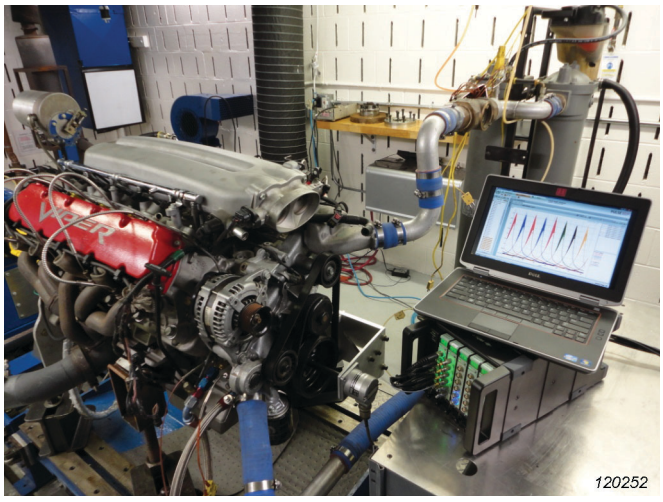
PRODUCT DATA

BK Connect Angle Domain Analysis Type 8440

BK Connect® Angle Domain Analysis Type 8440 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/power train systems, but it can be used to analyse any rotating system where cyclic phenomena are to be investigated.

Type 8440 uses the BK Connect common database, which enables free exchange of results and data with other BK Connect applications.



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
- Calculation of angular vibration vs time for use in downstream processing
- 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 LAN-XI Module Type 3056 (auxiliary and high-speed tachometer)
- Angle vs time calculation, as a post-processing operation, from tachometer pulse signals with or without missing pulses
- Angular vibration vs time calculation as a post-processing operation
- 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
- Integrated Microsoft® Office reporting capabilities
- Integrated recording and post-processing solution using BK Connect Time Data Recorder Type 8402 and BK Connect Angle Domain Analysis Type 8440
- Open, stand-alone post-processing application for use with existing data acquisition systems or recorders

Brüel & Kjær

Introduction

BK Connect Angle Domain Analysis Type 8440 is a dedicated application that 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

Time data for Type 8440 can come from any recorder having formats compatible with BK Connect, as the software is capable of processing tachometer/encoder data (regardless of source) to calculate angle vs time in preparation for cycle extraction.

Recordings can be made inside the application itself. With the addition of a BK Connect Hardware Setup Type 8401 licence, the real-time monitors, including simple start/stop recording, become an integrated part of the application. With the further addition of a BK Connect Time Data Recorder Type 8402 licence, full featured recording with triggers and markers is also available.

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

Angle Calculation

The data input for BK Connect Angle Domain Analysis Type 8440 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 built-in Time Editor 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 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.

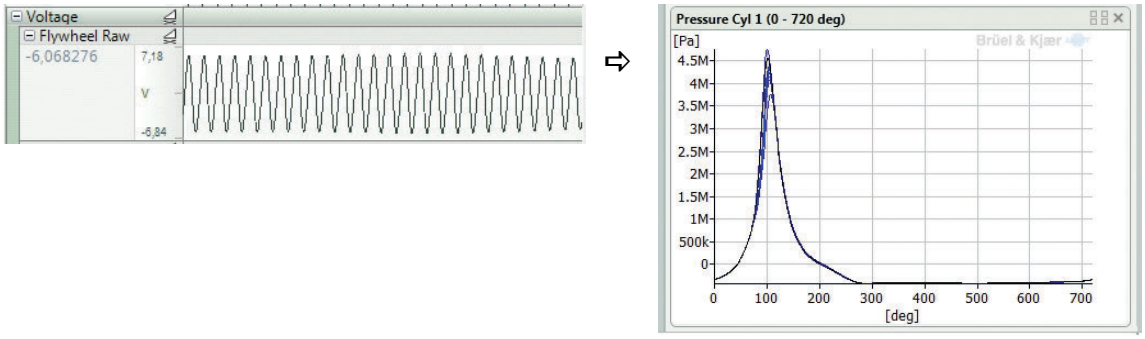
In cases where the tachometer pulse rate is beyond the frequency range of the measurement, for example a transistor-transistor logic (TTL) signal from a test bed crank angle encoder, the angle vs time data can be acquired directly using LAN-XI Module Type 3056. In this case, a 360° angle signal, with 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.

