PRODUCT DATA

Ometron Scanning Laser Doppler Vibrometers — Types 8330, 8330A, 8330B and 8330C

The Ometron family of Scanning Laser Doppler Vibrometers (SLDVs), Type 8330, are 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 can often replace an array of accelerometers or microphones.

Maul-Theet Systeme

OMETRON

8330, A, B, C

Brüel & Kjær

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

Compact laptop based system with compact head makes system extremely portable

High optical sensitivity through homodyne optical/electronic principle means surface treatment is rarely required, even on dark/black surfaces like 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 (Types 8330, 8330 A and 8330 C)
– Systems with non-steady, time variant excitation: Operating Deflection Shapes (ODS) based on Ratio-based Phase-Assigned Spectrum
– 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 and ASCII file formats

Introduction

Type 8330 SLDVs are turnkey systems that include all the optical/electronic hardware (and accompanying software) necessary to obtain and represent most global, field vibration parameters. For those users with more demanding requirements, additional, optional software packages can provide result presentations related to multi-shaker excitation (MIMO) and/or advanced modal analysis.

Based upon a safe and visible Class II laser, the systems avoid the need for special safety facilities or protective equipment. The compact size and low weight of the systems offer a portability that makes them suitable for both laboratory and field work. Type 8330 SLDVs are based on the VPI+ Sensor (Vibration Pattern Imager), which includes high resolution digital mirror control, a full-colour CCD camera, self sensing

power supply, and a high velocity range. The VPI+ Sensor is the latest version of Ometron's scanning laser Doppler vibrometers. The original VPI Sensor was the world's first SLDV and the VPI+ Sensor represents 15 years of continuous development of the VPI family. The four systems (8330, 8330 A, 8330 B, and 8330 C) vary with regards to supplied PC (desktop or laptop), number of input and output channels, frequency range of analysis, and available options for expansion.

The main differences between the four systems are described in the following sections and an overview of the different types of analysis available is provided in Table 1.

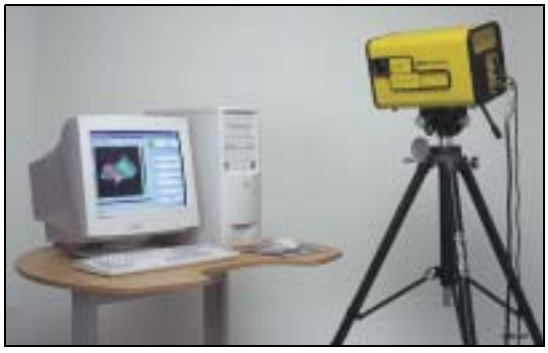
System Descriptions

The following descriptions detail the main differences between the four types of SLDVs.

Type 8330

Type 8330 is based on a desktop computer and it is the most moderately priced system. It has four input channels up to 20 kHz bandwidth and two signal generators. (If two inputs of up to 80 kHz are required, the 80 kHz input option [ZD 0859] is also available).

