HBK
HOTTINGER BRÜEL & KJÆR

PRODUCT DATA

PULSE Operational Modal Analysis Types 8760 – 8762, Batch Processing Option BZ-8527 and Structural Health Monitoring Modules BZ-8550 – 8554

PULSE™ Operational Modal Analysis is the analysis tool for effective modal parameter estimation in cases where only the output is known. The software allows you to perform accurate modal analysis under operational conditions and in situations where the structure is impossible or difficult to excite using externally applied forces.

For an integrated, easy-to-use modal test and analysis system, use BK Connect® software for geometry-guided data acquisition and measurement validation, then seamlessly transfer the data to Type 8760, 8761 or 8762 for analysis and results validation.

Batch Processing Option BZ-8527 allows for stochastic subspace identification (SSI) analysis of large amounts of data without user interaction, while Structural Health Monitoring Modules, BZ-8550 to BZ-8554, enable damage detection, mode tracking and inter-storey drift analysis.

The software is available with perpetual node-locked and floating licensing or as node-locked annual lease licensing.

Uses

- Modal identification using only measured responses – no hammer or shaker excitation required
- Modal identification of structures under real operating conditions
- Forced dynamic deflection analysis in time and frequency domain (ODS analysis)
- Estimation of modal parameters to be used for finite element (FE) model correlation and updating, design verification, benchmarking, troubleshooting and quality control
- Structural health monitoring (SHM) using damage detection indicators, mode tracking and inter-storey drift analysis

Features

- One integrated solution from measurement to analysis with BK Connect software, PULSE Operational Modal Analysis Types 8760 – 8762 and Structural Health Monitoring Modules BZ-8550 – 8554
- Geometry creation using points, lines, surfaces and objects
- Statistics on imported time data
- Short-time Fourier transforms (STFT) to discriminate structural resonances from deterministic signals
- Removal of deterministic signals (harmonics) in the time or frequency domain
- Time and frequency domain ODS analysis
- Three frequency domain techniques: FDD, EFDD and CFDD
- Four unbiased time domain stochastic subspace identification techniques: PC, UPC, UPCX and CVA
- Crystal Clear SSI® stabilization diagrams to discriminate between physical modes, computational modes and deterministic signals
- Estimation of uncertainties of extracted natural frequencies, damping ratios and mode shape complexities (using UPCX)
- Automatic mode estimation in all techniques: FDD, EFDD, CFDD, SSI-PC, SSI-UPC, SSI-UPCX and SSI-CVA
- Complexity plot including mode normalization
- Modal assurance criterion (MAC) plots and tables
- All windows can be repositioned or torn off to other PC monitors
- Export of animations using AVI or GIF movie files
- Embedded reporting in Microsoft® Word and PowerPoint®
- Fast SSI analysis of large amounts of data files without user interaction (Batch Processing mode)

Features of Structural Health Modules:

- Automatic file upload and processing from designated file folders
- Modal, classic and robust damage indicators as a function of analysis session
- Mode tracking as a function of analysis session
- Notifications: visual and auditive alerts, email and web call services
- Analysis of inter-storey drift

Experimental Modal Analysis

Experimental modal analysis is the process of determining the modal parameters (natural frequency, damping ratio, and mode shape) of a structure from measured data. Modal parameters are important because they describe the inherent dynamic properties of a structure. They are used for correlating and updating FE models, design verification, benchmarking, quality control and troubleshooting.

In classical modal analysis, the modal parameters are found by fitting a model to frequency response functions (or impulse response functions), relating excitation forces to vibration responses. In operational modal analysis (OMA), the modal identification is based on the vibration responses only, and different identification techniques are used.

The Concept Behind OMA

Operational modal analysis is used instead of classical modal analysis for accurate modal identification under actual operating conditions and in situations where it is difficult or impossible to control artificial excitation of the structure.

For many civil engineering and mechanical structures, it is difficult to apply the excitation by means of either hammer or shaker(s) due to their physical size, shape, fragility or location. Also, civil engineering structures are loaded by ambient forces, for example, waves (offshore structures), wind (buildings) or traffic (bridges), and operating machinery exhibits self-generated vibrations. These natural input forces cannot easily be controlled or correctly measured. In OMA, the forces are used as unmeasured input, but if classical modal analysis was used, they would be superimposed as noise on the controlled artificial forces and would provide erroneous results.

For mechanical structures like aircraft, vehicles, trains, ships and operating machinery there is a need to determine 'real-life' modal parameters using actual operating conditions, that is to say, actual boundary conditions, actual spatial and frequency distributions of forces, actual force and response levels, and actual environmental conditions.

Advantages of Using OMA

The main advantages of OMA are:

- The measured responses are representative of the real operating conditions of the structure
- The set-up is simple, straightforward and fast, because only accelerometers are used. No hammers or shakers are required. No elaborate set-up of the structure, shakers or force transducers is required
- The measurement procedure is simple and quite similar to ODS analysis. Measurement data acquired for OMA can be reused for ODS analysis and vice versa
- In situ testing during normal operation can reduce costly downtime. No interruption or interference with the operation of the structure is required

Usually, OMA is used in cases where the excitation is relatively broadband and can be considered to be approximately Gaussian. However, it can also be used in cases where rotating machinery exhibits strong deterministic excitation due to rotating parts if broadband noise from bearings or other excitation forces is present. Similarly, it can be used for measurements on rotating machinery performing run-up/down tests.

When performing structural run-up/down tests, OMA is a powerful complement to run-up/down ODS. Together they provide in-operation determination of the modal parameters (the dynamic properties of the structure) and determination of the actual forced dynamic deflections of the structure.

Accuracy of OMA

Discarding information about the input will add some uncertainty to modal estimates. However, with the advanced techniques included in PULSE Operational Modal Analysis
Types 8760 – 8762, the added uncertainty is very small. In practice, the only major difference between modal parameters estimated from classical modal analysis and those from OMA is that OMA produces unscaled mode shapes. Different techniques for scaling an OMA modal model are, however, available. Scaled mode shapes are needed when absolute simulations (such as forced responses and structural modifications) are applied to modal data.

OMA can have a significant advantage over classical modal analysis when only a few artificial excitation forces can be applied. In this case, higher estimation accuracy can often be obtained by letting the better, spatially distributed, natural loading excite the structure. The OMA techniques are implemented as true multiple-input (multiple-reference) techniques.

Data acquisition and measurement validation in BK Connect can be performed using either:

- **The Monitor recorder in Hardware Setup Type 8401**
  Type 8401 provides real-time monitoring with 2D and 3D time and frequency displays during time data recording.
- **Time Data Recorder Type 8402**
  Type 8402 adds additional features such as geometry-guided recordings, triggered start/stop of recordings and the ability to add markers to recordings and to trim recordings.
- **Data Processing Type 8403**
  Type 8403 provides geometry-guided time recordings in parallel with various time and frequency real-time measurements.

NOTE: Geometry-guided recordings and measurements require BK Connect Geometry Type 8410.

BK Connect fully integrates with PULSE Operational Modal Analysis Types 8760 – 8762, resulting in a streamlined testing solution for OMA. For more information on BK Connect applications, visit the BK Connect web page.

Import from Universal File Format

Geometry and measurement data can be imported as UFF files, making it easy to import data from any standard measurement system. Both ASCII and binary UFF are supported for the measurement data.

Import from ASCII Files Using the Configuration File

All geometric data can be specified in the OMA configuration file that can be generated using any ASCII file editor. Response data can be read from ASCII or binary files where the data is stored in a time series matrix organized column by column.

Fig. 1 Data acquisition and real-time monitoring using the monitor recorder included in BK Connect Hardware Setup Type 8401. STFT contour plots can reveal potential structural modes and harmonic components before transferring data to PULSE OMA Types 8760 – 8762

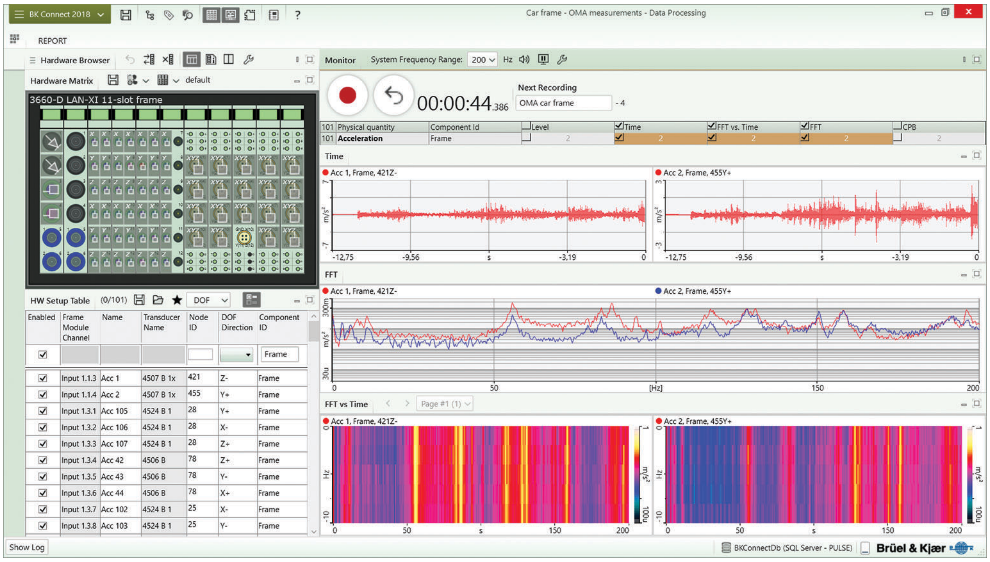
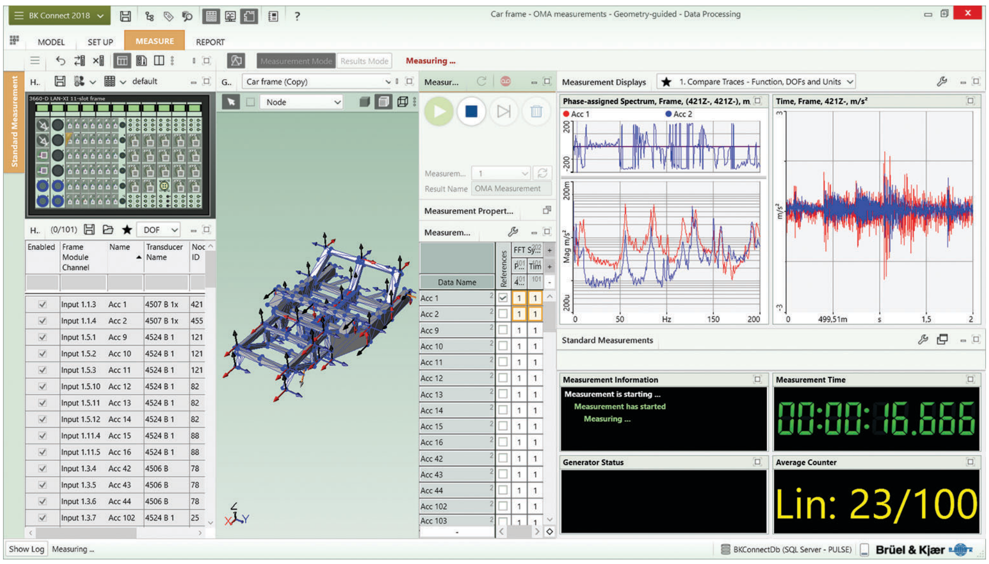


