PRODUCT DATA

PULSE Reflex™ Angle Domain Analysis Type 8740

PULSE Reflex Angle Domain Analysis Type 8740 is a time data post-processing application for analysing sound and vibration in the angle domain. Its primary use is crank-angle analysis of internal combustion engine/powertrain systems, but it can be used to analyse any rotating system where cyclic phenomena are to be investigated.

Type 8740 uses the PULSE Reflex common database, which enables free exchange of results and data with other PULSE Reflex applications such as PULSE Reflex Core.

Photograph courtesy of Linamar Corporation Inc.

Uses and Features

Uses

- Angle-domain (crank angle) analysis of sound and vibration of internal combustion engines
- Statistical analysis of cycle related phenomena
- Comparison of angle domain data sets from different test runs
- Calculation of crank angle vs. time, as post-processing operation, from recordings of tachometer pulses from an engine control unit, flywheel or test-bed encoder
- Resampling of time data into the angle domain for graphing, statistical analysis, reporting and export to external software; for example Microsoft® Excel®

Features

- Support of streamed angle vs. time signals recorded using 4-ch. Input, 8-ch. Aux Module LAN-XI 51.2 kHz Type 3056 (Aux and HS Tacho)
- Angle calculation, as a post-processing operation, from tachometer pulse signals with or without missing pulses
- Cycle statistics: minimum, maximum, mean, RMS and peak-peak values per cycle, vs. time or RPM
- Multiple “gate” definitions (crank-angle ranges) for separate graphical displays and cycle statistics, for example, around the angle of injection
- Contour, waterfall and Campbell plots of cycle history vs. time or RPM
- Ability to apply offset for Top Dead Centre (TDC) correction based on TDC signal or missing pulses
- Automatic, unequivocal identification of engine duty cycles (for example 720° for 4-stroke engines) by tachometer pulse signal, TDC signal and any measurement signal with duty cycle period
- PULSE Reflex Data Viewer with integrated Microsoft® Office reporting capabilities
- Integrated solution using PULSE Time Data Recorder Type 7708 and PULSE Reflex Angle Domain Analysis Type 8740
- Open, stand-alone post-processing application for use with existing data acquisition systems or recorders

Introduction

PULSE Reflex Angle Domain Analysis Type 8740 is a dedicated application which processes time data recordings into the angle domain, presenting results as:

- 3D displays of cycle vs. time or cycle number
- 2D displays of cycles (either overlaid or single)
- Gated statistics vs. cycle number

Data can be further processed and reported using the PULSE Reflex Data Viewer task (BP 2258), which is a common component to all PULSE Reflex software applications.

Time data for Type 8740 can come from any recorder having formats compatible with PULSE Reflex as the software is capable of processing tachometer/encoder data (regardless of source) to calculate angle vs. time in preparation for cycle extraction.

The angle data may already be included as signals in recordings if made using the high-speed tachometer channels of the LAN-XI module Type 3056, which produces angle vs. time signals from high-resolution encoders.

Angle Calculation

The data input for PULSE Reflex Angle Domain Analysis Type 8740 is recorded time data with crank-angle information in the form of either an Angle vs. Time signal or a tachometer pulse signal with multiple pulses per revolution. The Time Editor in Type 8740 (see also BP 2258) enables not only viewing and selection of signals and time ranges for analysis but also the calculation of Angle vs. Time information from raw recorded tachometer signals.

Up to three signals can be used to determine absolute crank-angle position. In cases where there are two revolutions per duty cycle, for example in four-stroke engines, the unique crank-angle position in a 720° cycle can be calculated from:

- A tachometer (encoder) pulse signal with multiple pulses/rev
- A one pulse/rev tachometer signal for identification of the 0° point or Top Dead Center (TDC)
- A measurement signal with one trigger point (or pulse) per cycle to determine the absolute starting point of each cycle

An angle offset can be keyed in for calibration/correction of the cycle starting point. Tachometer pulse signals with missing pulses, as obtained from internal engine tachometer data or from gear wheels with missing teeth (for example, the flywheel), can be used to calculate both the Angle vs. Time signal and the 0° point or TDC. In this case, the missing pulses provide the one pulse/rev information without the need for an additional tachometer signal.

