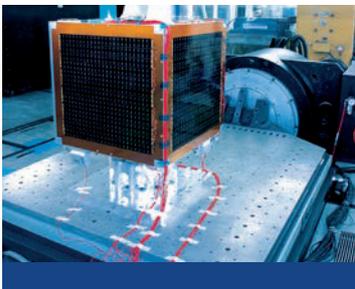


# Experts in Vibration

**Vibration Testing**  
**Noise and Vibration Analysis**  
**Data Acquisition and Monitoring**  
**Test Stand Engineering**





**Experts in Vibration. Since 1980.**

**Cover photos:**  
 left: Airbus Defence and Space, United Kingdom  
 third from left: Siemens AG, Germany

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# Our Profile



m+p international is well-known as a worldwide provider of top-level test and measurement solutions. All the products in this Product Guide are the result of 40 years' expertise and experience in vibration testing, noise and vibration analysis, multi-channel data acquisition, process monitoring and test stand engineering.

By working closely with our customers, we understand their applications from an engineer's point of view and this is apparent in our products. A policy of continuous research and development, which has led to many pioneering solutions, ensures that our products demonstrate superior performance and quality.

Our mission is to offer solutions which perfectly support you in the increasingly challenging test, measurement and

analysis tasks you encounter in the field, lab, or production plant. Performance, reliability, longevity, time to market, cost of ownership – these, among others, are important criteria for evaluating the results of your design or production process. We are proud that so many organizations in the automotive, aerospace, electronics and other high-tech industries use our products and trust in m+p international to obtain top quality results.

The Product Guide gives you an excellent overview of our current product range. Features, performance and applications are carefully described. New products will be added on a regular basis. If you have any questions or requirements, or simply need advice, please contact us, we'll be happy to help – remember “m+p international listens to customers ...”.



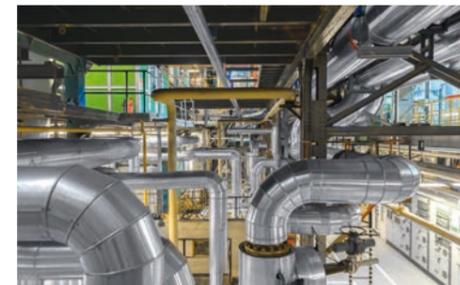
## Vibration Testing m+p VibControl

Sophisticated vibration testing procedures are needed to accurately simulate the toughest operating environments. Product designers and test engineers throughout the world count on m+p international's solutions for reliable vibration control on shakers, data reduction and acoustic control, from entry-level to high-channel count systems.



## Noise and Vibration Analysis m+p Analyzer

m+p international provides a family of highly accurate dynamic signal analyzers that can be operational in a matter of minutes to acquire, analyze and report the most complex noise and vibration data requirements in the field and the laboratory.



## Data Acquisition and Monitoring m+p Coda

A specialized engineering team will select, integrate and support the appropriate data acquisition or process monitoring solution to meet the needs of your application. Our fully featured software platform supports a range of USB, Ethernet, and LXIbus-based instruments to cover a wide variety of measurement tasks.



## Test Stand Engineering

m+p international has been supplying custom-made solutions for functional test stands across a wide range of industries. Many renowned companies appreciate our broad engineering experience, the reliability and performance of our products, and the close co-operation with our engineers.



## Measurement Hardware m+p Vibxx

We engineered our measurement hardware for the requirements of vibration testing, noise and vibration analysis and dynamic data acquisition: m+p VibPilot is a compact 4/8-channel front-end, the high-channel count m+p VibRunner can be used as desktop instrument or mounted into a 19" rack and the multi-channel m+p VibMobile offers versatile signal conditioning and computing power in a rugged, portable mainframe.

# Applications



## Automotive

To stay competitive, today's car manufacturers need to produce new or improved models much faster than before. The trend towards mass customization forces engineers to design and develop a large number of vehicle variants while at the same time meeting demands for improved quality, durability, occupant safety, ride comfort and fuel efficiency. m+p international has built strong, longstanding relationships with the automotive industry and its suppliers. We support engineering teams in the following areas:

- Vibration control on shakers
- Road load simulation
- Dynamic measurements and vibration analysis
- Modal analysis and impact testing
- Rotating machinery diagnostics
- Acoustic analysis and sound quality
- Hand-arm and whole body vibrations
- Strain measurements
- Experimental stress analysis
- High-frequency dynamic stiffness test stand for elastomer mounts
- Customized solutions and test stands



Photo courtesy of NASA, USA

## Aerospace

The high-tech aerospace industry is faced with the challenge of ever-shortening design and development times for products that must be safe, enduring, and economical and meet stringent environmental demands. Testing is an essential part of the development stage: spacecraft, aircraft wing or satellite tests must be completed successfully and the data stored securely for future use. m+p international has worked closely for many years with aerospace engineering companies throughout the world to assure the highest quality for their products. Our advanced solutions include:

- Dynamic testing and vibration analysis
- Vibration control on shakers, force limited vibration testing
- Structural and modal testing
- Rotating machinery diagnostics
- Strain measurements
- Experimental stress analysis
- Acoustic analysis
- Ground vibration testing
- Acoustic control in a reverberant chamber
- Direct field acoustic control for satellite testing
- Customized solutions and test stands



## Defence

Defence research and design teams develop systems and components which must be extremely reliable, safe, highly accurate and easy to operate. For armoured vehicles, for example, the performance and quality are crucial, but ride comfort is also an important factor. In some cases the materials to be tested are highly dangerous. m+p international provides high-quality, state-of-the-art vibration control, noise and vibration measurement and analysis systems for military equipment, where the instrumentation and vehicles often operate under extreme conditions. Tests are performed on individual components and, in the final development stage, on the whole system. We help companies to get this right first time. For special requirements, customized solutions can be provided.

## Electronics

The electronics sector continues to grow rapidly and influences our daily lives to a degree unthinkable just a decade ago. It is vital for manufacturers of devices such as smartphones, laptops, tablets, cameras, navigation systems, etc. to develop state-of-the-art, trendy products more and more rapidly. As electronics products become increasingly more powerful and complex, the functionality must be thoroughly tested before product launch. m+p international matches today's needs for reliable testing in a very limited timeframe by supplying high-performance and user-friendly test and analysis equipment for:

- Vibration control on a shaker
- Shock and drop testing
- Dynamic testing
- Acoustic analysis and sound quality



## Energy & Process

m+p international has developed sophisticated, high-precision dynamic measurement products for the energy sector including renewable energy, nuclear and turbomachinery. For wind turbine testing, m+p international provides highly accurate, integrated test, analysis, data storage and reporting capabilities for every stage from design and development to manufacturing and operating. m+p's products help to optimize efficiency and energy output and to minimize expensive downtime and repairs during operation. For monitoring product quality or real-time process monitoring, we supply full-featured, easy-to-operate data acquisition products that deliver precise, repeatable results. Our measurement technology ensures reliable results in the following areas:

- Continuous data acquisition and signal analysis
- Noise and vibration analysis
- Structural testing and modal analysis
- Performance and functional testing
- Multi-axis strain and stress analysis
- Real-time process monitoring
- Vibration testing on a shaker
- Customized solutions and test stands



## Test Houses

Independent test laboratories have to offer a wide range of test functionality in order to satisfy the requirements of many end-user industries, each with their own standards and test specifications. Their customers also demand the highest levels of test safety and reliability to protect their valuable products under test. To provide an efficient service it is also important that once tests are complete, reports can be quickly generated to provide proof of testing and any other data required. m+p international is able to offer all these capabilities and has become the industry standard for the world's best known test houses. Our activities include:

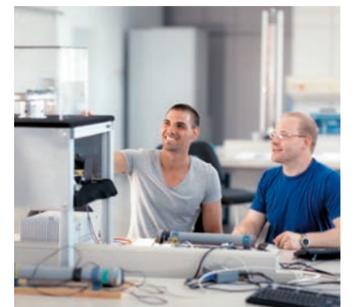
- Environmental simulation using vibration and shock testing
- Multichannel FFT data acquisition
- Structural testing and modal analysis
- Rotating machinery diagnostics
- Noise analysis



Photo courtesy of Stirling Dynamics, United Kingdom

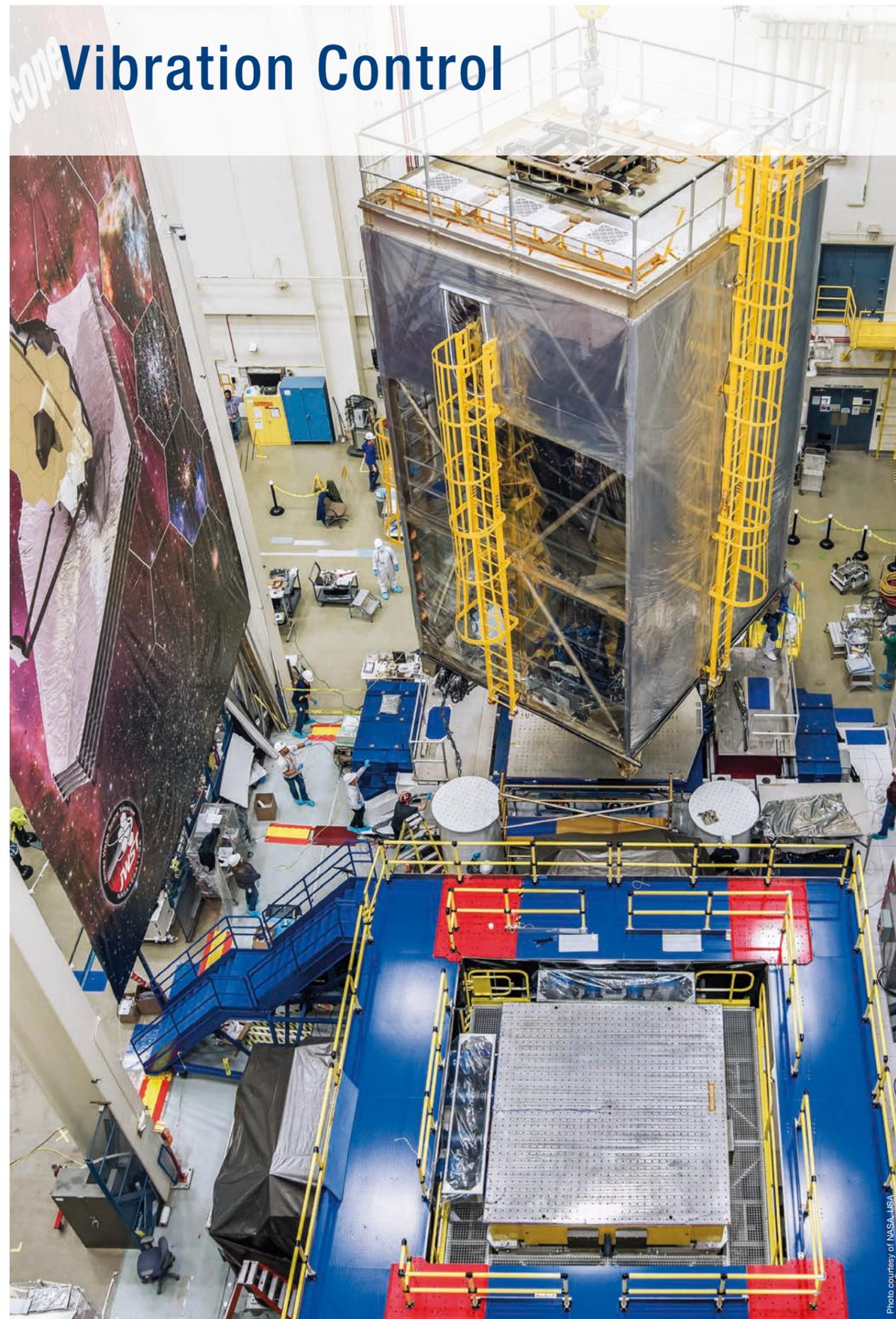
## Universities and Research

Universities worldwide benefit from m+p international's innovative test and measurement technology. Our high-quality products for structural dynamics testing, vibration testing and data acquisition are used by leading university engineering and research departments. We have successfully collaborated on many academic projects. Customers appreciate the ease of use, the flexibility of the systems and the integration of existing resources.



# Vibration Testing m+p VibControl





# Vibration Control

## YOUR BENEFITS

- Full range of excitation modes available
- Compliant with all relevant industrial standards (MIL-STD 810, DIN EN 60068, et al.)
- All current Microsoft Windows (32-/64-bit) operating systems supported
- Scalable software and hardware from 4 to 256 channels with the same user interface and functionality
- Vibration monitoring for maximum protection of specimen and equipment
- Time domain displays and data storage for all excitation modes
- Notching/Force Limiting for sine and random minimizes overtesting
- Multi-monitor support for high channel counts
- Automated and customizable report generation
- Test schedules and external hardware control with digital I/O
- Selectable user interface languages

The m+p VibControl products for advanced vibration and shock testing from four to hundreds of input channels are used by many of the leading environmental test laboratories throughout the world. End users appreciate the simple operation, extensive analysis and reporting functions, and powerful upgrade possibilities, as well as the excellent stability and high quality of the systems.

In cooperation with renowned partners, m+p international provides complete vibration test systems including shaker and accessories as well as combined climatic and vibration test stands.



Vibration testing of a PC

## Future-Proof Software and Hardware

Thanks to the modular design of software and hardware, m+p VibControl can be configured and expanded at any time to tackle other measurement tasks and higher channel counts. Software add-ons are possible for all test modes, including special post-processing functions, automatic test sequencing, etc.

m+p international regularly adds enhancements to its m+p VibControl software. These software revisions ensure that you always benefit from the latest technology, helping to increase testing efficiency.

Our state-of-the-art, high-precision measurement hardware ensures long-term support and system longevity. What if you want to replace the measurement front-end you have used for many years with the latest hardware technology? No problem, we will equip your existing m+p vibration controller with the newest generation of m+p hardware without making changes to the familiar user interface.



m+p measurement hardware from 4 to hundreds of input channels

### Common User Interface

All m+p VibControl systems are controlled by the same proven Microsoft Windows-based software. A single interface with the same look and feel means that test specifications can be transferred from engineering to production without change or error and test data can be compared directly between one system and another. Common reporting formats improve communication and data can easily be shared over a network and accessed from anywhere.

This makes intra- and inter-company data sharing simple and straightforward and improves productivity. Since the user interface is common across the whole platform, features typically integrated in high-end systems (e.g. notching in sine and random test mode) are also available for low-channel count system configurations.



Single interface from four to high-channel count vibration control systems simplifies communication and data sharing

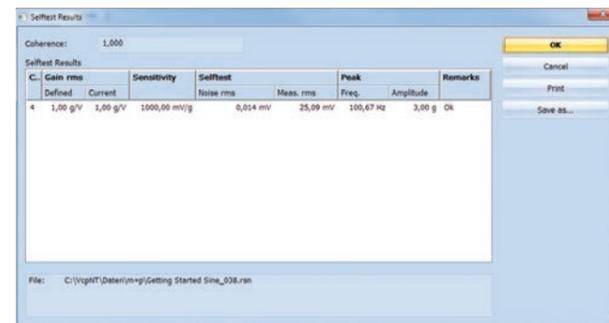
The m+p VibControl solutions for data reduction with time history recording to throughput disc and acoustic testing in a reverberant chamber are based on the same user interface and hardware platform as the shaker control systems. Therefore they can be configured for different applications simply by adding software modules, significantly reducing purchase costs and operator training.

Our user interface is multi-language.

### Test Item Protection and Safety

Protecting your valuable unit under test is our top priority. Our software and hardware utilize many safety features to ensure reliable closed-loop vibration control – from pre-test checks to abort checking, notching and controlled shutdown.

The self-check function is an extremely powerful tool for detecting possible set-up problems before your test is started. During closed-loop control the m+p VibControl software performs RMS and line-by-line abort checks, sigma clipping and drive limitation and continuously checks for open channels and overloads. Notching limits the upper vibration level on any number of control or measurement channels, thus minimizing overtesting of the structure. m+p international's hardware ensures rapid, safe shutdown under any circumstances.



The self-check results indicate that the test was properly configured

### True Multi-Tasking

Since the real-time measurement and control processes are independent of the user interface, you can utilize all the capabilities of the host computer, e.g., generate and print out a test report or set up a new test while the front-end performs the measurement and vibration control tasks.

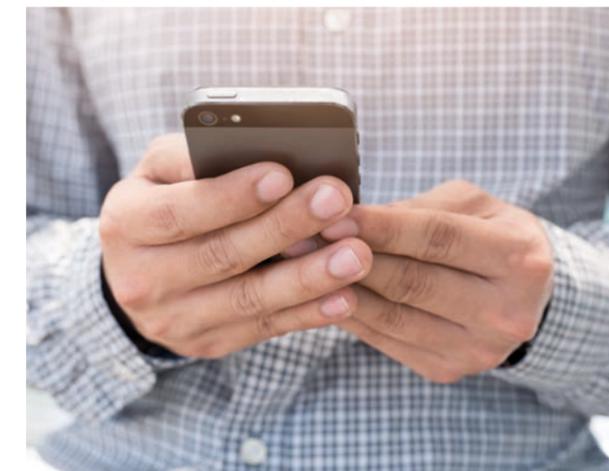
This multi-tasking concept not only guarantees powerful and time-efficient vibration testing even with time-critical tests but is also an important safety feature, as any unwanted computer command or failure cannot affect the vibration controller.

### Automated Functional and Climatic Testing

With the m+p VibUtil module, our vibration controllers offer a versatile tool for automated vibration testing and combined climatic and functional testing. m+p VibUtil easily combines individual vibration tests of identical or different test modes in any complexity of nested loops.

Test status reports can be sent via email or SMS text message to your mobile phone. A protocol file documenting the most important test events is attached.

m+p VibUtil can be easily extended to control eight digital input channels and eight digital output channels which provide links to external equipment such as environmental chambers for combined testing. You can automatically control the power amplifier, i.e., shut it down at the test end and switch it on when a new vibration test is to be started.



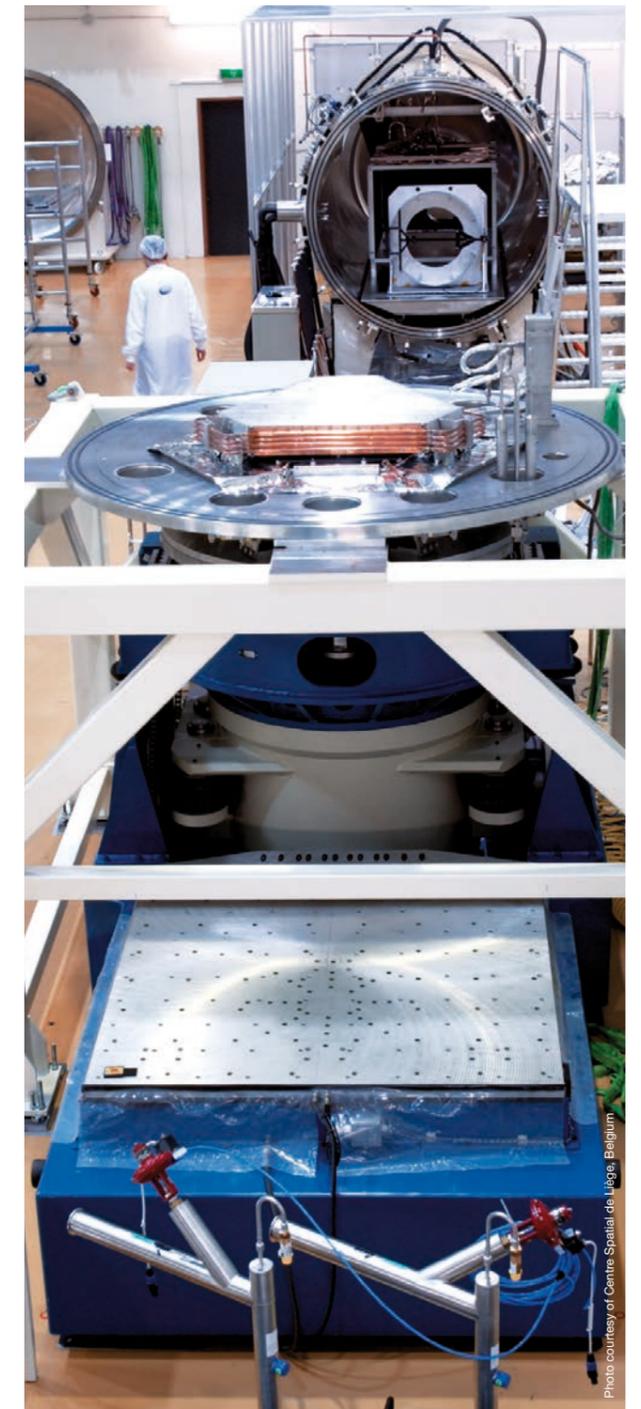
Always in control: test status report via SMS text message

### Remote Client

The m+p VibControl systems also provide an optional remote client licence which is invaluable to many operators. Often a controller is crowded by engineers trying to view a vibration test during the test run. However, with the remote client, live data can be viewed during an actual test via network or wireless network on a tablet or desktop PC in an entirely different area. The licence allows full m+p VibControl functionality except running the test.

### Transducer Calibration

m+p SensCal program provides a quick and simple process for calibrating accelerometers (piezo-electric with charge output or IEPE, piezo-resistive, capacitive) in your laboratory, as well as velocity or displacement transducers. We offer the m+p SensCal program as an add-on to a wider m+p vibration test system for checking its transducers without any additional acquisition hardware; or it can be utilized as a standalone calibration system. The results (amplitude and phase) are automatically recorded and output to a detailed calibration certificate for later reference.



Reliable, high-speed multi-channel vibration controller for spacecraft testing

### Transducer calibration in your laboratory



*We selected m+p international following the good experience of other Continental Automotive Labs and also because the technical specification of the controller completely matched our needs. I'd also like to commend the very good support we received from them.*

Christian Tibke, Group Leader Qualification Laboratory at Continental Automotive, Timisoara, Romania

**Multi-Screen Support**

The highly flexible online display capabilities are expandable, thus making monitoring of high-channel count systems quicker and easier. Operators can open up to 16 online graphics windows on a single monitor to display 64 channels and see all the necessary information at a glance. The remote monitoring function enables customers to observe the channel information on remote PCs without any measurement hardware connected. If you need to observe more than 64 channels, simply use the multi-screen option. A system can be configured with the multi-screen module and a dual or quad graphics card for support of up to four monitors and 256 channels; if required, even more monitors are supported. Channel layouts for each monitor can be set up and stored for quick access.



Displaying 32 online graphics windows on two screens

**Vibration Monitoring and Overtest Protection**

Vibration tests must be safe and reliable and this is especially true for high value specimens in critical testing applications. Here, our monitoring system offers maximum safety: It captures and records data such as acceleration, temperature and strain continuously during the vibration test. Each channel can be configured separately for total flexibility. m+p international's monitoring system protects the specimen and shaker reliably, e.g. against misconfiguration. If required, the shaker will be switched off immediately. Alarm events are entered into a log file and can be reviewed at any time. Continuous monitoring before, during and after a test with m+p VibControl online or offline is also provided.

**Excitation Modes**

m+p VibControl supports all control modes used in today's vibration testing – everything from simple ESS random to mixed mode gunfire, drop table capture and unlimited time data replication. All tests are fully compliant with ISO, DIN, MIL-STD 810 and many other standards. In sine and random modes, you can designate all input channels as control, watchdog and/or measurement channels. DC signals can be measured and monitored for functional testing in all test modes.

**Random incl. Notching/Force Limiting**  
Resolution up to 25,600 lines, selectable in 8 steps. Frequency range up to 12.8 kHz or 40 kHz, hardware dependent. Control strategies: average, maximum or minimum. Frequencies or frequency bands can be defined where limiters take control if the response vibrations exceed a predetermined limit. Kurtosis control increases the peak level content to enable a wider range of real-world situations to be simulated.

**Sine incl. Notching/Force Limiting**  
Frequency range up to 20 kHz or 40 kHz, hardware dependent. Measurement filters: RMS, peak, averaged or digital tracking filter. Control on acceleration, velocity, displacement and force.

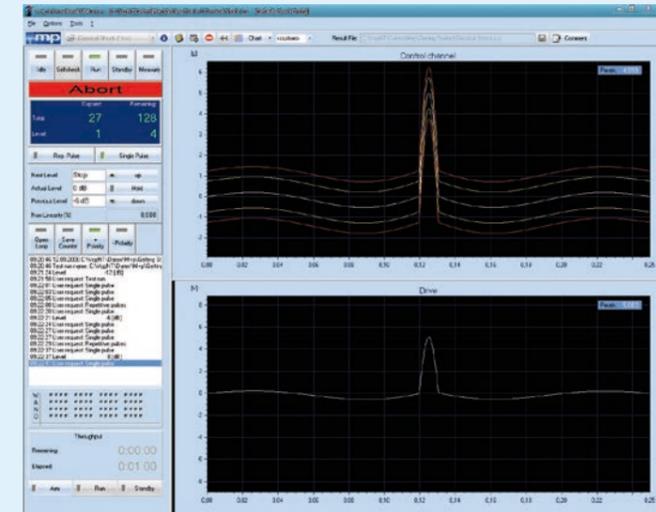
**Sine Resonance Search & Dwell**  
Control criteria: fixed frequency, fixed phase, defined phase, auto phase, peak amplitude.

**Sine Displacement and Velocity Control**  
For sine testing starting at very low frequencies, displacement transducers can be used. At a defined frequency, the control changes automatically from a displacement transducer to an accelerometer.

**Classical Shock**  
Reference waveforms: half-sine, haversine, sawtooth, triangle, rectangle, trapezoid. Alarm limits as per MIL-STD 810, DIN, GAM-EG 13 and user-defined. Peak-to-peak displacement to guarantee the best shaker performance.

**Shock Response Spectrum (SRS)**  
Frequency range up to 20 kHz. Calculation of maximax, positive and negative SRS. Automatic SRS optimization. Wavelets and damped sine components. 1/1-1/24 octave analysis.