Fig. 2 Geometry-guided measurements using BK Connect Data Processing Type 8403



User Interface and Workflow

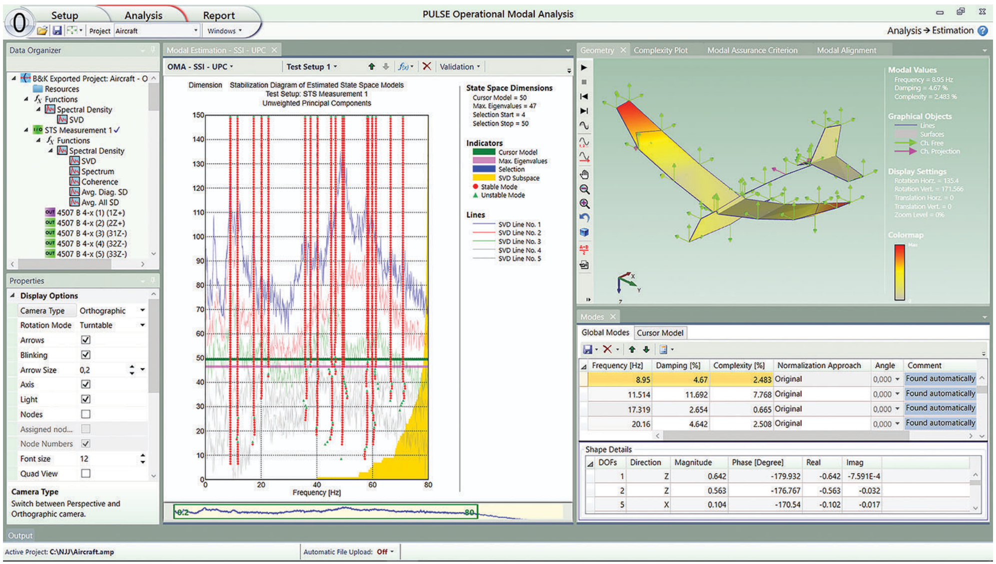
The PULSE OMA software divides related tasks into three groups: Setup, Analysis and Report.

PULSE OMA allows multiple projects to be open at the same time to validate results easily across projects, and the user interface can be laid out using either an SDI (single document interface) or an MDI (multiple document interface) style.

For the SDI user interface, each window can contain multiple tabbed views providing a clear and logical overview, which is useful when a large amount of information needs to be accessed quickly without changing the screen layout. Windows can be re-positioned or torn off to other PC monitors.

Both the SDI and MDI layouts can be saved.

Fig. 3   Example of a tabbed SDI user interface. The Geometry window contains tabs for Complexity Plot, Modal Assurance Criterion and Modal Alignment views



Setting Up in PULSE OMA

The Setup tasks in PULSE OMA are useful if you are not using BK Connect for geometry-guided data acquisition and measurement validation, or if you, after a test, need to modify your geometry or measurement data.

Prepare Geometry Task

Geometries can be created using points, lines and surfaces grouped into user-defined objects. Predefined objects such as rectangles, cuboids (boxes), circles, cylinders and truncated cones can be used as well. Geometries can be drawn and edited in a 3D geometry view or using coordinates in a table. Geometries can also be imported in various formats such as UFF, DXF, DWG and STL.

Manage Measurements Task

In PULSE OMA, measurement data is organized into Measurements, Test Setups (positions of the transducers) and Data Sets (configurations of measurement channels and DOFs).

In the Manage Measurements task, you can:

- Organize measurements into Test Setups and Data Sets
- Upload measurement files in various file formats and store them into Data Sets
- Optionally merge uploaded measurements into an already created Data Set
- View raw measurement time histories and optionally cut them into a new Data Set
- Calculate statistics (max., min., rms, median, mean, variance, skewness and kurtosis) for each measurement channel
- Optionally single- or double-differentiate or integrate measurements and store results into a new Data Set

Assign DOF Information Task

If measurements are performed using BK Connect, DOFs are assigned during the measurement and the information automatically transferred to PULSE OMA. For other system configurations, the Assign DOF Information task lets you assign the measurement channels to the DOFs (nodes and directions) on the geometry either graphically or by using a table. The task can also be used to edit existing DOF information.

The Analysis task group guides you from processing the raw time data to validating the final results.

Prepare Data Task

Different kinds of signal processing can be applied to the imported time data and the results immediately visualized. It is possible to de-trend the data to remove any bias or linear trend in the time signals. Data can be decimated to reduce the sampling frequency; and, low-pass, high-pass, band-pass and band-stop filters can be applied. Filtering can be useful in removing high-frequency modes (low-pass), DC components (high-pass) or harmonics (band-stop); or concentrating on a narrow frequency range (band-pass).

It is possible to set a reduced number of projection channels for the analysis either manually or by letting the software select the optimum number. The use of projection channels reduces the amount of cross-information calculated between the response channels when estimating spectral density matrices and the common SSI input matrix. This is done to maximize the amount of independent information. The benefits of using a reduced number of projection channels are: faster algorithms, smaller project size, more accurate results due to cancellation of noise channels, and easier fitting of state-space models of smaller dimensions due to less redundant information. The actual channels are automatically selected by the software.

Deterministic signals (harmonic components) can be reduced in the time domain before performing the modal parameter estimation. In addition, automated methods for identification and suppression of the deterministic signals in the frequency domain can be applied based on the enhanced frequency domain decomposition (EFDD) and curve-fit frequency domain decomposition (CFDD) techniques.

Fig. 4 and Fig. 5 show the singular value decomposition (SVD) plots before and after reduction of harmonic components using a time-domain method.

Fig. 4 *SVD plots before reduction of harmonic components* ***Upper:*** *Harmonic components at 374, 748 and 1496 Hz;* ***Lower:*** *Harmonic components have been selected*

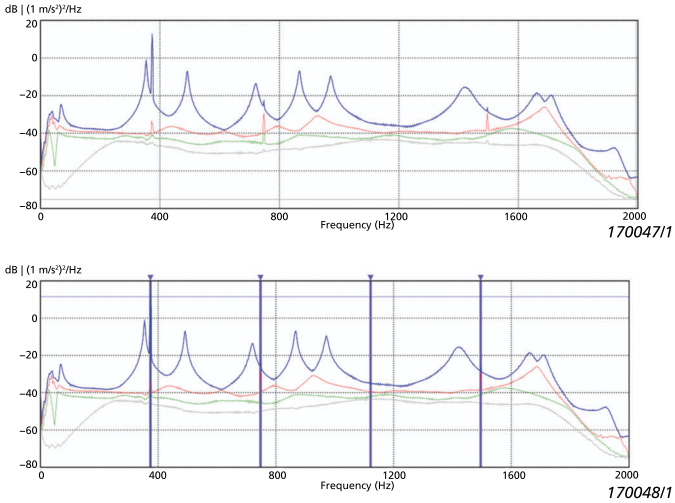
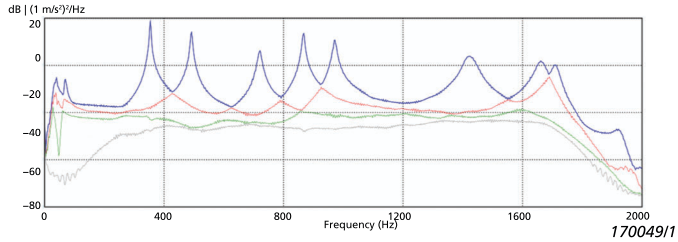


Fig. 5 *SVD plots after reduction of harmonic components*



For the frequency domain decomposition (FDD), EFDD and CFDD techniques, spectral density matrices are calculated. For the SSI techniques, a Hankel matrix is estimated that constitutes the basis for calculation of the stabilization diagram. It is also possible to do an automatic mode estimation simultaneously using one or more SSI techniques.

Signal processing in PULSE OMA comes with logical default values, but configuration files can also be saved and reloaded making signal processing extremely efficient.

Forced Dynamic Deflections Analysis

ODS analysis is very beneficial in combination with OMA as it determines and visualizes the combination of the actual forcing functions acting on the structure and the dynamic behaviour of the structure.

Where OMA is the process of creating a mathematical model of the dynamic properties and behaviour of a structure, operating deflection shapes (ODS) analysis is the process of determining the forced dynamic deflections of a structure. As a model is not created in ODS analysis, no assumptions are made about linearity, characteristics of input forces or boundary conditions. In both cases, the measurements are done under operating conditions by response testing only.

In PULSE Operational Modal Analysis, both time domain ODS and frequency domain ODS are included, allowing the determination and visualization of deflection shapes as a function of time or for specific frequencies. Decimation and various filters (low-pass, band-pass, band-stop and high-pass) can be applied in time domain ODS to frequency limit the analysis. For frequency ODS, an STFT plot can be shown to reveal frequency content vs time. Shapes can be saved in a shape table and selected for animation (absolute or relative) or validation such as complexity (in a complexity plot) or linearity (in a MAC plot).

