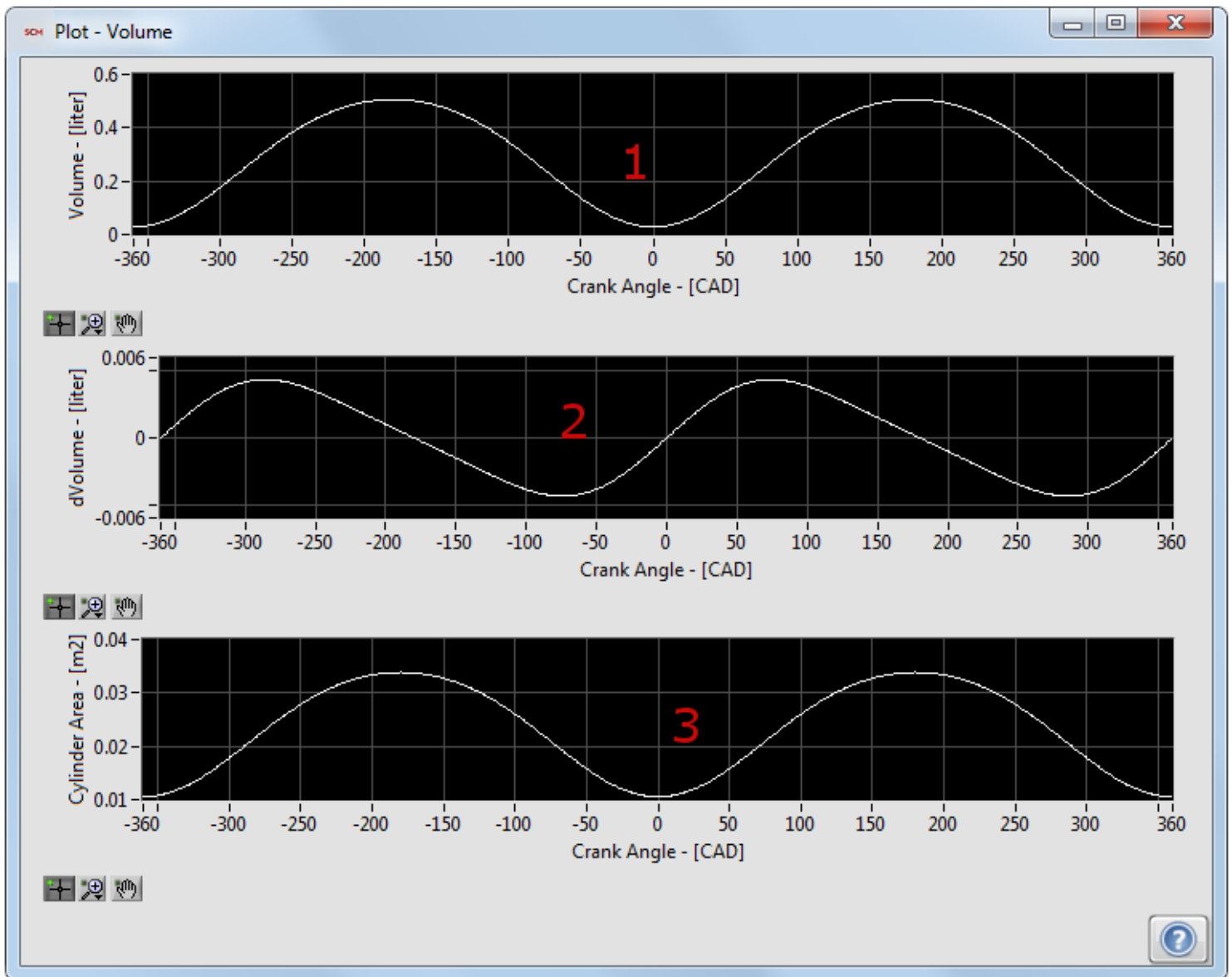
1. Plot Legend - Displays plot names and units with the ability to turn off a plot.
2. Plot Data - Data display area.
3. Plot Controls - Controls for controlling zoom and cursors.
4. Cylinder Selection - Select the cylinder to display.
5. Y-Axis mode - Select between using absolute units or % of range for the Y-axis.
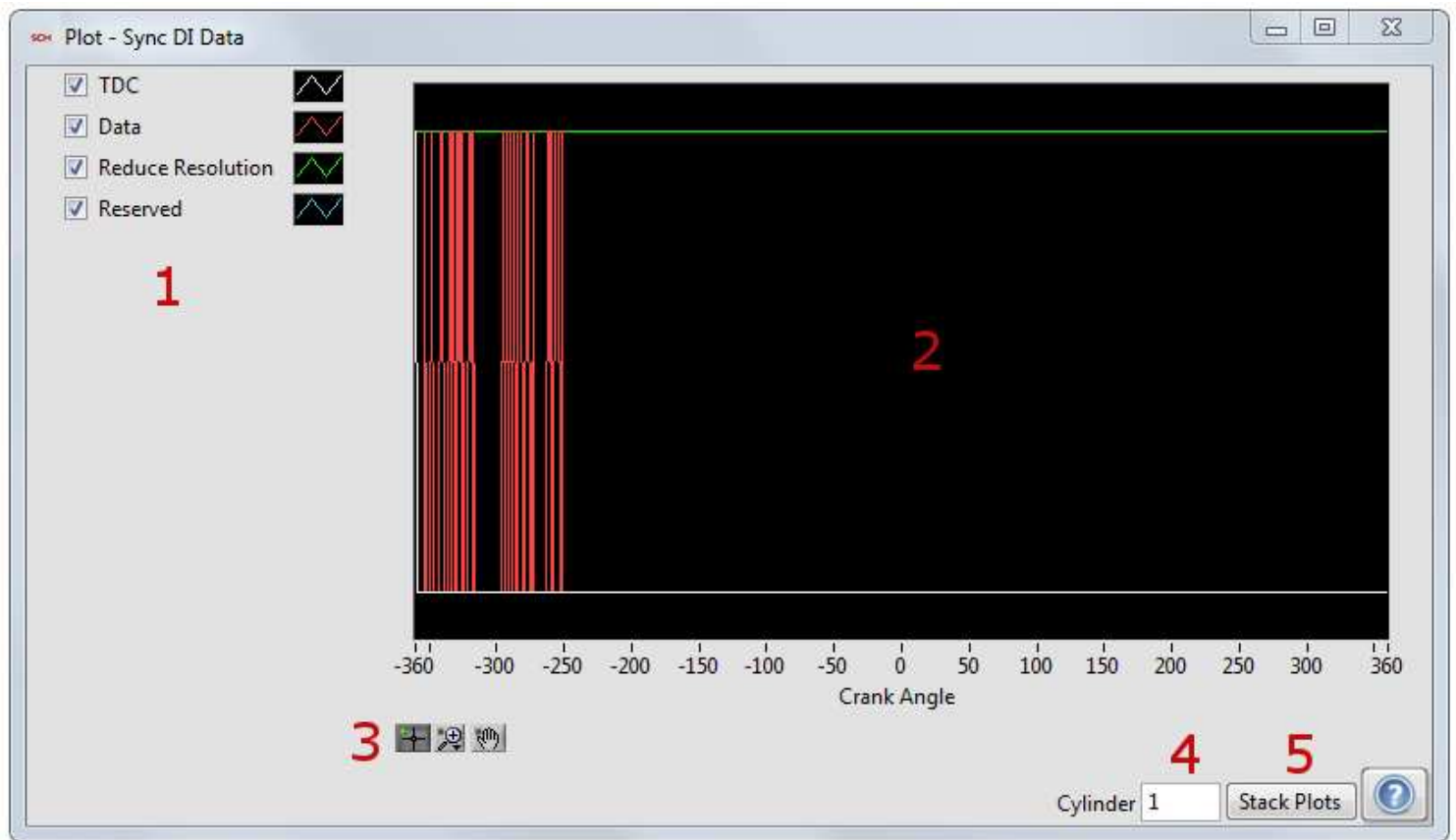
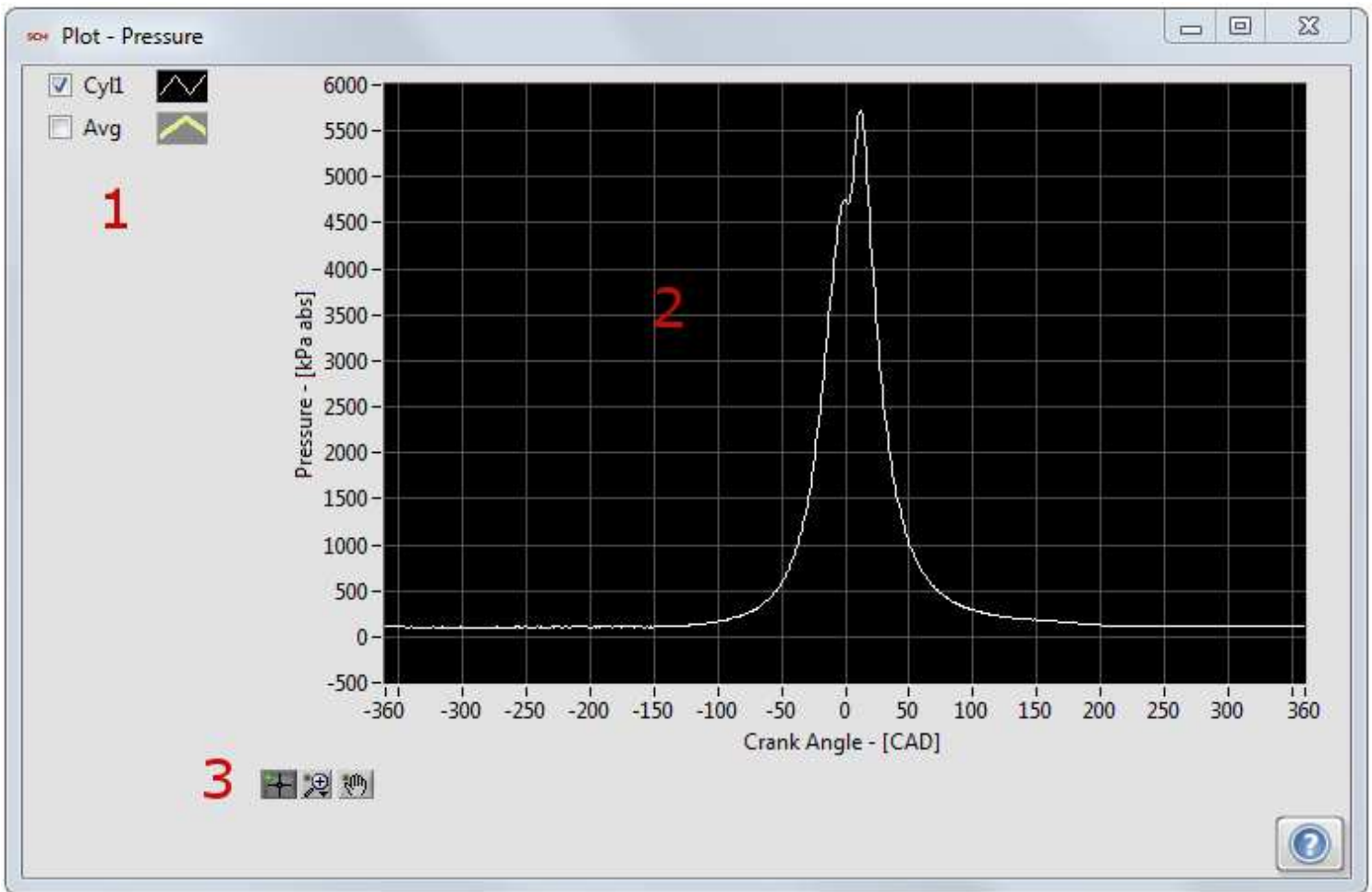This type of plot displays digital results for a single cylinder of data at a time.

1. Plot Legend - Displays plot names with the ability to turn off a plot.
2. Plot Data - Data display area.
3. Plot Controls - Controls for controlling zoom and cursors.
4. Cylinder Selection - Select the cylinder to display.
5. Y-Axis mode - Select between using a separate or combined Y-axis.

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This plot displays the results of the volume calculations or loading a volume file.

1. Volume - Cylinder volume as a function of crank angle.
2. dVolume - Differential cylinder volume as a function of crank angle.
3. Cylinder Area - Cylinder, head, and piston area as a function of crank angle.

This type of plot displays the results of a specific type of signal for all the cylinders and engine average for a single cycle.

1. Plot Legend - Displays plot names and units with the ability to turn off a plot.
2. Plot Data - Data display area.
3. Plot Controls - Controls for controlling zoom and cursors.
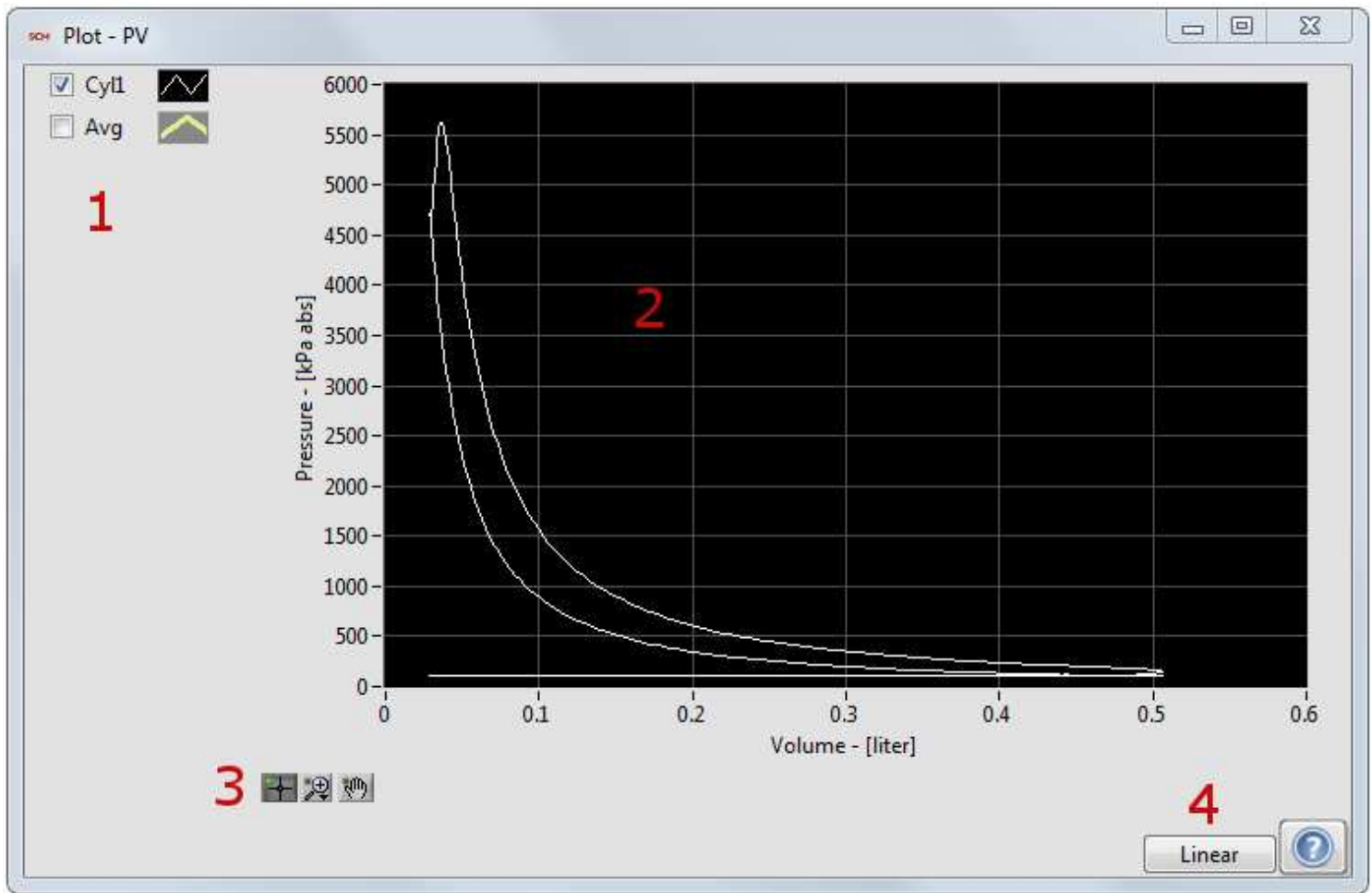
This plot displays the pressure vs. volume for all the cylinders and engine average for a single cycle.

1. Plot Legend - Displays plot names and units with the ability to turn off a plot.
2. Plot Data - Data display area.
3. Plot Controls - Controls for controlling zoom and cursors.
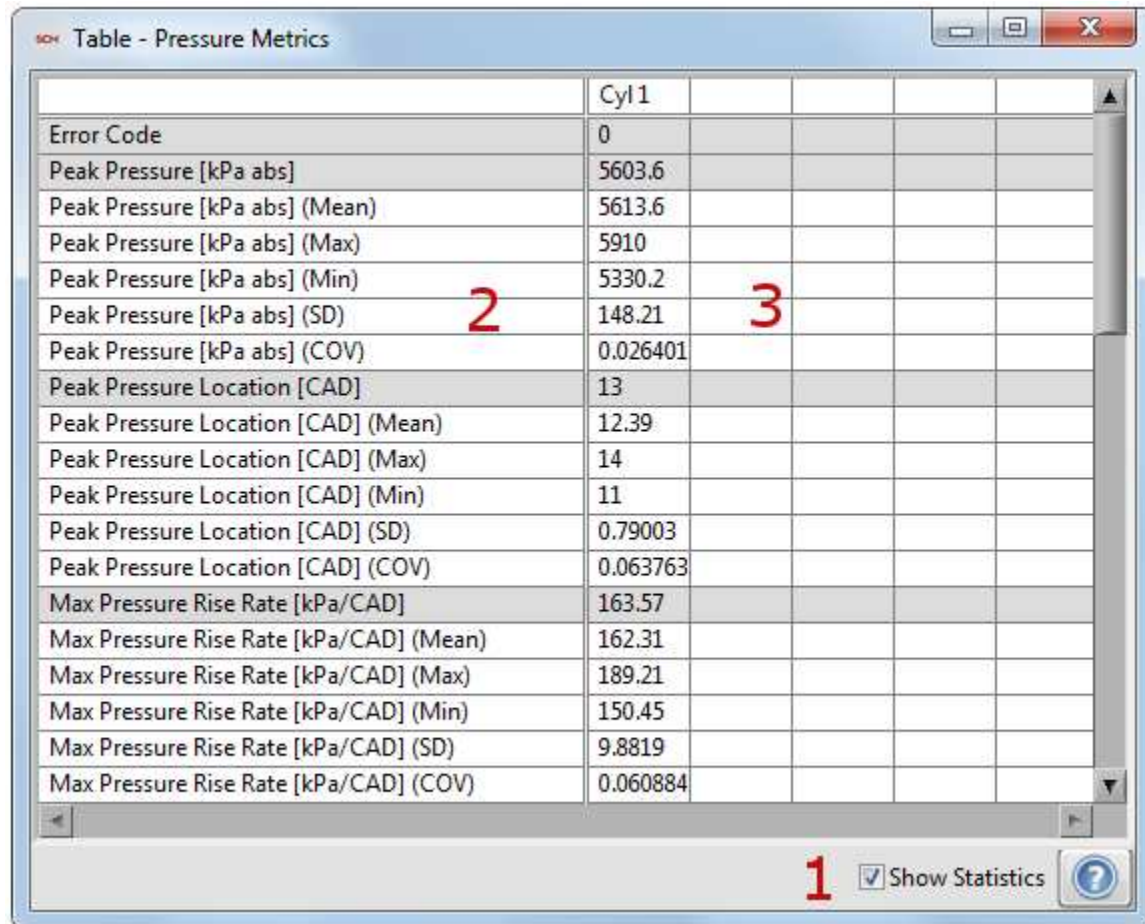4. Axis - Changes the axis to a log or linear scale.
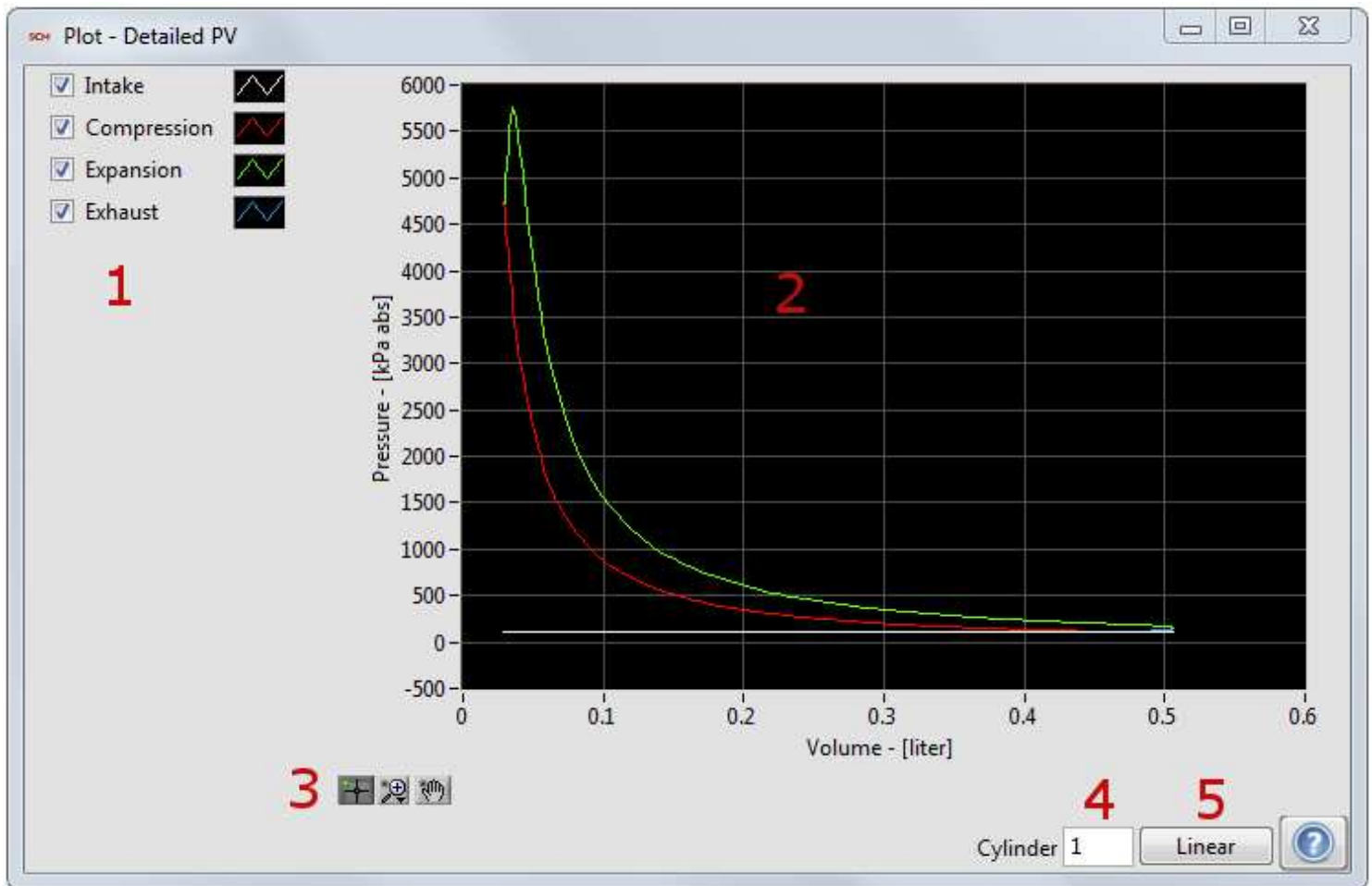
This plot displays the pressure vs. volume for a single cylinder and a single cycle.

