Brüel & Kjær

PULSE ANALYZERS AND SOLUTIONS

Brüel & Kjær

PULSE SOFTWARE

PULSE PLATFORM

7700/70/71	FFT and CPB Analysis	8703	Reflex Advanced Processing
7705	Time Capture	8704	Reflex Order Analysis
7708	Time Data Recorder	8705	Reflex Advanced Order Analysis
7709	Viewer License	8706	Reflex Standardised CPB Option
8700	Reflex Base	8710	Reflex Sound Quality Metrics
8701	Reflex Data Viewer	BZ-5610	CAN Bus
8702	Reflex Basic Processing		

TEST AND DATA MANAGEMENT

7767	PULSE Data Manager	7796	Automotive Test Manager
7789	PULSE Time	8605	ASAM-ODS Option

ACOUSTICS

3644	NVH Vehicle Simulator	BZ-5636	Array Acoustics Transient Calculations
7698	Sound Quality	BZ-5637	Array Acoustics Conformal Calculations
7752	Noise Source Identification	BZ-5638	Array Acoustics Metrics Calculations
7758	Acoustic Material Testing		
7759	Advanced Intensity Analysis	BZ-5639	Array Acoustics Refined Beamforming Calculations
7761	Acoustic Test Consultant		
7788	Vehicle Pass-by	BZ-5640	Array Acoustics Panel Contribution
7793	Indoor Pass-by	BZ-5641	Array Acoustics Intensity Component Analysis
7799	Sound Power		
8606	Array Acoustics Spherical Beamforming	BZ-5642	Array Acoustics In Situ Absorption
		BZ-5939	Array Acoustics Rail Vehicle Moving Source Beamforming
8607	Array Acoustics Acoustic Holography		
8608	Array Acoustics Beamforming	BZ-5943	Array Acoustics Road Vehicle Moving Source Beamforming
8780	Reflex Building Acoustics		
BZ-5635	Array Acoustics Quasi-stationary Calculations	BZ-6047	Automotive Sound Quality

ELECTROACOUSTICS

6712	Telephone Test on PULSE	8770	Reflex Telephone Test
7797	Basic Electroacoustics	BZ-5137	Telephone Test

MACHINE DIAGNOSTICS

7702	Order Analysis	7790	Multi-plane Balancing Consultant
7703	Vold-Kalman Order Tracking Filter	7795	Vibration Check for Aircraft Engines
7773	Envelope Analysis	8740	Reflex Angle Domain Analysis

VIBROACOUSTICS

7798	Source Path Contribution

STRUCTURAL DYNAMICS

7753	Modal Test Consultant™	8719	Reflex Geometry
7765	ODS Test Consultant	8720	Reflex Modal Analysis
7754	ME'scopeVES™ Post-test Analysis	8721	Reflex Advanced Modal Analysis
7755-A	Bridge to ME'scope	8722	Reflex Correlation Analysis
7760	Operational Modal Analysis	8730	Reflex Shock Response Analysis
7764	Multiple-Input Multiple-Output Analysis	BZ-8527	Batch Processing for OMA Pro
8718	Reflex Finite Element Interfaces		

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WELCOME

Brüel & Kjær supplies integrated solutions for the measurement and analysis of sound and vibration. As a world-leader in sound and vibration measurement and analysis, we use our core competencies to help industry and governments solve their sound and vibration challenges, leaving them free to concentrate on their primary tasks: efficiency in commerce and administration.

OUR MISSION is to help our customers measure and manage the quality of sound and vibration in their products and in the environment.

OUR VISION is to be the first-choice and long-term business partner, delivering innovative technical solutions which create sustainable value for our customers.

THE WHOLE MEASUREMENT CHAIN

Brüel & Kjær delivers advanced technological solutions and products of renowned quality. These cover the entire sound and vibration measurement chain, from a single transducer to complete turnkey systems.

PRODUCTS

Our market-leading product portfolio covers all of the components and tools required for high-quality measurement and analysis of sound and vibration. We are unique in the industry, allowing you to source all of your components from one supplier.

SYSTEMS

Our products are designed to fit together and cooperate intelligently. This simplifies the process of creating systems that are optimised to solve your specific issues.

SOLUTIONS

In certain instances, we supply both the systems themselves and highly skilled engineers to operate them and supply analysis results, meaning you can focus on your core business without worrying about operating and maintaining equipment.

SERVICES

We offer a full range of services for our products and systems including: installation, training, support, software updates, calibration, planned maintenance, repair and rental.

QUALITY ASSURANCE

All products, systems and solutions are thoroughly tested in harsh environmental conditions. Our status as an ISO 9001-certified company gives you the peace of mind that extremely high standards are met in all aspects of our products and services.

CUSTOMER DRIVEN

Our most important skill is listening to the challenges customers meet in their work processes, where increasing functional demands, time pressures, regulatory requirements and budget constraints mean that getting it right the first time is becoming ever more critical. Receptive dialogue allows us to fully understand specific customer needs and develop long-term sound and vibration solutions.

Responding to the challenges faced by our customers has lead us to cover a diverse range of applications including: traffic and airport noise, car engine vibration, evaluation of building acoustics, cabin comfort in passenger aeroplanes, production quality control, and wind turbine noise. Over the years, we have developed creative and technically advanced solutions to innumerable customer problems, some of which you can see on our website at: **www.bksv.com/casestudies.**

LOCAL ACCESS TO A GLOBAL ORGANISATION

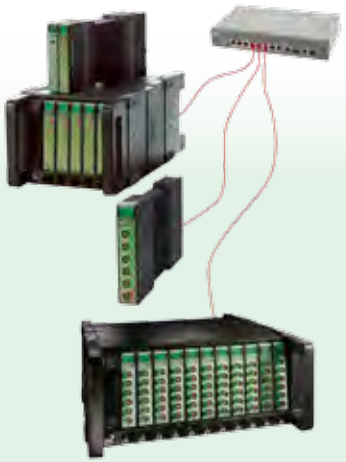
Brüel & Kjær is a global company. We operate through our network of sales offices and representatives in 55 countries. These local teams are supported by our global group of engineering specialists, who can advise on and solve all manner of sound and vibration measurement and analysis problems. To augment our service, we regularly hold courses and roadshows, and participate in sound- and vibration-focused exhibitions and conferences worldwide.

LAN-XI DATA ACQUISITION HARDWARE FOR PULSE

LAN-XI Data Acquistion Hardware is a versatile data acquisition system of modular units. Every module can be used individually as a smaller system front-end, or become part of a distributed-module setup. LAN-XI is fully compatible with our older IDA^{e} hardware, and works with both PULSE™ and Test for I-deas software platforms.

ONE PLATFORM IS ALL YOU NEED

The simplest setups and the most complex systems are all possible with LAN-XI, which is based on independent front-end modules. These work independently or combined with others, so you can easily add more modules to expand your system, and can divide and distribute it as necessary.



ONE CABLE OPERATION

The only cable you need is the network cable – a standard LAN cable that is used for both power and data transfer. This is especially useful in distributed systems, making large and confusing cable bundles a thing of the past, and bringing valuable installation flexibility.

QUALITY MEASUREMENTS THE FIRST TIME

Our unique Dyn-X technology avoids overloads and level-setting runs. It gives a market-leading, 160 dB dynamic range that means LAN-XI is always ready to capture your measurements.

Overload and cable-break detection mechanisms ensure there is little risk of ever needing to re-take measurements, while user-friendly features minimise human errors.

INTERCHANGEABLE FRONT PANELS

A unique feature of the LAN-XI modules are the interchangeable front panels which enable you to quickly adapt to the cables or transducers required for your task.

BUILT FOR FIELD AND LAB USE

Small and tough, LAN-XI modules are made of cast magnesium and can withstand being dropped, shaken and subjected to demanding environmental conditions.

The interchangeable front panels are easy to replace should connectors become damaged.

FERRARI S.P.A. – SCUDERIA FERRARI

Scuderia Ferrari was founded by Enzo Ferrari over 80 years ago in Modena. The original name is, still today, the name of the racing team division of Ferrari S.p.A.

Scuderia Ferrari recently invested in a 6-channel PULSE LAN-XI data acquisition system. This is mainly used for engine test bench balancing, a major issue when Ferrari's Formula One engines run at up to 20000 RPM.

Ferrari – Speed, performance, prestige

Italian sports car manufacturer Ferrari was founded in Modena by Enzo Ferrari in 1929 as Scuderia Ferrari. Originally, the main aim of the company was to allow owner-drivers to race. In time, it became a technical-racing outpost of Alfa Romeo and took over as its racing department in 1933. In 1939, Enzo Ferrari left Alfa Romeo and opened Auto Avio Costruzioni in Modena at the headquarters of the old Scuderia Ferrari. In 1943, Auto Avio Costruzioni moved to Maranello where the first part of what would become the Ferrari factory was built and in 1946, the company started to design and build the first Ferrari. In 1960, Ferrari became a Limited Liability Company in which Fiat became a 50-50 partner in 1969.

Maranello, a town in northern Italy, near Modena, has been home to Scuderia Ferrari and Ferrari's road car factory since the 1940s. At more than 250,000m^2, the factory's 45 buildings house more than 3000 workers. It is here that passion, innovation and technology combine to create the company's GT and Formula One cars. The team owns and operates a test track on the same site, the Fiorano Circuit built in 1972, which is used for testing road and race cars. Although the costs involved in Formula One are phenomenally high, motor racing is, and always has been, part of Ferrari's DNA and Ferrari's road cars benefit not only from the brand image of the racing cars but also from the unique technical expertise gained from Formula One racing.

Getting the right balance

With Formula One cars, vibration is a critical issue. Under new FIA rules (Federation Internationale de L'Automobile), and in order to double engine life, each driver is only allowed to use a maximum of eight engines per season plus a total of four for testing (that is, 20 per Formula One team) and each engine is expected to run for more than 2000 km. Testing has also been strictly limited and no in-season testing is allowed except during race weekends during scheduled practice.

Balancing and vibration have therefore taken on new importance. Imbalance is the most common source of vibration in engines. It is a very important factor to be considered in modern engine design, especially where high speed and reliability are significant considerations. By reducing these vibrations, deterioration of the engine and, ultimately, fatigue failure can be avoided. This can be done by balancing the crankshaft where masses are added or removed at certain positions in a controlled manner. Important factors in modern engine design are dictated by increasing speeds, higher performance/weight ratios and enhanced reliability. Balancing leads to more optimal design, superior performance, and increased safety and reliability.

Scuderia Ferrari works closely with Centro Ricerche Fiat S.C.p.A. (CRF) – Fiat Group's major source of expertise in innovation, research and development – to establish targets on vibration that are very important for engine and powertrain development. Consequently, a lot of durability testing is done in a dynamometer test cell (which can simulate the world's Formula One race tracks, including time history, torque, RPM, etc.) and the test results compared to actual data taken from a car on the test track.

Scuderia Ferrari recently invested in a 6-channel PULSE LAN-XI module with Multiplane Balancing software for test bench balancing of their Formula One engines. In addition to the PULSE LAN-XI system with its real-time capabilities for FFT analysis, order tracking and time-data recording on unlimited channels, Scuderia Ferrari also acquired two sets of Brüel & Kjær's PULSE Reflex™ Core for post-processing.

In the past, Ferrari appointed a third party for this balancing task, which was carried out one plane at a time. With the new system they can save substantial time and money as a Ferrari engineer now does the task every time a test bench needs to be checked or shows balancing issues. Furthermore, Ferrari can now perform two-plane and multi-plane balancing.

Photo courtesy of Ferrari S.p.A.

The intention is to evaluate the possibility of implementing the PULSE data acquisition and analysis system as the de facto vibration analysis platform for the Ferrari Formula One team. Ferrari's relationship with Brüel & Kjær goes back 30 years and they have a huge installed base of Brüel & Kjær transducers and conditioning amplifiers including many piezoelectric charge accelerometers – Types 4393 and 4326-A – and several CCLD accelerometers including Types 4520, 4525-B and 4526-HT. The accelerometers are mainly used for vibration testing of Formula One engines. In addition, Ferrari has used Type 2634 charge amplifiers connected to Type 4393 accelerometers for vibration testing on Formula One cars for many years.

Driver/pit communication

A second PULSE system including a Brüel & Kjær Head and Torso Simulator Type 4128 with built-in mouth simulator and calibrated ear simulators is used at Scuderia Ferrari to test the radio communication link between the racing driver and the engineers at the pit. Drivers are exposed to 140 dB(A), which is equivalent to a jet engine taking off, and miniature loudspeakers are built into special silicone earplugs that protect the driver's hearing while, at the same time, allowing him to listen to messages from the pit lane via the radio link. The PULSE-based solution tests speech intelligibility to evaluate and ensure reliable communication in these highly adverse conditions.

The future

The engineer in charge of Ferrari Formula One track testing will soon evaluate NOTAR™, a multi-channel LAN-XI data acquisition front-end that allows time data recording on up to 12 channels on each module, without connection to a PC but directly onto an SDHC card. This is intended to replace an existing system for data acquisition on the full vehicle and will also include subsequent post-processing with PULSE Reflex.

Brüel & Kjær looks forward to continuing the long relationship with Scuderia Ferrari and our aim is to continue to add value by providing cutting-edge technologies, efficient support, professional service and cooperation with Scuderia Ferrari's exceptional engineers.

PULSE SOLUTIONS

PULSE is Brüel & Kjær's platform for noise and vibration analysis.

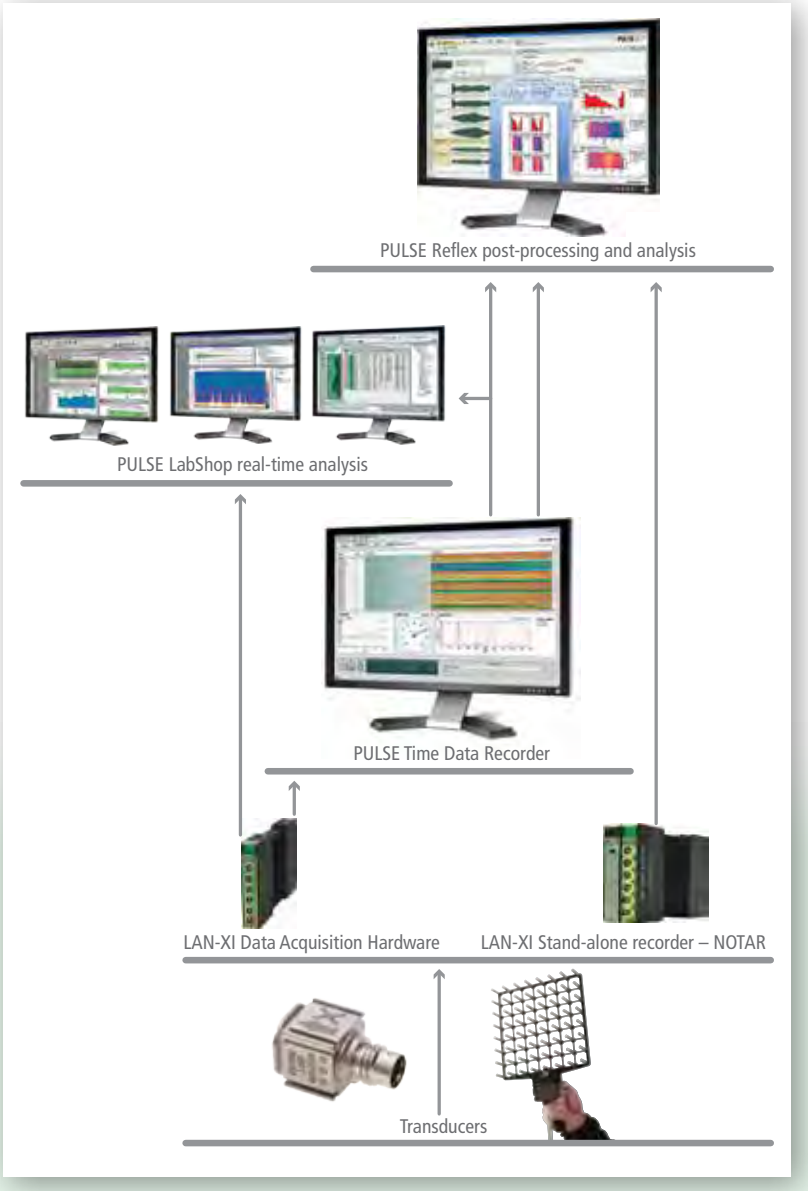
PULSE is probably the most popular analyzer solution in the world, with over 11,000 systems sold, with a vast range of software applications and hardware configurations. PULSE is a truly mature product, building on over 70 years of measurement experience and innovation.

Our industry-leading LAN-XI Data Acquisition Hardware naturally teams up with PULSE to make an unbeatable combination. Real-time measurement and analysis, intuitive time-data acquisition, and powerful post-processing are complemented with optional embedded-recording capabilities.

Many different possible workflows are supported, from ad hoc troubleshooting to targeted performance optimisation, across applications as diverse as telephone testing and wind turbine sound estimation.

For highly customised solutions, PULSE supports remote control through VBA and other high-level programming languages. And as an open solution, PULSE has the capability to import and export data from a multitude of sources in many different formats. Raw and analysed data can be stored in multi-user databases with embedded metadata, or through industry standards like ASAM-ODS.

No matter what your needs may be, PULSE offers an attractive solution.



PULSE REAL-TIME DATA

PULSE PLATFORM

At the heart of a PULSE system lie PULSE LabShop and PULSE Reflex Core, which are the main data acquisition and post-processing components.

PULSE LABSHOP

Our well-established flagship for real-time data acquisition from 2 to 1000+ channels. Equipped to perform fundamental analysis software tasks as standard, it is limited only by the computer running it.

PULSE LabShop is the real-time acquisition and multi-analysis platform for many of the other PULSE solutions presented in this catalogue. By itself, PULSE LabShop is one of the most popular stand-alone recording, FFT, CPB and order analyzers in the world, with more than 11,000 installations to date.

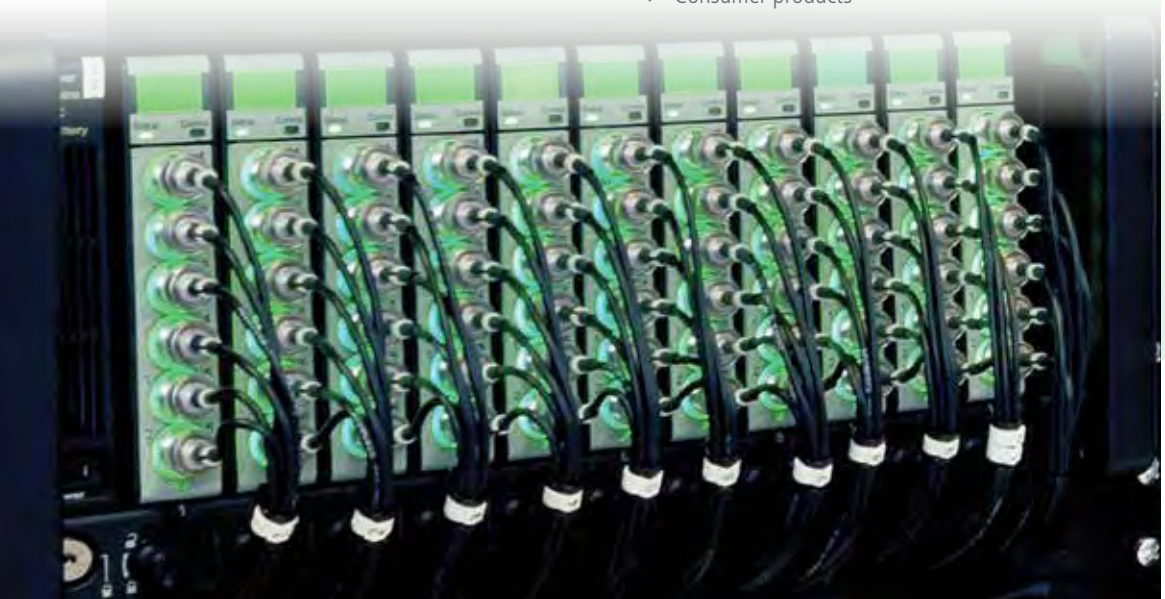
PULSE LabShop is built on:

- Powerful analysis capabilities
- Multi-analysis
- Best-in-class real-time performance
- Customisation and programmability
- Modular data acquisition hardware – LAN-XI

SOLID FOUNDATION

The flexibility of PULSE, combined with its industry-specific solutions, has made it the best-selling analyzer platform in a wide range of industries, including:

- Automotive
- Electroacoustics
- Telecommunications
- Aerospace and defence
- Consumer products



POWERFUL ANALYSIS CAPABILITIES

Standard PULSE LabShop analysis tools are:

- FFT analysis
- CPB real-time 1/n-octave analysis
- Order tracking analysis
- Envelope analysis
- Cepstrum analysis
- Steady-state response (SSR) analysis
- Time-capture analysis
- Time data recording option

MULTI-ANALYSIS

Since most tests can only be run once with the same conditions, with PULSE LabShop's multi-analysis capability you can:

- Capture test data and run it through PULSE LabShop's multiple analyzers in parallel
- Combine any kind of analysis and recording tools to analyse your data simultaneously, based on the same raw time-data samples
- Display consistent results in real-time
- Get immediate confidence in the achieved test results.
- Save significant time

Multi-analysis capability is a great strength of PULSE LabShop.

ACQUISITION

BEST-IN-CLASS REAL-TIME PERFORMANCE

PULSE LabShop continuously keeps pace with advances in computing power, adapting to get the most from your PC's performance.

- Runs on Microsoft® Windows® 32-bit and 64-bit operating systems
- Allows use of standard office PCs for measurement tests
- Analyses typically 160 FFT signals or 80 CPB signals up to 25 kHz
- Achieves extremely high real-time performance with high-end PCs and LAN switches
- Analyses 320-channel data up to a 50 kHz bandwidth / 131 kHz sampling frequency.

Scan here to see a video of a large satellite test system:

CUSTOMISATION AND PROGRAMMABILITY

Versatile and highly customisable, PULSE LabShop can be tailored to your needs. Its built-in 'Smart Start' concept:

- Eases the setup of new analyses
- Automatically presents the results on screen
- Stores often-used setup and results views for recall at the push of a button

PULSE LabShop includes an extensively programmable interface.

- PULSE LabShop integrates with your application, test cells and third-party solutions
- Built-in VBA (Visual Basic® for Applications) allows easy customisation
- Supports Microsoft® Visual Studio® environment (C++, C#, Visual Basic® .NET, as well as MATLAB®)

MODULAR DATA ACQUISITION HARDWARE

LAN-XI Data Acquisition Hardware is a versatile system of modular units. Every module can:

- Be used individually as a small system front-end with up to 12 channels (depending on module)
- Become part of a distributed-module setup connected via LAN
- Be arranged with many others in convenient racks to make systems of any size

LAN-XI features:

- Dyn-X technology, which eliminates the need for input ranging giving a single measuring range of 160 dB
- Interchangeable front-end panels

Integrated system features include:

- Cable-break detection
- Automatic transducer identification using TEDS (IEEE 1451.4)
- Automatic calibration sequence for transducers

PULSE BASIC ANALYZERS

PULSE BASIC ANALYZERS

At the core of PULSE are a series of basic analyzers that represent the beating heart of any PULSE system.

Our PULSE Basic Analyzer solutions contain all you need for simple sound and vibration tests, operating competently as stand-alone applications. They are easily expanded to fit larger, industry-specific solutions.

BASIC FFT ANALYZER

Simple, real-time FFT analysis is available from 2+ channels for mobility measurements, vibration diagnostics, or narrow-band analysis of acoustic signals, featuring:

- Autospectrum and cross-spectrum
- Waterfall spectrum
- Resonance and damping estimation
- Harmonic and side-bands detection
- Pure tone detection and sound intensity
- Zoom FFT
- Cepstrum analysis

BASIC CPB 1/N OCTAVE ANALYZER

Real-time, Constant Percentage Bandwidth (CPB) standardised digital filter-based analysis using 1/1, 1/3, 1/12 and 1/24 octaves for analysing noise, determining sound power levels, measuring sound intensity, and monitoring machine vibration. Basic CPB 1/n-octave analysis is available from 2+ channels, featuring:

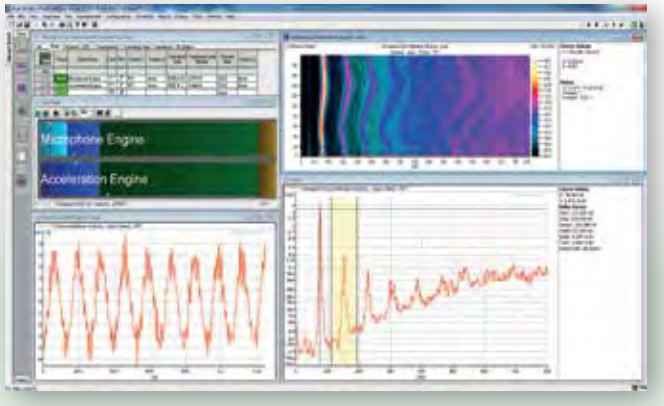
- Sound level meter – octave spectrum
- L_{eq} logging – sound levels vs. time
- Sound intensity – pure tone location while measuring
- Reverberation time calculation – using a loudspeaker or gunshot
- Machine vibration level monitoring – including pass/fail tolerance check

PULSE multi-analysis allows you to combine FFT and CPB analysis and recording tools to analyse your data simultaneously and display consistent results in real-time.

