PRODUCT DATA

Ometron Scanning Laser Doppler Vibrometers — Types 8330 D and 8330 E

The Ometron family of Scanning Laser Doppler Vibrometers (SLDVs), Type 8330, comprises highly accurate, compact and versatile, non-contact vibration systems. They are used for applications where it is impossible or undesirable to mount an array of vibration transducers on a vibrating object.

Type 8330 SLDVs are full-field systems that quickly produce vibration maps depicting the structural response at multiple measurement points. In such applications, they often replace an array of accelerometers or microphones.

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USES

- Experimental modal analysis
- Inspection of operating machinery
- Structural integrity assessment studies
- Analytical modelling
- Validation of FE models
- Noise control
- Non-destructive inspection
- Quality assurance
- Conditioning monitoring
- Design studies
- Production-assembly techniques

FEATURES

- The compact sensor-head and 3560 C PULSE™ front-end, as well as the recommended laptop PC, make Types 8330 D and 8330 E extremely portable, scanning-laser vibrometers
- High optical sensitivity through homodyne optical/electronic principle means surface treatment is rarely required, even on dark/black surfaces such as tyres and speakers
- Lenses for working ranges from <50 mm to >200 m are provided as standard, allowing a wide range of objects to be measured
- Full-colour, in-line Charge Coupled Device (CCD) camera avoids possible parallax errors in background image
- High-resolution, digitally controlled, Moving Magnet Galvo motors practically eliminate position hysteresis to ensure repeatability of scan locations
- Wide range of applications covered with amplitude range from 0.5 μm/s to 2 m/s
- User-friendly software, with built-in, high-end FFT analyzer, makes geometry definition, data acquisition and analysis easy
- High-resolution scanning of background image eliminates need for optical zooming
- Wide range of analysis techniques to handle real-world structures, for example:
  - Non-linear systems: lock-in analysis, chirp and swept-sine excitation
  - Systems with non-steady, time-variant excitation: Operating Deflection Shapes (ODS) based on ratio-based, phase-assigned spectra
  - Structures with repeated or closely spaced modes: multi-shaker Excitation and MIMO Analysis optional BZ 5452 Advanced Modal Analysis/MIMO Bundle)
- One click export of data to optional integrated modal analysis software
- Standard export of data and results in UFF, DIAdem™ and ASCII file formats
- Uses PULSE IDA^{e} data acquisition front-ends for hardware compatability with PULSE systems

Maul-Theet Systeme OMETRON Brüel & Kjær

Introduction

Types 8330 D and 8330 E include all the optical/electronic hardware (and accompanying software) necessary to obtain and represent most global field-vibration parameters. Systems can be configured with either a laptop or desktop PC, making them highly portable or laboratory-based as desired.

For users with more demanding requirements, additional (optional) software packages can provide result presentations related to advanced modal analysis and multi-shaker excitation (MIMO). Types 8330 D and 8330 E share IDA^e front-end hardware with the PULSE system, meaning that they can expand an existing PULSE system or that other PULSE system software can be run, thus adding considerable value to the investment.

Based upon a safe and visible Class-II, He-Ne laser, the Type 8330 D and 8330 E scanning-laser vibrometer systems avoid the need for special safety facilities or protective equipment.

The compact size and low weight of both systems offer a portability that makes them suitable for both laboratory and field work.

Types 8330 D and 8330 E are based on SB 2507–001 VPI+ (Vibration Pattern Imaging) sensor-head, which includes high-resolution, digital mirror-control, a full-colour CCD camera, self-sensing power supply, and a high velocity range. SB 2507–001 is the latest version in Ometron's Scanning Laser Doppler Vibrometer range; the original VPI sensor was the world's first SLDV and the new generation of sensor heads represent more than 15 years of continuous development of the VPI family. The two systems, Type 8330 D and Type 8330 E, vary with regard to the supplied PULSE front-end and thus the number of input and output channels, and frequency range of analysis.

The main differences between the two scanning-laser vibrometer systems are described in the following sections and an overview of the different analysis types is seen in Table 1.

System Descriptions

General

SLDVs Types 8330 D and 8330 E both consist of a SB 2507–001 sensor-head, a PULSE sound-and-vibration analyzer front-end and a small external frame-grabber unit, plus all the necessary cables and software.

The only additional item required to make a complete measuring system is a PC that has both an built-in FireWire® connector and an OpenGL® (or better) graphics card. To make your system as portable as possible, Brüel & Kjær recommends its high-end laptop PC UL 0175 A–XX, where XX is a country-specific code that ensures the user gets the correct keyboard layout and power cable.

Type 8330 D

Type 8330 D is based on a Type 3560 C PULSE front-end with a Type 3109 module installed. It has four input channels and two signal generators, all with up to 25 kHz bandwidth.

Type 8330 D has an excellent price/performance ratio and is the preferred, non-contact, vibration-analysing 'workhorse' of every well-equipped vibration laboratory.

When combining the Type 8330 D with a laptop PC, you obtain an extremely portable solution that can easily be moved between fixed locations and also be used in field applications.

Special, structural-testing options like Advanced Modal Analysis Software BZ 5318 and the Multi-shaker (MIMO) Analysis Software BZ 5319 make Type 8330 D the ideal system for modal analysis of large structures.

The portability of the system and the extreme, long-range capabilities of Sensor-head SB 2507–001, make Type 8330 D an excellent choice for measurements on large, civil-engineering structures such as buildings, dams, and bridges.

Type 8330E

Type 8330 E is based on a Type 3560 C PULSE front-end with a Type 3110 module installed. It has two input channels and one signal generator. The input channels have a 200 kHz bandwidth, while the output channel has a 100 kHz bandwidth[1].

Some applications require extended frequency ranges: hard-disk drives, harmonic-distortion analysis of loudspeakers, and measurements on scale models sometimes require measurements beyond 25 kHz, which makes Type 8330 E very suitable for these application types.

The high frequency range and small size of Type 8330 E, especially when configured with a laptop computer, also makes it a good choice for space-limited hard-disk and speaker-testing laboratories.

MIMO analysis by multiple shaker inputs requires multiple signal generators. A second Type 3560 C PULSE front-end and a LAN switch add two more input channels and one more signal generator. Type 8330 E can either be purchased with additional channels or upgraded any time after purchase. The modularity of PULSE hardware makes system configuration easy which customers themselves can perform, eliminating delays incurred by having to send systems out for upgrade. One of the input channels of the second Type 3110 module can also be used to enable the dropout detection feature.

Having both high-frequency input channels and a signal generator makes Type 8330 E the best choice for universities and multi-application R&D laboratories.

Fig. 1
Type 8330 desktop-based system

[1] In a Type 8330 E with two input channels, the dropout detection feature is disabled.