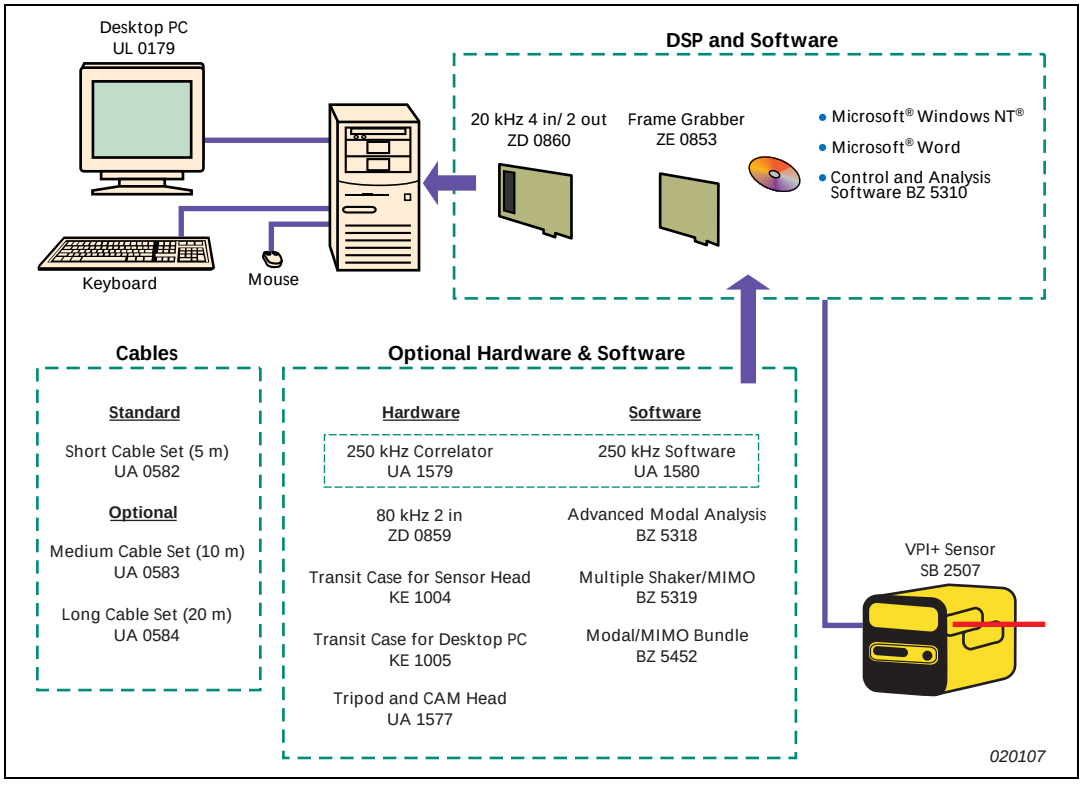
Fig. 1
Type 8330 – desktop based system



It is the optimal system for fixed installations where a larger monitor and expandability are more important than portability.

Type 8330 is the only system that supports the very high frequency 250 kHz Lock-in technique. The 250 kHz option is comprised of External Correlator UA 1579 and Integrated Software for External Correlator UA 1580.

Fig. 2
Type 8330 – system configuration



Type 8330 A

Fig. 3
Type 8330 A/B – laptop based system

Type 8330 A has the same features as the 8330 (four 20 kHz inputs and two signal generators) but the 8330 A has a laptop/ docking station in place of the desktop. The laptop/docking station combined with the very compact VPI+ Sensor makes for a portable solution that can be easily transported between multiple locations or can be used for field applications.

The portability of the system, and the extreme long range capabilities of the VPI+ Sensor, make Type 8330 A an excellent choice for measurements on large civil engineering structures like buildings, dams, and bridges.

The special structural testing options (Advanced Modal Analysis software BZ 5318 and Multi-shaker and MIMO analysis software BZ 5319) make Type 8330 A the ideal system for Modal Analysis of large and complicated structures.