BASIC 2-CHANNEL FFT ANALYZER

7770-N2

- Smart Start – a quick, three-step start-up guide
- FFT resolution up to 6400 lines
- FFT analysis bandwidth standard up to 50 kHz (or higher depending on LAN-XI hardware module used)
- Multi-buffer spectrum logging
- Triggered FFT analysis
- Exponential and linear averaging
- Time-averaging signal enhancement
- Frequency weighting: A, B, C, and D
- Integration and differentiation



Basic 2-channel FFT measuring sound and vibration, with time monitor and colour contour plot showing vibration levels vs. time and delta cursor readout

BASIC 6-CHANNEL FFT ANALYZER

7770-N6

- Contains all features of 2-channel FFT analyzer
- Dyn-X technology, which eliminates the need for input ranging, giving a single measuring range of 160 dB
- Ultra-compact system
- Uses one LAN-XI module

Optional:

- More than 7 hours of autonomous use with LAN-XI Battery Module Type 2831-A add-on
- Expandable with Time Data Recorder Type 7708

BASIC 2-CHANNEL CPB ANALYZER

7771-N2

- Smart Start – quick three-step start-up guide
- CPB 1/n-octave analysis up to 1/24-octave
- Multi-buffer spectrum logging
- Linear - L_{eq} logging
- Exponential averaging – including slow and fast
- Exponential confidence level averaging for accurate measurements
- Exponential minimum and maximum hold
- Gated CPB analysis
- Frequency weighting A, B, C and D

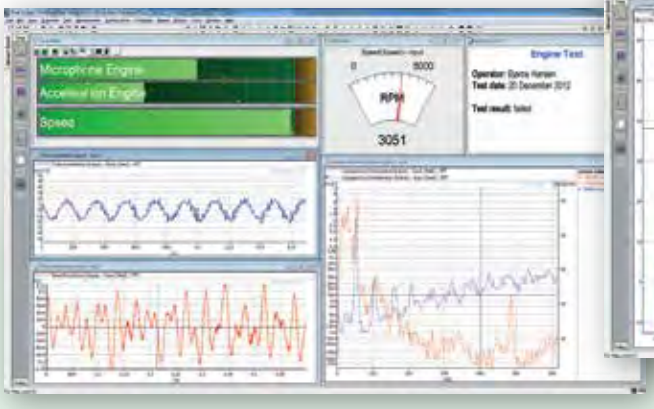
BASIC FFT AND CPB ANALYZER

7700-N, UNLIMITED CHANNELS

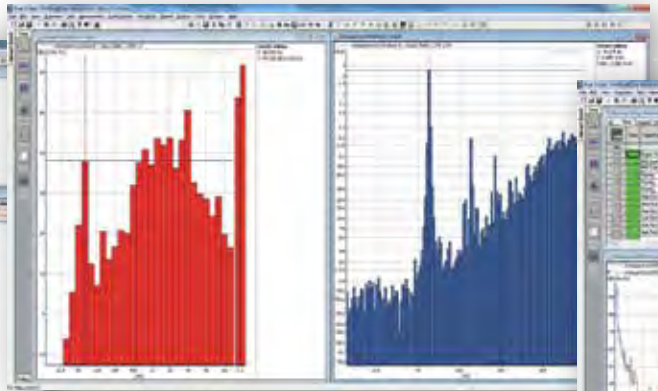
- Portable system combining the best of two worlds
- Up to 60 channels in one portable LAN-XI C-Frame module rack
- Multi-analysis allows you to use FFT and CPB analysis simultaneously
- The foundation for a multi-channel system
- Based on modular LAN-XI Data Acquisition Hardware

Optional:

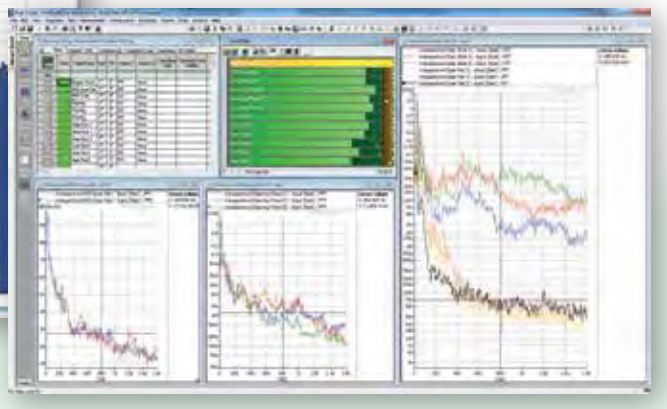
- Up to 3 hours of autonomous use with LAN-XI Battery Module Type 2831-A added to LAN-XI C- or D-frame module rack
- Expandable with Time Data Recorder Type 7708



Basic FFT including overal level meter and time-and-speed monitor, comparing sound and vibration FFT results in one plot for observing vibro-acoustic effects



Basic 2-channel CPB comparing 1/3-octave analysis from the engine's sound with detailed 1/24-octave analysis from the engine's real-time vibration levels



Basic FFT and CPB analyzer featuring easy setup using Smart Start, spreadsheet -type table, overall level monitor giving a quick overview of all channels, and easy data comparison in customisable displays

TIME DATA RECORDING AND

Recording time data and then post-processing the results allows you to decide the analysis parameters later and manipulate the raw data at leisure. In circumstances such as troubleshooting – when the exact nature of a problem is unknown – important information in the results can otherwise be missed due to the assumptions made when setting up the analyzer.

Time data acquisition and post-processing can also be essential when real-time analysys are impossible due to the number of measurement channels required, even with the continuing increases in computing power.

While recording data, the flexibility of PULSE Time Data Recorder allows you to transfer data to another computer or server for post-processing and analysis. PULSE Time Data Recorder allows recording and analysing data on separate computers, or combining computers into one system as a measurement and analysis workstation, to further optimise processing capability.

The flexibility of the LAN-XI Data Acquisition Hardware platform allows configuration of any recording solution from 2 to 300 channels, for mobile or lab-based use. Battery- and DC-powered options combined with LAN connection to the host PC provide maximal efficiency and minimal test setup time.

Post-processing is easy to perform in PULSE Reflex – our intuitive post-processing software.

TIME DATA RECORDER – 12 INPUTS

7708-N, 1 MODULE

A compact, battery-operated acquisition system with 12 dynamic channels. This is an ideal for unit for benchmarking measurements, with a battery life of up to 8 hours.

TIME DATA RECORDER – 60 INPUTS

7708-N, 1 FRAME

A highly flexible, battery-powered unit with 60 dynamic channels providing the ultimate in mobile data acquisition.

PULSE Time Data Recorder with level meter and level history for monitoring during data acquisition

POST-PROCESSING

TIME DATA RECORDER – 320 INPUTS

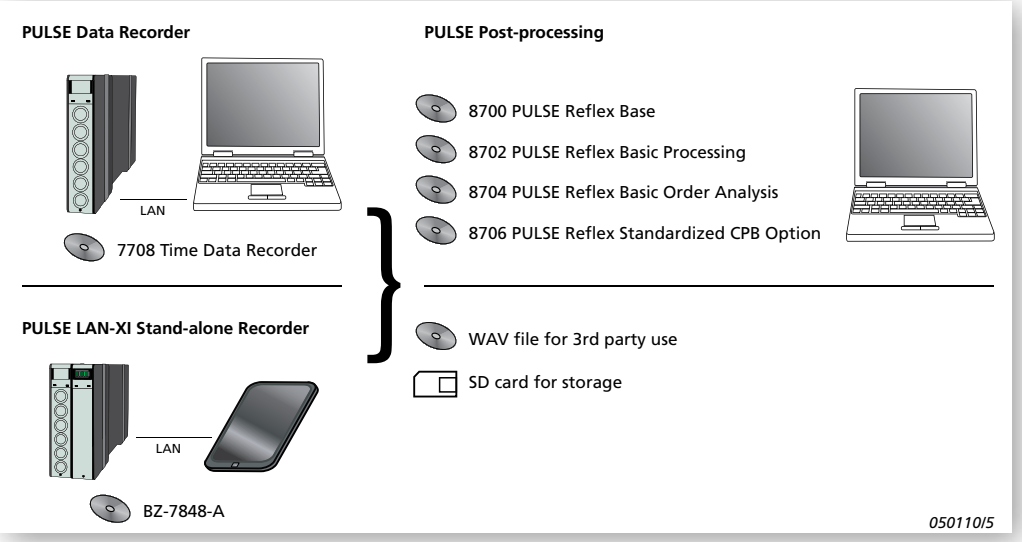
7708-N, MULTIPLE FRAMES

The premier DC- or battery-powered solution is custom built for data acquisition uses requiring a large number of dynamic channels.

LAN-XI STAND-ALONE RECORDER

BZ-7848-A

LAN-XI Notar™ adds solid-state stand-alone recording capabilities to one of your existing LAN-XI modules, which is controllable via the web or the module's built-in interface. Supports TEDS for fast setup time, and features long battery life for extended recording periods.



PULSE Time Data Recorder showing FFT monitor and a tachometer with RPM readout and speed profile

PULSE Time Data Recorder with a time/FFT channel monitor, allowing users to listen to all the channels while the recording is in progress

PULSE Time Data Recorder with a level meter indicating overload occurrences and coloured level history keeping track of optimal dynamic range selection

CASE STUDY

CONTINENTAL TESTS PULSE REFLEX

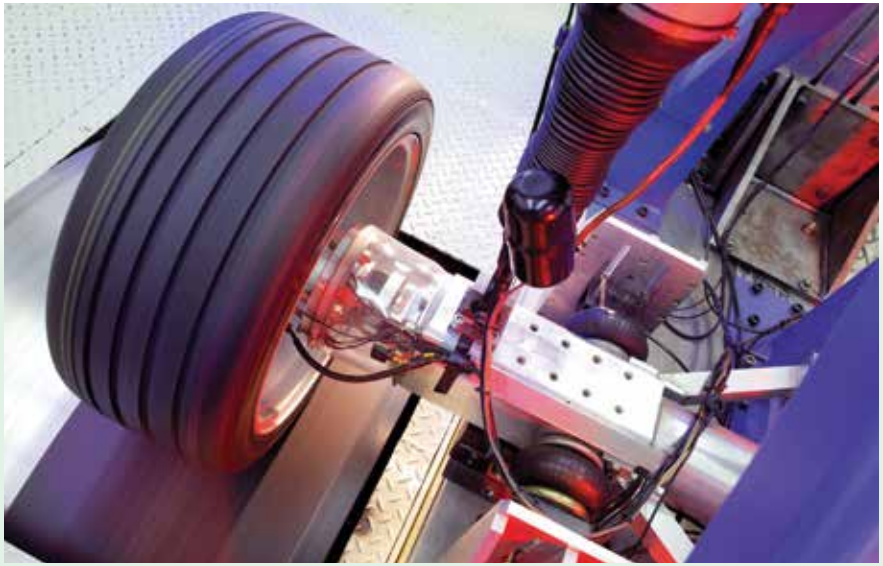
When Brüel & Kjær needed assistance during the beta development phase of the post-processing platform PULSE Reflex, getting Continental's input was a high priority. For Continental AG's NVH Engineering department it was an opportunity to 'try before you buy', so they set about comparing the results between their existing PULSE LabShop real-time analysis platform and the new post-processing platform PULSE Reflex – which turned out to be even better than they expected.

The company

The Continental Corporation is based in Hannover, Germany and is divided into the Rubber Group and the Automotive Group (Continental AG). With approximately 2000 tyre retailers and franchises in 15 European countries including various retail organisations, Continental ranks among the top five automotive suppliers worldwide.

Continental AG (the Automotive Group) is a world-leading manufacturer of tyres, brake systems, vehicle stability control systems, engine injection systems, tachographs and other parts for the automotive and transport industries. It achieved sales of approximately €16 billion in 2010.

Continental AG's three divisions – Chassis & Safety, Powertrain and Interior – employ around 87,000 people in more than 170 locations worldwide, with NVH centres in the USA, Malaysia and Europe, and a new R&D centre in Shanghai. The famous tyre business is run as a separate unit of Continental AG, and is the world's fourth largest tyre manufacturer after Bridgestone, Michelin and Goodyear.



History

Continental was founded in Hannover in 1871, as the stock corporation "Continental-Caoutchouc- und Gutta-Percha Compagnie". At that time, manufacturing at the main factory in Hannover included soft rubber products, rubberised fabrics, and solid tyres for carriages and bicycles. With an impressive string of firsts, Continental has remained at the cutting edge of tyre development ever since.

1898 – Production of automobile pneumatic tyres with a plain tread
1900 – Continental balloon fabric seals the gas cells of the first German airship
1904 – Develops the first grooved tyres for automobiles in the world
1905 – Commences production of riveted anti-skid tyres
1909 – French aviator Louis Blériot becomes the first person to fly across the English Channel, with Continental Aeroplan material covering the flying surfaces of his monoplane
1951 – Continental commences production of steel-cord conveyor belts
1955 – Develops the first air springs for trucks and buses
1974 – Supplies the European automotive industry with the first extrusion blow-moulded polyurethane gaiters
1991 – Launches the first environmentally friendly tyres for passenger cars
1997 – Presents key technology for hybrid drive systems
2003 – Unveils the world's first road tyre approved for speeds up to 360 km/h (224 mph) – the ContiSportContact 2 Vmax

Tyre assembly at the factory in Hannover-Vahrenwald, 1921

"I love the batch-processing functionality of Reflex. It has great usability, and is very flexible. It's also very intuitive"

Dr. Oliver Schürmann

A long-term development partner

The Continental Group's headquarters at Hannover is also where the European NVH department is located. Here, the NVH group works with tyres and automotive components to refine the overall vehicle experience. Describing themselves as experts for the entire range of vibration perception from hearing to feeling, the NVH department performs engineering services for external customers as well as the Continental Group – sharing test data and results globally. "Comfort lastingly determines the perceived quality of a vehicle" is a mantra for the NVH department, who declare that their common goal is "a quiet and comfortable ride."

Continental's NVH Engineering Department has used Brüel & Kjær's equipment for many years almost exclusively, developing a strong relationship between the two companies in the process. Central to this are Dr. Oliver Schürmann and Dr. Ernst-Ulrich Saemann, both highly experienced members of Continental's NVH Engineering team.

Dr. Schürmann has worked at Continental since 1995, and has experience in R&D, and within the truck-tyre and car-tyre business units. He designed, installed and commissioned their modal analysis test facility.

The mutual trust earned through working together over the years led to Continental's NVH Engineering Department becoming involved in the beta testing programme for PULSE Reflex Core software. As well as giving Brüel & Kjær valuable feedback during the beta testing stages of the new solution, the testing served as an introductory demonstration that allowed the NVH Engineering Department to evaluate PULSE Reflex Core as an extension for their Brüel & Kjær PULSE LabShop software.

"We joined in the beta testing because we wanted to validate PULSE Reflex as an upgrade to LabShop. In the testing we primarily wanted to see if we could get the same result in Reflex as in LabShop," says Dr. Schürmann.

The test setup

The application in question is to test the sound a tyre makes, and specifically to test for peaks in the noise data that correspond to tyre rumble. The test in the images is called a 'cleat test' that checks for structure-borne vibration in the Y and X axes, while performing simultaneous noise testing.

In order to simulate events that are normally noisy for tyres such as potholes, bridges, and expansion joints, a 5 mm-high steel plate is added to the rolling-road 'drum' that the tyre makes contact with, as shown in the picture. Five microphones and five vibration channels capture the data during the test, which is run at a steady 40 km/h.

Each test takes about two minutes, and then an average of a number of tyre rotations is taken. The intention is to evaluate peaks in the range from zero to 6.4 kHz, and specifically, the engineers are interested in four ranges between 4 and 260 Hz – which are in the range where tyre rumble is found.

Comparing PULSE Reflex with LabShop

After one day of training on PULSE Reflex Core, Continental's NVH department found the software was so intuitive that they were able to just get on with using it, without any further help. As Dr. Schürmann says, "We could see the peaks and read the frequency, and found that the reporting function is intelligent and flexible."

"I can now filter time signals in Reflex. For example, I found I could set up band pass filtering for each range separately," says Dr. Schürmann, before adding, "The search and sorting functions for files in Reflex is a great improvement over LabShop."

Not surprisingly after such successful beta testing, Continental's NVH Engineering department was convinced. The interface was a key point for Oliver, "It has great usability, and is very flexible. Handling chains is automatic and the 'drag-and-drop' operation is very easy and intuitive. I can now create chains, save them, and then reload them into another project. Then I can process the data with the same set-up, so there are no errors," he says.

Batched and dispatched

At Continental, reports from the tests typically go to either the tyre development manager if it is being conducted for Continental, or to the vehicle manufacturer if it is a project. Reporting is eased thanks to PULSE Reflex. "Comparison of results from different tyres is now much easier with PULSE Reflex, as we now have an identical reporting format. So now I can set up a batch calculation which is very quick and easy, and process the data with the same chain. So A-B comparison is totally accurate," says Dr. Schürmann. "Ultimately, Reflex saves a great amount of time and produces very accurate reports. I love the batch processing as I can set it up and walk away to do another task."

Drum speed and tyre speed are put into Continental's PULSE LAN-XI analyzer front-end using normal high-speed sampling

PULSE REFLEX CORE

PULSE Reflex Core is our post-processing software for fast and efficient analysis, viewing and reporting of sound and vibration data. At the heart of the system is a relational database for managing test projects and their associated sound and vibration data.

SIMPLE AND INTUITIVE

An innovative GUI controls a workflow concept that is easy to learn and consistent across applications, making PULSE Reflex Core genuinely easy to use. It deals with both repetitive (test bench) procedures and ad hoc troubleshooting by including automation in the workflow without constraining the user to a pre-defined sequence of operations.

POWERFUL ANALYSIS CAPABILITIES

Multiple parallel analyses can be performed simultaneously, including stationary and non-stationary spectral analysis, order analysis, statistics, and sound quality metrics. Results are automatically sorted for easy post-processing.

HIGH PRODUCTIVITY

Batch processing is included as standard in PULSE Reflex Core, enabling many recordings to be processed in a single batch operation. No matter how many tests or data types, the results from any number of tests are automatically sorted for quick comparison and reporting.

FLEXIBLE DATA MANAGEMENT

Test data and processed results can either be entirely managed inside the PULSE Reflex Core database or stored in external files. Metadata is used throughout the workflow for easy data searching, display annotation and automated report generation.

DATA VIEWING AND REPORTING

8700, 8701

PULSE Reflex Data Viewer provides automated viewing and reporting tools that are both flexible and easy to use. This software is designed to take data from any source, making it the ideal viewing and reporting hub for sound and vibration engineers.

STATIONARY AND NON-STATIONARY TEST DATA ANALYSIS

8700, 8702

PULSE Reflex Basic Processing is an analysis toolbox for FFT and overall level analysis of recorded data, including acoustic and human vibration filtering. Batch processing enables collections of time files to be processed in one operation, and includes the option of automatic reporting.

The Result Matrix provides an easy overview and simple comparison of large data sets from any number of tests or test runs

Scan here for an overview of PULSE Reflex Core:

ADVANCED ORDER ANALYSIS

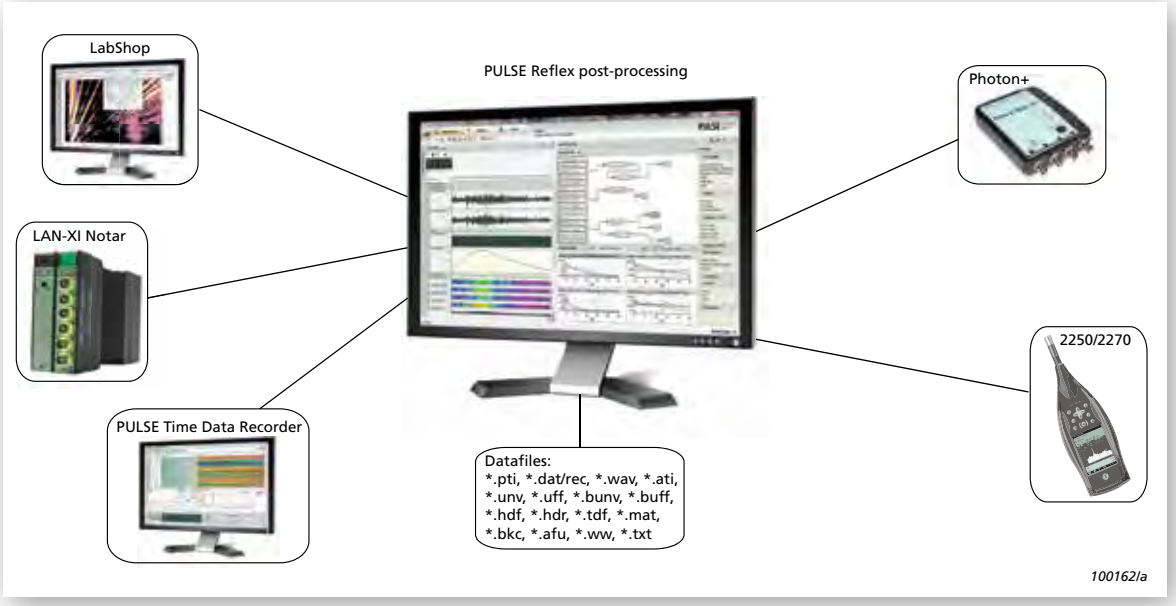
8700, 8702, 8704, 8705

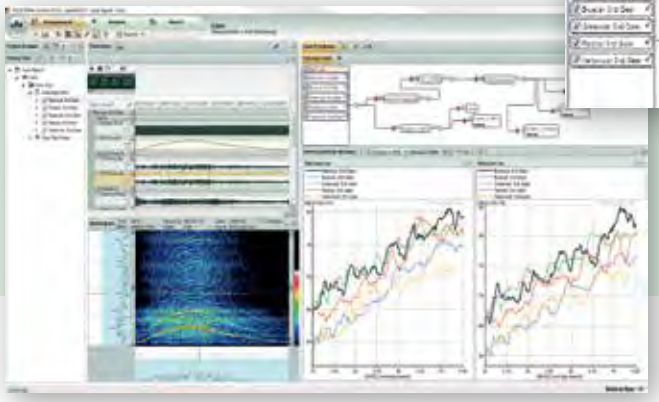
PULSE Reflex Advanced Order Analysis includes both fixed bandwidth and tracked resampled FFT analysis using a tachometer speed reference. Special tools include the graphical auto-tracker for deriving speed information without a tachometer, and tachometer repair.

SOUND QUALITY METRICS

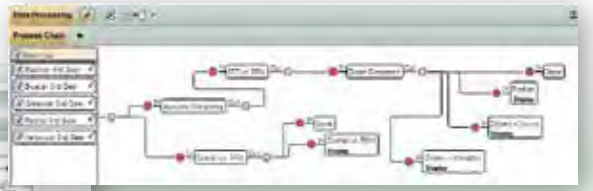
8700, 8702, 8710

PULSE Reflex Sound Quality Metrics adds a comprehensive range of commonly used metrics to the basic processing module. Metric calculations can run in parallel with other analyses such as FFT or overall analysis, and can easily be set up to process a large number of recordings in a single batch operation.





Recordings can be previewed and edited in preparation for analysis. The spectrogram display allows quick evaluation of frequency and order content.



Automation is built into the workflow. Batch processing and automatic reporting are included as standard.

Microsoft® PowerPoint® and Microsoft® Word are embedded to enable seamless report generation

NVH TESTING

Noise Vibration and Harshness (NVH) testing is critical for refining the human experience of vehicles, making NVH a key vehicle area of concern, and a vital differentiator between comparable models.

To achieve the desired attributes, the vehicle must be engineered to specified NVH targets from its inception, and subsequently validated to see that these targets are met following the development process.

Failure to meet targets necessitates troubleshooting to find the root cause of the problem and eliminate it in a cost-effective manner – where cost is also measured in terms of weight and therefore fuel economy.

For an analysis system to suit NVH testing it needs to be portable and robust for in-vehicle use, scalable and easy to use.

For standardised or repeated tests, real-time multi-analysis gives results as soon as you have completed a measurement. Avoiding the additional steps required for post-processing ensures high productivity and allows you to validate your results on-site.

Our data-centric architecture means the systems are built around the data flow, so tests and results are documented from start to finish. Consequently, storing, retrieving and reporting are efficient processes that do not require additional tools or applications. Additional time can be saved by automating report generation in whatever measurement report format your company uses.

AUTOMOTIVE TEST MANAGER

7796-A

A complete NVH toolbox covering stationary and run-up/run-down order tracking, time signal inspection, filtering and analysis, narrow-band analysis and mobility testing, featuring:

- Real-time multi-analysis across all channels, covering FFT, 1/n-octave, order tracking and overall levels
- Option of recording time data and saving automatically to database
- Time domain filtering and manipulation
- Virtual tacho support for Continuously Variable Transmission (CVT)
- Sideband extractor for Hybrid Electrical Vehicles (HEV) switching noise
- Sound power determination for engine testing

Validator provides targeted automatic retrieval of test results for averaging, reporting and comparison to other relevant measurements or target data

DATA MANAGEMENT (SOUND AND VIBRATION)

Following data acquisition and analysis comes the second vital half of the measurement process. Analysing results is where the in-depth engineering work starts, where conclusions need to be drawn and decisions made. Examining the large amounts of data generated across an entire organisation requires a clear overview and sophisticated capabilities.

PULSE Data Manager (PDM) is our family of data management systems, which streamlines data handling, test documentation and archiving, and encompasses our extensive experience of data management.

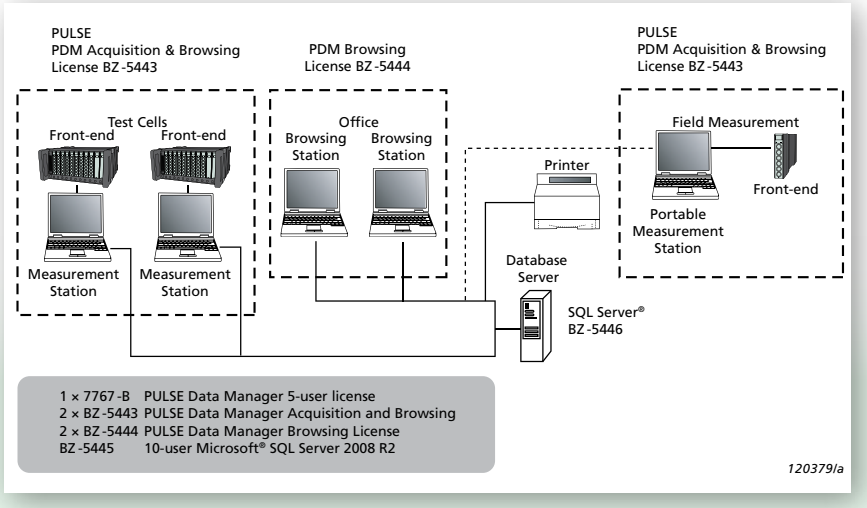
- Safe and orderly data storage
- Efficient searching and inspection of historic data
- Access to all data across the test organisation
- Cross-project data comparisons and calculations
- Fast and efficient reporting

Metadata information of any kind can be attached to label sound and vibration measurements and application data. Intuitive database searching ensures easy data retrieval for display, comparison, additional calculation, and reporting.