Fig. 2
Type 8330 D system configuration

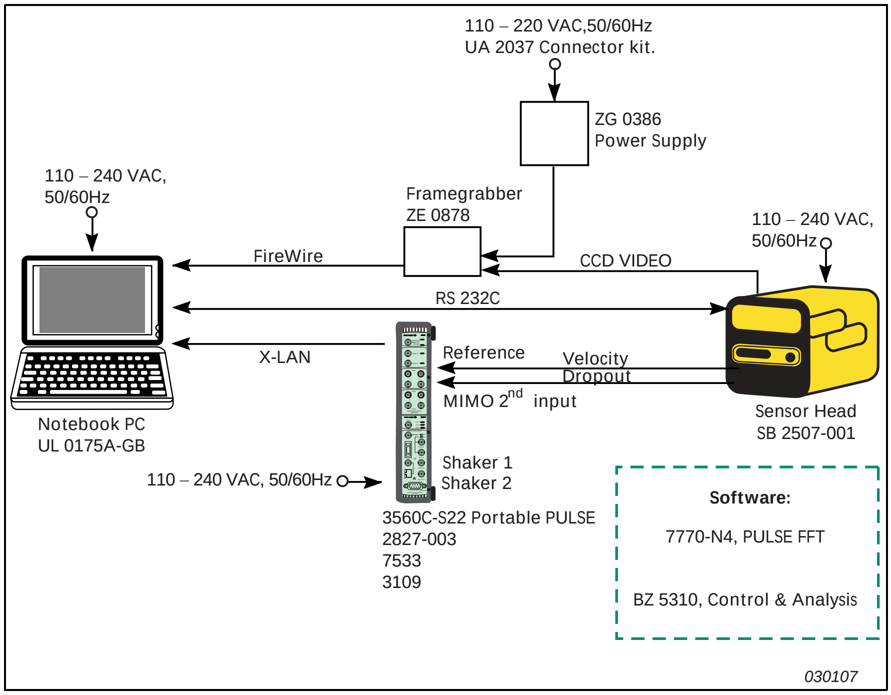


Fig. 3
Type 8330 E 2-channel system configuration

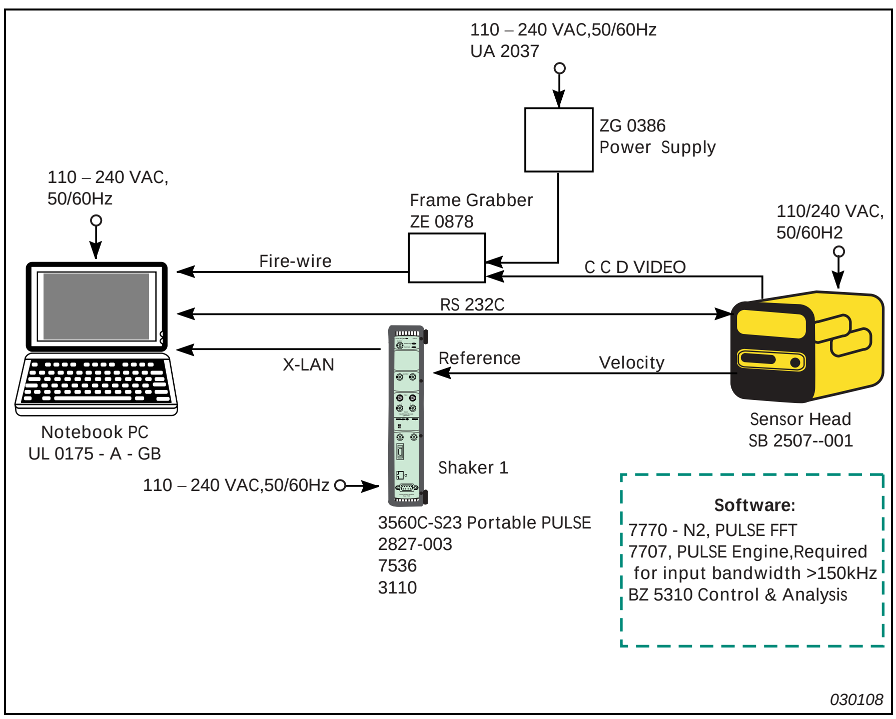
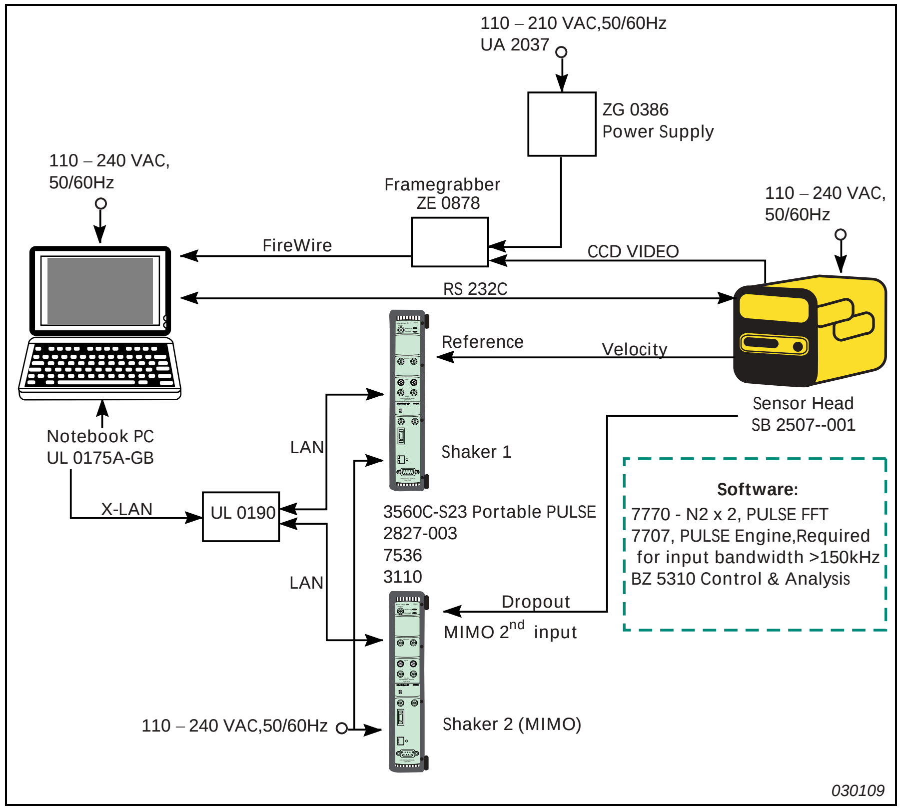


Fig. 4
Type 8330 E 4-channel system configuration



Analysis Types

Introduction

Types 8330 D and 8330 E can analyse vibration in several ways. The analysis type chosen depends on the application, whether the input to the system can be controlled and measured, whether there is a reference signal available, and the amount of time required to make the measurement.

Operating Deflection Shapes (ODS)

ODS analysis measures amplitude and phase at multiple scanned points. The technique uses the Fast Fourier Transform (FFT) to calculate amplitude and phase as a function of frequency. (See Ref. [1] for a more in-depth description of ODS testing). Scanning lasers measure the motion of every scanned point individually and the relative phase between scanned points is calculated by measuring a reference channel with each scanned point.

Several types of signals can be used as the reference:

- the input voltage into a speaker or hard-disk drive controller
- the motion of a location on the structure measured by a fixed accelerometer or single-point laser
- a shaker's drive signal or the measured force input into the structure by the shaker

Because a scanning laser vibrometer measures one point at a time, time-domain ODS based on simultaneous data acquisition is not possible – time-domain ODS with a scanning laser would be possible if the motion was constant and repeatable for the entire scan. This type of motion is rare, so the software is limited to ODS animation in the frequency domain. Frequency-domain ODS yields an operating deflection shape at every analysed frequency. For example, if a 400-line FFT is used for analysis, 400 operating deflection shapes are available.

ODS measurements are often made on structures excited by an internal engine, motor or other vibration source. The vibration amplitude from the source often shows random variation. Animations based on a simple, phase-assigned spectrum (PAS), based on the magnitude from the autospectrum and the phase from the cross-spectrum, would need many averages to obtain a sufficient statistical accuracy of the amplitude. A high number of averages would significantly increase the scan time for the large number of measurements in a typical scanning-laser measurement.