Fig. 6 *Time domain ODS analysis of a sports-car frame. Dwell and sweep animation is supported*

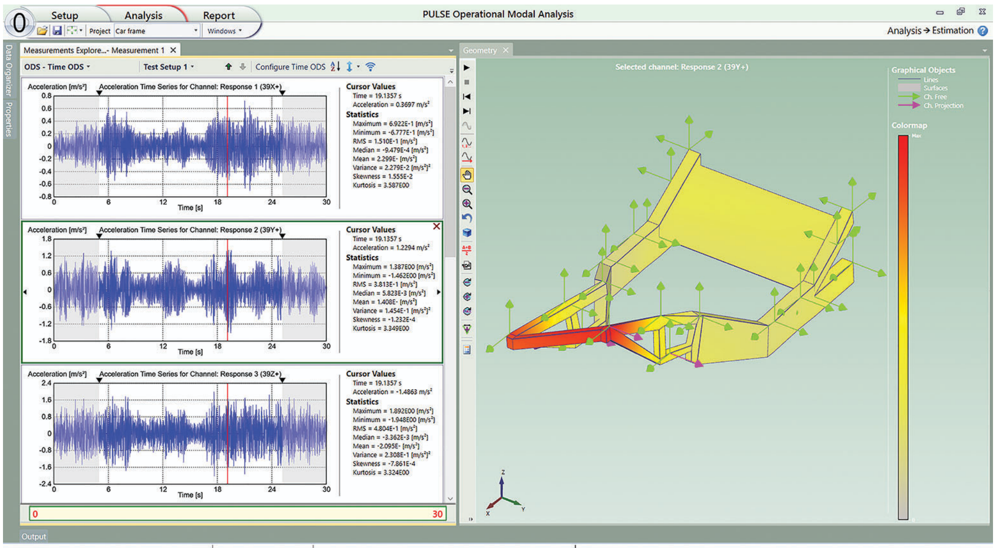
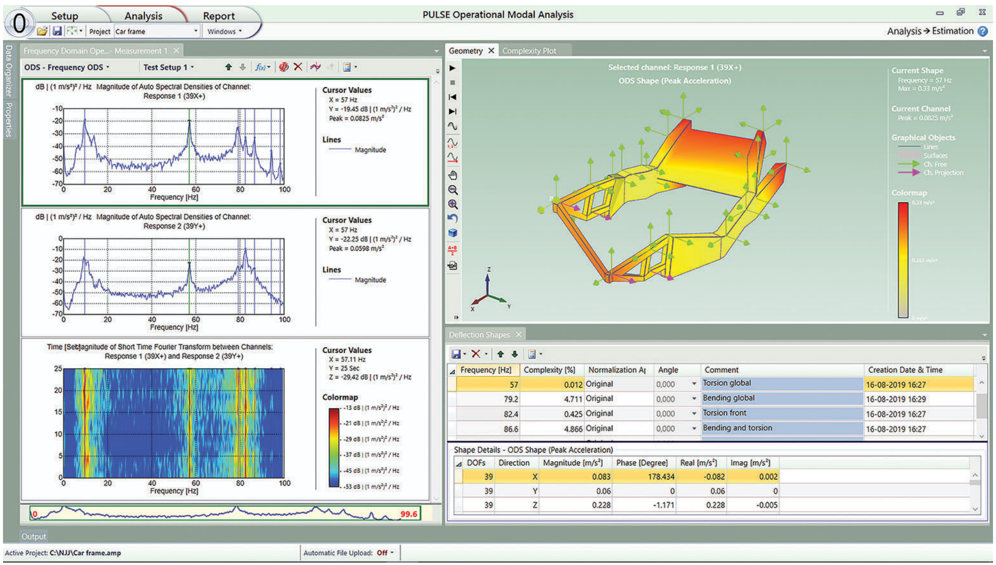


Fig. 7 *Frequency domain ODS analysis of a sports-car frame at specific frequency components*



Estimation Technique: Frequency Domain Decomposition (FDD)

Quick and Easy Identification

The concept behind the FDD technique is to express the system response as a set of independent single-degree-of-freedom (SDOF) systems, one for each mode. The decomposition is based directly on SVD of the spectral density matrix, where the singular values are estimates of the auto-spectral density of the SDOF systems, and the singular vectors are estimates of the mode shapes.

FDD is extremely quick and easy to use. Use the plot to identify the SDOF functions, and pick their peaks by using the snap-to-peak facility. The animated mode shape can then be displayed immediately. The technique deals effectively with close modes and noise, and you can define, delete or edit modes with user-friendly modal editing facilities. Since information from just a single frequency line is used for each mode in this technique, damping estimates are not provided.

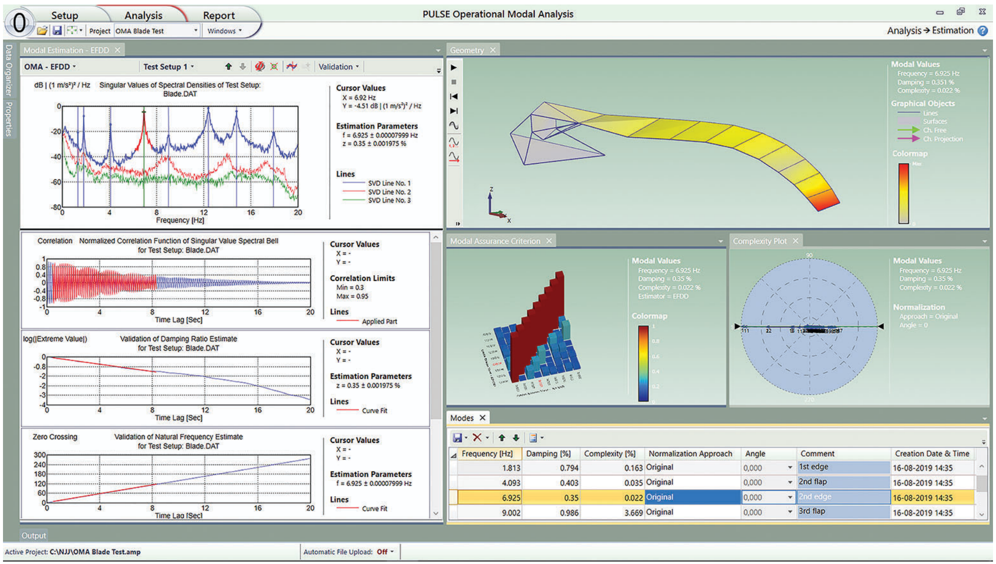
Estimation Technique: Enhanced Frequency Domain Decomposition (EFDD)

Improved Modal Identification

The EFDD technique is an extension of the FDD technique. In EFDD, the SDOF function, identified around a resonance peak, is taken back to the time domain using the inverse discrete Fourier transform (IDFT). The natural frequency is obtained by determining the number of zero-crossings as a function of time, and the damping by the logarithmic decrement of the corresponding SDOF normalized auto-correlation function. The SDOF function is estimated using the shape determined by the previous FDD peak-picking technique as a reference vector in a correlation analysis based on the MAC. A MAC value is computed between the reference FDD vector and the singular vector for each frequency line around the resonance peak. If the MAC value is above a user-specified MAC rejection level, the corresponding singular value is included in the description of the SDOF function.

Compared to the FDD technique, the EFDD technique includes damping estimation and gives an improved natural frequency and mode shape estimation.

Fig. 8 *Modal identification of a wind turbine blade by peak-picking using the EFDD technique. The example shows the modal parameter estimation of the 2nd edge mode at 6.9 Hz*



Estimation Technique: Curve-fit Frequency Domain Decomposition (CFDD)

The CFDD technique is an extension of the EFDD technique. Both techniques find modes shapes in the same way, and both techniques include damping estimation and improved estimation of natural frequencies and mode shapes. The main difference between the two techniques is how they estimate the natural frequencies and damping. The EFDD technique uses time-domain methods while the CFDD technique curve-fits the estimated SDOF functions in the frequency domain.

The CFDD technique is superior to the EFDD technique when the SVD plot is noisy, which can be caused by short recording lengths or deterministic signals.

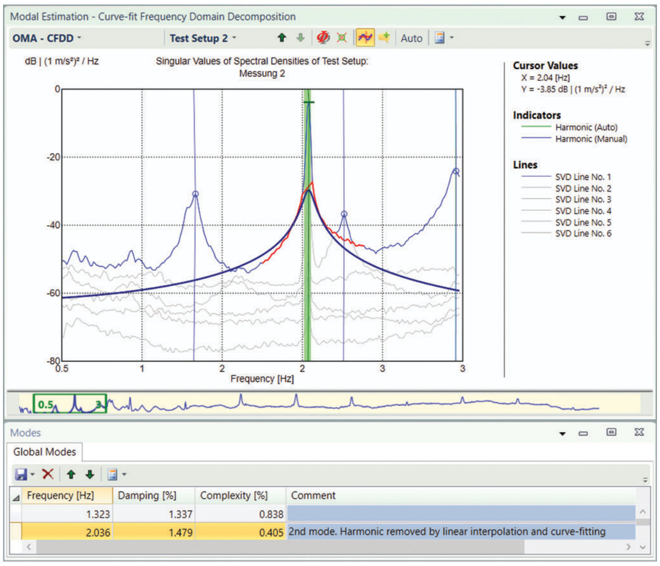
The techniques used in OMA assume that the input forces are stochastic in nature. This is often the case for civil engineering structures like buildings, towers, bridges and offshore structures, which are mainly loaded by ambient forces like wind, waves, traffic or seismic micro-tremors. The loading forces of many mechanical structures are, however, often more complex. They are typically a combination of deterministic signals originating from the rotating and reciprocating parts and broadband excitation originating from either self-generated vibrations from, for example, bearings and combustion or from ambient excitations like air turbulence and road vibrations. However, civil engineering structures can also have broadband responses superimposed by deterministic signals from, for example, ventilation systems, turbines and generators. The deterministic forces are seen as harmonic components in the responses, and their influence should be significantly reduced before extracting the modes in their vicinity.

As the input forces to the structure are not measured in OMA, special attention must be paid to identify and separate deterministic signals from the response of true structural modes and reduce the influence of the deterministic signals in the modal parameter extraction process. In addition to the techniques for harmonic reduction in the time domain, the EFDD technique includes an automatic two-stage method, where first the deterministic signals are identified using various kurtosis calculations and subsequently suppressed using interpolation across the deterministic signals in the SDOF functions. The CFDD technique goes one step further by curve-fitting the interpolated SDOF functions. This is particularly useful when deterministic signals are located at or very near resonance frequencies.

It should be noted that the techniques do not involve any time or frequency domain filtering as this would bias and potentially destroy the estimation of the structural modes. In addition, prior knowledge of the number of deterministic signals, their frequencies and their stability is not required.

If significant deterministic signals are present in the responses, high dynamic-range measurements might be required to extract 'weak' modes.