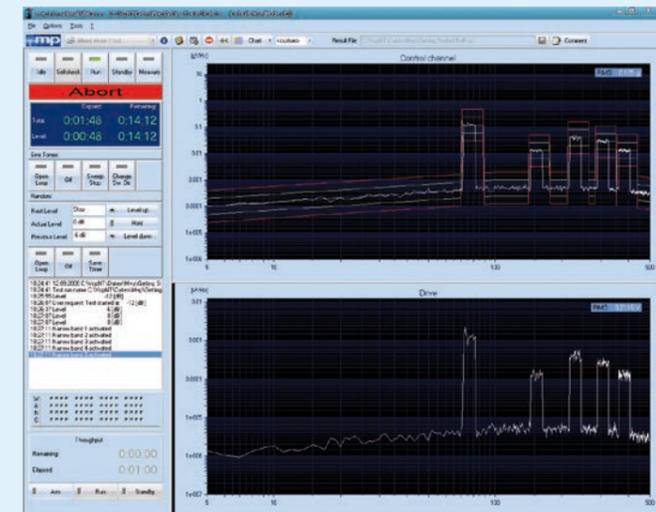
**External Pulse**  
Import of ASCII data for replication with pulse editor. Synthesis of any pulse form. Kinematic compensation for minimum shaker displacement.



Classical shock test run



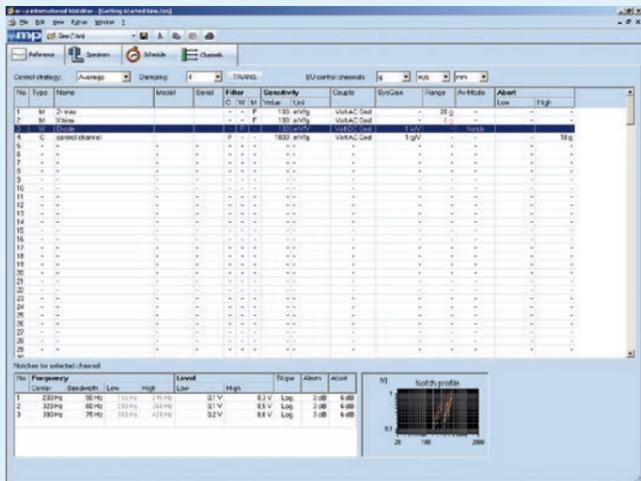
Setting up a shock response spectrum (SRS) test



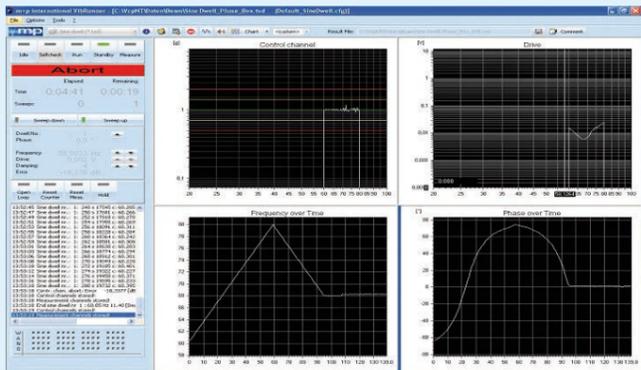
Mixed mode testing: the ultimate in vibration control



Setting up a random test



Notching on defined channels to protect against over-testing



Sine dwell test run with frequency/phase over time charts



Road load simulation provides an easy way to transfer data from the true environment to the test lab for reproduction on the shaker table

**Sine-on-Random (SoR)**

Up to 10 independently sweeping sine tones are overlaid onto a random background. Sine tones and broadband random signal are generated separately. Gunfire burst simulation.

**Random-on-Random (RoR)**

Up to 25 independently sweeping narrowband random signals are overlaid onto a random background. Each narrowband has its own profile and limits.

**Sine-on-Random-on-Random (SoRoR)**

Sine-on-random is combined with random-on-random.

**Multi-Sine Excitation**

Simultaneously sweeping up to 10 sine tones at different levels across the desired frequency range using different levels and profiles. Also known as “no random option for mixed mode”.

**Time Domain Replication (e.g. Road Load Simulation)**

Complete solution for the transfer of data from the true environment to the vibration test lab. Unlimited time data replication. Continuous closed-loop control.

**Time History Recording to Throughput Disc**

For the most critical tests time sample data can be recorded in parallel to control with no reduction in control performance. Complete time domain history is available, recorded with high sample rate. This facility is also available in recorder modes without closed-loop control. Post-analysis of the time history data is possible using the Sine and Random Data Reduction modules with the benefit of using the same familiar user interface. Data can be exported for analysis to m+p Analyzer package or other advanced analysis systems.

**Data Reduction Modes**

**Random Data Reduction**

Online analysis of measured data or taped random data (PSD averaging). Measured data can be recorded on throughput disc.

**Sine Data Reduction**

Track and online analysis of measured data or taped swept sine data using a COLA signal. Time data can be recorded on throughput disc.

**Transient Capture**

Capture of transient signals such as drop table or pyroshock pulses with calculation and overlay of SRS or classical shock limits. For applications with high “g” hammer/tap impact. Scope function. Various triggers. Measured data can be recorded on throughput disc.

**Analysis**

m+p VibControl’s post-testing includes extensive data handling, advanced cursor functions, single and multiple data graphing, peak search, mathematical functions, and transfer function analysis, as well as displaying and printing traces from different sources in a single window.

**Transfer Function and Transmissibility**

Linking the behaviour of control and measurement channels in the test run.

**Mathematical Functions**

Converting the measured acceleration signal into velocity and displacement, or vice versa (sine and random test mode).

**Automatic Peak Search**

Peak values will be marked automatically in the graphics and listed with their numerical data in a table, single or multiple plots. Q-factor calculation in sine.

**Graphical and Numerical Measurement and Reference Data Analysis**

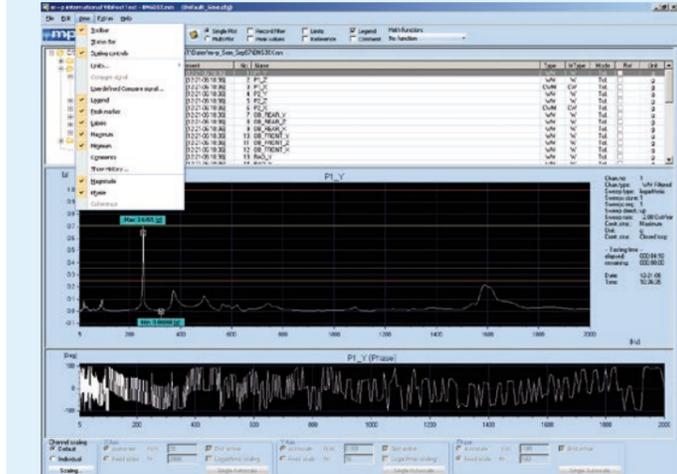
- Control and response spectra with reference, alarm, abort and notch limits
- Error
- Drive
- FFT amplitude and phase in sine and random
- Coherence in random

**Printouts**

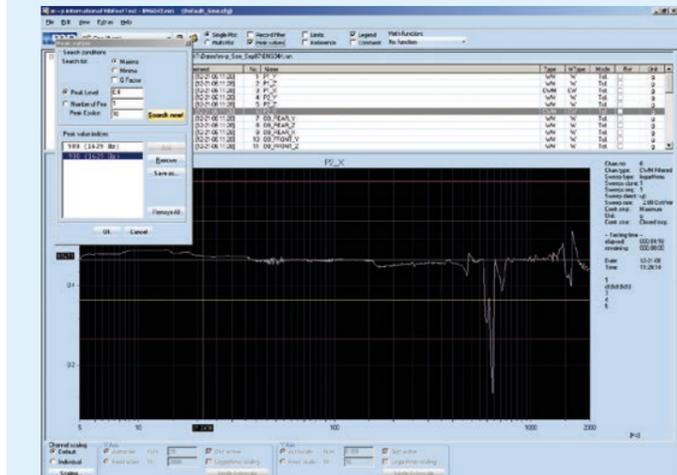
- Multiplot: displaying and printing traces from different test types, several test runs or multiple test specimens in one graphic window.
- Peak search
- Autoplot: automatically printing a preselected series of graphics.
- Printing a list of preselected test parameters.
- Printing directly to MS Word using a customer-defined template.

**Reporting**

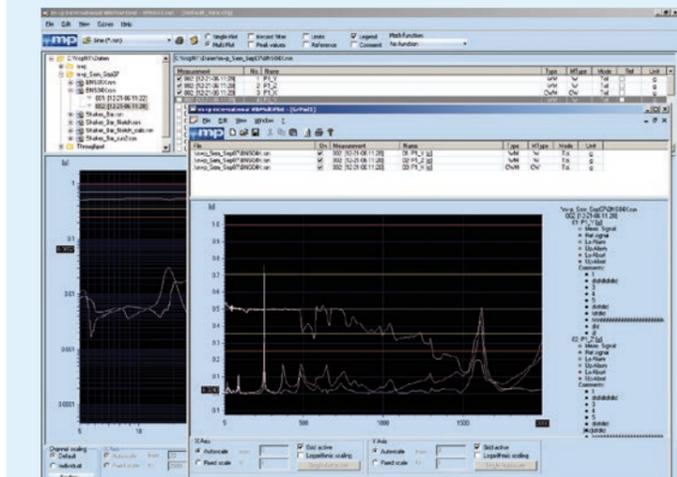
The presentation of the test results is as important as a successful test completion. The m+p vibration controllers are perfectly positioned to meet the most demanding requirements. The reports are generated online while running a test or upon test completion. User comments, company logos and graph markers can all be added to create a complete report-ready display. Data and graphics are copied and pasted to standard Microsoft Windows applications such as Word and Excel and can be exported into Universal File Format. The ultimate step in electronic report generation is using the m+p eReporter software package to which the m+p VibControl data can be directly exported.



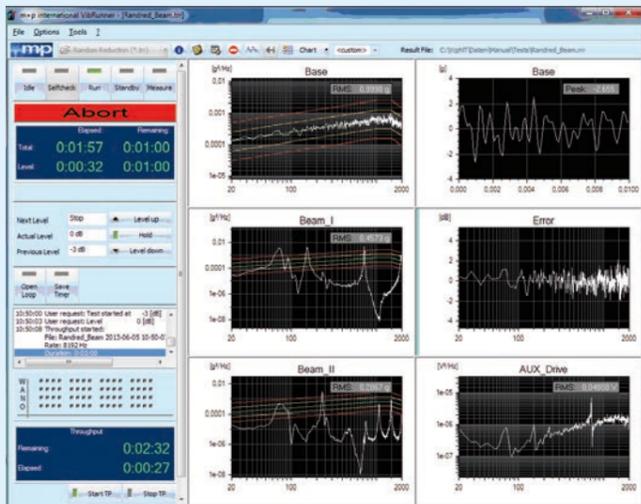
Comprehensive analysis functions



Automatic display of peak values



Multiplot with data from different result files



Online random data reduction with throughput to disc recording



Photo courtesy of ACS Group, France

Combined climatic and vibration testing of car sunroofs

# Data Reduction and Throughput to Disc



High-channel count data acquisition and vibration control system for large-scale spacecraft testing

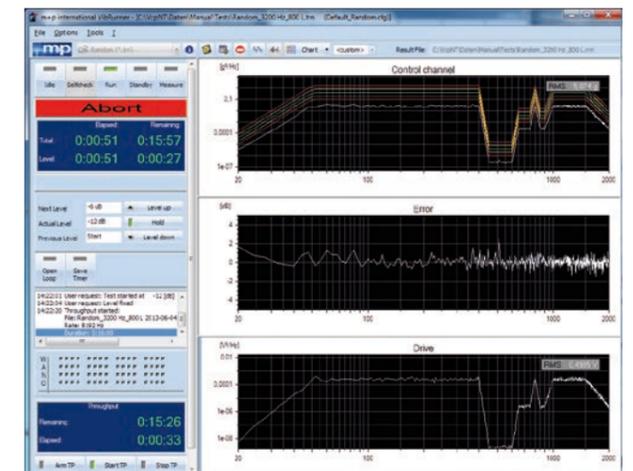
## YOUR BENEFITS

- Online data reduction for sine/random/transient capture testing
- Fully replaces tape recorder
- Time history recording to throughput disc in parallel with data reduction
- Instant online results
- Common hardware platform and user interface with m+p's vibration control system
- Post-test tools including file format conversion and data export
- Common data and plot formats of m+p VibControl data reduction and vibration control systems for transparent test reporting
- Multi-monitor support enables easy online monitoring of up to 1,280 channels
- High sample rates for time domain data storage: up to 32,768 Hz for sine and random and 102.4 kHz for transient capture (per channel)

## Gap-Free Time History Recording during Vibration Control

For the most critical tests time history data can be recorded in parallel with vibration control with no reduction in control performance. This facility is also available in recorder modes without closed-loop control. The real-time throughput data capture function allows you to record all selected channels continuously in the time domain on the embedded data server ("throughput to disc") irrespective of the channel count and the frequency range utilized. This means that you can always access all the original data for analysis purposes.

One method which is still widely used consists of the time data recording of a vibration test to a second measurement acquisition system in parallel with the usual frequency data recording. This results in additional costs for hardware and more complex system operation. Using m+p international's throughput function simplifies the process and, in addition, you can easily post-process the recorded time data after the test run. The throughput function can be started and stopped independently of the vibration control process. The time data are analyzed using the data reduction software.



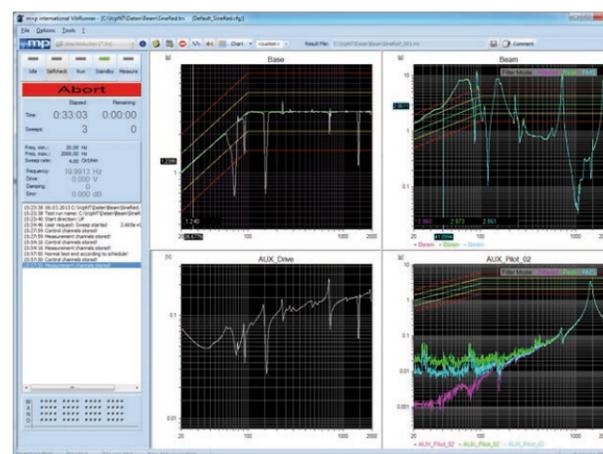
Parallel time data recording and random vibration testing

## Data Reduction for High-Channel Count Systems

Data reduction systems with or without time history recording are frequently used in critical aerospace testing applications where complete measurements of a high number of channels are required for post-test and possible failure analysis. The m+p VibControl data reduction system configurations are tailored to the specific needs of high-performance measurement applications requiring hundreds or thousands of input channels.

The online analysis and display functions give a fast overview of the test results during the test or when stored data are replayed. Advanced data analysis tools include the m+p Analyzer post-processing software for random, sine, shock and acoustic data, providing seamless integration with Microsoft Office products for comprehensive test reporting.

Data formats and data plots of the m+p VibControl data reduction and vibration control systems are the same allowing for a common reporting environment.



Online data reduction during closed-loop sine vibration test

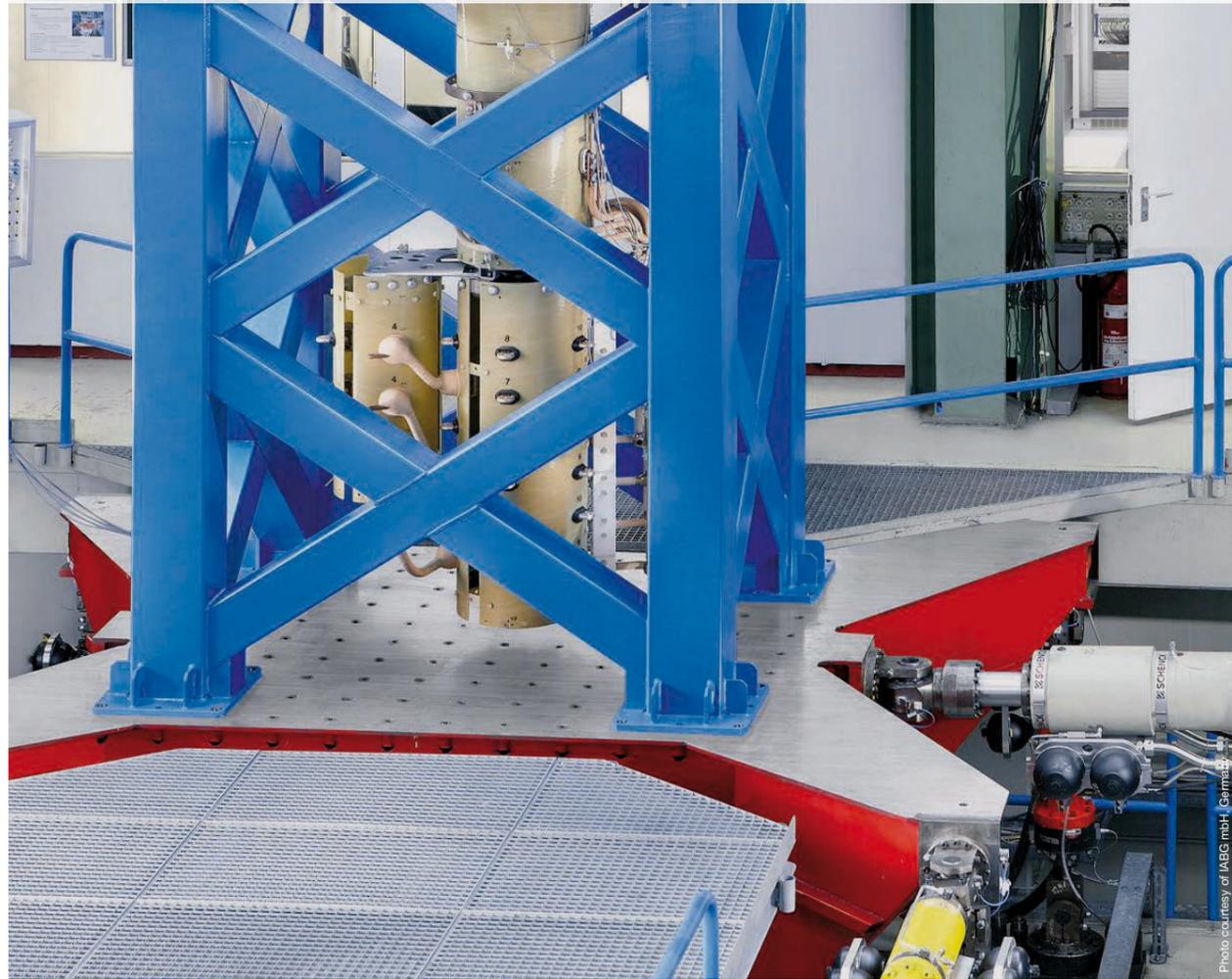
*With data reduction, throughput data capture and vibration control running in parallel in one m+p VibControl system, laboratories can reduce their test costs and operator training significantly.*

Solar array testing



Photo courtesy of Airbus Defence and Space, Germany

# Multi-Axis Vibration Control



## YOUR BENEFITS

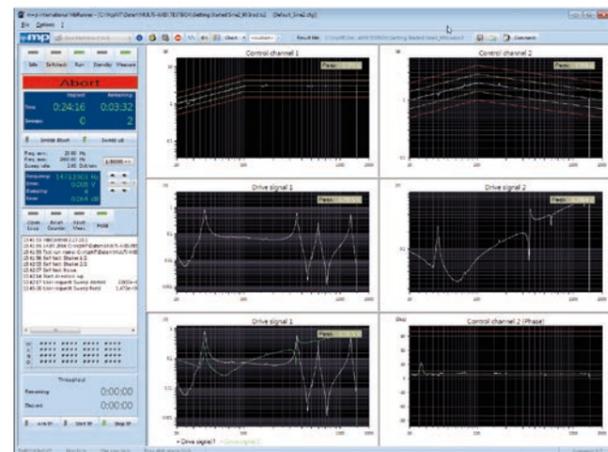
- MIMO test modes: random, sine, shock including SRS, time domain replication (road load simulation)
- Control using unique vibration profiles for each shaker
- Combine multiple vibration profiles and excite all frequencies at the same time using true random
- Kurtosis control for decoupled systems
- Reproduce measured time histories at each load input
- True multi-tasking without loss of real-time control increases test efficiencies
- Cross-coupling compensation of dynamic responses from multiple shakers
- Test sequencing for automated long-term durability testing
- Powerful m+p eReporter analysis tool for browsing, viewing, editing, analyzing and reporting data
- Easy-to-use GUI with familiar Microsoft Windows style
- Seamless import/export of test results into Microsoft Windows applications makes plenty of analysis options available
- Phase and amplitude control unit for up to four shakers

Simulating the real-world vibration environment for a structure in the laboratory is complex and sometimes requires simultaneous force inputs along several axes. Testing two or more axes in parallel reduces traditional test times considerably and reproduces the true environment more closely than with classical single-axis, single-shaker excitation.

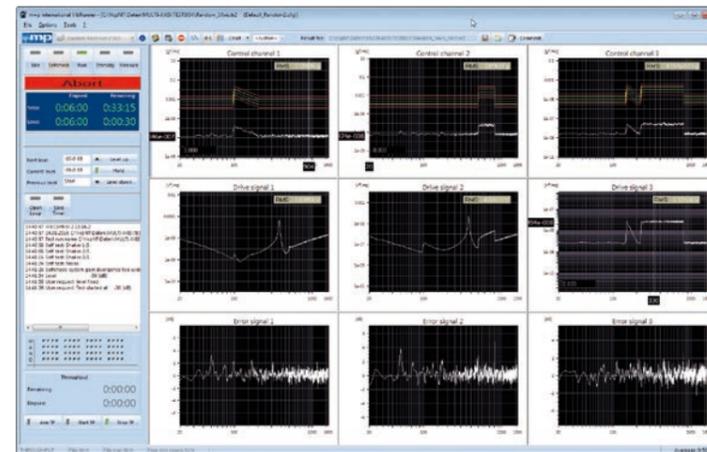
Applications of the m+p VibControl multi-axis controller include vehicle road load simulations for durability tests, testing of large and complicated structures for operational loading as well as earthquake simulation as per IEEE 344. Components and sub-assemblies are tested on specially designed shaker tables with motion in several degrees of freedom. For seismic qualification the test specimen is fixed to a multi-axis earthquake shake table. Large structures such as complete automobiles, aircraft, rockets and railroad cars are excited on multiple shakers each directly attached to a load input point. This simulates the real-world vibration environment in a precise and realistic way.

m+p VibControl provides coupled and uncoupled multi-axis vibration testing (MIMO) in a closed control loop. Test modes include random, sine, shock and time domain replication (road load simulation). Multi-axis motions are characteristic of field environments. The more a vibration test can replicate the field environment, the more realistically it can induce a vibration stress loading equivalent to that experienced by the product in the field.

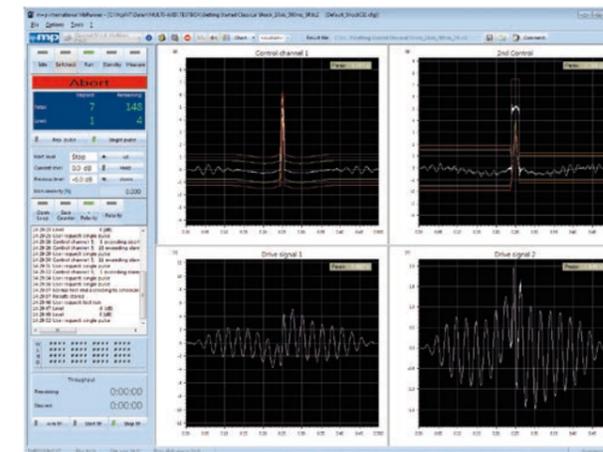
Multi-axis sine testing



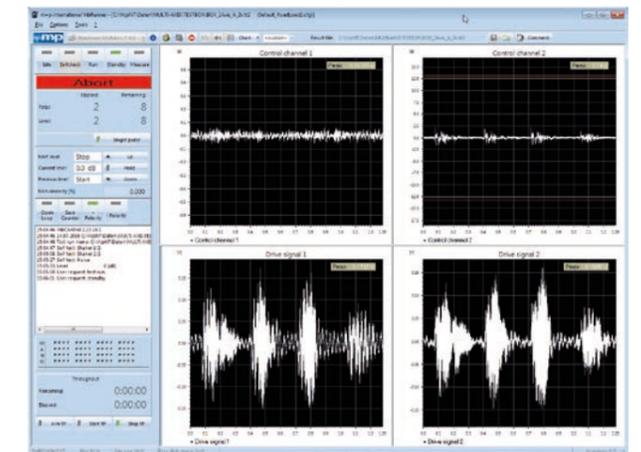
Multi-axis random testing

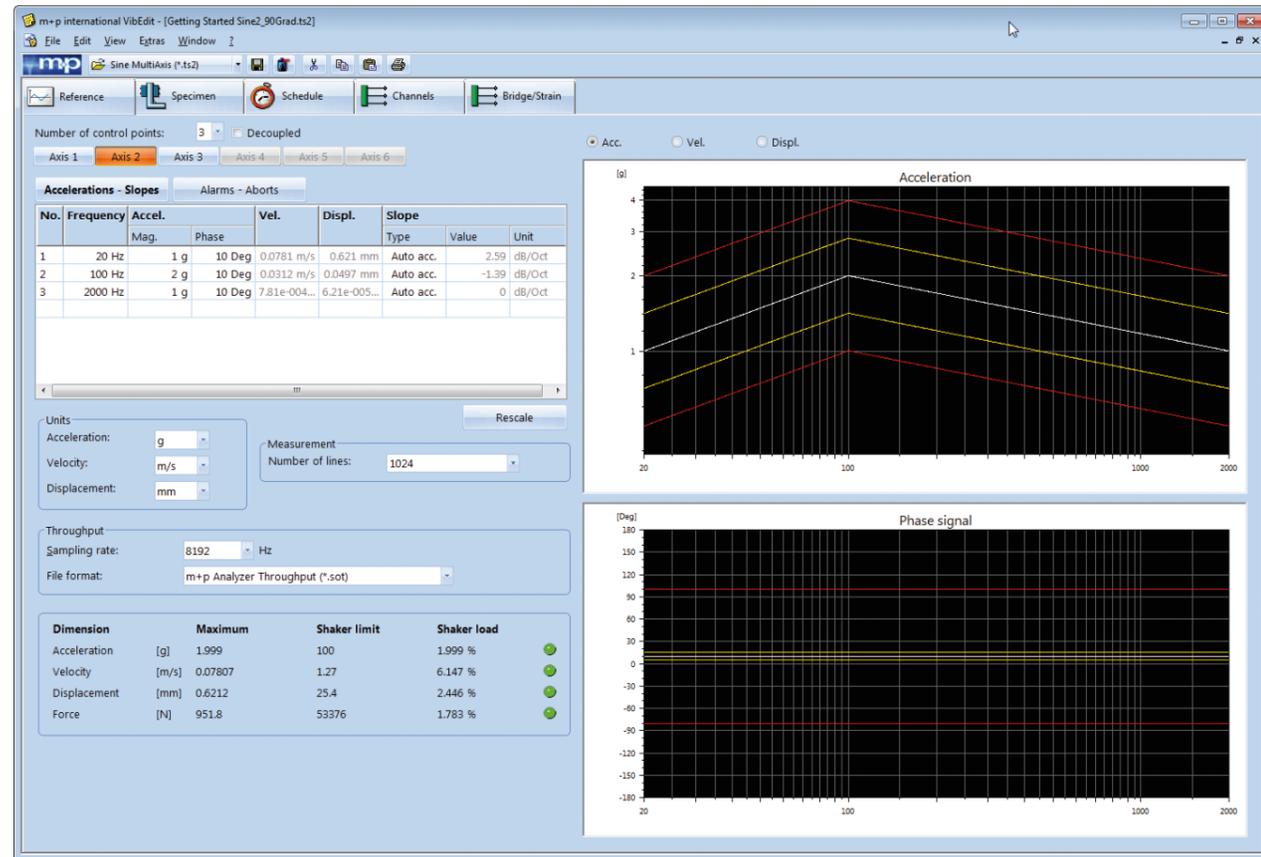


Multi-axis shock testing



Multi-axis time domain replication testing





Clearly arranged set-up window simplifies multi-axis test definition

**Focus on the Essentials**

Whereas a single-axis random or sine test can be defined by a single value at each frequency, a multi-axis test requires the definition of a complex matrix at each frequency representing all the demand levels, as well as the coherence and cross-phases between each pair.