A transmissibility estimation, based on the Frequency Response Function (FRF), reaches high statistical accuracy in fewer averages than a PAS. (See Ref. [2] for information on statistical errors for different FFT-derived functions). The disadvantage of transmissibility is that it shows only relative motion. The units are, for example, $m/s/m/s^2$ when a laser uses an accelerometer as a reference. Absolute units of displacement (m), velocity (m/s) or acceleration (m/s^2) are preferable for most applications.

It is possible to multiply the transmissibility by the autospectrum of reference for a single measurement. This gives amplitude units in displacement, velocity or acceleration but with the same statistical accuracy as the single autospectrum from the reference. Unlike animations based on PAS estimates with limited averages, animations based on transmissibility do not show variations in the response's amplitude caused by some random sources. This is because all the transmissibility measurements are multiplied by a single reference autospectrum. This compensates for one issue encountered with vibrations from random sources – point-to-point amplitude variation in the roving response as a function of time. Multiplying the transmissibility by a single reference measurement does not remove the other issue of random vibrations – insufficient statistical certainty about the reference's autospectrum based on a low number of averages.

To reduce uncertainty, Control and Analysis Software BZ 5310 uses the average of the reference from all measurements taken during the scan. This optimises the statistical accuracy for a given data set while keeping absolute scaling (Bruel & Kjær pioneered the original PAS technique and the improved ratio-based PAS technique).

The averaged spectra at each point are saved and available in the software for analysis, or can be exported as ASCII, DIAdem™ or as Universal File Format (UFF) 58 for analysis in other software packages. One time-block is available at each measurement location. The time data can also be exported as ASCII or DIAdem™ for analysis in other software packages.

Single-Input Multiple-Output (SIMO) Modal Analysis

If the reference for the measurements is the measured force from a shaker, then the data can be used for Modal Analysis. (See Refs. [1] and [3] for a detailed description of Modal Analysis). The standard Control and Analysis Software BZ 5310 can acquire data for SIMO Modal Analysis and can export the data in UFF file format 58. The standard software also exports the geometry in UFF file formats 15 and 82. These UFF file formats can be imported by most third-party modal-analysis packages and the modal analysis and animation can continue in the third-party modal package.

Advanced Modal Analysis Software BZ 5318 allows modal analysis to be highly integrated with SLDVs Types 8330 D/E and provides the user with additional vibration parameters like damping factor and Eigen-vectors. Results of both standard ODS measurements and mode shapes can be displayed and animated in Control and Analysis Software BZ 5310.

The BZ 5318 software also has the ability to combine the results of two (or more) sequential measurements, such as looking at the same application from different angles or combining the results of two parts of a huge, vibrating surface; axis transformation between the two sensor-head positions is part of this feature.

Multiple-input Multiple-output (MIMO) Modal Analysis

There are several types of structure where a single input force is insufficient:

- large structures such as buildings and satellites where the high force levels with only one input location can either drive the system into non-linear behaviour or damage fragile test objects
- symmetrical structures like brake rotors where the physical symmetry causes two or more modes at or near the same frequency
- flexible structures like aircraft wings where modes are closely spaced (< 0.1 Hz)

- complex structures with poor coupling between the vertical direction and the horizontal directions (car bodies) or with local modes

An accurate modal model, especially one used to update finite-element (FEA) models, assumes linear behavior and all modes need to be identified in a given frequency range.

For many real-world structures, one single-input measurement is definitely not sufficient. Either two or more separate single-input measurements need to be taken or one measurement with multiple inputs. Multiple inputs require a more complex formulation of the frequency-response function (FRF) to account for the response to multiple sources. (See Refs. [4] and [5] for more information on MIMO analysis).

The integrated Multi-shaker Excitation and MIMO Analysis Software option BZ 5319 allows modal-data acquisition and analysis on structures requiring multiple input forces.

Lock-in Analysis

The lock-in technique uses a sine-wave excitation at the frequency and amplitude of interest. The response from the scanning laser is compared to the input sine-wave to get the amplitude and phase at the measurement point. Additionally, the amplitude and phase at harmonics of the excitation frequency can also be measured. Since only a few cycles of the input frequency need to be measured, the lock-in approach is fast compared to the FFT technique for frequencies above a couple of hundred hertz.

Many structures have non-linearities with respect to amplitude and frequency. Amplitude non-linearities can be seen in structures with multiple connected components. At low force-levels, the connections (bolts, rivets, or bearings) between the components are rigid and components move as one continuous structure. At higher force-levels the connections are no longer rigid and the individual components begin to move, relative to each other.

Frequency non-linearaties are present in speakers and other audio components. Input energy at one frequency is transferred to energy in more than one frequency at the response (that is, clipping). (See Ref. [6] for more information on handling non-linearities).

Amplitude and frequency non-linearities can be avoided in SIMO modal acquisition by choosing an excitation signal which contains only one force-level and/or frequency, at a given time. A chirp signal has only one amplitude, so it is a good choice for systems with amplitude non-linearities. However, a chirp signal is not suitable for structures with frequency non-linearities because it excites multiple frequencies within the same analysis time block. A stepped sine, with only one frequency per analysis time block, is the best choice for structures with both amplitude and frequency non-linearities.

The stepped sine-signal has longer data-acquisition times compared to broadband FFT excitation signals, like chirp and random. If the structure’s motion is only of interest at a few frequencies, then a stepped-sine or broadband FFT technique provides more information than required with an increase in test time. The lock-in technique is the fastest way to determine the structure’s motion, at a single frequency. The lock-in analysis approach can be used to investigate both amplitude and frequency non-linearities since it uses a sine wave at a single amplitude and frequency.

RMS Analysis

For some types of engineering analysis, especially the study of sound radiating from a vibrating body, it is desirable to measure the total motion over a range of frequencies. RMS analysis allows the motion to be ‘summed’ over a frequency range of interest, giving a representation of the overall energy. Phase over a frequency range is not meaningful, so a reference is not used. RMS analysis is the only option for applications where a reference is not available.

Table 1 *Overview of the types of analysis available across both systems*

Types of Analysis	Type 8330 D	Type 8330 E	Remarks
25 kHz ODS	✔	✔	Requires reference signal (internal coherent signal, accelerometer or single-point laser)
200 kHz ODS		✔	
25 kHz Lock-in	✔	✔	
100 kHz Lock-in		✔	Can measure harmonics to 200 kHz
25 kHz RMS	✔	✔	
100 kHz RMS		✔	
SIMO Modal Data Aquisition	✔	✔	
Advanced Modal Analysis	✔	✔	Requires BZ 5318
MIMO Analysis	✔	(✔)	Requires BZ 5318 and BZ 5319. Type 8330 E requires expansion to 4/2-ch. Input/Output

Standard Software and Upgrades

Control and Analysis Software

Control and Analysis Software BZ 5310 comes ready installed on Type 8330. It includes the following advanced features that make Type 8330 a powerful and easy-to-use tool for testing:

Fig. 5
Hard-disk geometry

Acquire a parallax-free image of the test object – parallax errors are caused by mis-alignment of the camera and laser beam. Avoiding parallax error is especially important when working on small objects at close range, such as hard-disk read-write heads. The Ometron VPI+ Sensor avoids parallax errors by having the CCD camera and laser located together.

View live video of the object under test – when the object is not visible from the computer workstation.