Fig. 9 *Ship structure example showing an identified deterministic signal (green vertical line) at the second mode, a restored SDOF function for the mode (red curve), and a curve-fitted SDOF function (blue curve)*



Estimation – Stochastic Subspace Identification (SSI)

Time-domain Techniques

In the time domain, you can perform modal identification using four different kinds of data-driven, SSI techniques: unweighted principal components (UPC), extended unweighted principal components (UPCX), principal components (PC) and canonical variate analysis (CVA). These techniques fit a full modal model in discrete time to the data in the time domain. The theoretical assumption for these advanced time-domain methods is that the input to the modal model is a stationary force signal that can be approximated by filtered, zero-mean, Gaussian white noise. In practice, the methods work with most broadband excitation, including run-up/down excitation.

The SSI techniques are the most powerful and accurate techniques available on the market for OMA. Because the techniques work entirely with time-domain data, the benefits are unmatched. These benefits include:

Unbiased Estimation

- **No leakage** – The SSI techniques are data-driven methods working in the time domain. Since the model estimation is not relying on any Fourier transformations to the frequency domain, no leakage is introduced and hence there is no unpredictable overestimation of the damping
- **No problems with deterministic signals** – Since the modal parameters are extracted directly by fitting parameters to the raw measured time histories, the presence of deterministic signals does not create problems. Deterministic signals are just estimated as very lightly damped modes and can consequently be excluded. For cleaner stabilization diagrams, one of the time-domain methods for harmonics reduction can, however, be applied. In contrast, methods relying on the estimation of half-power spectral densities all assume that the excitation is broadband (white noise) and thus the presence of deterministic signals introduce bias in the modal parameter estimation

Less-random Errors

- **Low-order model estimator used** – The SSI techniques are born as linear least-squares fitting techniques, fitting state-space systems with correct noise modelling. The benefit is that low-order model estimators can be used. High-order model estimators are often used to approximate a non-linear least-squares fitting problem with a linear least-squares fitting problem. This approximation is often used when fitting, for example, polynomial matrix fractions, where a high polynomial order is required. As a result, more parameters have to be estimated (compared to using low-order technique), and with the same amount of data available, less independent information per estimated parameter is obtained. Consequently, the uncertainties of high-order parameter estimates become significantly larger
- **All modal parameters are fitted in one operation** – All parameters fitted are taking advantage of the noise cancellation techniques of the orthogonal projection used in SSI. Other available techniques often fit the poles (frequency and damping) first, and then use the noisy spectral data and the estimated poles to fit the mode shapes resulting in poorer mode shape estimates

Crystal Clear Stabilization Diagrams

A stabilization diagram is used to display the natural frequencies of all the estimated eigenvalues (modes) as a function of state-space dimension (model order). For an enhanced overview, the stabilization diagram is shown on top of a wallpaper of the SVD of the spectral density matrix of the currently selected data set. Modes are classified as either stable, unstable or noisy (that is, computational non-structural modes used by the algorithms to account for non-fulfilled assumptions). Using modal indicators, you can set up a series of requirements that modes must repeatedly fulfil, from one model order to another, in order to be classified as stable.

Crystal Clear SSI® (CC-SSI) is an improvement to the well-known SSI techniques resulting in even cleaner stabilization diagrams. By specifying the maximum number of poles (eigenvalues) to be estimated, any less significant poles will not be shown in the stability diagram. PULSE Operational Modal Analysis Type 8762 automatically sets the maximum number of poles using a special data-dependent technique, but it can also be specified by the user.

CC-SSI is also significantly faster than the traditional SSI techniques by using a special algorithm for creating the stabilization diagrams. The CC-SSI technique is extremely robust in many difficult cases such as:

- Heavily damped modes
- Weak modes mixed with dominant deterministic signals
- High mode density

Due to the highly consistent estimation of the poles across model orders, the search for the optimal model order is less critical when using CC-SSI.

Using SSI techniques, both structural modes and non-reduced deterministic signals are estimated. The deterministic signals are estimated as modes with very low damping, and can consequently be excluded.

In addition to the stabilization diagram, a frequency vs damping diagram and a modal alignment view can be shown for a selected mode. The latter shows the modal parameters as a function of model order for the selected mode.

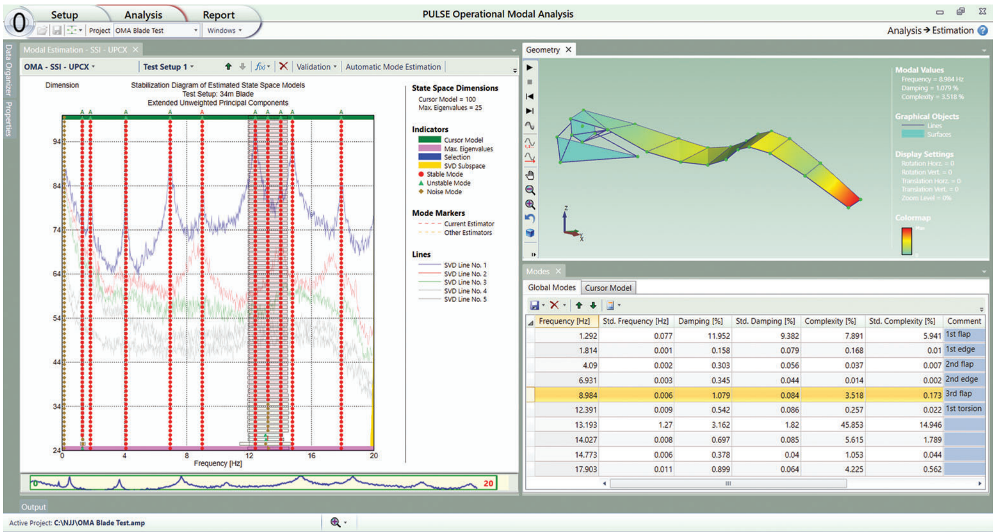
Uncertainty Calculations

The extended unweighted principal components technique (UPCX) extends the functionality of UPC by adding uncertainty calculations of the natural frequency, damping ratio and mode shape complexity visualized as confidence bounds. In addition, uncertainty calculations can be used to disregard model orders where the mode estimates have high confidence bounds and give a higher weight to model orders, where the mode estimates have low confidence bounds thereby improving the modal parameter estimation when performing automatic mode estimation.

As for classical modal analysis using hammer or shaker(s) excitation, the use of different SSI techniques is important in order to validate extracted modal parameters by comparison.

Uncertainty estimates are also shown in the Modal Alignment view as confidence bounds and in the Complexity Plot as ellipsoids on the mode shape vectors.

Fig. 10 *The SSI techniques provide Crystal Clear stabilization diagrams showing stable modes in red. This example uses the SSI-UPCX technique including uncertainty calculations of the natural frequencies, damping estimates and mode shape complexities as well as improved parameter estimation. Confidence bounds are clearly visible around 12.4, 13.2 and 14.0 Hz. Modes are found using Automatic Mode Selection*



Model Validation

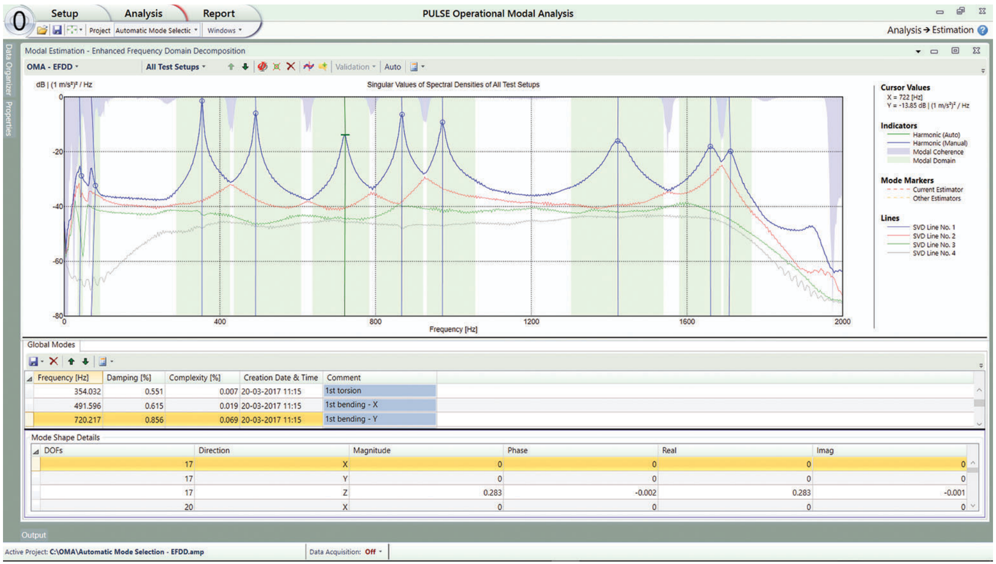
You can validate the quality of a selected model for each of the SSI techniques by comparing the synthesized modal model results to the directly measured and processed data. You can synthesize the magnitude of the response auto-spectra and cross-spectra and the magnitude of the prediction errors. This assists in the selection of an adequate model order.

Automatic Mode Estimation

Automatic mode estimation is possible for all available identification techniques. For the FDD, EFDD, and CFDD techniques, an automatic mode estimation can find well-excited modes in a specified frequency band. Deterministic signals are automatically excluded in the estimation process. Apart from presenting the modes, two indicators are displayed for assessing the quality of the estimates: modal coherence and modal domain.

Automatic mode estimation is supported by all SSI techniques. For the traditional SSI techniques (PC, UPC and CVA), all stable modes of all estimated models across all data sets are included in a search. The result is very accurate modal estimates of natural frequencies, damping ratios and mode shapes. For the UPCX technique, the confidence bounds are used to further improve the modal parameter estimates.

