VDD – Digital Laser Vibrometer

Introduction

Digital Laser Doppler vibrometers (LDVs) offer answers when analog LDVs are pushed to their limit in very difficult and stringent applications as some measurements in data storage, micro-electro-mechanical structures (MEMS) or hearing dynamic applications.

Polytec customers can chose from analog, digital and combined LDV systems. The PC based digital LDVs VDD-650 & VDD-660 are utilizing a combination of highest performance dual channel data acquisition, a comprehensive software package VibSoft for processing of the data and an analog front-end for filtering/amplifying of the signal prior to digitisation.
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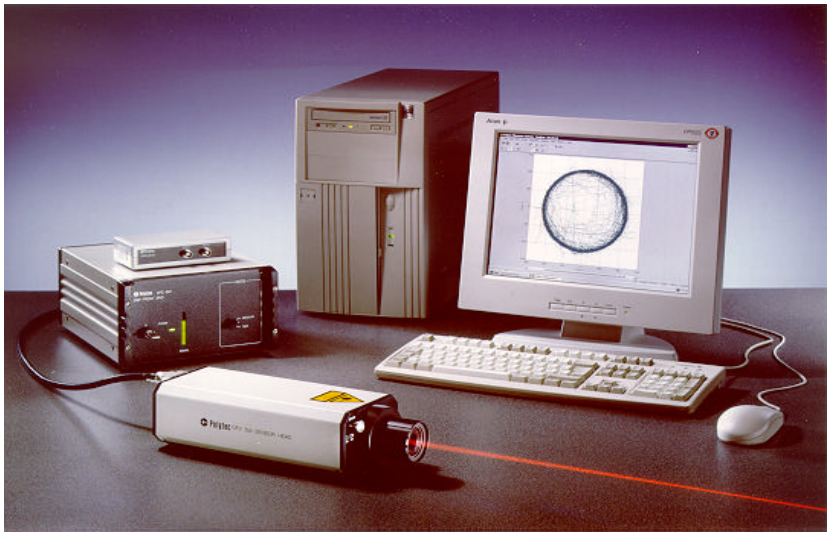
Advantages of digital demodulation

- Higher linearity, accuracy, resolution (sub nanometer) and dynamic range with lower noise floor than analog outputs.
- 2MHz bandwidth for the LDV and the reference channel
- Allows measurements of nanometer-scale transient vibrations (down to 2 picometer resolution)
- The existing line of analog LDV systems model OFV-3001 can be up-graded to digital demodulation to access both analog & digital signals (model VDD-660)
- Stand alone digital controller DFE-650 front- end for application where only digital demodulation is required (model VDD-650)
- Comprehensive dual channel data acquisition software VibSoft for acquiring, processing and export of the data
- Data are acquired in displacement and can be converted to velocity and acceleration data in time and frequency (FFT) domain
- No analog electronics which could alter the VDD systems accuracy. Insensitivity to drift and ageing effects.

The System



Model VDD-650

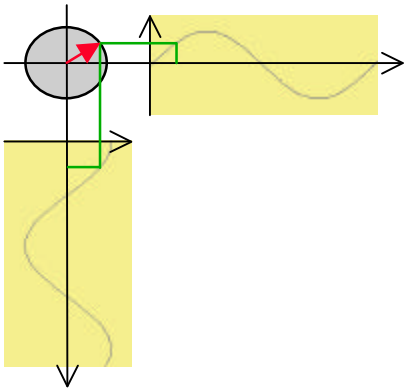
The VDD-650 system as shown above comprises a controller DFE-650 for signal shaping and providing power to the LDV sensor. Output of the DFE-650 controller connects via model VDD-Z-011 junction box to a Data Management System (DMS). The DMS incorporates a 4 channel acquisition board with high sampling bandwidth (5 MHz) and an on board signal generator for excitation of the test object. VibSoft is running on the DMS for acquisition and processing of the data.