Interactively create geometry with image – to precisely control location of measurement points. Use rectangle, ellipse, and polygon tools to define areas to scan, and areas to exclude from scan. Because the image is parallax error-free, there is no difference between the geometry on the screen and the geometry of the object. Digitally controlled mirror-motors remove hysteresis errors to ensure repeatability of scan locations. Like parallax errors, hysteresis errors affect very short-range measurements on small objects such as hard-drive components. As a standard feature, geometries can be exported in UFF formats 15 and 82.

Fig. 6
Loudspeaker geometry

Control data acquisition settings – lock-in analysis provides the fastest measurements but is limited to one frequency and its harmonics. FFT analysis requires more time at each measurement point but yields operating deflection shapes at each FFT line. FFT results can also be exported in UFF 58 format, a standard feature, for analysis in third-party software like ME'ScopeVES™. Optionally, FFT data can be sent to Advanced Modal Analysis software BZ 5318, with one mouse click.

Verify data integrity – with standard signal processing functions like coherence and six levels of colour annotation at each measurement point. The software can be set to automatically rescan points for any combination of detected anomalies. Additionally, the software can also automatically search for measurement locations that maximise returning, back-scattered light.

Animate Operating Deflection Shapes – or optionally, Mode Shapes (BZ 5318), have the ability to animate the object image and interact with the animation for an easier visualisation of the ODS and immediate correlation between points on the animation and points on the specimen. Animations can be saved as AVI files for display in other applications.

Dropout Detection – low amounts of back-scattered light can cause the Doppler signal to drop in amplitude leading to data with a poor signal-to-noise ratio. The electronics in the VPI+ Sensor (SB 2507) detect when a dropout event occurs and Control Software BZ 5310 marks data at points where the quality of the measurement can be improved for subsequent rescan. Users can benefit from the 'dithering' function that automatically searches the structure for nearby locations with improved, back-scattered light level for the best possible quality vibration measurement. Point positions in the user-defined scanning mesh are automatically updated without any loss of spatial-positioning accuracy.

A 'Measurement Assistant' – has been written into the software to aid operation of the equipment by guiding the operator through the complete measurement process.

Advanced Modal Analysis Software Option

Advanced Modal Analysis Software BZ 5318 is an optional software package for integrated modal analysis within the Type 8330 system. Data is available for modal analysis within the system's software package. BZ 5318 calculates mode shapes (eigen-vectors), natural frequencies and damping (eigen-values). Mode shapes can be compared in the software using the modal assurance criteria (MAC). Most importantly, the mode shapes can be superimposed and animated on a picture of the test structure. ODS and mode shapes can be animated and compared in the same software. Calculated data from BZ 5318 are also available for export in UFF and ASCII formats. For further information, see Specifications.

Multi-shaker Excitation and MIMO Software Option

The BZ 5319 multi-shaker excitation and MIMO analysis software package is used for multiple-input/multiple-output modal analysis. BZ 5319 requires that the BZ 5318 advanced modal-analysis option is already installed on the PC. BZ 5319 also requires at least two signal generators to excite the application with a shaker at two different locations. The option enables the two signal generators to output two uncorrelated, random signals and calculates the MIMO FRF-function. For further information on this, see Specifications.

Advanced Modal Analysis/MIMO Software Bundle Option

For customers who do not already own Advanced Modal Analysis Software BZ 5318, a software bundle containing BZ 5318 software, together with Multi-shaker Excitation and MIMO Software BZ 5319, is available. Advanced Modal Analysis/MIMO Software BZ 5452 is less expensive than purchasing BZ 5318 and BZ 5319 separately.

To avoid problems with the installation of required drivers for the graphics card, frame grabber and PULSE front-end, Brüel & Kjær strongly recommends ordering the system PC together with the scanning laser vibrometer system. Brüel & Kjær recommends ordering one UL 0175 A high-end laptop PC with each Type 8330 D or Type 8330 E. With PC included, each Type 8330 D or Type 8330 E is typically delivered as a configured and tested system.

The specifications of the configured laptop PC follow the general trend in the development of the world-wide PC market and are therefore subject to change. See the Specification section here, or contact your local Brüel & Kjær representative for the most up-to-date computer specifications.

By considering Sensor Head SB 2507–001 and Control and Analysis software BZ 5318 to be an integral part of a PULSE sound-and-vibration analysing system, the user can add a number of other PULSE applications to the scanning laser vibrometer. For stand-alone, scanning laser vibrometers, Brüel & Kjær recommends its Type 3560C portable PULSE front-end, adding to the portability of the complete system. PULSE users with an IDA^e front-end can also add scanning laser vibrometry to their existing system.

If your current PULSE software is not regularly updated via a M1 software maintenance agreement, a PULSE M2 or M3 software upgrade may be required. If your current (desktop) PC does not have a FireWire® connector, a PCI-based frame grabber can be used – please ask your local Brüel & Kjær representative for the recommended type(s).

If your current (desktop) PC does not have an OpenGL® (or better) graphics card, a PCI bus-based card must be added. Please ask your local Brüel & Kjær representative for the recommended type(s). If the PC is an older laptop or a newer laptop with lower specifications, Brüel & Kjær-recommended UL 0175 A must replace it.

A minimum of three input channels is required to facilitate inputs for the reference signal (from accelerometer, force transducer or single-point laser vibrometer), the velocity signal coming from Sensor Head SB 2507–001, as well as the dropout signal coming from the same sensor head. Any remaining signal(s) can be used for additional reference signals.

The on-board signal generator(s) can be used to independently control a shaker(s) with, for example, stepped-sine, random, chirp, triangle or rectangular (pulse) signals. This feature is especially useful when used in combination with multi-shaker excitation and MIMO Analysis Software BZ 5319.

All options and features are available for both the Type 8330 D and Type 8330 E scanning laser vibrometer systems, the only exception being that multi-shaker excitation and MIMO Analysis Software BZ 5319 can only be used in connection with a 2-channel Type 8330 E after it has been extended with a second Type 3110 module and the required accessories.

SB 2507–001 Sensor Head

Introduction

Sensor Head SB 2507–001 is a non-contact transducer for the measurement of vibration. It is based on optical-sensing techniques to give uniquely high sensitivity and reproducibility over a wide dynamic range.

Features

SB 2507–001 consists of a single, rugged, optical frame of which mounting fixtures for the mirror form an integral part. This ensures that the internal optical path is not affected by the mounting of the sensor head.

Optical Sensitivity

The optical system is very efficient and uses carefully optimised components to achieve the maximum possible optical sensitivity. In practice, this means that reflectivity target-surface treatments are rarely required. Measurement can be taken directly from dark/black surfaces like tyres and speakers or die-cast produced components.