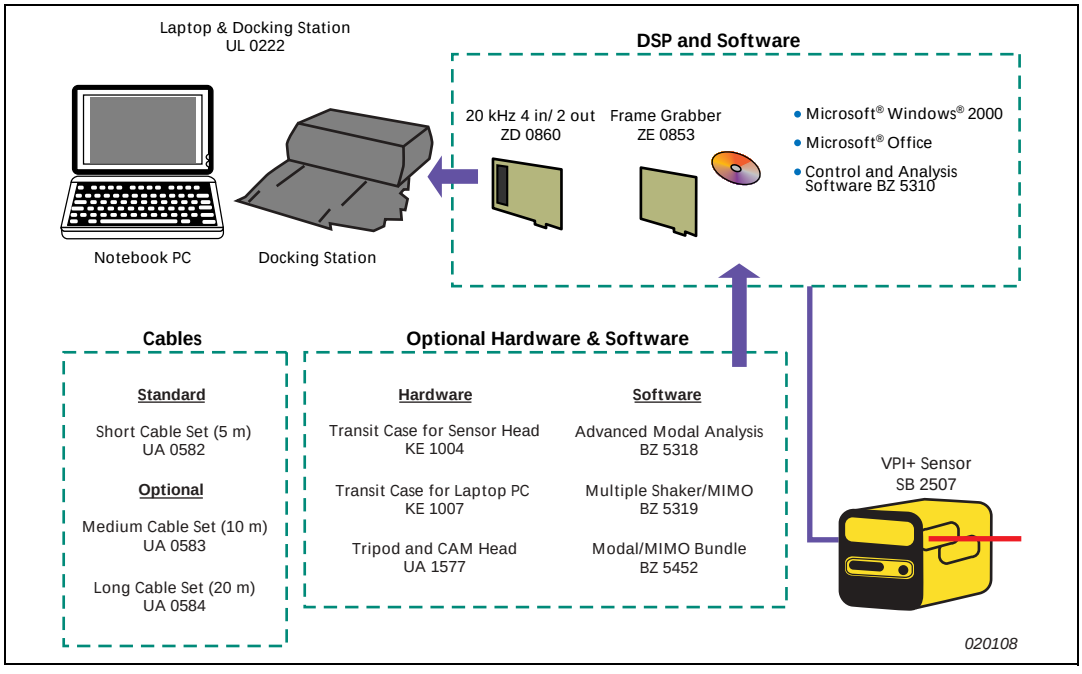


Fig. 4
Type 8330 A – system configuration

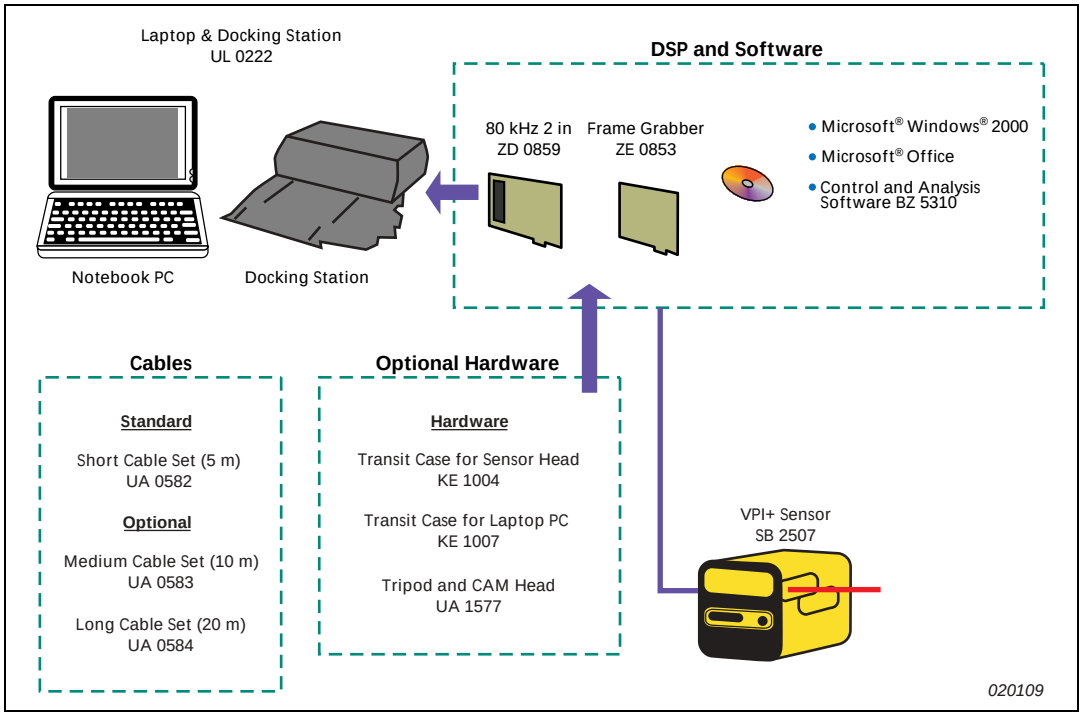
Type 8330 B

Some applications require extended frequency ranges. Hard disk drives, harmonic distortion analysis of speakers, and measurements on scale models sometimes require measurements beyond 20 kHz.

Type 8330 B is based on a laptop/docking station and has two inputs up to 80 kHz. The 8330 B does not include a signal generator, so it is normally used for ODS and RMS analysis. Lock-in and Modal Analysis is possible with the 8330 B if a third-party signal generator is used.

The high frequency range and small size of Type 8330 B make it a good choice for space limited hard disk and speaker testing laboratories.