The flexible display arrangements allow tailoring to show just the required information for maximum clarity during test operation, while all measured data is recorded and available for later analysis.

Where the cross-phases and coherences are defined, m+p VibControl will verify that the demanded control values are feasible and also within the capabilities of the system.

Multi-axis seat testing



m+p PCU4 front panel

**Phase and Amplitude Control**

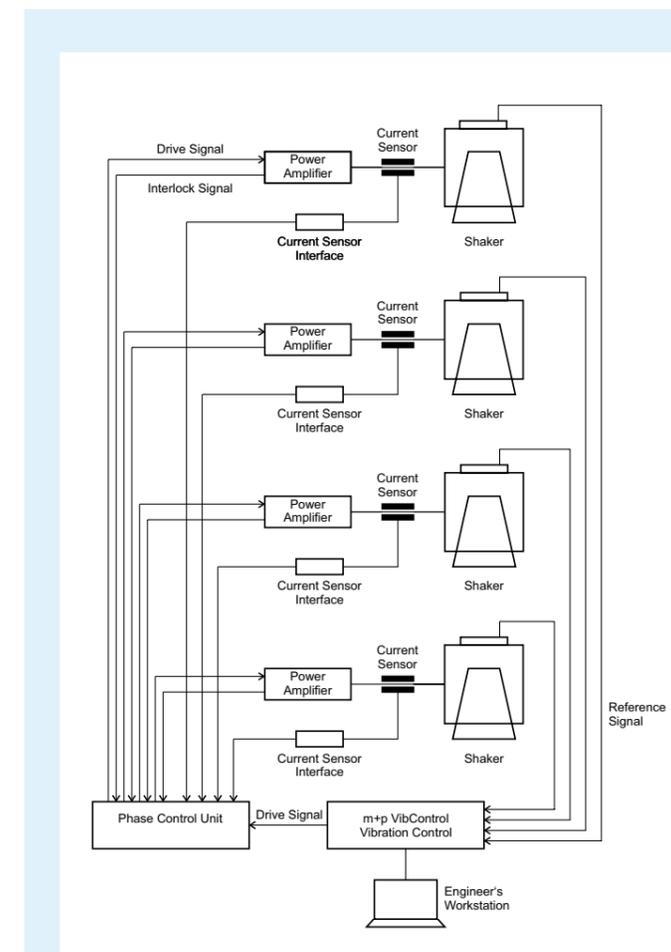
The m+p PCU4 phase and amplitude control unit ensures that up to four shakers are reliably synchronized and coupled together to act as one system. It processes sine, random and shock data in a frequency range from 5 Hz to ca. 3 kHz (typical 5 to 500 Hz for hydraulic shakers or 20 to 2,000 Hz for electrodynamic ones). Low- and high-frequency phases as well as magnitude and gain are accurately controlled.

Features of the m+p PCU4 include selectable push-pull and push-push configuration, master gain selectable by input range setting, overload protection and 4-channel supervisor. A bypass configuration switch and interlock reset as well as LEDs for phase and magnitude status ensure ease of use and test safety.

This specialist phase and amplitude control unit is used for optimization of the effective shaker force in the special application case where shakers are rigidly coupled via a head expander or slip table.



m+p PCU4 rear panel



Schematic functioning diagram

# Acoustic Control



Photo courtesy of NASA, USA

m+p international is considered the market leader for reverberant chamber excitation. Our m+p VibControl performs acoustic testing in reverberant chambers and direct field environments as well as progressive wave tube testing. It is a fully automatic digital control system, providing fast, accurate and repeatable control of high-level noise to a reference octave band spectrum and the overall sound pressure level (OASPL). The control guarantees a high level of product safety.

The m+p VibControl acoustic control system provides features such as support for up to 40 microphones for control and/or measurement, continuous time domain octave analysis in 1/3 and 1/1 octave bands, a control bandwidth up to 10 kHz with multi-horn control, equalizer

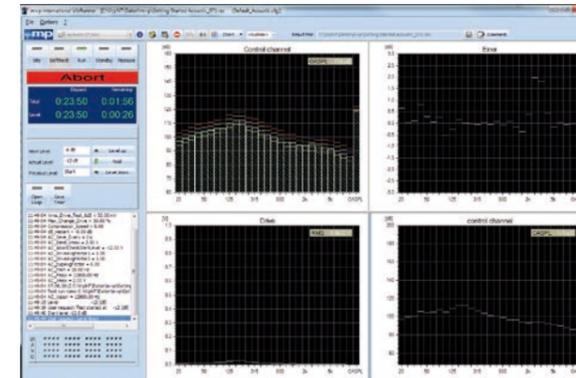
tool, calibration tool, automatic microphone drop-out detection and exclusion from control, extensive octave band and OASPL alarm and abort checks for safe testing as well as comprehensive post-test analysis and reporting functions in 2D and 3D.

In addition to the stored octave spectra, PSD's are calculated and stored for individual measurement channels. They allow monitoring of the mechanical response of the structure to be tested.

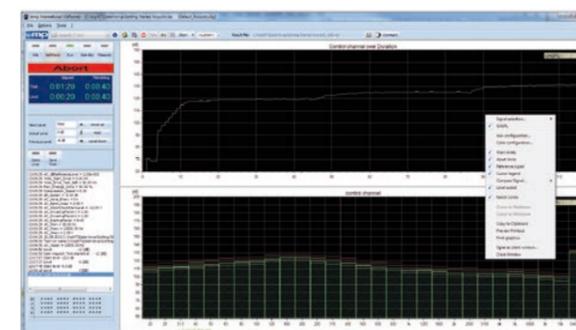
Supporting the same Ethernet-based m+p VibRunner hardware, m+p VibControl for acoustic control can be configured as a shaker control system by simply adding software modules.

## YOUR BENEFITS

- Fully automatic closed-loop acoustic fatigue testing in a reverberant chamber
- 1/1 and 1/3 octave bands usable for control and measurement
- PSD measurements for monitoring mechanical responses during acoustic load
- Protection against open loop/drive runaway
- Easy runtime display configuration
- Display of min, max and average for each octave band over a period of time with a few mouse clicks
- Visual time domain signal verification for each channel
- OASPL over time displays for full test documentation
- Continuous time history recording during test run to stream all raw time data to throughput disc
- Advanced time domain data analysis using m+p Analyzer software
- Direct field acoustic control system for satellite testing
- Progressive wave tube (PWT) testing

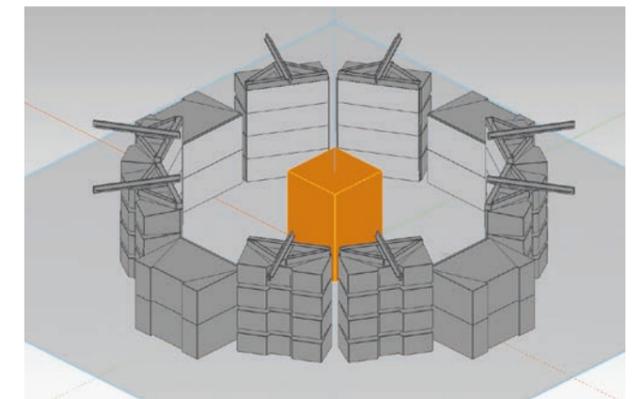


OASPL over time display



Acoustic control test run

Revolutionizing the acoustic testing of minisatellites, m+p international developed a direct field acoustic control system. This high-end system greatly reduces test time and costs. The software controls the complete test procedure and logs all steps of the process. In most cases, the test period during which the satellite is subjected to the 146 dB sound pressure field is only one minute. The satellite test scenario does not require any specially prepared environment or test stand. Considering certain specifications, a multitude of different rooms will instead suffice to ensure significant results that are accepted by experts.

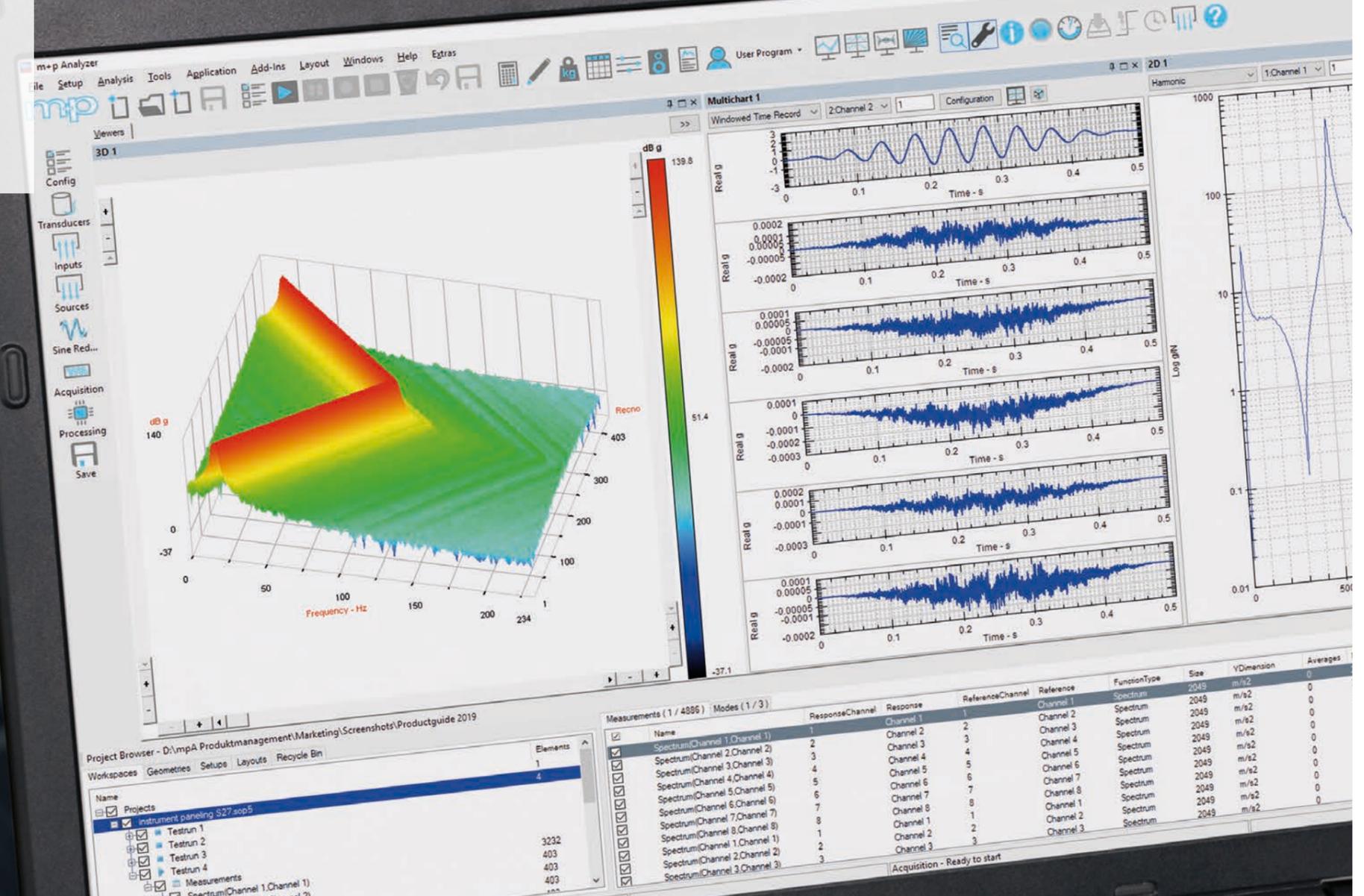


Minisatellite testing: loudspeakers circularly positioned around the specimen to create a sound pressure field

*"The m+p acoustic control system in place at NASA Plum Brook, which can drive all of our reverb chamber's 36 noise modulators (23 hydraulic type, and 13 electro-pneumatic type), suits our needs very well. I have been relying on the m+p acoustic control system at NASA, and elsewhere, since 2003 and I have always been given attentive and accurate support from the m+p office."*

Aron Hozman, Vibroacoustic Test Systems Manager at NASA Glenn Research Center, Sandarsky, Ohio/USA

# Noise and Vibration Analysis m+p Analyzer



# Dynamic Signal Analysis



## YOUR BENEFITS

- Measurement, analysis and reporting in one application for minimal training and ease of use
- Supports standard hardware to suit all your projects
- Wide range of integrated applications to satisfy all your NVH needs
- Import 3<sup>rd</sup> party files for analysis and integration of all related data for common reporting
- High-speed SQL-based data storage for secure, fast and efficient data access
- Customization of macros and online functions to meet your specific requirements
- Mobile, laboratory and network based for optimal access and utilization
- Compatibility with wide range of sensors and signals for future-proofing
- Online and offline processing and data viewers for the clearest picture of your test
- Proven performance and product evolution for long-term reduced cost of ownership

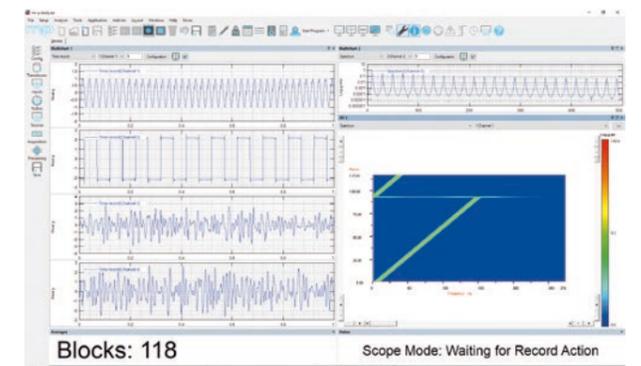
m+p Analyzer is a fully integrated solution for dynamic signal measurement, analysis and advanced reporting of all of your noise and vibration, acoustics and general dynamic signal applications. Comprehensive time and frequency analysis is available with both online and offline data processing. Complete with advanced application wizards the system makes light work of gathering data, displaying results, performing specialized analysis and generating customer ready reports – all within one user interface.

## Applications

- Data Acquisition with Time and Frequency analysis of all types of dynamic signals and sensors
- Time history recording and post-processing
- Structural Analysis data acquisition including geometry guided impact hammer, shaker drive outputs with random, swept and stepped sine, random and sine burst to drive one or more shakers with full MIMO analysis
- Modal Analysis with Operating Deflection Shape, Circle fit, SDOF and MDOF curve fitters, OMA and Modal Model Validation tools
- Ground Vibration Testing with Normal Mode Tuning handling multiple shakers
- Rotating Machinery Diagnostics with spectral mapping and order tracking with both online and offline analysis tools
- Octave Analysis with real-time fractional octave filters and sound meter functions meeting relevant standards – covering both acoustics and ultrasonics
- Sound Power measurements to IEC standards with ECMA tonality for assessing machines, components or sub-assemblies
- Sound Quality analysis for product refinement and diagnostics
- Sound Intensity measurements with acoustic intensity field mapping and sound power analysis
- Environmental Vibration testing with full compliance to vibration test standards such as MIL-STD 810, DEF STAN 00-35 and IEC 60068
  - Independent measurement of additional channels over those available on the vibration controller



Impact hammer testing



Acquiring dynamic data

- Random Data Reduction
- Swept Sine Tracking and Data Reduction
- Classical Shock Data Reduction with full limit overlays for shakers or drop tables
- Shock Response Spectrum analysis
- Acceptance and qualification tests of shakers

## Measurements

m+p Analyzer systems are available for field and laboratory use from two to hundreds of measurement channels. From gathering simple time history data to narrowband (FFT) spectra, fractional octaves, wavelets, shock response spectra and much more. m+p Analyzer can be used with a wide range of instrumentation hardware including our own m+p VibPilot, m+p VibRunner and m+p VibMobile systems as well as National Instruments (USB, CDAQ, PCI, PXI) and others. Low cost portable instruments to systems for distributed measurements can be configured for maximum flexibility. Measurement data from all sources are stored in a common format so it is easy to compare and handle results from any measurement source.

Continuous real-time and triggered data acquisition modes are set up by the operator offering sampling frequencies from 32 Hz upwards into the MHz range and with FFT block sizes up to 256 k for the highest frequency resolution.

Sampled data is fed to parallel processing streams so that time history recording, narrowband analysis and octave based analysis can all be done together. A scheduling function even allows repeated measurements at intervals over a long period of data acquisition.

Over 50 standard measurement functions are available from time, spectra and frequency response functions to histograms and statistical results. Instantaneous data blocks can be stored for spectral mapping and averaging methods include ensemble block average, exponential and peak hold modes. Custom online functions can be defined including cross channel calculations and averaging. All common weighting and windowing types are included as is online integration making easy work of deriving velocity and displacement results from acceleration inputs. Single-channel and cross-channel functions are all available for signal correlation and transfer function analysis including full matrix FRF computation for Multiple Input/Multiple Output (MIMO) applications. Additionally user defined online filtering and resampling can be applied when required.

Rotating machinery diagnostics



Powerful throughput to disc recording can store raw time history data at high throughput rates in parallel to normal analysis functions. All these recordings can then be used to perform offline post-processing analysis to review field data in more detail or revise analysis settings.

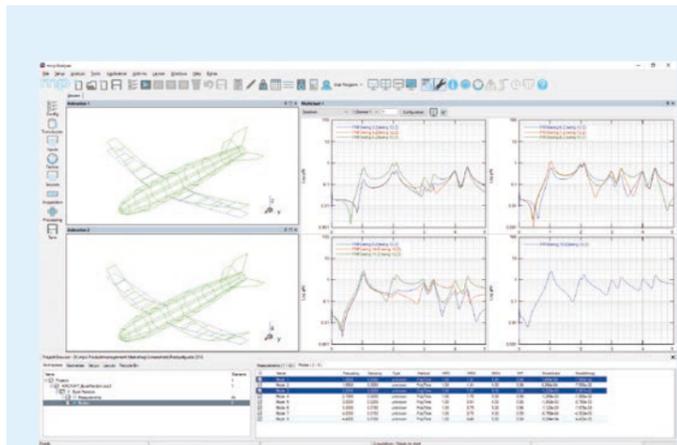
Flexible data import and export facilities enable post-processing of third-party data files. Stream based binary data files can be used directly as a post-processing data source simulating data direct from an online sampling system.

## Data Display

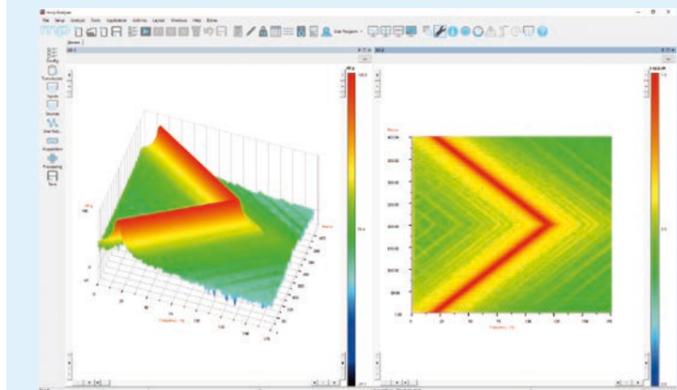
Chart displays are the key to viewing and analyzing dynamic data and the m+p Analyzer 2D, 3D and animation viewers have a wealth of functionality to satisfy any requirement. They are easy to use for new users and offer a wide range of features for experienced engineers.

Custom layouts can be defined using multiple 2D, 3D and animation viewers and these can be extended over multiple monitors for viewing large number of data channels. Real-time and offline data can be displayed and mixed as required.

- The 2D chart includes simple X/Y chart, bode plot and Nyquist formats with linear, log and dB axes together with flexible scaling and zooming modes including chart linking. Dual Y-axis scales allow different data types to be overlaid. Charts can be stacked or tiled or randomly snapped to size for layout flexibility.
- Each 2D chart can handle any number of overlaid traces for comparison, has flexible cursors, labels and markers as well as comprehensive computation of scalar properties and calculation functions such as FFT, Integration etc. for instant data conversions. Over 40 calculation functions are built into the chart and additional tool windows provide features such as trace, trigger, tacho, Least Squares Fit and upper/lower limit indicators.
- Multi-chart viewers display up to 64 individual channels with unlimited overlays for rapid review of many hundreds of channels in real-time.
- The 3D chart has both waterfall and colour map modes and like the 2D has a built-in calculator for XYZ and order cut calculations direct from the cursor positions.
- The animation viewer is used together with the various structural analysis tools for displaying and comparing mode shapes using wire frame geometry models.
- All chart viewers can be copied for instant paste into a report using a variety of formats including full ActiveX control in MS Office and video clips for reporting mode animation results.
- All data is also available in tabular form for copy and paste exchange with spread sheets etc. Comprehensive header and user Meta-data are included with bulk editing of parameters.



2D and 3D animation viewers



3D spectral map and 2D colour map displays



Ground vibration testing



Acoustic and Human Vibration Analysis

**Data Analysis**

Time and frequency analysis are the mainstay of many applications and m+p Analyzer's drag/drop data handling makes it easy to get data into charts for investigation. The time domain stacked charts provide transient and sequence of events analysis and the frequency domain chart cursors can search for multiple peaks and calculate frequency, amplitude and damping on the fly. Chart legend and markers with over 50 built-in calculations produce report ready results quickly.

m+p Analyzer's powerful data browser handles a large quantity of data from multiple measurement runs or saved projects. The data can be sorted, organised and displayed for graphical comparisons and for more advanced analysis. An editable engineering units database ensures all data is fully calibrated and derived functions are correctly scaled and identified in ready to report formats. Data is converted and displayed in any engineering unit at the touch of a button ensuring maximum data integrity during analysis and reporting.

Sequence of event analysis is performed on large time history recordings which can be handled direct from file when they are too large to load directly into memory. Many gigabytes of data can be quickly scanned and zoomed across many channels of data making this an ideal tool for reviewing large data files such as those recorded by our m+p VibControl system.

The chart based calculator is further augmented with a full array calculator that uses a reverse polish stack to compute cross channel and cross function results using over 50 advanced operations. Equations can be stored as macros for repeated use.

For your own special calculations an online cross-channel calculator defines multiple user functions or a fully embedded Visual Basic programming language can also be used. You can create macros and add these to the standard menus for frequently repeated analysis operations. Advanced wizards guide the user through the most complex of applications analysis. These are available to assist with measurement procedures and for post-test

*m+p Analyzer's ease of use and flexibility to utilize our National Instruments data acquisition hardware as well as the 8-channel m+p VibPilot allows us to verify product quality prior to shipment with no process delays. Thanks to the excellent pre- and post-sales technical support from m+p we can respond to complex customer demands in a timely manner and continue to expand the system capabilities into modal analysis and FE model validation.*

Arthur Kohn, President of IVS Industrial Ventilation Systems, Houston, Texas/USA

analysis to ensure users of all levels of experience can derive the required results. These analysis wizards are available:

- Modal Analysis – ODS, SDOF, MDOF, Circle Fit, Geometry creation, Modal Model Validation
- Rotating Machinery – Tacho spline fit, RPM mapping, Order tracking, Orbit analysis
- Environmental Test – SRS, Sine Reduction, Classical Shock
- Acoustics – Sound Power, Sound Intensity mapping, Transmission loss, pitch and warble
- Time/Frequency analysis using Morlet wavelet transforms

**Report Generation**

The m+p eReporter configuration is a powerful offline data analysis tool for reviewing and exchanging third-party data. Many standard import and export filters are provided and automated links to programs such as MATLAB are available. It is now possible to collect all of your dynamic data from any source into one common review, charting and reporting tool with m+p eReporter. In this configuration you can continue to enjoy all the post-processing and analysis wizard functionality.

For use across your site, the network based license server allows concurrent use by analysts anywhere on your network. This provides flexible and cost effective application deployment in large departments or where data is shared across different departments so the most effective and efficient use of the data can be employed.

From a simple copy and paste of a chart into a document to creating automated custom reports, m+p eReporter has a wide range of reporting capabilities to suit all needs. Graphical and tabular data can be copied to clipboard for instant reports or data exchange with a spread sheet application making m+p Analyzer a great tool for use with all dynamic data reporting requirements.

Templates are used to define report layouts for frequently used reports which can be executed immediately from any measurement(s) or chart. The Reporting tool includes grouping, select and sort feature to handle large numbers of measurements and also uses templates to define multi-page reports with charts, tables and animations.

Data stored in m+p Analyzer contains comprehensive header data which can also be incorporated into report templates as text or tables and automatically filled from the selected measurements.

ActiveX charts and animations can be copied to Microsoft Word, Excel and PowerPoint. The documents are opened with the same chart functionality as available in the full application but without having m+p Analyzer installed.

The free m+p Analyzer Viewer is available from our website to share this functionality with your customer or a colleague who does not have an m+p Analyzer license.