1. Plot Legend - Displays the name and color for each stroke.
2. Plot Data - Data display area.
3. Plot Controls - Controls for controlling zoom and cursors.
4. Cylinder Selection - Select the cylinder to display.
5. Axis - Changes the axis to a log or linear scale.

3.3.3 Tables

Tables contain all of the calculated values and rolling statistics for each result. The results are grouped by calculation group that can be turned on or off. See Calculations.vi to turn or off the calculation groups.
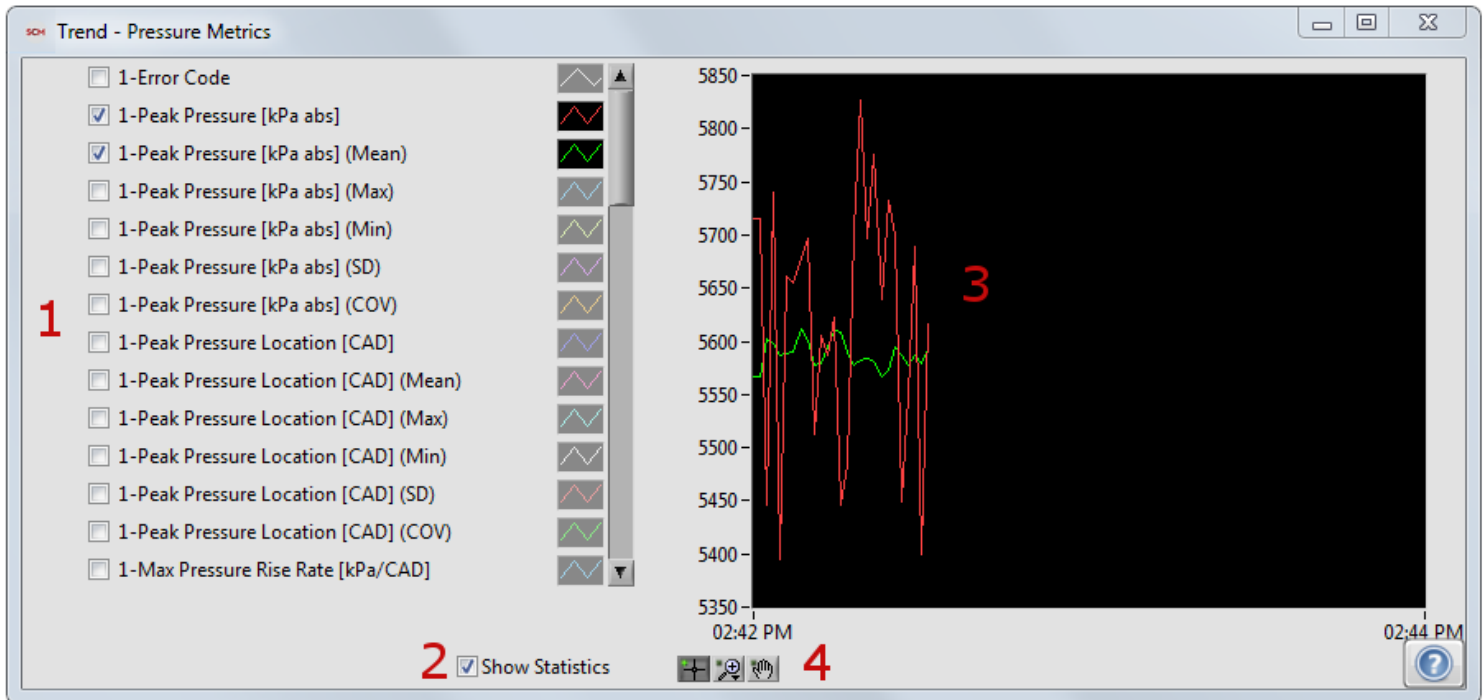

1. Show Statistics - Turns on or off rows of statistics.
2. Parameter - A list of parameters calculated by the specific calculation group.
3. Values - Calculation results for each cylinder and the engine average for multi-cylinder engines.

3.3.4 Trend Charts

Trend charts contain a history of all the calculated values and rolling statistics. The trend chart captures the current values at a fixed rate. Therefore, they are good for looking at global trends and not for individual cycle events. The results are grouped by calculation group that can be turned on or off. See Calculations.vi to turn or off the calculation groups.

1. Parameter - A list of parameters calculated by the specific calculation group.
2. Show Statistics - Turns on or off rows of statistics.
3. Values - History of calculated results.
4. Plot Controls - Controls for controlling zoom and cursors.

4. Processing and Calculations

4.1 Cylinder Volume

Cylinder volume is calculated using the following equation for the typical crank-slider mechanism (no wrist-pin offset)[1,2] :

$$s_{max} = a + l$$

$$s = a * \cos(\theta) + \sqrt{l^2 - (a * \sin(\theta))^2}$$

$$V = V_c + \left(\frac{\pi * B^2}{4}\right) * \left((a + l) - \left(a * \cos(\theta) + \sqrt{l^2 - (a * \sin(\theta))^2}\right)\right)$$

$$A = A_h + A_c + (\pi * B) * \left((a + l) - \left(a * \cos(\theta) + \sqrt{l^2 - (a * \sin(\theta))^2}\right)\right)$$

For engines requiring a wrist-pin offset, the following geometry calculations are used:

$$s_{max} = \sqrt{(a + l)^2 - x^2}$$

$$s = a * \cos(\theta) + \sqrt{l^2 - (a * \sin(\theta) - x)^2}$$

$$V = V_c + \left(\frac{\pi * B^2}{4}\right) * \left(\left(\sqrt{(a + l)^2 - x^2}\right) - \left(a * \cos(\theta) + \sqrt{l^2 - (a * \sin(\theta) - x)^2}\right)\right)$$

$$A = A_h + A_c + (\pi * B) * \left(\left(\sqrt{(a + l)^2 - x^2}\right) - \left(a * \cos(\theta) + \sqrt{l^2 - (a * \sin(\theta) - x)^2}\right)\right)$$

where:
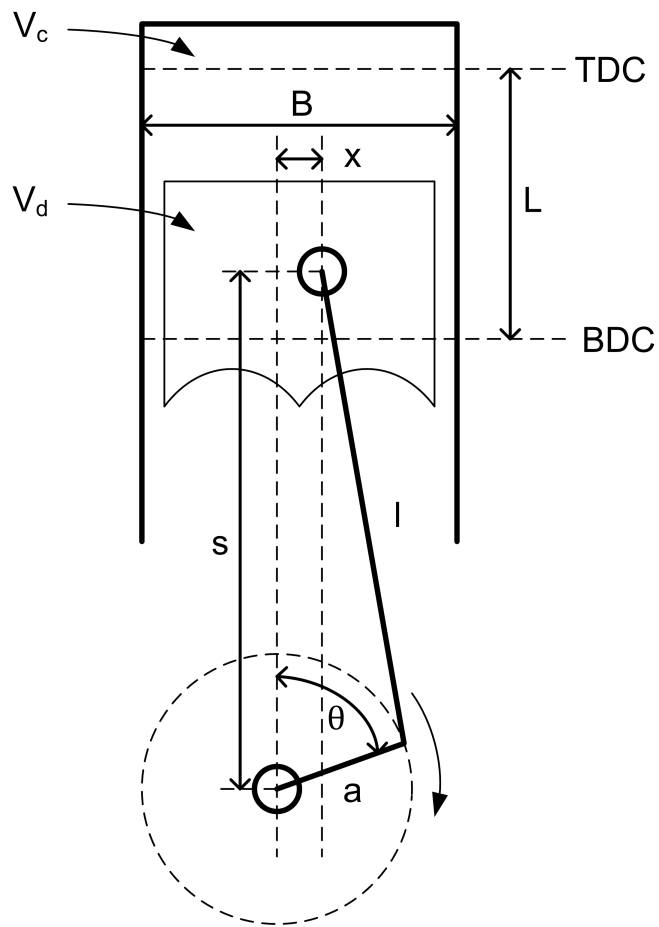
1. Heywood, J. B., Internal Combustion Engine Fundamentals. McGraw Hill, Inc., New York, NY. 1988.
2. Stone, R., Introduction to Internal Combustion Engines, 3rd Edition. Copyright Richard Stone, 1999.

4.2 Waveform Filters

Four different filter types with customizable parameters can be used to remove unwanted noise from the synchronous and asynchronous signals: Boxcar, Rolling N Cycles, Forward and Reverse IIR, and FIR Filter with Rollback.

4.2.1 Boxcar

The 'Boxcar' filter requires 'N' points for input. This filter, also known as a 'moving average,' is a very simple FIR filter which smoothes a signal by 'marching' through the waveform and averaging 'N' points before and after each given point (including the point itself).

4.2.2 Rolling N Cycles

The 'Rolling N Cycles' filter requires 'N' cycles for input. This filter is an ensemble average of the last 'N' consecutive cycles, as shown in the following equation:

$$\bar{F}_x = \frac{1}{N} \sum_i^N F_{x\,i}$$

Note: The 'Rolling N Cycles' filter tends to be resource intensive, scaling with the number of cycles used.

4.2.3 Forward and Reverse IIR

The 'Forward and Reverse Infinite Impulse Response (IIR)' filter requires filtering frequency (lowpass) and filter order inputs. The Butterworth filtering method is used, with a sampling frequency of 200 Hz. The filter order dictates the response of the signal roll-off, where a higher order has a steeper roll-off.

This filter is passed in both forward and reverse directions to avoid shifting the phase of the waveform.

4.2.4 FIR Filter with Rollback

The 'FIR Filter with Rollback' requires filtering frequency (lowpass) and filter order inputs. This filter is a backward-looking 'moving average' which smoothes a signal by 'marching' through the waveform and averaging 'N - 1' points before each given point (including the point itself). In this case, 'N' is also the filter order.

This filter method shifts the phase of the waveform N/2 points to the right, therefore rollback is necessary to correct the phase of the signal.

4.3 Cylinder Pressure Pegging

In the case that in-cylinder pressure is measured using a dynamic pressure transducer (e.g., piezoelectric), the captured waveform must be 'pegged' to an absolute value in order to obtain accurate results. Using this software, cylinder pressure can be pegged using a constant value, synchronous manifold absolute pressure (MAP) signal, or a polytropic coefficient. Note: If a pre-chamber pressure is used, it will be pegged in the same manner as the primary cylinder pressure.

4.3.1 Constant

The 'Constant' pegging setting requires a constant, scalar value as the pegging reference, a pegging location, and a pegging window.

The pegging location (typically near a relatively quiescent period within the cycle and while the intake valve(s) are open) specifies the crank angle at which the pegging reference will exactly equal the average of the cylinder pressure waveform over a given pegging window. The pegging window is centered about the pegging location.

4.3.2 Synchronous MAP

The 'Synchronous MAP' pegging setting requires a configured sync analog channel (Manifold Absolute Pressure - kPa) as the pegging reference, a pegging location, and a pegging window.

The pegging location (typically near a relatively quiescent period within the cycle and while the intake valve(s) are open) specifies the crank angle at which the pegging reference will exactly equal the average of the cylinder pressure waveform over a given pegging window. The pegging window is centered about the pegging location.

4.3.3 Polytropic

The 'Polytropic' pegging setting requires a pegging location, a pegging window, and a constant polytropic coefficient to define the pegging reference.

The pegging location / window should be positioned during the compression stroke after the intake valve is closed, e.g., from -90 to -60 DATDC.

The following calculations are used to define the pegging reference:

$$P_{2\_new} = \frac{P_2 - P_1}{1 - \left(\frac{V_1}{V_2}\right)^n}$$

$$P_{ref} = P_2 - P_{2\_new}$$

Where location 1 and 2 are the average values at the respective endpoints of the pegging window specified, 'P' is pressure, 'V' is volume, and 'n' is the desired polytropic coefficient. At each endpoint, a smaller window is specified of which the average value is taken as the endpoint value (2 CAD means 2 CAD before and after a given point).

Finally, the cylinder pressure is pegged by adding P_{ref} to the original unpegged pressure waveform(s).

4.4 Pressure Metrics

Several important results are derived from the pressure waveform, including peak pressure, peak pressure location, peak pressure rise rate, peak pressure rise rate location, polytropic coefficient of compression, and polytropic coefficient of expansion.

The TDC probe location result is calculated and recorded with the pressure metrics as it relates to the phasing of the pressure and volume waveforms.

4.4.1 Pressure and Pressure Rise Rate

The standard method of calculating the peak pressure and peak pressure rise rate values and locations involves simply using the built-in LabVIEW array functions to search a pre-defined window of the pressure and pressure rise rate arrays for the maximum values and locations.

The spline method of calculating the peak pressure and peak pressure rise rate values and locations involves creating a splined waveform for each array that has ten times the resolution of the pressure array. The splined waveform arrays are searched for peak values and locations using the built-in LabVIEW array functions.

Note: The spline method is very resource intensive and should be avoided on less powerful processors.

4.4.2 Polytropic Coefficients

The compression and expansion of the gas inside the engine cylinder can be approximated as a polytropic process.

The compression and expansion of the gas obeys the relationship $P_I * V_i^n = C$, where C is a constant. Applying the relationship to several points on the compression or expansion curve allows for the calculation of the polytropic coefficient. The polytropic coefficient is uses in many other calculations, including heat release. Therefore, it is necessary to calculate the polytropic coefficient.

The polytropic coefficient, n, is derived in the following equations:

$$P_{I-1} * V_{i-1}^n = P_I * V_i^n$$

$$n = \frac{\log\left(\frac{P_i}{P_{i-1}}\right)}{\log\left(\frac{V_{i-1}}{V_i}\right)} = \log\left(\frac{P_i}{P_{i-1}}, \frac{V_{i-1}}{V_i}\right)$$

In order to calculate the polytropic coefficients of compression (PolyC) and expansion (PolyE), the associated ranges for PolyC and PolyE must be set within the 'Pressure Metrics Settings' window of the NI CAS Software Interface. The following methods are then available for the calculation of PolyC and PolyE.

1. The 'Point-by-Point' method uses the entire ranges specified for PolyC and PolyE. Within the ranges, the equation for 'n' is solved repeatedly for each successive pair of discrete points. The collection of PolyC and PolyE results is then averaged for the reported PolyC and PolyE.

2. The 'Endpoints' method uses the start and end locations of the ranges specified for PolyC and PolyE as endpoints. In order to eliminate error caused by noise in the pressure waveform, a window around each endpoint is specified in which the values are averaged to calculate the endpoint value (2 CAD represents 2 CAD on each side of the given point). The equation for 'n' is solved using the endpoints resulting in the reported PolyC and PolyE.

3. The 'Power Fit,' or Least Squares Fit - Power Law, method uses the entire ranges specified for PolyC and PolyE.

As our function $P_I * V_i^n = C$ can be rearranged to match the form $y = A * x^B$, the following system of equations can be used to solve for PolyC and PolyE:

$$y = A x^B$$

$$b = n \frac{\sum_{i=1}^n (\ln x_i \ln y_i) - \sum_{i=1}^n (\ln x_i) \sum_{i=1}^n (\ln y_i)}{n \sum_{i=1}^n (\ln x_i)^2 - \left(\sum_{i=1}^n \ln x_i\right)^2}$$

$$a = \frac{\sum_{i=1}^n (\ln y_i) - b \sum_{i=1}^n (\ln x_i)}{n},$$

where

$$B \stackrel{\text{def}}{=} b \qquad A \stackrel{\text{def}}{=} e^a$$

$$y = \frac{1}{P} \qquad A = \frac{1}{C}$$

$$x = V \qquad B = n$$

4.4.3 TDC Probe

The TDC probe location is a calculation taken from the waveform generated by a TDC probe sensor used during engine setup. The TDC probe location can be used to correctly phase the acquired engine data with engine position and calculated volume data. The first step in calculating the TDC probe location is determining which TDC peak in the waveform is the relevant compression TDC peak. In the case of a two-stroke engine there is only one peak.
  The compression / firing TDC peak is typically the lowest of the peaks due to increased pressure in the cylinder. Based on the selected peak, a window of the TDC probe signal surrounding the peak is selected and analyzed using one of the following methods:

1. The standard method of calculating the peak TDC probe location involves simply using the built-in LabVIEW array functions to search the pre-defined window of the TDC probe array for the maximum value location.

2. The spline method of calculating the peak TDC probe location involves creating a splined waveform for the array that has ten times the resolution of the TDC probe array. The splined waveform array is searched for peak value location using the built-in LabVIEW array functions.