Fig. 5
Type 8330 B – system configuration



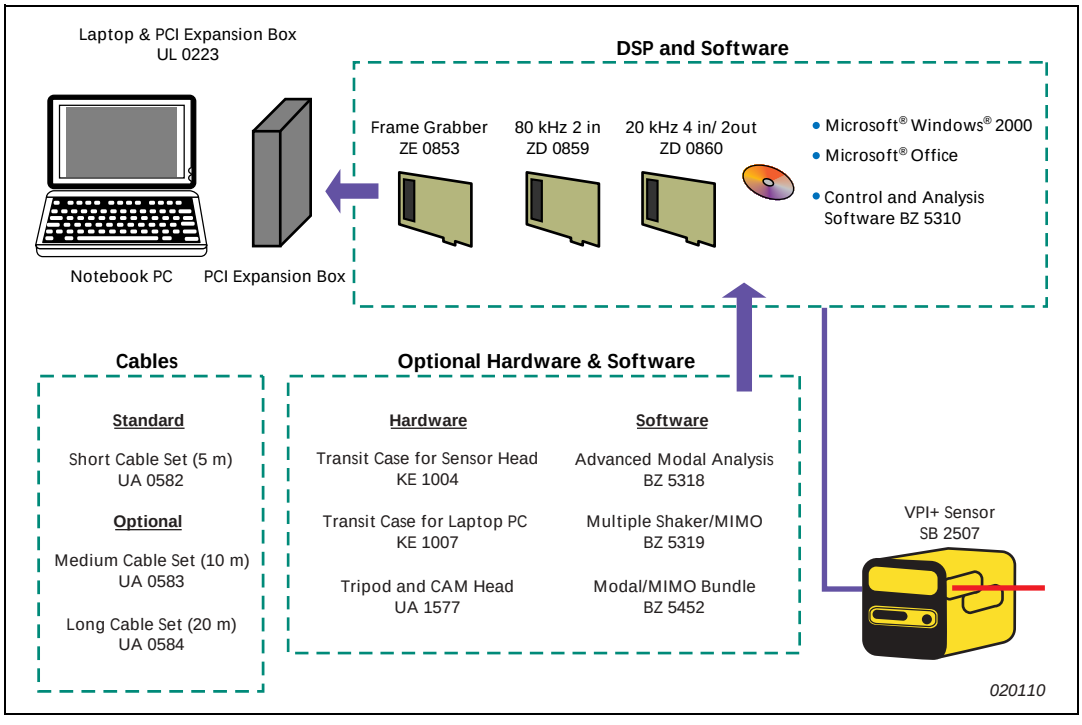
Type 8330 C

Fig. 6
Type 8330 C – laptop based system

Type 8330 C uses an expansion box with a laptop, combining the 20 kHz 4 inputs/ 2 outputs and 80 kHz 2 inputs, in one portable package.

Having both high-frequency input channels and signal generators makes Type 8330 C the best choice for universities and for multiple application R & D laboratories.

Fig. 7
Type 8330 C – system configuration



Types of Analysis

Introduction

Types 8330, 8330 A, 8330 B, and 8330 C can analyse vibration in several ways. The type of analysis 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 the 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). The scanning laser measures the motion of each scanned point individually. 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
Motion of a location on the structure measured by a fixed accelerometer or by a 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 analyzed 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 auto-spectrum 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 auto-spectrum of reference for a single measurement. This gives amplitude units in displacement, velocity or acceleration but with the same statistical accuracy as the single auto-spectrum 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 auto-spectrum. 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 auto-spectrum 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.

The Advanced Modal Analysis Software Option BZ 5318 allows the modal analysis to be highly integrated with the Type 8330 system. ODS and mode shape animations can then performed in the standard control and analysis software package, BZ 5310.

Multiple-Input Multiple-Output (MIMO) Modal Analysis

There are several types of structure where a single input force is not sufficient:

Large structures like 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 [i.e. clipping]. (See Ref. [6] for more information on handling non-linearities).

Amplitude and frequency non-linearaties 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-linearties. However, a chirp signal is not suitable for structures with frequency non-linearites 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 then 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-linearties 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.

Table1 *Overview of the types of analysis available across all four systems*

Types of Analysis	Type 8330	Type 8330 A	Type 8330 B	Type 8330 C	Remarks
20 kHz ODS	✔	✔	✔	✔	Requires reference signal (internal coherent signal, accelerometer or single-point laser)
80 kHz ODS	Option		✔	✔	Requires reference signal (internal coherent signal, accelerometer or single-point laser)
20 kHz Lock-in	✔	✔		✔	8330 C can measure harmonics to 80 kHz
250 kHz Lock-in	✔				Requires UA 1579 and UA 1580
20 kHz RMS	✔	✔	✔	✔	
80 kHz RMS	Option		✔	✔	
SIMO Modal Data Aquisition	✔	✔		✔	
Advanced Modal Analysis	✔	✔		✔	Requires BZ 5318
MIMO Analysis	✔	✔		✔	Requires BZ 5318 and BZ 5319

Standard Software and Upgrades

Control and Analysis Software

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

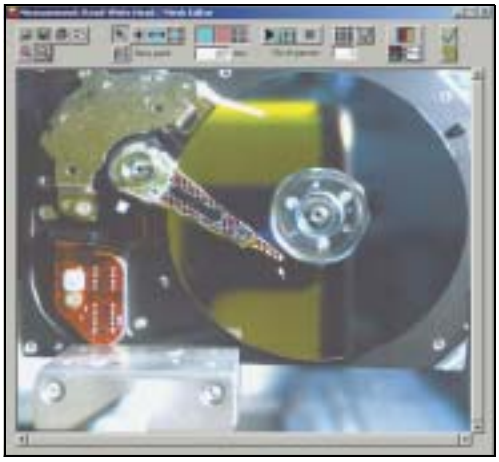


Fig. 8
Hard disk geometry

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

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. Digital 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 like hard drive components. As a standard feature, geometries can be exported in UFF formats 15 and 82.

Fig. 9
Loudspeaker geometry

Control data acquisition settings – lock-in analysis provides the fastest measurements but are 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 analysis 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 maximize the 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.