Databases can be hosted on a laptop for field measurements, or on a network for cross-organisational use, allowing them to be accessed throughout the organisation. Storage is in a standard Microsoft® SQL database.

INCLUDED FEATURES

- A report generator allows you to create report templates in the layout of your choice. The reports can be generated in your preferred Microsoft® Office application – Microsoft® Word, Microsoft® Excel® or Microsoft® PowerPoint®
- A calculator provides a dynamic post-processing environment for arithmetical calculations and statistical operations on test data



CASE STUDY

CHRISTIE DIGITAL SYSTEMS CANADA INC.

Christie Digital Systems Canada Inc., a privately held company that manufactures, most notably, DLP®, DLP Cinema® projectors and DLP with LED illumination display devices (Christie® MicroTiles®), is a leader in visual solutions for world-class organisations, offering diverse applications for business, entertainment, and industry. Brüel & Kjær products, including the PULSE LAN-XI data acquisition platform in conjunction with an LDS V875 shaker are used as part of the stringent product testing regime to improve the design and performance of Christie's projectors.

Christie – The company

With more than 80 years of technological firsts and a long list of product awards under its belt, Christie is no stranger to prestigious events. They have provided solutions for both the Grammy and Emmy Awards and were sponsors for numerous Shanghai World Expo 2010 multimedia pavilions, which included one of China's largest curved screen displays, a multimedia theatre and an interactive digital book. Other global organisations using Christie visual solutions include Boeing, General Motors, Microsoft®, Pixar Animation Studios, Shell, Sony Picture Studios, NASDAQ MarketSite, Weill Cornell Medical College and Starbucks.

Established in 1929, and a leader in visual solutions for world-class organisations, Christie offers diverse applications for business, entertainment, and industry.

With expertise in film projection since 1929 and professional projection systems since 1979, Christie has established a global reputation as the world's single-source provider of a variety of display technologies and solutions for cinema, large audience environments, control rooms, business presentations, training facilities, 3D and virtual reality, simulation, education, media and government. Christie has installed over 100,000 projection solutions worldwide.

With more than 1300 employees globally, Christie has an ISO 9001 and ISO 14001 certified facility in Kitchener, Ontario, Canada, as well as a manufacturing facility in Shenzhen, China. Although its core expertise is in projection technology, Christie has four strategic business units – Business Products, Entertainment Solutions, Visual Environments including Control Rooms and Advanced Visualisation, and Managed Services.

Environmental Testing Laboratory

In Christie's Environmental Testing Laboratory, large digital projectors are tested to ensure robustness for transportation and operations aspects. The lab contains a variety of equipment for conducting all types of required tests. The tests range from vibration, drop, thermal, sound, pull testing as well as equipment to measure and check part accuracy.

LDS V875 shaker

For this purpose, a Brüel & Kjær LDS V875 shaker with a 6 ft × 6 ft slip table and a 5 ft × 6 ft head expander is used. Senior Mechanical Engineering Manager Mark Barfoot, B.Sc. P.Eng., has been at Christie for over 10 years and previously worked for an aerospace company. He says, "This testing used to be done externally but by doing it in-house, we improve the cycle time as we don't have to wait for a slot at an external facility. I had used LDS shakers at my

The Christie CP2220 digital cinema projector is just one of the products subjected to Christie's rigorous environmental tests using the LDS V875 from Brüel & Kjær

Photos courtesy of Christie Digital Systems Canada Inc.

Their Brüel & Kjær LDS V875 shaker with slip table and guided head expander is located in Christie's Environmental Testing Laboratory

previous place of work, so that helped in the decision to buy the V875 three years ago." He continues, "Also, the slip tables at the external test facility were not big enough for our needs, so the 6 ft × 6 ft slip table Brüel & Kjær could provide together with the unique head expander were key in our decision making."

The shaker, used in conjunction with the 8-channel laser controller, is used every day for pre-testing prototypes and package testing. The table can create DOF (X, Y, Z) vibration and products undergo tests in and out of transport boxes and include:

- *ASTM restrained cargo vibration test*
- *ISTA Loose Cargo Test*
- *Half-sine shock pulse test*

A number of other Brüel & Kjær products are used in the Christie Environmental Testing Lab for a range of applications. These include:

- *Miniature Tear-drop IEPE Accelerometer Type 4517*
- *Hand-held, Battery-powered Stroboscope Type 4912*
- *Accelerometer Calibrator Type 4294*
- *Piezoelectric IEPE Accelerometer Type 4507*
- *Triaxial IEPE Piezoelectric Accelerometer with TEDS Type 4524-B*
- *Photon+™ Dynamic Signal Analyzer*

Anechoic chamber

Last year, Christie purchased a 10-year old full anechoic chamber with a background noise of 18 dB(A). Christie added a false floor to allow the chamber to be converted to a hemi-anechoic chamber when required. Here, using up to three 6-channel LAN-XI modules, sound quality, sound power and noise source identification software, Christie performs sound power measurements according to ISO 3744 and sound pressure measurements according to a Japan Business Machine Makers Association Data Projector Standard.

Christie has also invested in the sound quality software as well as the Binaural Head to allow them to better characterise the sound quality of their products. For most products, not only the level but also the quality of the noise it makes is part of what attracts or repels the customer – the right sound can lead to increased sales. Mark Barfoot says, "Christie will be moving more towards sound quality in the future. Along with brightness and image quality, sound is one of our customers' concerns and is, therefore, an increasingly important competitive parameter."

A number of other Brüel & Kjær products are used in their sound testing:

- *6-channel LAN-XI modules*
- *Sound Intensity Calibrator Type 3541*
- *½-inch Free-field Microphones Type 5189-A*
- *Head and Torso Simulator Type 4100*
- *Various PULSE software packages*

A bright future

The future certainly looks bright for Christie and not just because its projectors are the brightest in their class – over 30,000 ANSI-lumens, which is impressive against a typical 3,000-lumen projector commonly used in a classroom or boardroom. The number of screens worldwide featuring Christie digital cinema projectors is over 16,000, and Christie has 60% market share of North American digital theatres. And the launch of Christie® MicroTiles® in 2009 looks set to change future displays in architecture, digital-out-of-home (DOOH), command and control and event production.

The rapid growth in digital cinema projector sales around the world has led Christie to open a 60,000 ft² manufacturing facility in Shenzhen, China. This will enable Christie to invest more in the research and development of other types of digital media products at the Kitchener facility and free up capacity for future product development.

"Once we got the shaker set up, it has worked well," says Mark, "and we've never had to call anyone out to service it."

Sound power measurements in the anechoic chamber using LAN-XI modules

SOUND POWER

For determining the noise emissions of products, sound power is the preferred quantity to investigate because it measures the absolute power of a noise source independently from its acoustic environment. The three main methods used are:

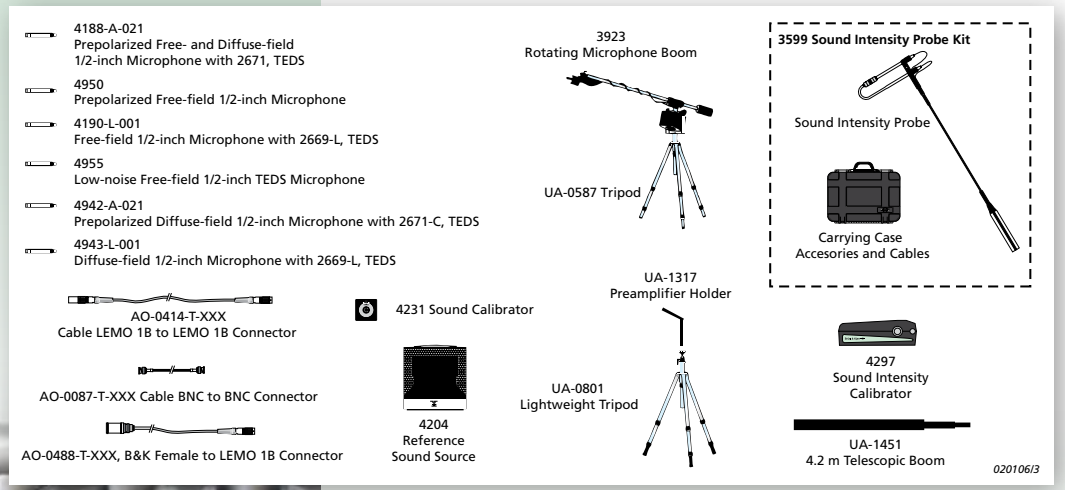
- Free-field – placing the source in an acoustically open area (free-field) and determining its sound power from sound pressure measurements
- Reverberation room – placing the source in a reverberation room (diffuse sound-field) and determining its sound power from sound pressure measurements
- Sound intensity – directly measuring the sound intensity from the source in any sound field, to determine its sound power

The first two sound pressure-based methods are most often used for production audits and high volume testing, while sound intensity-based methods are used for engineering and in situ measurements.

Whatever the method you choose, we can provide a system to measure and determine sound power in accordance with international standards and directives.

SOUND POWER SOLUTIONS

These solutions determine sound power according to international standards and measure sound pressure levels at specified points. They are all based on our PULSE Sound Power Type 7799, which also assesses annoyance due to tonal components using tone-to-noise ratio and prominence ratio calculations.



ENTRY LEVEL SOLUTION

7799

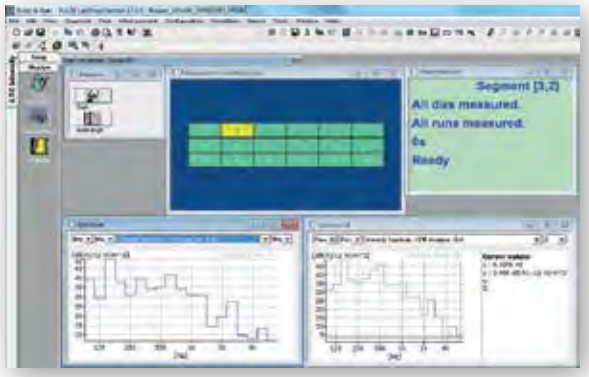
A single microphone is used to determine sound power in a free-field by making serial measurements according to ISO 374X-series standards. For reverberant room measurements, the system can be augmented with a rotating microphone boom.

To learn more about noise labelling scan here:

SOUND INTENSITY-BASED SOLUTION

7799

Determines sound power in any sound field using a serial measurement technique. This solution is designed to take advantage of the scanning intensity method ISO 9614-2 while minimising costs.



Sound Intensity based sound power and mapping

HIGH-PRODUCTIVITY SOLUTION

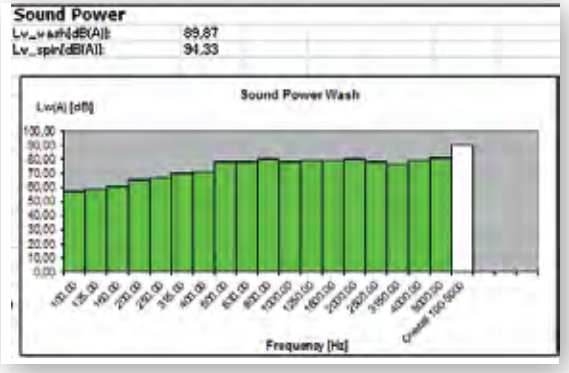
7799

Enables simultaneous measurement of sound pressure levels at all of the positions designated by a sound power standard, e.g., six microphone positions for the reverberant field method, and 10 positions for free-field measurements.

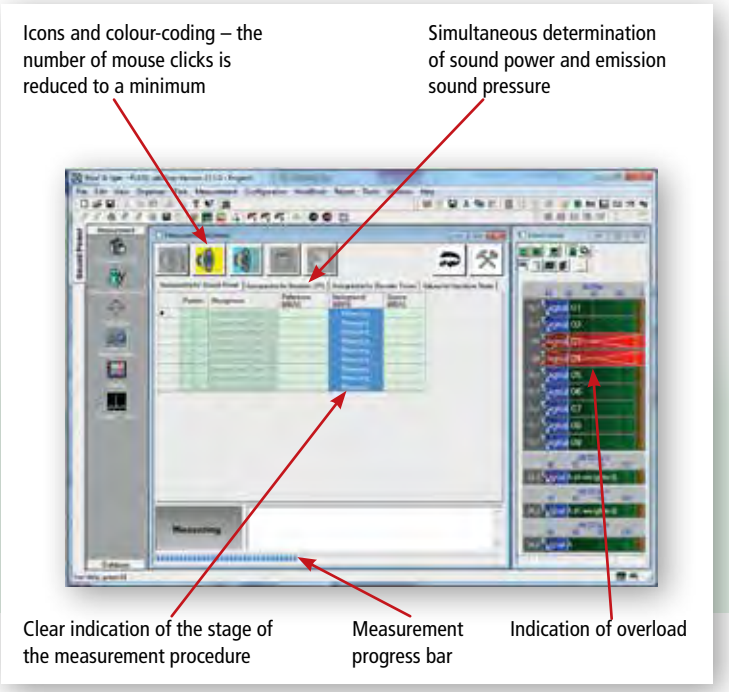
LABELLING FOR WASHING MACHINES

7799

Simplifies the EU-required measurement procedure right up to the final report, in accordance with EU Directive 2009/125/EC. All household appliances sold in the EU must feature an energy label including sound power information, and for washing machines this must cover both wash and spin cycles.



Extract from sound power report showing values used for labelling



The graphic user-interface is seamlessly integrated into PULSE LabShop

Standards supported	
Free-field	ISO 3744
	ISO 3745
	ISO 3746
	ISO 11201
	ISO 7779
	ECMA 7
	EU Directives
	2000/14/EC
	2009/125/EC
	IEC 60704-2-4
Reverberation room	ISO 3741
	ISO 3743-1
	ISO 3743-2
Sound intensity-based	ISO 9614-2
	ECMA 160

CASE STUDY

THE RENAULT GROUP

In order to achieve higher test efficiency, Renault needed to enhance its existing installed Brüel & Kjær system and reduce the time spent in the test cell. Renault wanted to ease the setup, data processing and measurement validation processes before activation of batch calculations. Another important requirement was a new reporting functionality. The overall objective was to simplify the workflow and calculations in the measurement process and thus decrease idle time when measuring according to a predefined procedure.

The company

The Renault Group, with headquarters in Boulogne-Billancourt, France, was founded in 1899 as Société Renault Frères by Louis Renault and his brothers Marcel and Fernand. They quickly made a name for themselves in motor racing, notching up a string of wins with their voiturettes. Indeed, the Renault reputation for innovation was fostered very early on – in 1902 Renault launched the first production sedan car as well as patenting the first turbocharger. In 1996, the company was privatised to create Renault S.A. Today, Renault is present in 118 countries and has a work force of over 127000 employees. Brands include Renault, Dacia and Renault Samsung Motors. Renault-Nissan sold 7,276,398 vehicles worldwide in 2010.

As well as its distinctive styling, Renault is also known for its car safety and is currently the car manufacturer with the largest number of models achieving the maximum 5 star rating in EuroNCAP crash tests.

Located in Lardy, 40 km south of Paris, the main testing centre dedicated to Renault's powertrain engineering, covers an area of over 130 ha. With 13 km of tracks and over 250 test benches of all types, it employs nearly 2000 people. Integrated in the NVH department, more than 70 of them devote their activity to controlling various powertrain noises in specialised testing facilities that are among the most modern in Europe.

The NVH development process

NVH is critical in the development process. Customer perception is an important factor in vehicle quality. The sound of an engine is designed to avoid or limit disagreeable noise and tune others to be more pleasant.

Jean-Marc Kieffer, NVH engineer and expert in powertrain radiated noise has been with Renault for 21 years. He says, "The NVH development process is a parallel between the engine and powertrain on one side and the whole vehicle on the other. These eventually converge to obtain relevant solutions for both sides. In this process, the role of the powertrain department is to characterise the noise and vibration of the powertrain, compare the results with the requirements/specifications and to design, redesign and tune the technical solutions according to the requirements. This ensures that the powertrain that is mounted in the vehicle won't cause a noise problem for the customer."

The challenge

To evaluate noise source location for powertrain and engines, Renault GMP looked at Brüel & Kjær's array applications for beamforming and holography measurement techniques to enable standard benchmark testing.

For Renault, it is important to get standardised sound power values and report them, not only because of vehicle regulations and legislation but also as a key competitive, qualitative element in the field of engineering, research, and development. Jean-Marc Kieffer, explains, "We have two principle areas of emphasis. The first is the law – the sound level that is required for the vehicle in, for example, pass-by – and the second is customer comfort. As well as these two, we also have the pollution issues and the rules/legislation that apply. These often contradict with vehicle noise. For instance, when you want to reduce the carbon dioxide levels of emissions you must act on injection parameters and this will affect the noise level. Other different rules and regulations also often conflict so we have to find compromises."

In order to achieve higher test efficiency, Renault needed to enhance its existing installed Brüel & Kjær system and reduce the time spent in the test cell. Renault wanted to ease the setup, data processing and measurement validation processes before activation of batch calculations. Another important requirement was a new reporting functionality. The overall objective was to simplify the workflow and calculations in the measurement process and thus decrease idle time when measuring according to a predefined procedure.

Photo courtesy of The Renault Group

It is, therefore, important to be able to locate and quantify noise sources with reliable, fast and accurate techniques. Mr. Kieffer says, "Much of our work is dedicated to optimising our processes and to reducing the cost or duration of development especially in NVH measurement, which involves a lot of expensive systems. Being able to validate fast solutions on the same prototype is also a major advantage for quick trouble-shooting tests." Brüel & Kjær's challenge was to try and simplify the workflow and calculations in the measurement process in order to reduce standardised testing time.

Proposed solution

In order to address the requirements from Renault, Brüel & Kjær proposed a range of enhancements to the current version of the beamforming and SONAH application together with associated noise source identification software in PULSE. Noise source identification was targeted as a method to characterise sound power for predefined areas on an engine/powertrain. The solution would enable Renault to make the measurements suited for standard benchmark testing while using a simple and effective user interface from setup of data acquisition to reporting the results in Excel®. Brüel & Kjær's proposals included:

- *Simplified data acquisition setup and GUI*
- *Predefined calculation setups for the different sides of an engine*
- *Automated calculation setup simplifying the procedure and post-processing workflow*
- *Combined stationary beamforming and SONAH calculation on the same dataset*
- *Overnight management and performance of batch calculations*
- *Sound power areas defined as part of calculation setup*

Unique array design

When working with arrays on a running car engine, it is a challenge to practically position the array close to the surfaces that have protruding parts that cannot be removed. To solve this, Brüel & Kjær's array has removable outer sectors. With one sector removed the array can, for example, span a driveshaft and still cover the entire engine side. When a sector is removed, this is automatically detected by the

cable break detection feature in the front-end and the missing measurement points are automatically ignored in subsequent calculations. Renault were pleased with the proposition. "The most important area within which we work with Brüel & Kjær is to identify and quantify the noise sources," says Mr. Kieffer. "A few years ago we were working with intensity measurements and a complete measurement for powertrain took around one week to complete," he explains. "Renault and Brüel & Kjær worked together to improve the way we make sound power measurements and we decided to work with the new array. Today, we have reduced the time of characterisation from five days to one or two days. On top of that, we can now get information that intensity measurements are unable to provide. At higher frequencies you have a higher resolution than with intensity measurements, even if you measure with points that are close to each other, and you improve the resolution in the NSI localisation. You can also characterise your sources in non-stationary ways of running, especially in run-up. It is, for us, the chance to simulate the behaviour of the engine during, for example, a pass-by test measurement."

A ten-year relationship

Brüel & Kjær and Renault's relationship goes back more than 10 years and there are several reasons why this relationship came about. As Mr. Kieffer explains, "First of all, Brüel & Kjær is known worldwide as a microphone manufacturer and has a reputation for being one of the best. For us it was important to have a good transducer as the basis of our measurement chain. That's one reason for our choice. Another is that Brüel & Kjær was the most advanced in the domain of sound power measurement whether with intensity probe or array. That's why, ten years ago, we chose a holography system with Non-stationary STSF from Brüel & Kjær. Following that, Brüel & Kjær continued to improve its systems and what cemented our choice was when Brüel & Kjær proposed the combined system with holography and beamforming. Using the same transducer and the same acquisition system for both beamforming and holography measurements was extremely important to us and made us more productive as we didn't have to make any changes during measurements. Moreover, choosing the PULSE platform was a guarantee to getting a versatile, upgradeable and sustainable solution in terms of both hardware or software. Finally, the ability for target setting and data correlation, for example, acoustic vs. vibration, through the database management of the PULSE PDM tool was also a determining factor."

The future

There is increasing pressure an the automotive industry to be more cost effective while producing ever more sophisticated and refined vehicles, for example, the development of electrical/hybrid powertrains which represents one of the automotive industry's fastest growing segments. Mr. Kieffer explains, "The problem we encounter with energy and the environment is the extreme pressure on reducing development time. Whether it be traditional, hybrid or electrical engines, we are obliged to develop quickly and efficiently. That's a constant pressure in our industry." He continues, "We have less time because circumstances are moving faster. There are some critical factors that force us to produce answers as soon as possible, for example, energy availability and the problem of environmental pollution. These demand a quick reaction so we have to be more efficient than we actually are today."

Photo courtesy of The Renault Group

However, testing time is not the only issue at Renault. Renault has largely succeeded in reducing this by using array measurements. According to Mr. Kieffer, "The next big challenge is to make a lot of improvements to how we post-process data. One reason for this is that we deal with huge amounts of data today. For example, it's possible nowadays to measure the behaviour of the powertrain in non-stationary conditions but post-processing the measurements is very time-consuming. Our challenge and priority is to improve our post-processing and data storage capabilities."

The technologies that drive the development of hybrid and battery-driven vehicles are changing the perception of NVH in the automotive industry. "Just run a little test with an electrical vehicle," says Mr. Kieffer, "and you will soon realise that the sound is quite different to that of traditional vehicles." He continues, "It is clear that we have to develop new methods of processing, new algorithms, etc., to improve the performance of our systems in measuring high frequencies. For us, another aspect of the problems with electrical engines is the very low sound level of the engine compared to other components. Keeping the ability to analyse the noises and to evaluate and localise their sources is vital to us. Recently Brüel & Kjær has, on our request, added the order filtering option to their beamforming solution. That is essential for engine investigations."

In addition to all the new technologies experienced by the automotive industry, Mr. Kieffer believes that fast exchange of data and images is also an absolute must. "This is important," he explains, "because when you have to deal and communicate with people it is often quicker and easier to show them an animation or a mapping where the different sources at different frequencies or different engine speeds can clearly be seen. Audio files are another possible option."

Animation and simulation are, therefore, becoming increasingly important and are a way of reducing the length of the development process because they affect more accurate calculations. And there are different ways of using these. "You can modify your development process and make more calculations at the first stages of the process and less at a later stage," says Mr. Kieffer. "This means you can reduce the number of prototypes which are expensive. You can also reduce the number of test bench hours. A great way of developing is to be able to provide accurate measurement results in order to improve and validate new calculation methods especially in complex matters like engine radiated noises. Undoubtedly, the coming years will present exciting challenges for Renault and Brüel & Kjær; challenges that will strengthen our cooperation to improve the comfort and performance of the next generation of vehicles."

NSI – ARRAY BASED

Noise Source Identification (NSI) techniques help to optimise the noise emissions of products and their components – on vehicles, aircraft, power-tools, household goods, wind turbines and much more. Identifying the most important sub-sources of noise in terms of position, frequency content and sound power radiation helps decide where design changes can most effectively improve overall noise radiation.

Array-based NSI provides the fastest measurement process and the highest quality results, and our range of arrays varies enormously in size and shape to suit the task in hand.

The three main array software applications are Acoustic Holography Type 8607, Beamforming Type 8608 and Spherical Beamforming Type 8606, which can all be enhanced with a large number of options. All calculation and post-processing is performed in the same user-interface.

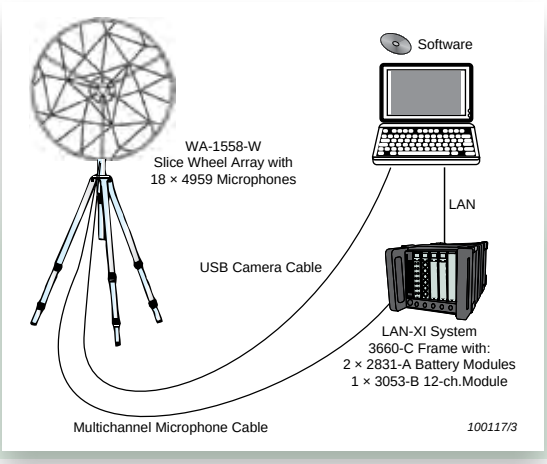
For a specific challenge, our Customised Project Department will tailor an optimal solution, drawing on over 30 years' experience of designing and installing hundreds of array-based solutions. Whether the test object is a hearing aid mounted on a test bench, a high-speed train racing from city to city, or an aircraft flying overhead, Brüel & Kjær can provide a complete, turnkey solution.

Scan here to see a video on the use of arrays:

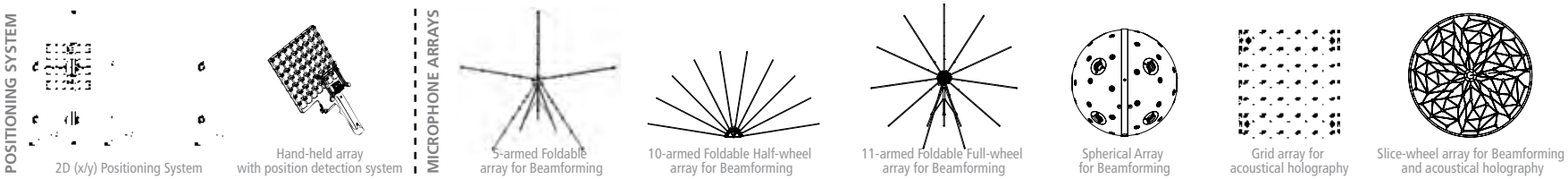
NSI ACOUSTIC HOLOGRAPHY

8607, 7770-N, 7761, BZ--5635, BZ-5636, BZ-5638

For measurements close to a source, this application provides fast and accurate acoustic maps of sound pressure, sound intensity and other sound-field parameters at low to medium frequencies (100 Hz to 5 kHz). Our patented algorithms 'SONAH' and 'ESM' allow accurate measurement with relatively small arrays without encountering edge effects. Acoustic holography also allows results to be calculated closer to and further away from the source, and the capability of the system can be augmented with an automatic positioning system, transient and quasi-stationary calculations and sound quality metrics.