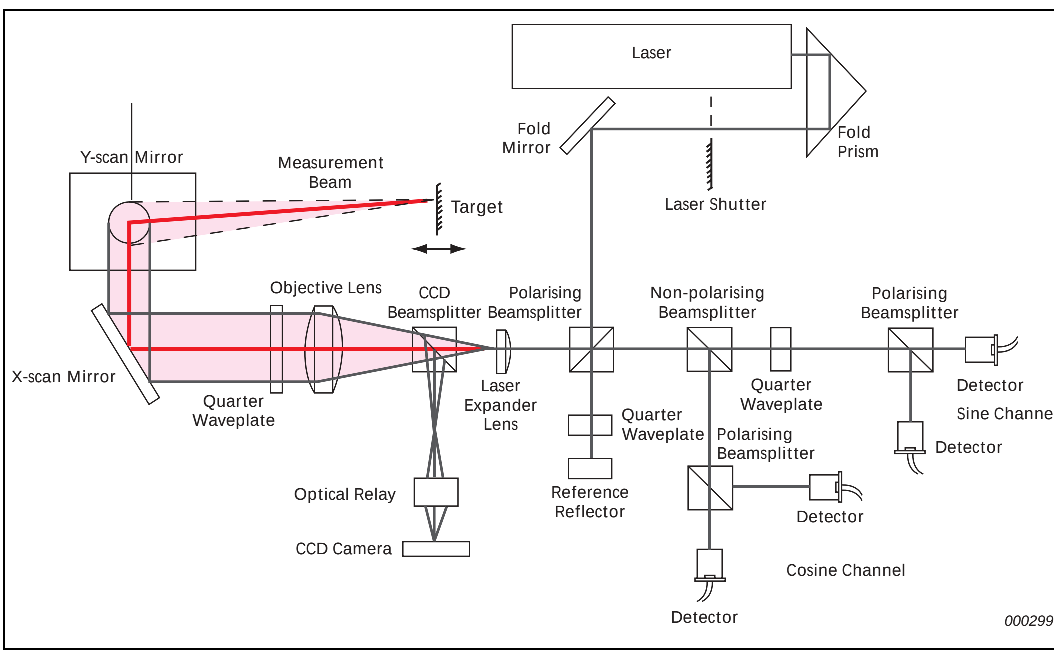
Measurement Principles

Sensor Head SB 2507–001 is based on a Michelson interferometer in which a laser beam is divided into a reference and a measurement beam (refer to Fig. 7). The measurement beam is directed onto a vibrating test surface, and the back-reflected light recombined with the internal reference beam.

When the test surface moves, the path difference between the routes followed by the reference and measurement beams changes, resulting in light-intensity modulation of the recombined beam due to interference between the reference and measurement beams. One complete cycle of the light-intensity modulation corresponds to a surface movement of $\lambda/2 = 3.16^4 \times 10^{-7}$ m, that is, half the wavelength of the Helium-Neon laser source. Hence, the frequency, F_d, of the intensity modulation corresponding with a velocity, v, is given by $F_d = 2v/\lambda$, where F_d is the 'Doppler frequency' associated with a surface velocity, v.

The recombined beam is shared between two independent detection channels in such a way that the interferometric path difference presented to one channel is effectively one quarter of a wavelength longer than that presented to the other channel. This configuration results in a 90° phase shift between the signals from the two channels. The direction of surface motion can thus be determined by looking at which signal leads the other in phase.

Fig. 7
Type 8330 SLDV optical layout



The sine and cosine signals at frequency F_d are fed to a dual-channel balanced modulator where they are respectively modulated by internally generated sine and cosine signals at a carrier frequency, F_c.

Summation of the two modulated outputs described above yields a single, frequency-shifted output at $F_c + F_d$ or $F_c - F_d$, depending on the direction of surface motion. In this way, electronic mixing results in frequency-shifted Doppler signals.

Scanning System

Sensor Head SB 2507–001 includes all the optical parts necessary to form a Michelson interferometer, as well as two (X and Y) 16-bit, digitally controlled mirrors that have an angle resolution of 11.00 μRad or 0.0006307°. The mirrors are positioned by digitally controlled Moving Magnet Galvo motors which practically eliminate position hysteresis to ensure repeatability of scan locations. This results in minimum step sizes of approximately 0.5 μm at 50 mm with the short-range lens, or 0.5 mm at 50 m with the long-range lens (see ‘Lenses’).

Lenses

Fig. 8
Lens kit for Type 8330

SB 2507–001 is provided with two lenses (35 mm short-range, and 95 mm long-range), each having its own range of working distances. One provides close focus capabilities (< 50 mm) and is better designed for short working distances. The other offers greater light-gathering capabilities and is the appropriate choice for long working distances. Interchanging the lenses accordingly influences the depth of focus and working distance of the SLDV systems.

For extremely close-range measurements, please contact your local Brüel & Kjær representative for information on an optional macro lens.

The lens can be changed quickly and has no effect on the calibration of the system.

Focusing

Fig. 9
Rear and side-panel view of Sensor Head SB 2507–001

On the side-panel of the sensor head is a focusing knob to help focus the laser beam on the target structure. The focusing quality can be optimised while observing an LED bar graph just beside the knob that shows the average level of the Doppler signal. The same information is available in the controlling software.

Shutter

A laser shutter, controlled by the software in the PC, interrupts the laser beam during the scanning of the image. This prevents strong, red light from the laser beam, which would otherwise be reflected by the target surface, from entering the optics and overshadowing the colour information of the image.

Cables and Connectors

Cables

The complete Type 8330 D and Type 8330 E scanning laser vibrometers consist of only three main units – a SB 2507-001 sensor head, a Type 3560C portable PULSE sound-and-vibration front-end, as well as a configured (laptop) PC with BZ 5310 control and analysis software installed. The only cables required are standard, low-cost coaxial cables, mains cables, a video cable, a LAN cable and a serial RS–232 C cable. The instrument is supplied with 5 m cables between the sensor head and the configured PC; this covers most laboratory situations. For applications where the sensor head has to be placed farther away from the configured PC, optional cable sets with 10 m and 20 m cable lengths are available. Please contact your nearest Brüel & Kjær office if your application requires a distance larger than 20 m between the sensor head and target.

The available cables are:
- AO 0582 Short Cable Set (5 m), default
- AO 0583 Medium Length Cable (10 m)

- AO 0584 Long Cable Set (20 m)

Signal Output Connectors

SB 2507–001 is provided with a number of output connectors:

- Analogue Velocity Signal – a test surface moving towards, or away from, the sensor head generates, respectively, a positive or negative analogue signal that is directly proportional to the velocity in the direction of the laser beam at the point where the laser beam hits the surface. The maximum output voltage is 5 V_{peak} for the maximum velocity in each of the 5 ranges. The output sensitivity is factory calibrated according to a traceable calibration procedure. This analogue velocity signal is the main signal that is sent to the vibration analyzer
- D1 and D2 – these sockets are the Doppler signals monitoring the basic analogue interferometer signals. D1 and D2 show the modulation at a frequency directly proportional to the instantaneous velocity of the test surface. The relationship between frequency and velocity output is 3.16 MHz per m/s. Taken together, D1 and D2 permit the determination of the velocity direction of the measured velocity component parallel to the laser beam. D1 leads or lags D2 by 90° in phase, depending on whether the surface is moving towards or away from the sensor head

Fig. 10
Sensor Head SB 2507–001 showing side-panel with connectors

- Low vibration-levels at a point or low amounts of back-scattered light can cause the Doppler signal to drop in amplitude. The electronics in Sensor Head SB 2507-001 detect when the amplitude of the Doppler signal becomes low. The sensor asserts a TTL signal for the period of low Doppler signal. Control software BZ 5310 marks data at points with low Doppler signal and can automatically search the structure for nearby locations with improved back-scattered light
- Video Out – the video output signal of the sensor head carries the video signal representing the image and is connected to the frame grabber by means of a video-type coaxial cable
- Serial output – the RS–232 C serial output is used to send information on the sensor-head setup back to the configured PC

Serial Input Connector

SB 2507–001 is provided with a serial input connector. This is for setup of the instrument and advanced diagnostics, an RS–232 C serial cable takes care of the signal flow between the sensor head and the controlling PC. The internal shutter and scanning mirrors are also operated via serial link.