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.

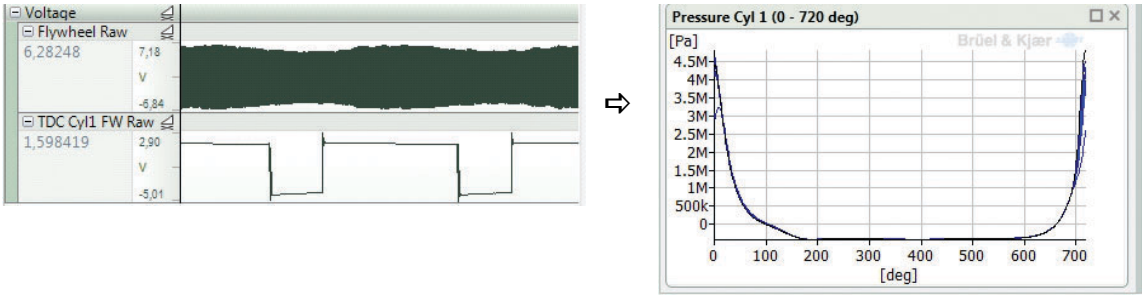
The simplest measurement that enables angle domain analysis of the signals, is acquisition of a tacho pulse signal from a shaft encoder or a magnetic pickup on a flywheel (see Fig. 1).

Fig. 1
Engine cycles with TDC at arbitrary position



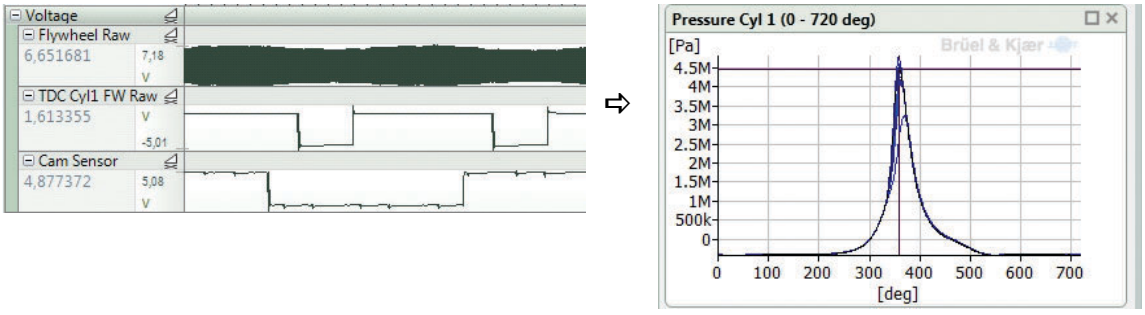
If another tacho signal with one pulse per revolution and indication of TDC is available, the angle calculation can take that into account (see Fig. 2). In this way the angle calculation, and therefore angle analysis results, will automatically refer to an angle axis starting at TDC, but the angle axis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

Fig. 2
Engine cycles starting at TDC based on a one-pulse/ rev synchronization tachometer signal



Angle calculation can also be set up to take a third signal, with one 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).

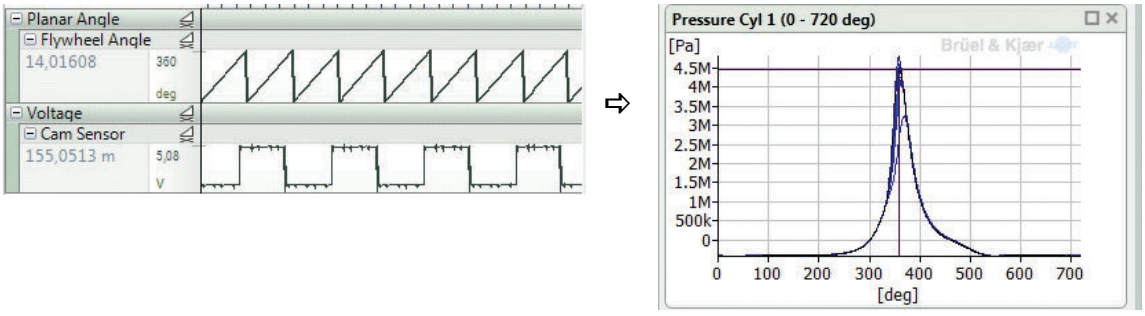
Fig. 3
Engine cycles always starting at correct TDC based on two synchronization tachometer signals