3. The final method of calculating the TDC probe location, the Horizontal Cut, assumes a symmetrical profile of the TDC probe signal. A horizontal window below the peak is selected in which numerous 'horizontal cuts' are taken. For each cut, the crank angle, or x-axis, values at each point intercepting the waveform are taken and the midpoint is found. The collection of midpoints for each horizontal cut are averaged, resulting in the TDC probe location.
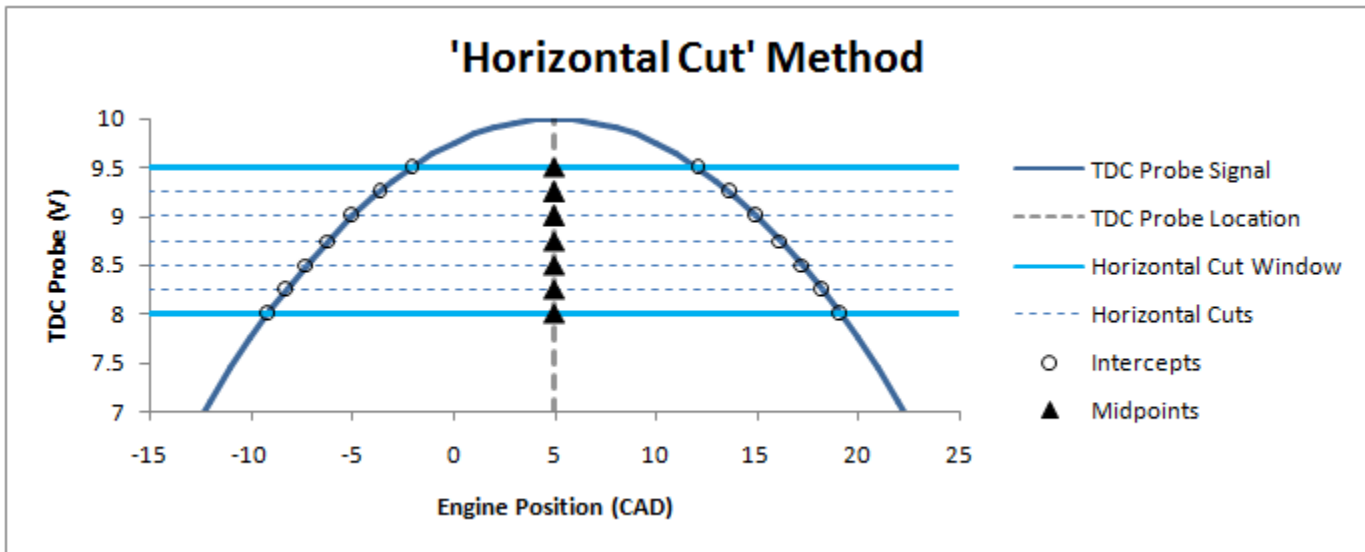
4.5 Mean Effective Pressure

Mean effective pressure (MEP) is a value commonly used to quantify engine load, or work output, independently of engine size. All MEPs in this software are indicated values as the calculations are based on cylinder pressure. The following equation is used to calculate the various MEPs[1]:

$$MEP = \frac{W_i}{V_d}$$

where:

W_i = indicated work for a given engine revolution
V_d = displaced cylinder volume

The indicated work, W_i, is calculated using the following equation[1]:

$$W_i = \sum_{rev} p \, dV$$

where:

p = cylinder pressure
dV = change in cylinder volume

Gross IMEP - Gross IMEP ($IMEP_g$) is calculated for each non-pumping engine revolution. A six-stroke engine, therefore, will have two independent $IMEP_g$ values.

Pumping MEP - Pumping MEP (PMEP) is calculated for the pumping stroke, except in the case of a two-stroke engine.

Net IMEP - Net IMEP ($IMEP_n$) is calculated by summing the $IMEP_g$ value(s) and the PMEP.

1. Heywood, J. B., Internal Combustion Engine Fundamentals. McGraw Hill, Inc., New York, NY. 1988.

4.6 Motoring Pressure

The motoring pressure is modeled based on cylinder pressure, volume, valve timing, and either a constant or calculated polytropic coefficient. The pressure is modeled assuming a polytropic pressure, as in the following equation:

$$P_{m,i} = P_{m,i-1} * \left(\frac{V_{i-1}}{V_i}\right)^n$$

starting at the point

$P_{m,i-1} = P_{IVC}$

where:

P_m = motored cylinder pressure (kPa)

V = volume (m^3)
n = polytropic coefficient
P_{IVC} = cylinder pressure at intake valve closing (kPa)

4.7 Global Gas Temperature

The global (bulk) gas temperature is modeled based on cylinder pressure, volume, valve timing, intake temperature and pressure, exhaust temperature and pressure, residual gas fraction, and either a constant or calculated polytropic coefficient.

$$T = \left(\frac{T_{IVC}}{P_{IVC} * V_{IVC}}\right) * P * V$$

$$T_{IVC} = T_i * (1 - f) + 1.39 * T_e * (P_i - P_e)^{\frac{n-1}{n}} * f$$

where:

T = global gas temperature
T_{IVC}, P_{IVC}, V_{IVC} = bulk cylinder temperature, cylinder pressure and cylinder volume at intake valve closing, respectively
P = cylinder pressure
V = cylinder volume
T_i = intake temperature
f = residual fraction
T_e = exhaust temperature
P_i = intake pressure
P_e = exhaust pressure
n = polytropic coefficient

1. Gatowski, J. A., Balles, E. N., Chun, K. M., Nelson, F. E., Ekchian, J. A., Heywood, J. B., 1984, "Heat Release Analysis of Engine Pressure Data", SAE Technical Paper Series 841359
2. Sharief, A., Chandrashekar, T. K., Antony, A. J., Samaga, B. S., 2008, "Study on Heat Transfer Correlation in IC Engines", SAE Technical Paper Series 2008-01-1816
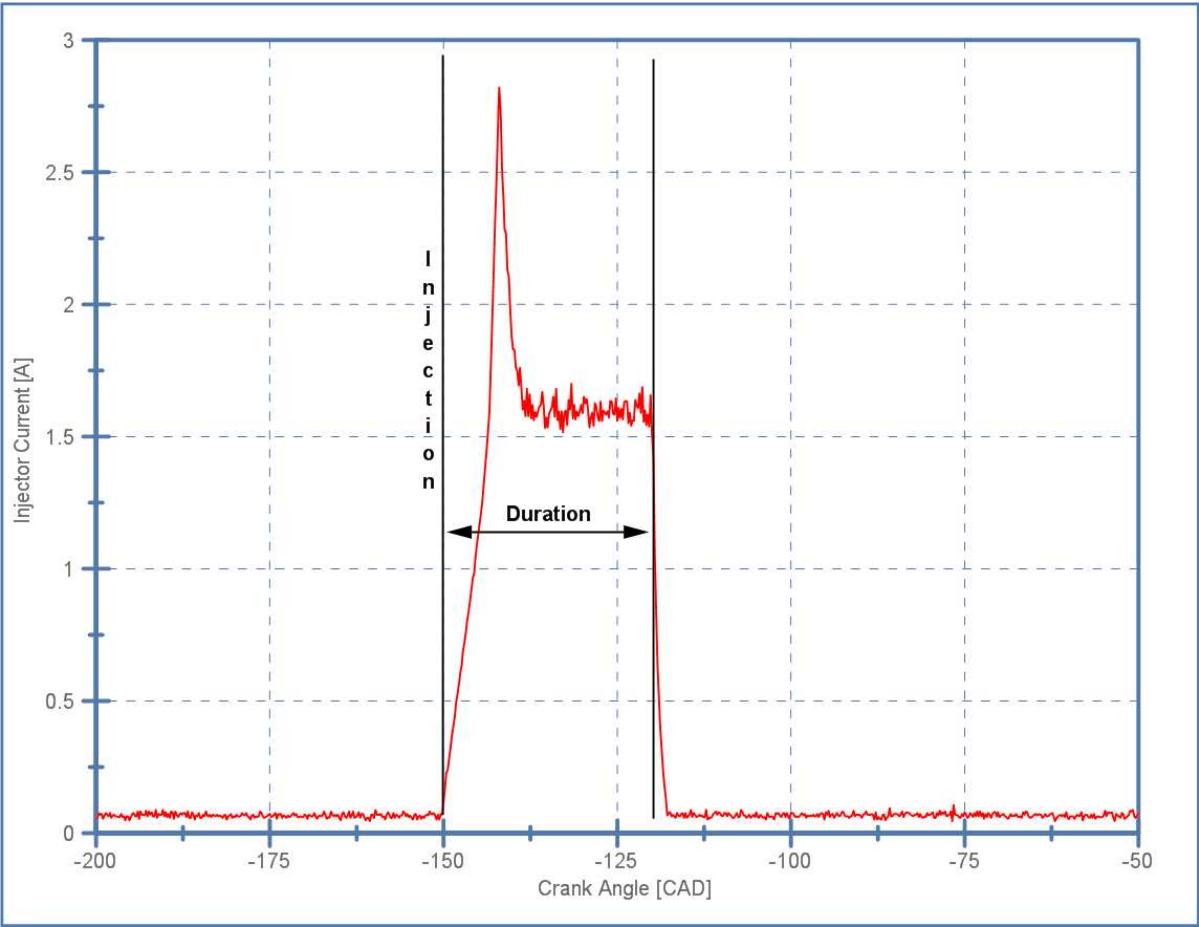
4.8 Injector

NI CAS Software uses a current or voltage measurement to determine the injection events. The user must specify the type of injector used: PFI, DI, or Piezo.
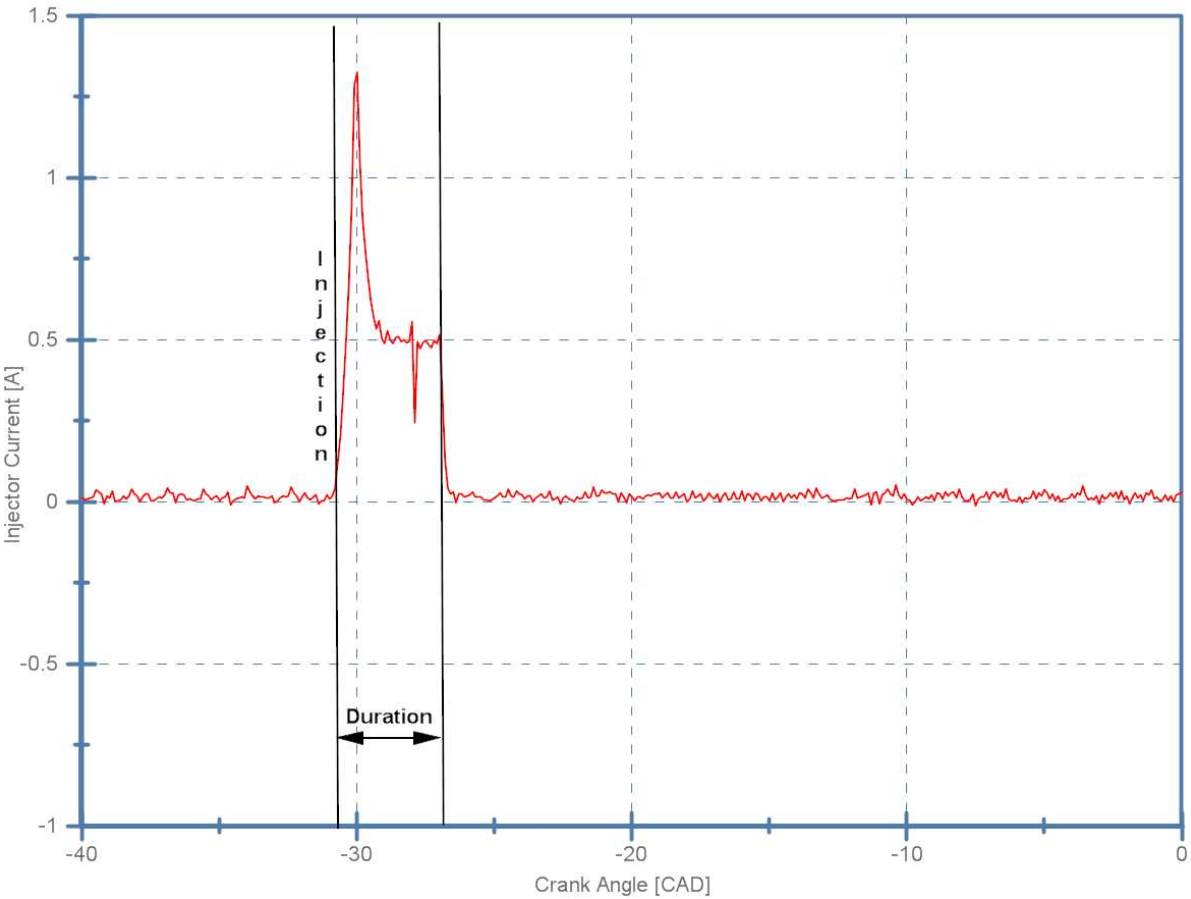
Injector Current

To measure the current drawn by the injector module, attach a current probe to the to the injector wiring.
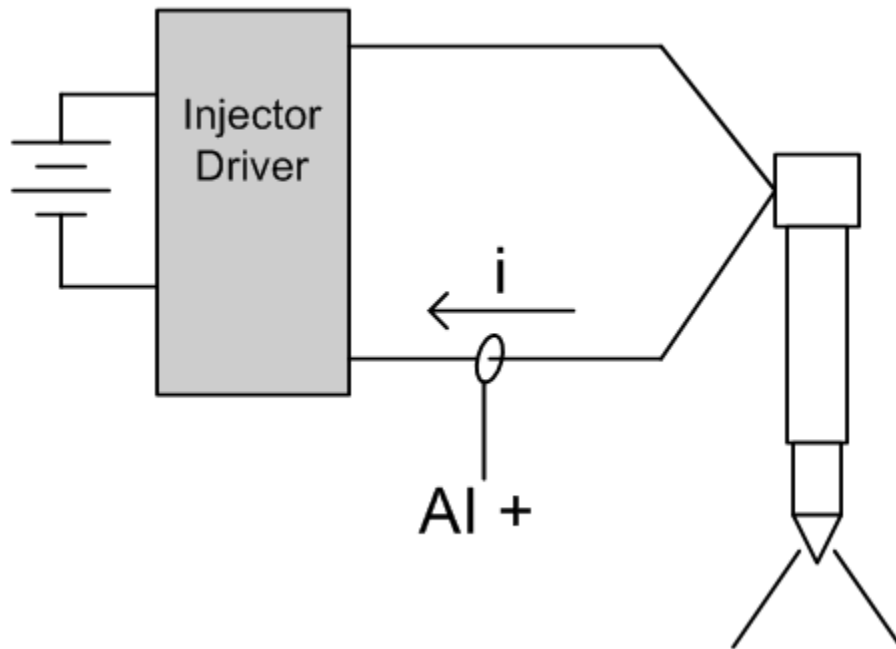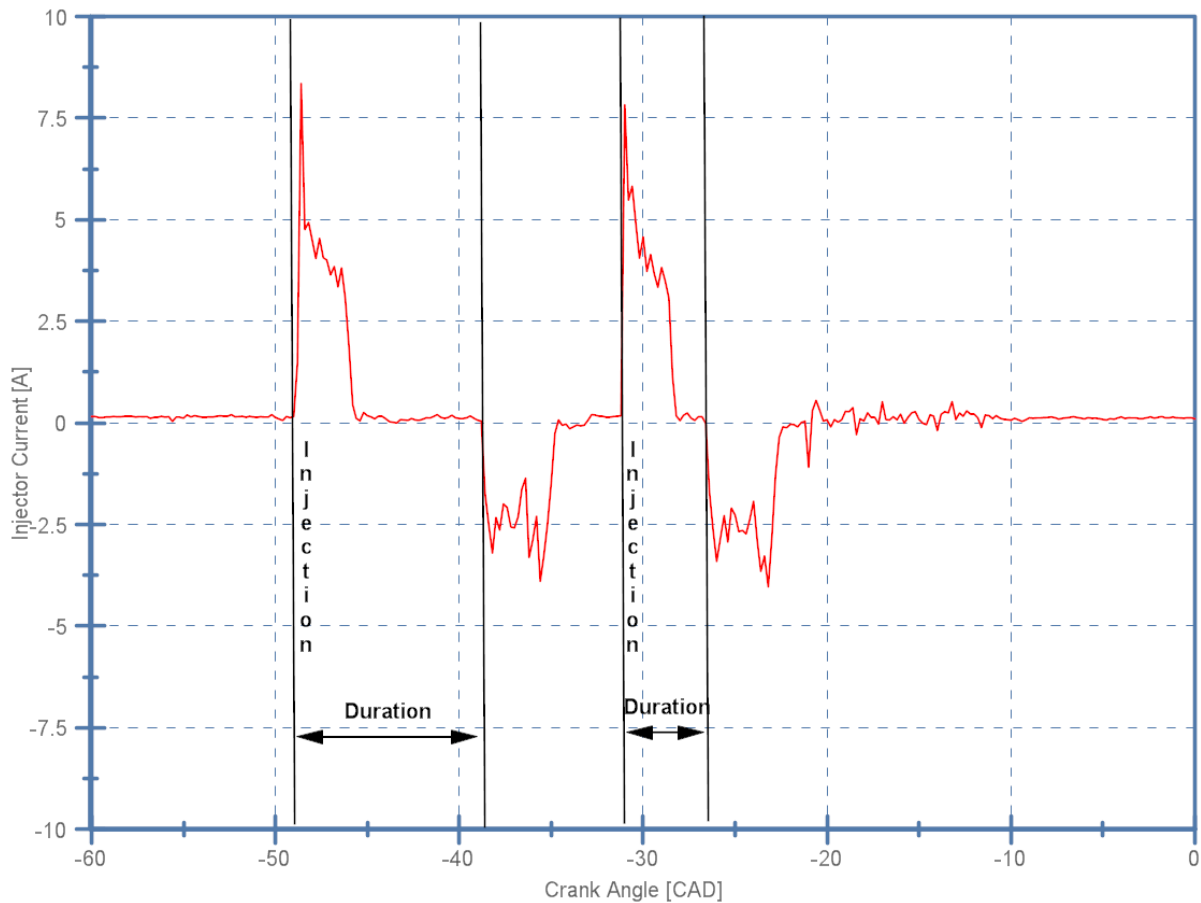