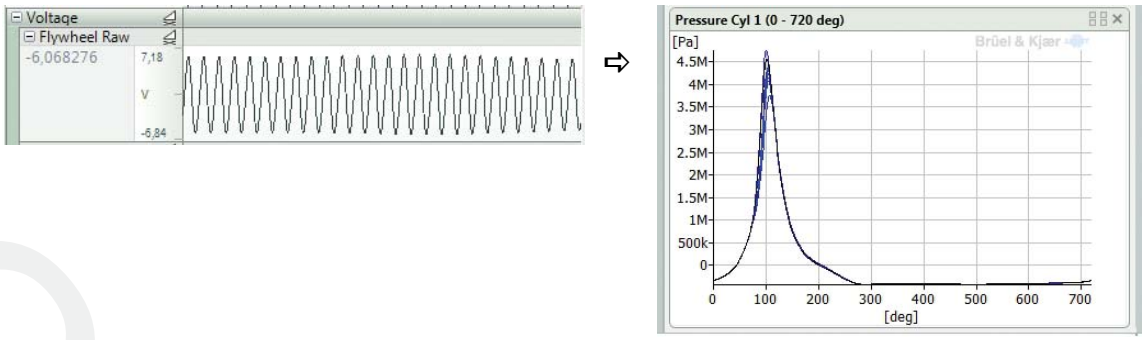
In cases where the tachometer pulse rate is beyond the frequency range of the measurement, for example a TTL signal from a test bed crank-angle encoder, the Angle vs. Time data can be acquired directly using a Type 3056 LAN-XI module. In this case, a 360° angle signal, with the TDC pulse taken into account, is calculated in real time during the measurement. When supplemented by a once per cycle signal, this provides all the information needed for angle-domain analysis with absolute angle in the full duty cycle. Data acquisition options include the PULSE Data Recorder Type 7701 and PULSE Time Data Recorder Type 7708.

In the absence of either a TDC signal or a signal with unique 720° cycle, the analysis can still be performed but the angle information will be relative to an arbitrary starting point. However, this will often be sufficient to identify and understand cycle related vibration or noise phenomena.

During analysis, the crank angle can be calculated more or less automatically, depending on the available input signals.

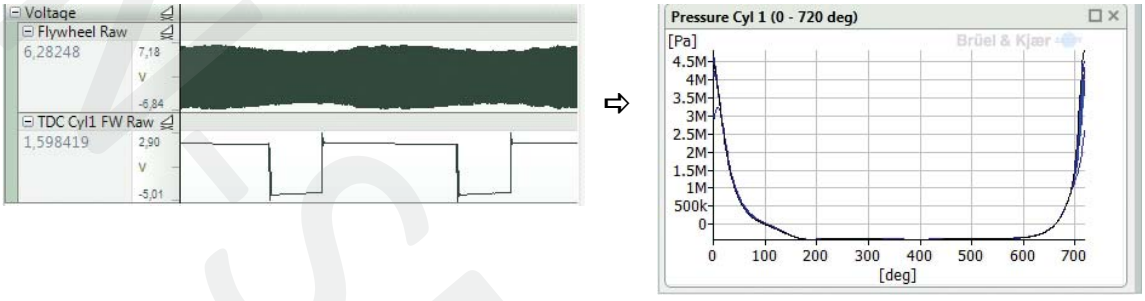
The simplest measurement that enables angle-domain analysis of the signals, is acquisition of a tacho pulse signal from a shaft encoder or a magnetic pickup on a flywheel (see Fig. 1).

Fig. 1
Engine cycles with Top Dead Center at arbitrary position



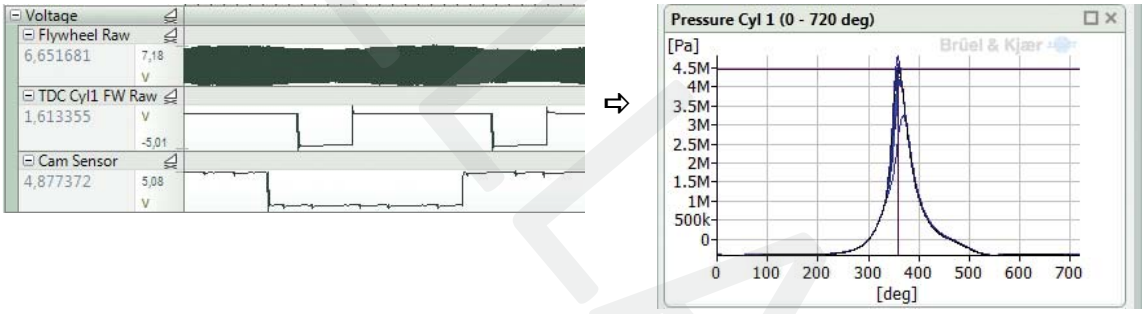
If another tacho signal with one pulse per revolution and indication of TDC is available, the angle calculation can take that into account (see Fig. 2). In this way the angle calculation, and therefore angle analysis results, will automatically refer to an angle axis starting at TDC, but the angle axis may switch by one revolution from one measurement to another.