Real-time Crank Angle Acquisition

If a LAN-XI system with Module Type 3056 (for auxiliary and high-speed tacho signals) 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)

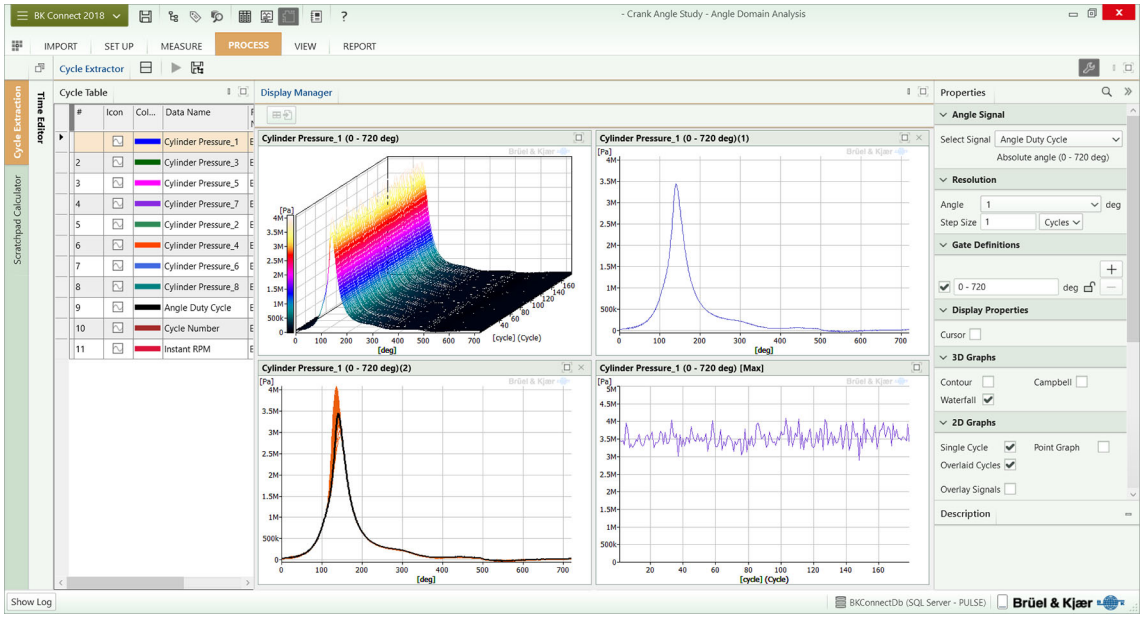
Fig. 4
Engine cycles always starting at correct TDC based on directly measured angle signal and a one pulse/cycle signal



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.