PFI Current

DI Current

Piezo Current

Injector Voltage

Injector voltages vary from battery voltage to several hundred volts. Therefore, a protective circuit is needed to prevent the high voltage from reaching the DAQ device. The operating voltage of the injectors should be verified before connecting the injector to the DAQ device. Resistor rated above the maximum operating voltage are also required.
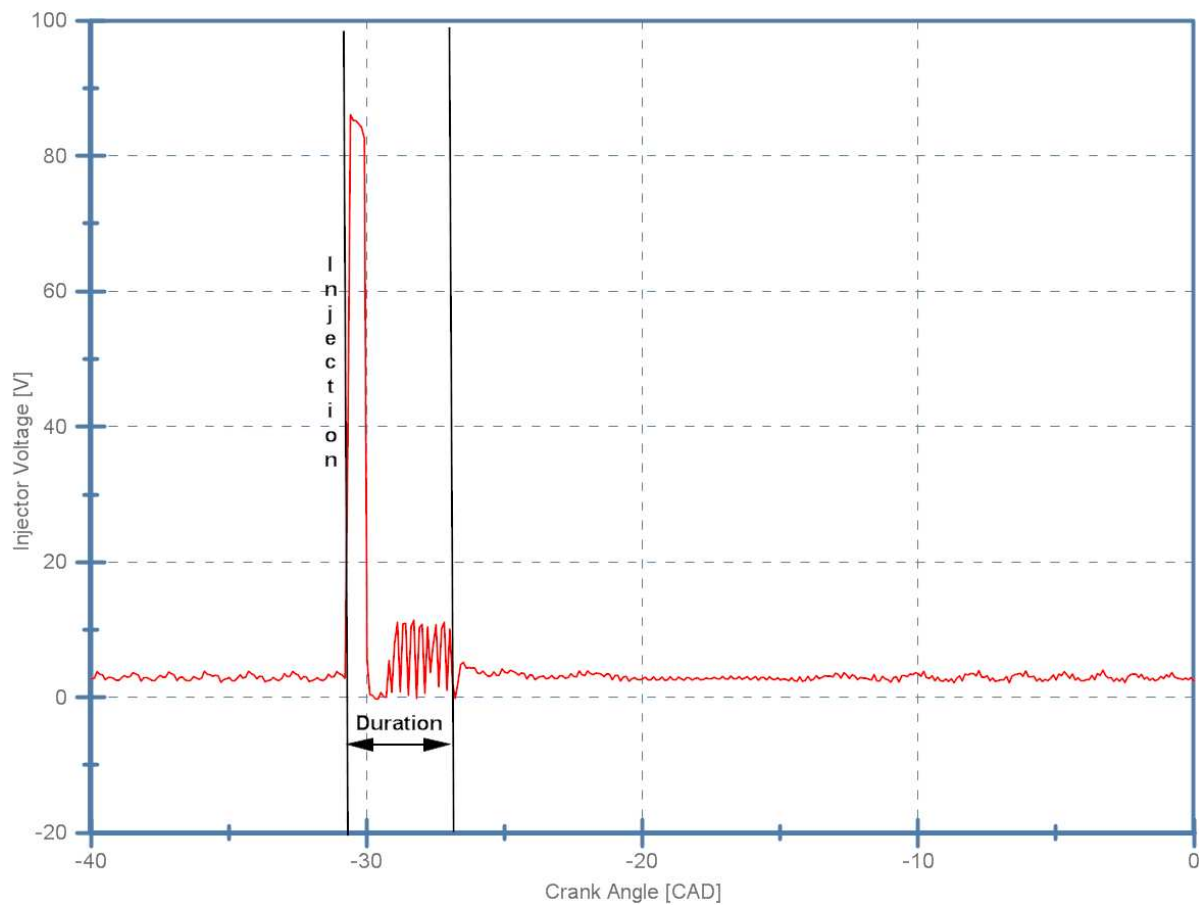
Please note: Most DAQ devicess and accessories have maximum voltage limits that should be followed. Please refer to your hardware documentation for details. IE. the SCB-68 has a maximum voltage of 48V listed in the user's manual.
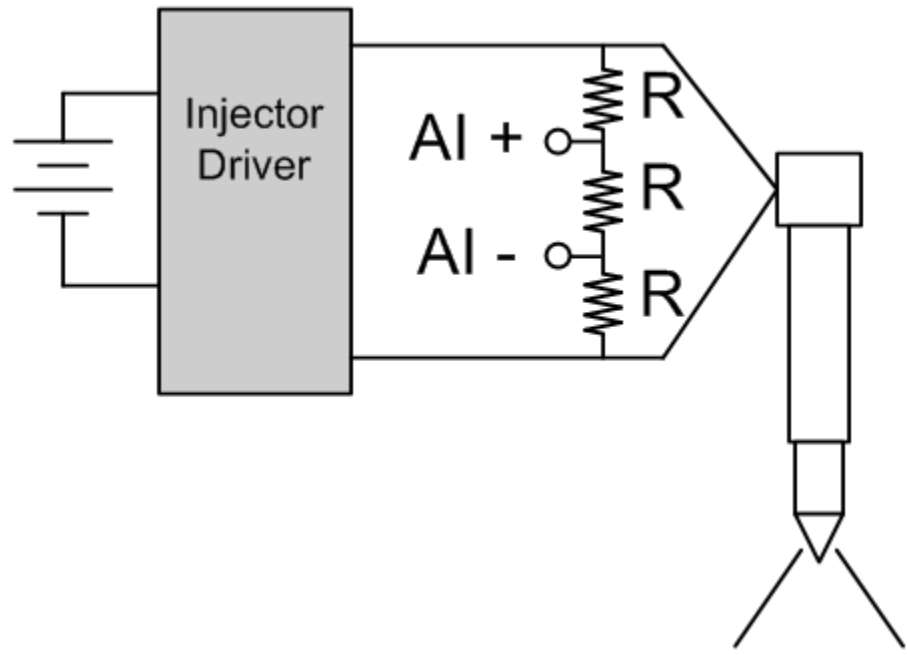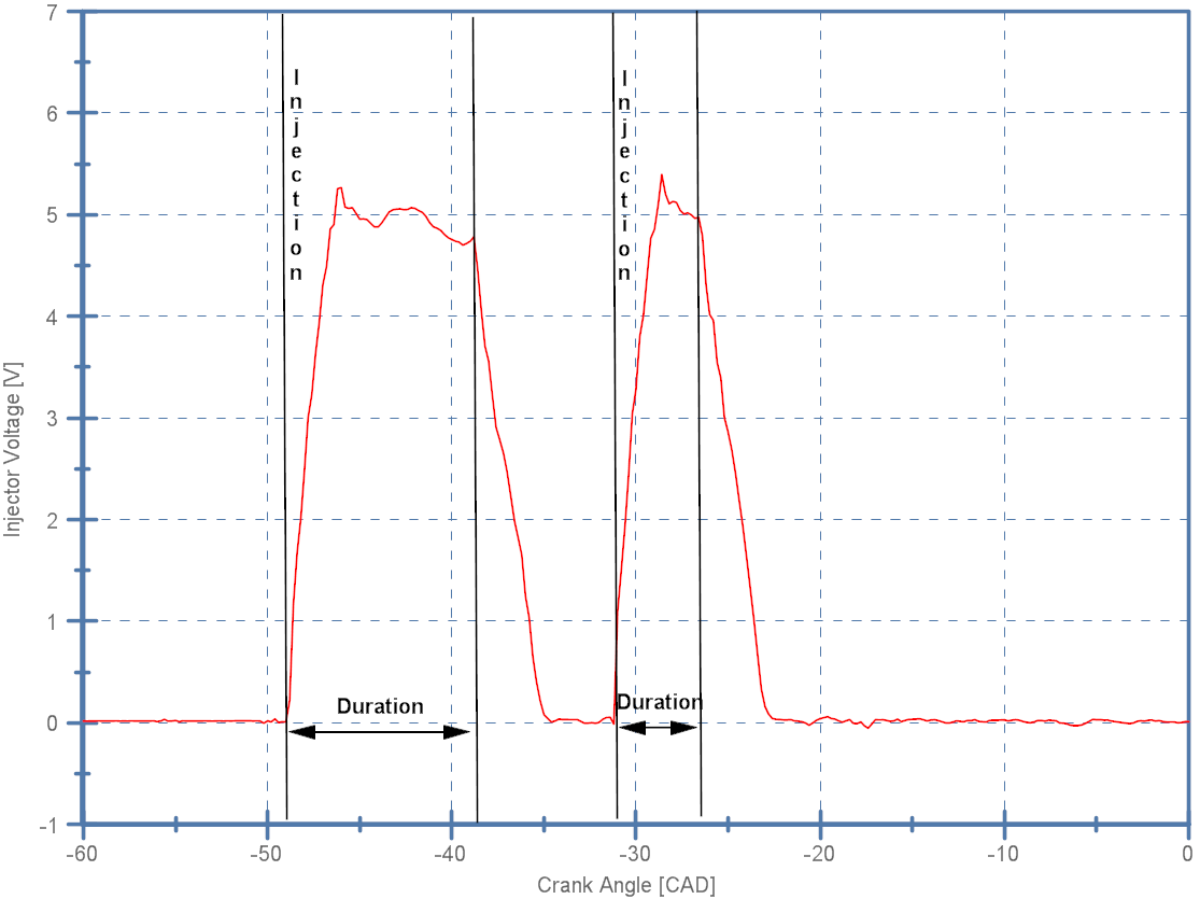
PFI Voltage
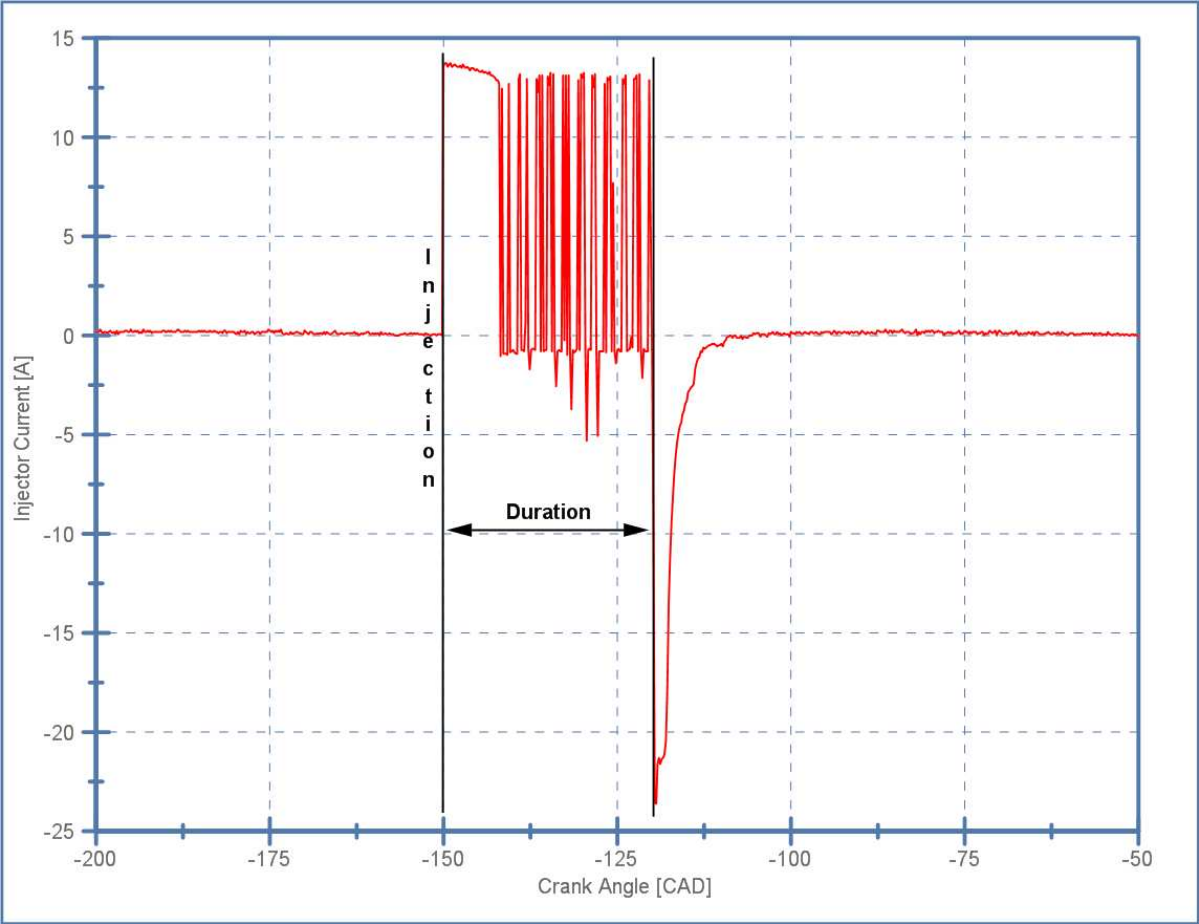
DI Voltage

Piezo Voltage

4.9 Heat Release

The heat release rate, or *dQ/dt*, represents "the difference between the chemical energy or heat released by combustion of the fuel... and the heat transfer from the system."[1]

The CAS software calculates the heat release rate using several user selectable mathematical models, including:

- Single Zone
- Single Zone + Heat Transfer
- Single Zone Dual Transducer
- Single Zone Dual Transducer + Heat Transfer
- Modified Rassweiler and Withrow
- Pressure Ratio

For those models including heat transfer, the following correlations are available for selection:

- Constant
- Woschni 1967
- Woschni 1990
- Hohenberg

In the cases where heat transfer is neglected (adiabatic), the polytropic process is considered reversible and therefore isentropic. If an ideal gas is assumed, the polytropic coefficient is constant and equal to the ratio of specific heats (γ = n).[2] However, when heat transfer is calculated, the following polytropic correlations are available for selection:

- Hayes
- Indolene
- Propane
- Custom

Note: Whenever heat transfer is being calculated, the 'Gas Temp' calculations must be enabled in the Calculations subhost.

1. Heywood, J. B., <u>Internal Combustion Engine Fundamentals</u>. McGraw Hill, Inc., New York, NY. 1988.
2. Russel, L. D., and Adebiyi, G. A., <u>Classical Thermodynamics</u>. Saunders College Publishing, Fort Worth, TX. 1993.

4.9.1 Heat Release Models

4.9.1.1 Single Zone

$$\frac{dQ}{d\theta} = \left(\frac{1}{n-1}\right) * V * \frac{dP}{d\theta} + \left(\frac{n}{n-1}\right) * P * \frac{dV}{d\theta}$$

where:

dQ/dθ = rate of heat release
n = polytropic coefficient
V = cylinder volume
dP/dθ = cylinder pressure derivative with respect to (w.r.t.) crank angle
P = cylinder pressure
dV/dθ = cylinder volume derivative w.r.t. crank angle

1. Grimm, B. M., Johnson, R. T., 1990, "Review of Simple Heat Release Computations", SAE Technical Paper Series 900445.
2. Cheung, H. M., Heywood, J. B., 1993, "Evaluation of a One-Zone Burn-Rate Analysis Procedure Using Production SI Engine Pressure Data", SAE Technical Paper Series 932749.

4.9.1.2 Single Zone + Heat Transfer

$$\frac{dQ}{d\theta} = \left(\frac{1}{\gamma - 1}\right) * V * \frac{dP}{d\theta} + \left(\frac{\gamma}{\gamma - 1}\right) * P * \frac{dV}{d\theta} + \frac{dQ_{ht}}{d\theta}$$

$$\frac{dQ_{ht}}{d\theta} = h * A_w * (T - T_w)$$

where:

$dQ/d\theta$ = rate of heat release
γ = ratio of specific heats, c_p/c_v
V = cylinder volume
$dP/d\theta$ = cylinder pressure derivative w.r.t. crank angle
P = cylinder pressure
$dV/d\theta$ = cylinder volume derivative w.r.t. crank angle
$dQ_{ht}/d\theta$ = heat transfer derivative w.r.t. crank angle
h = heat transfer coefficient
A_w = cylinder wall surface area
T = cylinder global gas temperature
T_w = cylinder wall temperature

1. Gatowski, J. A., Balles, E. N., Chun, K. M., Nelson, F. E., Ekchian, J. A., Heywood, J. B., 1984, "Heat Release Analysis of Engine Pressure Data", SAE Technical Paper Series 841359.
2. Hayes, T. K., Savage, L. D., Sorenson, S. C., 1986, "Cylinder Pressure Data Acquisition and Heat Release Analysis on a Personal Computer", SAE Technical Paper Series 860029.

4.9.1.3 Single Zone Dual Transducer

$$\frac{dQ}{d\theta} = \left(\frac{1}{n-1}\right) * \left(V_{mc} * \frac{dP_{mc}}{d\theta} + V_{pc} * \frac{dP_{pc}}{d\theta}\right) + \left(\frac{n}{n-1}\right) * P_{mc} * \frac{dV_{mc}}{d\theta}$$

where:

$dQ/d\theta$ = rate of heat release
n = polytropic coefficient
V_{mc} = main chamber volume
$dP_{mc}/d\theta$ = main chamber pressure derivative w.r.t. crank angle
V_{pc} = pre-chamber volume
$dP_{pc}/d\theta$ = pre-chamber pressure derivative w.r.t. crank angle
P_{mc} = main chamber pressure
$dV_{mc}/d\theta$ = main chamber volume derivative w.r.t. crank angle

1. Grimm, B. M., Johnson, R. T., 1990, "Review of Simple Heat Release Computations", SAE Technical Paper Series 900445.

4.9.1.4 Single Zone Dual Transducer + Heat Transfer

$$\frac{dQ}{d\theta} = \left(\frac{1}{\gamma - 1}\right) * \left(V_{mc} * \frac{dP_{mc}}{d\theta} + V_{pc} * \frac{dP_{pc}}{d\theta}\right) + \left(\frac{\gamma}{\gamma - 1}\right) * P_{mc} * \frac{dV_{mc}}{d\theta} + \frac{dQ_{ht}}{d\theta}$$

$$\frac{dQ_{ht}}{d\theta} = h * A_w * (T - T_w)$$

where:

$dQ/d\theta$ = rate of heat release
n = polytropic coefficient
V_{mc} = main chamber volume
$dP_{mc}/d\theta$ = main chamber pressure derivative w.r.t. crank angle
V_{pc} = pre-chamber volume
$dP_{pc}/d\theta$ = pre-chamber pressure derivative w.r.t. crank angle
P_{mc} = main chamber pressure
$dV_{mc}/d\theta$ = main chamber volume derivative w.r.t. crank angle
$dQ_{ht}/d\theta$ = heat transfer derivative w.r.t. crank angle
h = heat transfer coefficient
A_w = cylinder wall surface area
T = cylinder global gas temperature
T_w = cylinder wall temperature

1. Grimm, B. M., Johnson, R. T., 1990, "Review of Simple Heat Release Computations", SAE Technical Paper Series 900445.
2. Gatowski, J. A., Balles, E. N., Chun, K. M., Nelson, F. E., Ekchian, J. A., Heywood, J. B., 1984, "Heat Release Analysis of Engine Pressure Data", SAE Technical Paper Series 841359.

4.9.1.5 Modified Rassweiler and Withrow

$$\frac{dQ}{d\theta} = \left(\frac{1}{n-1}\right) * V * \frac{dP_c}{d\theta}$$

$$\frac{dP_c}{d\theta} = P_i - P_{i-1} * \left(\frac{V_{i-1}}{V_i}\right)^n$$

where:

$dQ/d\theta$ = rate of heat release
n = polytropic coefficient
V = cylinder volume
$dP_c/d\theta$ = cylinder pressure change due to piston motion and heat release w.r.t. crank angle
P = cylinder pressure

1. Grimm, B. M., Johnson, R. T., 1990, "Review of Simple Heat Release Computations", SAE Technical Paper Series 900445.
2. Rassweiler, G. M., Withrow, L., 1938, "Motion Pictures of Engine Flames Correlated with Pressure Cards", Society of Automotive Engineers, Paper 380139.

4.9.1.6 Pressure Ratio

$$\frac{dQ}{d\theta} = \frac{P}{P_m} * \frac{NMEP * V_d}{d\theta}$$

$$P_{m,i} = P_{m,i-1} * \left(\frac{V_{i-1}}{V_i}\right)^n$$

where:

$dQ/d\theta$ = rate of heat release
P = cylinder pressure
P_m = motored cylinder pressure
NMEP = net (indicated) mean effective pressure
V_d = displaced cylinder volume
$d\theta$ = crank angle differential
V = cylinder volume
n = polytropic coefficient

1. Sellnau, M. C., Matekunas, F. A., Battiston, P. A., Chang, C. F., Lancaster, D. R., 2000, "Cylinder-Pressure-Based engine Control Using Pressure-Ratio-Management and Low-Cost Non-Intrusive Cylinder Pressure Sensors", SAE Technical Paper Series 2000-01-0932.

4.9.2 Heat Transfer Correlations

4.9.2.1 Constant

This setting uses a constant user input for the heat transfer coefficient in units of W/m^2-K.

4.9.2.2 Woschni 1967

$$h = \frac{3.26}{(6 * N)} * B^{-0.2} * P^{0.8} * T^{-0.55} * w^{0.8}$$

$$w = C_1 * \overline{S_p} + C_2 * \frac{V_d * T_{IVC}}{P_{IVC} * V_{IVC}} * (P - P_m)$$

Gas Exchange
$C_1 = 6.18$
$C_2 = 0$

Compression
$C_1 = 2.28$
$C_2 = 0$

Combustion and Expansion
$C_1 = 2.28$
$C_2 = 3.24 \times 10^{-3}$

where:

h = heat transfer coefficient (W/m^2-K)
N = engine speed (RPM)
B = cylinder bore (m)
P = cylinder pressure (kPa)
T = cylinder global gas temperature (K)
w = mean cylinder gas velocity (m/s)
S_p = mean piston speed (m/s)
V_D = displacement per cylinder (m^3)
V = cylinder volume (m^3)
P_m = motored cylinder pressure (kPa)
n = polytropic coefficient
T_{IVC}, P_{IVC}, V_{IVC} = bulk cylinder temperature, cylinder pressure and cylinder volume at intake valve closing, respectively

1. Heywood, J. B., Internal Combustion Engine Fundamentals. McGraw Hill, Inc., New York, NY. 1988.
2. Woschni, G., 1967, "A Universally Applicable Equation for the Instantaneous Heat Transfer Coefficient in the Internal Combustion Engine", Society of Automotive Engineers, Paper 670931.

4.9.2.3 Woschni 1990

This modified version of Woschni's correlation[1,2] takes part load operating conditions into account[3]:

$$w = C_1 * \overline{S_P} * \left[1 + 2 \left(\frac{V_{TDC}}{V_{IVC}} \right)^2 * \text{IMEP}^{-0.2} \right]$$

when

$$C_2 * \frac{V_D * T_{IVC}}{P_{IVC} * V_{IVC}} * (P - P_m) \geq 2 * C_1 * \overline{S_P} * \left(\frac{V_{TDC}}{V_{IVC}} \right)^2 * \text{IMEP}^{-0.2}$$

where:

w = mean cylinder gas velocity (m/s)
Sp = mean piston speed (m/s)

V_{TDC} = cylinder clearance (squish) volume (m^3)

T_{IVC}, P_{IVC}, V_{IVC} = cylinder global gas temperature, cylinder pressure and cylinder volume at intake valve closing, respectively
IMEP = indicated mean effective pressure (kPa)

V_D = displacement per cylinder (m^3)

P = cylinder pressure (kPa)
P_m = motored cylinder pressure (kPa)

1. Woschni, G., 1967, "A Universally Applicable Equation for the Instantaneous Heat Transfer Coefficient in the Internal Combustion Engine", Society of Automotive Engineers, Paper 670931.
2. Sihling, K., Woschni, G., 1979, "Experimental Investigation of the Instantaneous Heat Transfer in the Cylinder of a High Speed Diesel Engine", Society of Automotive Engineers, Inc., Paper 790833.
3. Huber, K., Woschni, G., and Zeilinger, K., 1990, "Investigations on Heat Transfer in Internal Combustion Engines Under Low Load and Motoring Conditions," Society of Automotive Engineers, Inc., Paper 905018.