Fig. 2
Engine cycles starting at Top Dead Centre based on a one pulse/rev synchronization tachometer signal



Angle calculation can also be set up to take a third signal, with 1 event per cycle, into consideration. In this case, the results from angle analysis of a series of measurements will refer to a common angle axis and all angle-domain analysis results can be compared directly (see Fig. 3).

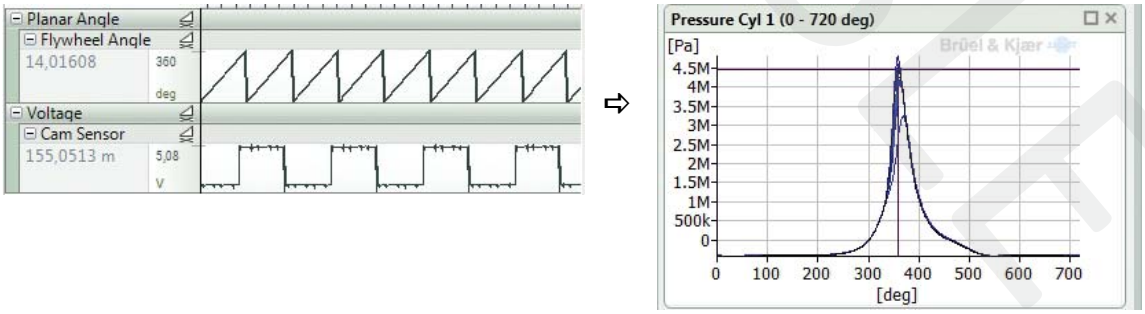
Fig. 3
Engine cycles always starting at correct Top Dead Centre based on two synchronization tachometer signals



Real-time Crank-Angle Acquisition

If a PULSE LAN-XI system including a Type 3056 aux and tacho module with high-speed tacho option is used for data acquisition, the processing of encoder pulses and TDC can be done in real time during acquisition. The crank-angle signal, together with any measurement signal with one event per cycle, will provide the correct angle axis. (see Fig. 4)

Fig. 4
Engine cycles always starting at correct Top Dead Centre based on directly measured angle signal and a one pulse/ cycle signal



Cycle Extraction and Resampling into the Angle Domain

The next step in the process is to extract precise duty cycles with fixed angle increments. This is done by resampling the time data to align it with angular position so that each cycle contains the required angle increment and number of data points. Time signals are resampled into the angle domain by use of the chosen angle signal. Angular resolution is user definable from 0.1° to 15° and the cycles can be extracted continuously or spaced a given number of cycles apart. For speed sweep measurements, up or down, rpm spacing can be specified.

Once the data is in this format, it can be displayed in 2D or 3D – see Fig. 5, where cylinder 1 pressure is shown as cycle vs. cycle number, single cycle, all cycles overlaid, and the maximum per cycle.