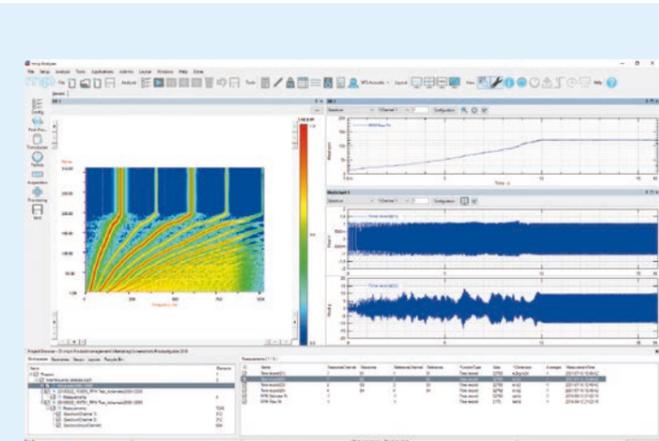
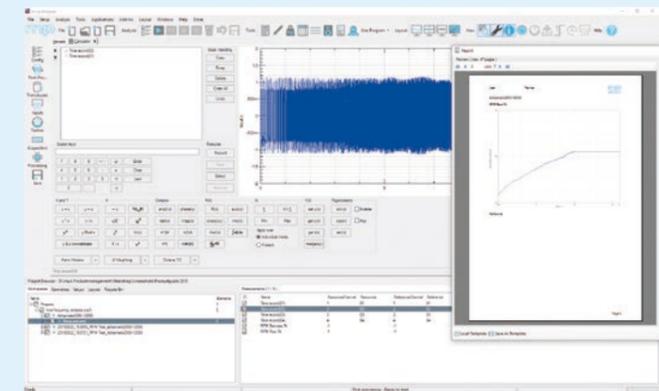
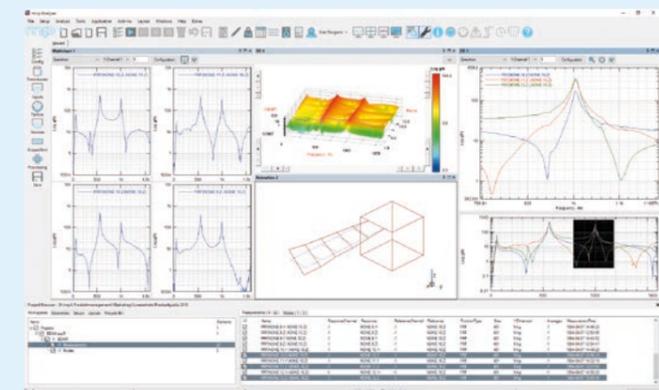


Chart displays for viewing and analyzing dynamic data

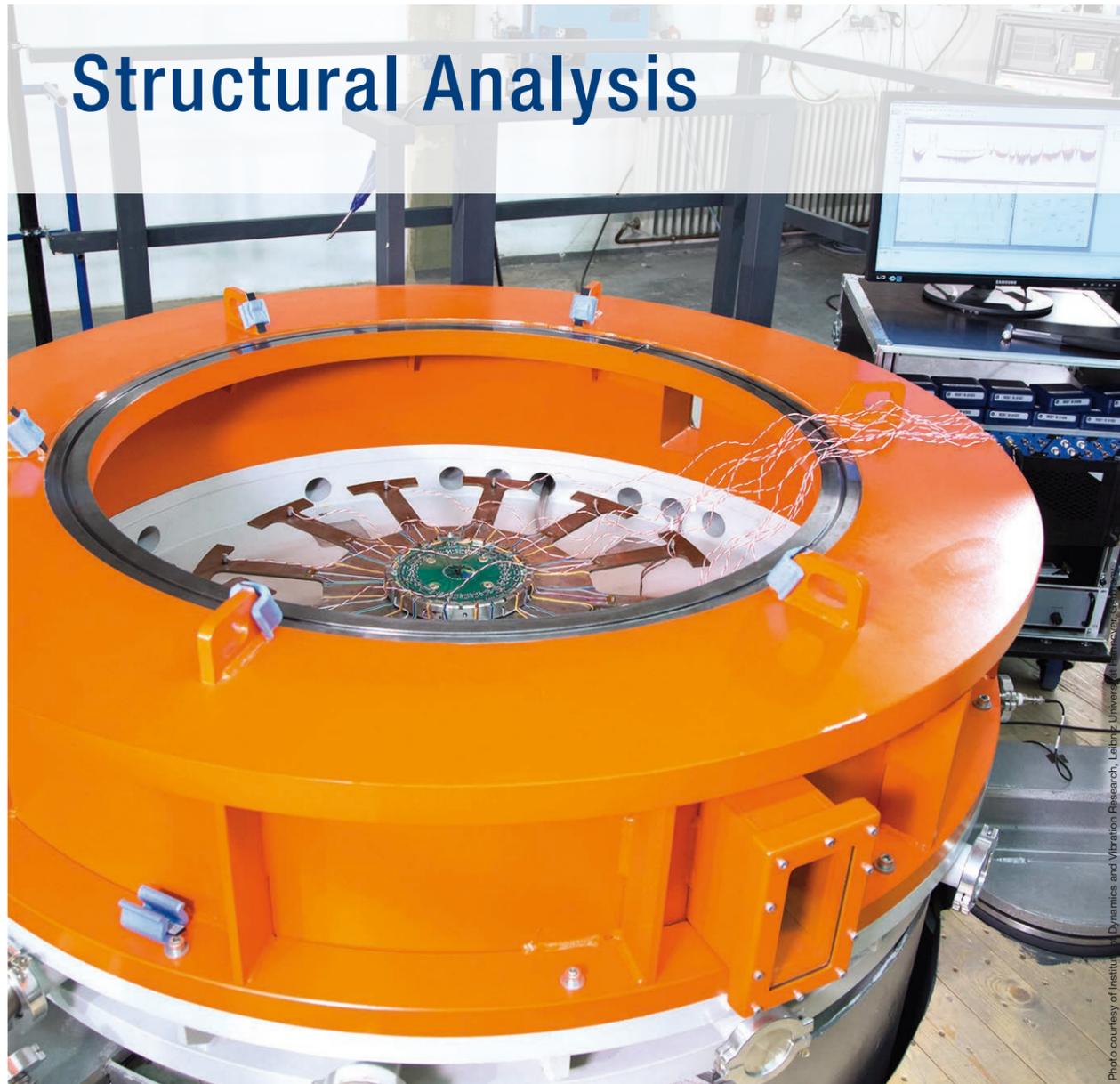


m+p eReporter for advanced data management and reporting



Comprehensive data analysis tools

# Structural Analysis



m+p Analyzer's structural analysis package provides a complete set of tools for observing, analyzing and documenting the vibrational behaviour of machines and mechanical structures. Different software modules cover a wide range of techniques including impact testing, shaker measurements (SIMO and MIMO), experimental and operational modal analysis, ground vibration testing, operating deflection shape analysis, and modal model validation.

The standard structural dynamics package includes:

- Impact testing using a modal hammer
- Creation of component-based geometries
- Operating Deflection Shape (ODS) analysis

Optional software modules are available to cover the most demanding and advanced modal analysis applications:

- Single Degree of Freedom (SDOF) analysis

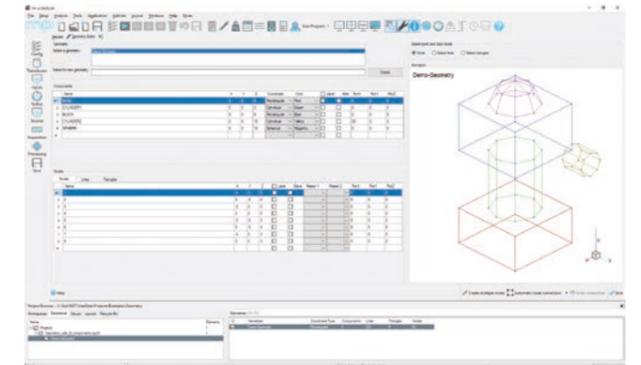
- Multiple Degree of Freedom (MDOF) analysis
- Circle fit wizard to review and validate FRF data and mode shapes
- Operational modal analysis (OMA)
- Modal model validation (MAC, MPD, MPC, MOV, MIF)
- Polyreference Time Domain algorithm (PTD/PolyTime)
- Polyreference Time Domain Plus algorithm (PTD+/Polytime+)
- Polyreference Least-Squares Complex Frequency domain algorithm (p-LSCF/Polyfreq)
- Multiple Input/Multiple Output (MIMO) analysis including multi-source outputs
- Swept and stepped sine analysis
- Ground vibration testing (GVT) with Normal Mode Tuning (NMT)
- Interface to FEMtools for Structural Dynamics Modification (SDM) analysis

## YOUR BENEFITS

- Fully integrated measurement and modal analysis for efficient testing
- Wizard guidance simplifies process for all experience levels
- Advanced Guided Impact Hammer wizard for single operator hands-free operation
- ODS wizard for rapid assessment of vibration shapes
- MDOF analysis using the latest algorithms that handle the widest range of applications
- Modal Model Validation to check modal data and compare with FE shapes and data
- Integrated signal sources for multi-shaker excitation
- MIMO analysis to resolve coincident modes
- Normal Mode Tuning with search and tune using live mode shape animations and MIF

## Geometries and Animation

m+p Analyzer makes it simple to create a model of the structure's geometry and animate its modal deflection shapes. The geometry editor allows intuitive creation of geometry models. Substructures, nodes, connecting lines and triangles can be entered by keyboard, pasted from a spreadsheet or imported from CAD programs via STL file format.

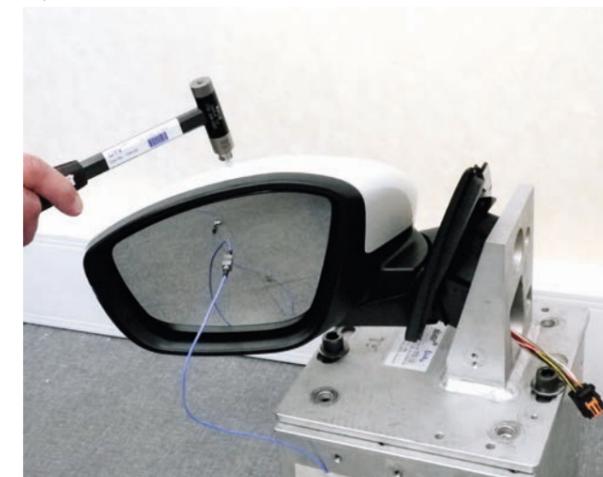


Geometry creation

## Impact Testing

Our Advanced Guided Impact Hammer wizard assists the user in running impact tests. In a step by step wizard, the user is guided to define all acquisition settings which makes it easy to set everything correctly even for inexperienced users. Predefining the points to measure enables a single operator hands-free operation which is especially useful on large structures. Online display of the coherence function, double impact warnings and a predefined customizable layout complete the impact testing capabilities of m+p Analyzer.

Impact hammer test of a rearview mirror

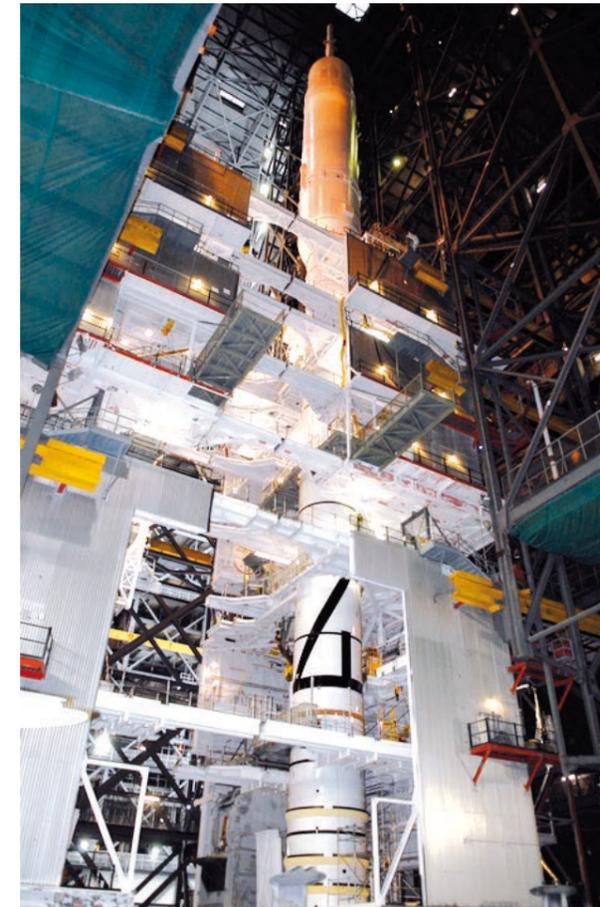


Modal analysis on a train carriage

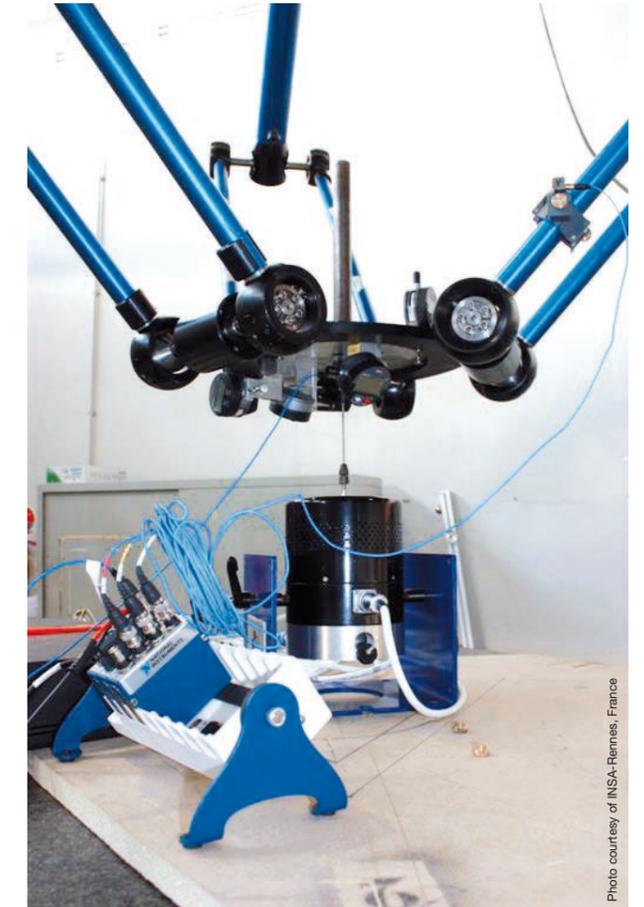




Wind turbine blade testing



Rocket evaluation



Modal analysis on a parallel robot

**Shaker Tests**

m+p Analyzer supports several different source modes (e.g. random, burst random, swept sine, stepped sine, arbitrary etc.) for shaker excitation. Multiple sources are available as well as open- and closed-loop amplitude control.

Random and burst random modes are the methods of choice when broadband excitation e.g. in modal testing is required. They offer the possibility of exciting the structure with uncorrelated signals at different exciter locations using the MIMO capabilities of m+p Analyzer. Swept and stepped sine can be used for single- or multi-shaker excitation of larger structures when high input powers are required. A typical application of stepped sine testing in the space and aircraft industry is ground vibration testing also known as normal mode tuning. Arbitrary source mode allows the replay of recorded or synthesized excitation signals.

**Modal Analysis**

The experimental modal data is obtained by curve fitting a set of Frequency Response Function (FRF) measurements. Wizards take you through a simple series of steps to complete the acquisition and analysis process and also

make accurate estimates of all analysis options. The Multiple Degree of Freedom (MDOF) wizard, for example, handles the most sophisticated modal analysis tasks, such as detecting repeated or closely spaced modes.

Industry-proven time and frequency domain curve fitting algorithms with wizard-guided operation simplify result interpretation. The time domain method is optimized for lightly damped structures and can also be enhanced by the optional PTD+ algorithm to filter spurious modes. The frequency domain algorithm is optimized for more heavily damped structures. All methods include clear stabilization diagrams and synthesized FRFs for optimum analysis. Mean-Phase-Deviation (MPD), Mean-Phase-Correlation (MPC), Mode-Overcomplexity-Value (MOV) and Mode-Indicator-Function (MIF) are additional measures that offer valuable clues to the quality of the extracted modal parameters.

Modal model validation is used for mode comparisons between different tests or between tests and FE analysis results. The Modal Assurance Criterion (MAC) is an effective way to compare the resulting mode shapes and check their agreement.

The m+p Analyzer software also features operational modal analysis based on response signals without the

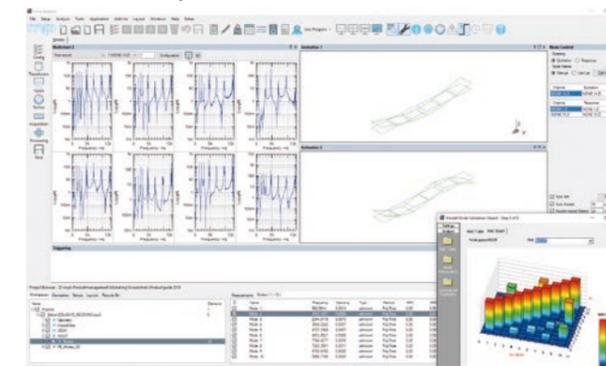
need to measure the excitation. Assuming broadband white-noise excitation this technique can be applied wherever natural excitations are present but excitation forces cannot be measured.

**Ground Vibration Testing**

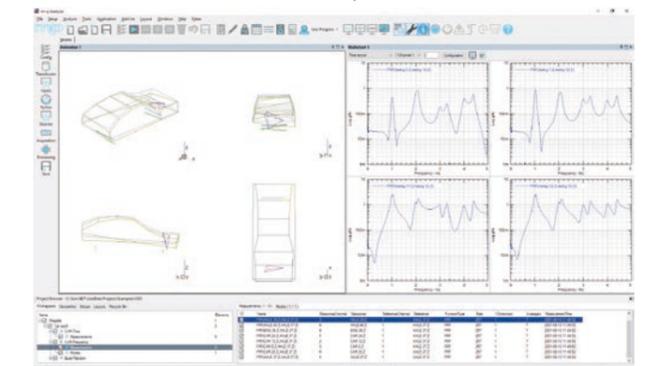
In testing space and aircraft structures, ground vibration testing is a common method. In addition to conventional

modal tests, ground vibration tests are used for further inspection of critical modes. Normal Mode Tuning uses several shakers to force the structure to vibrate in one single mode of vibration. By interactive tuning with online displays of mode shape, MIF, etc., the shaker excitation frequency and amplitudes are optimized. The Mode Indicator Function (MIF) indicates when the optimal tuning is reached.

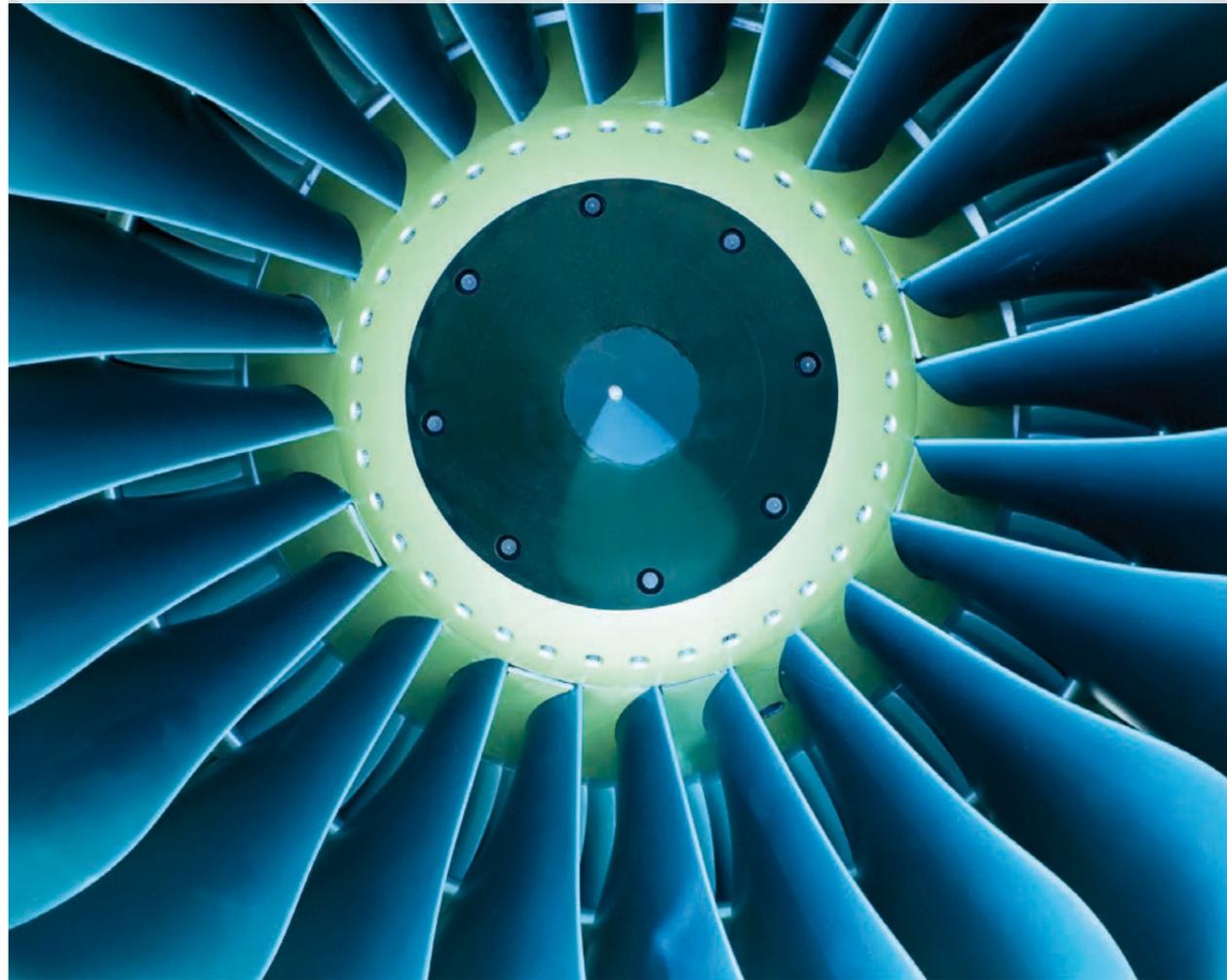
Structural data analysis tools



Flexible derivation of ODS and mode shape animation



# Rotating Machinery Analysis



m+p Analyzer provides a complete package of data acquisition and analysis tools for capturing and understanding noise and vibration induced in rotating and reciprocating machines by their motion.

Fixed and variable speed machines are accommodated as are both structural vibration and condition monitoring diagnostics. Multiple tachometer inputs can be processed for accurate speed tracking during analysis. Spectral mapping, order tracking, time history, orbit analysis, balancing and envelope analysis are all available.

## Spectral Mapping

A cost effective solution for investigating run-up and run-down vibration uses m+p Analyzer's real-time measurement

system and the built-in online and offline 3D waterfall and colour map viewer. Time-based capture of spectra can be augmented using an analog tachometer input to provide RPM steps and if a tachometer is not available, a simple tool will track using a dominant order response from the spectra.

XYZ + order cursors on the 3D chart read off RPM, frequency and amplitude information and the chart calculator computes order and frequency tracks directly from the waterfall data. Rotational and structural resonance components can be easily identified and quantified.

The advanced rotate module is fully synchronized to a tachometer input for fixed RPM step analysis at any resolution and the analysis can accommodate the highest rates of change and high-speed machines.

## YOUR BENEFITS

- Flexible time, frequency and order domain analysis
- Narrowband and 1/3 octave analysis from vibration and microphone sources
- Analog and digital tachometer inputs to suit any available sensor
- Spectral mapping for simple identification of order and resonant responses
- Order tracking for detailed analysis
- Orbit analysis, 1 and 2 plane balancing, envelope analysis
- RPM and time-based measurements cover all variable and constant speed machines

The Throughput to Disc time history recording is useful for post-processing in difficult measurement conditions where the offline post-processing wizard includes a spline fit tool to overcome noisy tachometer signals followed by comprehensive spectrum and order tracking analysis.

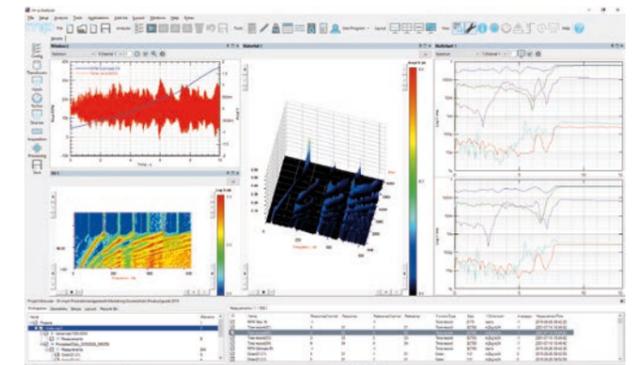
## Order Tracking

Tachometer signals can be measured on both analog and high-speed digital counter inputs with order tracks computed from spectral data or using digital tracking filters for the highest resolution. Tachometer pulse ratios can be used to compute any number of different order numbers in parallel. There are no restrictions on fractional order numbers that can be included so complex engine and gearbox order components are quickly identified.

The advanced TVDFT (Time Variant Discrete Fourier Transform) algorithm is applied for the computed order tracking analysis. This algorithm provides the benefits of both the computation speed of the FFT based order tracking and the precision of the resampling technique.

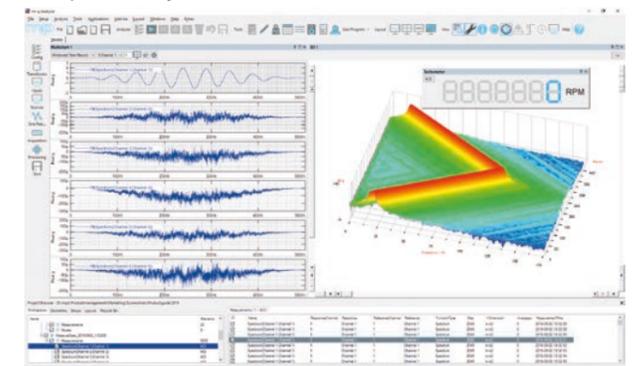
## Orbit Analysis

Online orbits can be displayed and monitored on a standard two-channel orbit diagram chart. Single rotations as well as multiple rotations are calculated and averaged over time. For advanced analysis a throughput recording including a tachometer or TDC signal can be post-processed using the orbit analysis wizard. This provides averaging, filtering and order based orbit displays with a replay feature for visualizing changes over a change in machine speed. A simple configurable bandpass filter allows removal of unwanted signals and noise.