4.9.2.4 Hohenberg

$$h = \frac{4.94}{(6*N)} * V^{-0.06} * P^{0.8} * T^{-0.4} * (\overline{S_p} + 1.4)^{0.8}$$

where:

h = heat transfer coefficient (W/m^2-K)
N = engine speed (RPM)
V = cylinder volume (m^3)
P = cylinder pressure (kPa)
T = cylinder global gas temperature (K)
Sp = mean piston speed (m/s)

1. Hohenberg, G. F., 1979, "Advanced Approaches for Heat Transfer Calculations", Society of Automotive Engineers, Inc., Paper 790825.

4.9.3 Polytropic Correlation

4.9.3.1 Hayes (SAE860029)

$$\gamma = \frac{\overline{C_p}}{\overline{C_p} - \overline{R}}$$

$T < 1000K$

$$\overline{C_p} = (3.6359 - 1.33735 * 10^{-3} * T + 3.29421 * 10^{-6} * T^2 - 1.9112 * 10^{-9} * T^3 + 0.275462 \\ * 10^{-12} * T^4) * \overline{R}$$

$T > 1000K$

$$\overline{C_p} = (3.04473 + 1.33805 * 10^{-3} * T - 0.488256 * 10^{-6} * T^2 + 0.0855475 * 10^{-9} * T^3 \\ - 0.005701327 * 10^{-12} * T^4) * \overline{R}$$

where:

γ = ratio of specific heats
T = cylinder global gas temperature (K)
c_p = specific heat for constant pressure
R = the universal gas constant

1. Hayes, T. K., Savage, L. D., Sorenson, S. C., 1986, "Cylinder Pressure Data Acquisition and Heat Release Analysis on a Personal Computer", SAE Technical Paper Series 860029

4.9.3.2 Indolene (SAE841359)

$$\gamma = 1.392 - 8.13 * 10^{-5} * T$$

where:

γ = ratio of specific heats
T = cylinder global gas temperature (K)

1. Gatowski, J. A., Balles, E. N., Chun, K. M., Nelson, F. E., Ekchian, J. A., Heywood, J. B., 1984, "Heat Release Analysis of Engine Pressure Data", SAE Technical Paper Series 841359

4.9.3.3 Propane (SAE841359)

$$\gamma = 1.375 - 6.99 * 10^{-5} * T$$

where:

γ = ratio of specific heats
T = cylinder global gas temperature (K)

1. Gatowski, J. A., Balles, E. N., Chun, K. M., Nelson, F. E., Ekchian, J. A., Heywood, J. B., 1984, "Heat Release Analysis of Engine Pressure Data", SAE Technical Paper Series 841359

4.9.3.4 Custom

The custom option for the polytropic correlation allows the user to input values for coefficients a and b to be used in the following linear correlation:

$$\gamma = a * T(K) + b$$

where:

γ = ratio of specific heats
T = cylinder global gas temperature (K)

4.9.4 Start and End of Combustion

A precise definition of the start of combustion (SOC) and end of combustion (EOC) is required for accurate calculation of the mass fraction burned (MFB) crank angle locations. The SOC and EOC are used to define a window over which the cumulative heat release is calculated from the heat release rate (HRR) waveform. The following methods are used to define these locations:

Start of combustion (SOC)

1. Constant - Defines a constant crank angle (DATDC) as the SOC.
2. N Below Zero - Sets a crank angle (DATDC) to begin looking for a negative zero crossing in the HRR waveform. After 'N' points are found past the negative zero crossing, the crossing is confirmed to be the SOC.
3. Boxcar N Below Zero - Same definition of 'N Below Zero', except that a Boxcar filter of window 'N' is applied to the HRR waveform. Also, rather than using 'N' points to confirm the crossing, the first negative zero crossing is taken as the SOC.
4. N Above Zero - Sets a crank angle (DATDC) to begin looking for the last positive zero crossing in the HRR waveform. After 'N' points are found past the positive zero crossing, the crossing is confirmed to be the SOC.
5. Boxcar N Above Zero - Same definition of 'N Above Zero', except that a Boxcar filter of window 'N' is applied to the HRR waveform. Also, rather than using 'N' points to confirm the crossing, the first positive zero crossing is taken as the SOC.

The following figure represents both the 'N Below Zero' and 'N Above Zero' conditions for calculating the SOC, where 1 < N < 6.
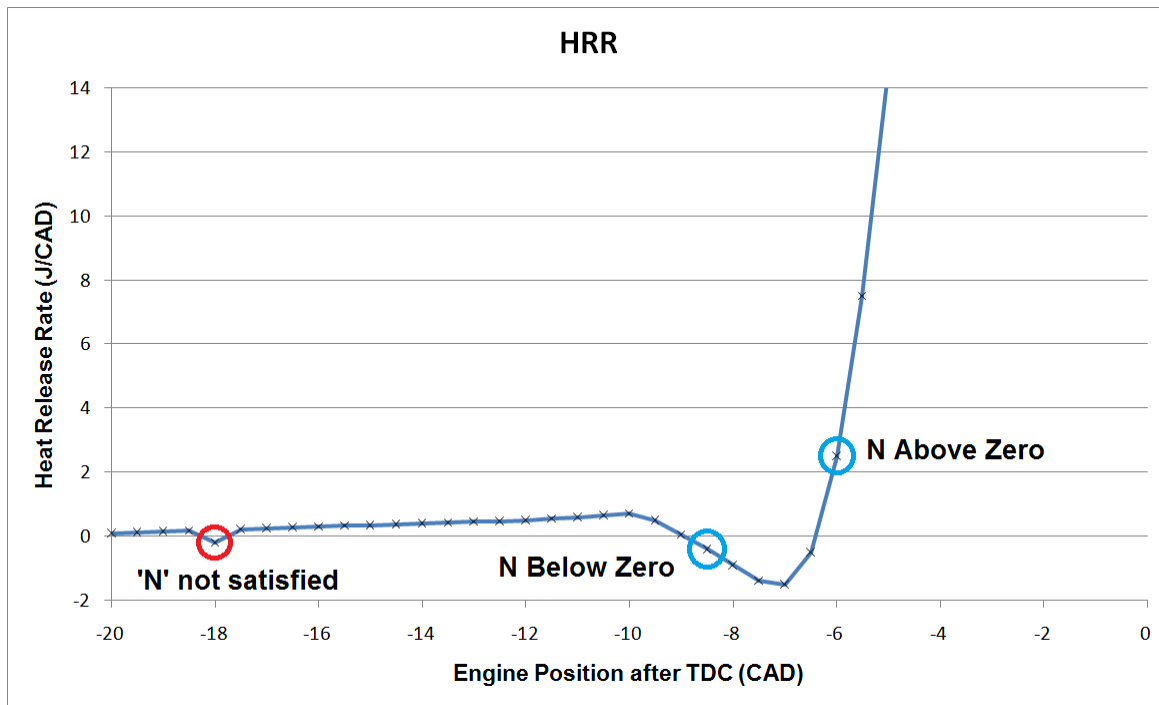
End of combustion (EOC)

1. Constant - Defines a constant crank angle (DATDC) as the EOC
2. N Below Zero - Sets a crank angle (DATDC) to end looking for the first negative zero crossing in the HRR waveform. After 'N' points are found past the negative zero crossing, the crossing is confirmed to be the EOC. If a negative zero crossing is not found, the 'End Angle' will be used as the EOC.
3. Boxcar N Below Zero - Same definition of 'N Below Zero', except that a Boxcar filter of window 'N' is applied to the HRR waveform. Also, rather than using 'N' points to confirm the crossing, the first negative zero crossing is taken as the SOC.

4.10 Combustion Noise

Combustion noise is calculated based on the power level (dB) from the cylinder pressure waveform using the following steps:

1. Converting the cylinder pressure waveform from the engine-position domain to the time domain
2. Converting the cylinder pressure signal from the time domain to the frequency domain using Fast Fourier Transform (FFT)
3. Converting the cylinder pressure frequency domain into a third-octave spectrum to simulate analog devices
4. Filter the spectrum for human auditory attenuation using the A-weighting curve[2] and for engine structure attenuation using the SA1-7dB[3,4] curve (Lucas plot).

1. Scarpati, J., Wikstrom, A., Jonsson, O., Glav, R., Handel, P., and Hjalmarsson, H., 2007, "Predication of Engine Noise using Parameterized Combustion Pressure Curves", SAE Technical Paper Series 2007-01-2373.
2. International Electrotechnical Commission, "Electroacoustics - Sound level meters," IEC 61672, 2003.
3. Herbert, A., and Russell, M., 1982, "Measurement of Combustion Noise in Diesel Engines", *Mechanical Engineering Technology*.
4. Reinhart, T., 1987, "An Evaluation of the Lucas Combustion Noise Meter on Cummins 'B' Series Engines", SAE Technical Paper Series 870952.

4.11 Misfire

The misfire calculation returns a Boolean output (0 or 1). The calculation is based on one of the following misfire threshold (kPa) comparisons:

1. Peak Pressure < Misfire Threshold
2. Net Mean Effective Pressure = NMEP < Misfire Threshold
3. Combustion Pressure = Cylinder Pressure - Motored Cylinder Pressure < Misfire Threshold

4.12 Cam

NI CAS Software uses a digital signal with rising and falling edges to determine the cam phasing. The user must specify the edge count, location (CAD), and whether each edge is rising or falling. The user specified pattern is compared with the actual pattern to determine the cam advance or retard. The user specified position is usually the default cam position or the position where the cam returns without power.
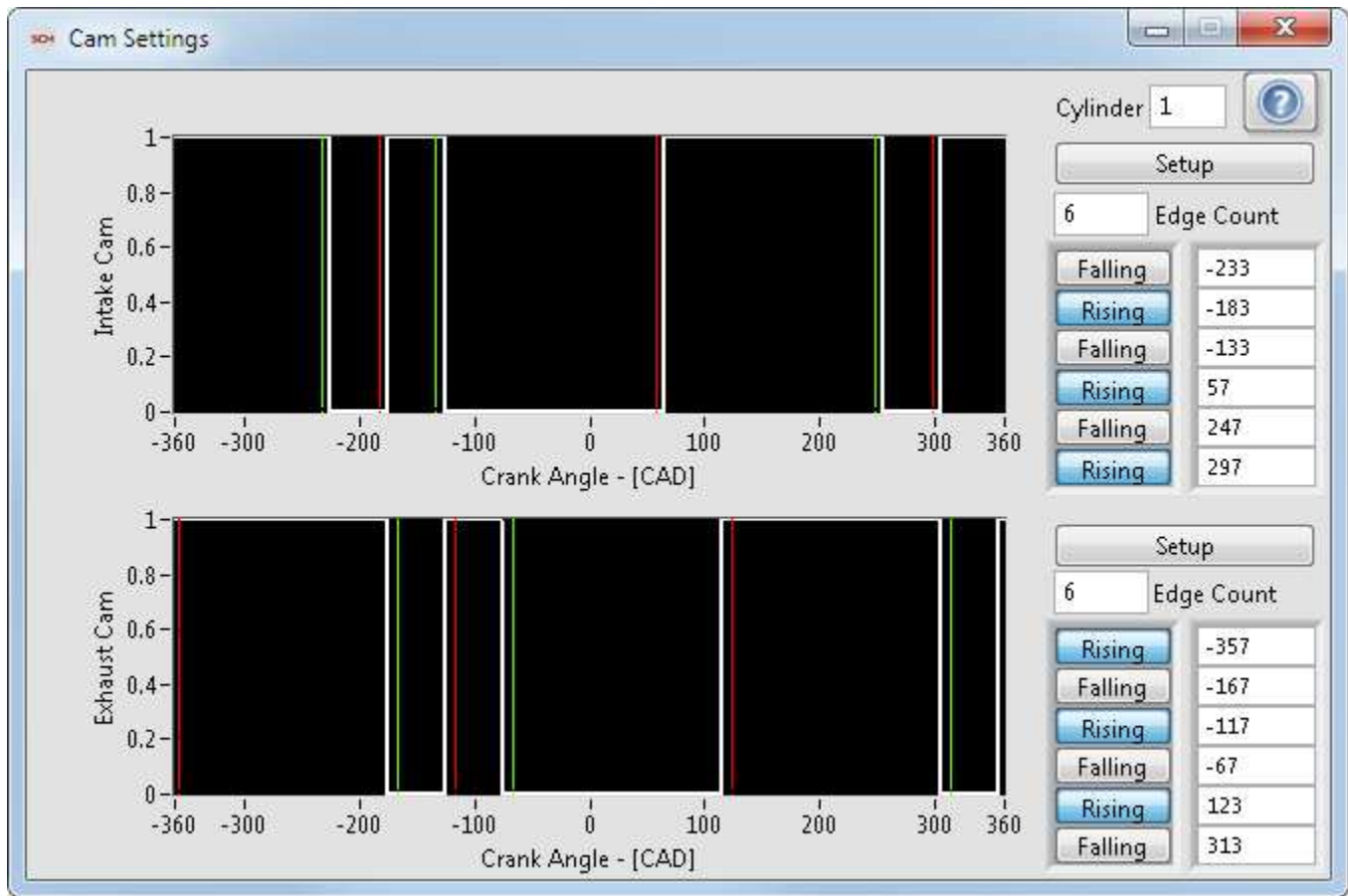
4.13 Synchronous Pump

NI CAS Software uses a digital signal with rising and falling edges to determine the start, end, and duration of multiple pulses over the span of one engine cycle. The number of pulses is reported along with the start, end, and duration for each pulse.
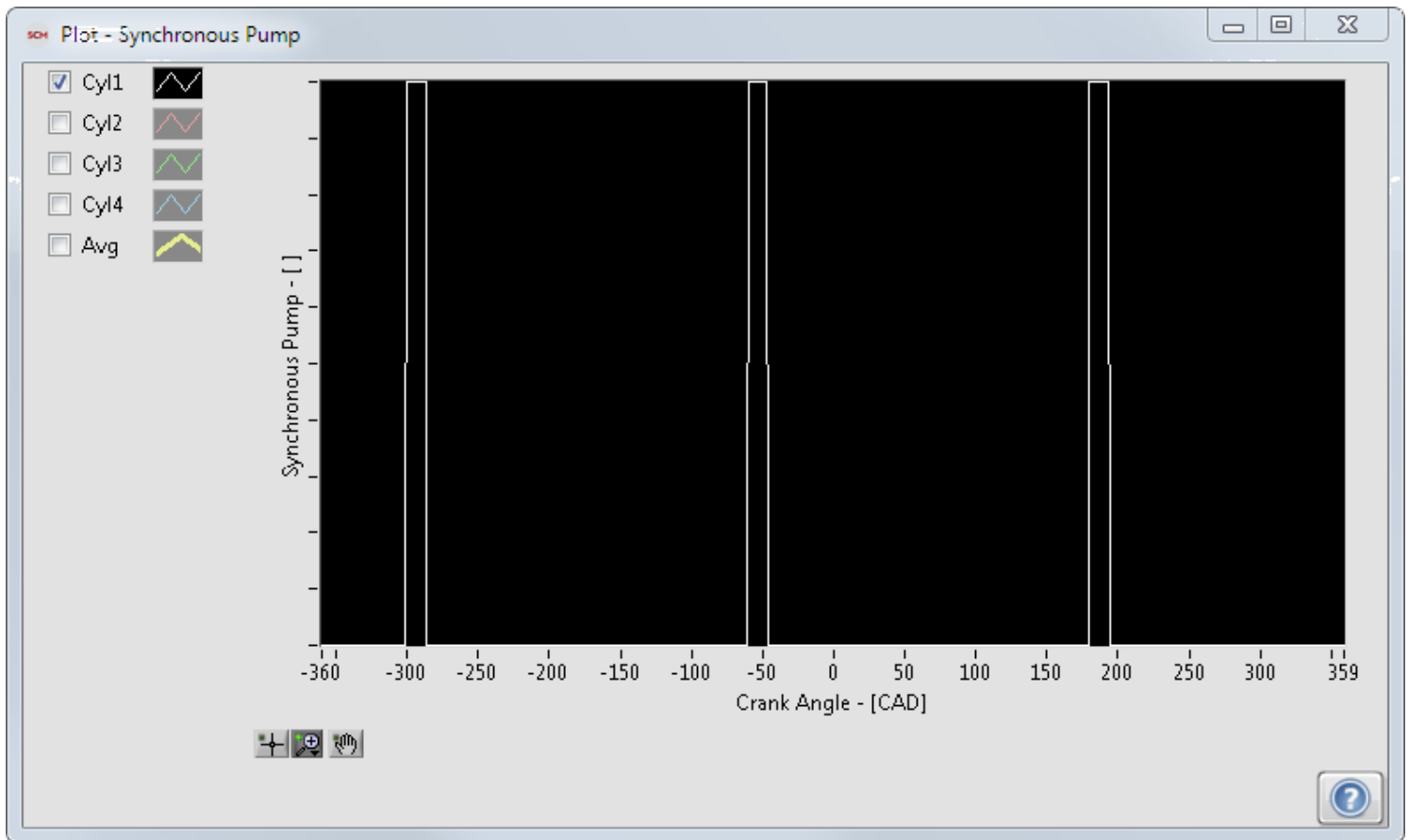
4.14 PWM

NI CAS Software uses a digital signal with rising and falling edges to determine the frequency and duty cycle of a PWM signal. The frequency is calculated using the rising edges of the signal. The duty cycle is calculated using the ratio of signal high time compared to the time between rising edges. The cycle results are averaged over the entire cycle.