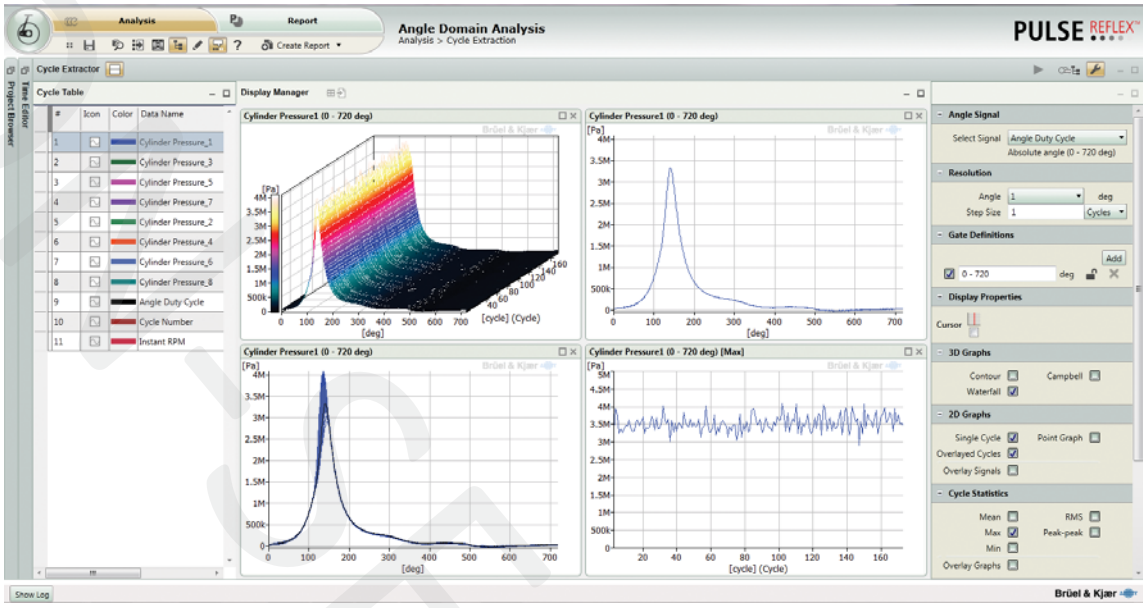


Fig. 5
Typical angle-domain display – views of all cycles: in 3D, singly, overlaid and statistics (max)

Synchronised cursors between displays enable easy insights into the data, see Fig. 6.

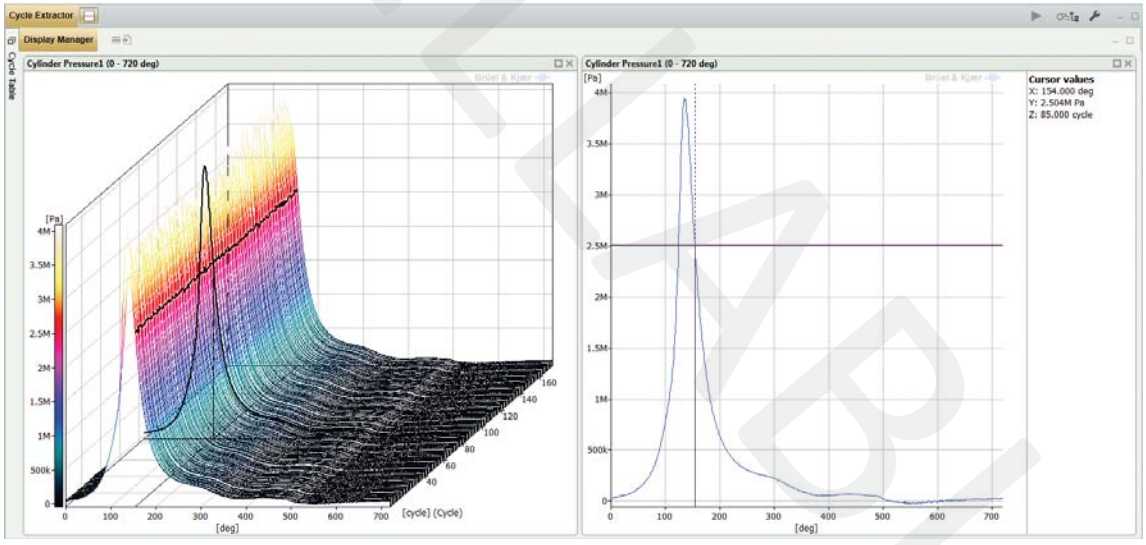
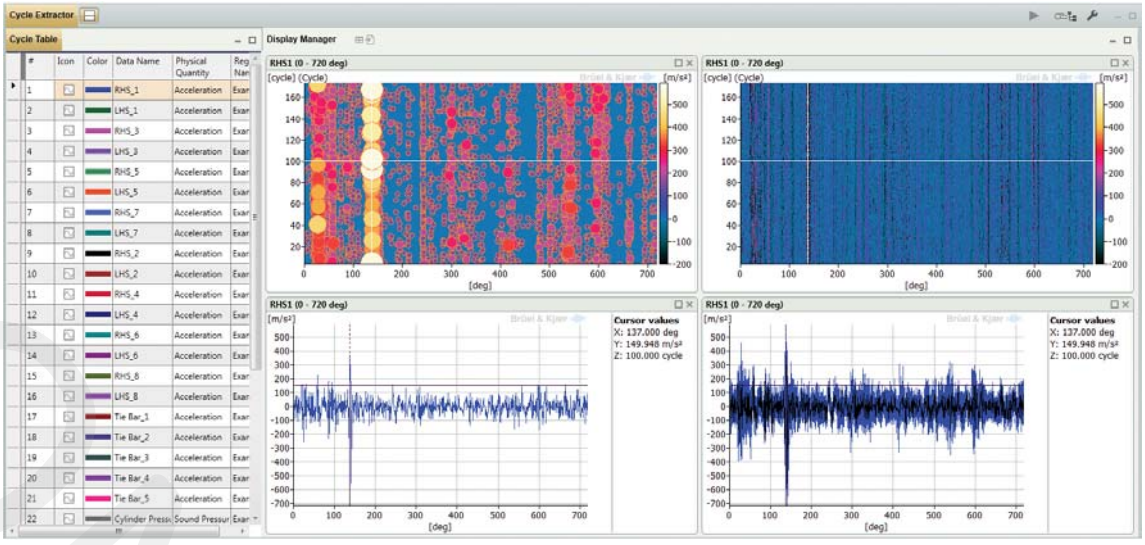