Fig. 11 *Automatic mode estimation in EFDD. The modal coherence indicator (purple area) defines the extent to which a frequency region is primarily dominated by modal information or noise. For frequency regions dominated by modal information, the modal domain indicator (green area) defines for each mode the frequency region dominated by that particular mode*



Analysis Validation

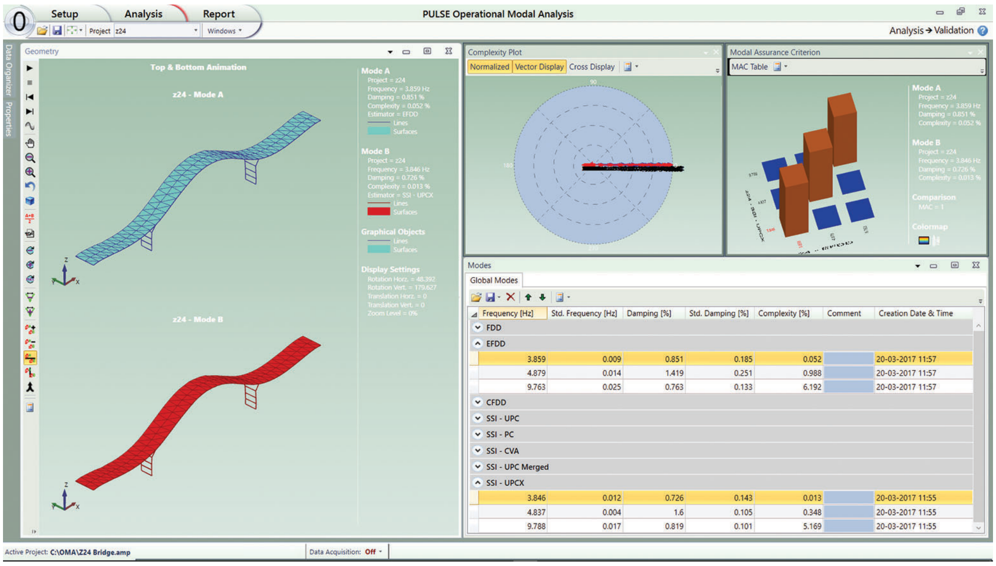
Validation of Results

Modal results from different identification techniques as well as frequency ODS results of the same project can be compared. This is also possible across projects, as long as the geometries of the two projects are exactly the same. It is possible to import modes from other programs, such as classical modal analysis programs, and compare them with modes estimated in PULSE OMA.

Visual inspection of two mode shapes can be done using animation. The mode shapes can be compared in a single- or quad-view as overlaid or difference animation. Alternatively, two modes can be compared using a top-bottom view or a side-by-side view. Animations can be shown as wireframes with or without coloured surfaces and with or without arrow animation. Slave node equations and interpolation of non-measured DOFs are also supported.

In order to examine how well two (mode) shapes compare, a 3D MAC plot or a table MAC view can be shown. To judge the quality of the modal model, up to two mode shapes can be displayed in a polar view (complexity plot) showing their phase scatter. The mode shapes can be normalized.

Fig. 12 *Analysis validation by comparing the results from the different modal identification techniques in PULSE OMA. In this case, comparing the EFDD with the SSI UPCX techniques for the Z24 Bridge in Switzerland*

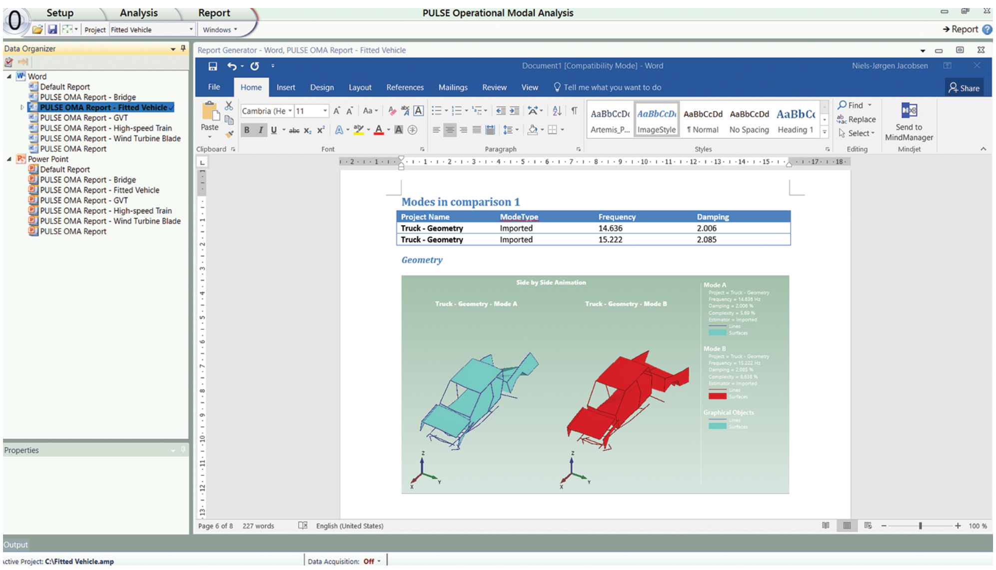


Reporting

If Microsoft® Word or PowerPoint® is installed on the PC, reporting based on default or user-defined templates is available. The reports are embedded in the PULSE OMA application within the Report window. Once the report is initially generated, you can start editing and save the document directly in the software. The reporting feature is available in the Prepare Data, Estimation and Validation tasks for creation of reports containing images and tables.

In the Data Organizer, a hierarchy of the available report types is shown, and under each report type, the available report templates will be displayed. You can easily switch between report templates to generate a new report based on the newly selected template.

Fig. 13 *PULSE OMA supports embedded reporting in Microsoft Word and PowerPoint based on default and user-defined templates*



Exporting

Tables and 2D/3D plots can be immediately printed or transferred as pictures using standard copy/paste procedures and plots can be saved as bitmaps or JPEG files.

Geometry data (nodes, trace lines and surfaces) and modal results (natural frequency, damping and mode shapes) can be exported in UFF to be used for FE model updating, for example.

You can also export the estimated parametric models from the SSI techniques in state-space format to an ASCII file.

Animations can easily be saved as AVI or GIF movie files. Various compression modes are available for selectable quality. Movie files can be shown in Windows Media® player or inserted in a Microsoft® Office file such as Word, Excel® or PowerPoint® for creation of live reports.

Configurations

The PULSE OMA software is available in three versions: Basic, Standard and Pro. Each version is also available as a fully featured academic version for academic purposes only.

PULSE OMA Basic Type 8760

This version contains all of the setup tasks for preparing geometry, managing measurements and assigning DOF information as well as full reporting functionality. It offers identification of natural frequencies and mode shapes with just a few clicks of the mouse. The FDD technique is included as it is often the first technique used to get an overview of the natural frequencies and mode shapes before continuing with more advanced techniques. Time and frequency ODS functionality is included as well.

PULSE OMA Standard Type 8761

This version adds more advanced tools for preparing your data, including removal of outliers and harmonics detection and reduction using kurtosis analysis. It includes the efficient frequency domain identification tools (EFDD and CFDD) for accurate estimation of natural frequencies, damping ratios and mode shapes. In addition, more analysis validation tools are available such as comparison of mode shape animations and mode complexity plot.

PULSE OMA Pro Type 8762

This version offers the most powerful identification techniques and the best validation of results. With PULSE OMA Pro, you can perform accurate identifications in the time domain as well as in the frequency domain using the most powerful identification techniques available today. The best validation you can perform is to compare frequency and time domain results with each other. The Pro version adds harmonics reduction in the time data using either non-linear minimization or orthogonal projection and Crystal Clear stabilization diagrams using the unbiased time domain SSI techniques. With the SSI-UPCX technique, the uncertainty of the estimated modal parameters (natural frequency, damping estimate and mode shape complexity) can be obtained.

Table 1 Overview of PULSE OMA software

PULSE OPERATIONAL MODAL ANALYSIS	PULSE OMA BASIC TYPE 8760	PULSE OMA STANDARD TYPE 8761-S (BUNDLE)	PULSE OMA PRO TYPE 8762-S (BUNDLE)
Setup Task – Prepare Geometry			
Create test geometry	•	•	•
Import/modify existing geometry	•	•	•
Setup Task – Manage Measurements			
Import measurement files	•	•	•
Merge measurement files	•	•	•
Integrate/differentiate measurements	•	•	•
View raw time histories	•	•	•
Connect/disconnect channels and Test Setups	•	•	•
Setup Task – Assign DOF Information			
Link channels with geometry nodes and directions	•	•	•
Link using drag-and-drop or by direct editing	•	•	•
Automatic identification of reference channels across Test Setups	•	•	•
Analysis Task – Prepare Data			
Configure all pre-processing of measurements	•	•	•
Repair tool for removal of outliers		•	•
View processed data of channels and Test Setups	•	•	•
Option for automatic selection of projection channels	•	•	•
Compare processed data of reference channels	•	•	•
Harmonics detection and reduction using fast and extended kurtosis analysis		•	•
Harmonics reduction using non-linear minimization			•
Harmonics reduction using orthogonal projection			•
Analysis Task – Operating Deflection Shapes			
Animation at user-selectable frequencies or as a function of time	•	•	•
Store specific frequency ODS shapes	•	•	•
Results in acceleration, velocity or displacement	•	•	•
Analysis Task – Modal Estimation			
Estimation of natural frequencies	•	•	•
Estimation of damping ratios		•	•
Estimation and animation of mode shapes	•	•	•
Estimation of modal parameter uncertainties			•
Frequency domain decomposition (FDD)	•	•	•
Enhanced frequency domain decomposition (EFDD)		•	•
Curve-fit frequency domain decomposition (CFDD)		•	•
Crystal Clear SSI unweighted principal components (SSI-UPC)			•
Crystal Clear SSI extended unweighted principal components (SSI-UPCX)			•
Crystal Clear SSI principal components (SSI-PC)			•
Crystal Clear SSI canonical variate analysis (SSI-CVA)			•
Crystal Clear SSI merged Test Setups			•
Analysis Task - Validation			
Modal assurance criterion (MAC) plot and table	•	•	•
Overlaid, difference, side-by-side and top-button shapes animation		•	•
Comparison of mode shape complexity including mode shape normalization		•	•
Comparison between estimated and imported modes		•	•
Report Task			
Easy selection of graphics and tables	•	•	•
Store selected in 'as-is' colours or in black & white	•	•	•
Seamless integration with Microsoft Office	•	•	•
Generate Word documents and PowerPoint presentations	•	•	•
Predefined standard templates	•	•	•

Software Packs

Software packs (bundles) consisting of BK Connect for measurement and PULSE OMA for analysis are also available. Export of UFF geometry and time data from BK Connect is included in all packs. BK Connect Type 8400-B is not required. "Academic packs" are fully featured versions for academic purposes only.

Software packages can be added to the predefined packs for increased functionality.

PULSE OMA Basic Measurement and Analysis Pack Type 8760-C

This pack provides real-time monitoring with 2D and 3D time and frequency displays during time data recording using the Monitor and its recorder included in BK Connect Hardware Setup Type 8401 (see Fig. 1). The time recordings are seamlessly exported using UFF to PULSE OMA Basic Type 8760 for analysis. In PULSE OMA Basic, a geometry can be created or imported.