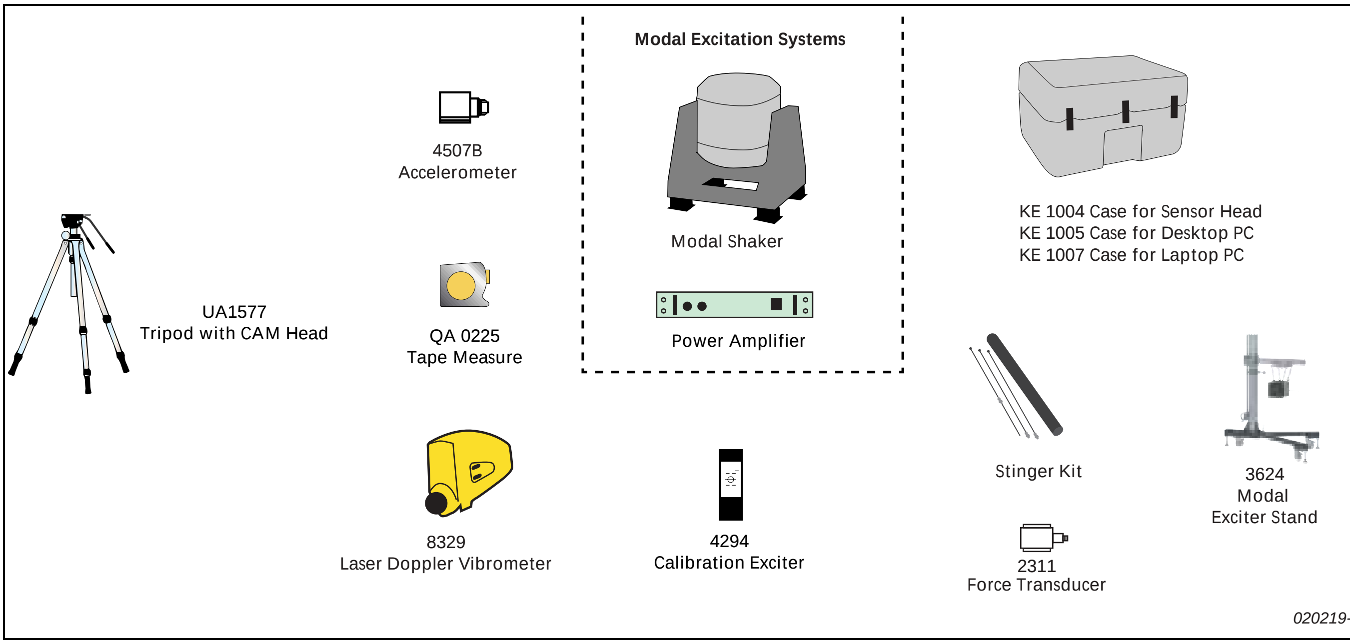
Accessories

Fig. 11
Type 8329 – used to provide a reference signal

Single-point Laser Doppler Vibrometers

For situations that do not allow the fixture of a contacting reference transducer, Brüel & Kjær recommends the use of single-point laser doppler vibrometers such as Types 8329, 8333, 8334 and 8335. Applications include ODS measurements on very light, hot and/or small structures.

Fig. 12 Type 8330 optional accessories



Mounting and Transport Options

Fig. 13
Tripod, including Multi-directional Head UA 1577

Tripod

As Type 8330 SLDVs measure the relative motion between the sensor and the target, it is important that the sensor head is placed on a tripod that can absorb disturbing environmental vibrations. The optional tripod offered by Brüel & Kjær (Tripod UA 1577, including multi-directional head) is very rugged and designed to carry television-studio cameras.

Transit Cases

Transit case KE 1004 is for the VPI+ Sensor Type SB 2507.

The case is manufactured from vacuum-formed ABS plastic and come with hinges, two recessed handles and two recessed catches/locks. This case protects the delicate optical sensor head during road and air-freight transport.

The foam interior of the transit case has cavities for the sensor head and all its accessories, as well as all accompanying cables. Notebook PC UL 0175 comes with a carrying bag with enough room for the PC and its accessories, including the ZE 0878 External FireWire® Framegrabber unit, as well as its power supply and its own accessories.

Calibration

The factory adjusts the analogue velocity output of the sensor head to a sensitivity of ±5 V_{peak} for the maximum velocity in each of the 5 velocity ranges: 5, 20, 100, 500 and 2000 mm/s

The resulting output sensitivity for each of the ranges can be found in the specifications of the sensor head.

Each product is delivered with a ‘Certificate of Traceable Calibration’, which certifies that each product has been checked and calibrated against test procedures. The test procedures are listed on the certificate.

A quick calibration of one point of the sensor head’s calibration curve can be performed by positioning a Calibrator Type 4294 in front of the sensor head.

Applications

Scanning vibrometers are used in many industries and for various applications. Common applications in the automotive and aerospace industries include:
- structural analysis of car/aeroplane bodies and frames (chassis)
- vibration analysis of car doors, wing profiles, etc.
- wind-induced vibration and sound studies of (parts of) cars in wind tunnels
- sound-emission studies on jet engines (gas turbines) and IC engines
- vibration and shriek analysis of rotating parts, such as tyres, brake systems and engine belts
- vibration analysis of hot components, such as manifolds and exhaust pipes
- vibration studies of lightweight structures, such as ducts and fuel pumps

Other common SLDV applications include:
- non-destructive and non-invasive quality testing of cracks and other damage in materials, such as, castings
- loudspeaker, microphone and telephone testing
- vibration testing of consumer goods like power tools, dishwashers, washing machines and dryers
- vibration and damping measurement of hard-disk drive components
- investigation of the structural dynamic behaviour of complex structures
- dynamic-response measurements on full size or models of civil structures, such as dams, towers, bridges and high-rise buildings
- investigation of machine-tool vibrations or chatter

Ometron SLDVs have been successfully used in some unique applications:
- measurement of damage to frescoes, paintings and icons in, for example, churches
- investigation of the body vibrations of musical string-instruments

References

[1] DØSSING, OLE.: *“Structural Testing, Part 1: Mechanical Mobility Measurements”*, Primer No. BR 0458, Brüel & Kjær, Denmark, Revision April 1988.

[2] HERLUFSEN, HENRIK: *"Dual-channel FFT Analysis (Part II)"*, Technical Review No. BV 0014–11, Brüel & Kjær, Denmark, 1984.

[3] DØSSING, OLE.: *“Structural Testing, Part 2: Modal Analysis and Simulation”*, Primer No. BR 0507, Brüel & Kjær, Denmark, March 1988.

[4] DØSSING, OLE.: *“Multi-reference Impact Testing for Modal Analysis using Type 3557 Four-channel Analyzer and CADA-PC”*, Application Note No. BO 0422, Brüel & Kjær, Denmark.

[5] HERLUFSEN, HENRIK: *“Modal Analysis using Multi-reference and Multiple-input Multiple-output Techniques”*, Application Note No. BO 0505, Brüel & Kjær, Denmark.

[6] TEMME, STEVE: *"Audio Distortion Measurements"*, Application Note No. BO 038512, Brüel & Kjær, Denmark.