Note: The sample rate of the system must be much greater than the PWM frequency to get accurate results.
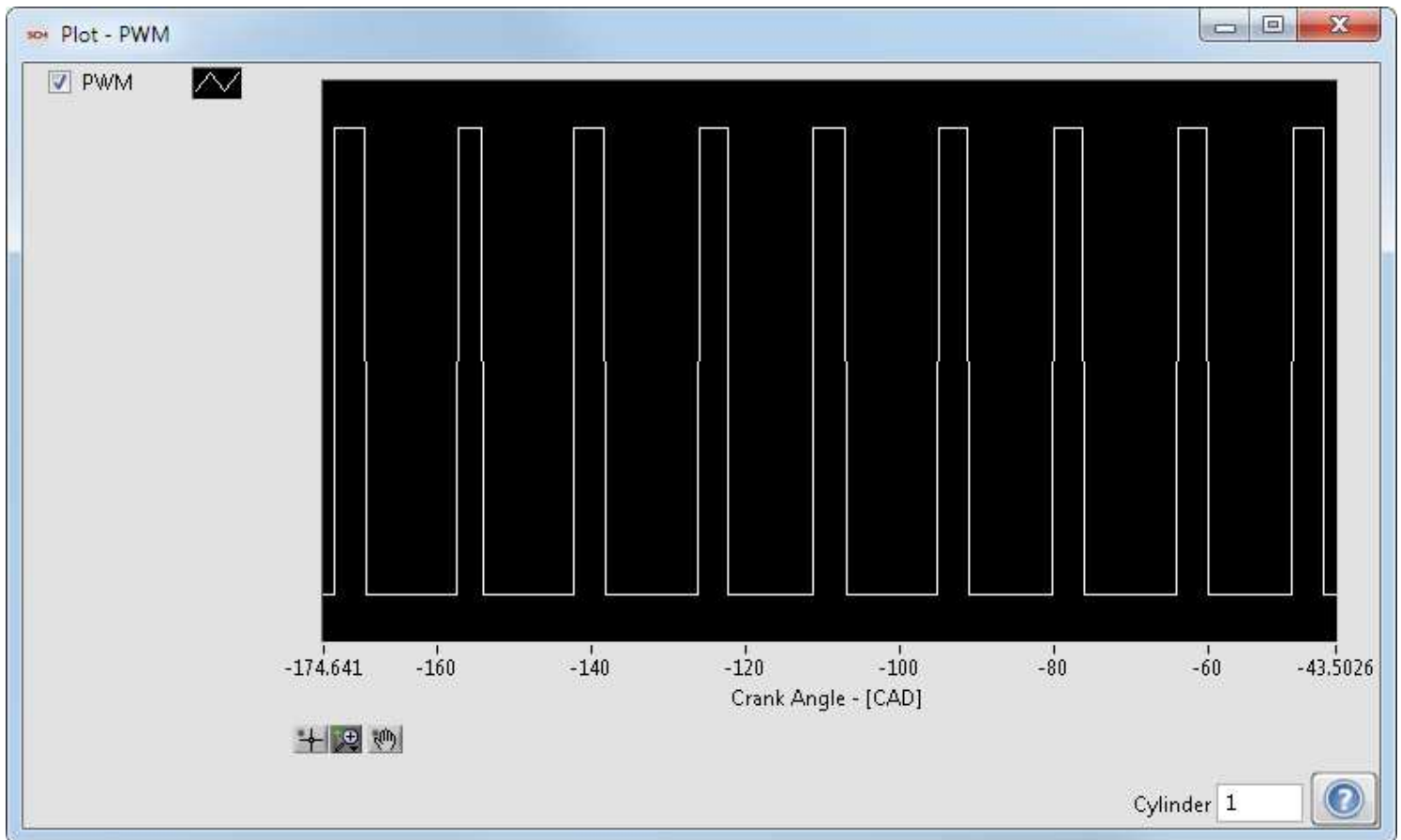
4.15 Knock

NI CAS Software uses the Bandpass, Rectify, Integrate, Compare (BRIC) knock detection method. This method requires the user to define calibration windows where there is little electrical and mechanical noise. The user also must provide cutoff frequencies for the bandpass filter (2nd order Butterworth IIR), which allow the fundamental frequencies of knock to pass but not background noise. The last required user input is the threshold where the raw knock intensity is considered to be knock.
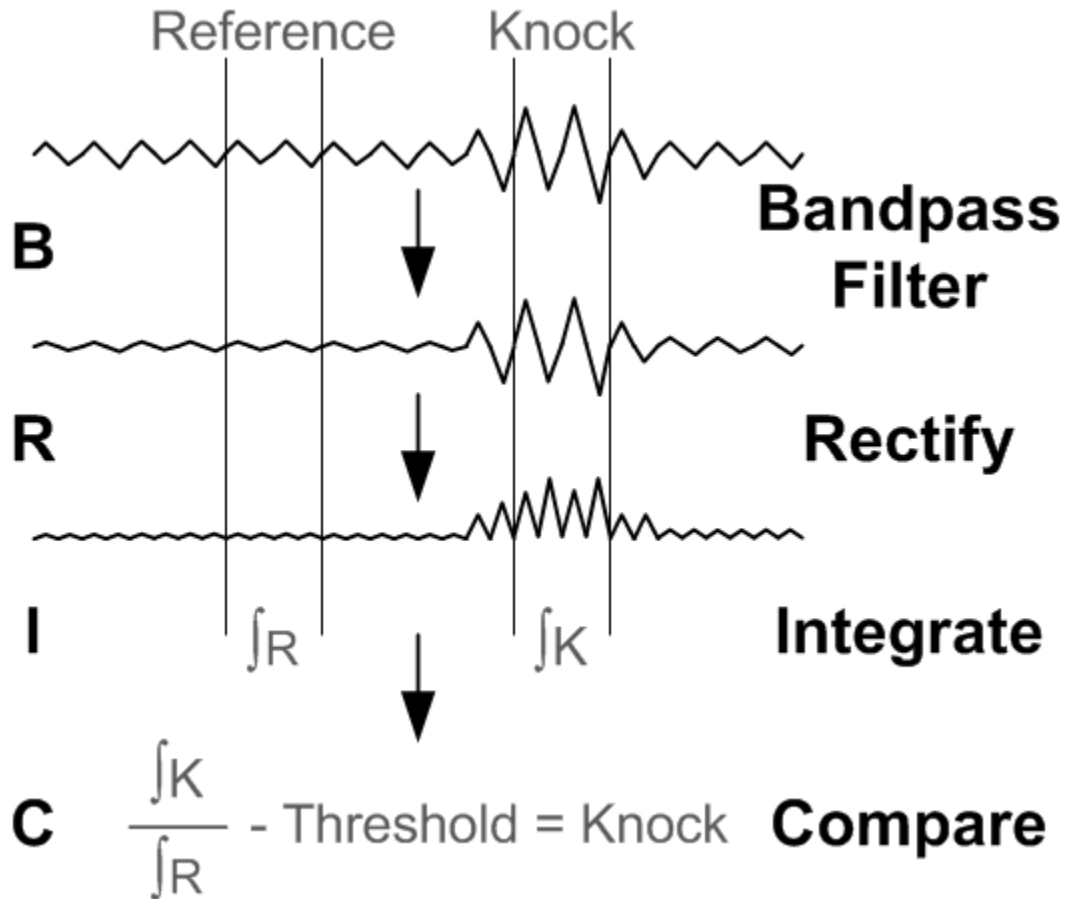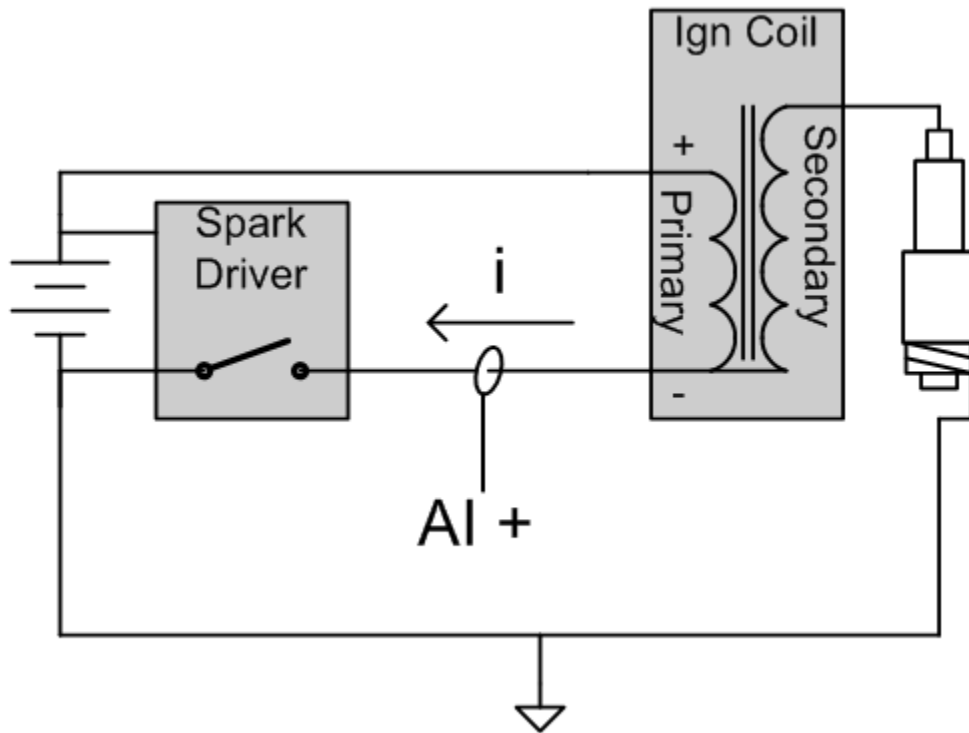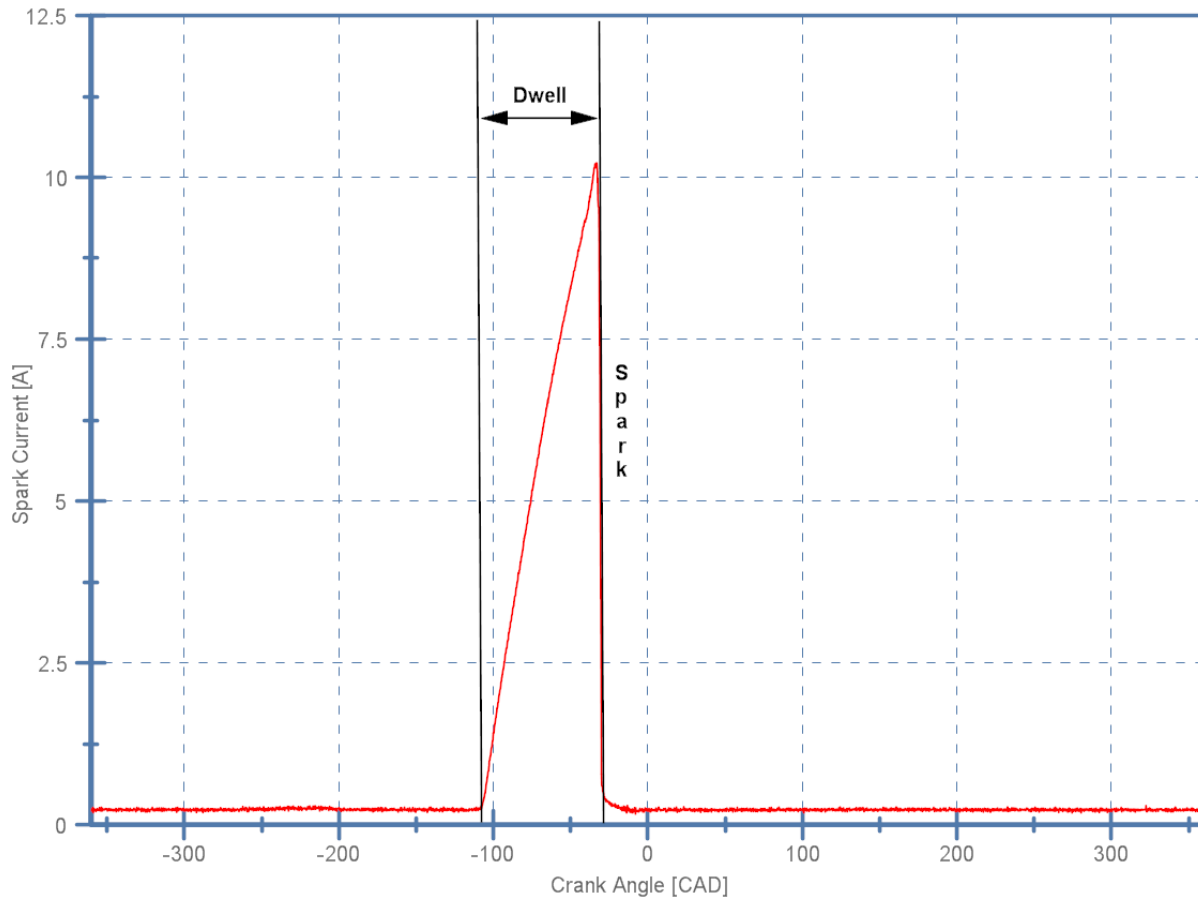
4.16 Spark

NI CAS Software uses a current or voltage on the low side of primary ignition coil to measure the spark event and spark dwell.

Spark Current
To measure the current drawn by the spark module, attach a current probe to the low side of the primary ignition coil.
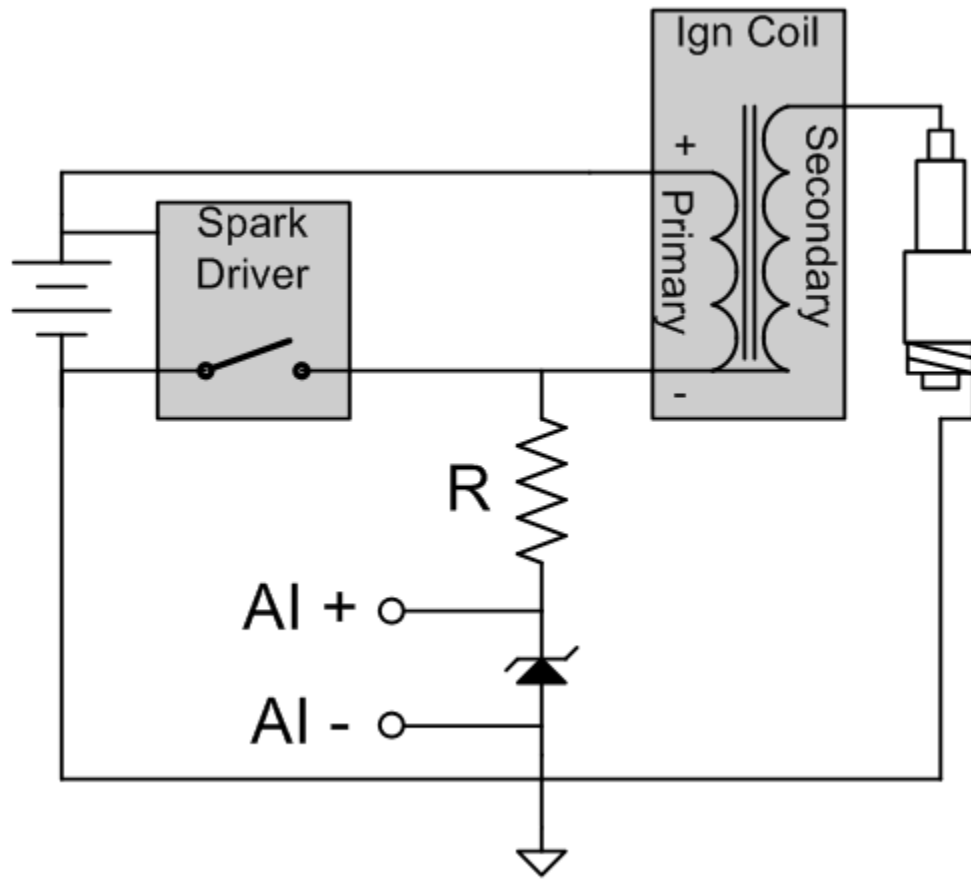

The signal should be similar to the following.

Spark Voltage

The low side of the primary ignition coil can reach 400V. Therefore, a protective circuit is needed to prevent the high voltage from reaching the DAQ device. A zener diode with a breakdown voltage of 1/2 the maximum analog input voltage is required (10V ADC = ~5V zener diode). A resistor rated above 400V is also required. It should be sized to limit the current flow to the zener diode (100 kΩ and 1/4 W).

Please note: Most DAQ devices and accessories have maximum voltage limits that should be followed. Please refer to your hardware documentation for details. IE. the SCB-68 has a maximum voltage of 48V listed in the user's manual.

The signal should be similar to the following.
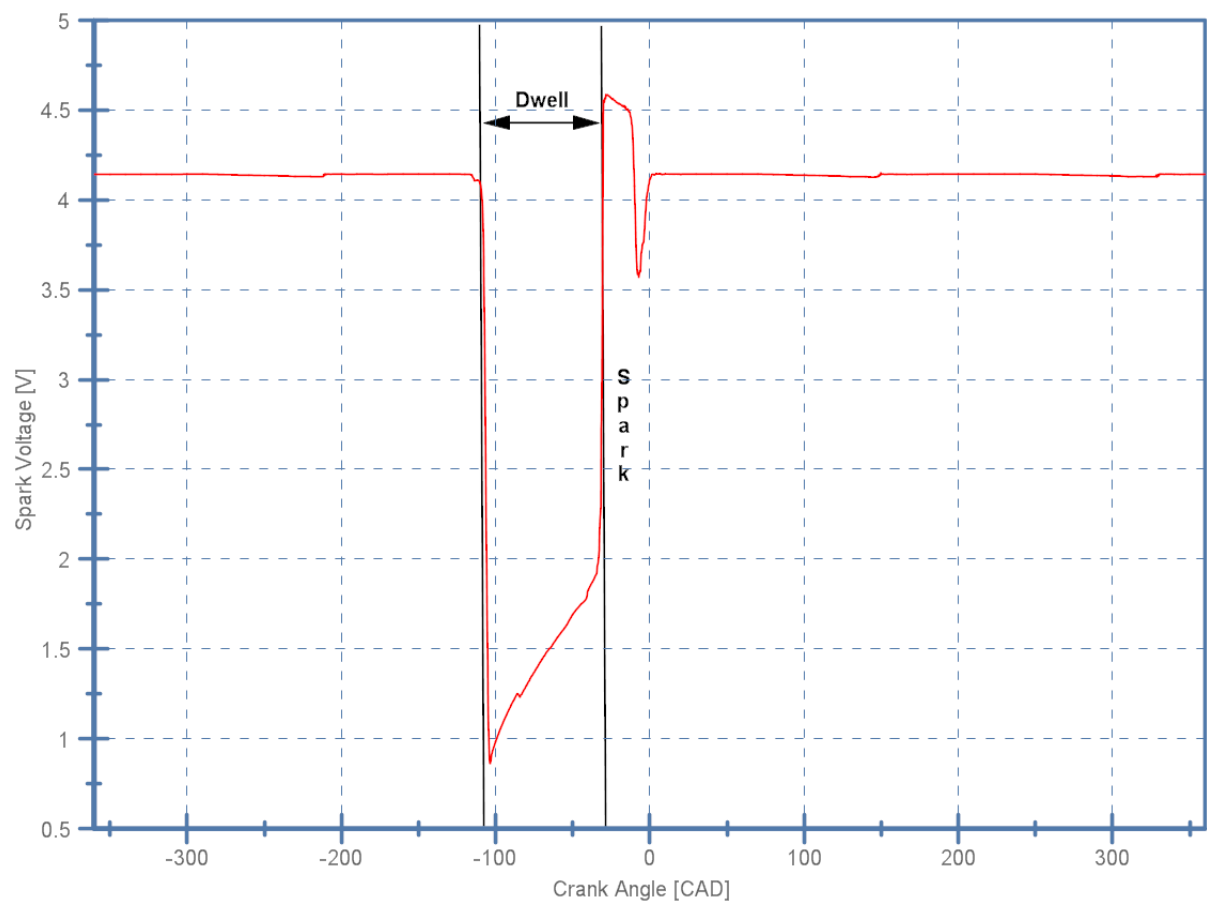
4.17 Custom User VIs

While NI CAS Software incorporates many well known calculations and processing operations useful for combustion analysis, inevitably each project is different and may require calculations not included in NI CAS Software by default. To accommodate this, NI CAS Software has the ability to execute custom user programmed VIs in three different locations: processing, heat release, and calculations. Processing algorithms are intended to manipulate waveforms, e.g., cylinder pressure pegging, before other calculations are performed. Custom heat release allows the user to designate a non-standard model for heat release. Finally, the outputs of user calculations are scalar values for which statistics are automatically calculated.