Up to two hardware modules are supported (up to 24 input channels), which makes this an ideal pack for simple measurements and analysis where geometry-guided measurements are not needed and the FDD technique is sufficient for the analysis. Full Time ODS and Frequency ODS functionality is included as well.

PULSE OMA Standard Measurement and Analysis Pack Type 8761-C

This pack adds geometry creation using BK Connect Geometry Type 8410 and geometry-guided measurements using BK Connect Time Data Recorder Type 8402. In addition features like triggered start/stop of recordings and the ability to add markers and trim recordings are supported.

In this pack, the full range of frequency domain decomposition techniques is available (FDD, EFDD and CFDD) as well as more tools for data preparation and analysis validation as part of PULSE OMA Standard Type 8761.

PULSE OMA Pro Measurement and Analysis Pack Type 8762-C

This comprehensive pack offers geometry-guided OMA measurements with no hardware module limitation. Additional setup features such as Accelerometer Mounting Check is supported.

This pack adds powerful time domain techniques for removal of

Table 2 Overview of PULSE OMA measurement and analysis packs

			Geometry-guided measurements			
Included in pack:	OMA BASIC MEASUREMENT AND ANALYSIS TYPE 8760-C-XS	OMA BASIC MEASUREMENT AND ANALYSIS, ACADEMIC TYPE 8760-D-XS	OMA STANDARD MEASUREMENT AND ANALYSIS TYPE 8761-C-XS	OMA STANDARD MEASUREMENT AND ANALYSIS, ACADEMIC TYPE 8761-D-XS	OMA PRO MEASUREMENT AND ANALYSIS TYPE 8762-C-XS	OMA PRO MEASUREMENT AND ANALYSIS, ACADEMIC TYPE 8762-D-XS
BK Connect Data Viewer Type 8400-X	•	•	•	•	•	•
BK Connect Hardware Setup Type 8401-X	•	•	•	•	•	•
BK Connect Hardware Setup (advanced) Type 8401-A-X					•	•
BK Connect Time Data Recorder Type 8402-X			•	•	•	•
BK Connect Geometry Type 8410-X			•	•	•	•
PULSE OMA Basic Type 8760-X	•					
PULSE OMA Basic, Academic Type 8760-A-X		•				
PULSE OMA Standard Type 8761-XS			•			
PULSE OMA Standard, Academic Type 8761-A-XS				•		
PULSE OMA Pro Type 8762-XS					•	
PULSE OMA Pro, Academic Type 8762-A-XS						•

Batch Processing Option BZ-8527 for PULSE OMA Pro

The Batch Processing Option for PULSE OMA Pro makes it possible to do SSI analysis on a large amount of acquired time data without user interaction.

Typical applications include repetitive testing and SHM.

An executable can be run from a command prompt, from a batch (.bat) file or from a Visual Basic® script file. The results are automatically saved in result files.

The option allows for:
- **Increased productivity** – Process data automatically, freeing your time to do other tasks
- **Ease of use** – Even less experienced operators can use the option
- **User-independent results** – Analysis based on predefined configurations

Structural Health Monitoring Modules BZ-8550 – 8554 for PULSE OMA Pro

Five Structural Health Monitoring (SHM) modules are available for PULSE OMA Pro. Data Manager Base Module BZ-8550 is required for all configurations. The other SHM modules can be added without restrictions. They perform different types of analysis on long-term monitoring data.

Table 3 Configuration overview of the SHM modules. Structural Health Monitoring Pack BZ-8553-S contains the modules BZ-8550 – BZ-8553

<table>
<tr><td>Automatic File Upload BZ-8551</td><td>Modal Parameter History BZ-8552</td><td>Damage Detection BZ-8553</td><td>Drift Analysis BZ-8554</td></tr>
<tr><td colspan="4">Data Manager Base BZ-8550</td></tr>
<tr><td colspan="4">PULSE Operational Modal Analysis Pro Type 8762</td></tr>
</table>

Data Manager Base Module BZ-8550

This is a mandatory module providing the foundation for the other SHM modules. It extends PULSE OMA Pro functionality to handle multiple analysis sessions – the containers where the measurement files and results are uploaded. The Data Manager Base Module is responsible for the administration of the analysis sessions. It stores and retrieves the different analysis sessions when requested by the analysis modules.

The module provides historical measurement statistics (min., max., median, mean, variance, skewness and kurtosis) and includes notifications (visual and auditive alerts, email and Web services).

Automatic File Upload Module BZ-8551

The Automatic File Upload Module is designed to automatically upload and process measurement files arriving in designated file folders on the user network. It is possible to configure the file location and file type as well as the type of processing that should be initiated after file upload.

This module allows PULSE OMA Pro to fully plug into any data acquisition system and perform automatic data analysis using the Modal Parameter History or Damage Detection Module or using native OMA techniques of PULSE OMA Pro.

Modal Parameter History Module BZ-8552

The Modal Parameter History Module presents modes as a function of the analysis sessions. Both natural frequencies (absolute or normalized), damping estimates (absolute or normalized) and shapes (MAC value between reference and current state) can be shown. In addition, the module can automatically track modes determined in a reference state. Even though the modes change slightly in subsequent analysis sessions, the mode tracking algorithm is capable of keeping track of them.

The tracked modes are presented as modal indicators that are interconnected. Based on user-defined significance levels, threshold curves for critical zone and unsafe zone can be shown. Clicking on the line with the mouse allows further information of the particular tracked mode.

The module also includes the Damage Indicator – Modal based on mode tracking of the natural frequencies and their uncertainties using the SSI-UPCX technique.

Damage Detection Module BZ-8553

The Damage Detection Module consists of two different damage detection algorithms that have been developed for long-term monitoring of structures. The algorithms are robust to changes in ambient conditions and can be set up not to react on such changes.

The module also includes a control chart that can take the different damage indicators as input and unify them to a single control value with a corresponding statistical based threshold. This control chart can automatically notify (alert) when the threshold is being passed after an analysis. The notification can be sounds, emails or Web service calls to third-party systems.

In Fig. 14, an example case of damage detection is shown for a bridge. Eight reference measurements are performed on an undamaged bridge. From the first six reference measurements, a baseline (reference) model is determined by the module, and a threshold is automatically estimated based on the statistical evaluation of the damage indices of those measurements. The last two reference measurements stay under the threshold, which indicates that the bridge is still undamaged. Damage is introduced and 14 more measurements are performed. All 14 measurements exceed the threshold significantly, indicating permanent damage.

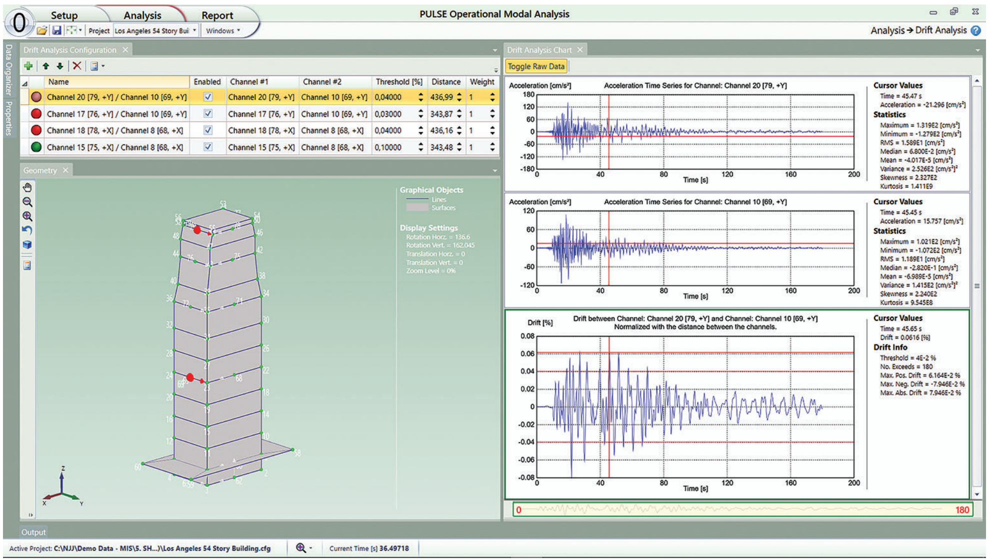
Mode tracking was done as well using the UPCX technique in Modal Parameter History Module. The lower-left display indicates that the first two modes are basically unaffected by the damage, whereas the natural frequency for the third mode is clearly affected, but can still be tracked. Mode tracking provides useful information but cannot be used as a robust damage indicator.

Fig. 14 *Mode tracking and damage detection on a bridge. Eight reference measurements of the undamaged bridge (green bars) and 14 measurements of the damaged bridge (red bars) were performed*

Drift Analysis Module BZ-8554

The Drift Analysis Module is designed to analyse inter-storey drift based on measurements from sensors located at the top and bottom of structural elements. These elements can, for example, be columns. If the drift exceeds a certain percentage of the distance between the sensor locations, the module will automatically alert in terms of sounds, email or web service calls.