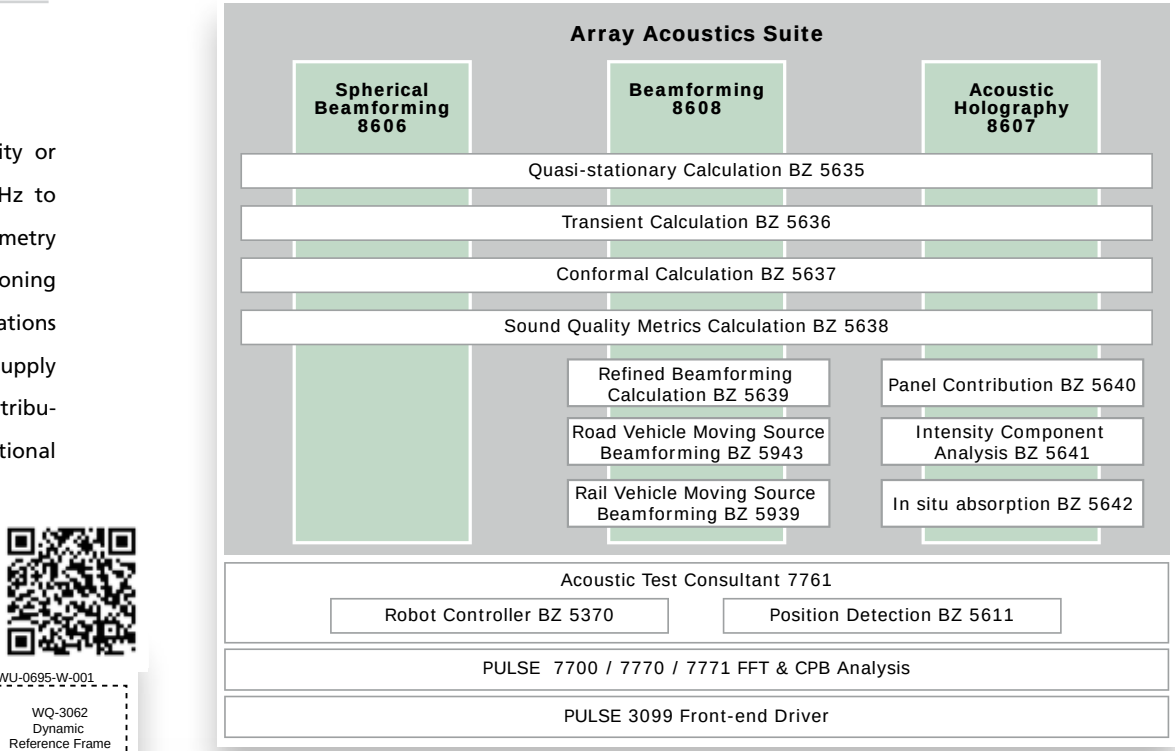
Slice wheel arrays and combo arrays are suitable for both holography and beamforming



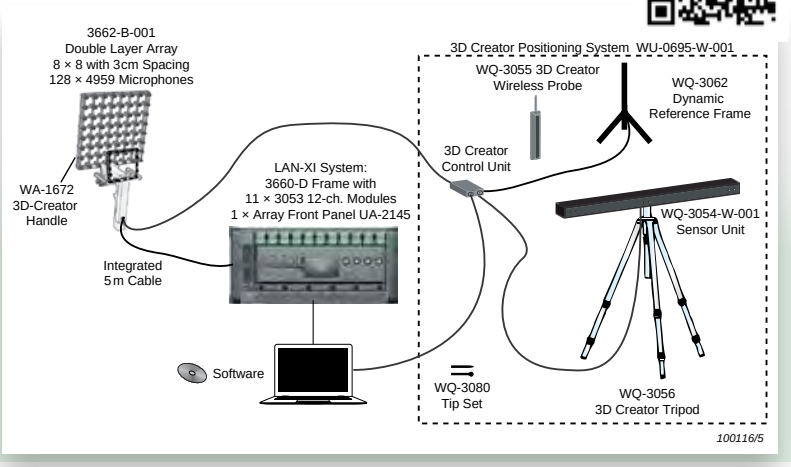
NSI PATCH HOLOGRAPHY

8607, 7770-N, 7761, BZ-5637, BZ-5640, BZ-5641, BZ-5642

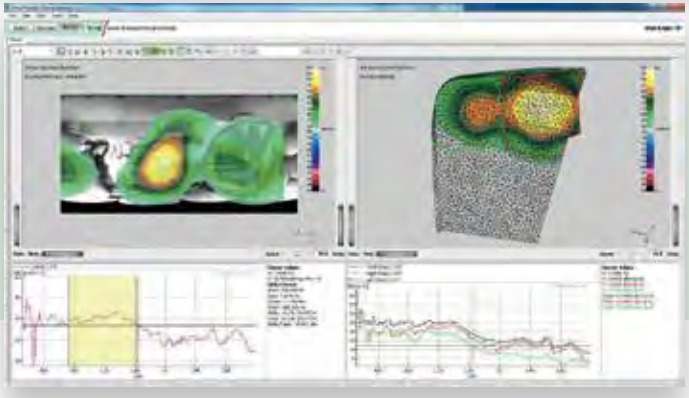
Creates conformal maps of pressure, velocity, sound intensity or sound quality metrics at low to medium frequencies (150 Hz to 5 kHz), using a single- or double-layer hand-held array. The geometry of the source under test is obtained from either a 3D positioning system or an imported IGES or mesh model. For in-cabin applications such as inside cars, trains and aircraft, additional options can supply in situ absorption, intensity component analysis and panel contribution – all of which are two-step measurements requiring operational and FRF measurements.



Scan here to see how to connect a complete array in three seconds:



The double-layer array has an integral cable, enabling all signal channels to be connected in seconds



A conformal sound intensity map of the ventilation vents on a vehicle console. Sound power contributions for the vents are shown.

See a video on conformal mapping:

NSI BEAMFORMING

8608, 7761, 7770-N, BZ-5639

An easy, one-shot measurement process for mapping the relative sound pressure and sound intensity contribution from a source. The solution is well-suited for large objects such as vehicles in wind tunnels, where the array is placed relatively far from the source, outside the turbulent airflow.

The number of microphones in the acoustical array can vary from 18 to 144, and an integrated camera provides simple and intuitive documentation of results. Results can be calculated using the delay-and-sum technique or the refined beamforming technique – which employs deconvolution algorithms to improve the spatial resolution.

Beamforming is valid for medium to high frequencies (500 Hz to 20 kHz), and combining beamforming with acoustical holography creates a system capable of measuring over a very wide frequency range. The addition of a transient option enables averaging in the domains of time, RPM and angle, making it ideal for powertrain analysis.

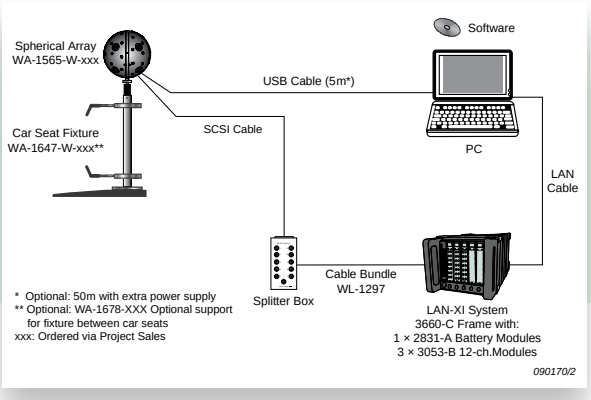
Scan here to see a video on beamforming:

NSI SPHERICAL BEAMFORMING

8606, 7761, 7770-N

A quick method to map relative sound pressure and sound intensity arriving from all directions; ideal for in-cabin noise and leak detection.

The array consists of 36 or 50 microphones distributed across the surface of a solid sphere, in which there are also 12 integrated cameras. The acoustical parameters measured over the surface of the sphere are then projected onto a 2D surface in the same way that information on a globe is represented on a flat map in an atlas. The algorithms used are 'SHARP' and our patented 'Filter and Sum' algorithm, which increases the dynamic range of the array and suppresses virtual images caused by sidelobes.



Spherical beamforming system for in-vehicle applications

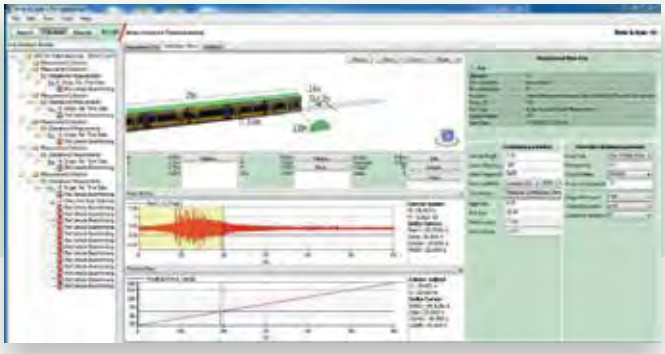
NSI MOVING SOURCE BEAMFORMING

8607, 7761, 7770-N, BZ-5939, BZ-5943

Maps moving noise sources such as lorries, trains, aircraft and wind turbines by detecting the direction from which sound arrives at the microphone array, using special measurement techniques, algorithms and array designs.

For measurements on wind turbines and flying aircraft we have developed dedicated solutions that meet the specific needs of our industrial partners, using large ground-based arrays.

The solution for road vehicles can be used alongside a standardised pass-by measurement, providing R&D engineers with immediate information on any test runs that exceed pass-by limits.



Calculation setup for PULSE Rail Vehicle Moving Source Beamforming showing site setup, a microphone signal and position profile

NSI – INTENSITY MAPPING

Sound intensity mapping is a versatile tool to measure the magnitude and direction of energy in a sound field for a variety of applications such as determining sound power, sound absorption and sound transmission.

Sound direction and noise 'hot spots' can be quickly determined regardless of background noise, with visual and aural feedback during measurements allowing convenient, on-the-spot results for operational sound sources.

Colour-contour noise maps provide intuitive documentation and easy communication of results with others, and the selective sound intensity option can further identify the internal root sources and radiation mechanisms involved.

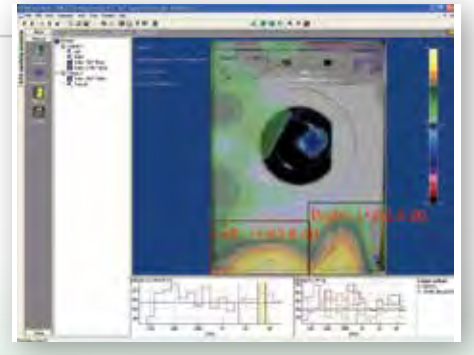
When measuring a large number of points, robotic systems can accurately automate microphone positioning, while for use on-site or inside moving vehicles we offer hand-held systems based on a sound level meter.

NSI INTENSITY MAPPING

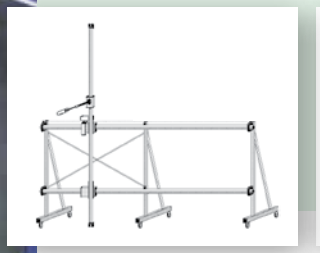
7761, 7752, 7700-N2, 2 INPUTS FOR A SOUND INTENSITY PROBE, 3 INPUTS ARE REQUIRED FOR SELECTIVE INTENSITY MEASUREMENTS.

Measurement and mapping of sound pressure, sound intensity and other directly measured sound field parameters

- Calculation of partial sound power for ranking of sub-sources
- Easy, geometry-guided measuring process
- Intuitive documentation using image overlay
- Expandable with:
  - Selective intensity mapping
  - Automated positioning system



Two- and three-dimensional sound maps overlaid on an image make documentation of the noise sources easy to understand. An integrated database stores results, compares maps, and assists sound power ranking.



Two-dimensional positioning system for a sound intensity probe or array

A sound intensity probe with remote-control handle

The sound intensity front-end LAN-XI module has a third input for a reference signal, a socket for the remote control, and a generator output for leak detection tasks

CASE STUDY

EPA WIND FARM PROJECT FOR OPEN SPACE AND SITE,

As wind energy becomes a new strategy to reduce greenhouse gas emissions and, thereby, contribute towards reducing global warming, the Taiwanese government has decided to dramatically increase its number of wind farms. In order to understand the noise impact on the environment and its residents, The Environmental Protection Administration (EPA) has initiated a project to study the noise impact and measure wind turbine noise.

Environmental Protection Administration (EPA)

EPA is a Cabinet level executive agency responsible for protecting and conserving the environment in the Republic of China including air quality, noise control, monitoring and inspection of the environment, solid waste, recycling, sustainable development and international cooperation. It is led by the Minister for Environment, Stephen Shu-hung Shen. The Environmental Protection Agency has evolved and been part of different departments over decades. In August 1987, the Environmental Protection Administration, as it is known today, was established becoming the one-stop shop for all environmental policies, regulation, standards and enforcement.

Background

Taiwan lacks energy resources and highly depends on import, so the Taiwanese government has chosen to prioritise the development of clean, sustainable, and independent energy and achieve the balance among energy security, environmental protection, and industrial competitiveness, and reduce CO_2 emissions through various strategies. As an island, Taiwan has excellent potential for developing wind energy. To capitalise on this, the Government has built a number of wind farms, which currently consist of a total of 263 wind turbines from different suppliers. These are mainly located along the west coast of Taiwan.

The goals

Although wind energy is renewable energy, there are shortcomings. Wind farms are often considered to be eyesores in what are mainly rural landscapes. Other worries include the noise generated by the turbines, and the resulting devaluation of nearby property.

To be able to understand the noise impact on the environment and its residents, EPA has initiated a project to study the noise impact and implement a procedure for on-site monitoring of wind turbine noise generated by operating wind farms. Phase 1 of the project, was carried out in 2009. Phase 2 of the project was started in 2010.

The goal of the EPA project was to find out the actual noise level of wind turbines and to set up suitable noise measuring procedures for open space and site facilities. The project would also conduct noise measurement and evaluation at sensitive spots as a result of complaints from local residents.

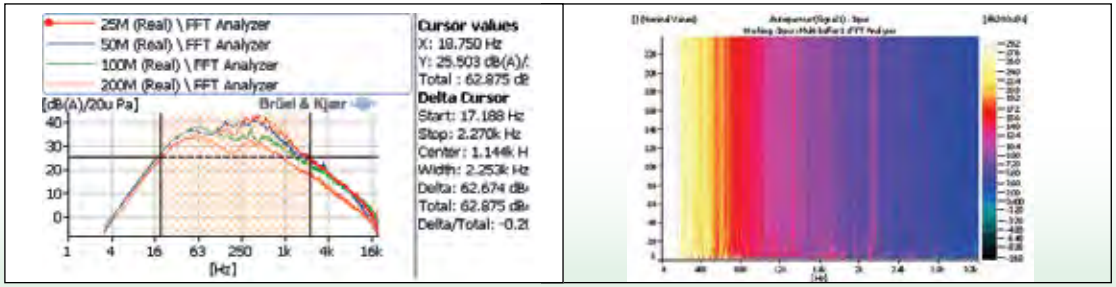
To achieve the goal, EPA deemed it necessary to measure 10 wind turbines in 10 noise-sensitive locations. When the measurements were completed, the wind turbine noise levels were correlated with wind speed. At high wind speeds, the noise levels exceeded 60 dB(A), and frequencies were mainly between 20 Hz and 1 kHz. Following this, 10 houses situated close to the wind turbines were selected and the noise levels measured. The results primarily showed low-frequency noise (below 100 Hz), and the difference between indoor and outdoor measurements was up to 10 dB(A).

The measurements

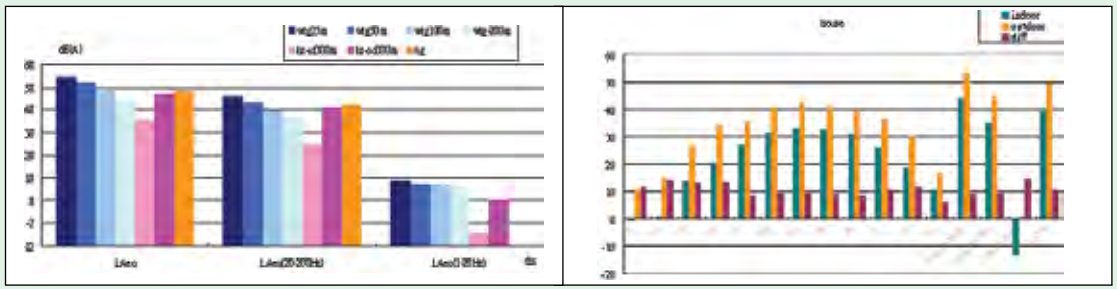
After discussions with EPA, it was concluded that the measurements should be made with Brüel & Kjær's Sound Level Meter Type 2250 and a PULSE data acquisition system. The PULSE system was configured using Brüel & Kjær's LAN-XI Data Acquisition Hardware, PULSE LabShop software together with ½-inch Pressure-field Microphone Type 4193. The system was used to identify whether the low frequency went below 20 Hz. And although this was not a conformance test to meet IEC61400-11:2006, there were some measurement criteria from the standard that were applicable, for example, placing the microphone on the round plate with double shield windscreen on the ground. This reduces the wind noise generated at the microphone and minimises the influence of different ground types.

Four points were measured to get the average result and each of these were also measured at distances of 25 m, 50 m, 100 m, and 200 m.

The measurement system also recorded sound data for future analysis. Mr. Y. H. Chen says, "This capability is a great feature of the LAN-XI platform, especially in the exposed, harsh working environment of wind farms. The test data and wind turbine noise were recorded for detailed post-processing."



The PULSE software displays the FFT analysis at four different distances (left) and in a colour contour plot

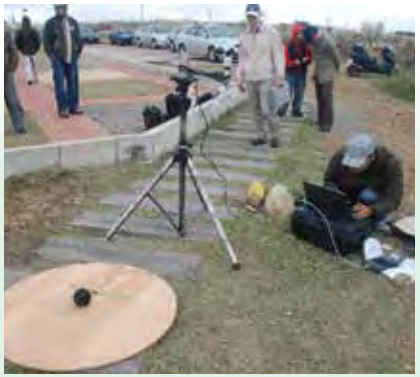


Wind measurement output analysis

NOISE EVALUATION AND MEASUREMENT CRITERIA

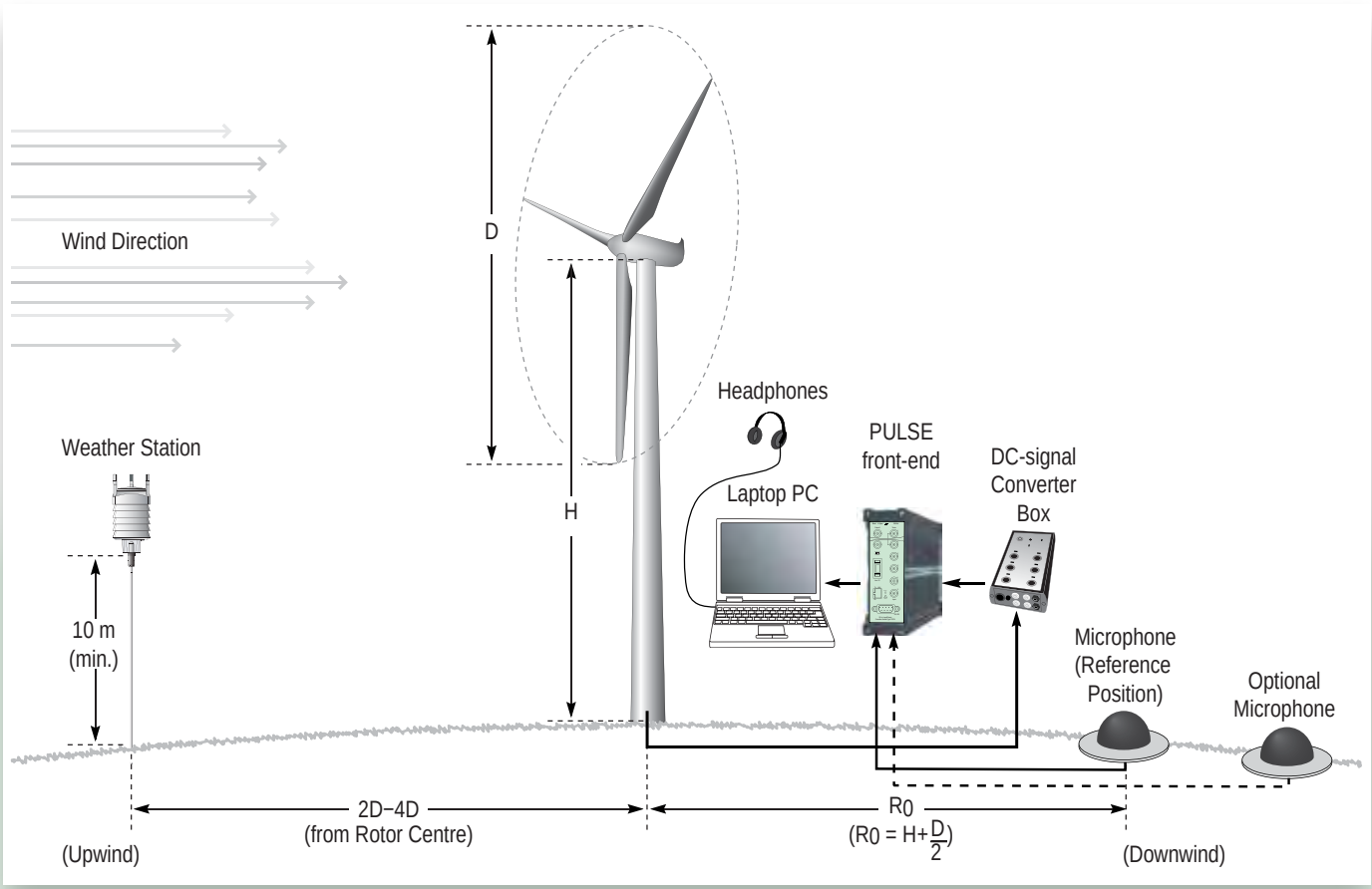
The conclusions deducted from the measurements were:

1. *Wind speed dominates the measurements, so placing the microphone on the ground is a necessity.*
2. *A suitable windscreen is required.*
3. *Low frequency (1 to 100 Hz) is of concern but difficult to measure.*
4. *By using Type 4193 microphones, a range from 1 Hz to 20 kHz could be covered. All frequencies can be measured simultaneously using the PULSE platform and post-analysis is quick and easy.*
5. *Analysis tools, such as colour contour plots, can be used to identify the pure tone components. Sound quality can be evaluated to verify the dominant frequency ranges.*
6. *The wind speed can also be recorded with PULSE for correlation and analysis with the noise data.*



Photos courtesy of EPA Wind Energy

Making measurements at Miaoli County Chunan Tawn wind farm. The microphone is mounted at the centre of a flat board with its axis pointing towards the wind turbine.



ACOUSTICAL APPLICATIONS FOR

The enormous growth of the wind turbine industry makes noise problems ever-more pertinent to personnel in design, R&D and production. We continuously develop solutions to address these new challenges, helping to optimise operation, increase product quality and simplify measurement procedures.

A uniform methodology to ensure consistency and accuracy in the measurement and analysis of acoustical emissions is provided by the international standard 'IEC 61400-11 Wind turbine generator systems: Acoustic noise measurement'. Brüel & Kjær supports the standard with a complete system to determine sound power, tonality and impulsivity.

For manufacturers of wind turbine components, our sound and vibration systems ensure quality control in gearbox and generator test rigs, and our data acquisition and analysis systems are equally suited for on-site troubleshooting, production, and R&D facilities.

Improvements in acoustical array design and calculation algorithms have led to our current rugged, battery-operated systems that are ideal for outdoor use and quick to set up. Large, ground-based arrays for precision noise source identification help researchers and blade designers locate troublesome areas on full-scale test turbines.

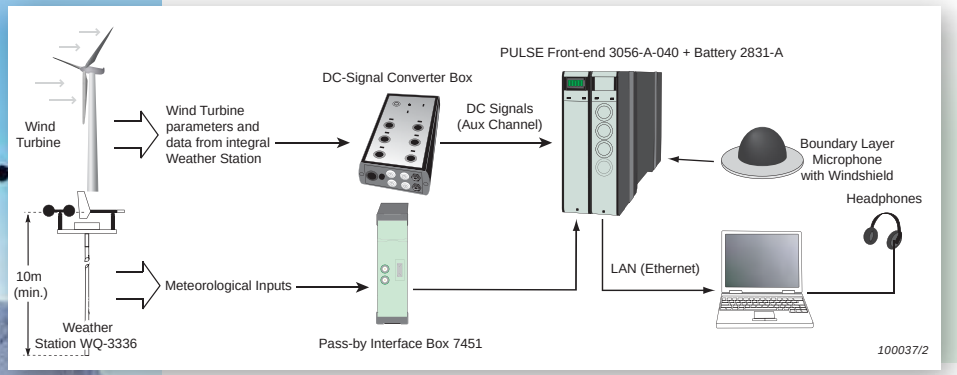
In wind tunnels, array technology is widely used on scale models, while our flat surface microphones are ideal for blade profile investigations.

NOISE SENTINEL

7871, SINGLE OR MULTIPLE INPUTS

Permanent and semi-permanent solutions for gathering accurate data for planning and noise management of wind turbines and wind farms. Reliable data enables noise complaints and regulation compliance to be dealt with in a cost-effective manner.

- Web-based subscription solution
- **Supply** – We install and maintain the noise monitoring equipment
- **Operation** – We collect, verify and manage the noise data, sound recordings, weather data and video
- **Presentation** – We provide data that is ready to incorporate into site-specific compliance reporting



Setup for wind turbine noise measurements according to IEC-61400-11

WIND TURBINES

WIND TURBINE SOUND POWER AND TONALITY

7700, 7708, 7914, 1 MICROPHONE INPUT

Dedicated solution to support the IEC 61400-11 standard and FGW guides for determination of sound power and tonality.