Model VDD-660

The VDD-660 is intended for up-grades of existing OFV-3001 LDV controllers. Instead of the DFE-650 controller a set of boards (OVD-060) is installed inside of the OFV-3001 LDV controller. The combination of VDD-660 and OFV-3001 controller is particular attractive because analog velocity output signals plus digital displacement demodulation are available at the same time.

Both VDD-650 and VDD-660 can be combined with Polytec's standard optical heads (OFV-303, OFV-353) and fiber optical sensor heads (OFV-511, OFV-512).

Principle of operation



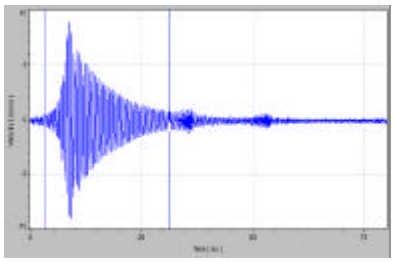
The output signal from the LDV sensor contains information about the velocity (frequency of the signal) and displacement (phase of the signal). By decoding either the frequency or the phase of the signal the velocity or displacement of the test object are achieved. In the VDD system a *quadrature demodulator* generates the sin and cosine components of the sensor signal. These sin and cosine signals are digitized by a high sampling rate ADC board inside of the data management system.

These 2 signals can be represented as a rotating vector whose phase is directly related to the displacement of the test object and the laser wavelength. By numerically decoding this phase the displacement information is achieved with highest accuracy and resolution. Velocity and acceleration data become available by differentiation of the displacement signal through VibSoft.

$$F(Dx) = \frac{4\,P}{l} Dx$$

VibSoft is a powerful software package for real time acquisition of the LDV signal (sine and cosine) and of a reference channel which is needed for calculation of Frequency Response Functions (FRF) etc.

VibSoft Features



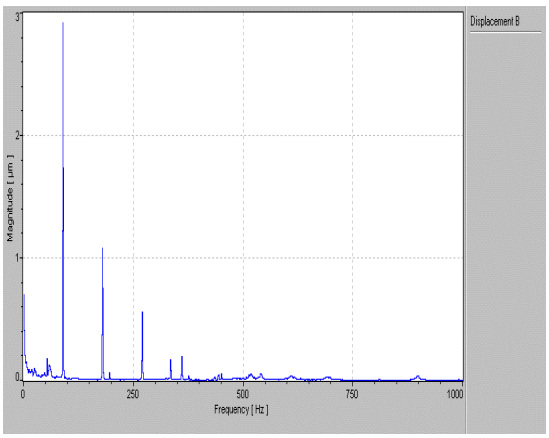
- Real-time acquisition, numerical processing, display and export of LDV data
- Calculation of FRFs, Coherence and other signal properties
- Digital high, low and band pass filters. User can load his own ASCII format filters
- Differentiation and integration in time and frequency domain
- Time domain averaging of the input signal
- FFT transformation with 12800 lines resolution
- Integrated signal generator software supporting many different waveforms
- Automatically test routines and interfacing to other software are programmed via Visual Basic scripting (VBS).
- Data export in ASCII format, via Universal file UFF or direct data access to binary data using PolyFileAccess software

When using VibSoft and VDD-660 together with an OFV-3001 controller VibSoft gives full access to all settings of the controller via RS-232 interface.

Applications

New capabilities for ever increasing measurement needs:
Most people assume that “digital” is always better, not necessarily true. Analog LDV controllers offer more than enough performance and have real-time analog outputs. For most common LDV applications, analog LDVs are extremely well suited and deliver excellent data. However continuing technological breakthroughs require progressive demanding measurements requirements. The digital LDV line VDD is an answer for these new and difficult applications.

Run-out testing



Repetitive & non-repetitive run-out of precision spindles has always been a very challenging application because the hub surface finish modulates the overall spindle displacements and at the same time there are small variations in the spindle angular velocity. NRRO requires an LDV sensor with extremely low overall noise between DC and 20kHz. The user acquires all the data with the VDD and can do the NRRO analysis using his own proprietary software programs.