Fig. 15 *Drift analysis of a 54-storey building. Three of the configurations exceed the specified threshold as indicated by the red symbols in the Drift Analysis Configuration table and the exceeded positive and negative thresholds in the relative drift time series for the selected configuration (#1). The DOFs/channels for the selected configuration are indicated in red on the geometry*



From PULSE version 27.0 (PULSE OMA v7.2.2.4, 64-bit)

PC System

MINIMUM SYSTEM REQUIREMENTS

- Microsoft® Windows® 10 or 11 Pro or Enterprise (x64) with either Current Branch (CB), Current Branch for Business (CBB), Semi-annual Channel (Targeted) or Semi-annual Channel servicing model
- Microsoft® Office 2019 or 2021 (x32 or x64) or Microsoft 365® Desktop version (x32 or x64)
- Microsoft® SQL Server® 2019 or 2022

RECOMMENDED PC

- Intel® Core™ i9, 3 GHz processor or better
- 32 GB RAM
- 1 TB Solid State Drive (SSD) with 100 GB free space, or better
- 1 Gbit Ethernet network*
- Microsoft® Windows® 10 Pro or Enterprise (x64) with CB
- Microsoft® Office 2021
- Microsoft® SQL Server® 2022
- Screen resolution of 1920 × 1080 pixels (full HD)
- Adobe® Reader® XI or newer

User Interface

- SDI (single document interface) or MDI (multiple document interface) with export/import of layouts
- All windows can be torn off and displayed on other PC monitors

Data Input

- Import of measurement time data in a single data set or using multiple data sets (roving transducers)
- Time data, geometry and DOF information input from BK Connect
- Universal file format (ASCII or binary) from UNIX and PC
  - Geometry: Data sets 15 (nodes), 2411 (nodes), 82 (trace lines), 2431 (trace lines) and 2412 (triangular plate elements)
  - DOF information and measurements: Data sets 58 (ASCII) or 58b (binary) time series format
- CAD geometries (dxf, dwg, stl)
- OMA configuration file and data file (ASCII or binary)
- Maximum number of channels: Not limited by the software
- Maximum amount of data points: Not limited by the software
- Maximum number of test setups: Not limited by the software
- Automatic identification of reference channels when using multiple test setups

Data Output

- Export of channel information table (CSV)
- Export geometry and DOF information using configuration (CFG) files
- Universal file format (ASCII or binary) from UNIX and PC
  - Geometry: Data sets 15 (nodes), 2411 (nodes), 82 (trace lines), 2431 (trace lines) and 2412 (triangular plate elements)
  - DOF information and measurements: Data sets 58 (ASCII) or 58b (binary) time series format
- Export of the estimated parametric models from the stochastic subspace identification (SSI) techniques in state-space format (ASCII)
- Copy/paste and print of tables and 2D and 3D plots
- Export of 2D and 3D plots as bitmaps and JPEG files
- Export of animations using AVI or GIF movie files
- Embedded report generation in Microsoft Word and Microsoft PowerPoint using default or customized templates. Requires the installation of Microsoft Office

Geometry and Animation

GEOMETRY CREATION

- Object-oriented drawing enabling drawing of complex structures using more basic sub-elements (rectangle, cuboid, circle, cylinder, truncated cone) each with its own grid plane and coordinate system
- Drawing options: Points, lines and triangular surfaces. Elements can be drawn using the mouse or by entering information in tables using the keyboard or copy/paste operations
- Drawing of high-level objects both in Cartesian and cylindrical coordinate systems

LAYOUT

- Single or quad view
- Free 3D or predefined views: Top, bottom, left, right, front, back
- Orthographic or perspective views

ANIMATION

- Wireframe geometry with optional coloured surfaces
- Texture: Off, static, dynamic
- Arrow animation
- Optional node numbers and lighting
- Single, overlaid, difference, side-by-side, top-bottom or quad view mode or deflection shape animation
- Animation of non-measured nodes using slave node equations (fixed or linear combination of measured nodes)
- Animation of non-measured nodes using interpolation (user-defined number of nearest measured/slave nodes in X-, Y- and/or Z- direction)
- Animation with/without undeformed geometry
- Animation control: amplitude, speed, start/stop, step backward/forward

Signal Processing

Detrending: Removal of the mean value and any linear trend in the measurements
Scale Data: No scale, Max. rms channels, Individual channel rms
Decimation: 1, 2, 3, 4, 5, 10, 20, 30, 40, 50 and 100 times, including digital, anti-aliasing filter, cut-off at 0.8 times Nyquist frequency
Filtering: Low-pass, high-pass, band-pass, band-stop, Butterworth filter, filter order 1 – 50 poles, selectable 3 dB cut-off frequencies, test for filter stability
Projection Channel: All channels or a reduced number (manually or automatically selected). Recommended minimum stated. Best projection channels automatically selected
Spectral Density Estimation Using FFT: Includes processing of auto- and cross-spectra:

- Number of frequency lines: 2 – 65536 (radix-2) only limited by the amount of data
- Overlap: 66.7%
- Window: Hanning

Harmonic Reduction: In the time domain before performing modal parameter estimation using non-linear minimization or orthogonal projection
Harmonic Detection and Suppression: Automated frequency domain method for identification and suppression of deterministic signals using the EFDD and CFDD techniques, extended kurtosis check and fast kurtosis check methods
SSI: Data Hankel matrix estimation to be used in all SSI algorithms

- Maximum state space dimension – arbitrary, but limited by the amount of data
- Automatic model estimation for one or more of the SSI methods (PC, UPC, UPCX and CVA)

Configuration: Reload original (raw) data or keep processing current data:

- Reset configuration
- Load configuration from file
- Save configuration to file

* 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

View Processed Data

Display of signal processing results of a selected data set or across all data sets:

- Function plots: Auto-spectra, cross-spectra and coherence
- Condensed plots: Singular value decomposition (SVD) of spectral matrix, average of spectral matrix, average of main diagonal of spectral matrix
- Harmonics plot: Identified harmonic components
- Short-time Fourier transform (STFT) time-frequency plots

Time Domain ODS

Operating deflection shapes (ODS) analysis as a function of time:

- Integration filter to remove DC effects
- Selectable time range for animation
- Decimation factor
- Sweep animation (forward, backward) with selectable dwell cycles
- Display results in displacement, velocity or acceleration with SI or imperial units
- Statistics can be shown for each measurement channel: max., min., rms, median, mean, variance, skewness and kurtosis

Frequency Domain ODS

ODS analysis at specific frequencies:

- Shapes can be selected and saved in a shape table
- Sweep animation (forward, backward) through selected shapes in shape table
- Shapes animated with absolutely or relatively scaled deflection
- Display results in displacement, velocity or acceleration in SI or imperial units
- Results scaled as peak, peak-peak, rms, or power

Frequency Domain Decomposition

Frequency domain peak-picking technique based on SVD of the system response into a set of independent single degree of freedom (SDOF) systems, one for each mode:

- **Frequency Resolution:** As the frequency resolution in the spectral-density function. Set by frequency range and number of frequency lines
- **Damping:** No damping estimated
- **Mode Shape Estimation:** From the singular vector at the identified natural frequency
- **Automatic Mode Estimation:** Identification of most well-excited modes based on peak identifications, modal coherence and modal domain indicators, and mode shape correlation analysis

Enhanced Frequency Domain Decomposition

Frequency domain peak-picking technique based on SVD of the system response into a set of independent SDOF systems, one for each mode:

- **SDOF Estimation:** MAC rejection level
- **Auto-correlation Function:** From inverse discrete Fourier transform (IDFT) of SDOF. Limited by Max/Min settings
- **Frequency Estimation:** Determined by the number of zero-crossing as a function of time in auto-correlation function
- **Damping Estimation:** Determined by the logarithmic decrement of the corresponding SDOF normalized auto-correlation function
- **Mode Shape Estimation:** Based on using a weighted sum of the singular vectors and singular values around each natural frequency
- **Deterministic Signals:** Automatic two-stage method (identification and suppression) requiring no prior knowledge of the deterministic signals or, use of tacho signals. Identification using kurtosis calculations (extended kurtosis check and fast kurtosis check methods). Suppression using interpolation across the deterministic signals in the SDOF functions
- **Automatic Mode Estimation:** Identification of most well-excited modes based on peak identifications, modal coherence and modal domain indicators, and mode shape correlation analysis

Curve-fit Frequency Domain Decomposition

Frequency domain peak-picking technique based on SVD of the system response into a set of independent SDOF systems, one for each mode:

- **SDOF Estimation:** MAC rejection level
- **Natural Frequency and Damping Estimation:** From frequency domain curve-fitting of SDOF functions
- **Mode Shape Estimation:** Based on using a weighted sum of the singular vectors and singular values around each natural frequency
- **Deterministic Signals:** Automatic two-stage method (identification and suppression) requiring no prior knowledge of the deterministic signals or use of tacho signals. Identification using kurtosis calculations (extended kurtosis check and fast kurtosis check methods). Suppression using interpolation across the deterministic signals in the SDOF functions followed by curve-fitting
- **Automatic Mode Estimation:** Identification of most well-excited modes based on peak identifications, modal coherence and modal domain indicators, and mode shape correlation analysis

Stochastic Subspace Identification (SSI)

Time domain data-driven SSI technique:

- Methods: Unweighted principal components (UPC), extended unweighted principal components (UPCX), principal components (PC), canonical variate analysis (CVA) and UPC merged data sets
- Uncertainty estimation with confidence bounds of the natural frequencies, damping ratios and mode shape complexities using the UPCX method
- More accurate estimates of modal parameters compared to using conventional 'mean value' based clustering techniques, when using the UPCX technique
- Fast techniques compared to traditional SSI techniques by using a special algorithm for creating the stabilization diagrams
- Unbiased estimation: No leakage
- Less random errors: Low-order modal estimators, all modal parameters fitted in one operation
- Crystal Clear stabilization diagram shown on wallpaper of the SVD of the spectral density matrix of the currently selected data set
- Stability indicators: Stable modes, unstable modes and noise modes
- Stabilization criteria: Natural frequency, damping ratio, mode shape MAC, modal amplitude MAC
- Physical mode separation: Damping ratio range
- Can estimate negative damping
- SVD diagram for subspace selection
- Select and link: Selected models from each data set are linked with snap functions and editing facilities (using the UPC merged data sets method no select and link is required. The individual data sets are automatically merged before UPC is performed)
- Model validation: Comparison of synthesized results for cursor model vs measured results. Magnitude of auto-spectra and cross-spectra. Magnitude of prediction errors
- Deterministic signals can be reduced in the time domain before performing SSI analysis. If not reduced beforehand, they can be excluded as they are estimated as modes with very low damping
- Automatic mode estimation: Identification of stable modes of all estimated models across all data sets, modal parameters presented in terms of mean value and standard deviation
- For the UPCX technique, the confidence bounds are used to further improve the modal parameter estimates
- Modal alignment view showing natural frequency, damping ratio and mode shape complexity as a function of model order
- Export of the complete estimated model (state-space system) in ASCII format

Analysis Validation

Comparison of modes between different projects and/or identification techniques including imported modes in UFF:

- Common mode table divided into the different estimation techniques for easy comparison
- Animation of single- or dual-frequency ODS or mode shapes in various formats
- Complexity plot and modal assurance criteria (MAC) plot/table can be shown for frequency ODS and mode shapes
- Normalization of ODS shapes and mode shapes
- Frequency vs damping diagrams presenting damping ratios as a function of natural frequencies. Including confidence ellipsoids using SSI-UPCX

On-line Help

- Web-based, but help system can be downloaded to local computer
- Tool-tips on all buttons
- Context-sensitive help on controls and plots
- Description of all menus and control bars
- Introduction to the idea of OMA and SHM
- Detailed description on the whole modal identification process
- Demo projects (example files) included

Specifications – Batch Processing Option BZ-8527 for PULSE OMA Pro

From PULSE version 27.0 (PULSE OMA v7.2.2.4, 64-bit)