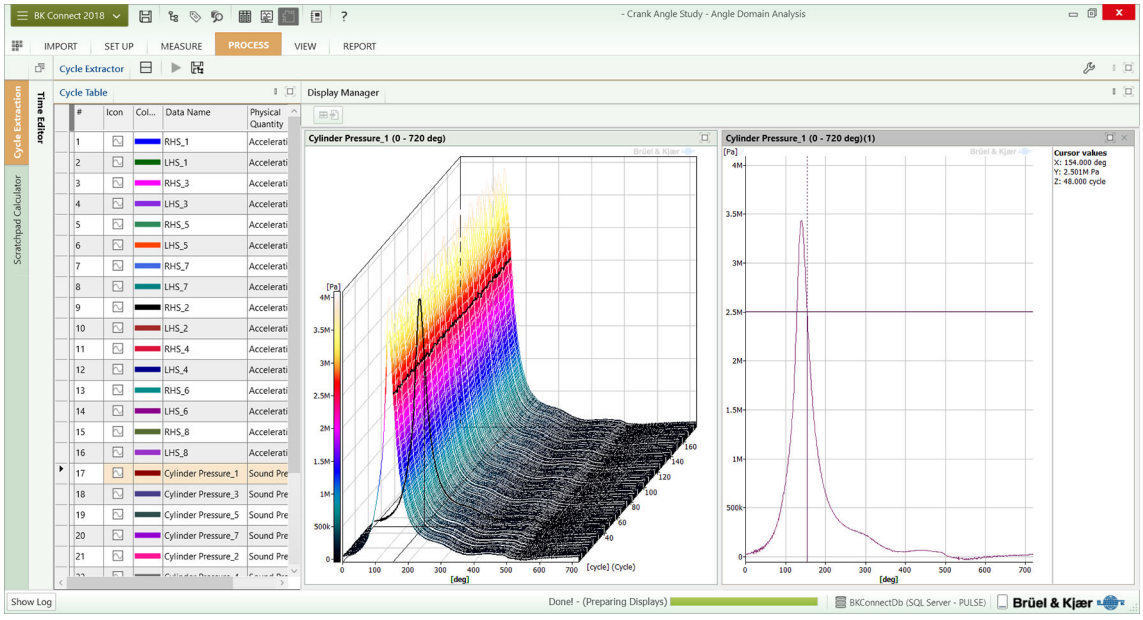
Once the data is in this format, it can be displayed in 2D or 3D – see Fig. 5, where cylinder 1 pressure is shown as cycle vs cycle number, single cycle, all cycles overlaid, and the maximum per cycle.

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



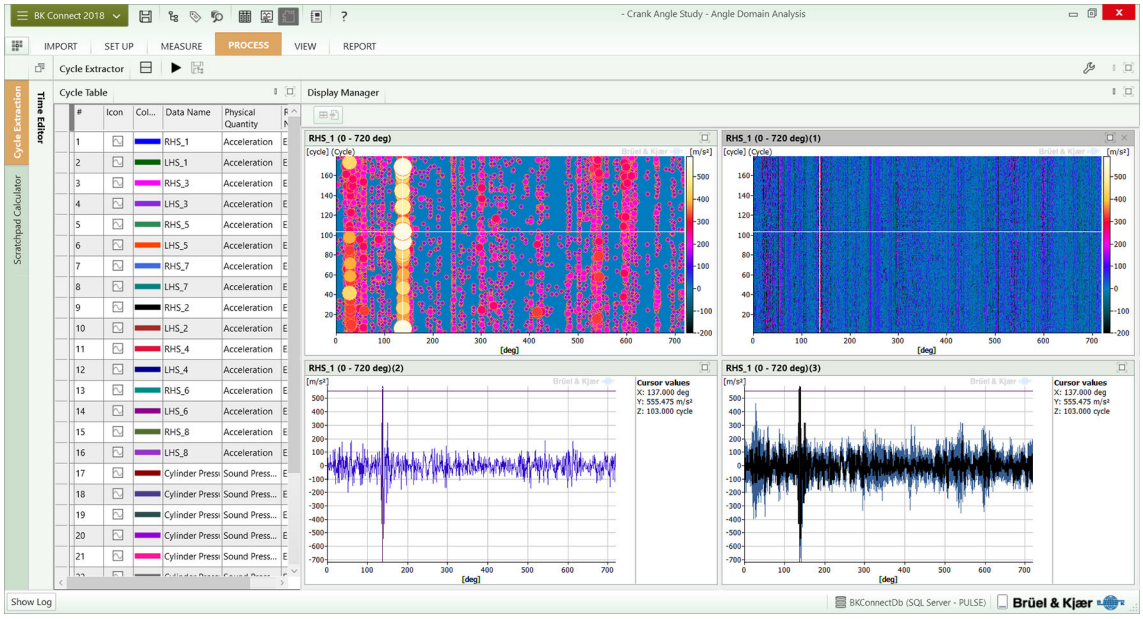
Synchronised cursors between displays enable easy insights into the data, see Fig. 6.

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 that 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 see 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, that is, the “average cycle”
- **Mean + 2σ** and **Mean – 2σ**: the average cycle plus or minus the standard deviation.

Reporting

Reports are easily generated using the report button, which sends displays to the active Microsoft® Word or PowerPoint® report.