Drop-out Detection – Low amounts of back-scattered light can cause the Doppler signal to drop in amplitude leading to poor signal/noise ratio data. The electronics in the VPI+ Sensor (SB 2507) detect when a dropout event occurs and the control software BZ 5310 marks data at points where the quality of the measurement can be improved for subsequent rescan. Users can now 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 (eigenvectors), natural frequencies and damping (eigenvalues). 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 is also available for export in UFF and ASCII formats. For further information, see Specifications.

Multi-shaker Excitation and MIMO Software Option

Multi-shaker Excitation and MIMO Analysis Software package BZ 5319 is used for Multiple-Input Multiple-Output modal analysis. BZ 5319 requires BZ 5318 Advanced Modal Analysis and an 8330 system with two signal generators (8330, 8330 A, and 8330 C). The option enables the two signal generators to output two uncorrelated random signals and calculates the MIMO FRF function. For further information, see Specifications.

Advanced Modal Analysis/MIMO Software Bundle Option

For those 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 then purchasing BZ 5318 and BZ 5319 separately.

Vibration Analyzer Accessories and Options

The Type 8330 system is typically delivered as a configured and tested system.

The specifications of the Configured Desktop and Laptop PCs follow the general trend in the development of the worldwide PC market and are therefore subject to change. See the specification section or contact your local Brüel and Kjær representative for the most up to date computer specifications.

4-channel, 20 kHz (per channel) DSP (FFT) Card

This is the vibration analyzer, PCI-based DSP card (ZD 0860) that comes as standard with Type 8330 and Type 8330 A SLDVs.

The card has 4 channels of analogue input. One channel will always be connected to the analogue velocity output of the VPI+ Sensor. The remaining three channels can be connected to the reference accelerometer, single point laser or force transducer of up

to three shakers. The two on-board, Digital-to-Analogue Converters (DACs) can be used to independently control two shakers with stepped sine, random, triangle, rectangular (pulse) or chirp signals. This feature is especially useful if used with the Multi-shaker Excitation and MIMO Analysis Software BZ 5319.

2-channel, 80 kHz (per channel) DSP (FFT) Card

For high-frequency vibrations exceeding 20 kHz, a 2-channel, 80 kHz card ZD 0859 can be used.

This card is similar in specification to the 4-channel, 20 kHz card, the key differences being the number of channels and the fact it does not have an integral signal generator (DAC). Either the ZD 0860 (included in 8330 C) or a third-party signal generator is needed for Lock-in or Modal Analysis.

In the 8330 C system, the two 20 kHz signal generators of the ZD 0860 can be used with the two 80 kHz inputs of the ZD 0859.

For the 8330 desktop system, the ZD 0859 can optionally be replaced by, or added to, the ZD 0860 at the time of order. An 8330 system with both the ZD 0859 and ZD 0860 will have the same analysis capabilities as an 8330 C system. An 8330 system with a ZD 0859 will have the same analysis capabilities as an 8330 B system.

250 kHz Correlator

For applications which encounter extremely high vibration frequencies of up to 250 kHz from a target surface, Brüel & Kjær offers a solution with an external correlator for the external lock-in input of Type 8330's VPI+ Sensor Head – EG & G 250 kHz Correlator UA 1579 (including accessories). This option adds one unit to the scanning laser vibrometer system and is available at an additional cost. The correlator is connected to the PC via an RS–232 serial port. This interface and a software driver, (UA 1580), are ordered separately and are only available for the desktop based system, Type 8330.

The VPI+ Sensor

Introduction

The VPI+ Sensor (SB 2507) is a non-contacting 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

The VPI+ Sensor consists of a 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 optimized 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 tires and speakers or die cast produced components.