Fast SSI analysis of acquired time data without user interaction. Requires PULSE Operational Modal Analysis Pro Type 8762 to be installed

- Run executable file from a command prompt, a .bat file or a Visual Basic script
- Results saved in .uff or .svs result file

The executable:

- Uses the fast Crystal Clear SSI techniques
- Supports multiple measurements and multiple SSI techniques at a time
- Supports measurements done in a single or multiple data sets
- Supports automatic selection of projection channels

Specifications – Data Manager Base Module BZ-8550 for PULSE OMA Pro

From PULSE version 27.0 (PULSE OMA v7.2.2.4, 64-bit)

Requires PULSE Operational Modal Analysis Pro Type 8762 to be installed

- Support for multiple analysis sessions
- External storage with saving and loading of measurements and results for each analysis session
- Historical measurement statistics (maximum, minimum, rms, median, mean, variance, skewness, kurtosis)
- Master Session definition, allowing automatic processing across all analysis sessions using the settings of the Master Session. Includes automatic SSI modal estimation
- Analysis Sessions table including damage value and damage zone for the used damage indicators
- Notification (alert) services: Visual, sound, email or Web service

Specifications – Automatic File Upload BZ-8551 for PULSE OMA Pro

From PULSE version 27.0 (PULSE OMA v7.2.2.4, 64-bit)

Requires Data Manager Base Module BZ-8550 to be installed

- Automatic measurement file upload from a specific folder on a specific interval
- Automatic signal processing of uploaded measurements
- Automatic file post-processing (move, delete, rename)
- Supports all PULSE Operational Modal Analysis Types 8760 – 8762 input file formats

Specifications – Modal Parameter History Module BZ-8552 for PULSE OMA Pro

From PULSE version 27.0 (PULSE OMA v7.2.2.4, 64-bit)

Requires Data Manager Base Module BZ-8550 to be installed

- Automatic mode tracking based on the estimation of a set of reference modes obtained from a specified set of reference analysis sessions
- Modal parameters shown as a function of the analysis sessions. Natural frequencies and damping ratios – absolute or normalized, and relative to their reference mode. Modal assurance criterion of the mode shapes relative to the mode shape of their reference mode. Threshold curves for critical zone and unsafe zone. Clicking on the line of interconnected modes reveals further information of the particular tracked mode
- Export of tracked modes in UFF or SVS file format
- Damage Indicator – Modal based on mode tracking of the natural frequencies and their uncertainties using the SSI-UPCX technique

Specifications – Damage Detection Module BZ-8553 for PULSE OMA Pro

From PULSE version 27.0 (PULSE OMA v7.2.2.4, 64-bit)

Requires Data Manager Base Module BZ-8550 to be installed

- Two statistical subspace-based damage detection indicators (classic and robust) for long-term monitoring of structures. Robust to changes in ambient conditions
- Damage indicators update automatically when new measurements are uploaded
- Control Chart prediction for unification of damage indicators
- The control chart can automatically notify (alert) when the threshold is being passed after an analysis

Specifications – Drift Analysis Module BZ-8554 for PULSE OMA Pro

From PULSE version 27.0 (PULSE OMA v7.2.2.4, 64-bit)

Requires Data Manager Base Module BZ-8550 to be installed

- Supports multiple drift definitions. Each definition specifies two measurement channels and a relative drift threshold
- Display of sensor displacements and relative drift time series of selected drift definitions
- Visual alerting in relative drift time series, in the definition table and on the geometry

Type 8760--XY	**PULSE Operational Modal Analysis Basic**
Type 8760-A-XY	**PULSE Operational Modal Analysis Basic (Academic Version)**
Type 8761--XSY	**PULSE Operational Modal Analysis Standard**
Type 8761-A-XSY	**PULSE Operational Modal Analysis Standard (Academic Version)**
Type 8761--X	**Upgrade from Basic to Standard**
Type 8761-A-X	**Upgrade from Basic to Standard (Academic Version)**
Type 8762--XSY	**PULSE Operational Modal Analysis Pro**
Type 8762-A-XSY	**PULSE Operational Modal Analysis Pro (Academic Version)**
Type 8762--X	**Upgrade from Standard to Pro**
Type 8762-A-X	**Upgrade from Standard to Pro (Academic Version)**

NOTE: If using Types 8760 – 8762 as stand-alone products, order Micro USB Security Key Type 7450-D with the Type 8760, 8761 or 8762 licence

OPTIONS AND MODULES FOR PULSE OMA PRO

BZ-8527-A-XY	Batch Processing Option
BZ-8527-B-XY	Batch Processing Option (Academic Version)
BZ-8550--X	Data Manager Base Module
BZ-8550-A-X	Data Manager Base Module (Academic Version)
BZ-8551--X	Automatic File Upload Module
BZ-8551-A-X	Automatic File Upload Module (Academic Version)
BZ-8552--X	Modal Parameter History Module
BZ-8552-A-X	Modal Parameter History Module (Academic Version)
BZ-8553--X	Damage Detection Module
BZ-8553-A-X	Damage Detection Module (Academic Version)
BZ-8553-XSY	Structural Health Monitoring Pack
BZ-8553-A-XSY	Structural Health Monitoring Pack (Academic Version)
BZ-8554--X	Drift Analysis Module
BZ-8554-A-X	Drift Analysis Module (Academic Version)

PULSE OMA MEASUREMENT AND ANALYSIS PACKS

Type 8760-C-XS	PULSE OMA Basic Measurement and Analysis Pack
Type 8760-D-XS	PULSE OMA Basic Measurement and Analysis Pack (Academic Version)
Type 8761-C-XS	PULSE OMA Standard Measurement and Analysis Pack
Type 8761-D-XS	PULSE OMA Standard Measurement and Analysis Pack (Academic Version)
Type 8762-C-XS	PULSE OMA Pro Measurement and Analysis Pack
Type 8762-D-XS	PULSE OMA Pro Measurement and Analysis Pack (Academic Version)

Accessories

TRANSDUCERS

A wide range of transducers and accessories are available for OMA. Different sensitivities for accelerometers with or without TEDS are available. Visit bksv.com/transducers or contact HBK for more information.

Type 4326-A	Triaxial Piezoelectric Charge Accelerometer
Type 4393	Piezoelectric Charge Accelerometer
Type 4394	Miniature Piezoelectric CCLD Accelerometer
Type 4397-A	Miniature Piezoelectric CCLD Accelerometer
Type 4507-B	Miniature Piezoelectric CCLD Accelerometer
Type 4508-B	Miniature Piezoelectric CCLD Accelerometer
Type 4524-B	Miniature Triaxial Piezoelectric CCLD Accelerometer
Type 4527	Triaxial Piezoelectric CCLD Accelerometer
Type 4529-B	Triaxial Piezoelectric CCLD Accelerometer
Type 8340	Seismic Piezoelectric CCLD Accelerometer
Type 8344	Seismic Piezoelectric CCLD Accelerometer
Type 4575	DC Response Variable Capacitance Accelerometer
Type 2981	CCLD Laser Tacho Probe

MOUNTING

UA-1473	Set of 100 Big Swivel Bases
UA-1478	Set of 100 Small Swivel Bases
UA-1480	Spirit Level for Swivel Bases

CONDITIONING

Type 2647	Charge to CCLD Converter

CALIBRATION

Type 4294	Calibration Exciter
DV-0459	Small Calibration Clip
DV-0460	Big Calibration Clip

* Item number legend:
X = licence model, either N for node-locked or F for floating.
Y = annual lease license available for node-locked licenses. When expired, a new annual lease license can be purchased or it can be traded in for a perpetual license at a discounted price.

Maintenance and Support Agreements

M1-8760--X	Agreement for PULSE OMA Basic
M1-8760-A-X	Agreement for PULSE OMA Basic (Academic Version)
M1-8760-C-XS	Agreement for PULSE OMA Basic Measurement and Analysis Pack
M1-8760-D-XS	Agreement for PULSE OMA Basic Measurement and Analysis Pack (Academic Version)
M1-8761--XS	Agreement for PULSE OMA Standard
M1-8761-A-XS	Agreement for PULSE OMA Standard (Academic Version)
M1-8761--X	Agreement for Upgrade from Basic to Standard
M1-8761-A-X	Agreement for Upgrade from Basic to Standard (Academic Version)
M1-8761-C-XS	Agreement for PULSE OMA Standard Measurement and Analysis Pack
M1-8761-D-XS	Agreement for PULSE OMA Standard Measurement and Analysis Pack (Academic Version)
M1-8762--XS	Agreement for PULSE OMA Pro
M1-8762-A-XS	Agreement for PULSE OMA Pro (Academic Version)
M1-8762--X	Agreement for Upgrade from Standard to Pro
M1-8762-A-X	Agreement for Upgrade from Standard to Pro (Academic Version)
M1-8762-C-XS	Agreement for PULSE OMA Pro Measurement and Analysis Pack
M1-8762-D-XS	Agreement for PULSE OMA Pro Measurement and Analysis Pack (Academic Version)
M1-8527-A-X	Agreement for Batch Processing Option for PULSE OMA Pro
M1-8527-B-X	Agreement for Batch Processing Option for PULSE OMA Pro (Academic Version)
M1-8550--X	Agreement for Data Manager Base Module for PULSE OMA Pro
M1-8550-A-X	Agreement for Data Manager Base Module for PULSE OMA Pro (Academic Version)
M1-8551--X	Agreement for Automatic File Upload Module for PULSE OMA Pro
M1-8551-A-X	Agreement for Automatic File Upload Module for PULSE OMA Pro (Academic Version)
M1-8552--X	Agreement for Modal Parameter History Module for PULSE OMA Pro
M1-8552-A-X	Agreement for Modal Parameter History Module for PULSE OMA Pro (Academic Version)
M1-8553--X	Agreement for Damage Detection Module for PULSE OMA Pro
M1-8553-A-X	Agreement for Damage Detection Module for PULSE OMA Pro (Academic Version)
M1-8553-XS	Agreement for Structural Health Monitoring Pack
M1-8553-A-XS	Agreement for Structural Health Monitoring Pack (Academic Version)
M1-8554--X	Agreement for Drift Analysis Module for PULSE OMA Pro
M1-8554-A-X	Agreement for Drift Analysis Module for PULSE OMA Pro (Academic Version)

hbkworld.com · info@hbkworld.com
Local representatives and service organizations worldwide

HBK HOTTINGER BRÜEL & KJÆR