Compliance with Standards

CE	CE-mark indicates compliance with: EMC Directive and Low-Voltage Directive
Safety	EN 61010 – 1 and IEC 61010 – 1: Safety requirements for electrical equipment for measurement, control and laboratory use
Electromagnetic Compatibility	EN 61326 – 1 and IEC 61326 – 1: Electrical equipment for measurement, control and laboratory use – EMC requirements CISPR 22: Radio disturbance characteristics of information technology equipment. Class B limits FCC rules, Part 15: Complies with the limits for a Class B digital device
Laser Safety	21 CFR 1040.10, 21 CFR 1040.11: FDA regulations for laser products EN 60825 – 1 and IEC 60825 – 1: Safety of laser products

Specifications – Scanning Laser Doppler Vibrometers Types 8330 D and 8330 E

VPI+ Sensor (SB 2507)

Velocity Ranges, Frequency Ranges and Velocity Output Sensitivity:

Nominal Measurement Range			Output Sensitivity	Output Bandwidth
	Minimum	Maximum		
	μms^{-1}	mms^{-1}	$Vm^{-1}s$	kHz
1	0.5	5	1000	200
2	4	20	250	200
3	20	100	50	200
4	100	500	10	2000
5	400	2000	2.5	2000

Laser: He-Ne continuous wave laser, <1 mW output power, 632.8 nm (red light)
Laser Safety: Class II
Noise Floor: 0.045 $\mu ms^{-1}/\sqrt{Hz}$ for *Range 1* (see table above), 0.2 $\mu ms^{-1}/\sqrt{Hz}$ for *Range 2*, 0.45 $\mu ms^{-1}/\sqrt{Hz}$ for *Range 3*, 3 $\mu ms^{-1}/\sqrt{Hz}$ for *Range 4* and 10 $\mu ms^{-1}/\sqrt{Hz}$ for *Range 5*
Lenses: Short-range (35 mm) and long-range (95 mm) lenses included
Working Distance: With short-range lens from <50 mm (2 inches) to 5 m (16 feet), recommended maximum distance. With long-range lens from 1 m to >200 m (1 to 220 yards). Dependent on surface finish
Laser Spot Size: The size of the laser spot is determined by the working distance and the choice of lenses. Typical values are:
- approx. 0.04 mm (0.0016 inch) at 50 mm (2 inch) working distance
- approx. 0.2 mm (0.008 inch) at 1 m (3.2 ft) working distance
- approx. 0.3 mm (0.012 inch) at 5 m (16 ft) working distance
- approx. 1.3 mm (0.05 inch) at 20 m (66 ft) working distance

Dropout Detection: Hardware detection of points with low S/N ratio or otherwise unreliable data. Software 'dithering' rescan function allows the quality of measured vibration to be maximised
Accuracy of the Analogue Velocity Output Signal: Better than 1%
Accuracy of the Doppler Output Signals: Better than 0.01%
Velocity Polarity: Positive analogue velocity signal when the test surface is moving towards the VPI+ Sensor head of Type 8330 SLDV and a negative signal if the test surface is moving away.
Interferometer Principle: Homodyne

Two Orthogonal Mirrors, 16-bit Digitally Controlled Actuators with:
- **Scan Angle:** 25° × 25° field of view
- **Scan Resolution:** 11 μRads, i.e., 0.0006307°, allowing 0.5 mm spatial resolution at 50 mm working distance and 2 mm spacial resolution at 200 m working distance
- **Scanning Speed:** 50 points per second, while not collecting data (dependent on analyzer settings)

CCD Camera: Full-colour, in line with the laser (no parallax errors)
Laser Shutter: prevents the laser light from disturbing the image
Resolution of Static Image: Depends on distance between VPI+ Sensor and target surface. Typical 800 × 800 pixels at 400 mm distance and 1500 × 1500 pixels at 3 m distance
Outputs: Analogue velocity output (±5 V, 50 W), Analogue Doppler signals 1 and 2 in quadrature (±6 V, 50 W), Dropout detection (TTL compatible) and CCD camera composite video
Interface: RS–232 C for sensor control (including shutter and mirrors), status monitoring and advanced diagnostic tools
Remote Control from PC: Mirrors, velocity range and laser shutter

Configured Laptop PC For Types 8330 D and 8330 E

Laptop PC: UL 0175 A-XX[1] where 'XX' is a country code (default = GB) for keyboard layout, language version of Windows®, etc.
Note: The specifications of the laptop PC change over time with developments in the PC market and PC accessories.
Please ask your local Brüel & Kjær representative to inform you about the latest PC configuration

Control and Analysis Software BZ 5310

Operating System: Microsoft® Windows NT®, Windows® 2000 and Windows® XP
Format of Exported Data Files: UFF, ASCII or DIAdem
The analyzer section of the software can calculate and display the following vibration parameters with cosine correction (user-selectable):
- Time and Weighted Time
- Fourier Spectra (FFT)
- Auto-power Spectra (APS) and Cross-spectra
- Coherence
- Frequency Response Functions 1, 2 and 3
- KB-weighted
- RMS
- Magnitude FFT (signal A + signal B, signal A - signal B)
- Complex FFT (signal A + signal B, signal A - signal B)
- Octave, 1/3-octave
- Cepstrum

[1] UL 0175 notebook PC comes with a carrying bag with enough room for the PC and its accessories, including ZE 0878 external FireWire® framegrabber unit, as well as its power supply and its own accessories

Results from ODS, Lock-in, RMS (time and frequency domain), and SIMO and MIMO Modal, (optional), can be shown in life-like animation modes, including:

- Hidden lines
- Coloured surfaces
- Colour map
- 3D wire frame
- Animated image of target surface
- Complete image with animated target area
- Image with grid overlay and/or colour map overlay
- User-selectable smoothing
- Absolute ODS deflections from ratio-based, phase-assigned spectra in displacement, velocity and acceleration, calculated at cursor position in the frequency domain
- Animations can be saved as AVI files for display in other applications
- Dithering of measuring points with low signal-to-noise
- Live display of camera picture for easy focussing of wallpaper
- Laser contour indication of measuring area on target surface

Advanced Modal Analysis Software Option BZ 5318

BZ 5318 is fully integrated with Control and Analysis Software BZ 5310

The Advanced Modal Analysis software option includes:

- Modal parameters – Natural frequency, damping and mode shape
- Single-degree-of-freedom (SDOF), Multi-degree-of-freedom (MDOF) and handfit curve-fitters
- Modal Assurance Criterion (MAC), fit quality, complex mode indicator, function validation tools
- Forced response simulation in time and frequency domain
- Structural modification
- Animation of wire frame, including hidden lines, or animated colour maps
- Animation of image

Multi-shaker Excitation and MIMO Analysis Software Option BZ 5319 (Requires BZ 5318)

BZ 5319 is fully integrated with Control and Analysis Software BZ 5310

The Multi-shaker excitation and MIMO software option includes:

- Simultaneous excitation with uncorrelated noise for a maximum of 3 shakers (2 generator outputs available on the 4-channel, 20 kHz/ch. DSP (FFT) card ZD 0860)
- Lock-in mode with on-line Nyquist diagram
- MIMO data acquisition and analysis

Advanced Modal Analysis/MIMO Software Bundle Option BZ 5452

BZ 5452 is a software bundle containing:

- Advanced Modal Analysis Software Option BZ 5318
- Multi-shaker Excitation and MIMO Analysis Software Option BZ 5319

Environmental

Operating Temperature: +5° C to +40° C (+40° F to +104° F)

Operating Altitude: up to 2200 m (7200 ft) – this is a laser specification

Operating Humidity: relative humidity up to 80% or more (non-condensing)

Power:

- VPI+ Sensor head SB 2507: 85 – 264 V AC, 47 – 63 Hz, 72 VA, self-sensing
- Configured Laptop PC: 100 – 240 V AC, 50 – 60 Hz, 90 VA, self-sensing
- ZE 0878 External FireWire® frame-grabber unit: 100 – 240 V AC, 50 – 60 kHz, 25 VA if used with ZG 0386 power supply and optional UA 2035 connector kit

Dimensions and Weight:

- VPI+ Sensor head SB 2507: 240 × 380 × 240 mm (9 × 15 × 9 inches), 15 kg (33 lbs.)
- Configured Laptop PC: 330 × 277 × 45 mm (13 × 11 × 2 inches), 3.6 kg (8 lbs.)
- Type 3560 C PULSE System, cables and accessories: 5 kg (11 lbs.)
- ZE 0878 External FireWire® frame-grabber unit: 58 × 32 × 95 mm (2.3 × 1.3 × 3.8 in.)