Measurement Principles

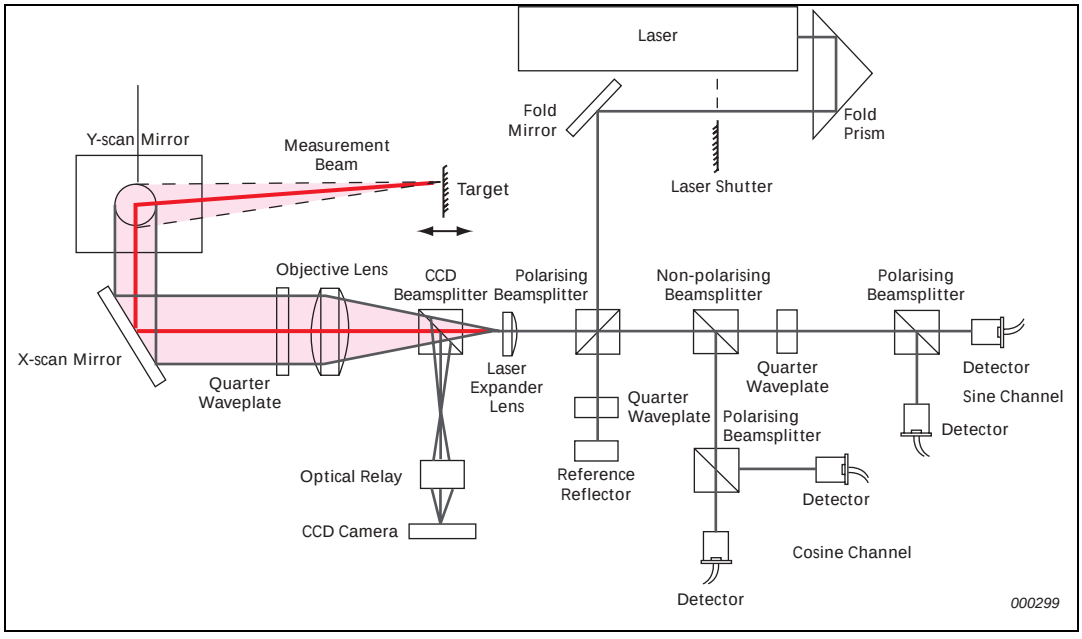
The optical sensor of Type 8330 SLDV is based on a Michelson interferometer in which a laser beam is divided into a reference and a measurement beam, refer to Fig. 10. The

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 $\lambda/2 = 3.16 \times 10^{-7}$ m, i.e., 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. 10
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

The VPI+ Sensor 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 section that follows).

Fig. 11
Lens kit for Type 8330

Lenses

The VPI+ Sensor 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 affect on the calibration of the system.

Focusing

Fig. 12
Rear and side-panel view of VPI+ Sensor Head SB 2507

On the side-panel of the sensor head, there 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 that is 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 SLDV configuration consists of only two main units – a VPI+ Sensor (SB 2507) and a Configured PC, including the vibration signal analyzer and the control and analysis software. The only cables required are standard low-cost coaxial cables, mains cables, a video cable and a serial RS–232C 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

The VPI+ Sensor is provided with a number of output connectors:

Analogue Velocity Signal – A test surface moving towards, or away from, the VPI+ 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 – The sockets D1 and D2 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.

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 the VPI+ Sensor Head 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 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 Framegrabber in the PC 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.

Fig. 13
VPI+ Sensor Head SB 2507 showing side-panel with connectors

Serial Input Connector

The VPI+ Sensor 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 VPI+ Sensor and the controlling PC.

The internal shutter and scanning mirrors are also operated via serial link.

Accessories

For users who would like to have full control over a scanning vibrometer sensor head by adding their own vibration analyzer front-end, as well as their own control and analysis software, it is possible to purchase VPI+ Sensor (SB 2507) separately. However, Brüel & Kjær cannot guarantee that the specifications quoted in this Product Data Sheet will be valid for any combination of sensor head and controller/analyzer not included in the Brüel & Kjær product range.

Fig. 14
Type 8329 – used for 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 like Types 8329, 8333, 8334 and 8335. Applications include ODS measurements on very light, hot and/or small structures.

Mounting and Transport Options

Fig. 15
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

Optional transit cases are available for the 8330 systems. Transit case KE 1004 is for the VPI+ Sensor Type SB 2507. Transit Case KE 1005 is for the Type 8330 Desktop based system and Transit Case KE 1007 is for Types 8330 A, 8330 B and 8330 C Laptop based systems.

These are manufactured from vacuum-formed ABS plastic and come with hinges, two recessed handles and two recessed catches/locks. These cases protect the delicate optical sensor head and PC during road and air-freight transport.

The foam interior of one transit case has cavities for the sensor head and all its accessories, as well as all accompanying cables. The cavities in the computer cases are designed to take the configured PC (desktop; laptop and docking station; or laptop and PCI expansion box), keyboard, mouse and their accompanying cables, (but not a monitor).