User Templates

In order to ensure successful integration of a custom user VI, user VI templates must be used as a starting point for all custom user VIs. User VI templates are included with the installation of NI CAS Software in the example project as well as the following location in the LabVIEW directory:

\...\examples\Combustion Analysis\

Note: The LabVIEW development environment is required to create a custom user VI

Custom Application: Cumulative Heat Release

In this application, the user desires to calculate the cumulative heat release in Joules for one cycle of combustion. Mathematically, this is done by integrating calculated heat release rate (dQ/dθ) between the defined start of combustion (SOC) and end of combustion (EOC), as in the following equation:

$$Q = \int_{SOC}^{EOC} \frac{dQ}{d\theta}\, d\theta$$

The following steps were accomplished to achieve this goal:

1. Open the template for custom user calculations in the Combustion Analysis examples folder. The block diagram should appear as follows:
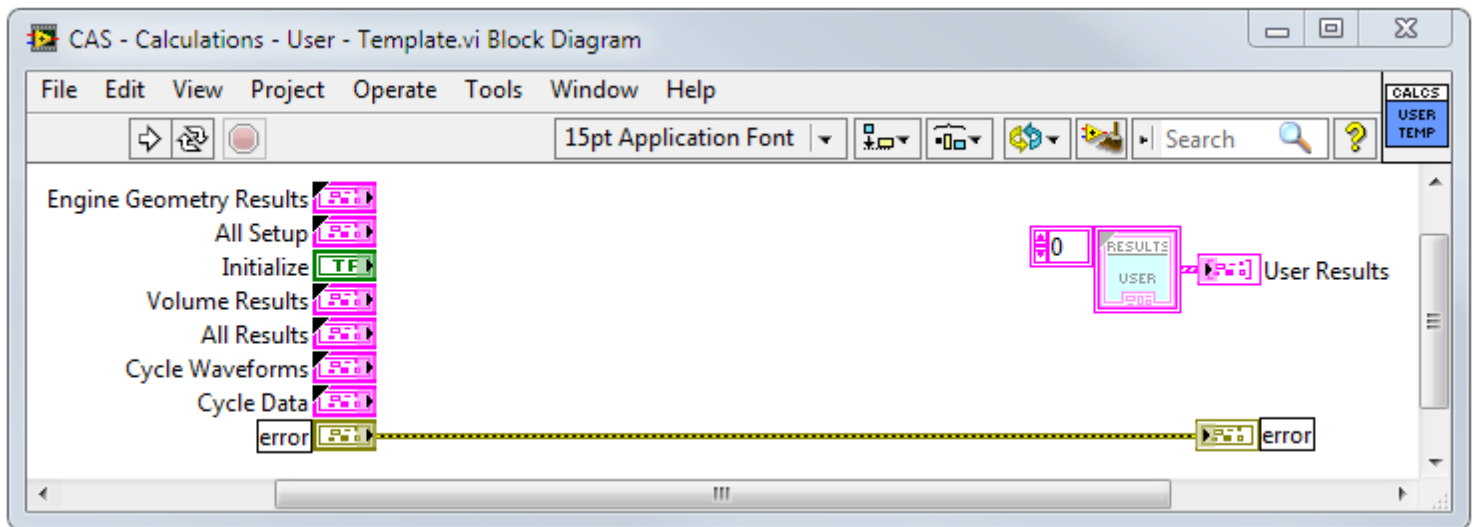
User Calculations Template

2. Use the 'Unbundle by Name' function from the 'Cluster, Class, & Variant' function palette to unpack the following inputs:

- Cycle Waveforms \ Heat Release Rate [J/CAD]
- All Setup \ Engine Geometry Setup \ Rotations Per Cycle
- Engine Geometry Results \ Sample Resolution [ppr]
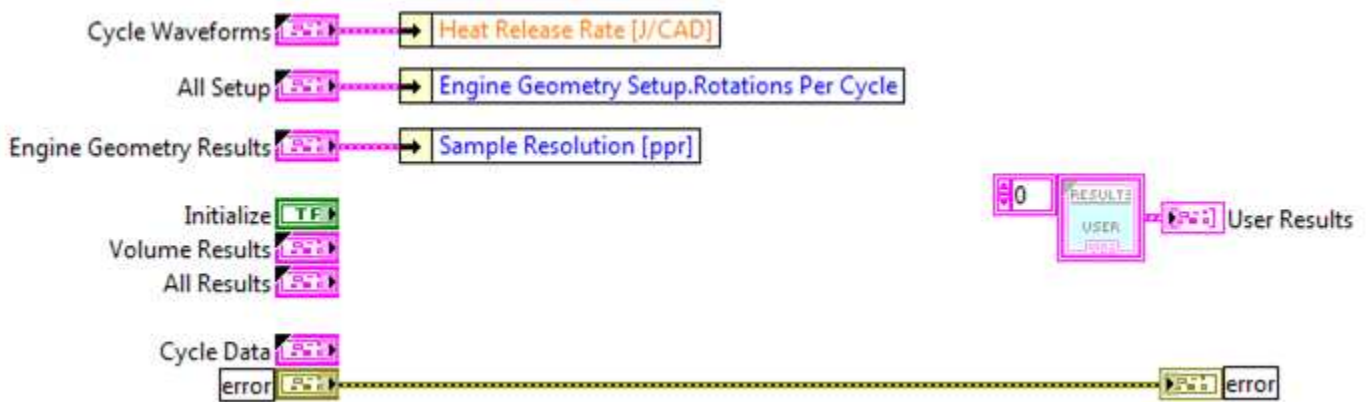
Unbundling calculation inputs

3. Create start and end of combustion constants in degrees after top dead center (DATDC), then convert them to array indices using the 'Rotations Per Cycle' and 'Sample Resolution' inputs.
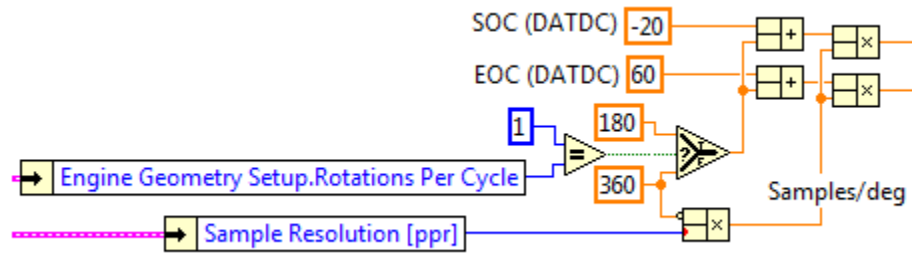
Defining and converting SOC and EOC to indices

Note: Waveform array indices start with '0' at 180 (2-stroke) or 360 CAD (4+ stroke) before compression TDC. For example, with a 3600 pulse-per-revolution encoder on a 4-stroke engine, the indices will range from 0 to 7200, with 3600 being compression TDC.

$$Index = [DATDC + (180 \ or \ 360)] * \frac{Sample \ Resolution}{360 \ deg}$$

4. Index an array subset from the heat release rate waveform, starting with the SOC and ending at the EOC (with duration EOC-SOC). This array subset corresponds to the period during which combustion is occuring. Using a For Loop, this discrete subset can be integrated using shift register terminals and an add block. The result is the scalar value for cumulative heat release in Joules.
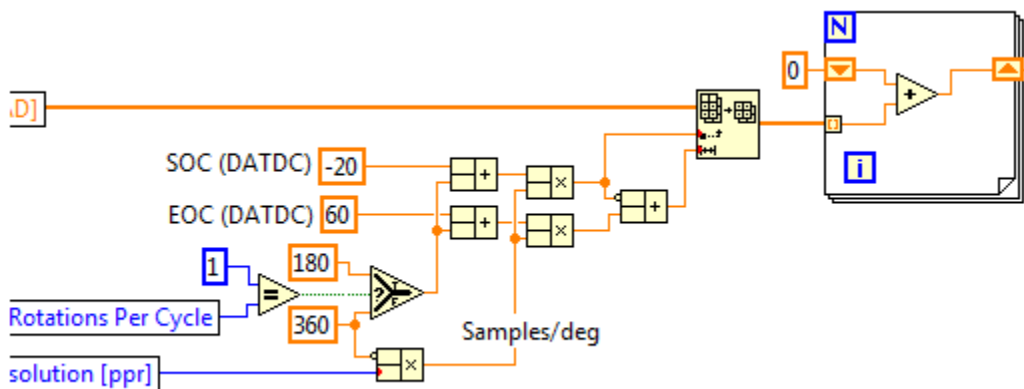
Indexing the heat release waveform and calculating the integral

5. Pack the scalar result and value name into a cluster using the 'Bundle by Name' function block and typedef provided. Convert the bundle to an array of bundles and connect this to the 'User Results' indicator.
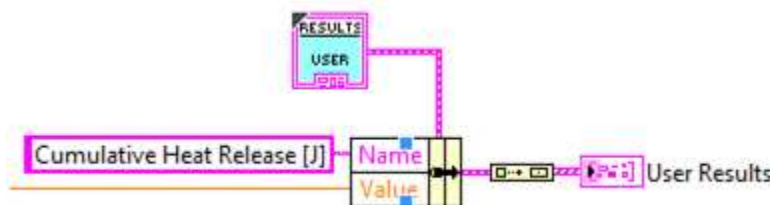
Packing outputs into an array of bundles

6. Use the 'Save As...' function to save your VI as a copy, renaming the new variant so that the template is not overwritten. Finally, select your VI in the 'Calculations' subhost of NI CAS Software and view the result in the 'User' table.
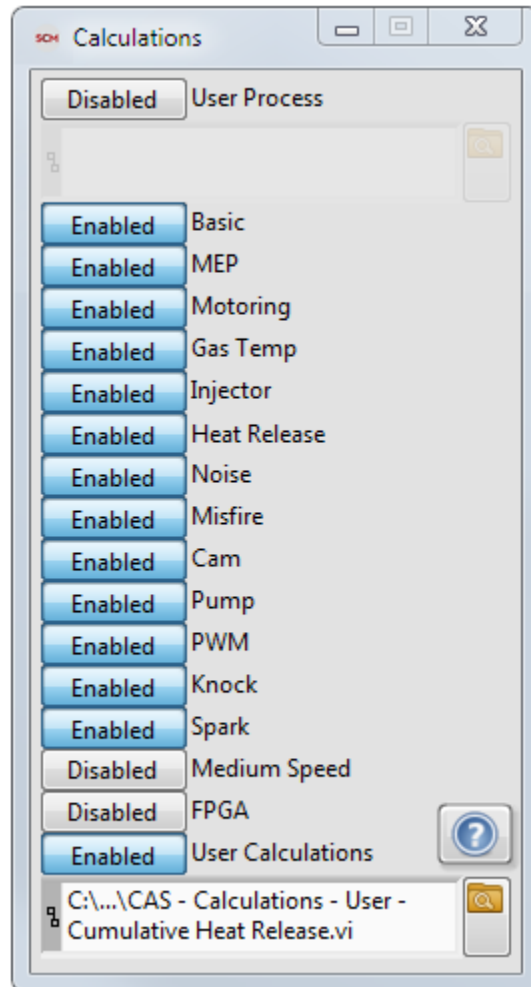
Selecting and enabling User Calculations

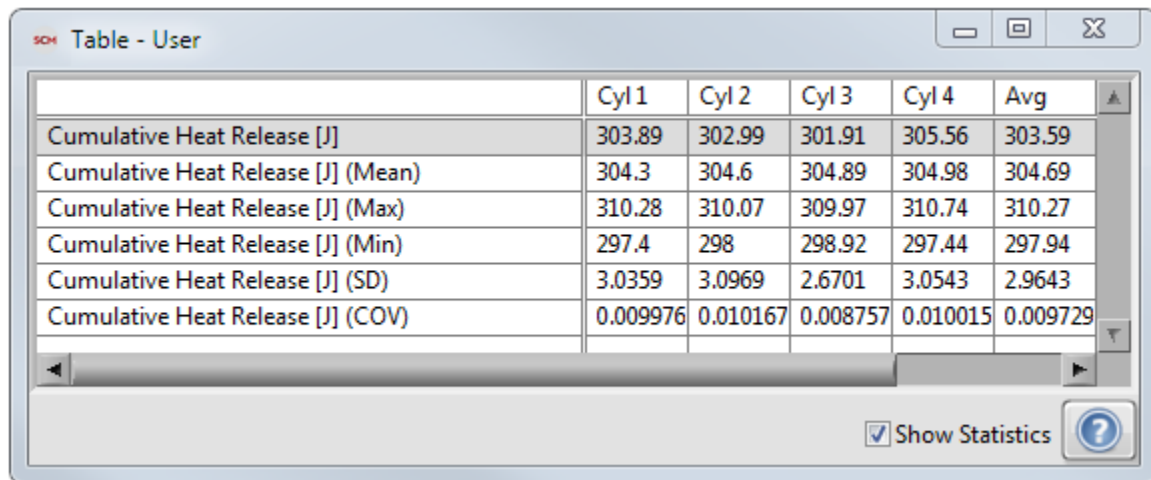|	Cyl 1	Cyl 2	Cyl 3	Cyl 4	Avg
Cumulative Heat Release [J]	303.89	302.99	301.91	305.56	303.59
Cumulative Heat Release [J] (Mean)	304.3	304.6	304.89	304.98	304.69
Cumulative Heat Release [J] (Max)	310.28	310.07	309.97	310.74	310.27
Cumulative Heat Release [J] (Min)	297.4	298	298.92	297.44	297.94
Cumulative Heat Release [J] (SD)	3.0359	3.0969	2.6701	3.0543	2.9643
Cumulative Heat Release [J] (COV)	0.009976	0.010167	0.008757	0.010015	0.009729

☑ Show Statistics

Viewing User results

5. Post Processing

5.1 NI CAS Software File Structure

Groups-Channels	Use	Description
Volume	R-S	Pre-calculated volume related waveforms
• Crank Angle	R-S	Cycle crank angle
• Volume	R-S	Cycle volume
• dVolume	R-S	Cycle volume derivative
• Cylinder Area	R-S	Cycle cylinder area
User Properties	C	User specified properties
File Settings	C	File settings
Basic Settings	C	Basic settings
Cam Settings	C	Cam settings
• 0...15	C-O	Cam settings for each cylinder
Filter Settings	C	Filter settings
• 0...15	C-O	Filter settings for each filter
Engine Geometry Setup	C	Engine geometry setup
Synchronous	R-S-C-O	Engine synchronous data
• Time	R	Sample timestamp
• AI0...15	R-C-N	Synchronous channel
• TDC	C	Digital channel setup
• Data	C	Digital channel setup
• Reduced Resolution	C	Digital channel setup
• Reserved	C	Digital channel setup
• DI4...15	C-N	Digital channel setup
• DI Data	R	Digital channel data in bit field
Heat Release Settings	C	Heat release Settings
Injection Settings	C	Injection Settings
Knock Settings	C	Knock Settings
• 0...15	C	Knock settings for each cylinder
Misfire Settings	C	Misfire settings
Pegging Settings	C	Pegging settings
Gas Temperature Settings	C	Gas temperature settings
Separate Settings	C	Separate settings
TDC Offset Settings	C	TDC offset settings
Asynchronous	R-C-O	Asynchronous data
• Time	R	Sample timestamp

• AI0...15	R-C-N	Synchronous channel
• TDC	C	Digital channel setup
• Data	C	Digital channel setup
• Reduced Resolution	C	Digital channel setup
• Reserved	C	Digital channel setup
• DI4...15	C-N	Digital channel setup
• DI Data	R	Digital channel data in bit field
Medium Speed	R-C-O	Medium speed data
• Time	R	Sample timestamp
• AI0...	R-C-N	Medium speed channel
FPGA	R-C-O	FPGA data
• Time	R	Sample timestamp
• ID	R	Sample ID
• Data	R	Sample Data
• AI0...	R-C-N	FPGA channels
User Setup	C	User defined calculation setup
Cycle	R	Cycle properties
• Time	R	Cycle start timestamp
• Speed	R	Previous cycle speed
• Cycle	R	Cycle number
Slow Speed	R-C-O	Slow speed data
• Time	R	Sample timestamp
• AI0...	R-C	Slow speed channel
Array Data - 1...	S-O	Post process cycle-by-cycle waveforms for each cylinder
• Crank Angle	S	Cycle crank angle
• AI0... - 0...	S	Cycle-by-cycle data
Synchronous Waveforms - 1...	S-O	Engine synchronous ensemble averages for each cylinder
• Crank Angle	S	Cycle crank angle
• AI0...	S-N	Ensemble average waveform
Asynchronous Waveforms - 1...	S-O	Asynchronous ensemble averages for each cylinder
• Crank Angle	S	Cycle crank angle
• AI0...	S-N	Ensemble average waveform
Calculation Waveforms - 1...	S-O	Calculated ensemble averages for each cylinder

• Crank Angle	S	Cycle crank angle
• AI0...	S-N	Ensemble average waveform
Calculation Results - 1...	S	Calculated results for each cylinder
• AI0..	S-N	Calculated values

R = Raw Data
S = Summary Data
C = Configuration Properties
O = Optional
N = Names Vary

5.2 Summary Files

Summary files contain all the calculated results and ensemble averages for all the waveforms.

Opening Summary Data Files
1. Determine the file version and if it is a raw or summary file.
2. Read configuration data.
      a. General settings are found at the group level.
      b. Channel settings are found at the channel level.
3. Read ensemble averages for desired cylinder
4. Read calculated results for desired cylinder

5.3 Raw Files

NI CAS Software includes several SubVIs to handle all the raw opening and processing. These subVIs are are part of an example application that can be used to view raw data files. Please note that the raw data files start at an arbitrary crank angle and must be aligned using data encoded in the file. The files store data as it is read from the device. Therefore, the individual cylinder offsets must also be accounted for. In the figure below, cycle X is the first available cycle. LabVIEW VIs and examples have been provided to allow easy access to the cycle by cycle data without any need to know the specifics of the encoded data. Please note that the data in the files is stored as voltages and must be scaled and pegged (when appropriate) to be useful.
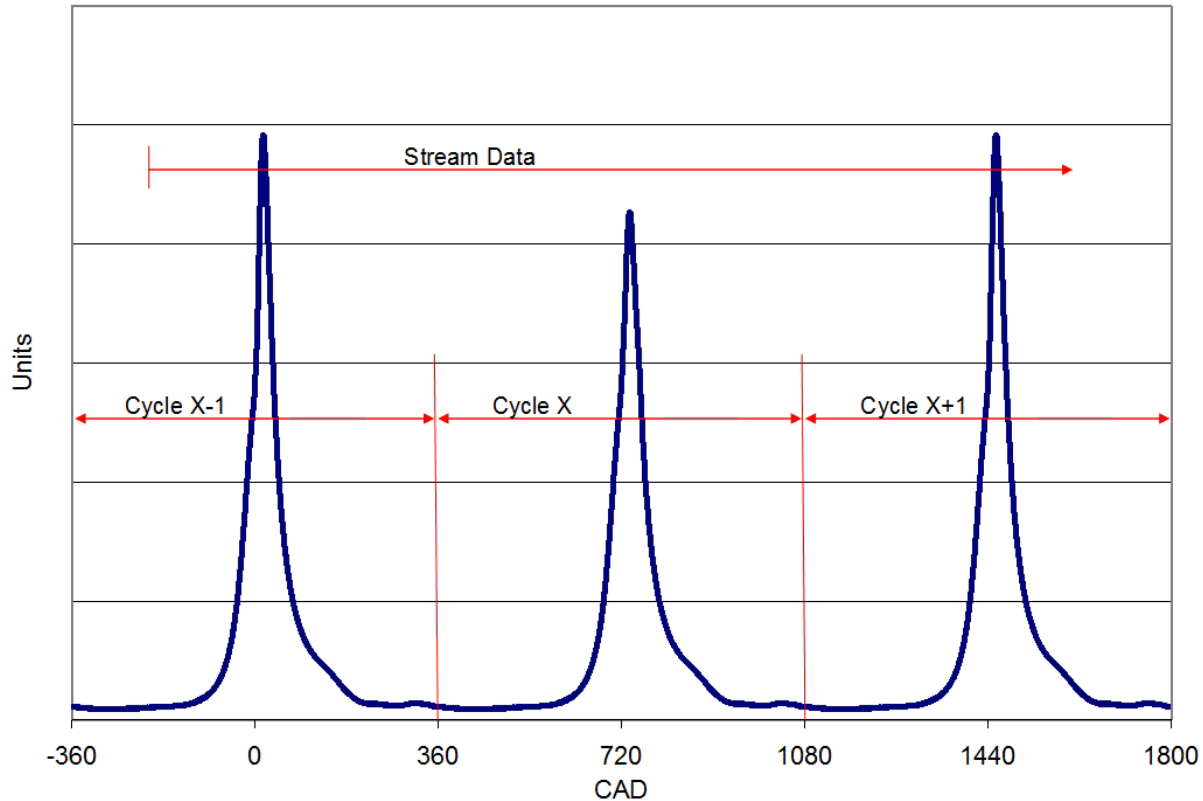

Opening Raw Data Files
1. Determine the file version and if it is a raw or summary file.
2. Read configuration data.
      a. General settings are found at the group level.
      b. Channel settings are found at the channel level.
3. Determine the TDC offsets
      a. Use the first bit of "DI Data" ("TDC") to get the global TDC offset.
      b. Use "Engine Geometry Setup" properties to determine resolution and cylinder TDC offsets.
      c. Use the third bit of "DI Data" ("Reduced Resolution") to reconstruct asynchronous data.
4. Decode "Data" to determine cycle speed, time, and cycle number.
5. Use engine synchronous or asynchronous timestamps to reconstruct FPGA and medium speed data.
6. Separate different types of data for each cylinder.
7. Apply channel gains and offsets to get to engineering units.
8. Apply calculations to get results.