Note: For PULSE specifications, please consult relevant Brüel & Kjær literature

Ordering Information

Type 8330 systems include the following parts and accessories:

TYPE 8330 D[1]

SB 2507–001	VPI+ Sensor Head (Ometron) *including*
AO 0582	Connection Cable, Short (5 m)
Type ZE 0878	External FireWire® Framegrabber Unit
Type ZG 0386	Power Supply
Type UA 2037	Connector Kit for ZG 0386
Type 3560 C-S34	Scanning Laser Vibrometer Analyzer Front-end *including*
Type 3560 C	Portable PULSE Front-end *including*
Type 2827–003	Mainframe and Accessories
Type 7533	LAN Module
Type 3109	4/2-ch. Input/Output 25/25 kHz module
Type 7770-N4	PULSE FFT Software, 4-channel License
BZ 5310	Control and Analysis Software (Maul-Theet)

TYPE 8330 E[1+2]

SB 2507–001	VPI+ Sensor Head (Ometron) *including*
AO 0582	Connection Cable, short (5 m)
Type ZE 0878	External FireWire® Framegrabber Unit
Type ZG 0386	Power Supply
Type UA 2037	Connector Kit for ZG 0386
Type 3560 C-S35	Scanning Laser Vibrometer Analyzer Front-end *including*
Type 3560 C	Portable PULSE Front-end *including*
Type 2827-003	Mainframe and Accessories
Type 7536	LAN Module
Type 3110	2/1-ch. Input/Output 200/100 kHz module
Type 7770-N2	PULSE FFT Software, 2-channel License
BZ 5310	Control and Analysis software

Note: the PULSE 7707 Analysis Engine Type must be included in the PULSE software package to allow input frequency of 150 Hz or higher per channel (up to 200 kHz per channel)

TYPE 8330 E 4-CHANNEL UPGRADE

Type 3560 C-S2	Scanning Laser Vibrometer Analyzer Front-end *including*
Type 3560 C	Portable PULSE Front-end *including*
Type 2827-003	Mainframe and Accessories
Type 7536	LAN Module
Type 3110	2/1-ch. Input/Output 200/100 kHz module
Type 7770-N2	PULSE FFT Software, 2-channel License
UL 0190	4-port Ethernet Switch

Optional Accessories

AO 0583	Medium Cable Set (10 m)
AO 0584	Long Cable Set (20 m)
BZ 5318	Advanced Modal Analysis Software Option
BZ 5319	Multi-shaker Excitation and MIMO Analysis Software option
BZ 5452	Advanced Modal Analysis/MIMO Software Bundle
KE 1004	Transit Case for VPI+ Sensor Head
UA 1577	Tripod for SB 2507–001 Sensor Head including Cam Head
UA 1554	Mirror Kit, small
QA 0225	Tape Measure

NON-CONTACT REFERENCE SIGNAL UP TO 25 kHz

Type 8329	Single-point Laser Vibrometer
UA 0898	Tripod (optional)
AO 0087-5M	BNC/BNC Coaxial Cable (5 m)

NON-CONTACT REFERENCE SIGNAL UP TO 400 kHz

Type 8334	Single-point Laser Vibrometer
UA 0898	Tripod (optional)
AO 0087-5M	BNC/BNC Coaxial Cable (5 m)

ODS ACCESSORY KIT

Type 4507 B	Reference Accelerometer (TEDS)
AO 0122	Coaxial Cable, 10–32 UNF Connector (3m)
JP 0145	BNC/10–32 UNF Plug Adaptor
YJ 0216	Beeswax

MODAL EXCITATION SYSTEM (REQUIRES BZ 5318)

Type 3624 *or*	
Type 3625	Modal Shaker System (100 N or 200 N)
Type 2311	Force Transducer
AO 0122	Coaxial Cable, 10 – 32 UNF Connector (3 m)
JP 0145	BNC/10 – 32 UNF Plug Adaptor, Stinger Kit

3D MEASUREMENT ACCESSORIES

Type 4506 B	Triax Accelerometer (TEDS)
AO 0527	Triaxial Coaxial Cable, 10 – 32 UNF Connectors
3 × AO 0122	Coaxial Cable, 10 – 32 UNF Connector (3 m)
3 × JP 0145	BNC/10 – 32 UNF Plug Adaptor
JJ 0032	10 – 32 UNF Extension Connectors

QUICK CALIBRATION TOOLS

Type 4294	Calibrator
DV 0460	Calibration Clips
DV 0459	Calibration Clips

[1] The Type 8330 D and 8330 E configurations mentioned above are only complete if a UL 0175A–XX High-end Notebook PC has been added. UL 0175A–XXis delivered with the Microsoft® operating system, PULSE software, and BZ 5310 software installed. (XX is a country-specific code)

[2] At least a third input channel must be available if dropout detection is required with Type 8330 E. With Type 8330 D having a 4-channel Type 3109, this is no problem. The cable 'dropout' is connected to input channel 3 of the Type 3109 module. Type 8330 E has only 2 input channels on the Type 3110 module. Dropout (and MIMO) is only possible if a second Type 3560 C with Type 7536 and Type 3110 modules is integrated in the system.

Scanning Laser Doppler Vibrometer Type 8330 has been developed by Ometron (UK) and can be purchased exclusively through the worldwide Brüel & Kjær sales and marketing organisation.

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HEADQUARTERS: DK-2850 Nærum · Denmark · Telephone: +45 4580 0500
Fax: +45 4580 1405 · bksv.com · info@bksv.com

Australia (+61) 2 9889-8888 · Austria (+43) 1 865 74 00 · Brazil (+55) 11 5188-8166
Canada (+1) 514 695-8225 · China (+86) 10 680 29906 · Czech Republic (+420) 2 6702 1100
Finland (+358) 9-755 950 · France (+33) 1 69 90 71 00 · Germany (+49) 421 17 87 0
Hong Kong (+852) 2548 7486 · Hungary (+36) 1 215 83 05 · Ireland (+353) 1 807 4083
Italy (+39) 0257 68061 · Japan (+81) 3 3779 8671 · Republic of Korea (+82) 2 3473 0605
Netherlands (+31) 318 55 9290 · Norway (+47) 66 77 11 55 · Poland (+48) 22 816 75 56
Portugal (+351) 21 47 11 4 53 · Singapore (+65) 377 4512 · Slovak Republic (+421) 25 443 0701
Spain (+34) 91 659 0820 · Sweden (+46) 8 449 8600 · Switzerland (+41) 1 880 7035
Taiwan (+886) 22 713 9303 · United Kingdom (+44) 14 38 739 000 · USA (+1) 800 332 2040

Local representatives and service organisations worldwide

Brüel & Kjær

BP 2012 – 11 03/06 Rosendahls Bogtrykkeri