SLDV for Users with a Vibration Analyzer Running with I-DEAS Software

MasterScan for Vibration Analyzers running under I-DEAS™ from MTS

For those who already have a multichannel vibration analyzer running with I-DEAS software, Brüel & Kjær offers a solution where an existing analyzer can form an integral part of a scanning laser vibrometer system. This makes it unnecessary to purchase the configured PC/analyzer and the standard laser vibration analysis software. It should be kept in mind that the specifications of such a scanning vibrometer system depend greatly on the specifications of the existing vibration analyzer. To configure a complete

scanning laser vibrometer, you need VPI+ Sensor Head SB 2507 and one of the following MasterScan I-DEAS software drivers for control of the sensor head:

BZ 5313 MasterScan 8330-7 (for I-DEAS version 7)
BZ 5312 MasterScan 8330-8 (for I-DEAS version 8)
BZ 5311 MasterScan 8330-9 (for I-DEAS version 9)

Upgrade Kits for Previous Models of Ometron Scanning Vibrometers

It may be possible for those with an earlier version of the Ometron scanning laser vibrometer (models VPI or VPI-4000) to upgrade their systems to a standard close to that of Type 8330 systems. Please contact your nearest Brüel & Kjær representative and provide them with the type and serial numbers of the units that form your current Ometron scanning laser vibrometer, plus information on whether your current system has the optional CCD camera fitted. We will then return with an offer of a turnkey upgrade of your scanning laser vibrometer, which consists of an upgrade kit for the current sensor head and a Configured PC (Desktop or Laptop).

Calibration

The factory adjusts the analogue velocity output of the sensor head to a sensitivity of $\pm 5\,V_{peak}$ 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.

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, e.g., 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, e.g., churches
Measurement of middle-ear ossicular vibration patterns for direct-drive, implantable hearing systems
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, October 2002.
[6] TEMME, STEVE: *"Audio Distortion Measurements"*, Application Note No. BO 0385-12, 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 Vibrometer Types 8330, A, B, C

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 feet) working distance
- approx. 1.3 mm (0.05 inch) at 20 m (66 feet) working distance

Drop-out 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 μm 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 Ω), Analogue Doppler signals 1 and 2 in quadrature (±6 V, 50 Ω), Drop-out 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 Desktop PC (For Type 8330)

Tower PC with monitor, keyboard and mouse: Pentium® ≥ III, ≥ 733 MHz CPU, ≥ 256 MB RAM, ≥ 20 GB HDD, 1.44 MB FDD, CD-ROM and CD-RW drive
FrameGrabber card, OpenGL graphics card, Ethernet LAN card
Note: The specifications of the Desktop 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

Configured Laptop PC (For Types 8330 A, 8330 B and 8330 C)

Laptop PC: Pentium® ≥ III, ≥ 1.2 GHz CPU, ≥ 512 MB RAM, ≥ 40 GB HDD, Modular 1.44 MB FDD, 56 K modem, 10/100 Ethernet and Modular CD-RW drive
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

Docking Station (For Types 8330 A and 8330 B)

- Two 3.3v and 5v PCI expansion slots
- Standard I/O ports – serial, parallel, video, PS/2 style mouse, PS/2 style keyboard, two USB and audio ports
- 10/100 Base-TX Ethernet connection

PCI Expansion Box (For Type 8330 C)

- Three PCI expansion slots
- CardBus adaptor card and 1 m cable

4-channel/20 kHz DSP Card (For Types 8330, 8330 A and 8330 C)

- Bits ADC per channel: 20
- Max. input voltage: ±10 V
- Input signal bandwidth: 23 kHz
- Inputs: Direct, CCLD (individual for all channels)
- Coupling: AC, DC (individual for all channels)
- Anti-aliasing filter: > 200 dB/Oct slope, ripple < ±0.01 dB
- Dynamic range: >100 dB
- Phase accuracy: better than 0.1°
- Sensor power supply: 4 mA @ 18 – 32 V DC, selectable for each input (IEPE compliant)
- Maximum resolution of FFT: 6400 lines
- Minimum resolution of FFT: 100 lines
- Selectable triggering, overlap processing, and averaging

Signal generators for shaker excitation (for 4-channel card only):
- Two totally independent signal generators enabling uncorrelated, random signal outputs
- Each output has signal conditioning and direct connection
- Each output with one 16-bit DAC, synchronised with ADC clock
- Max. sinusoidal frequency per channel: 20 kHz
- Max. output voltage: ±10 V
- Type of output signal: Sine, Stepped sine, Random, Triangle, Rectangle (pulse), Chirp and Sawtooth

For more specifications, contact your nearest Brüel & Kjær representative

2-channel/80 kHz DSP Card (For Types 8330 B and 8330 C)

- Bits ADC per channel: 16
- Max. input voltage: ±10 V
- Input signal bandwidth: 80 kHz
- Inputs: Direct, CCLD (individual for all channels)
- Coupling: AC, DC (individual for all channels)
- Anti-aliasing filter: > 200 dB/Oct slope, ripple < ±0.01 dB
- Dynamic range: >85 dB
- Phase accuracy: better than 0.1°
- Sensor power supply: 4 mA @ 18 –32 V DC, selectable for each input (IEPE compliant)
- Maximum resolution of FFT: 6400 lines
- Minimum resolution of FFT: 100 lines
- Selectable triggering and averaging