2D and 3D displays of rotational data

Run up/down analysis

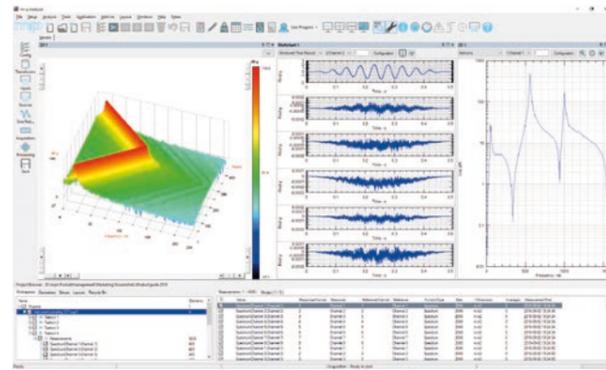


**Condition Monitoring**

At the heart of machine condition metrics are acceleration, velocity and displacement measurements which can all be derived from a single sensor with time histories of peak, pk-pk and rms values in any engineering unit displayed. Both short-term measurements over seconds to long-term monitoring over days and weeks are possible. Flexible pre-filtering of signals meets the standard metrics available for different groups of machines.

History and trends can be based on machine speed or, when running at constant speed, with time-based logging. Both cases providing time history statistics, spectrum and order analysis with both amplitude and phase results. All these functions are available in parallel for complete and immediate online results and flexible post-test diagnostics.

Balance, bearing condition and performance characteristics can be evaluated meeting the requirements of the numerous standards in this area such as ISO 13373, ISO 7919, ISO 10816, VDI 2056, ISO 2372, NF 90-300/310, BS 4675 or the API acceptance testing series etc.



Multichart viewers

Condition monitoring of compressors

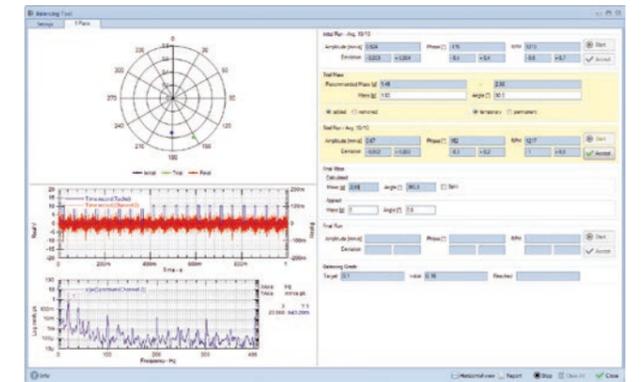


**Balancing**

Rotating machines are often subject to high vibrations caused by unbalance, therefore balancing is important in the manufacture and maintenance process of machines to reduce these vibrations. m+p Analyzer provides single- and dual-plane balancing procedures. The task-oriented user interface enables simple test setup, acquisition, analysis and correction. Comparative results can be displayed from any previous data. For reporting purposes, a result sheet can be saved for each balancing procedure.

**Bearing Fault Detection and Diagnosis**

Envelope analysis is a sensitive indicator of defects and can predict the location of developing faults. It is used as a diagnostics tool for ball and cylindrical roller bearings. Defects on a rolling-element bearing exhibit peaks of characteristic frequencies or orders in the power spectrum of the envelope signal. Time based condition monitoring of this data together with overall levels can also predict failure time and hence assist in maintenance scheduling.

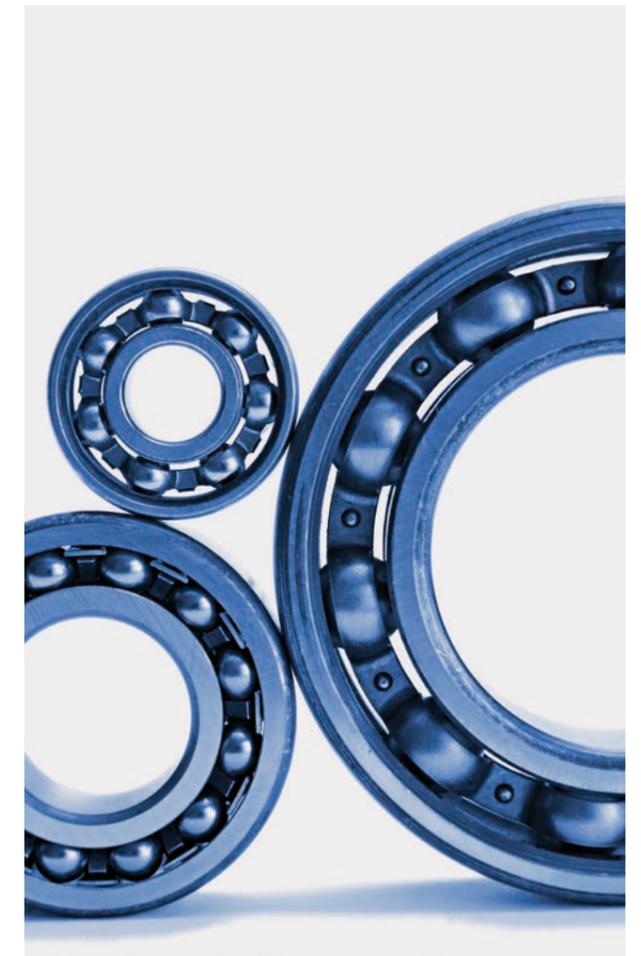


Trial run for calculating the balancing masses

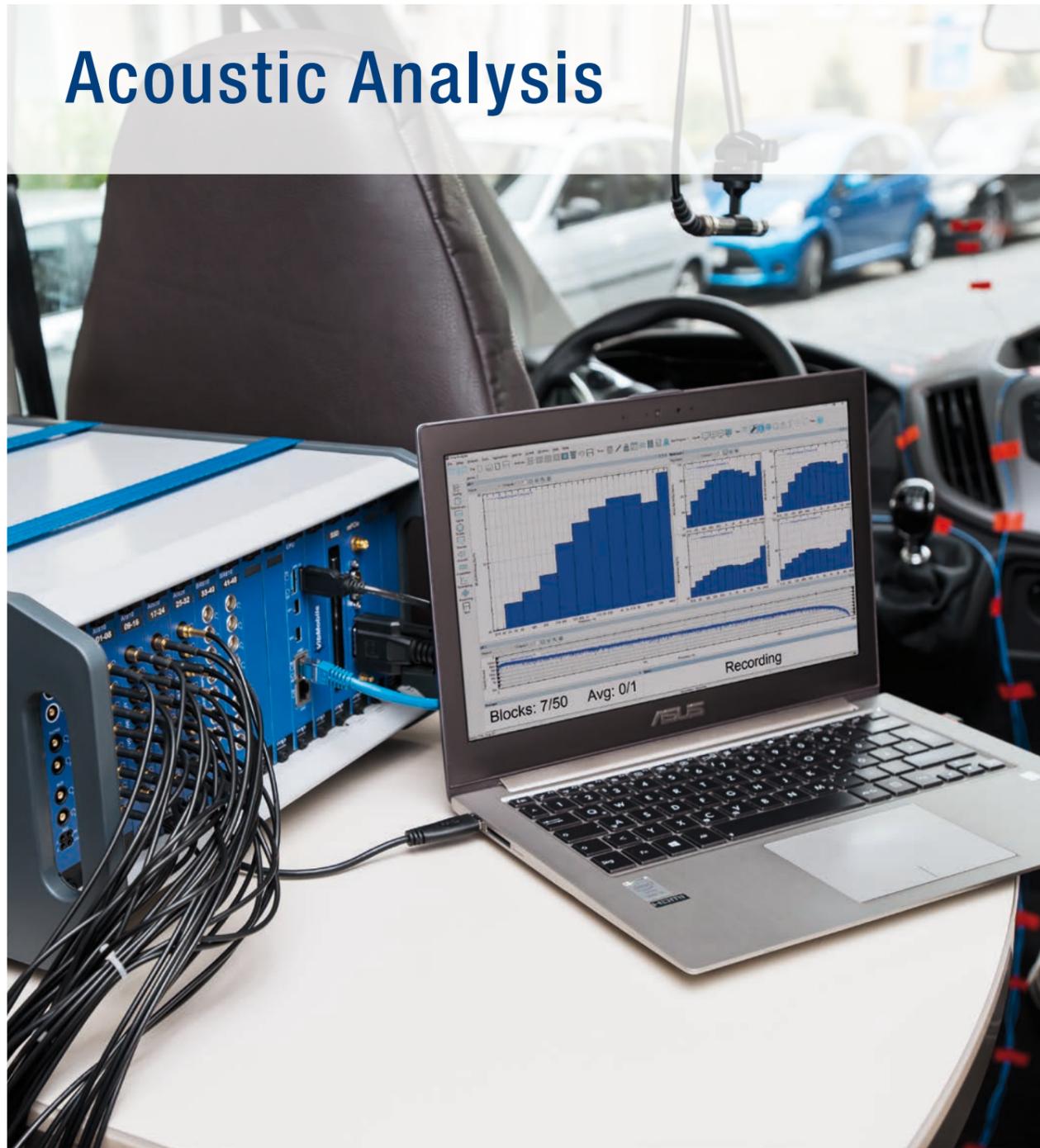
Balancing the rotor of an electric motor



Envelope analysis of rolling-element bearings: detection of cracks in race and ball/roller defects



# Acoustic Analysis



Noise is increasingly the subject of new regulations for the protection of human health and safety as well as for improving the environment in general. As well as sound levels, the perceived sound quality of products from washing machines to vehicles is often an important part of the customer purchasing decision and must be considered during product development.

m+p Analyzer provides a full range of capability for these applications. Real-time fractional octave filters satisfy all acoustic applications from simple sound pressure, sound power for equipment legislative requirements, intensity mapping to isolate sources to sound quality metrics for

product refinement. All this in parallel with narrowband analysis and time history throughput to disc for fully detailed analysis online and offline post-processing of any data source.

## Octave Analysis

Fully compliant with ANSI S1.4 and IEC 61672 type 1 sound meter specifications including A/B/C weighting and 1/1 to 1/24 octave spacing from 1 Hz to 100 kHz even with high channel counts. Response types include fast, slow, impulse, custom, linear average and LEQ.

## YOUR BENEFITS

- Traditional 1/3 octave sound meter features plus fractional octaves to cover all needs
- Traditional microphones and intensity probe measurements for flexibility
- Sound power procedures for all popular measurement methods with full validity analysis
- Sound power using intensity probe for use within noisy backgrounds
- Sound intensity mapping to identify and visualize noise sources
- Sound quality evaluation to refine your products
- Transmission loss, pitch, warble and tonality to develop your own quality metrics
- LOFAR and DEMON analysis for sonar applications

## Sound Meter Functions

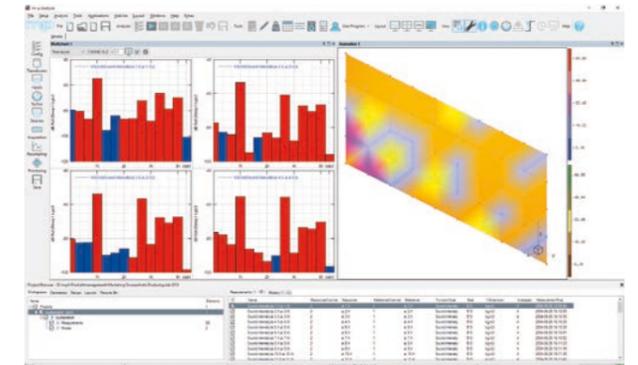
With m+p Analyzer there is no need for a separate sound level meter as these functions are already built-in with fast, slow and impulse settings, LEQ, peak hold by band or OASPL. Sound pressure histories and trends over long periods can be captured continuously or sampled.

## Sound Intensity

Sound (or acoustic) intensity can be measured in any sound field. Real-time sound intensity measurements use a standard dual microphone intensity probe calculating real-time pressure, intensity and pressure residual intensity index. This technique is directionally sensitive making it ideal for source localization or background noise cancellation. It enables accurate measurements directly in the field without the need for expensive acoustic laboratories.

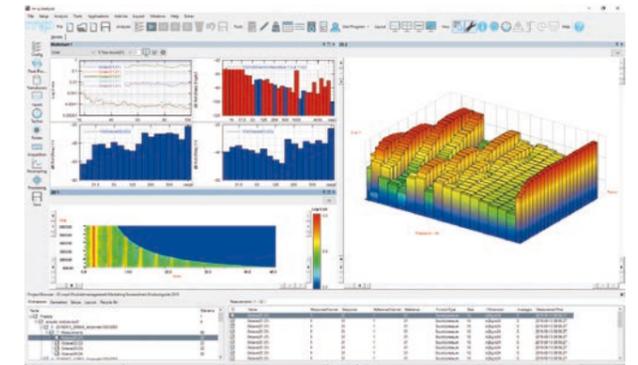
## Sound Intensity Mapping

A wire frame 3D model of your equipment under test is used to guide an operator around a sequence of sound intensity measurements. These results are then mapped to the colour coded 3D image for identification of the principal sound sources and their levels.



Sound intensity measurements

Comprehensive acoustic data analysis



*“Using m+p’s system, we were able quickly to identify the issues and the effect of component modifications, which saved us time and money. We are now looking to see how we can use the system to investigate other noise and vibration issues with a view to further improvements in design, including forthcoming electric vehicles.”*

Amit Satav, Mechanical Design Engineer at The London Taxi Company, Coventry, UK

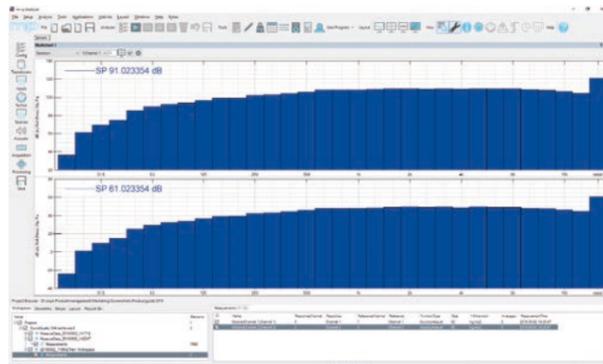


Identifying the root cause of sound issues helps making the right decisions at the design stage

**Sound Power**

Sound power is an absolute measure to determine the noise emissions of a product. All equipment from PC fans to heavy machinery must have published sound power emission levels for environmental regulation. m+p Analyzer wizards guide the operator through the maze of requirements in the ISO 374x standards and, using the intensity measurements, the ISO 9614 standards. The latter method has high tolerance to background or reverberation effects so is suitable for use in most on-site environments rather than needing expensive anechoic chambers or field sites. More specialized applications such as wind farm methods like IEC standard 61400-11 and tonality using ECMA-74 are also available.

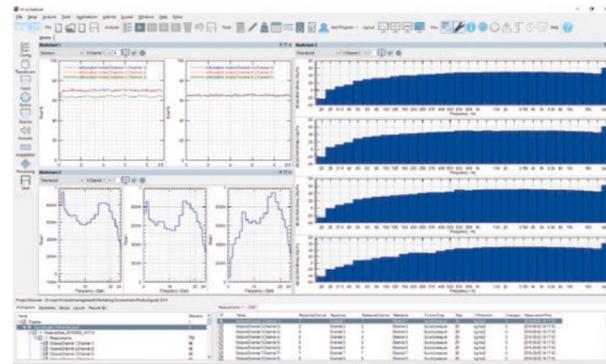
Sound power measurements



**Sound Quality**

Human perception is critical in improving product competitiveness: Designers face a challenging task in that they not only have to reduce the product noise level, but also have to find the “right” sound that attracts the customer. Sound quality metrics can be used to rank and evaluate different product designs. The basis of the m+p Analyzer Sound Quality Analysis is Zwicker loudness according to ISO-532 and DIN-45631. The following metrics are available both online and for post-processing and can be computed from either narrowband or octave band spectra:

Sound quality for psychoacoustic noise evaluation



- Specific loudness and transient loudness (in terms of sones and bark)
- Loudness and percentile loudness time history
- Articulation index and extended articulation index time history
- Sharpness time history
- Pitch and warble analysis wizards for squeak and rattle analysis
- Statistical analysis of any function, e.g. LSF, L(10), L(50), L(90), L(n)

These functions can be viewed as 2D, 3D charts or as colour maps (spectrograms) for further detailed analysis. Other statistical tools are available for least-squares curve fitting and trend analysis which are useful, for example, in squeak and rattle evaluation.

**Human Vibration**

Alongside environmental noise, evaluation of other human factors such as hand-arm vibration from the use of power tools or the evaluation of whole body vibration from riding in vehicles as per the various ISO and BS standards are available. These include C/D/H/K weighting and functions such as VDV (vibration dose value) calculations. In conjunction with sound quality algorithms, these vibration results can form a comprehensive set of metrics for vehicle comfort assessment and refinement engineering.

**Impedance Tube Testing**

With its optional Impedance Tube Testing software package, m+p Analyzer allows the calculation of important acoustic characteristics of materials such as absorption coefficient, reflection coefficient, acoustic impedance and transmission loss coefficients based on impedance tube measurements. Measurements and calculations are possible in compliance with ISO 10534-2, ASTM E2611-12 and ASTM E2611-17. Depending on the test standard, measurements are taken in two different ways using either two or four microphones. The latter method allows calculation of the transmission loss as two microphones are placed on either side of the specimen. The software package uses pre-test

Impedance tube testing using m+p Analyzer software and m+p VibPilot front-end



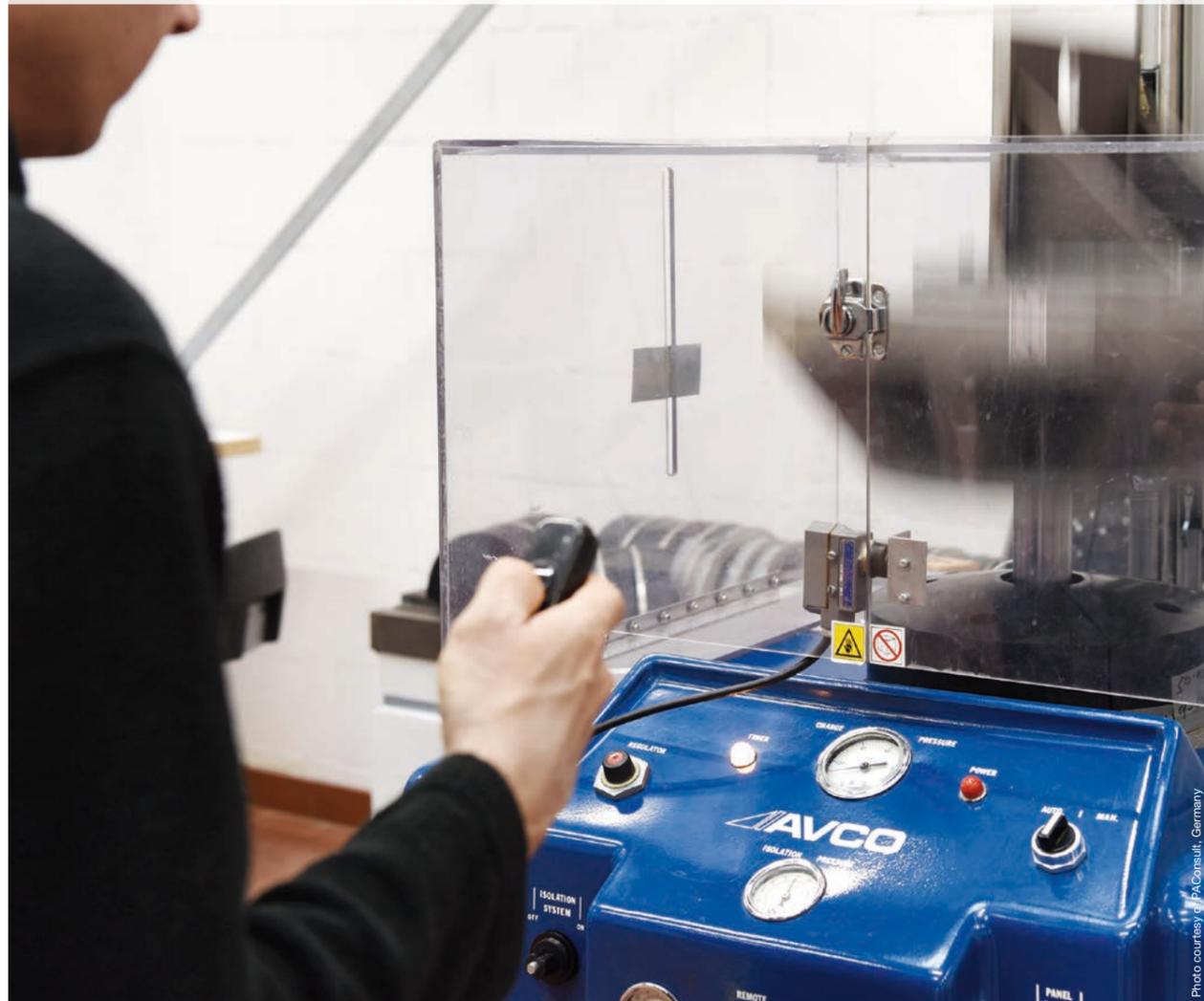
Finding the best possible sound



Measurement and evaluation of human vibrations with the aim of reducing the exposure to these vibrations

measurements to establish the signal-to-noise ratio, the appropriate volume of the speaker and the calibration coefficients for microphone mismatch correction. The measurement results are displayed online and the desired acoustic coefficients are calculated. Of course, all results can be gathered together into a report, including the setup, the results and specific information of the test.

# Environmental Vibration Testing



Whether for independent monitoring or just adding additional channels to an existing vibration controller, m+p Analyzer provides an ideal solution for measuring vibration and other responses during a shaker test or with shock machines:

## Random Vibration

Power Spectral Density (PSD) data with single or multiple average results can be computed during the vibration test run. m+p Analyzer's "scope mode" allows pre-monitoring of the test start-up before averaging starts and averages can be manually reset if required during the process. Transfer functions, coherence and many other functions

are easily included for a more thorough analysis of the test data. Sampling frequency and various measurement windowing can be selected for full compatibility with the vibration controller.

## Swept Sine Vibration

m+p's expertise in vibration control technology has been embedded into m+p Analyzer to give accurate and fully compatible swept sine tracking results using the COLA output reference. Sampling, bandwidth and result estimator filters can all be selected to match the controller or indeed used to provide alternative higher resolution results for example. As with all test modes, time history recording can

## YOUR BENEFITS

- Independent response channel monitoring for test data security
- Cost effective for addition of large number of monitoring channels
- Fully compatible results with vibration controller so easy to combine data
- Data reduction in all test modes for flexibility and integrity
- Throughput to disc recording at any sample frequency
- Powerful sequence of event analysis on largest of time history files
- Integrated modal analysis for on-the-spot mode shape animation
- Built-in m+p VibControl test report templates
- Utilize same hardware as m+p VibControl for improved hardware utilization
- Acceptance and qualification testing of shakers

be run in parallel for post-processing or detailed sequence of event analysis. Post-processing of both m+p VibControl and m+p Analyzer time history recordings provide the opportunity to re-analyze data runs with different settings such as filter bandwidth, etc. as well as doing sequence of event analysis of a premature test abort.

Calculations are also done of pulse duration, peak amplitude, velocity change and within limits so that these data and their pass/fail criteria are displayed for each pulse immediately on capture. Special report templates that handle control and triax response channels automatically make for rapid report generation.

## Classical Shock

For use with shaker tests, drop tables, pneumatic hammers or any other shock machines, the classical shock capture wizard enables a full test specification to be entered and overlaid with the measurements. Control and response channels can be independently filtered in real time to avoid out-of-band noise and the result limit overlays are automatically adjusted to best fit the triggered shock waveform.

## Shock Response Spectrum

Online and offline wizards are available to cover all aspects of capturing and reporting SRS data. These can be used with shaker or shock machine testing and include limit overlays for instant test assessment and report generation. As well as real-time low pass filters, the online wizard computes the standard maximax results whereas the offline wizard computes all intermediate SRS functions as well as displaying the actual time response waveforms at each frequency for the most detailed of analyses.

Shock Response Spectrum testing using an impact hammer



## Throughput to Disc Recording and Post-Processing

All test modes allow in-parallel throughput to disc recording so that the raw sample data is available for post-test analysis. This is particularly useful for sequence of event analysis if the vibration test should abort mid-test. Multi-gigabyte file sizes can be quickly reviewed and zoomed for detailed cross channel analysis. Peak time histories are computed and kurtosis time history provides a more sensitive identification of transient events in the data. Furthermore all data reduction test modes can be re-run on the recorded data for more detailed analysis using alternative settings.

## Shaker Qualification

m+p Analyzer provides an advanced software tool for acceptance tests and regular qualification tests of shakers. Total harmonic distortion, amplitude uniformity, table lateral vibration ratio and other relevant measures are evaluated to verify functionality and performance data and to minimize the risks of downtime and associated costs.

# Data Acquisition and Monitoring m+p Coda



# Data Acquisition, Signal Analysis and Condition Monitoring



Photo courtesy of Siemens AG, Germany

## YOUR BENEFITS

- Complete turnkey solution for highest test efficiencies
- Mobile and stationary data acquisition and monitoring
- Scalable from 2 to more than 2,000 channels to match your test requirements
- Ethernet, USB, LXIbus-based acquisition hardware from different manufacturers
- Sample rates from 1 Hz to 125 kHz
- Online data access from any networked PC
- Support of all common types of transducers and sensors
- Automatic instrument identification and configuration for fast and easy test set-up
- Full-featured alarm monitoring and event handling
- Different user interface languages supported
- Standalone data acquisition for environments where PCs cannot go

m+p Coda is a full-featured software platform for data acquisition, signal analysis and monitoring. Complete turnkey operation provides quicker time to test by eliminating costly application programming and long learning curves. The extensive built-in features and tools offer a functionality that was previously available only in custom packages. The intuitive GUI facilitates set-up, operation and analysis, thus leading quickly to precise, repeatable results.