- Tonality
- Impulsivity, low-frequency noise, infrasound
- Full measurement report including wind turbine operating details, third-octave and octave spectra for sound pressure and sound power at the various wind speeds

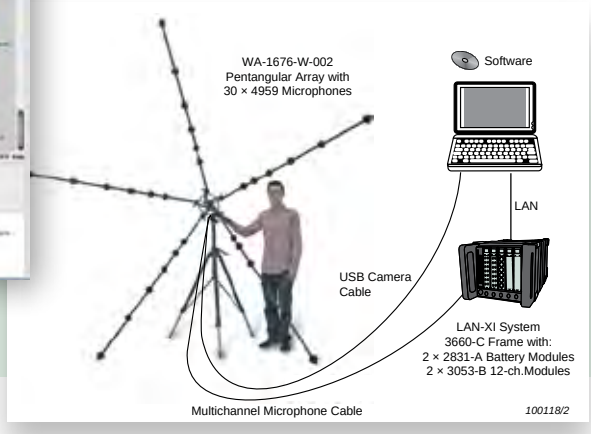
Result of sound intensity mapping from a beamforming measurement

ACOUSTICAL ARRAY SYSTEMS

8608, BZ-5636, BZ-5638, BZ-5639, 30 TO 108 INPUTS FOR ARRAY MICROPHONES

Pentangular array for rapid outdoor beamforming measurements using delay-and-sum beamforming and refined beamforming for improved spatial resolution.

- Rugged and easy to use
- Mapping of sound pressure, sound intensity, loudness and other sound field parameters as a function of time
- Customised arrays for blade tracking
- Customised, large ground-based arrays for improved spatial resolution – to distinguish between the leading and trailing edge of blades



Pentangular array system for rapid outdoor beamforming measurements

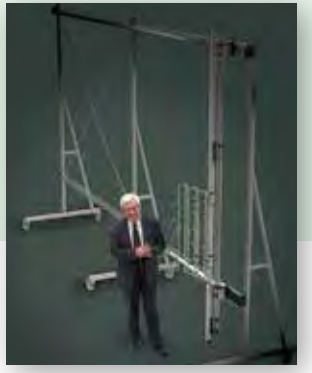
SOUND POWER OF COMPONENTS

7700-N2, 7752, 7761, 2 INPUTS FOR SOUND INTENSITY PROBE AND 1 OPTIONAL REFERENCE INPUT

Sound intensity mapping system for measurement and mapping of sound pressure, sound intensity and other field parameters.

- Calculation of partial sound power for ranking sub-components
- Expandable with:
  - Automated positioning system
  - Selective intensity mapping

Sound intensity map of a gearbox test rig



Automated positioning system with an array of 30 microphones to cover an area of 4m X 6m

Scan here to see a video of acoustic noise measurement on wind turbines:

ACOUSTIC MATERIAL TESTING

Growing focus on noise control issues combined with the emergence of sound quality in product design makes acoustic material testing increasingly relevant to engineers, designers and manufacturers from a broad range of industries.

Acoustic material testing is the process for determining the acoustic characteristics of materials in terms of absorption, reflection, impedance, admittance and transmission loss.

A range of standards covers acoustic material testing, prescribing well-defined acoustical conditions and special instrumentation to ensure accuracy and repeatability.

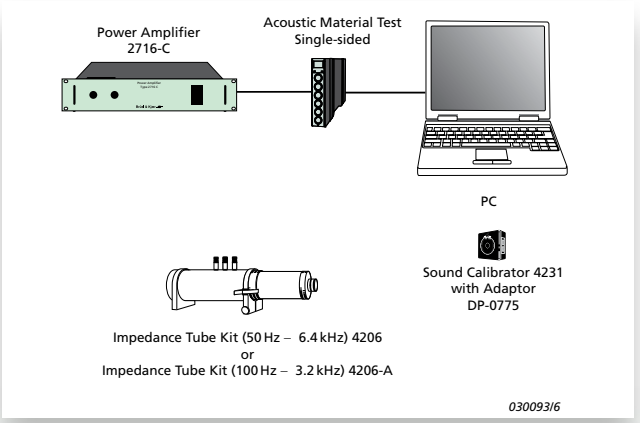
Our complete acoustic material testing systems make measurements on small samples according to ISO 10534-2, ASTM E1050 and ASTM E2611-10 international standards. They calculate transmission loss based on transfer matrix representation.

Simulation software can then help to predict the impact of specific noise control materials at an early stage in product development, once the acoustic characteristics of the materials are accurately known.

ACOUSTIC MATERIAL TEST – SINGLE-SIDED

7770-N2, 7758, 2 INPUTS, 1 OUTPUT

- Sound absorption coefficient and impedance measurements based on the two-microphone transfer-function method (ISO10532–2 and ASTM 1050 standards)



Acoustic Material Test – Single-Sided Type 3560-B-T72

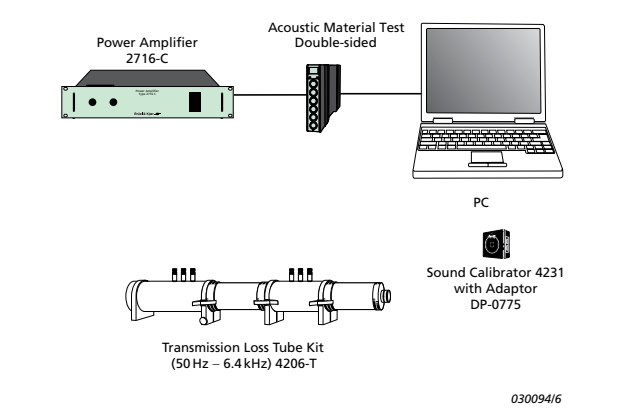
Standard	Tube kit	Frequency range
ISO 10534 – 2	Type 4206	50 – 6400 Hz
ASTM E1050 – 08	Type 4206	50 – 6400 Hz
ASTM E1050 – 08	Type 4206-A	100 – 3200 Hz
ASTM E2611 – 10	Type 4206-T	50 – 6400 Hz

We offer different kits according to the standard required

ACOUSTIC MATERIAL TEST – DOUBLE-SIDED

7700-N4, 7758, 4 INPUTS, 1 OUTPUT

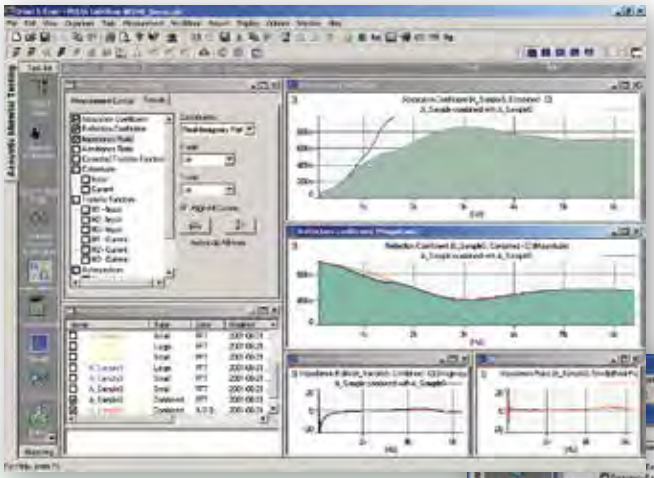
- Sound absorption coefficient and impedance measurements based on the two-microphone transfer-function method (ISO10532–2 and ASTM 1050 standards)
- Normal incidence transmission loss and other acoustical properties
- Ratio of dissipated energy to incident energy
- Characteristic impedance and complex wave number
- Two loaded transmission loss measurement method (ASTM E2611-10)



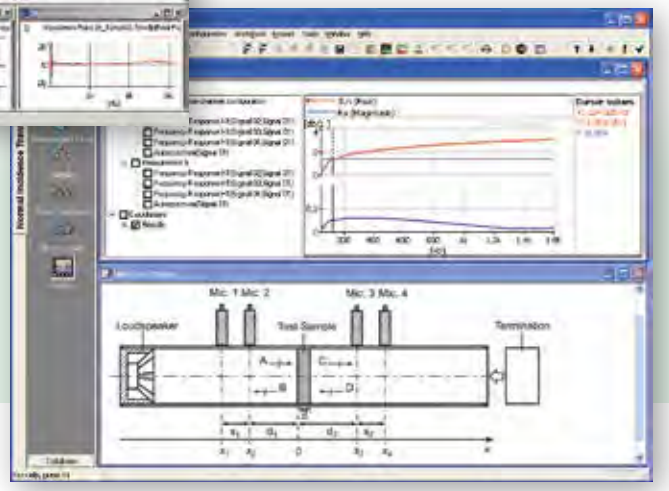
Acoustic Material Test – Double-Sided Type 3560-B-X73

		Type 4206	Type 4206-A	Type 4206-T
Frequency range	50 – 1600 Hz	•		•
	100 – 3200 Hz		•	
	500 – 6400 Hz	•		•
Parameters	Sound absorption coefficient	•	•	•
	Reflection coefficient	•	•	•
	Acoustic impedance	•	•	•
	Acoustic admittance	•	•	•
	Transmission loss coefficient			•

Tube guide matrix with the different tube types in the top row



Typical results of absorption measurements



Transmission loss measurement

CASE STUDY

ISUZU – IMPROVING THE SOUND QUALITY

In order to improve the perceived sound quality of diesel engines, Isuzu cooperated with Brüel & Kjær to develop mapping of sound quality metrics, where noise sources can be identified based on their sound character using perception-based metrics such as loudness, sharpness and roughness. Together, they also developed a new impulsiveness algorithm to clearly identify the source of impulsive noise in diesel engines. The result of the Isuzu/Brüel & Kjær project is now the world's first commercially available sound quality metrics mapping software for beamforming and Statistically Optimal Near-field Acoustic Holography (SONAH) systems.

The company

Isuzu Motors Limited is a Japanese commercial vehicle and diesel engine manufacturing company, with headquarters in Tokyo. Since the first truck rolled off the assembly line more than 80 years ago, Isuzu has been pioneering technological innovations. Isuzu's corporate vision is to be a leader in transportation, commercial vehicles and diesel engines, supporting its customers and respecting the environment.

Isuzu Motors Limited now focuses on trucks and buses with production in Japan, Thailand and various other countries. The trucks range from small pickups to very heavy trucks.

Today, engines are still the heart of Isuzu, and over 20 million of them have been delivered to customers worldwide. They range from 2.5-litre (4-cylinder) to 16-litre (6-cylinder) and are noted for their reliability and durability. In fact, Isuzu is the supplier of diesel engines to Opel and General Motors. As well as trucks, Isuzu engines are also used in the marine market and for industrial machinery such as excavators and cranes. Isuzu's main focus is on developing diesel powertrains and improving powertrain quality.

Isuzu's R&D facilities are located at its Fujisawa plant in Kanagawa Prefecture, south of Tokyo. First commissioned in 1961, this huge site also handles the assembly of commercial vehicles, and manufactures various components.

Isuzu's relationship with Brüel & Kjær goes back more than 30 years and all their microphones and the majority of their accelerometers are from Brüel & Kjær. In addition, Isuzu has many PULSE data acquisition and analysis systems and some wheel arrays. A large portion of FFT and CPB analysis at Isuzu is done using PULSE.

Why map sound quality metrics?

In recent years, environmental issues have placed emphasis on vehicle emission and vehicle noise including improved engine noise performance. It is becoming increasingly important not just to reduce the radiated sound pressure, but also to improve the sound quality of vehicles for the comfort of both passengers and local residents. Isuzu regards sound quality as a key selling point and differentiator.

Diesel engines make a characteristic noise known as diesel clatter, diesel nailing, or diesel knock. This is caused largely by the sudden combustion of fuel that has already evaporated when combustion starts. Although unavoidable, this sound is not desirable and it is notoriously difficult to identify precisely where the sound is coming from.

Traditional microphone array techniques, such as beamforming and near-field acoustic holography (NAH) localise noise sources based on physical quantities such as sound pressure and sound intensity. However, other sources may have higher values of sound quality metrics, so the objective data in the contour plot may not accurately reflect one's subjective perception. For example, improving the perceived sound quality of diesel engines may require the identification of noise sources emitting impulsive or rough sounds rather than having higher sound pressure level. For this reason, Isuzu got together with Brüel & Kjær to develop mapping of sound quality metrics, where noise sources can be identified based on their sound character using perception-based metrics such as loudness, sharpness and roughness. Together, they also developed a new impulsiveness algorithm to clearly identify the source of impulsive noise in diesel engines.

"The goal behind mapping sound quality metrics is to identify annoying or bad quality sound," says Mr. Haruki Saito, Manager and Specialist, Noise & Analysis Experiment Group. He continues, "In the past we could measure overall sound pressure level, but the measurement was objective and did not provide subjective analysis of the sound as perceived by humans."

Photos courtesy of Isuzu

Simulation

In order to validate the sound quality mapping, a simulation using ideal point sources with different sound characteristics was performed. It was carried out using both beamforming and acoustic holography techniques. In the simulation, individual sources had a dominant sound character, for example, sound pressure level, loudness, sharpness, roughness, and impulsiveness, and they were separated spatially on a source plane.

For the simulation of beamforming, a 66-channel wheel array with a diameter of 1m was used, and monopoles were distributed on the source plane 1 metre away from the microphone array. For the simulation of acoustic holography an 8 × 8 rectangular array of microphones was used with a spacing of 5 cm, and a distance to source of 7.5 cm.

In the simulation of both array techniques, the sound quality mapping was able to identify sound sources based on their individual characteristics rather than using traditional measures such as sound pressure, and the results corresponded well with those based on the designed characteristic of individual sources.

Integrating the algorithm

Following simulation and validation, Brüel & Kjær and Isuzu together developed an impulsiveness algorithm to reliably predict the perceived impulsiveness of diesel engine noise. It was confirmed to be useful by comparing the predicted impulsiveness with the results of a listening experiment where perceived impulsiveness of diesel engine noises was evaluated. The impulsiveness algorithm was then integrated

OF DIESEL ENGINES

Using an 84-channel sector wheel array, beamforming and SONAH measurements were carried out in a hemi-anechoic chamber on both engine A (left) and engine B (right)

with sound quality mapping in order to identify impulsive noises in a more efficient manner.

Engine noise testing

Finally, the mapping of sound quality metrics was applied to practical measurements of two diesel engines (A and B) designed for commercial vehicles – the first, a 5.2 l, in-line 4-cylinder engine and the second, a 9.8 l in-line 6-cylinder engine.

To cover a broad frequency range, both beamforming and SONAH methods were used – beamforming to identify noise sources at high frequencies and SONAH at low frequencies. An 84-channel sector wheel array of 0.5 m diameter was used to perform all measurements. Mr. Saito says, "It takes about a day to set up the system, make the measurements on three surfaces and process the data using Brüel & Kjær's PULSE platform software." Measurements included Run-up/run-down from idle to maximum RPM as well as steady state.

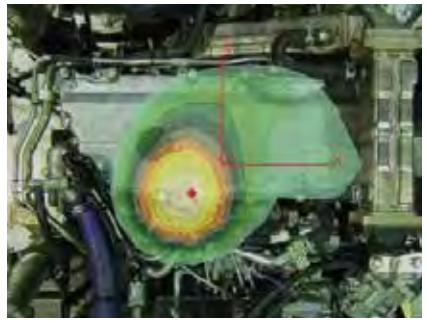
The resulting location of problematic noise sources in the sound quality maps disagreed largely with that of traditional sound pressure maps. In the case of the beamforming and SONAH tests on engines A and B, modifications were made on the head cover and the valve gap, and the effect of the modification was validated by performing measurements using a single microphone positioned at a distance of 1m.

Mr. Saito says, "By identifying the problems we can make design changes and ultimately improve the sound quality. But we have to decide which metrics are important for various engine conditions, for example, one of the methods is to record the sound quality metric followed by jury evaluation." He continues, "At the moment, we focus mainly on airborne noise. The dominant diesel engine noise is from 800 Hz to 4 kHz. Injector and turbo charger noise can reach 10 kHz and this is currently measured using PULSE and one microphone. We're very interested to see if the frequency range of sound quality metrics mapping can be increased so that these noise sources can be fully evaluated."

Isuzu no longer considers sound quality metrics mapping to be an experimental technology and is the first company in the world to actively use this solution to perform real measurements. Mr. Saito believes that, "Sound quality metrics mapping software will be very beneficial to Isuzu and will become an increasingly valuable tool. The initial tests were made to examine the sound quality of the powertrain on a test bench. However, having seen the results, the department responsible for testing on whole vehicles with engines installed is very interested in using the same technology." He concludes, "I am very satisfied with sound quality metrics mapping and it has huge potential to enable Isuzu to develop our diesel engines that will continue to lead the world."

Now available as standard

As a result of the cooperation between Brüel & Kjær and Isuzu, mapping of sound quality metrics has been implemented in PULSE Beamforming Type 8608 and PULSE Acoustic Holography Type 8607 and is the world's first commercially available sound quality metrics mapping software for beamforming and SONAH systems – a first class example of how Brüel & Kjær and one of its key customers worked together to develop cutting edge technology for the automotive industry.



Mapping various metrics using beamforming. From top to bottom – stationary loudness, roughness, and combined metrics.

SOUND QUALITY

Consumers identify the sound of any product as a major component of its overall quality, and while sound quality has been important to the automotive industry for decades, it is now a primary concern for manufacturers of items as diverse as consumer appliances, office equipment, power tools, marine equipment, and heavy machinery.

Achieving desirable sound quality requires tools to identify those key characteristics of sound that correlate to consumer perceptions of quality. Jury evaluation tools then allow developers and consumers to experience and evaluate the sounds.

PULSE Sound Quality Type 7698 provides tools for recording, playback, analysis, comparison, modification and characterisation, and it can be extended with the software options Zwicker Loudness BZ-5265, Order Analysis BZ-5277 and Psycho-acoustic Test Bench BZ-5301.

Automotive Sound Quality Bundle BZ-6047 contains an extensive tool set for recording, analysing, auditioning, dissecting, and synthesising sounds, and enables objective and achievable sound quality targets that are specified in engineering terms.

Starting a new family of sound quality software, PULSE Reflex Sound Quality Metrics Type 8710 offers a full suite of metrics integrated into the high productivity PULSE Reflex Core environment.

SOUND QUALITY – BINAURAL RECORDING

7698, BZ-6047, 7708, LAN-XI

Multi-channel, 160 dB dynamic range recording with Time Data Recorder Type 7708 and PULSE LAN-XI Data Acquisition Hardware.

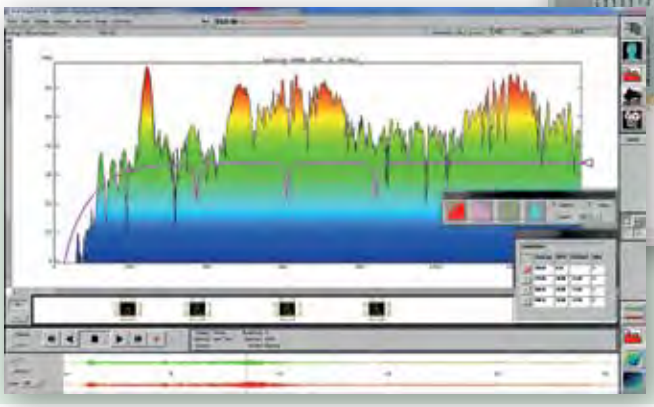
- 2 sound channels + 2 tachometer channels via sound card (Type 7698/ BZ-6047)
- Head and Torso Simulator (HATS) Type 4100 or Binaural Microphone Type 4101 for ultra-realistic binaural recording

PULSE Sound Quality Software Type 7698 provides many different ways to edit or modify sound signals. You can listen to the change in sound immediately after modifying it.

SOUND QUALITY – INTERACTIVE EVALUATION

7698, BZ-5265, BZ-6047

- Analyses signals in time and frequency domains
- Plays back sounds and compare sounds back-to-back
- Modifies sounds with filter types: high-pass, low-pass, band-pass, band-stop, notch and more
- Order-based analysis and filtering
- In Automotive Sound Quality Bundle Type BZ-6047, advanced tools include interactive playback displays, drag-and-drop-filtering, and transient analysis

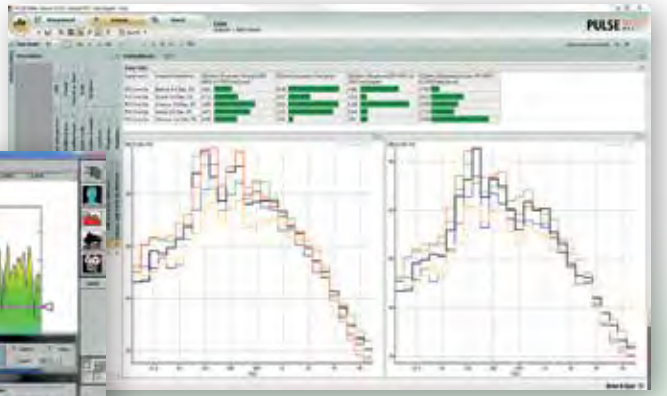


Interactive filtering, as shown here in BZ-6047, is an integral part of basic sound quality engineering

SOUND QUALITY – METRIC CALCULATION

7698, BZ-5265, BZ-6047, 8710

- Metrics include loudness, sharpness, roughness, fluctuation strength, tonality, prominence and tone-to-noise ratio
- Binaural loudness; Moore-Glasberg model (Type 8710), Robinson and Whittle (Types 8710 and 7698), for mean loudness between ears
- Concurrent spectral and overall broadband analysis
- Batch processing of multiple sound recordings (Type 8710)



Sound quality metrics calculations are integrated into the standard workflow of PULSE Reflex alongside overall, Nth octave, FFT and order analysis

JURY EVALUATION

BZ-6054, OPTIONS: BZ-6055, BZ-6056

Jury evaluation is an easy method of measuring human responses to sound characteristics, and is available for use in both individual and group jury evaluations. It enables sound characteristics to be controlled precisely, record responses, detect errors in real-time, and analyse responses

Subjective assessments are captured in jury evaluations to measure human responses to sound

VEHICLE

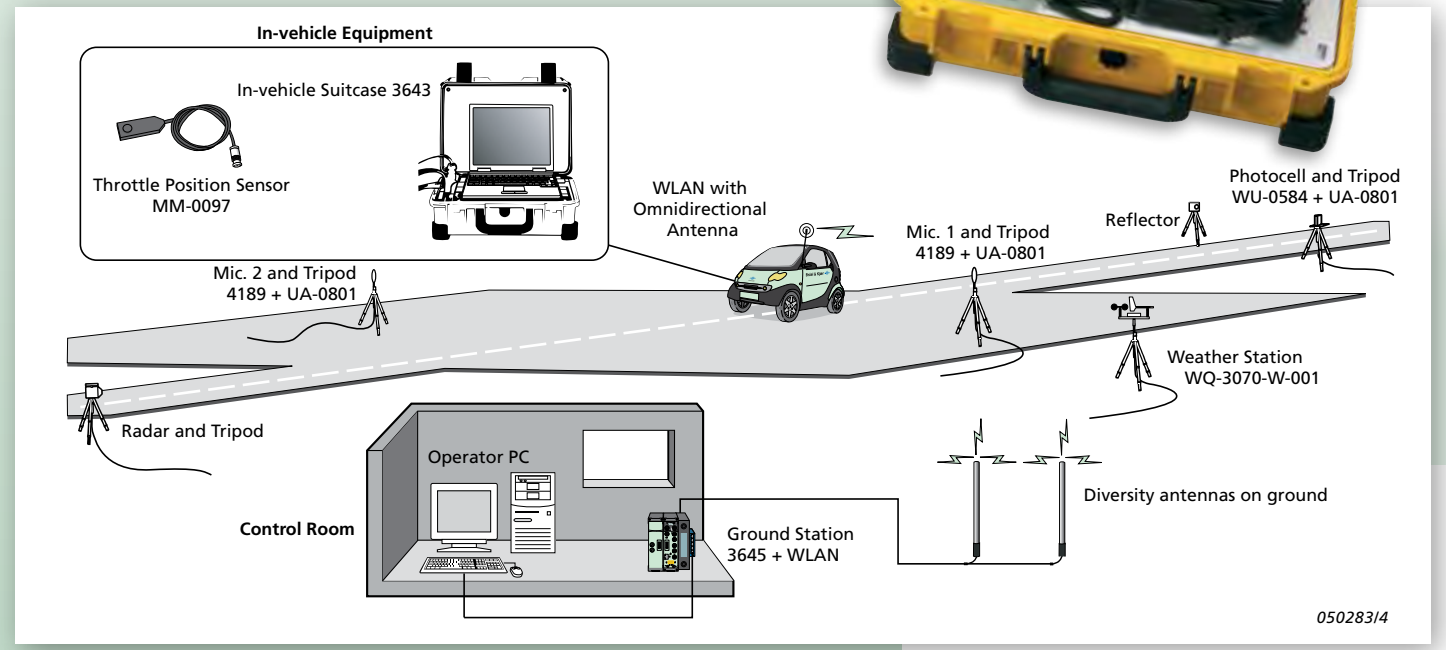
Certifying that vehicles comply with noise emission specifications requires measuring according to procedures defined by international standards. These specify a test of powertrain and tyre/road noise under typical urban traffic conditions, putting stringent demands on pass-by and coast-by noise testing.

Test equipment must support the specialised measurement methods and validate the defined values dictated by the test standard.

Our solutions cover the full spectrum of pass-by testing – from simple conformance testing to multi-channel diagnostics. All of our pass-by solutions (outdoor or indoor) support the most common international standards, including ISO 362, SAE J1470, ISO 13325 and ISO 5130.

In addition, our beamforming array selection provides outdoor sound mapping, helping to accurately locate the sound sources that contribute to the vehicle's sound.