Raw File Viewer

1. Make sure the Activation indicator is green.
2. Select a raw file to open.
3. Slide the cycle selector to the desired cycle.
4. Select a cylinder to display.
5. Select the appropriate tab to view and change settings.
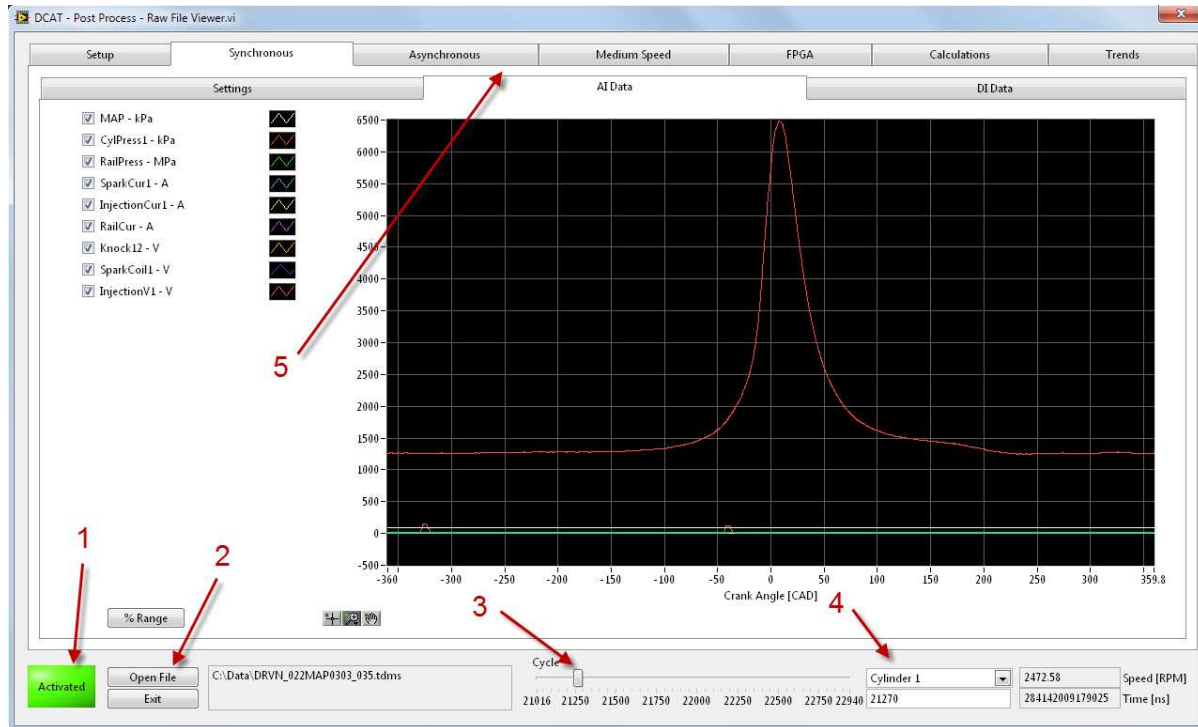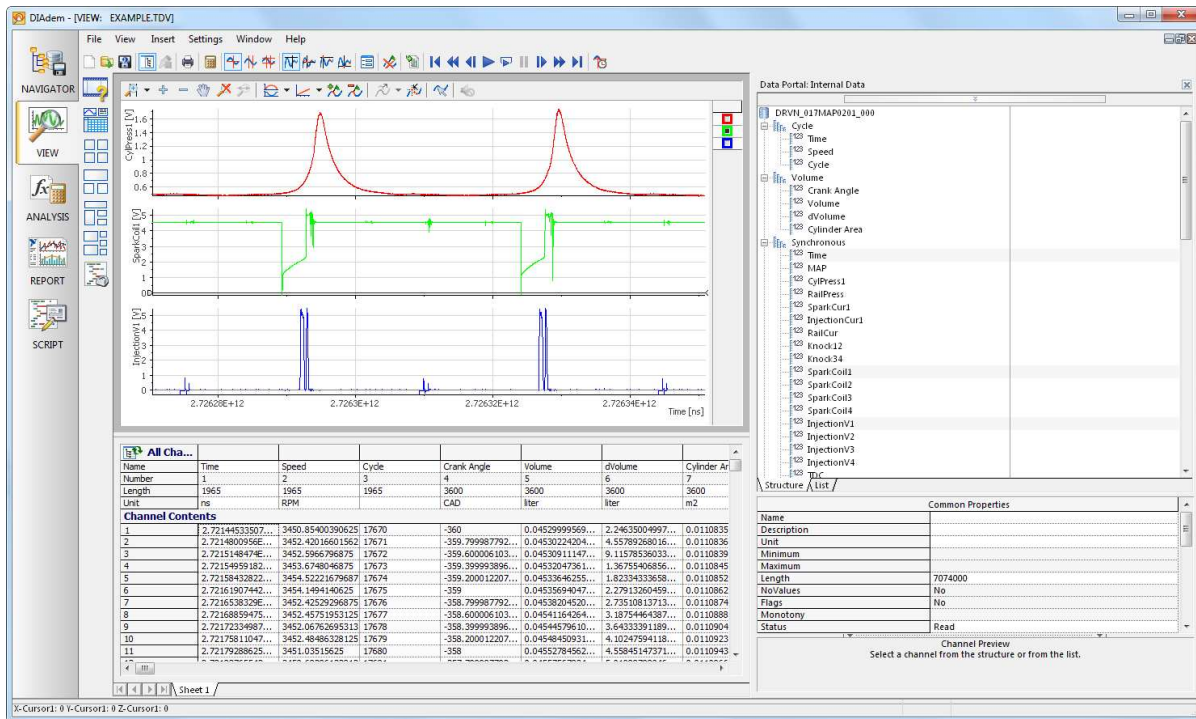
5.4 TDMS Files

Opening TDMS Files in Microsoft Excel

National Instruments provides a free Microsoft Excel plug-in that imports TDMS files. Importing a file creates a multi-page spreadsheet with all the data stored in the file. 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 Microsoft 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.

Opening TDMS Files in DIAdem

DIAdem is a power full tool for viewing, analyzing, and presenting data. When DIAdem is installed, double clicking on a tdms file will open it in DIAdem.

Converting TDMS Files to Other Formats

TDMS files can be converted to other formats and opened in a variety of interfaces. Many resources are available on at http://www.ni.com/. The NI CAS Software comes with an application to convert a group or folder of files from the TDMS format to text files. Due to the change in how data is being stored, text files will take ~10 times the disk space as the TDMS files. See Batch Processing for more details.

5.5 Batch Processing

Batch Process Raw Files to Summary files
NI CAS Software contains an application to process raw files to summary files. The application can process up to 8 files in parallel. The user selects a source folder and the desired files to process. The summary files are placed in the specified folder.
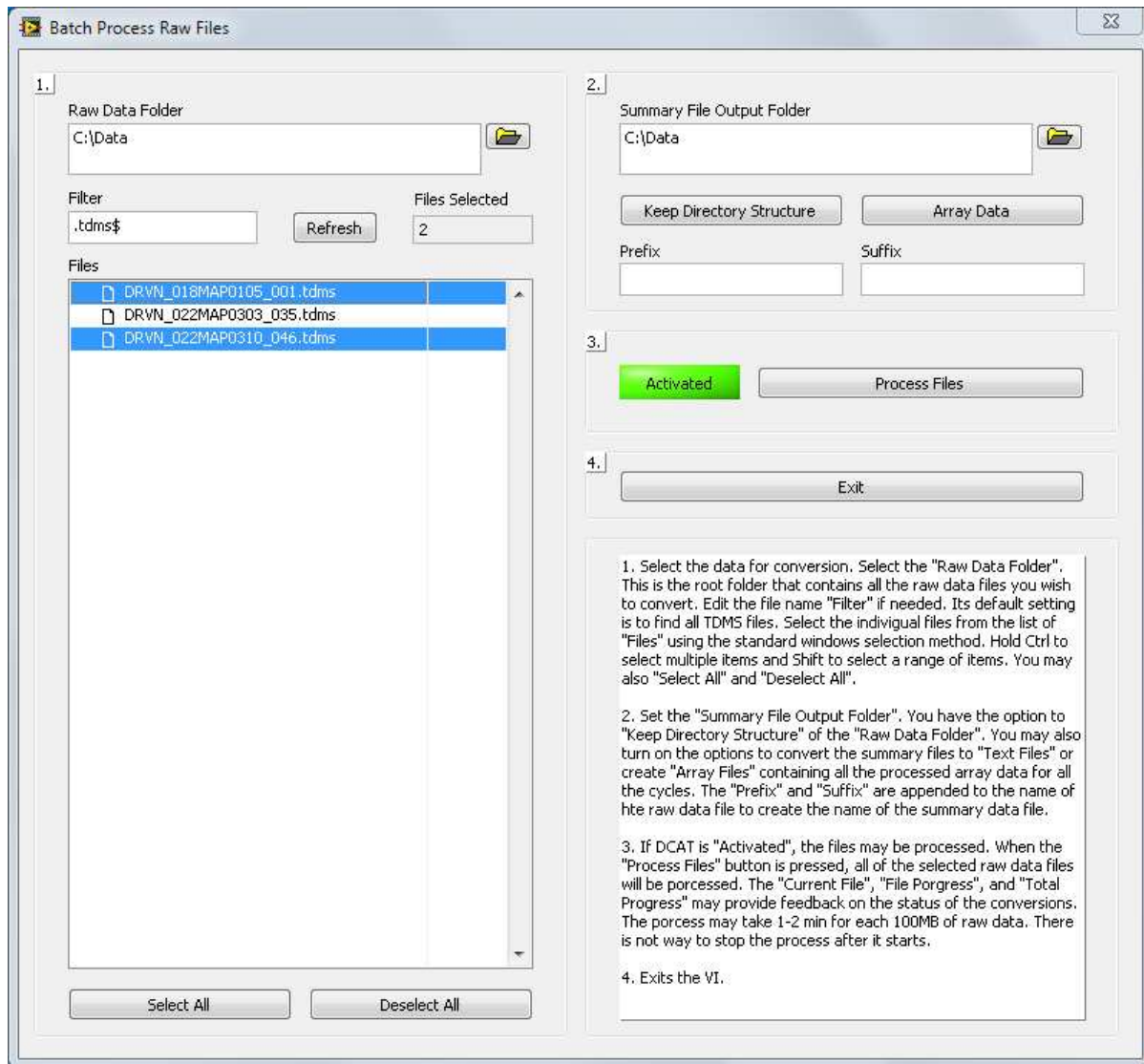
Batch Process TDMS files to Text files
NI CAS Software contains an application to process TDMS files to text files. The application can process up to 8 files in parallel. The user selects a source folder and the desired files to process. The summary files are placed in the specified folder.
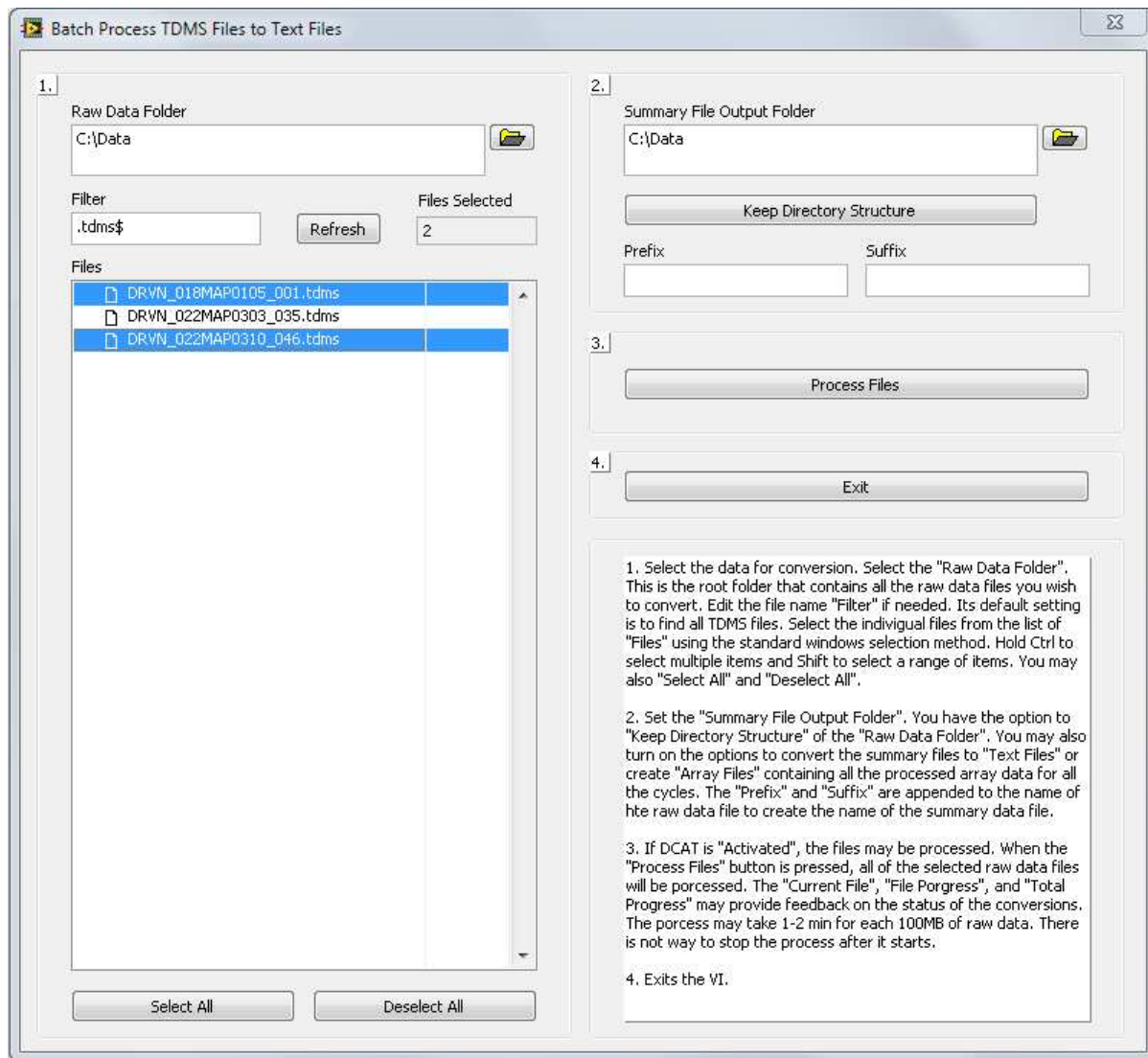
6. Troubleshooting

A Microsoft Windows Help file (.chm) for NI CAS Software is provided with the software download. Each window within the user interface contains a Help "?" button in the bottom right corner. Pressing this button will open the Help file to the associated help topic page.

Frequently Asked Questions (FAQs)

Q: I get an error message when I try to activate the software. What do I do?

A: Refer to the [Software Activation](#) section.

Q: How do I add my own calculations or results to the NI CAS Software?

A: NI CAS Software provides the ability to easily integrate user calculations in three areas; Processing, Heat-Release Rate, and Calculations.

1. **Processing**: All of the results of the processing steps (alignment, scaling, pegging, separation) are provided to the user calculations which can manipulate the waveform and other information before all of the calculations get the information.
2. **Heat Release Rate**: All of the results from the processing steps are provided to the user calculations which need to generate a heat release rate waveform. The resulting waveform is then used to calculate mass fraction burned and other heat release related parameters.
3. **Calculations**: All of the results from the processing steps and calculation steps are provided to the user calculations. The user calculations provide an array of calculated results to the NI CAS Software for display and saving in summary files.

NI CAS Software applications contain the ability to stream custom data from other parts of the application.

FPGA Data originates in the FPGA. Each parameter needs to be assigned an ID. All FPGA data streams to raw data files. Only data with ID defined in the FPGA Setup are processed in real-time and saved in summary files.

Slow Speed Data is read no more than once per cycle and is saved in raw and summary data files. The top level NI CAS Software example contains a template showing how to write the data. The data enters NI CAS Software through a global variable where the user defines the name, units, and value for each item.

User Properties can be added to raw and summary files. This data is captured at the beginning of a file and only written once. NI CAS Software example applications write all CalPoints to the properties by default.

Q: How do I add a miscellaneous sensor waveform to my display?

A: To display and save any signal, simply add it to the measurement setup and associate it with the appropriate cylinder. It will be displayed with all the AI or DI data for that cylinder.
When do I need to align the TDC offset?
A: The TDC offset must be aligned any time the encoder position is modified. This includes changing the encoder.
A: The TDC offset will change as a result of changing the encoder setup parameters. These parameters may have a small effect on the relation of TDC to the encoder Z pulse. Please see the section above for more details.
A: The TDC offset will change as a result of changing the encoder resolution, even if the Z pulse remains constant.

Q: How do I save the current configuration?

A: To save the current NI CAS Software settings, use the NI SCM "Save Current Calibration as Default" (purple) or the "Save Calibration As…" (blue) buttons on the SCM interface. This saves a file to the LabVIEW default data directory. (This is typically under ".\My Documents\LabVIEW Data" for Microsoft Windows and "C:\ni-rt\LabVIEW Data" for Real-Time.) Calibration files have a .cdl extension. These options can be found under the "Calibration" menu.

Q: How do I load a saved configuration?

A: To load a previous NI CAS Software calibration, copy the desired calibration file into the LabVIEW default data directory. (This is typically under ".\My Documents\LabVIEW Data" for Microsoft Windows and "C:\ni-rt\LabVIEW Data" for Real-Time.) Use the "Calibration > Load Calibration" if live loading is enabled. Use the "Calibration > Set Calibration" and restart the NI CAS Software target if live loading is disabled. Restart the NI CAS Software target application and select the appropriate file is the calibration selector is enabled. See the NI SCM User's Manual for more details.

Q: Why does Microsoft Excel fail to open a TDMS files?

A: The TDMS Microsoft 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, Microsoft Excel 2003 is limited to 255 columns. Open the TDMS plug-in properties and turn off custom property imports.

Q: How do I customize the user interface?

A: 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 NI CAS Software installation does not overwrite the changes.
A: See the NI SCM User's Manual.

Q: What font is used in the example applications?

A: The example applications use Segoe UI size 15 pt as the default font. In some circumstances, a different size is used.

Q: Why am I getting DAQ errors?

A: 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.
A: Verify that the device is not being used for other DAQ tasks.
A: Verify that a single DAQ device in not used for synchronous and asynchronous measurements.

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

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

Q: What do I do if I am having trouble obtaining encoder sync?

A: Verify that the Cam/Crank/TDC signals are set up correctly (polarity, offsets, etc.)

A: The TDC signal and the crank signals should not have rising edges at the same time. This condition can cause a situation where the TDC signal and the crank signals toggle position and cause an error. (One signal may be read as true before the other.)

A: Verify that the proper signals are connected to the FPGA. It may be helpful to pass the encoder signals through the FPGA and read them use an oscilloscope if available.

A: The encoder synchronization is controlled by the engine tracking VIs. Please refer to the EPT documentation for details on the specific flags and inputs.

Q: Why are the buffers or queues overflowing?

A: 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.

A: The performance of the system depends on many variables including user defined functions. It may be necessary to remove some real time processing to achieve the desired performance.

Q: Why are the speed and the timer not working correctly?

A: Check the PFI to P0 jumpers described in the hardware setup information. That data is transferred over these jumpers.

Q: Why is the NI CAS Software running but are doing nothing?

A: Please verify that you have activated the NI CAS Software. Please see Installation and Activation for details.

Q: Why doesn't the Deployment Version of NI CAS Software start correctly?

A: Verify that the appropriate version of DAQmx and LabVIEW Runtime are installed. The installers are available on National Instruments website and listed at the beginning of this manual.

A: Verify that NI SCM is installed and activated. Please see the NI SCM user's manual for details on installation and activation of NI SCM.

A: Verify that NI CAS Software for Deployment is activated. Check the Deployment Target Program front panel to verify that it is activated correctly.

A: Manually start the application. Please see the SCM user's manual for more details.

> 1. Launch the NI CAS Software for Deployment Target Program. It cam be started from LabVIEW, select Help > Find Examples. Search for "CAS".
> 2. Open NI SCM
> 3. Within NI SCM, define the Target IP address as "127.0.01" or your computer IP address.
> 4. Within NI SCM, set the Host VI to "<Program Files>\National Instruments\CAS 2014\Host\CAS Runtime.vi".
> 5. Within NI SCM, set the pairing file to "<Program Files>\National Instruments\CAS 2014\Host\CAS Runtime.par".
> 6. Within NI SCM, start the Host VI.

Q: Why does the real time controller crashed without warning?

A: Reboot the controller and try running the application again.

A: It may be possible to exceed the total physical memory of real time system. In this case, the real time controller will most likely crash (real time systems do not have virtual memory). The memory should be monitored using one of

the tools available with LabVIEW. Remove some of the memory use or add more memory to the system to prevent the crashes. (Please check with National Instruments for details on upgrading memory in a real time system.)

7. Abbreviations

API	Application Interface
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
CAS	Combustion Analysis System
cDAQ	Compact DAQ device
CPU	Central Processing Unit
DAQ	Data Acquisition
DI	Direct Injection
dV	Differential Volume
EPT	Engine Position Tracking
FFT	Fast Fourier Transform
FPGA	Field Programmable Gate Array
HRR	Heat Release Rate
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
SCM	Software Calbiration Management Toolkit
TDC	Top Dead Center
Sum	Summary
Sync	Synchronous (sampled at specific CAD)
V	Volume
VI	Virtual Instrument

8. Additional Support/Feedback

Contact your local NI branch office for support details or visit <http://www.ni.com/support/>

For additional help with getting your NI hardware and software installed and configured, visit: <http://www.ni.com/gettingstarted/>

9. Important Information

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