For more specifications, contact your nearest Brüel & Kjær representative

Control and Analysis Software BZ 5310

Operating system: Windows NT® and Windows® 2000
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

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

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 three 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: from +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 Desktop PC: 100 – 120/220 – 240 V AC, 50/60 Hz, 1 kVA, selectable
- Configured Laptop PC: 100 – 240 V AC, 50 – 60 Hz, 90 VA, self-sensing
- Docking Station: 100 – 240 V AC, 50 – 60 Hz, 180 VA (can power laptop), self-sensing
- PCI Expansion Box: 100 – 240 V AC, 47 – 63 Hz, 100 VA, self-sensing

Dimensions and weight:

- VPI+ Sensor head SB 2507: 240 × 380 × 240 mm (9 × 15 × 9 inches), 15 kg (33 lbs.)
- Configured Desktop PC: 209 × 483 × 452 mm (8 × 19 × 18 inches), 18 kg (40 lbs.)
- Configured Laptop PC: 330 × 277 × 45 mm (13 × 11 × 2 inches), 3.6 kg (8 lbs.)
- Docking Station: 420 × 460 × 110 mm (16.5 × 18.5 × 4.3 inches), 4.1 kg (9 lbs.)
- PCI Expansion Box: 254 × 386 × 70 mm (10 × 15.2 × 2.6 inches), 2.4 kg (5.3 lbs.)
- Cables and accessories: 5 kg (11 lbs.)

Ordering Information

Type 8330 systems include the following parts and accessories:

Type 8330:

SB 2507	VPI+ Sensor Head (Ometron)
AO 0582	Short Cable Set (5 m)
UL 0179	Configured Desktop PC (Including Microsoft® Windows NT® and Microsoft® Word, already installed)
ZD 0860	4-channel, 20 kHz/ch. DSP Card, including two shaker generators with 20 kHz frequency bandwidth (option to replace with ZD 0859, 2 channel, 80 kHz/ch. DSP Card)
ZE 0853	Framegrabber Card
ZE 0852	OpenGL Graphics Card
BZ 5310	Control and Analysis software

Type 8330 A:

SB 2507	VPI+ Sensor Head (Ometron)
AO 0582	Short Cable Set (5 m)
UL 0222	Configured Laptop PC, with Docking Station (Including Microsoft® Windows 2000® and Microsoft® Office, already installed)
ZD 0860	4-channel, 20 kHz/ch. DSP Card, including two shaker generators with 20 kHz frequency bandwidth
ZE 0853	Framegrabber Card
BZ 5310	Control and Analysis software

Type 8330 B:

SB 2507	VPI+ Sensor Head (Ometron)
AO 0582	Short Cable Set (5 m)
UL 0222	Configured Laptop PC, with Docking Station (Including Microsoft® Windows 2000® and Microsoft® Office, already installed)
ZD 0859	2-channel, 80 kHz/ch. DSP Card
ZE 0853	Framegrabber Card
BZ 5310	Control and Analysis Software

Type 8330 C:

SB 2507	VPI+ Sensor Head (Ometron)
AO 0582	Short Cable Set (5 m)
UL 0223	Configured Laptop PC, with PCI Expansion Box (Including Microsoft® Windows 2000® and Microsoft® Office, already installed)
ZD 0859	2-channel, 80 kHz/ch. DSP Card
ZD 0860	4-channel, 20 kHz/ch. DSP Card, including two shaker generators with 20 kHz frequency bandwidth
ZE 0853	Framegrabber Card
BZ 5310	Control and Analysis Software

Optional Accessories

ZD 0859	2-channel, 80 kHz/ch. DSP Card (option for Type 8330)
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
BZ 5317	Office software
BZ 5313	MasterScan 8330-7 driver for I-DEAS version 7
BZ 5312	MasterScan 8330-8 driver for I-DEAS version 8
BZ 5311	MasterScan 8330-9 driver for I-DEAS version 9
UA 1577	Tripod, including CAM Head
UA 1579	250 kHz EG & G Correlator
UA 1580	Driver Software for 250 kHz EG & G Correlator
KE 1004	Transit Case for VPI+ Sensor Head
KE 1005	Transit Case for Type 8330 SLDV Desktop PC
KE 1007	Transit Case for Types 8330 A, B and C SLDV Laptop PCs

Upgrade kits of previous versions of Ometron VPI scanning vibrometers are often available. The availability of an upgrade and the specific kit number depends on the serial number of the existing VPI+ Sensor and whether a CCD camera is already mounted.

Brüel & Kjær reserves the right to change specifications and accessories without notice

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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