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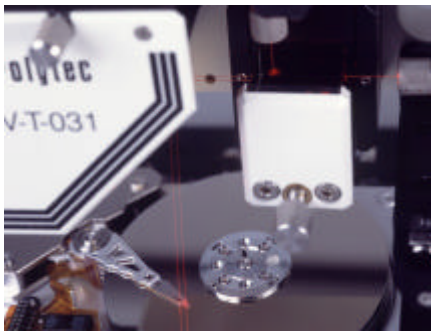
Resonance Testing

Customers performing frequency response tests on actuators and HGAs have always had to purchase an LDV plus a 2-channel FFT analyzer. Now, both the LDV and analyzer are available from and supported by Polytec in one cost-effective package.

Slider Displacement measurements



Measurement of slider displacement while track-following:
Researchers are interested in the precise, time-domain displacement history of a slider (in the off-track direction). Analog LDV systems generally have too much broad-band noise for this application. Digital LDVs offer one or two orders of magnitude better S/N for these measurements. Thus, it is possible to make a direct comparison between exact slider dynamic position and the position error signal (PES) with the additional input channel. Contributions to the PES from a number of different sources can thus be identified, for example; torsional HGA resonances, air bearing resonances E-block symmetric and asymmetric resonances, airflow induced excitation, different rigid rocking modes from the slider, etc.

Head Media Interface studies

The high resolution feature of the digital LDV permits highly accurate measurements for head/media interface dynamics during different experimental conditions. For example it is of great importance to know what happens to the slider at different flying heights when using media with certain specifications. If we fly the head at flying heights of 4nm and 7nm; the dynamics of the slider in track-follow state will be quite different. The graphs displayed on the left show those measurements in the off-track direction with remarkable differences.
Even though we would like to fly the slider around 4nm for better magnetic pick-up, the resonances at such flying height are so dominant in comparison with the ones with the 7nm flying height that this is best from the dynamics point of view for that particular product. Engineers thus can characterize a given HGA and slider configuration with a particular media product. If this is not satisfactory, engineers could measure other product combinations and evaluate them with the digital LDV. This documentation will support choosing a given HGA, slider and media combination for a given file product which in the end would minimize misregistration errors.

Similar results can be obtained for vertical and tangential slider motion, which will be related to phase data transfer errors. Digital LDV resolution is necessary to detect sway and torsion slider modes with sufficient resolution that arise during head-media contact events, furthermore it also has been shown that the amplitudes of the sway and torsion slider modes are a function of the slider skew angle. Those results hold for measurements at the center, leading and trailing edge of the slider.

Calibrations

Accelerometers, Shakers and Other Sensors Calibration. The digital LDV does a direct, highly precise mathematical phase demodulation thus generating an absolutely-calibrated mechanical vibration signal. The VDD-650 is the 1st commercially available LDV system receiving PTB (German National Bureau of Standards) certification for use as a primary calibration system according to ISO standards. The VDD-650 in conjunction with model OFV-303 sensor head was certified by the PTB to show deviations ≤ 0.1 % from the PTB reference for frequencies up to 20 kHz. For higher frequencies certification there was no reference available at the PTB.

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VDD Specifications

OFV-303 sensor head

OFV-512 sensor head

The digital vibrometer can be installed in your current OFV-3001 controller (OVD-60 decoder) as the VDD-660 or as a stand-alone system, the VDD-650. Depending on the scope of your measurements you could chose the dual fiber optics OFV-512 (shown on the left), single fiber optics OFV-511 or the standard non fiber heads OFV-303 and OFV-353. The non-fiber optics as shown on the left offers less intrinsic susceptibility to environmental noise, which can be introduced when the fibers are exposed to significant mechanical vibration or acoustic excitation.

Maximum velocity for the digital VDD is 0.840 m/s, while analog Polytec LDV products offer a range of options: 1.25 m/s, 10m/s, 20m/s and even 30m/s, upper limits depending on the chosen controller configuration

The maximum frequency bandwidth for the digital LDV is 2MHz, analog systems offer you up to 30MHz. Displacement resolution can reach down to 2pm on very specular surfaces, results however will depend on surface finish. Very accurate averaging can increase the resolution in rotating parts even with diffuse reflecting surfaces. The data management and acquisition system provides two channels, one for the Vibrometer (displacement, velocity or acceleration) and one reference channel, both of which can be displayed in time and FFT mode with an extensive number of functions including FRF, H1, H1, auto power spectra, cross power spectra, coherence, phase, real, imaginary, etc.