Fig. 6
Single cycle and waterfall plot of cycle history. The 2D and 3D plots are coupled for easy extraction of a single cycle by clicking in the 3D plot

The use of special displays, such as the Campbell diagram, can help identify interesting features which might otherwise be difficult to see using other display formats, Fig. 7.

Fig. 7
Campbell diagram and contour plot of cycle history. The Campbell diagram (top left) reveals details which are not so easy to in the other displays



Cycle Statistics Calculations

Cycle statistics can be calculated for complete cycles or for angle ranges (gates) within cycles. The available cycle statistics results are:

- **Max.** and **Min.**: maximum and minimum values of a signal within each engine cycle within specified gate limits
- **Mean**: the mean value of a signal over each engine cycle/gate
- **RMS**: Root-Mean-Square value of a signal over each engine cycle/gate
- **Peak-Peak**: the difference between the maximum value and the minimum value of a signal within each engine cycle/gate

Average Cycle Calculations

- **Max.** and **Min.**: maximum and minimum values of a signal at each angle step across the entire cycle history
- **Mean**: mean value of a signal at each angle step across the entire cycle history, i.e., the “average cycle”
- **Mean + 2σ** and **Mean – 2σ**: the average cycle plus or minus the standard deviation.

Reporting

For reporting purposes, results can be transferred to the PULSE Reflex Data Viewer, which is included in the angle-domain application.

Specifications – PULSE Reflex Angle Domain Analysis Type 8740

Requirements

SYSTEM REQUIREMENTS
- PULSE v.17 or later
- Windows® XP, Windows® 7 or Windows® 8 operating system
- PC requirements for PULSE Reflex Base Type 8700 must be fulfilled (see Software for PULSE Reflex Product Data, BP 2258)

Data Input

- Imports time data recordings with included tachometer pulse signal with multiple pulses per revolution or crank angle signal (Crank angle vs. time type of signal)
- Support of tachometer pulse signals with missing pulses
- Top point offset/calibration can be entered to get the crank angle signal correct according to the top dead center
- TTL output from industry standard crank angle encoders such as AVL 365 is supported by use of LAN-XI Module Type 3056 for data acquisition

Statistical Results

STATISTICAL CALCULATIONS WITHIN EACH ENGINE CYCLE
- Min.
- Max.
- Mean
- RMS
- Peak-peak

STATISTICAL CALCULATIONS ACROSS COLLECTION OF ENGINE CYCLES
- Min.
- Max.
- Mean
- Mean + 2σ
- Mean – 2σ

Result Displays

3D-PLOTS
- Contour plot
- Waterfall plot
- Campbell plot

2D-PLOTS
- Single cycle plot
- Overlaid cycles plot
- Point graph

Ordering Information

Type 8740-X*	PULSE Reflex Angle Domain Analysis

PREREQUISITES

Type 8702-X*	PULSE Reflex Basic Processing

RELATED PRODUCTS

Type 8701	PULSE Reflex Data Viewer
Type 8702	PULSE Reflex Basic Processing
Type 8703	PULSE Reflex Advanced Processing
Type 8704	PULSE Reflex Order Analysis
Type 8705	PULSE Reflex Advanced Order Analysis
Type 8706	PULSE Reflex Standardised CPB Option
Type 8710	PULSE Reflex Sound Quality Metrics

* Where “X” indicates the license model, either N: Node-locked or F: Floating

As PULSE Reflex Core currently only supports post-processing of time data, it requires recorded time files as input. These may come from external systems, using the file formats that PULSE Reflex reads, or from PULSE LabShop’s own internal recorder, Type 7701, or the stand-alone PULSE Time Data Recorder Type 7708.

MAINTENANCE AND SUPPORT AGREEMENTS

M1-8740-X*	PULSE Reflex Angle Domain Analysis Maintenance & Support Agreement

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HEADQUARTERS: Brüel & Kjær Sound & Vibration Measurement A/S · DK-2850 Nærum · Denmark
Telephone: +45 7741 2000 · Fax: +45 4580 1405 · www.bksv.com · info@bksv.com

Local representatives and service organisations worldwide

Brüel & Kjær