Pass-by In-vehicle Box Type 3643



Vehicle Pass-By system overview

PASS-BY NOISE TESTING

PASS-BY CONFORMANCE TEST SYSTEM

PULSE Vehicle Pass-by Software Type 7788-A

- Ground-controlled
- Speed measurements by radar
- Reporting and data storage using standard Microsoft® Word or Microsoft® Excel®
- RPM measurements using telemetry (option)
- Weather station (option)
- Two-directional (option)

CUSTOMISED, GROUND STATION ONLY

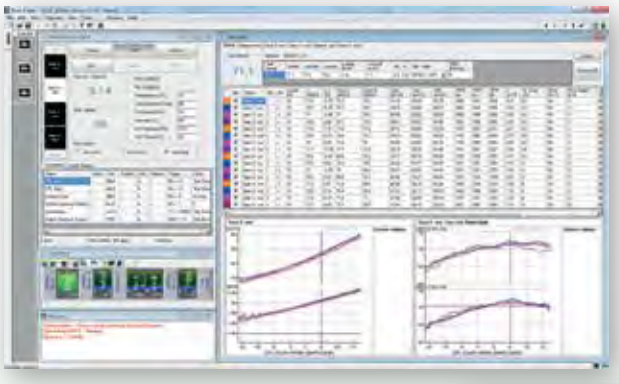
PULSE Vehicle Pass-by Software Type 7788-B

- Ground-controlled or vehicle-controlled via W-LAN
- Data storage in the PULSE Data Manager (PDM) database
- Post-processed results and time data
- Reporting in Microsoft® Word, Microsoft® Excel®, or advanced reporting using PDM
- Additional ground signals
- Data recording (raw time signals)
- Auto start/save

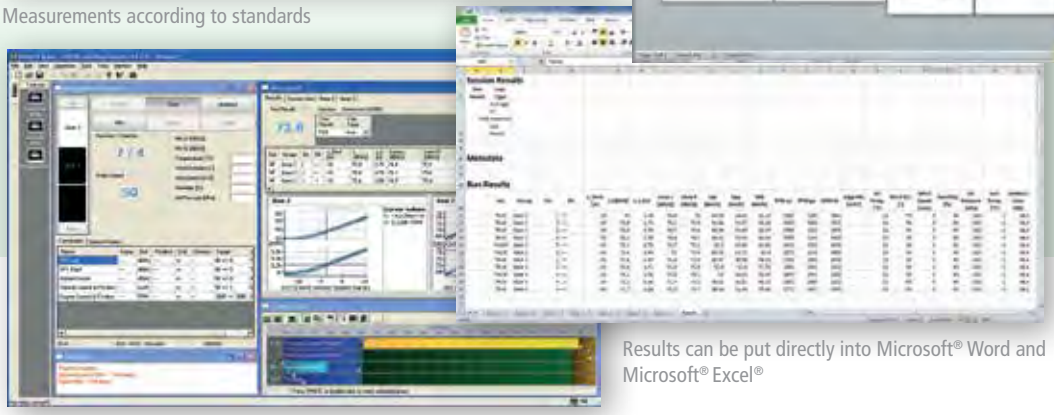
CUSTOMISED, GROUND STATION AND IN-VEHICLE, PASS-BY SYSTEM

PULSE Vehicle Pass-by Software Type 7788-C

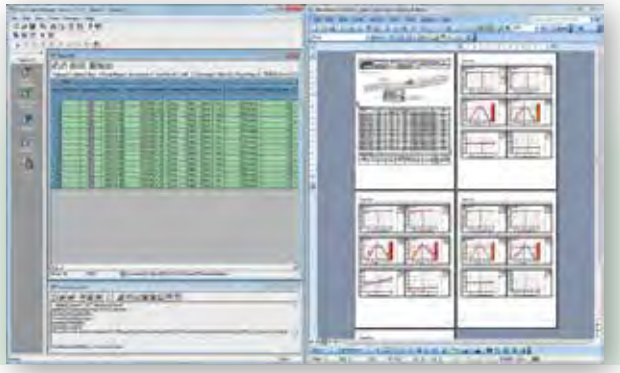
- Ground-controlled vehicle-controlled using W-LAN
- Data storage in the PDM database
- Post-processed results and time data
- Reporting in Microsoft® Word, Microsoft® Excel®, or advanced reporting using PDM
- Additional ground and in-vehicle signals
- Data recording (raw time signals)
- Auto start/save
- GPS speed can be used
- GPS sync for synchronising front-ends



Measurements according to standards



Results can be put directly into Microsoft® Word and Microsoft® Excel®



Advanced reporting with PULSE Data Manager (PDM)

INDOOR PASS-BY NOISE TESTING

Measuring a vehicle's interior and exterior noise during operation is far simpler indoors, using large semi-anechoic chambers containing chassis dynamometers – as many automotive manufacturers and sub-suppliers do. Eliminating variables such as weather and site variations makes measurements more reproducible, while the stationary vehicle allows more instrumentation.

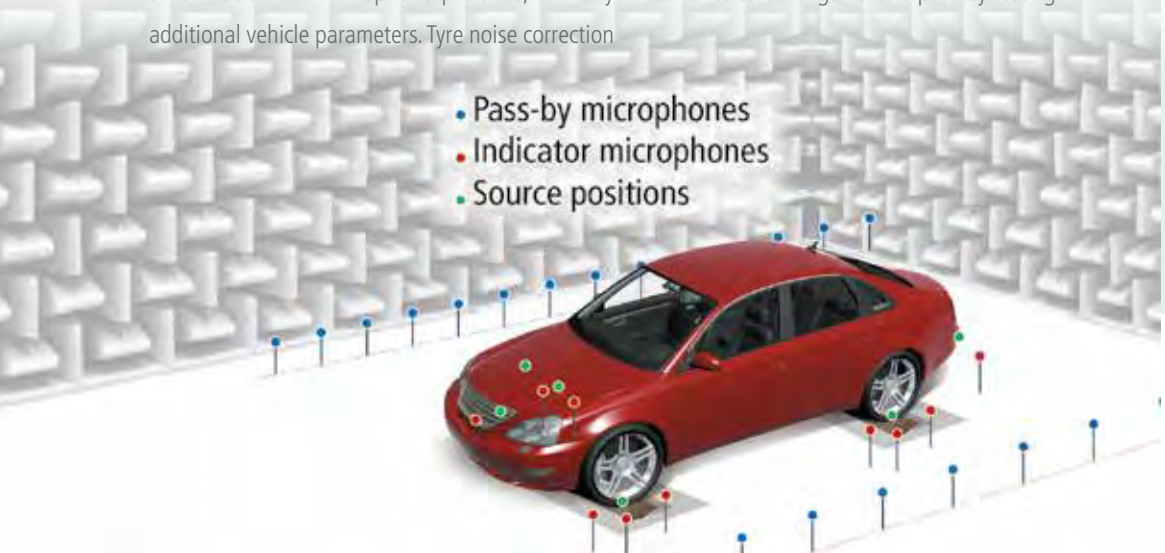
Simulation of normal pass-by noise is achieved by placing a row of microphones alongside the test vehicle so that there is no need to drive the test vehicle past stationary microphones, as is standard in a conventional outdoor pass-by measurement. Instead the vehicle is accelerated in the same way on a chassis dynamometer.

Simultaneous recordings are taken of a tachometer signal from the dynamometer, the vehicle's exterior noise at all microphone positions, and any additional vehicle parameters. Tyre noise correction then assists accurate comparisons with field pass-by measurement results.

Smaller rooms that lack the spatial dimensions dictated by the current ISO 362 pass-by standard are also suitable environments for indoor pass-by testing. Even where the required 7.5 m width from the vehicle centre-line and more than 20 m length will not fit in an anechoic room, our software accurately extrapolates the measurements.

The time-domain-based calculations enable Doppler-effect correction, as well as audible playback analysis with recorded and synthesised signals – helping you to quickly identify areas of interest.

The measurement and calculation procedure satisfies the ISO 362 pass-by standard and is ready for the new standard that will replace it, which will make indoor pass-by noise testing a standard conformance test alongside field pass-by testing.

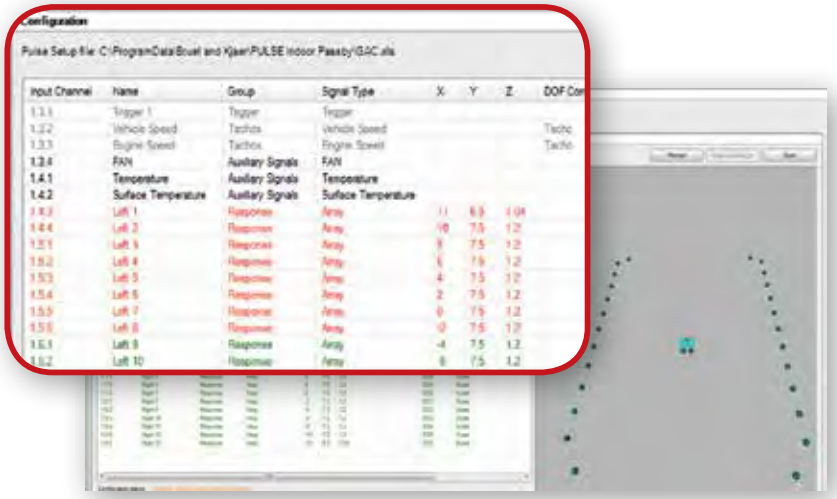


INDOOR PASS-BY TEST

7700-N, 7793

Simulation of vehicle pass-by noise testing in hemi-anechoic rooms for product development and trouble-shooting.

- Test setup can be created in Microsoft® Excel® and later imported into the system
- Support of non-optimal room size through flexible definition of microphone array
- Simulation of Doppler effect
- Tyre noise correction allows substitution with tyre noise measured on the test track
- Pass-by values automatically calculated upon completion of measurement
- Exterior noise contribution analysis is available with indicator microphones and volume velocity sound source

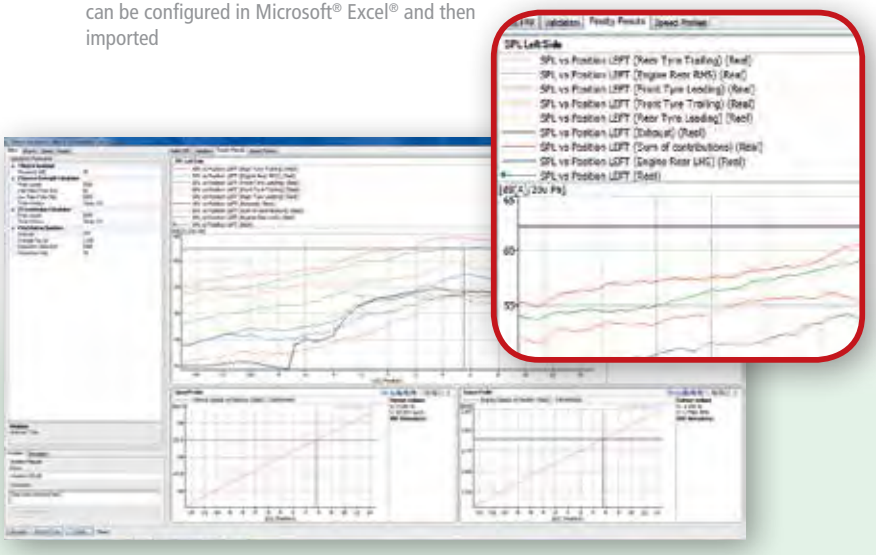


The microphone array for indoor pass-by setup can be configured in Microsoft® Excel® and then imported

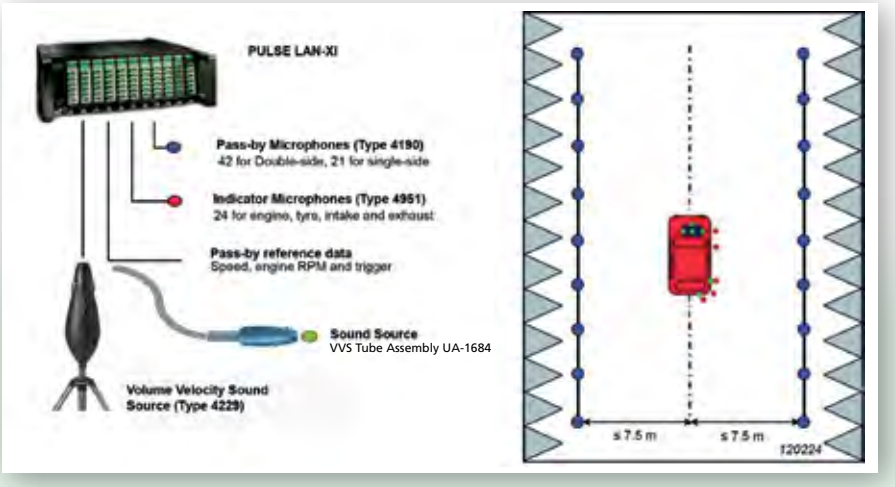
EXTERIOR NOISE CONTRIBUTION ANALYSIS

Calculation of exterior noise contribution in time-domain from the various noise sources.

- Sum of contributions may be compared with the measured total level to validate the component contributions
- Source modelling of components such as engine, transmission, exhaust/intake, tyres
- Contribution results may be exported to Microsoft® Word or Microsoft® Excel® for further analysis and reporting



Exterior noise contribution results of individual sound source components



System configuration for indoor pass-by and exterior noise contribution analysis

NVH SIMULATOR

NVH simulation accurately reproduces the noise and vibration of a vehicle in a realistic interactive driving environment, allowing measured data from vehicles and components, target levels, and data from CAE models to be evaluated.

Simulation improves understanding of customer preferences, vehicle-level target setting, cascading of subsystem and component targets, evaluating engineering changes, managing evaluation, target sign-off, and troubleshooting.

Engineering vehicle sound to match brand and customer expectations is assisted with a range of jury evaluation and engineering interfaces that allow assessors and engineers to interact with the NVH data in real-time.

PULSE NVH VEHICLE SIMULATOR VERSIONS:

- Desktop NVH Simulator – featuring a steering wheel, pedals, gear shift lever/paddles for interactive evaluation of NVH data by assessing the different sounds and vibrations as you 'drive' through a changing virtual scenario.
- Full-vehicle NVH Simulator – re-creates sound and vibration stimuli in a stationary, complete vehicle with a projection screen showing the virtual scenario. This provides a controlled, immersive evaluation environment for design evaluation of sound and vibration.
- DTS On-road Simulator – imports NVH data into an actual 'mule' car and re-creates vehicle sound in real-time, synchronising sounds to perfectly match vehicle speed, engine speed, pedal position and more parameters.
- DTS Exterior Sound Simulator – Facilitates sound design by assessing exterior sound and auditioning alternatives. It assists designing and assessing electric and hybrid vehicle sound, as well as 'conventional' vehicle sound such as exterior exhaust sound quality.

DESKTOP NVH SIMULATOR

3644, 8601

Data preparation software enables NVH and vehicle performance data to be extracted from recordings made on the road, a test bench (or any other source of NVH data) and prepared for free driving in an NVH simulator. Available modules include:

- Core and visuals module – enables the user to configure data into vehicle models, build virtual vehicles for assessment, choose which vehicles to compare in a test, and drive the vehicles interactively with virtual instrumentation for feedback of vehicle RPM, gear and speed information
- Jury evaluation module – enables the user to compare vehicle sounds in a structured jury evaluation, store results, and perform initial processing on them
- Engineering module – enables the user to control, modify and save individual sounds representing components of the vehicle
- Engineering and jury module – gives the benefit of both modules and allows the user to design and engineer the sound of the vehicle and perform structured evaluations to get qualified subjective opinions of the results

Scan here to see a video of the NVH Simulator:

The DTS On-road Simulator is used for back-to-back evaluations of benchmarked vehicles or proposed targets, while driving a real 'mule' vehicle

DTS ON-ROAD SIMULATOR

8601-N

The DTS On-road Simulator allows vehicle sounds created using the Desktop NVH Simulator to be experienced in a real car while driving on the road. The sounds of the existing vehicle are modified rather than replaced, resulting in a very natural presentation of the target sounds

EXTERIOR SOUND SIMULATOR

8601-T

The Exterior Sound Simulator utilises the powerful capabilities of the NVH Simulator for sound creation, modification and evaluation, and applies these to exterior vehicle sound.

- For 'quiet vehicle' applications
- For exterior sound quality applications

The DTS Exterior Sound Simulator is used to design and evaluate the sounds of the vehicle, as heard by pedestrians

A variety of visual road scenarios can be selected. Custom scenarios featuring real-world test tracks and roads can be easily created.

Real-time spectral analysis, modification, and recording of subjective preference (and the driver's actions) are always available while driving and interacting with sound contributions.

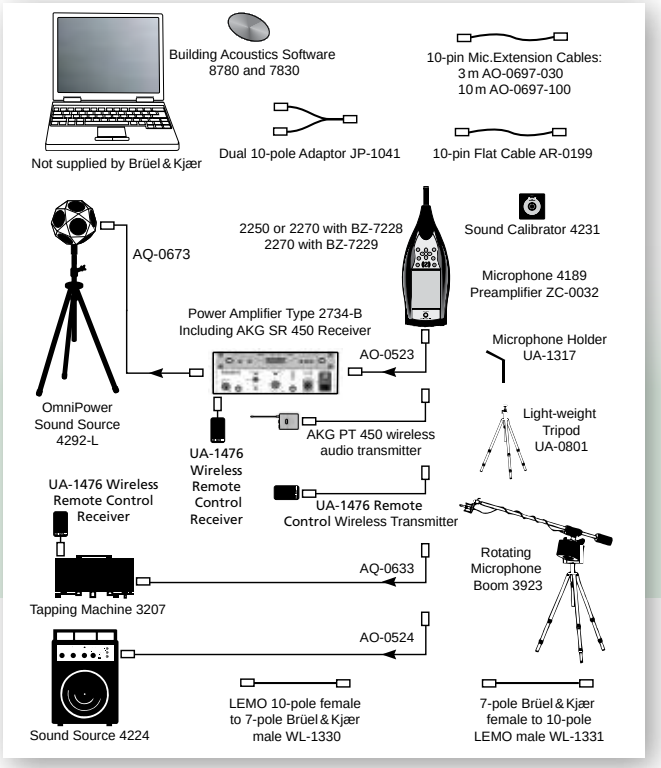
BUILDING ACOUSTICS

PULSE Reflex Building Acoustics is our software package for post-processing and reporting of building acoustics measurements made with our Type 2250/2270 hand-held analyzers. It allows measured data to be directly imported from your analyzer for viewing, analysis and reporting. Once imported, your measurement data are displayed numerically and graphically in one clear and concise environment.

Developed in cooperation with building acoustics professionals through user groups and customer clinics, many of the primary features came about as a result:

- 'Fast-track' report generation using the PULSE Reflex workflow concept and a library of user-defined report templates
- Versatile handling of measurement data to combine and compare assessments
- Interactive measurement integrity checks to ensure the best quality calculation
- Available in several languages, it can generate reports complying with national and international legislation
- Interactive measurement data editing to instantly reveal key contributing factors

Typical building acoustics project using PULSE Reflex Bulding Acoustics Type 8780. Data are presented graphically and numerically with detailed quality indications using the smiley system on Type 2250/2270 hand-held analyzers.



VIBRATION CHECK FOR AIRCRAFT ENGINES

To guarantee the maintenance of aircraft engines and optimise aircraft uptime, our vibration check systems perform field verification on specific engines. Measurements are made according to the procedures specified by the engine manufacturer's maintenance manual.

Turbomeca-based engine maintenance systems are available for 22 different variants, covering Arriel, Makila, Arrius, Turmo, Ardiden and RTM 322 engines among others. New systems for other engine types can easily be developed by our Customised Project Department.

All verification of vibration levels is performed in one engine run-up, with reference to two tachometer signals: one from the gas generator and one from the power turbine (free turbine). A warning is given if level limitations are exceeded.

Results are automatically stored in a database and displayed in a contour plot showing frequency, speed and level, in order to aid fault diagnosis. A report is produced immediately, according to the manufacturer's template.

VIBRATION CHECK SYSTEM FOR AIRCRAFT ENGINES

8324-G, 4 INPUTS

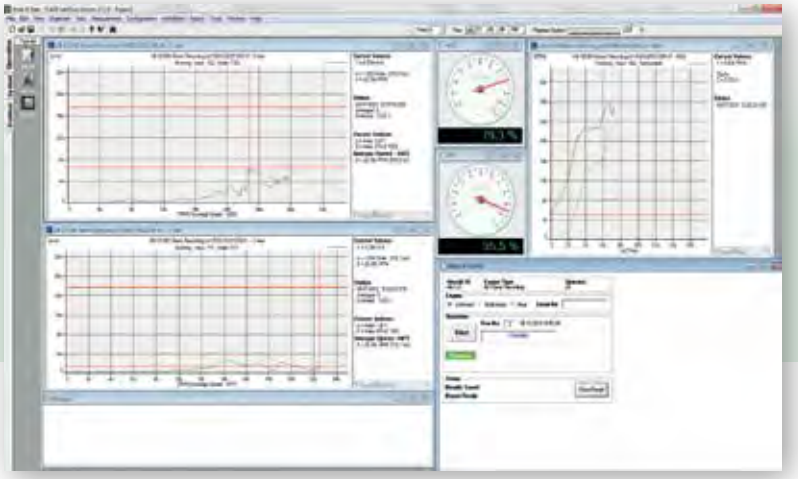
PULSE Vibration Check System including:

- Necessary software, portable PC, etc.
- Accelerometer with high-temperature cable, integrated charge converter/filter and TEDS (10 m in all)

ENGINE-SPECIFIC SETUP

UA-1678-A-0XX

- PULSE Vibration Check System for Turbomeca engines, node-locked license
- Annual Software Maintenance and Support Agreement
- Tacho harness
- Shoulder-bag for cables



Vibration referenced to the two tachos, engine run-up speed profile, and test and pass/fail information

ANGLE DOMAIN ANALYSIS

Rising fuel costs and growing environmental concerns put pressure on manufacturers to develop higher efficiency engines and powertrains with lower emissions. This development direction would traditionally lead to lower horsepower and degraded NVH performance:

TOUGHER EMISSIONS LEGISLATION

- In existing engines, this can result in higher combustion noise and an increase in the contribution from powertrain noise to overall vehicle noise

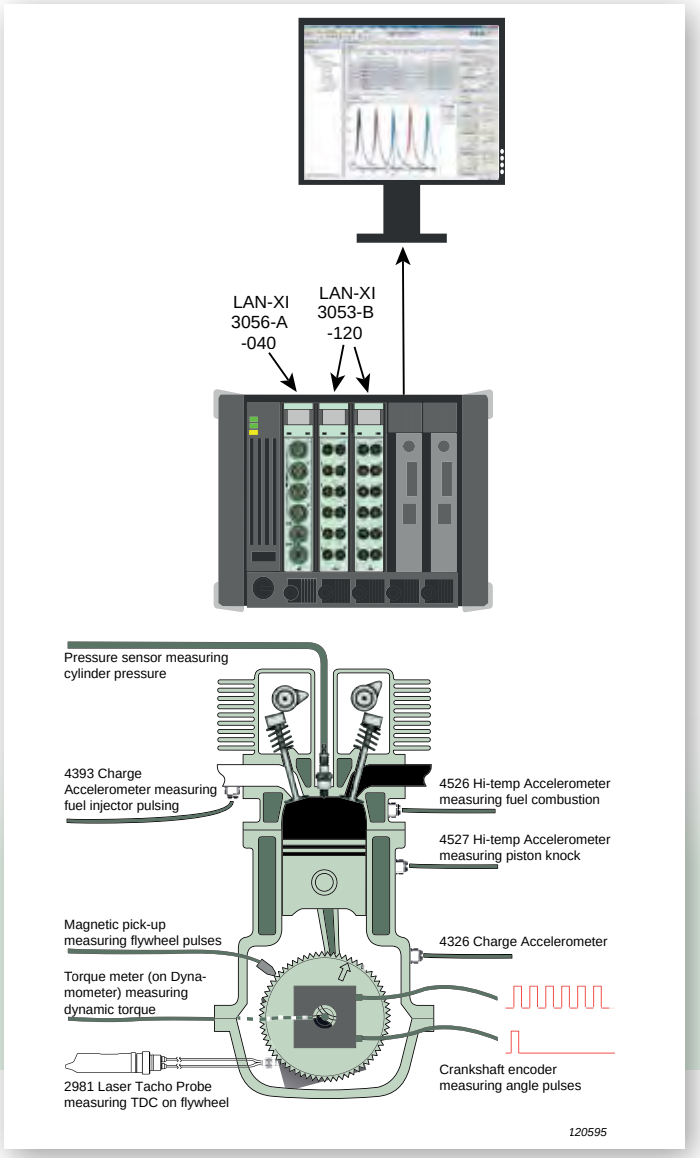
DEMAND FOR BETTER FUEL ECONOMY

- Leads to new and lighter engines with smaller water passages and less damping of powertrain noise
- Requires lightweight and low-friction gearboxes with increased gear noise and gear rattle
- Increasing use of 2- and 3-cylinder engines with inherent imbalance

The market, however, still expects good driving performance and superior comfort – thus increasing the challenge for NVH engineers.

The PULSE platform provides a wide range of tools for general powertrain NVH analysis and simulation in the context of the whole vehicle. Our systems perform angle domain analysis alongside other types of analysis, such as FFT and 1/3-octave noise analysis.

The angle domain offers a different perspective on NVH issues where the angular position of a rotating component (often the engine crankshaft) can reveal noise sources which are cyclic in nature, such as the firing of a particular cylinder, or a mechanical excitation occurring at a fixed point in the duty cycle.



For more information on angle domain analysis scan here:

DATA ACQUISITION

7700, 7702, 7708

A typical monitoring view during data acquisition includes:

- RPM and level meter for each channel
- Angle profile
- Cylinder pressure signals for five cylinders
- Time and frequency signatures of a vibration signal

ANGLE DOMAIN POST-PROCESSING

8740

Processes time data recordings into the angle domain, presenting results as:

- 3D displays of cycle vs. time or cycle number
- 2D displays of cycles (either overlaid or single)
- Gated statistics vs. cycle number

Data can be stored in the PULSE Reflex database for further processing and reporting in PULSE Reflex Core.