With a Data Viewer (advanced) Type 8401-A licence, you can have more flexible reporting options using the Data Table Viewer and/or Result Matrix Viewer inside the Angle Domain application.

SYSTEM REQUIREMENTS
- The following BK Connect applications:
  – Data Viewer Type 8400
- Microsoft® Windows® 10 Pro or Enterprise (x64) with either Current Branch (CB) or Current Branch for Business (CBB) servicing model
- Microsoft® Office 2016 (x32 or x64) or Office 2019 (x32 or x64)
- Microsoft® SQL Server® 2017 or SQL Server® 2019
  Note: Microsoft SQL Server 2017 is included in BK Connect installation

RECOMMENDED SYSTEM CONFIGURATION
- Intel® Core™ i7, 3 GHz processor or better
- 32 GB RAM
- 480 GB Solid State Drive (SSD) with 20 GB free space, or better
- 1 Gbit Ethernet network*
- Microsoft® Windows® 10 Pro or Enterprise (x64), with CB
- Microsoft® Office 2016 (x32)
- Microsoft® SQL Server® 2017
- Screen resolution of 1920 × 1080 pixels (full HD)

Data Input

- Imported time data recordings with included tachometer pulse signal (with multiple pulses per revolution), or crank angle signal (crank angle vs time type of signal)
- Recordings from integrated time data recorder (with BK Connect Time Data Recorder Type 8402 licence)
- Support of tachometer pulse signals with missing pulses

* A dedicated data acquisition network (LAN or WAN) is recommended; a network that only handles data from the front end improves the stability of the data

- Top point offset/calibration can be entered to get the crank angle signal correct according to the TDC
- 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 8440-X	**BK Connect Angle Domain Analysis**

PREREQUISITE

Type 8400-X	BK Connect Data Viewer

ADDITIONAL SOFTWARE FOR RECORDING WITHIN APPLICATION

Type 8401-X	BK Connect Hardware Setup (can use monitor recorder for basic recording functionality)
Type 8402-X	BK Connect Time Data Recorder (use with Type 8401 for expanded recording functionality)

SOFTWARE MAINTENANCE AND SUPPORT AGREEMENTS

M1-8440-X	Agreement for Type 8440
M1-8400-X	Agreement for Type 8400
M1-8401-X	Agreement for Type 8401
M1-8402-X	Agreement for Type 8402

There are software agreements for all software modules.

LAN-XI DATA ACQUISITION HARDWARE

Type 3056-A-040	4-ch. Input/HS-Tacho + 8-ch. Aux. Module, 51.2 kHz (Mic, CCLD, V), incl., Detachable Front Panel UA-2111-040 with 4 BNC input connectors and 2 LEMO auxiliary connectors

Other BK Connect Software

Type 8400-A-X	BK Connect Data Viewer (advanced)
Type 8400-B-X	BK Connect Native File Importers
Type 8400-C-X	BK Connect External File Importers
Type 8400-T-F	BK Connect Team Server – floating licence only
Type 8401-A-X	BK Connect Hardware Setup (advanced)
Type 8403-X	BK Connect Data Processing
Type 8403-A-X	BK Connect Data Processing Specialist
Type 8405-B-X	BK Connect Advanced Frequency Analysis Option
Type 8405-C-X	BK Connect CPB Option
Type 8405-E-X	BK Connect Order Analysis Option
Type 8405-F-X	BK Connect Order Tracking Option
Type 8405-G-X	BK Connect Sound Quality Metrics Option

For more information on core BK Connect software including Data Viewer, Hardware Setup, Time Data Recorder and Data Processing, visit the BK Connect page on the Brüel & Kjær website.
For more information on LAN-XI module Type 3056 as well as other LAN-XI data acquisition hardware, visit bksv.com/lan-xi.

† "X" indicates the license model, either N: Node-locked or F: Floating

Brüel & Kjær Sound & Vibration Measurement A/S
DK-2850 Nærum · Denmark · Telephone: +45 77 41 20 00 · Fax: +45 45 80 14 05
www.bksv.com · info@bksv.com
Local representatives and service organizations worldwide

Brüel & Kjær

2019-08
BP 2576 – 12