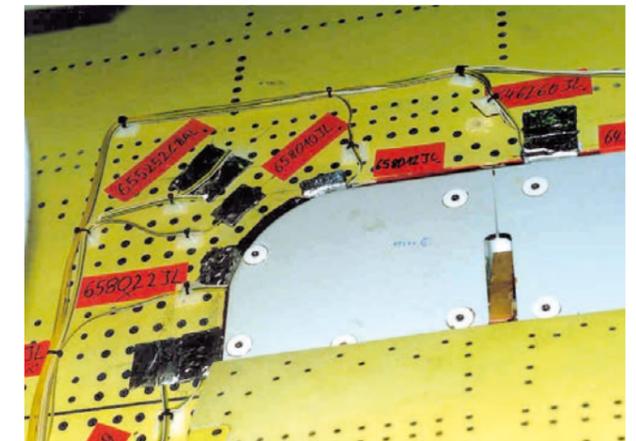
## Extensive Application Coverage

Thanks to its modular structure and easy parameterization, m+p Coda is the perfect solution for a wide range of measurement applications in industry and in the laboratory:

- Measurements and data analysis on test stands and test assemblies
- Performance, functional tests and condition monitoring of turbocompressors, gas and steam turbines, jet engines, rocket engines, gearboxes, generators
- Experimental structural testing, multi-axis strain and stress analysis
- Process monitoring in power plants, in refineries, on production lines
- Vibration monitoring during shaker tests
- Standalone data acquisition applications

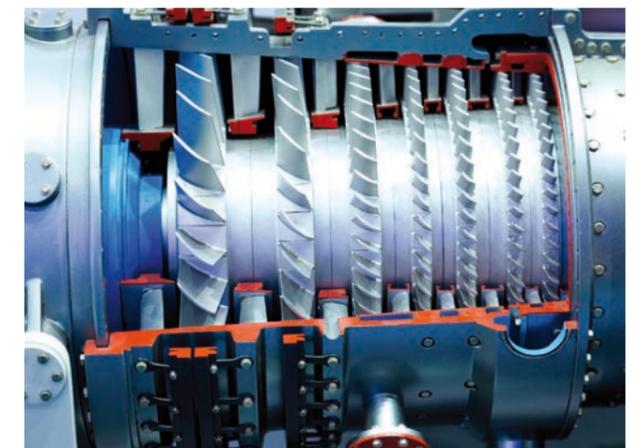
The acquisition system processes virtually every physical quantity, for example: temperature, voltage, stress, strain, pressure, force, acceleration and frequency. Even high-channel count applications using thousands of channels can be configured within a very short time and are handled safely and efficiently.

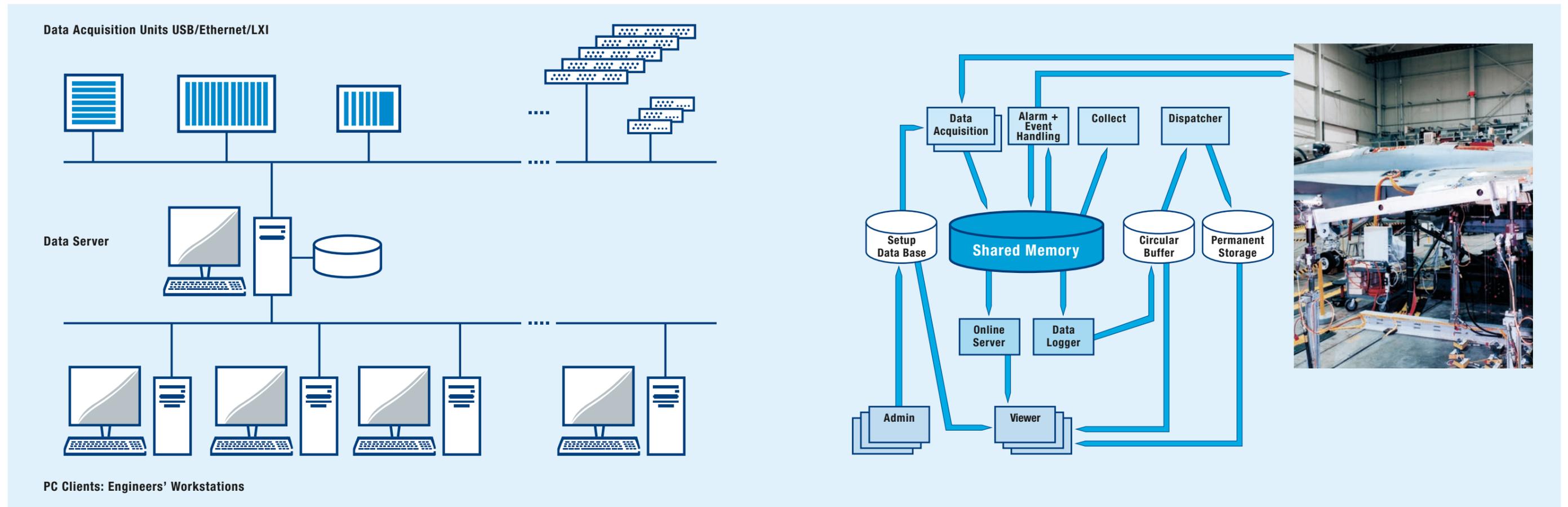
Features include measurements with single- and multi-channel strain gauges, real-time strain and stress calculations, limit checking and communication with the load control system.



Strain measurements on an aircraft

Performance and functional tests of turbines





**Instrumentation**

m+p Coda supports a range of USB, Ethernet and LXIbus-based instruments from established manufacturers. These instruments are known for their high performance, measurement accuracy and reliability. Users can select their preferred acquisition hardware for any test size. Other or existing acquisition devices can be integrated and communication with subordinate process computers for data transfer is also provided.

**Client/Server System**

The client/server architecture allows several test engineers to have concurrent online access to the acquired data for display and analysis operations. The online server approach also ensures reliable data archival and retrieval with integrated error diagnostics to guard against connection and data access issues.

**Modular System for any Test Size**

The modular architecture makes this package ideal for any test requirement, from tens to thousands of channels. m+p Coda can be expanded at any time to tackle additional tasks and higher channel counts.

**Powerful Data Management**

Configuration data are stored in a central SQL database for maximum flexibility and repeatability. m+p Coda stores and processes the acquired data in its uniform data model. Even different sampling rates for data groups or data acquired asynchronously are permitted. As a rule, the measured raw data are always stored to ensure access to the original data at any time.

**Automatic Instrument Identification and Channel Configuration**

Using a simple mouse-click, m+p Coda is able to identify the connected measurement hardware including across different manufacturers. The hardware will be listed together with some additional information in a table. The user selects the required instruments, whose samples rates can be different, for the subsequent parallel measurements. A channel configuration wizard, with user-definable default values, is also available. Additionally, virtual instruments can be selected for simulation purposes. The m+p Coda functionality is the same for real and virtual instruments.

*"We found m+p a capable and experienced engineering partner to develop and realize a state-of-the-art measurement system for our turbomachinery test field. They were able to integrate our existing proven and reliable software package for thermodynamic analysis into their Coda solution and to successfully implement our new highly efficient data acquisition and monitoring system."*

Manfred Praus, Manager of the Metrology and Electrical Assembly Department at Siemens AG, Duisburg, Germany

Set-up: connected measurement hardware is automatically identified

Discover and Select Instruments							
Discovered Devices							
Select	Master/Slave Order	Interface	Model	Manufacturer	Serial Number	IP Address	Vendor/Slot
<input type="checkbox"/>	S0 Slave 1	TCPIP	VbMobile	m+p international	VM08-10012		
<input checked="" type="checkbox"/>	S0 Master	TCPIP	VbMobile	m+p international	VM08-10026		
<input type="checkbox"/>	S0 Slave 2	TCPIP	VbMobile	m+p international	VM08-10028		
<input checked="" type="checkbox"/>		TCPIP	SIMULATOR	m+p international	1	1	
<input checked="" type="checkbox"/>		TCPIP	EX1016A	VTI Instruments Corporation	121002	1.20.0.122	
<input checked="" type="checkbox"/>		TCPIP	NI-9213	National Instruments	01B2F3A4	1.20.0.135	1
<input checked="" type="checkbox"/>		TCPIP	NI-9215	National Instruments	01B346DF	1.20.0.135	2
<input checked="" type="checkbox"/>		TCPIP	NI-9402	National Instruments	01B18FBA	1.20.0.135	7
<input checked="" type="checkbox"/>		TCPIP	EX1629	VXI Technology Inc.	119637	1.20.0.170	
<input type="checkbox"/>		TCPIP	SIMULATOR	m+p international	2	2	
<input type="checkbox"/>		TCPIP	SIMULATOR	m+p international	3	3	
<input checked="" type="checkbox"/>		USB	USB-6001	National Instruments	0198C18B		

### Standalone Data Acquisition

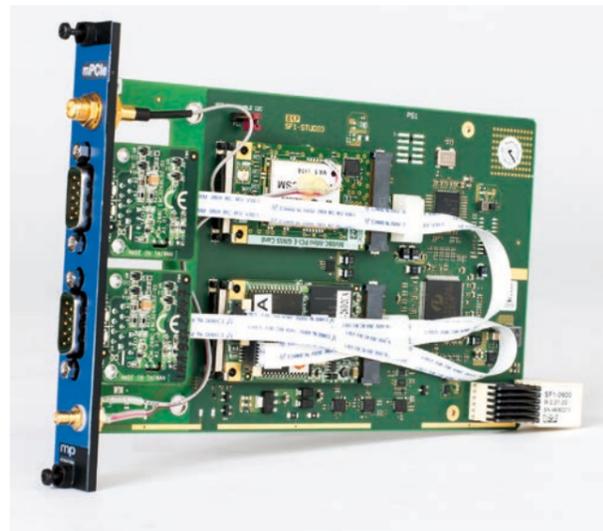
For standalone acquisition m+p Coda is used with the m+p VibMobile front-end. The application software is installed on the embedded CPU to which monitor, keyboard and mouse are connected. The data will be stored on an onboard SSD disc. You can analyze this data either directly on the monitor or on a remote PC or laptop.

### Measurement Functions

m+p Coda supports 1/4-, 1/2-, full-bridge configurations, rosette type sensors, standard thermocouple types (J, K, T, E, S, R, B, N, and user-definable) as well as voltage and current transducers. During the test run the relative zero point (or reference) of all or selected channels can be acquired at any time. A GPS receiver can be connected for time and location information as well as CANbus interfaces.

### Data Storage

Powerful storage functions allow for data management and temporary or permanent, preprogrammed or event-controlled data storage for all or selected channel groups.



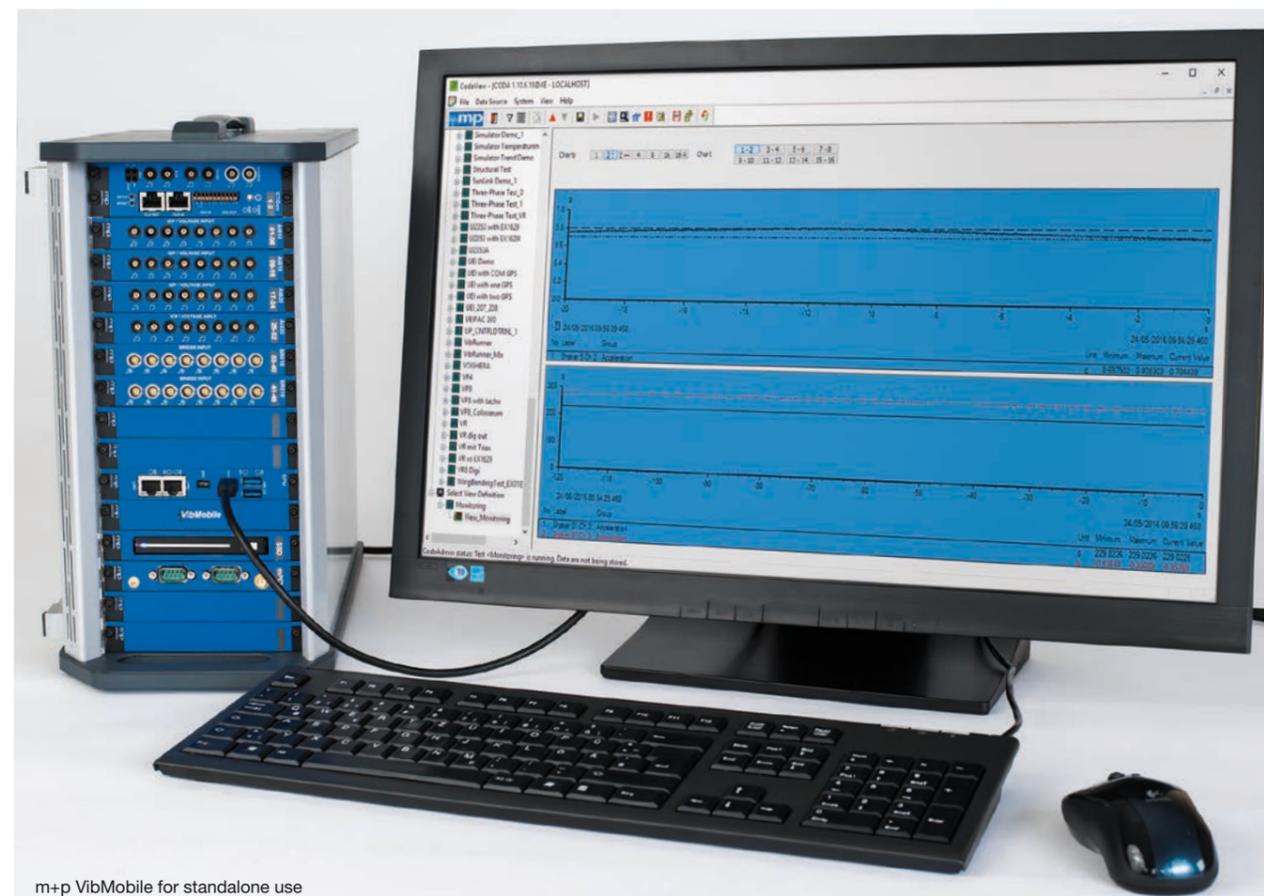
Two-port CANbus and GPS receiver on a single board

### Channel Grouping

Channels can be sorted into user-definable groups (e.g. sensor types, sub-assemblies of a large structure). Filtering channels according to groups simplifies configuration and subsequent analysis.



m+p Coda supports performance and functional testing of rocket engines



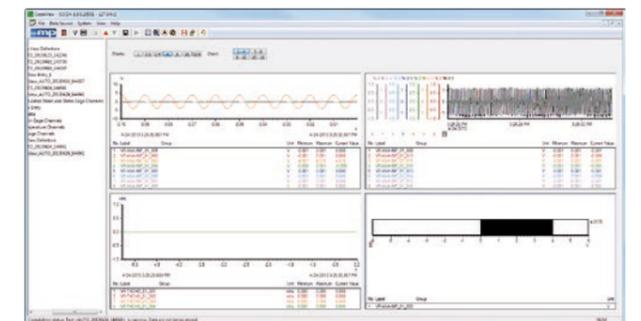
m+p VibMobile for standalone use

### Real-Time Alarm Monitoring

Full-featured limit checking and alarm monitoring capability for all active channels. Out-of-limit data is displayed in a separate window and logged.

### Comprehensive Visualization

As with the online data analysis, the measured values can be graphically displayed in a y/t- or y/x-diagram, as bar chart, tachometer, waterfall, FFT, PSD or digital numbers by a simple mouse-click. m+p Coda allows the user to design individual graphical interfaces.



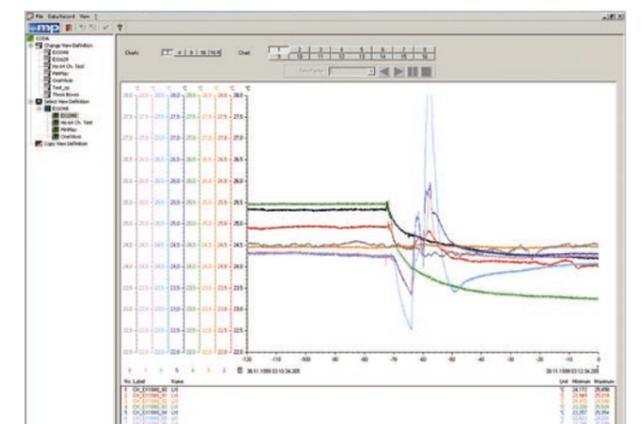
CodaView windows: displaying the channels in a multitude of ways

### Advanced Analysis and Reporting

Convenient analysis tools are included for viewing measured data. The ultimate step is using the m+p eReporter software. It provides test engineers with powerful tools for the most demanding analysis and reporting tasks.

### Data Export

The formatted data of selected or all channels can be easily exported into Excel, ASCII, MATLAB, m+p Analyzer or other popular analysis packages.



# Application Examples



glance. Alarm events are entered into a log file and can be reviewed at any time. You have the option to change the alarm limits online at any time without stopping the data acquisition.

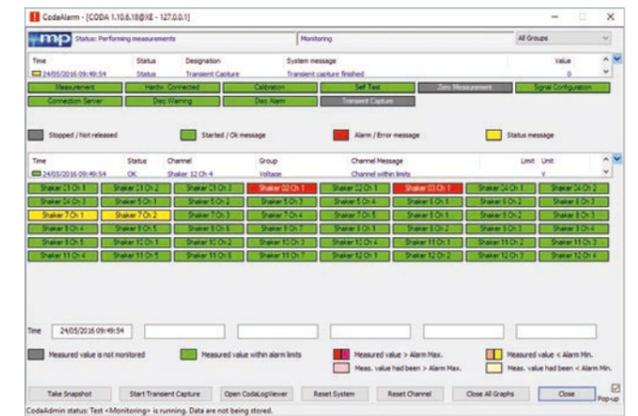
### Monitoring of Piping Systems

The mandatory inspection of piping systems in power plants is challenging because of their length and the severe environmental conditions. The networked monitoring system consists of the m+p Coda acquisition software installed on a standard PC and DAQ instruments which are located directly at the pipes.

m+p Coda supports hundreds of channels to measure and monitor the thermal expansion, temperature, pressure, vibration and weight of the pipes. These measurements are taken by using thermocouples, LVDT (Linear Variable Differential Transformer) sensors, pressure transducers and strain gauge load cells.

### Multi-Channel Monitoring of Turbocompressors

Turbocompressors for the oil, gas and process industries undergo comprehensive testing. m+p Coda is used for continuous data acquisition and real-time monitoring of performance data and thermodynamic parameters. Several compressors can be tested in parallel. To meet different demands, m+p Coda is available as a high-channel count stationary system as well as a rugged mobile system for acquisition and monitoring under original conditions at customers' sites.



Alarm window: alarm monitoring allowing the user to see the current status at a glance

### Vibration Monitoring during Shaker Test

Vibration tests must be safe and reliable and this is especially true for high value specimens. m+p Coda captures and records signals such as acceleration, temperature and strain during vibration tests, irrespective of the vibration control system in use. It allows you to set alarm limits for test shutdown or a warning on any of the active channels. Specimen and shaker are reliably protected, e.g. against misconfiguration or defective sensors.

Multi-channel monitoring of compressors and piping



The following examples illustrate some of m+p Coda's typical acquisition and monitoring tasks.

### Condition Monitoring

m+p Coda is a versatile monitoring system that captures and records signals coming from sensors such as accelerometers, thermocouples, strain gauges, and pressure transducers.

Limit checking and alarm monitoring is provided for every active channel. The active channels are clearly displayed in a separate window, out-of-limit data can be seen at a



Experimental structural testing in the aerospace industry



Thermo-Man® mannequin equipped with 122 heat sensors



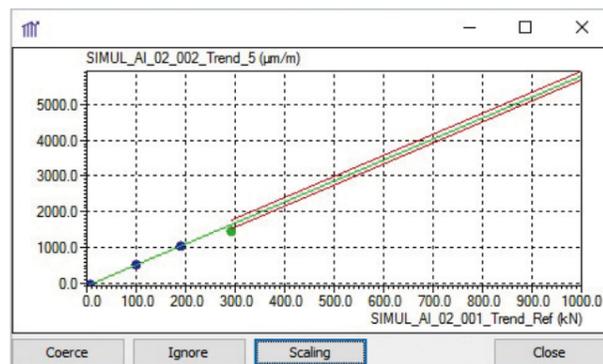
Thermo-Man® in action

### Strain Measurements and Experimental Stress Analysis

Experimental structural testing using strain gauges is necessary in a wide range of applications from airframes and sub-assemblies down to individual components such as turbine blades, satellites, wind turbines and many others. These tests enable the engineers to compare the acquired data with the predicted results from the design calculations.

Its modular design and easy parameterization make m+p Coda ideally suited for experimental structural testing and multi-axis strain and stress analysis. Features include measurements with single- and multi-channel strain gauges, real-time strain and stress calculations, limit checking and communication with the load control system. m+p Coda provides limit checking and alarm monitoring on every channel.

m+p Coda supports 1/4, 1/2, full-bridge configurations and rosette type sensors, also thermocouples and RTDs for temperature compensation are supported. An optional linear trend of strain gauge signals allows tracking with respect to the reference channel (e.g. force).



Linear trend tracking of strain gauge signals

m+p Coda supports the 8-channel bridge module VRBR810



### Temperature Measurements

Temperature is one of the most common types of measured quantities. With m+p Coda, you can measure temperature in various environments and for various test requirements. It also addresses demanding distributed measurement applications over large distances. m+p Coda accepts all standard thermocouple types and RTDs. Open channels are marked by the software.

Applications include:

- Climatic chamber testing
- HALT/HASS testing
- Temperature acquisition in turbine test cells for jet engines
- Vibration testing of exhaust systems with hot gas
- Temperature measurements of solar modules
- Testing of heat protective clothing



Testing in a thermal vacuum chamber

*“Your folks have done a great job converting our software requirements specification into an efficient GUI that addresses our specific needs. We look forward to continue working with m+p as we further refine the Thermo-Man® software package.”*

Roger Parry, Principle Investigator at DuPont Protection Technologies, Richmond, Virginia/USA

# Test Stand Engineering

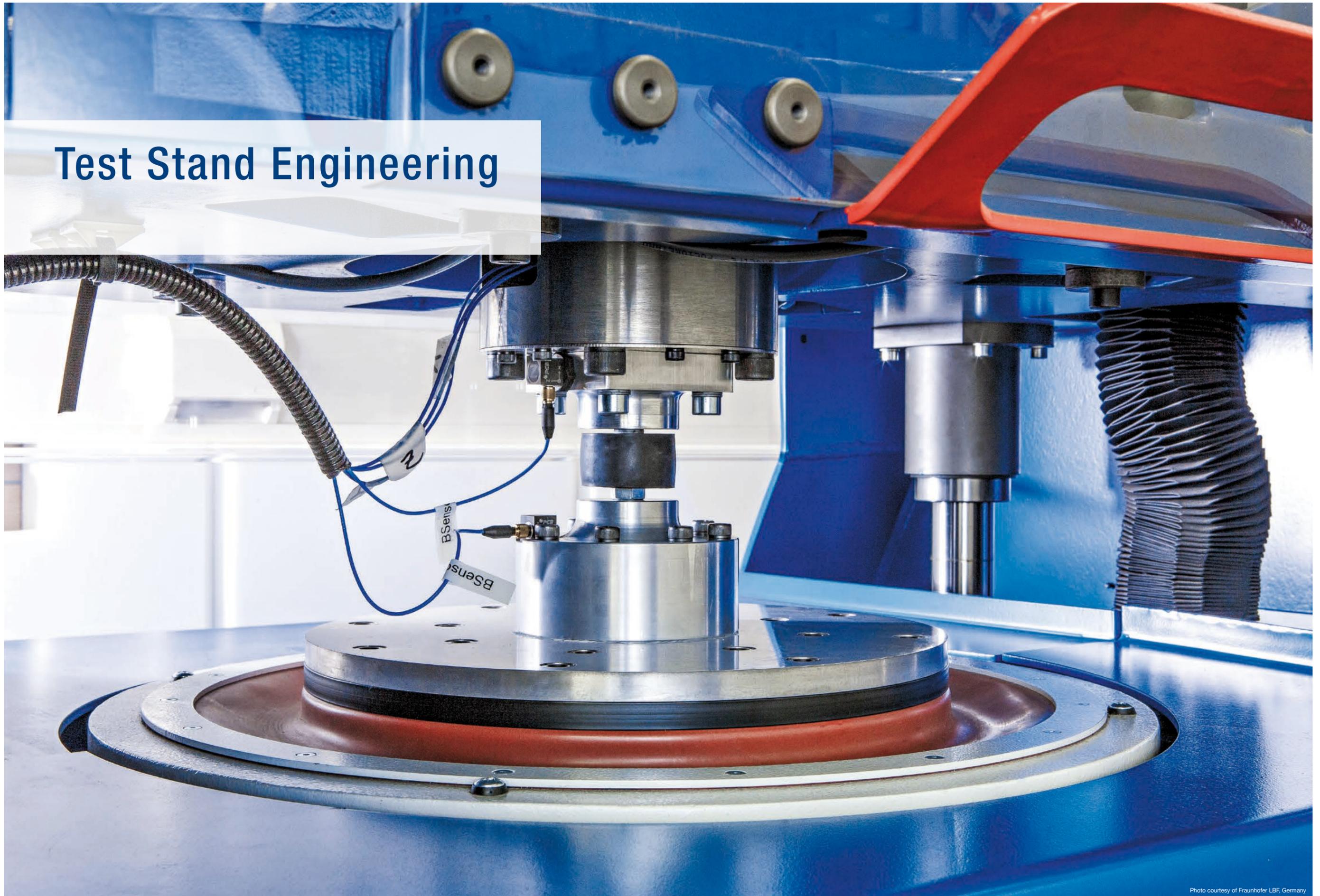


Photo courtesy of Fraunhofer LBF, Germany

# High-Frequency Testing of Elastomer Mounts

## m+p HFDST-3000-E



m+p HFDST-3000-E high-frequency test rig: measuring the dynamic stiffness of elastomer mounts up to 3,000 Hz



### High-Frequency Dynamic Stiffness Test Rigs for Elastomer Mounts

Car manufacturers are making ever greater efforts to generate a specific driving experience for the customer, which is essentially determined by the vibration and acoustic refinement. The sources of the noise and vibration, such as the engine and transmission or the exhaust system, must be supported by suitable mounts which are capable of being durable as well as able to attenuate noise and vibration transmission.

Modern elastomer mounts for supporting these systems are thoroughly investigated and optimized for their specific application. Dynamic stiffness is a key criterion in mount

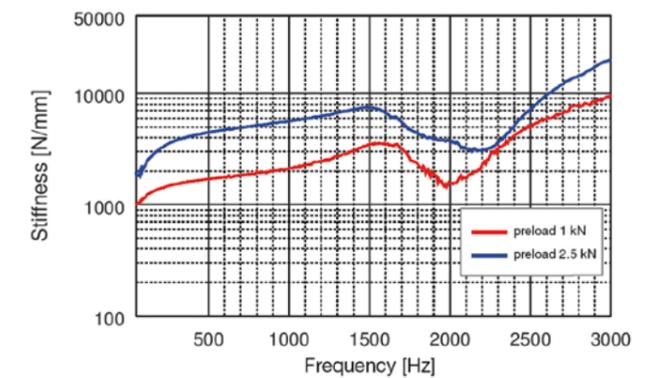
optimization and describes the reaction force of an elastomer mount due to deformation. Driven in particular by e-mobility, the test spectrum for determining dynamic stiffness is changing towards ever higher frequencies.