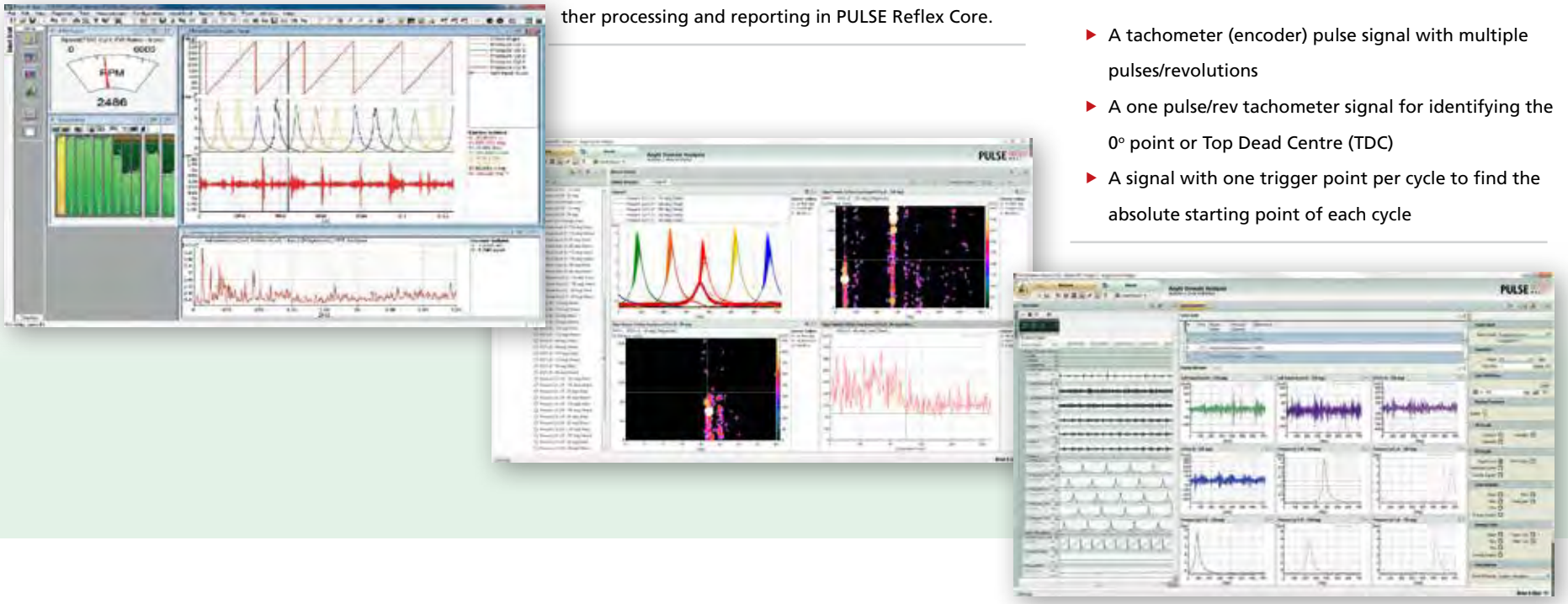
ANGLE AND CYCLE EXTRACTION

8740

An angle vs. time signal can be included in the recorded data if measured using the LAN-XI module Type 3056. Otherwise it can be calculated in the time editor.

Up to three signals can be used to determine absolute crank angle position. For example, in 4-stroke engines, the unique crank angle in a 720° cycle can be calculated from:

- A tachometer (encoder) pulse signal with multiple pulses/revolutions
- A one pulse/rev tachometer signal for identifying the 0° point or Top Dead Centre (TDC)
- A signal with one trigger point per cycle to find the absolute starting point of each cycle



TIME DOMAIN SOURCE PATH

How will each component contribute to the overall sound of a product? How can you tell where the sound is coming from? How does it travel to where you hear it? And what can you do to improve the sound of the vehicle?

Whether assessing the contributions of an engine on a test bed, or identifying operational contributions on the road, time-domain Source Path Contribution (SPC) allows you to assess transfer paths and contributions to quickly evaluate the noise and vibration perceived by vehicle occupants.

Our unique time-domain technology allows you to listen to and compare data sets back-to-back, and assess the effects that developments will have on the final products through SPC models. The system can also inspect data in the frequency domain, giving great flexibility.

Understanding how noise and vibration is transmitted through different paths in and around the vehicle allows you to rank contributions using various NVH methods such as mount-stiffness and impedance matrix methods for structure-borne NVH, and source-substitution for airborne NVH.

Using data recorded in the time domain means you can solve any potential problems during analysis from a safely captured data set, while you are listening to or evaluating the calculated time signals.

PULSE SPC VIEWER

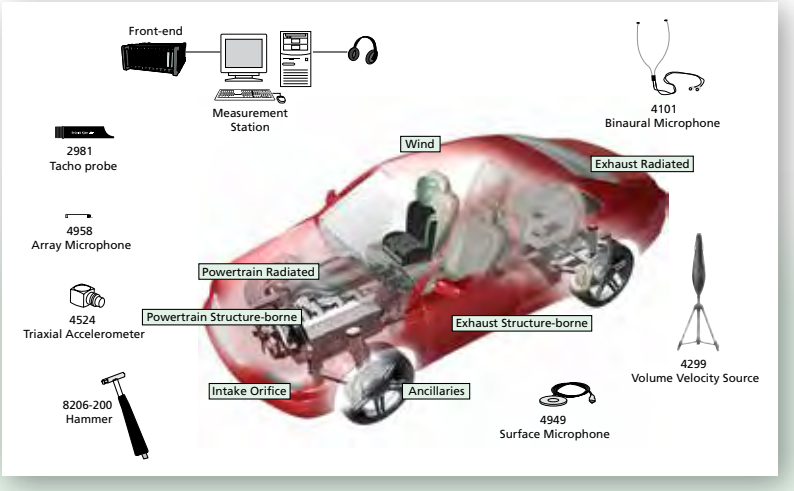
7798-A

General base license for all SPC methods.

PULSE SPC MOUNT STIFFNESS AND IMPEDANCE MATRIX METHODS

7798-B

Frequency-domain structure-borne and airborne contribution analysis (mount stiffness and impedance matrix). Post-processing analysis of contributions, source strengths and path sensitivities.



CONTRIBUTION

PULSE SPC MATRIX METHOD WITH PRINCIPLE COMPONENT DECOMPOSITION

7798-C

Frequency-domain quantification of non-correlated contributions to the receivers. Identifies source strengths of airborne sources via microphone indicator positions and the use of principal component analysis to derive proper acoustic source models.

PULSE SPC MULTIPLE COHERENCE METHOD TYPE

7798-D

The SPC Multiple Coherence module allows the quick assessment of contributions from multiple uncorrelated or partially correlated sources, such as tyre noise in a vehicle.

PULSE TIME DOMAIN SPC

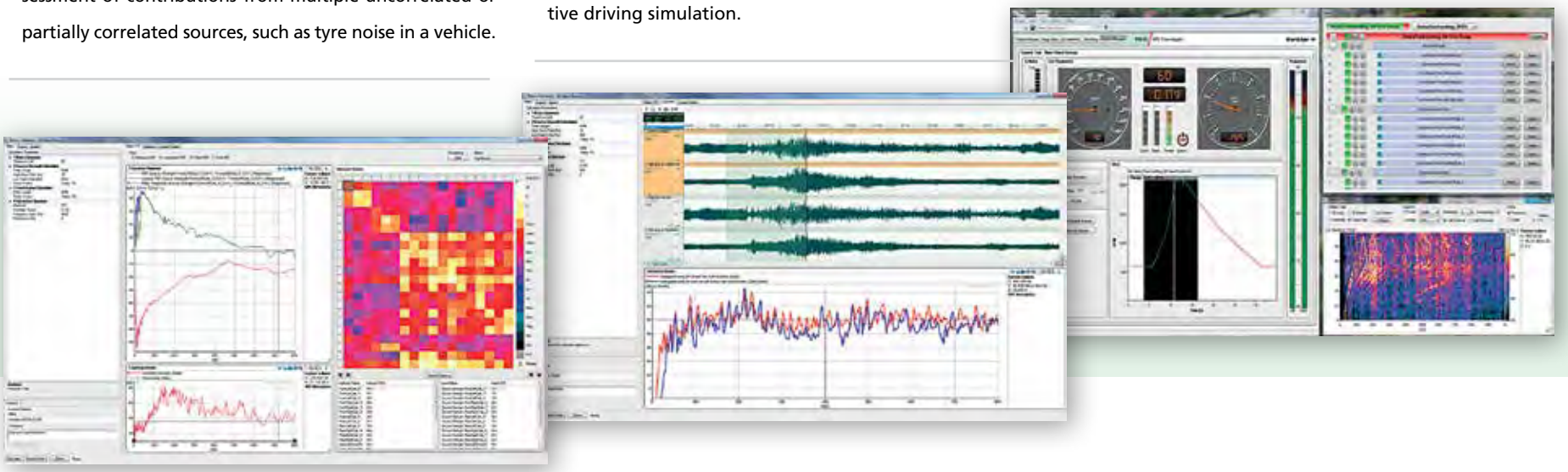
7798-E

Time-domain SPC calculates contributions, source strengths and forces using matrix inversion, source substitution and mount stiffness methods in the time-domain. The time-domain SPC results can be replayed and viewed in the SPC software. Typically they are analysed using SPC Time Insight to rapidly evaluate, analyse, modify, compare and communicate the results. They can be further analysed using PULSE Reflex to quickly and efficiently view orders, spectra, waterfall spectra, compare source and contribution levels, and generate test reports. The time-domain results can also be used in the PULSE NVH Vehicle Simulator as part of a fully interactive driving simulation.

SPC TIME INSIGHT

8601-S

SPC Time Insight allows you to play back, analyse and modify time-domain SPC results. It performs in-depth root-cause analysis, changes source levels and path sensitivities to reflect possible design changes, sets target levels, and compares measurements side-by-side. Users can observe and analyse data in real-time or off-line, and easily evaluate and communicate results.



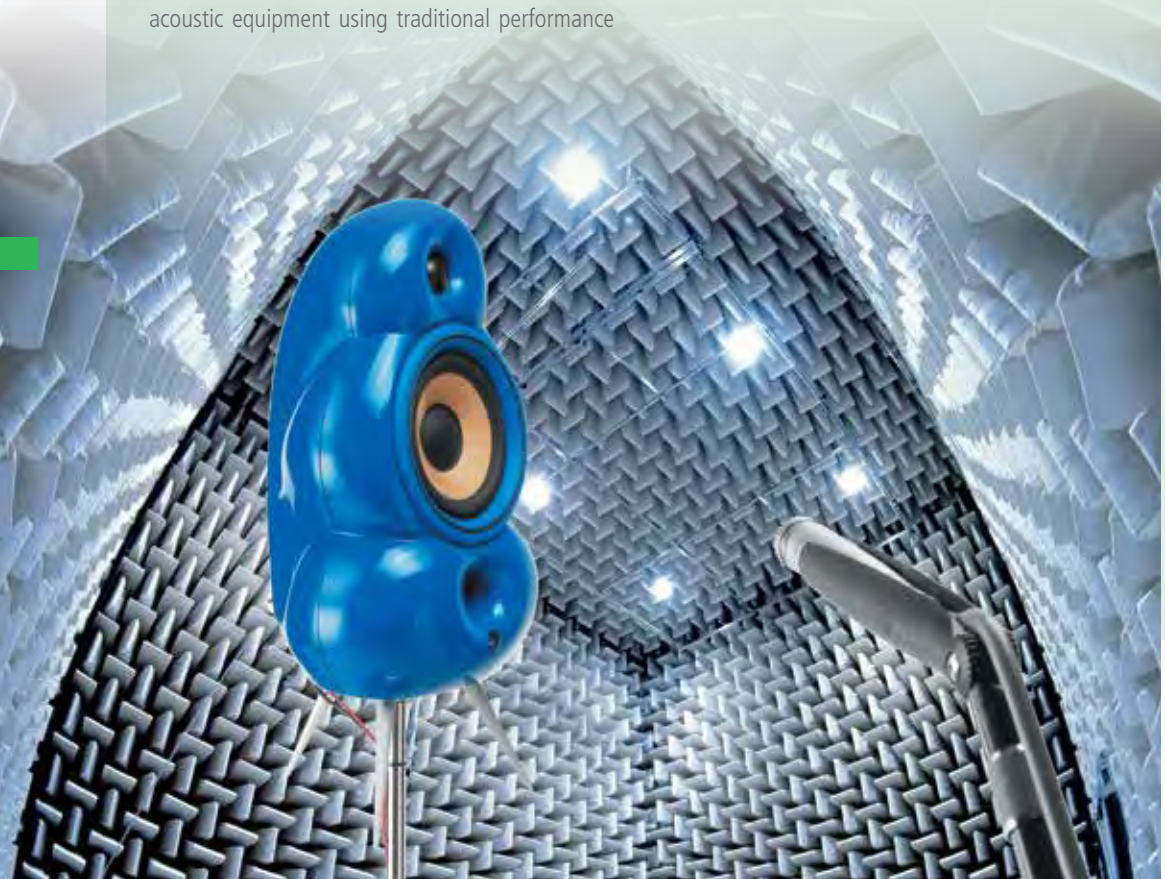
ELECTROACOUSTIC TESTING

Manufacturers of electroacoustic equipment such as loudspeakers, microphones, telephones, headsets, hearing aids and hydrophones consistently deliver high-quality acoustical designs by continuously innovating in their products and processes.

Measuring and documenting acoustical performance is a key element in this improvement process, during both the development and the manufacture of new products.

In the future, the ability to characterise electroacoustic equipment using traditional performance specifications such as frequency response, distortion, linearity, directivity, and delay will be combined with a wide range of other acoustical and vibration measurements.

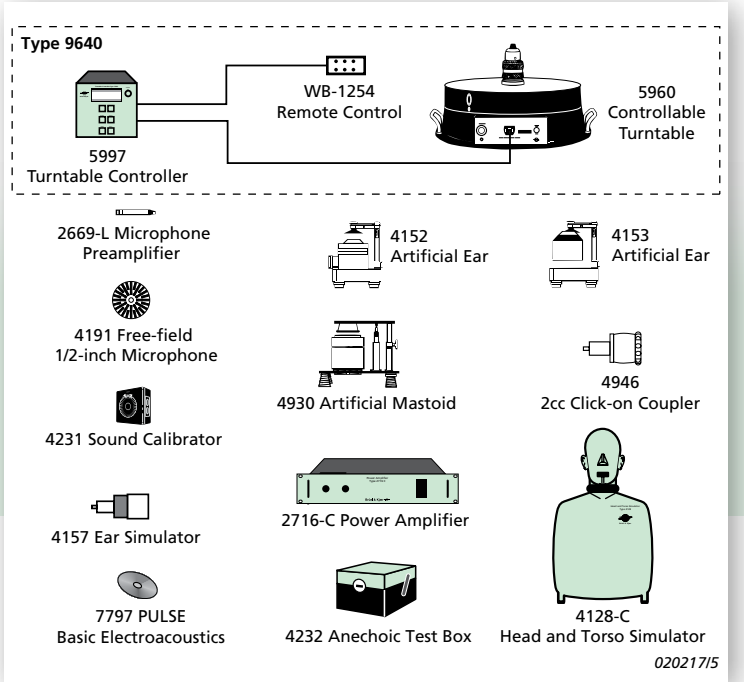
Acoustic and vibration measurements such as those performed in material testing and modal analysis are expected to become an important prerequisite for continued innovation and improvement within the development and manufacturing of electroacoustic equipment.



PULSE AUDIO ANALYZER, BASIC ELECTROACOUSTICS

7797, 3160-A-042

- Frequency response
- Near-field measurements
- Simulated free-field measurements
- Tolerance check
- Data manager
- Reporting using Microsoft® Word, Microsoft® Excel® or Microsoft® PowerPoint® templates
- Automation using Visual Basic®



PULSE PROFESSIONAL AUDIO ANALYZER, ADVANCED ELECTRO-ACOUSTICS

7907-S1, 3160-A-042

Features as Basic Electroacoustics, plus:

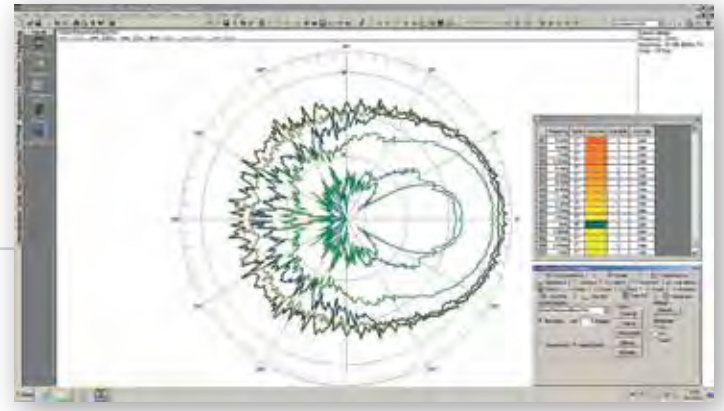
- Harmonic distortion measurements
- Intermodulation distortion for near-field measurements
- DIFF distortion measurement for near-field measurements
- Directional response measurements and polar plot
- Thiele-Small parameters
- PULSE sequencer for automation

PULSE WIDE RANGE AUDIO ANALYZER

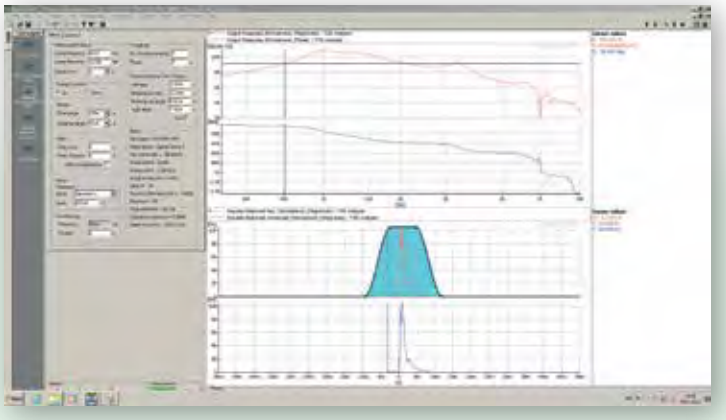
7797, 3560-C-T61

For measurement of loudspeakers and hydrophones.

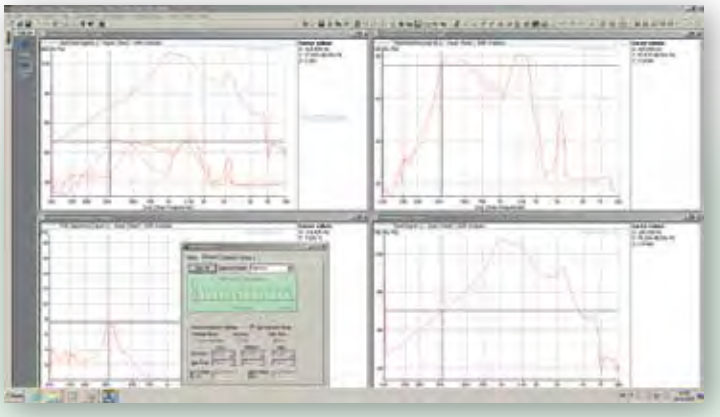
- Frequency response
- Reporting using Microsoft® Word, Microsoft® Excel® or Microsoft® PowerPoint® templates
- Sequencing using Visual Basic®
- Distortion analysis



Directivity measurements are performed using Steady State Response (SSR) or Time Selective Response (TSR) analysis, with the results displayed as a polar plot



Simulated free-field measurements using TSR analysis for determining frequency response and harmonic distortion



Frequency response and distortion measurements are performed using SSR analysis, revealing results with a known high accuracy

TELEPHONE TESTING

Mobile conversations can take place almost anywhere – from quiet offices to noisy outdoor environments. And since users demand high voice quality in all situations, the acoustic perception of devices is critical. Corded handset/headset telephones and mobile devices alike need advanced acoustic and electronic signal processing combined with superior design.

We offer two standardised test configurations, with one configuration based on a telephone test head equipped with a stand-alone mouth simulator and ear simulator. The second configuration is based on a Head and Torso Simulator (HATS), with an integrated mouth simulator and one or two integrated ear simulators.

Thanks to several decades of playing an active part in standardisation within the telecommunication industry, Brüel & Kjær is regarded as the worldwide industry reference, setting standards for telephone testing worldwide.

Our experience of providing high-quality acoustic solutions provides us with a solid foundation from which to develop new products for emerging telephone technologies and markets.

TELEPHONE TESTING USING STANDARDISED PROCEDURES

8770, 8771, 8772

For performing measurements in compliance with international and national standards for frequency response, loudness rating, noise, distortion, echo, switching, etc.

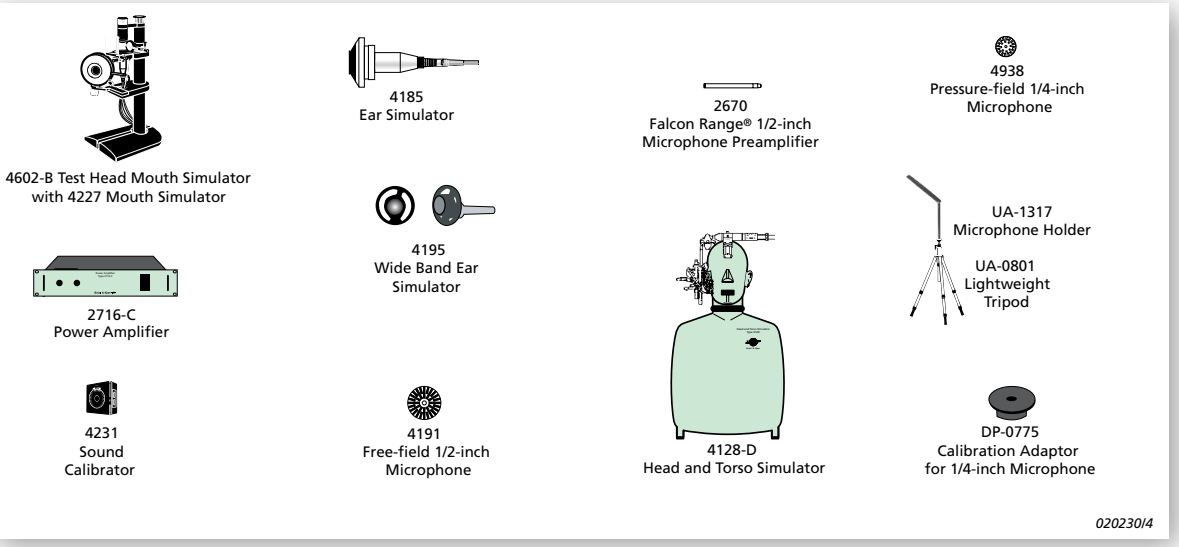
- Perception-based evaluation of speech quality
- Measurements on handsets, headsets and hands-free communication devices
- Imitates the use of communication devices in everyday life
- Supports Head And Torso Simulator (HATS) and telephone test head configuration
- Automated calibration procedures
- Easy control of measurements
- Imports measurements from legacy telephone testing software
- Ear and mouth simulator conforms to ITU-T P.51, P.57, P.58, P.64, IEEE 269 and IEEE 661 standards
- Automatic reporting in Microsoft® Word, Microsoft® Excel® or Microsoft® PowerPoint®

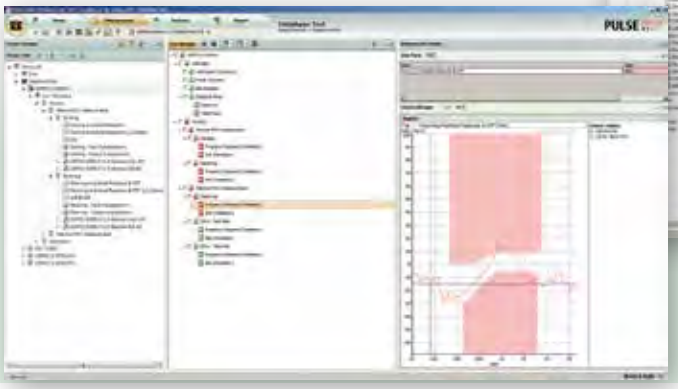
TELEPHONE TESTING IN SIMULATED NOISE ENVIRONMENTS

BZ-5830, BZ-5831, BZ-5832, BZ-5833

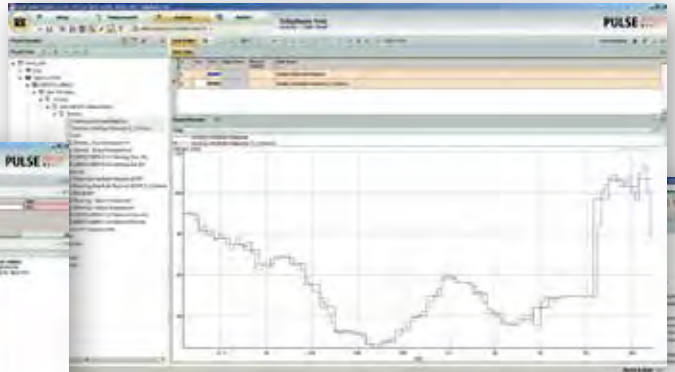
Evaluates noise suppression and speech enhancements techniques under controlled conditions, using real speech signals and environmental noises as background sound.

- Creation of simulated noise environment using standardised loudspeaker configurations
- Measurements of PESQ, SNRI, NPLR, ASL, etc.
- Measurements of S-MOS, N-MOS and G-MOS
- Automated calibration procedures
- Easy control of measurements
- Automatic reporting in Microsoft® Word, Microsoft® Excel® or Microsoft® PowerPoint®.

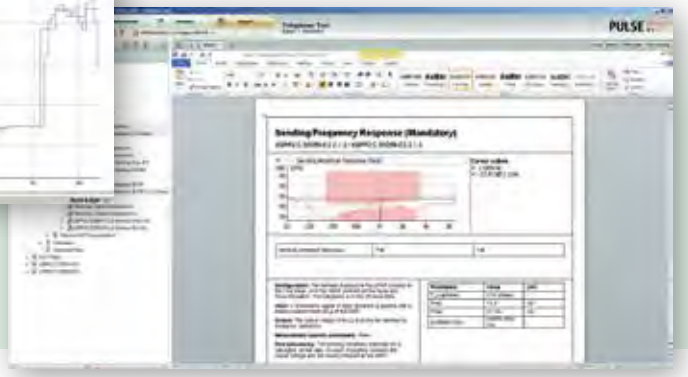




Automated measurement execution and presentation of results including pass/fail indication are provided in a single screen view



Data from various measurements which have been produced by the telephone test application can be compared with measurement data imported from the previous-generation telephone test application



Full documentation of the complete suite of tests is provided in a Microsoft® Word document exhibiting live curves and pass/fail indication

NANJING HIGH SPEED GEAR

Quality requirements for wind turbine components are high, especially for gearboxes. Nanjing High Speed Gear Manufacturing Co., Ltd. has implemented very stringent requirements – from materials to production – to ensure the highest product quality for its customers. NGC and Brüel & Kjær have worked together since 2006, and NGC has used Brüel & Kjær's PULSE data acquisition and analysis platform for a range of applications ranging from R&D, quality control, production testing and validation to field measurements.