VDD-650 Specifications	
Digital Front End DFE-650	
Dimensions	235 mm x 335 mm x 135 mm 9.3 x 13.3 x 5.3 inches
Weight	7 kg
Operating temperature	+5…+40°C (41 … 104°F)
Junction Box VDD-Z-011	
Signal Input Reference In	1 MOhm; up to ± 32 volts
Input Coupling	AC/DC adjustable by software
Trigger Input	TTL compatibility
Signal output	Internal generator output

VDD-660 Specifications	
Digital Front End OVD-060	
Board set for OFV-3001 controller	
Output	EXT.DEC connector on rear of OFV-3001 controller
Junction Box VDD-Z-011	
Signal Input Reference In	1 MOhm; up to ± 32 volts
Input Coupling	AC/DC adjustable by software
Trigger Input	TTL compatibility
Signal output	Internal generator output

Metrological Properties VDD-650 and VDD-660	
Max. velocity	405mm/s or 810mm/s depending on sample frequency and sample time
Frequency range	0Hz…2MHz
Maximum no. FFT lines	12800
Maximum no. of samples	Time mode: 524,288 FFT mode: 32,768
Maximum displacement error	± 1 % of RMS reading for 1nm to 100 nm ± 0.2 % of RMS reading for displacements > 100nm
Total harmonic distortions	<0.1% up to 50 kHz sinusoidal
Amplitude frequency response	Displacement: typ. ± 0.1 % Velocity: typ. ± 0.2 % Acceleration: typ. ± 0.2 %
Spurious signals	<10 pm for 0Hz < f ≤ 20 kHz <150 pm for 20kHz < f ≤ 2 MHz
*Resolution**	Displacement 2 pm Velocity 0.25µm/s @ 20 kHz 2.5µm/s @ 200 kHz 25µm/s @ 2000 kHz

**Resolution is defined as the signal amplitude at which the signal-to-noise ratio is 0dB in a 10Hz spectral bandwidth (RBW) measured on 3M Scotchlite Tape.*

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VDD-650/-660 Data Management System	
*Data Management System**	1.8 GHz AMD CPU, 256MB RAM, min. 60 GB HDD, Win2000 operating system
Acquisition and signal generator board (generator max. 512 kHz)	National Instruments VDD-NI-6110 plus VDD-CA clock adapter
External signal generator for full 2 MHz bandwidth	HP33120A or HP33250A connected via USB adapter

VDD-650/-660 Standard Software	
VibSoft	Data acquisition and processing, time & frequency domain displays, time & frequency domain averaging, digital filter program, time domain integration & differentiation. 2 input channels for vibrometer & reference. OFV-3001 settings control (VDD-660 only) via RS-232 interface.
VDD-Z-073	Gate input software TTL
VDD-Z-081	12800 FFT lines support
VDD-Z-082	Visual Basic engine for creating Visual Basic Scripts for automation of measurements and data presentation.

VDD-650/-660 Optional Software	
VDD-Z-061	Data conversion to Universal File Format
VDD-Z-079	Internal arbitrary signal generator, maximum output frequency 512 kHz
VDD-Z-065	Software for control of external HP33120A or HP33250A arbitrary signal generator via optional adapter. VDD-Z-065 software is included in item VDD-Z-079
Poly File Access	Software DLL to access data via Microsoft's standard Component Object Model (COM)
VIB-SM-12 *VIB-SM-24*	After delivery 12 (respectively 24) months of software up-grade's

**) The Data Management System can be provided by the customer but must utilize an AMD type processor with minimum of 1.3 GHz clock rate. To ensure trouble free performance it is recommended to purchase the Data Management System from Polytec with all boards and software ready-to-go installed.*

All specifications are subject to change without prior notice.

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