With the m+p HFDST-3000-E, m+p international has developed a new generation of test rigs, which measures the dynamic stiffness of elastomeric mounts up to 3,000 Hz with a simultaneous static preload of 5,000 N. The purpose is to characterize a wide range of different engine mounts, chassis mounts, suspension bushes, vibration absorbers, etc. dynamically under static preload.

Safe operation is a top priority: The test rig adheres to the latest safety regulations and the EU Machinery Directive 2006/42/EC. During operation, a fully enclosed test chamber protects the operator from all hazards. No person can unintentionally intervene in the test chamber.

The concept of the m+p HFDST-3000-E is based on a specially adapted electrodynamic shaker. The test specimen is mounted between the shaker and a seismic mass, which can be lowered to apply a static preload from 0 to 5,000 N. The test mode is automatically controlled by the well-proven m+p VibControl vibration control software. It enables users to easily parameterize the measurement and control channels and provides a variety of tools for the analysis of elastomeric mounts. During testing, dynamic stiffness and loss angles of the mounts are calculated and displayed online. Thus, the user has an overview of all important parameters at any time.

Due to the multitude of test specimens with different geometries and stiffnesses, a suitable test fixture is required to adapt each specimen to the shaker and the force sensor. These fixtures need to be designed carefully with the test frequency range of up to 3,000 Hz in mind. m+p international offers the design and manufacturing of these fixtures as a service along with the test rig.



Dynamic stiffness determined with a preload of 1 kN (red curve) and 2.5 kN (blue curve)



Elastomer mounts used in cars

*You will find this requirement for high-frequency evaluation up to 2 kHz in almost every specification. [...] Almost everyone wants to have its components dynamically measured and evaluated up to 2 kHz.*

Reinhard Eder, Head of Testing at SumiRiko AVS Germany GmbH, Steinau an der Straße, Germany

# Test Stand Solutions



Three m+p ACON stations operated in parallel

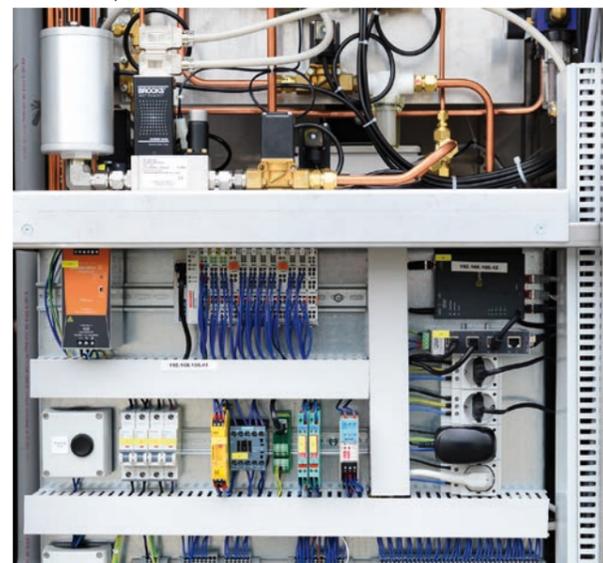
## Evaporative Emission Testing

Emissions from vehicles do not only come from the exhaust produced by the engine but also evaporate from the rest of the vehicle (mainly the fuel systems). Activated carbon canisters prevent evaporative hydrocarbon emissions escaping into the environment from the fuel tank.

With m+p ACON, we provide a fully automated canister conditioning and test system which meets the latest EPA, CARB, EU and Chinese requirements using butane/nitrogen and fuel vapour procedures. The test reliably verifies the correct functioning of the canister and is mandatory for subsequent evaporative emission measurements in the SHED chamber. The m+p ACON system controls and monitors the preconditioning procedure, records the results and displays the current state online on the monitor.

m+p ACON supports both in-vehicle and benchtop operations which can be left unattended.

Inside an m+p ACON station



## Exhaust Systems Test Stand

We do not only design and construct new test stands, but also help customers improve the performance and capabilities of their existing test stands. For example, we have updated and perfected an integrated exhaust systems test rig.

To realize the communication with the new m+p vibration control system, our engineers modified the existing ignition system control software which was achieved without the need for any additional hardware. The updated system controls the synchronization of the ignition and vibration test cycles and also detects and safely handles fault conditions. With the expertise of m+p engineers, vibration testing has been matched to the customers' special requirements, providing a much wider range of experimental testing methods.



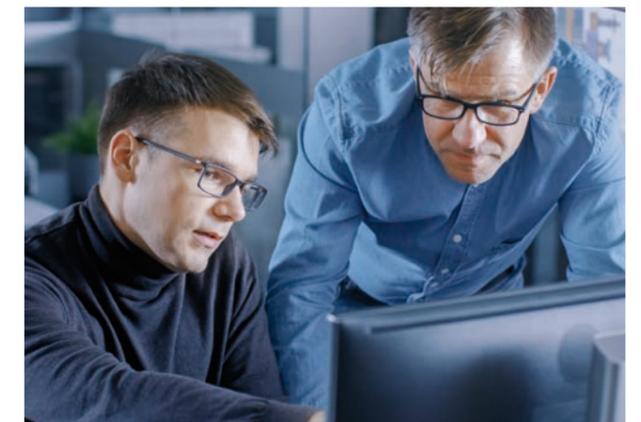
Exhaust systems test stand

## Engineering Expertise and Innovation

m+p international has been designing, developing and fabricating vibration and functional test stands for many years. Our engineers apply the latest techniques and a broad range of know-how and experience to create innovative solutions. A track record of successfully implemented test stands is proof of our expertise.

All these test stands are built in close co-operation with our customers and in accordance with their specifications. Often venturing into uncharted technological terrain, these requirements are frequently at the limits of what is technically possible.

Our engineering department would be pleased to help you solve your demanding test tasks.



Experienced and young engineers work hand in hand at m+p international

*"m+p always considers customers' requirements as first priority, doing their best to adapt controllers and design-specific software during operation. We also appreciate the quick response and after-sales support."*

Levin Sun, Component Test Manager at Faurecia Emissions Control Technologies, Shanghai, China



# Measurement Hardware m+p Vibxx

# Precision Instrumentation Built to Your Specific Needs



We tailored our measurement hardware specifically for the requirements of noise and vibration analysis, vibration testing and dynamic data acquisition: m+p VibPilot is a compact 4/8-channel instrument, the high-channel count m+p VibRunner can be used as desktop instrument or mounted into a 19" rack and the multi-channel m+p VibMobile combines channel density and robustness with versatile signal conditioning.

There is an m+p system for every application. Configure your measurement hardware exactly to your needs.

Our solution-oriented approach provides outstanding performance at an excellent price-performance ratio. Measurement hardware from m+p international achieves the highest reliability and system longevity.

Designed to be used with our proven m+p VibControl, m+p Analyzer and m+p Coda software solutions, m+p international hardware covers a wide range of applications:

- Vibration testing on electrodynamic and hydraulic shakers
- Multi-axis vibration testing
- Multi-channel vibration data acquisition including data recording and continuous time history recording
- Noise and vibration testing
- Structural testing
- Modal analysis and impact testing
- Rotating machinery analysis
- Data acquisition
- Experimental stress analysis
- Temperature measurements
- Process and condition monitoring
- Acoustic control in a reverberant chamber or direct field environments
- Test stand engineering



High-precision 24-bit D/A converter

*To keep you ahead of your competition, our measurement hardware is designed to put your products at the forefront for performance, durability and quality.*

“m+p was selected because of the flexibility offered by the modular controllers, intuitive front-end and the excellent support received from m+p over recent years.”

Richard Thompson, Environmental Test Manager at TÜV SÜD Product Service Ltd, Fareham, UK

# Compact 4/8-Channel Front-End m+p VibPilot



## KEY FEATURES

- 4 or 8 analog input channels
- 204.8 kHz simultaneous sampling
- IEPE sensor conditioning user selectable on each channel
- TEDS support
- 2 source output channels
- Safety shutdown and power loss protection for source channels
- 2 tacho inputs
- Digital I/O's for remote control, e.g. climatic chamber control
- DSP powered real-time processing
- Synchronization of multiple m+p VibPilot front-ends
- Ethernet and USB host interfaces
- Dust-proof, rugged housing
- Battery option
- Fan-less, noise-free operation
- AC/DC supply floating or grounded, only 20 W power consumption

With the 4/8-channel m+p VibPilot, m+p international sets a new standard for affordable performance in vibration control and dynamic signal analysis. m+p VibPilot is based on the latest generation of IC technology resulting in high-precision measurement ability and impressive real-time performance in signal analysis.

without influencing their excellent measurement performance. This allows you to use additional channels (e.g. 2 x 8 input channels) or to combine vibration tests and dynamic signal acquisition applications with ease. m+p Analyzer for noise and vibration analysis supports up to six m+p VibPilot devices with a total of 48 input channels.

## Operation Indoors and Outdoors

Compact and rugged, m+p VibPilot has a robust look and feel and a clearly arranged front panel with four or eight BNC connectors. Thanks to its dust-proof design, you can operate it indoors or outdoors even under harsh conditions. m+p VibPilot provides both Ethernet and USB connectivity to a host PC or laptop and is operated by either an external AC mains power supply or by a DC supply, e.g. for in-car operation. The fan-less, noise-free operation facilitates noise measurements requiring a quiet environment.

Battery operation enables portable applications in the field and in the lab: Whether you want to take professional on-site measurements, do some quick troubleshooting in the field or place the instrument close to the specimen and sensors to minimize cable runs and noise. The optional battery is helpful in all test environments where no power supply is available.

## Support of Multiple Front-Ends

To extend input channel capability, m+p VibPilot devices can be synchronized via the clock in/clock out circuitry

m+p VibPilot. Small in size. Huge in performance.



**Input/Output Channels**

Equipped with 24-bit sigma-delta A/D converters with up to 204.8 kHz sampling rate, m+p VibPilot allows for alias-protected measurements in a frequency range up to 80 kHz and with more than 120 dB spurious-free dynamic range. The analog input circuits have advanced sigma-delta converters which offer advantages such as simultaneous sampling by independent A/D converters on each input, reduced noise and improved accuracy due to 64 times oversampling on each input. Both analog and digital filtering are used for full aliasing protection and they provide excellent low-level signal-to-noise performance and differential linearity. The input voltage range of  $\pm 1$  V and  $\pm 10$  V peak full scale is selectable per channel.

As well as normal differential voltage inputs with AC/DC coupling, signal conditioning for the analog input channels also provides source capabilities for IEPE sensors, including cable break indicators, and an interface for accessing standardized Transducer Electronic Data Sheets (TEDS). TEDS support allows automatic front-end setup based on information stored in the transducer, e.g. sensitivity, calibration data and serial number.

Two precision low-noise analog outputs are available together with hardware shutdown circuitry which ramps down the source signals in a controlled manner in case of emergency.

**Tacho Inputs**

Two tacho inputs are included with 32-bit high-speed up/down counters for rotational vibration measurements or for use as COLA synch inputs for shaker sine reduction applications.

**Digital Inputs/Outputs**

Eight digital inputs and eight digital outputs enable engineers to directly execute control functions for combined environmental tests (climatic chamber control) or for parallel functional tests of the specimen. Individual tests can be easily combined in any complexity of nested loops.

**Dynamic Signal Processors**

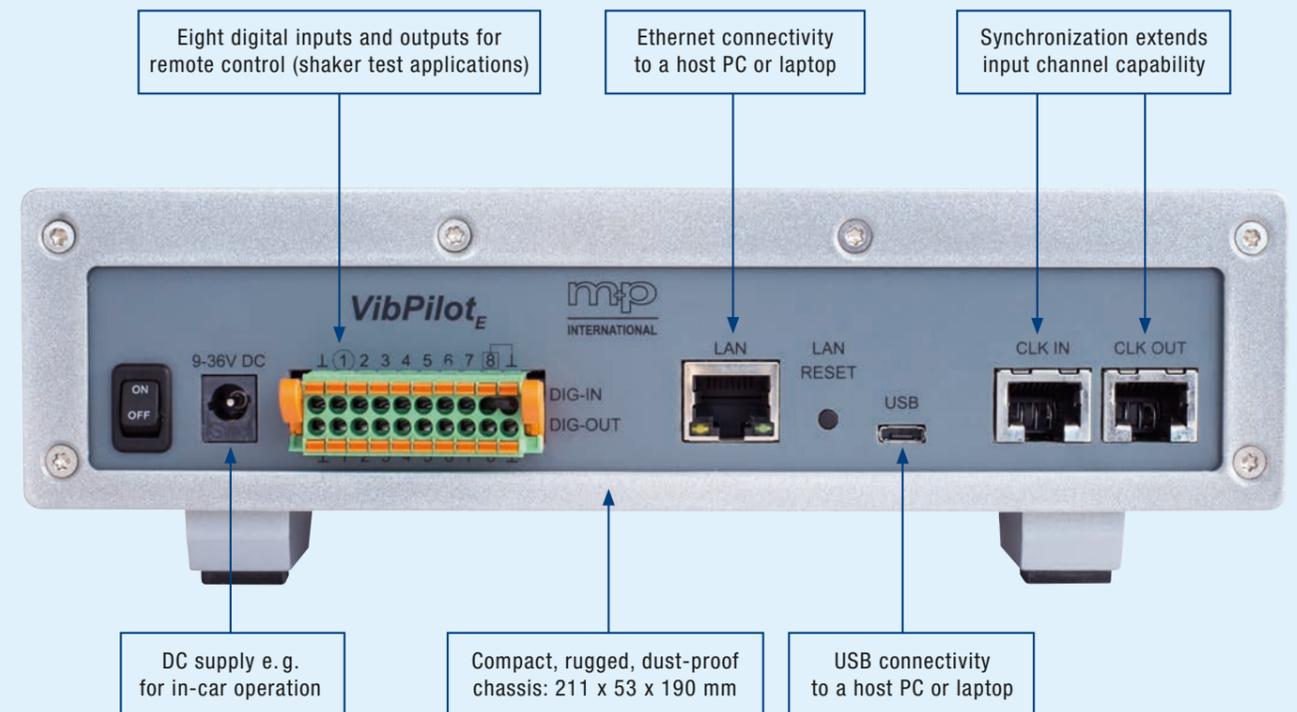
Two 300 MHz floating-point dynamic signal processors in each m+p VibPilot pre-process the data, thus guaranteeing the high performance and short control cycles.



4-channel m+p VibPilot



8-channel m+p VibPilot



# High-Channel Count Hardware Platform m+p VibRunner



## KEY FEATURES

- Desktop instrument or 19" rack-mounted system, 1U high
- AC and DC power supply, multi-range, silent operation, temperature-controlled fan
- Precise synchronization of multiple m+p VibRunner instruments
- DSP powered real-time processing and 1 Gbit/s Ethernet host interface
- Up to 24 analog input channels, 24 bits, 204.8 kHz max. sampling rate per channel, voltage, IEPE, bridge sensor conditioning
- Tacho inputs, source channels with emergency shutdown, digital I/O

m+p VibRunner is our measurement hardware platform for higher channel counts, designed for the specific needs of noise and vibration engineering and general data acquisition such as strain and temperature measurements. This solution-oriented approach provides superb performance at an excellent price-performance ratio.

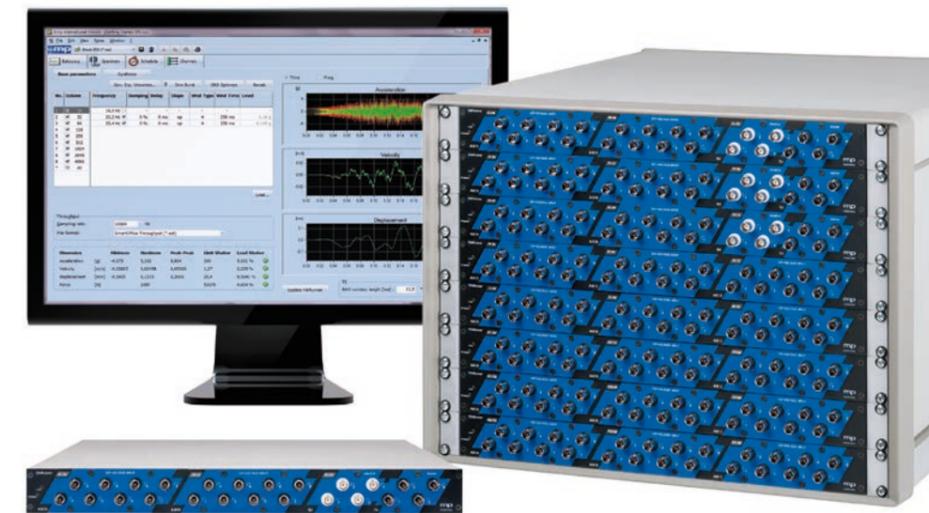
The hardware platform is ideal for projects such as engine test cells, where high data throughput is important; large structures where distributed inputs reduce sensor cabling; large channel count requirements such as sensitive satellite pre-flight testing; or simply where a wide range of testing needs demand the ultimate flexibility in test system configuration.

It integrates seamlessly with our m+p VibControl, m+p Analyzer and m+p Coda software products.

### Desktop or Rack Mounted

m+p VibRunner provides maximum modularity. The basic unit is a 19" mainframe that houses up to three front-mounted functional modules. The 1U mainframe can be equipped with feet for use as a desktop instrument or with mounting brackets for 19" rack mounting.

m+p VibRunner is equipped with multi-range AC and DC power supply. Cooling is performed by a high-quality, silent

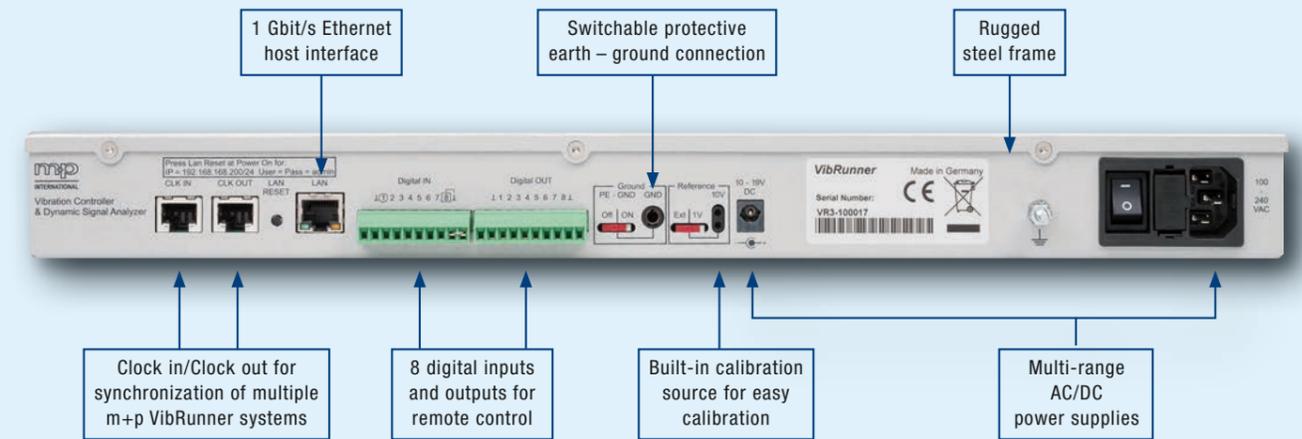
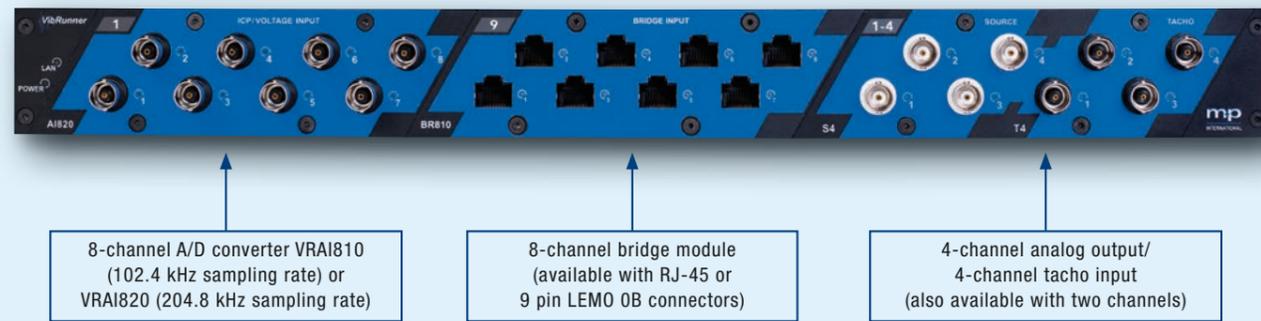


Configure m+p VibRunner to your precise needs.

fan whose speed is temperature-controlled. For sensitive noise measurements the fan can be turned off from the host PC.

### Scalability and Synchronization

For applications requiring a high number of measurement channels, data acquisition over multiple m+p VibRunner systems will be exactly synchronized. This is made possible by making the master clock available to all slave mainframes. For measurements of large objects, the m+p VibRunner systems can be placed close to the measuring points which minimizes costly transducer cabling.



**Digital Inputs/Outputs**

Each instrument has a digital interface with 8 inputs and 8 outputs (5 V TTL). These inputs/outputs enable engineers to directly execute control functions for combined environmental tests or for parallel functional tests of the specimen.

**Power of Ethernet**

The 1 Gbit/s Ethernet interface is used for communications with the host PC. To ensure safe and fast communication even with many input channels, the m+p VibRunner hardware is integrated into its own, independent subnet. High channel counts increase the required data rates considerably, but m+p international's choice of the Ethernet standard means that the host PC system can be configured using common off-the-shelf technology, including very powerful server systems.

**Input Channels**

m+p VibRunner provides high-precision measurement capability and outstanding real-time performance. With 24-bit sigma-delta A/D converters with up to 204.8 kHz sampling rate, it allows for alias-protected measurements in a frequency range up to 80 kHz and more than 120 dB spurious-free dynamic range. Input ranges are selectable from 100 mV to 20 Vpk, low noise and selectable high-pass input filtering allow for versatile acoustic measurements and pyro-shock capture. The input channels can be switched between single-ended and full differential mode, thus allowing potential-free measurements such as those required on bridge circuits. TEDS (Transducer Electronic Data Sheet) support is a time-saving tool to automatically enter information stored in the transducer, e.g. sensitivity, calibration and serial number. Operators can individually switch the IEPE power supply for every input channel.

**Strain Measurements**

The 8-channel bridge module VRBR810 enables experimental stress analysis and structural testing. It contains quarter-, half-, and full-bridge support. The built-in bridge excitation and completion is individually programmable for each channel, thus making time-consuming hardware re-configuration of different gauge types unnecessary.

The BR3205RJ (BR1605RJ) is a bridge instrument for strain gauge measurements, offering 32 (16) programmable input channels. It covers a large range of test and measurement applications from 16 to hundreds of input channels.

**Output Channels**

Additional m+p VibRunner modules provide analog outputs for vibration testing or modal analysis applications requiring a drive signal for the shaker. And here again, m+p VibRunner is optimally tuned to meet the specific requirements: high-precision 24-bit D/A converters are sampled by the master clock in the same way as the A/D converters on each input to ensure the excellent phase stability of the measurements. In case of emergency (for example, at power failure or when the connection to the host PC is lost), the source signal will be ramped down in a controlled manner to avoid damage to the specimen or the test equipment. This automatic, analog shutdown circuitry guarantees the highest safety possible during the test.

**High-End Solutions for Data Acquisition and Signal Analysis**

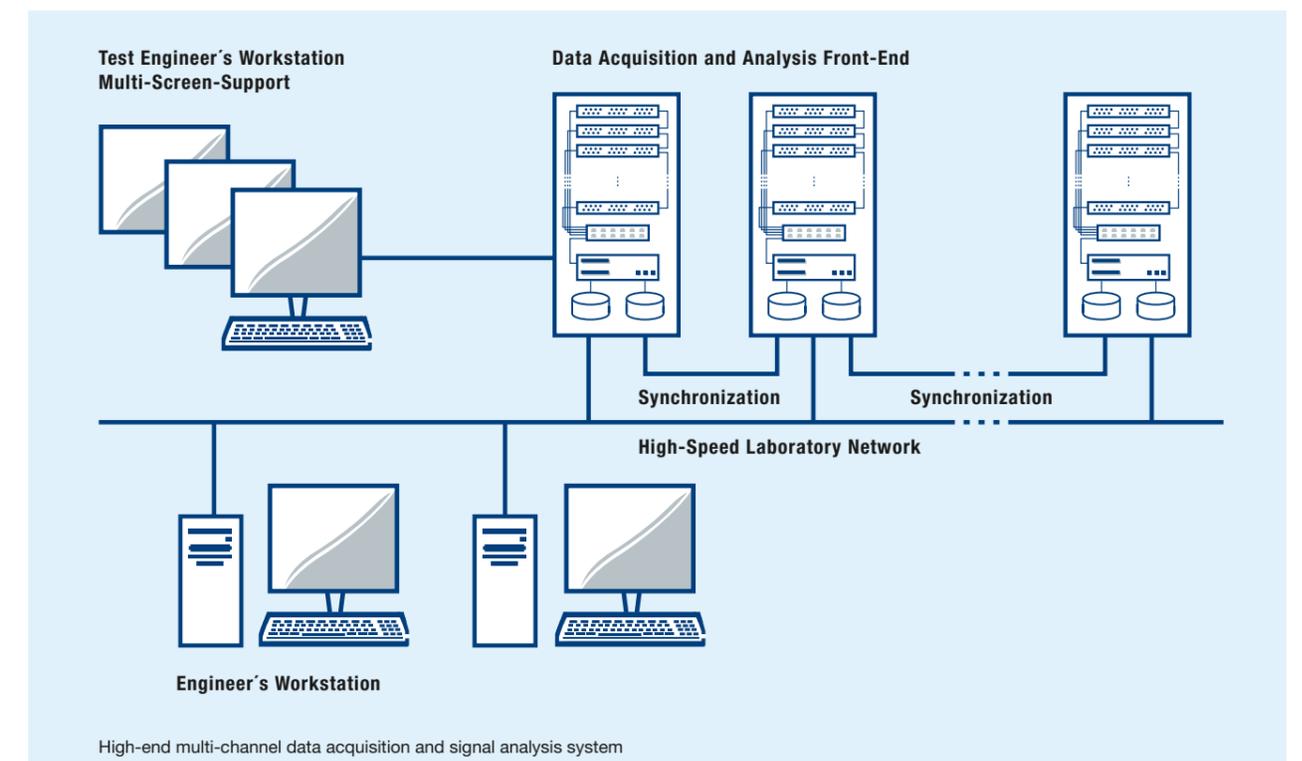
Based on our powerful software platforms we offer m+p VibRunner hardware configurations tailored to the specific needs of high-performance and multi-channel measurement applications.

The 24-channel m+p VibRunner front-ends are installed in a 19" cabinet to make up a 256-channel data acquisition system. For high-speed data processing and continuous data recording, a powerful data server is supplied with the data acquisition system. This data server can be equipped with terabyte disc storage to guarantee high-speed recording and fast data access.

If even higher channel counts are required, e.g. for sophisticated aerospace testing applications, several

systems can be combined. The measurement systems can be placed close to the measuring points and be synchronized over several hundred metres, thus minimizing transducer cabling and increasing flexibility of the test system configuration.

The data model ensures access to all input channels during setup, online monitoring and post-test analysis, no matter on which hardware unit within the network the channel is located.



# Mobile Multi-Channel Front-End m+p VibMobile



## KEY FEATURES

- Portable, for field and laboratory use, battery option, rugged housing, silent operation
- Embedded CPU i7 2.4 GHz, QuadCore, 8 GB DDR3L, 2 x GBit Ethernet, one of them supporting IEEE 1588 precision time protocol, SATA 6G Raid controller for 2 onboard SSD discs, Windows 7 embedded operation system
- Counter timer module for clock generation, trigger I/O, synchronization of multiple devices, incl. 2 sources, 2 tacho ports and 4/4 digital I/O ports
- 12-slot mainframe for up to 8 m+p proprietary I/O boards and up to 4 industry-standard CompactPCI® Serial boards opens almost unlimited choice of analog and digital I/O, communication interfaces and storage devices

m+p VibMobile was engineered for the requirements of mobile multi-channel noise and vibration measurements and dynamic signal analysis as well as demanding data acquisition and monitoring applications. Including multi-range AC and DC power supply and battery option, the front-end is ideal for portable use in the field or mounted in vehicles as well as for use in the lab.

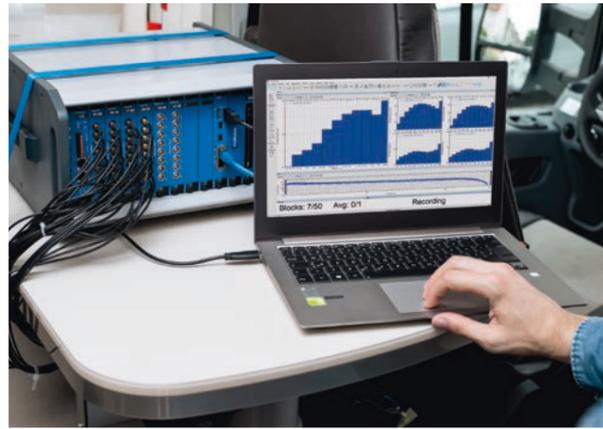
A wide choice of m+p proprietary analog I/O boards for high-speed data acquisition, simultaneous sampling, signal conditioning for voltage inputs, IEPE sensor supply and bridge measurements together with DSP powered real-time processing makes it ideally suited for all kind of measurement and signal analysis tasks. Up to four CompactPCI® Serial boards can be used additionally in the mainframe allowing for the free selection of industry standard I/O, interface and storage solutions.

The m+p VibMobile can be used as a front-end together with a remote PC or laptop or standalone by having all application software installed on the powerful embedded CPU with monitor, keyboard and mouse connected directly to the CPU. For very high channel counts and distributed measurements over long distances, several mainframes in a master-slave configuration can be used and all of them will be precisely synchronized by the master clock.

Just take your measurements, do online analysis, review the results, store raw data and results, share the results with colleagues and continue your work in the lab or in the office using the field data. m+p VibMobile fulfills both the robustness and channel density criteria needed for optimal test and measurement productivity.



Networking of three m+p VibMobile instruments housed in 19" wide shock-proof boxes



Data analysis directly in the field



Monitor, keyboard and mouse connected to CPU for standalone operation

**Use in the Field, in Vehicles or in the Lab**

The new m+p VibMobile with its compact form factor, robust design, embedded CPU and storage media and optional battery power is made for portable or standalone operation. The silent temperature-controlled fans make it ideally suited for acoustic measurements. With a broad selection of analog input and output boards and appropriate signal conditioning modules, it can be used in all kinds of dynamic and quasi-static measurement fields: noise and vibration, modal analysis, experimental strain and stress analysis, engine testing, functional testing, process monitoring etc.

**Reliable Acquisition in Harsh Environments**

The conditions under which you have to take measurements are sometimes tough. The robust steel housing qualifies the m+p VibMobile for operation under harsh ambient conditions and for high temperatures.

Lightweight polyurethane side panels provide extra protection if you carry your device. For very high shock and vibration exposure, for example during test runs in vehicles, we offer a shock-isolated mount in a strong steel box which has vapour-tight front and rear covers – also perfect for protected transport to the site.

You get reliable, accurate measuring data – anytime and anywhere.

**Networking of Multiple Systems**

For channel expansion and distributed measurements multiple m+p VibMobile front-ends can be combined to act as one system. The daisy-chained master-slave configuration makes it possible to place the front-ends close to the measuring points, resulting in reduced transducer cabling and much higher measurement quality. Fully synchronized, precise data from all devices are transferred via GBit Ethernet lines to the host PC and stored consistently in one measurement file.

**Analog and Digital I/O Boards and Signal Conditioning**

For NVH test and measurement applications we offer two sigma-delta A/D converters, 102.4 or 204.8 kHz sampling rate, each with 8 channels, configurable input architecture and gain as well as multiple clocking and trigger options. The switchable input voltage ranges provide improved sensitivity for very low level vibration signals and microphone measurements as well as higher voltage sources such as tachometers. 24-bit resolution, full anti-aliasing protection and more than 120 dB spurious-free dynamic range make these digitizers high-precision instruments for measurements in frequency ranges up to 40 or 80 kHz. The channel type can be switched between full differential and single-ended, thus enabling potential-free measurements. Other functions include TEDS support, IEPE sensor conditioning, cable break and overload detection.

The 102.4 kSa/s per channel bridge module is perfect for dynamic strain measurements, experimental stress analysis



- ① Control unit CTGen incl. two analog outputs, two tach channels, two auxiliary digital inputs
- ② 8-channel A/D converter VMAI810 (102.4 kHz SR) or VMAI820 (204.8 kHz SR), SMB connectors
- ③ 8-channel bridge module (available with 9 pin LEMO 0B or 7 pin LEMO 1B connectors)
- ④ 8-channel A/D converter VMAI810BDBW (102.4 kHz SR) or VMAI820BDBW (204.8 kHz SR), BNC connectors
- ⑤ Embedded CPU
- ⑥ Removable disc drive
- ⑦ Two-port CANbus and GPS receiver

and fatigue testing of mechanical structures. It enables connection of eight strain gauges in full-, half-, or quarter-bridge configurations. Up to 64 channels, all precisely synchronized, can be connected to one m+p VibMobile. Robust, reliable LEMO connectors are used for the 6-pin wiring. All channels support TEDS for fast and secure system set-up.

A 24-bit D/A converter provides four analog outputs for vibration testing or modal analysis applications requiring drive signals for the shakers. Control circuitry is implemented on all source channels for a controlled shutdown of the output voltage signal in case of emergency or power failure ensuring safe operation of the test system.

Tacho inputs with 32-bit high-speed up/down counters allow for rotating machinery testing. Digital inputs and digital outputs support various testing tasks such as combined environmental tests (climatic chamber control) or parallel functional tests.

**CompactPCI® Serial Boards**

m+p VibMobile covers many of your day-to-day data acquisition and dynamics testing tasks. And we will add more and more I/O boards to complete our offer for even more application ranges. For special requirements the m+p VibMobile has four slots of the industry-standard CompactPCI® Serial bus for freely selectable, 3<sup>rd</sup> party boards like mega-sampling high-speed transient recorders, GPS receivers, RS-232 or RS-485 serial interfaces, Fieldbus, CANbus, IRIG or ARINC time protocol interfaces and also fixed or removable disc modules with terabytes of storage space. We offer a selection of these boards as standard solutions, supported by our application software suites. Other boards may require a tailor-made solution which will be integrated on demand.



Removable disc for data storage

# Third-Party Measurement Hardware

## Wide Variety of Front-End Technology Supported

For highest system flexibility, our software products support not only m+p's own precision instrumentation, but also measurement hardware from other manufacturers. Our unique concept allows the user to select his preferred measurement hardware for any test

size. He can benefit from our software solutions without having to abandon the measurement hardware he has been successfully working with for many years. Our software is fully maintained and supported for the long term as well as being quicker to get up and running for your testing projects.

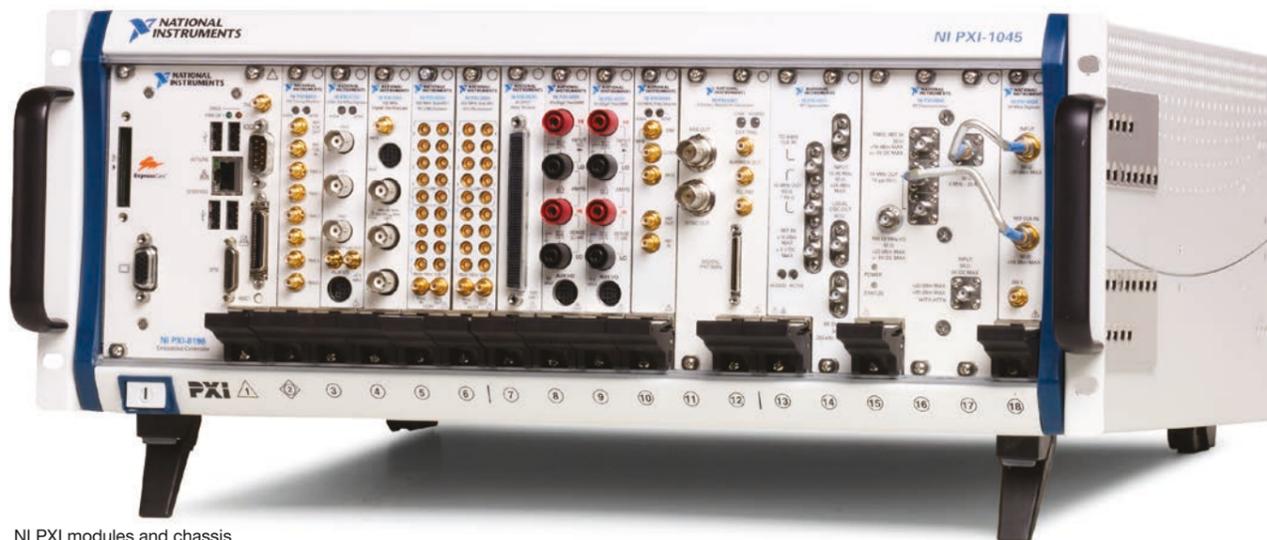
## General-Purpose Data Acquisition

With the m+p Analyzer, m+p international offers fully integrated multi-application NVH software that supports a wide range of National Instruments instrumentation as well as several digital USB devices and Spectrum PCI Express cards. Compared to a tool-kit approach, m+p Analyzer is a complete solution, from taking measurements, to generating reports, and taking care of all the complications of signal processing issues and data interpretation.

Operated with National Instruments high-precision data acquisition cards, m+p Analyzer is a flexible real-time analyzer for sensor and electrical measurements in the lab or in the field. It integrates seamlessly with National Instruments USB, Ethernet, Wifi, PCI and PXI modules for analysis, display and reporting.



m+p Analyzer and m+p Coda support National Instruments DAQ hardware



NI PXI modules and chassis



Mix of Spectrum PCI Express cards and m+p VibMobile front-ends in shock-isolated, vapour-proof boxes

m+p Analyzer software uses the plug-and-play simplicity of USB modules to acquire data from a multitude of sensors. With the popular PXI/PCI modules from National Instruments, it is utilized for sound and vibration applications, structural testing and strain measurements.

For on-the-go vibration measurements, m+p Analyzer supports pocket-sized, 2-channel IEPE hardware with standard USB audio digital output: the 485B39 signal conditioner from PCB/The Modal Shop as well as the PCB 633A01 and Digiducer 333D01 digital accelerometers.

High-speed multi-channel data acquisition applications are implemented using Spectrum PCI Express cards, M2i

and M2p families. This hardware is fully integrated into our m+p Analyzer to allow user-friendly setup, dynamic signal acquisition and comprehensive reporting.



Digital IEPE-USB signal conditioner 485B39

## Multi-Channel Data Acquisition

Our m+p Coda software supports proven instrumentation from VTI Instruments and National Instruments for multi-channel data acquisition and signal analysis.

For thermocouple and voltage measurements, the m+p Coda data acquisition software can be operated with the scalable, standalone 48-channel LXibus-based EX10xA series instruments. When combined with the LXI-based EX1629 remote strain gauge measurement unit, m+p Coda provides a powerful solution for static and dynamic structural tests, e.g. on aircraft and rail vehicles, and general multi-channel data acquisition.

In addition, m+p Coda supports the highly accurate thermocouple, analog input and digital I/O modules from National Instruments. Communication with the NI CompactDAQ chassis is done via Ethernet or USB.



VTI EX 1048A thermocouple measurement instrument



VTI EX1629 remote strain gauge measurement instrument



# Services and Support



## Software Updates and Revisions

We protect your investment in the long term – this is part of our product philosophy. Thanks to the modular design of our software products, they can be configured and expanded to meet other test requirements at any time.

m+p international provides customers with regular software updates which offer revised and enhanced software features to increase further the software performance. These updates result primarily from close co-operation with our customers and their valuable feedback. Software revisions keep your software up-to-date with the newest technology and ensure that it is compatible with the latest advances in hardware and operating systems.

## Hardware Warranty and Repair

Measurement hardware from m+p international achieves the highest reliability and system longevity. All functions are thoroughly checked and documented using automatic test procedures before they leave production. The hardware is calibrated and documented with a full calibration certificate.

Our measurement hardware is delivered with a 12-month or optionally 24- or 36-months warranty.

We provide a fast return-to-m+p repair service. Skilled service engineers use only original spare parts to ensure quality repair work and long service life for the measurement hardware.

## Hotline Support

If you need help, please call our hotline during normal working hours. Our experienced support engineers will assist you by phone or email. They will check the reported problem and provide the best solution as quickly as possible. Support covers every aspect of our products, from installation of software updates to specific test set-ups and understanding of analysis functions.

## Calibration Services

m+p international offers on-site or return-to-bench commercial re-calibration for all its measurement hardware. Keeping your equipment at peak precision by calibrating it minimizes your testing downtime. Regular calibration of your m+p international systems is not only an investment in quality; it is also a valuable tool to save costs. Errors caused by inaccurate or invalid measurements can become very expensive, e.g., if they necessitate product recalls. The system calibration includes system verification, calibration of all modules and system, system check, cleaning of the filters as well as a calibration certificate.

A2LA (DAkkS, NIST, UKAS) accredited ISO/IEC-17025 calibrations are provided by a third party, even on-site at the customer's location.



## Rental

If you lack instrumentation for special vibration measurement projects or when your instrumentation is being repaired, we offer short-term rental of our measurement hardware. This allows you to do your testing job at any time using the latest hardware technology.

## Training Classes

Gain valuable know-how in our training and seminar programs. Our practice-oriented training classes for users at different levels cover all aspects from the basics of vibration testing to in-depth expertise on special applications.



*The technical support from training to consultancy to user support and hardware calibration from m+p international is excellent.*



Christophe Barthes, Manager of the Environmental Testing Department at Continental Automotive, Toulouse, France

# References

This list gives some of the companies that chose m+p international to solve their test and measurement tasks.

## AUTOMOTIVE & SUPPLIERS

- Advanced Comfort Systems, France and Spain
- ARDIA, Tunisia
- Aston Martin, UK
- Autoliv, France and Sweden
- Bentley Motors, UK
- Bosch Automotive, China, France, Germany, Italy and Spain
- Boysen, Germany
- BYD Company, China
- Continental Automotive, China, France, Germany, India and Romania
- Cooper Tire, USA
- Cummins, China
- Daimler, Germany and USA
- Delphi Automotive, China and France
- Dongfeng Motor Group, China
- Eberspächer, Germany and USA
- Faurecia, China, France and Germany
- FAW Group Corp., China
- Ford Motor Company, Turkey and USA
- Honda Research, Germany
- Hyundai Motor Company, South Korea
- Knorr-Bremse, Germany, Italy and UK
- Mahle Behr, Austria, Germany and India
- PATAC, China
- Perkins Engines, UK
- Porsche, Germany
- Renault Sport Racing, UK

- SAIC Volkswagen, China
- SKF, France
- Tenneco, USA
- Toyota, UK
- Tyco Electronics, France and Spain
- Valeo, France and Tunisia
- Volkswagen, Germany
- Volvo, Sweden
- Volvo Trucks, France
- Westfalia, Germany
- Williams F1, UK
- ZF Friedrichshafen, Germany

## SPACE & AVIATION

- Academy of Aerospace Liquid Propulsion Technology (AALPT), China
- Academy of Aerospace Solid Propulsion Technology (AASPT), China
- Airbus Defence and Space, Germany, Spain and UK
- Auxitrol, France
- AVIC Aircraft Strength Research Institute, China
- AVIC Beijing Aeronautical Manufacturing Technology Research Institute, China
- Boeing, USA
- Bombardier Aerospace, UK
- BUAA, China
- Centre Spatial de Liège, Belgium

- Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP), China
- Changhe Aircraft Industries Group, China
- China Academy of Launch Vehicle Technology (CALT), China
- China Academy of Space Technology (CAST), China
- China Electronics Technology Group Corp., China
- Cobham Mission Systems, UK
- COMDEV, Canada and UK
- Dassault Aviation, France
- DLR, Germany
- Goodrich, USA
- Harris, USA
- Honeywell Aerospace, UK
- IABG, Germany
- IAI, Israel
- IAS, France
- INPE, Brazil
- ISRO, India
- Goodrich, USA
- Labinal Power Systems, UK
- Lockheed Martin, UK and USA
- Max-Planck-Institut, Germany
- Meggit Avionics, UK
- MTU Aero Engines, Germany
- NASA GRC, GRC-PBS, GSFC, JPL, KSC, LARC, MSFC and WWF, USA
- Nord-Micro, Germany
- Pratt & Whitney, USA
- RAL, UK
- Rolls-Royce, Germany
- RUAG Space, Austria
- Saab Ericsson Space, Sweden
- Safran Aircat Engines, France
- Safran Zodiac Aerospace, France
- Shenyang Engine Design & Research Institute, China
- Spire Global, UK
- SSTL, UK
- Tesat-Spacecom, Germany
- Thales, France, Netherlands and UK
- Turkish Aerospace Industries, Turkey
- Ultra Electronics, UK
- ZARM, Germany

## DEFENCE

- AIM Infrarot-Module, Germany
- Airbus Defence and Space, Germany, Spain and UK
- Atlas Elektronik, Germany
- Auxitrol, France
- AWE, UK
- BAE Systems, UK
- Boeing, USA
- Bofors, Sweden
- Dassault Aviation, France
- Diehl, Germany
- Leonardo, UK
- Lockheed Martin, UK and USA
- Martin Baker, UK
- MBDA, Germany and UK
- Meggit Avionics, UK
- Northrop Grumman, USA
- QinetiQ, UK
- Rafael, Israel
- Rheinmetall, Germany
- Safran Electronics & Defense, France
- Thales, France, Netherlands and UK
- Ultra Electronics, UK
- WTD, Germany

## TELECOM/ELECTRICAL

- Amphenol-Tuchel, Germany
- Esterline, France
- Fujitsu, Germany
- Grass Valley, Netherlands
- Hewlett-Packard, USA
- Hirschmann, Austria
- Johnson Controls, Italy
- Kodak, USA
- L-3 Communications, USA
- Lear Corporation, France, Germany and Italy
- LG Cable, South Korea
- Motorola, Germany
- Panasonic Electric Works, Germany
- Philips, Belgium
- Texas Instruments, USA
- ZTE, China

**OTHER INDUSTRIES**

- Alstom Nuclear Power, France
- Cummins, UK
- Danfoss, Denmark
- Deutsche Bahn, Germany
- Doosan Babcock, UK
- Doosan Corporation Mottrol, South Korea
- DuPont, USA
- Husqvarna, Sweden
- Korail, South Korea
- Laser Zentrum, Germany
- Parrot, France
- PTB, Germany
- Seagate, Singapore
- Siemens, Germany
- Stihl, Brazil and Germany
- Still, Germany
- Swarovski, Austria
- WEG Euro, Portugal
- Vestas, UK

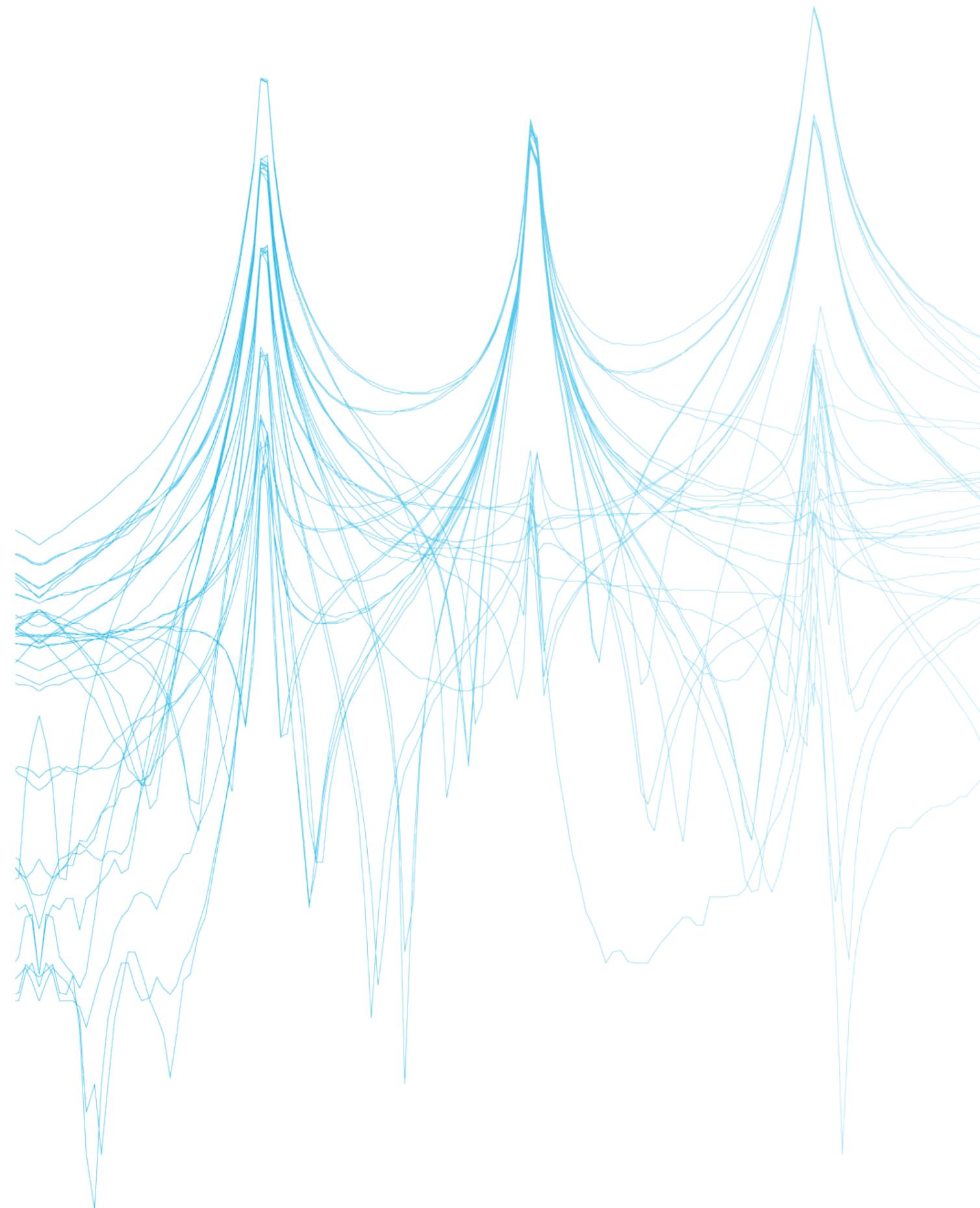
**TEST HOUSES**

- Adetests, France
- Bertrandt, Germany
- CSA Group, Canada
- Dayton T. Brown, USA
- Delserro Engineering, USA
- EDAG Testing, Germany
- E-Labs, USA
- Element Materials Technology, Germany, UK and USA
- ELTEC, France
- Environne'Tech, France
- Eurofins, Finland
- GREE, China
- HORIBA MIRA, UK
- Intertek, UK
- KAIST, South Korea
- Mecano ID, France
- Midea, China
- miTechnology, UK
- NTS, USA
- Phönix, Germany

- RST, Germany
- Sci-Labs, Canada
- SGS, France and Germany
- Stirling Dynamics, UK
- Telus, Germany
- Treo, Germany
- TÜV SÜD, Germany and UK
- VDE, Germany
- VTT, Finland

**R&D/EDUCATION**

- Beijing University, China
- Cnam, France
- Cranfield University, UK
- Diamond Light Source, UK
- EUPLA, Spain
- Fraunhofer Institut, Germany
- Fudan University, China
- Johns Hopkins University APL, USA
- Kingston University, UK
- Korea Institute of Energy Research, South Korea
- Loughborough University, UK
- MIT, USA
- MSSL, UK
- Nanjing University, China
- Nottingham University, UK
- Purdue University, USA
- RISE, Sweden
- Sichuan University, China
- Technische Universität Berlin, Braunschweig, Darmstadt, Erlangen, Hannover, Würzburg, Germany
- Tong Ji University, China
- Tsinghua University, China
- Università di Roma, Italy
- Université de Casablanca, Marocco
- Université de St. Etienne, France
- University of Alabama, USA
- University of Cincinnati, USA
- University of Edinburgh, UK
- University of Massachusetts Lowell, USA
- Wuhan University, China
- Xi'An Jiao Tong University, China
- Zhe Jiang University, China





## m+p international

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