The company

Nanjing High Speed Gear Manufacturing Co., Ltd. (NGC) is a leading gearbox manufacturer for the wind energy market. In 2010, NGC produced 2400 gearboxes and aims at producing 3400 gearboxes in 2011. This will put NGC's scale of production in the global top three.

The company has a 80% market share of the Chinese wind transmission equipment market and customers include GE Energy, Vestas, Repower, Nordex, Goldwind Science and Technology Co., Ltd., Dongfang Steam Turbine Works, Shanghai Electric Group Co., Ltd., and Sinovel.

A subsidiary of the holding company Nanjing High-Speed & Accurate Gear Group Co. Ltd., NGC was established on 8 July, 2003 and began supplying the wind energy market in 2004. Since then, it has expanded its customer base and production scale to become one of the world leaders. NGC is located in Jiangning Science Park, Nanjing, and of its 2437 employees, 295 are engineering technicians.

Wind energy growth in China

In China, the growth in wind energy is set to continue at a breathtaking pace. Already in 2009, China accounted for one third of the annual wind capacity additions, with 13.8 GW worth of new wind farms installed. This took China's total capacity up to 25.9 GW, thereby overtaking Germany as the country with the most wind power capacity by a narrow margin.

China will remain one of the main drivers of global growth in the coming years, with annual additions expected to exceed 20 GW by 2014. This development is underpinned by a very aggressive government policy supporting the diversification of electricity supply and the growth of the domestic industry. The Chinese government has an unofficial target of 150 GW of wind capacity by 2020, and with the current growth rates, it looks likely that this ambitious target will be met well ahead of time. (Source GWEC 2009)

Quality requirements for wind turbine components are high, especially for gearboxes. NGC has implemented very stringent requirements – from materials to production – to ensure the highest product quality for its customers. NGC and Brüel & Kjær have worked together since 2006, and NGC has used Brüel & Kjær's PULSE data acquisition and analysis platform for a range of applications ranging from R&D, quality control, production testing and validation to field measurements.

The company's gearboxes range in size – from 3 MW, 2 MW, 1.5 MW right down to 850 to 750 kW. With its latest 3 MW gearbox, NGC has signed agreements with several domestic companies to jointly develop and further improve its development capability and production. The gearboxes are designed and manufactured according to GL Rules, and all transmission components are machined according to ISO 6336 and DIN 3990 standards, ensuring gear accuracy and strength. The large ductile iron parts, such as planetary carriers, housings and torque arms, etc., are all analysed by FEM to ensure their rigidity and stability. Materials, manufacturing processes, heat treatment and assembly procedures are also strictly controlled thus guaranteeing safe production.

MANUFACTURING CO., LTD.

All gearboxes undergo a series of tests and validations. These include nominal power test, 300% load test and stress test. Results show that the gearbox working efficiency is higher, the noise level and temperature rising is lower, and the tooth stress and load distribution are qualified. During testing, a large amount of data was gathered for use as the groundwork for the development of large power gearboxes.

A special lubrication cooling system has also been designed for all gearboxes. This system is internally circulated, and bearings and meshing positions between gears are lubricated impulsively by the oil pump. The lubricating efficiency is highly improved and as a result is more reliable and safe.

Brüel & Kjær plays an important part in ensuring the highest gearbox quality at NGC. Every test bench at NGC's two production facilities has a Brüel & Kjær data acquisition and analysis system and every single gearbox is run through a production quality control measurement program that meets strict customer requirements and ensures the highest customer satisfaction.

Brüel & Kjær setups, similar to the one shown above, are used by NGC for research, design and development purposes. They were used during the development of the new 3 MW gearbox and will also be used for the even larger gearboxes that are currently under development.

NGC does not compromise with quality and totally trusts the products provided by Brüel & Kjær. Equally important are the local presence and the relationship built over the years between NGC and Brüel & Kjær.

In fact, Brüel & Kjær is used exclusively at NGC and key reasons for this include a strong field presence and assistance with test measurement setup, quick local support, reliable quality and the wide range of sound and vibration solutions.

NGC selected Brüel & Kjær back in 2006 for sound and vibration quality control testing after an in-depth evaluation of various suppliers. Today, it has Brüel & Kjær data acquisition and analysis systems installed at all test benches for both quality control in production and R&D.

NGC and Brüel & Kjær both look forward to future challenges, as the demands for larger gearboxes increase and new requirements for quality and reliability have to be met.

Photo courtesy of Nanjing High Speed Gear Manufacturing Co., Ltd.

NGC mainly produces wind turbine gearboxes. The plant covers an area of 258 acres (172 000 m²) and produces approximately 4000 MW annually

ORDER ANALYSIS

In rotating and reciprocating machines, varying load conditions and imperfections in the moving parts cause vibrations and associated sounds. The vibrations are shaped by the structural properties of the moving and stationary parts of the machine.

Order analysis relates measurements to revolutions of a rotating part, improving knowledge about machinery such as aircraft and automotive engines, powertrains, pumps, compressors and electric motors.

TYPICAL USES:

- Separation of rotational and structural noise and vibration phenomena
- Identification of noise generated by rotational vibrations
- Determination of critical speeds and excited resonances
- Investigation of instabilities in rotating machinery caused by varying load

ORDER ANALYSIS METHODS:

Without tracking – for analysis of lower orders and moderate RPM slew rates, based on frequency spectra from FFT analyses

With tracking – for analysis of higher orders or higher RPM slew rates, based on order spectra and tracked resampling from tacho signals used as reference

Both methods operate in real-time, providing spectra, 3D plots like 'colour contour' or 'Campbell diagram', individual order, and structural slices versus RPM of one or more rotating parts. All methods support the use of multiple tacho signals as references, and with the Autotracker functionality it is possible to extract the tacho signal directly from a measurement input, for example in cases where a tacho signal is not directly available.

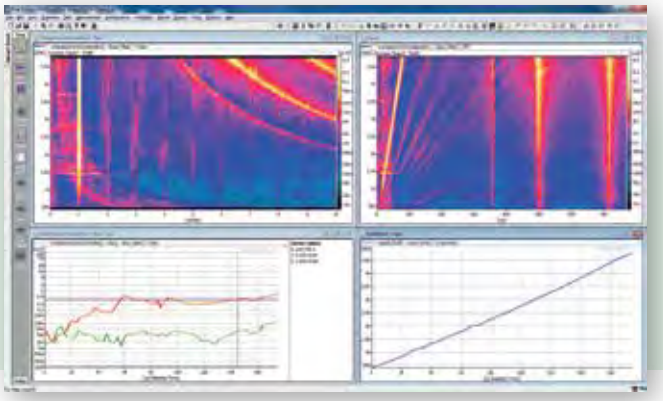
All data can be tagged with process data such as temperature, oil pressure, position, wind speed, and all order analysis results can be shown in relation to these auxiliary parameters.

ORDER ANALYSIS WITH TRACKING

7770-N, 7702-N, UNLIMITED INPUTS

This configuration provides FFT-based order analysis as well as order tracking on an unlimited number of channels. Order tracking is useful when frequency smearing will compromise the FFT-based analysis, and when:

- Higher orders are of interest
- Orders are not well separated
- RPM ranges are wide
- Slew rates are high



Order analysis with and without tracking, first and second order cut vs. time and run-up speed profile vs. time

ORDER ANALYSIS WITHOUT TRACKING

7770-N, 7702-N2, UNLIMITED INPUTS

This basic configuration provides FFT-based order analysis on an unlimited number of channels with up to 2 tacho signals. FFT-based order analysis is an attractive solution when:

- Only lower orders are of interest
- Orders are well separated
- RPM ranges are limited
- Slew rates are moderate
- Processing resources are scarce

MOBILE ORDER ANALYSIS

7770-N6, 7702-N6, 7708-N6, 6 INPUTS

This configuration provides FFT-based order analysis as well as order tracking and time data recording on six channels, which is possible on one LAN-XI module. This mobile order analysis solution is the solution when:

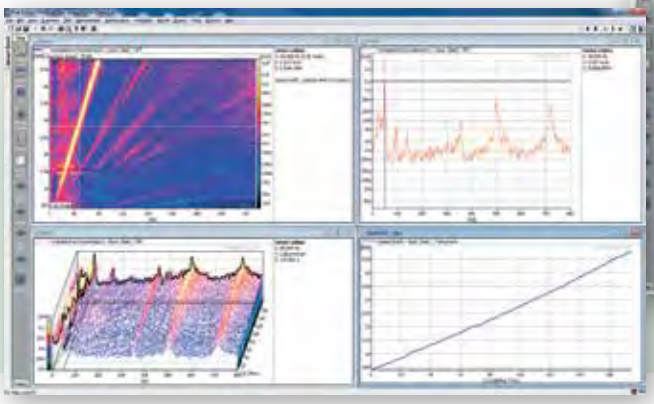
- The solution must be portable
- Order analysis with tracking is occasionally needed
- Time data recording is mandatory
- Post-processing is preferred

ADVANCED ORDER ANALYSIS

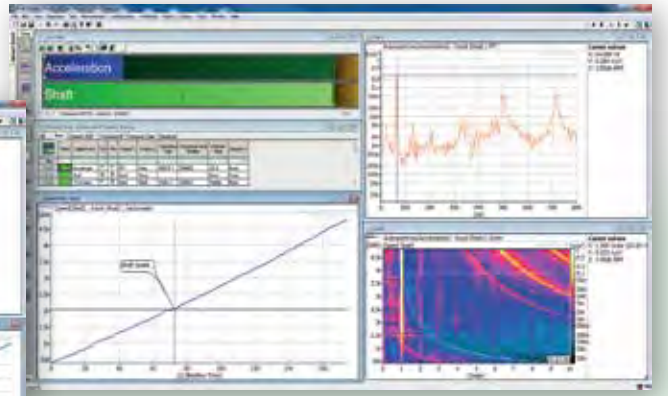
7700-N6, 7702-N6, 7703, 7705, 6 INPUTS

This configuration has order tracking on six channels. On top of this it has Vold-Kalman tracking filter (V-K) and time capture for V-K pre-analysis. Time capture comprises STFT (Short Time Fourier Transform), suited for analysis of transients. Vold-Kalman is the solution for:

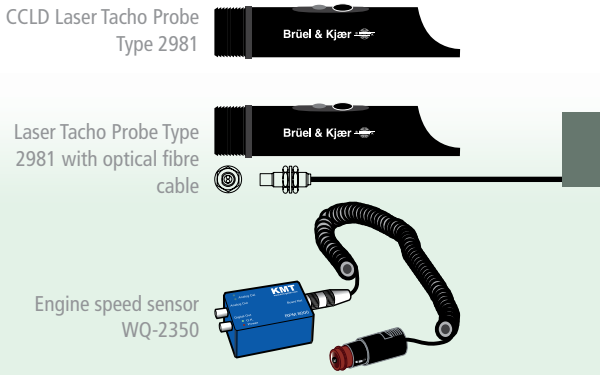
- Very high slew rate, gear shifts
- Close or crossing orders
- Extraction of order waves
- Tacho drop outs



FFT-based order analysis with colour contour and waterfall plot



Order acquisition with speed profile, monitoring critical speeds



MACHINE DIAGNOSTICS

Moving parts in any rotating machine will eventually cause annoying vibrations that ultimately lead to breakdowns due to production and assembly tolerances, wear, and load variation.

Machine diagnostics is the PULSE configuration for addressing vibration problems in rotating machines. Our tools can be used in run-up/down sessions, and combined to diagnose multiple faults – such as performing cepstrum analysis of order spectra or envelope spectra.

All analyses can be performed simultaneously, and the raw signals can be recorded for subsequent analysis using the extension PULSE Time Data Recorder. Diagnostics on transient phenomena is then performed with PULSE Time Capture.

All data can be tagged with auxiliary parameters such as temperature, oil pressure, position, and wind speed, and all results shown in relation to these.

MACHINE DIAGNOSTICS

7770-N, 7702-N, 7773

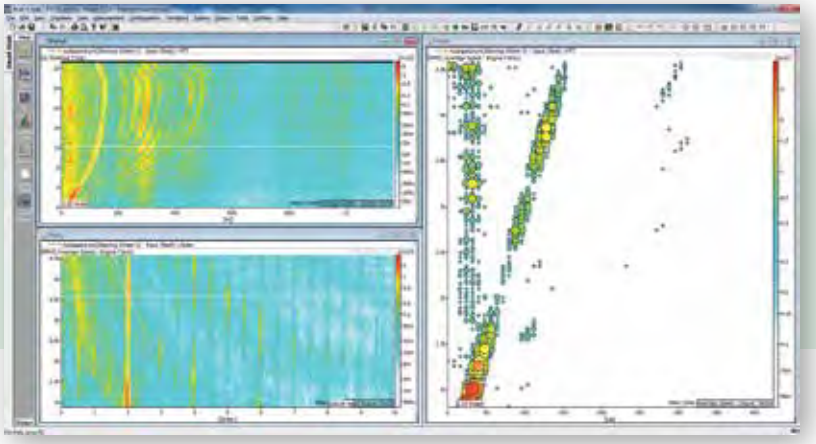
Machine Diagnostic system includes:

- Multi-tachometer
- FFT order analysis
- Order tracking
- Signal enhancement
- Envelope analysis on bearings
- Cepstrum analysis on gearboxes
- Process data /auxiliary parameter logging

Displays:

- Waterfall
- Colour contour
- Campbell diagram
- Order and frequency slices
- RPM profiles
- Order and spectral data as function of process data

The configuration comprises Order Analysis Type 7702-N. See Order Analysis on page 59 in this catalogue for properties and capabilities. Any LAN-XI Data Acquisition Hardware module is suitable for machine diagnostics, giving from 2 to 12 input channels. Auxiliary parameter logging requires LAN-XI module Type 3056.



Order analysis with Campbell diagram and colour contour plots with custom colours

BALANCING

Imbalance results from an uneven distribution of mass in a rotor, causing vibrations that are transmitted to the bearings and other parts of the machine. Imperfect mass distribution can be due to material faults, design errors, manufacturing and assembly errors, and especially faults occurring during operation.

Reducing these vibrations achieves better performance and more cost-effective operation, and avoids deterioration and fatigue failure. This requires the rotor to be balanced by adding or removing mass at certain positions.

Our system determines balance quality for single-plane and two-plane balancing according to the ISO1940–1 standard. Multi-plane Balancing Consultant Type 7790-B adds three- and four-plane balancing.

Balancing Consultant has an intuitive, task-oriented user-interface that leads you quickly through the necessary tasks for setup, measurement and reporting.

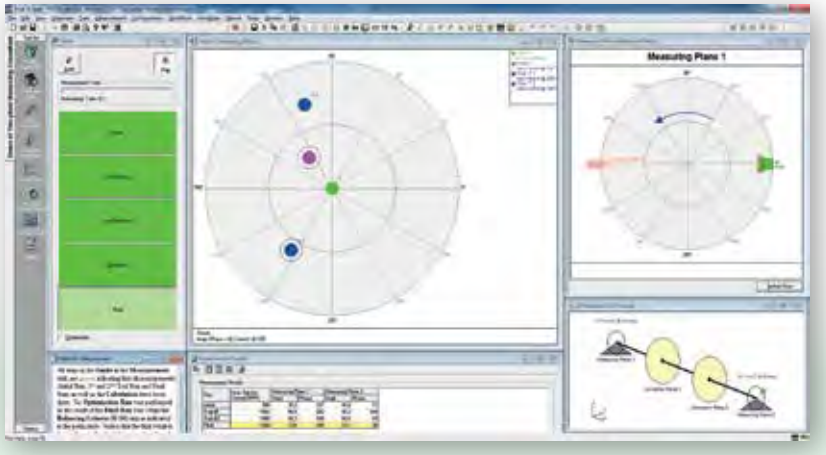
The balancing process can either be performed in situ, where the rotor is balanced in its own bearings and supporting structure, or by balancing the rotors in separate balancing machines.

Trim balancing is also supported, using rotor data stored from previous balancing sessions. This ensures fast correction of small residual imbalances in cases where balancing has to be repeated.

BALANCING FFT AND BALANCING TRACKING

7770-N3, 7702-N3, 7790-A, 2 INPUTS, 1 TACHO INPUT

Balancing can be based on either frequency spectra (FFT) or order spectra (order tracking). Traditional FFT-based balancing is sufficient in many measurement situations. However, in cases with unstable machinery speed and/or high-frequency resolution requirements, order tracking should be used to eliminate frequency smearing and provide more accurate results. Balancing using order tracking requires Order Analysis Type 7702.



Five-stage two-plane balancing including shaft vibration level and shaft centre position, sensor and trial masses layout

MODAL ANALYSIS AND PULSE REFLEX,

Automotive glass subwoofer technology has been in the development stage for a few years now. Read how the University of Windsor has played an integral role in its development, using Brüel & Kjær hardware and PULSE Reflex software.

The University of Windsor – Cutting-edge research

The University of Windsor with its 16,000 full-time students is located in the Canadian province of Ontario, where the Detroit River constitutes the border between Canada and the US city of Detroit. The area is dominated by the automotive industry and includes some of the world's biggest automakers, research and development centres, OEMs and sub-suppliers. It is no wonder then that automotive research and initiatives have a high priority at the University. The involvement of partners from the automotive industry, OEMs and suppliers often results in cutting edge research and collaborative partnerships which benefit businesses and industries in Canada and beyond.

"The industries from across the border have frequently approached the University for its NVH expertise to help them develop their products and solve their NVH problems," explains Dr. Colin Novak, Assistant Professor, Department of Mechanical, Automotive and Materials Engineering at the University of Windsor. "I think that the reason for our success is partly due to the quality of the faculty and the core competencies we represent. However, the major contributor is our well-established cooperation with leading automotive companies ensuring the use of the latest research and providing our students with hands-on experience."

Dr. Novak continues, "We have a full NVH program including a lot of application experience and theoretical knowledge. Companies and inventors have products they want to introduce to the market. They may have the concept but not the expertise to test product quality, nor the manpower or ability to get them launched and that's where we come in," says Dr. Novak. "And with Brüel & Kjær as our preferred supplier of sound and vibration applications we can provide our partners with accurate data and efficient service. So, for us, working with pioneers in the field of sound and vibration means that we are at the forefront of technology. In addition, Brüel & Kjær has one of the best NVH testing facilities just 45 minutes away – the unique ARC in Detroit. We enjoy using the facility together with our customers and it is also where we can learn new technologies that we can use to solve our customers' NVH problems," says Dr. Novak.

Turning car rear windows into sound systems

A recent project involved a large Canadian-based automotive supplier who approached The University of Windsor with an innovative Swedish audio technology it had acquired the rights to and that could potentially transform a car's rear window into a giant speaker. This would reduce the typical electrical load of an audio system by up to 75%, improve the fuel efficiency of a vehicle and provide valuable savings to vehicle manufacturers. In addition, the technology could reduce a vehicle's weight by up to nine kilograms, yet again contributing to fuel efficiency. The groundbreaking system would replace conventional subwoofers with the vehicle's rear window as the source of sound and free up space inside the vehicle.

Some in-house testing on the technology had been carried out by the automotive supplier but key areas such as psychoacoustics were missing, and this is where Dr. Novak and his team of nine graduates could help. "If we can move the glass in a particular fashion, then we can make the window act as a speaker," says Dr. Novak. His team developed a piezoelectric actuator – a bar-shaped device which receives the signal from the audio system and submits it to rigid, but highly-sensitive springs that run along the bottom of the window causing it to pulsate with the music. Dr. Novak explains, "Essentially, it's a spring system that's driven by a piezoelectric stack. We make the rear window of the car vibrate in phase with the music and that actually is the subwoofer of the car – light, simple and doesn't take up any space."

The prototype was installed in a Chrysler 300, one of two test cars for the system. Dr. Novak explains, "In the vehicle at the base of the windshield, we have two of these actuators installed between the glass and the structure of the car. The glass is fixed along the top and is free to move along the two sides and the bottom, so the windshield can move. By having two of these actuators mounted to the glass, we can move the two sides of the glass independently so that the one sheet will move like two different speakers." He continues, "Basically, the window itself will move, albeit very little – a fraction of a millimetre – because we have such a large surface area. That means the glass doesn't have to move as much as the speaker cone would."

One of Dr. Novak's main areas of expertise is psychoacoustics, so one aspect of the work of his AUTO 21 project team was to improve the quality of the sound generated by the glass speaker. To do this, a Head and Torso Simulator (HATS) and a ½-inch Prepolarized Free-field Microphone Type 4189 were used. The HATS is a mannequin with built-in mouth simulators and calibrated ear simulators that provide realistic reproduction of the acoustic properties of an average adult human head and torso.

Photos courtesy of University of Windsor

Dr. Colin Novak, Assistant Professor, Department of Mechanical, Automotive and Materials Engineering at The University of Windsor

"To begin with, we've been working on the subwoofer application on the windshield although we are looking into a more full-range speaker for the future", says Dr. Novak. "We're using the prototype installed in the vehicle to fine-tune the windshield's available frequencies according to the acoustic features of the cabin, and especially the low-frequency component of the speaker system. The bigger the diameter of the speaker, the lower the frequency it's capable of going," he explains. "We're aiming at between 10 and 120 Hz and hope to get it up to about 180 Hz whereas the most conventional subwoofers in your car only go up to about 90 Hz."

One of the main challenges facing Dr. Novak's team was the sensitivity of the actuators which function like springs and according to Dr. Novak, "have their own set of mechanical characteristics or natural frequencies." So setting an operating range for these is a challenge as it is so far removed from the natural mode.

In order to determine the natural frequencies and acoustic properties of the actuators, modal analysis was performed on the actuators two to three times a week for about a month. The test results were sent to the manufacturer on a regular basis and who, in turn, made design adjustments and submit for re-testing.

The initial testing of the actuator designs was performed on a test rig which consisted of a mass placed on top of the actuator, which had a weight equivalent to half of that of a windshield glass. Ten Miniature Triaxial CCLD Accelerometers Type 4524-B were mounted at the top of the mass and also to the mechanical elements within the actuator itself. A Mini-shaker Type 4810 was used as the excitation source using both sinusoidal and random input with a frequency range of 10 to 200 Hz. Other hardware included a CCLD Force Transducer Type 8230-001 and a PULSE C-frame with Type 7540 and Type 3040 Dyn-X modules. Data acquisition was done using PULSE Modal Test Consultant Type 7753 (MTC).

From the experiments, both the natural frequencies and the resulting mode shapes of the actuator were determined. This information was important as it was critical that the actuation did not have resonant frequencies within the 10 to 120 Hz operating frequency range. Using the animation capabilities of the MTC software, it was possible to ensure that the

UNIVERSITY OF WINDSOR, CANADA

movement of the actuator was a linear in and out motion without a 'rocking horse' effect.

Once a linearly operating prototype actuator was produced, it was installed in the Chrysler 300 test vehicle. The modal analysis activities were extended to study the characteristics of the entire system including the actuator/glass interactions.

In addition to audio applications, another innovative application for the window subwoofer device is to use the technology as the dynamic driver for an active noise control system to control automotive buffeting noise. Buffeting is a high-amplitude, low-frequency modulating noise which can occur inside the automotive cabin when a sunroof or rear window in the car is opened at moderate to high speeds. The shearing action of the outside moving air striking the static air inside the vehicle can result in the unwanted shock wave oscillations. Anyone who has experienced buffeting will appreciate how harsh this can sound. According to Professor Novak, "Given the very high amplitude and low frequency associated with buffeting noise, a very large subwoofer makes for a very good low-frequency noise source to control the onset of buffeting."

In order to implement the subwoofer in the rear glass of a vehicle, a very stiff structure to support the actuators is required. To implement this technology in a next generation vehicle design, PULSE Modal Test Consultant was again used to better understand the structural characteristics of the vehicle's rear support deck. Mini-shaker Type 4810 was roved across the instrumented rear deck in order to determine the mode shapes and deflection shapes. From this, the University of Windsor was able to help determine what structural stiffening was necessary to adapt the rear window subwoofer application to the future production car.

To better understand the buffeting phenomenon and its interaction with the vehicle, PULSE Reflex Core was used to post-process the buffeting noise measurement data and PULSE Reflex Modal Analysis for the structural measurements. Novak says, "While PULSE Modal Test Consultant has proven to be an excellent data acquisition and analysis application, PULSE Reflex has closed the loop necessary to perform curve fitting exercises to facilitate a determination of the structure's damping characteristics."

Having the ability in-house will save us both time and money by not having to go to external suppliers. As one of the earlier users of PULSE Reflex, Novak says that he really likes the way that PULSE Reflex Modal Analysis can also import UFF files from previously taken data for further post-processing and analysis.

The NVH research group at Windsor is not only a research facility but is also a leader in the education of acoustics to undergraduate and graduate level engineering students. Novak says, "Reflex lends itself well to the classroom and research laboratory given how very intuitive it is to use with simple features that allow students to perform meaningful analysis of their data without a high learning curve. And once the students have completed their analysis and validation through the supplied tools, it is very easy for the students to create professional looking reports by using the reporting tools within Reflex."

The automotive glass subwoofer technology has been in the development stage for a few years now and Brüel & Kjær hardware and PULSE software, including Reflex, have played an integral role in this development. Looking ahead, Dr. Novak says, "One of our targets is the electric and hybrid electric vehicle of the future where consumption of the electrical components is a critical concern because that's what's really driving the vehicle. These vehicles aren't cheap – you might be spending $50,000 on an electric vehicle and you still want a nice sound system. Well, here we can do it, without sacrificing the whole idea of an electrical vehicle."

Mini-shaker Type 4810 used to excite the rear deck of the car to determine the stiffness of the structure

PULSE Reflex Modal Analysis being used to examine the mode strength and the Frequency Response Functions (FRFs)

Comparing measured to synthesised FRFs using PULSE Reflex Modal Analysis

A force transducer and Type 4524-B accelerometers were mounted onto the car's rear deck to measure the FRFs

MODAL ANALYSIS

Modal analysis is vital to understand and optimise the inherent dynamic behaviour of many diverse kinds of structures, leading to lighter, stronger and safer constructions, less energy consumption, greater comfort and better performance.

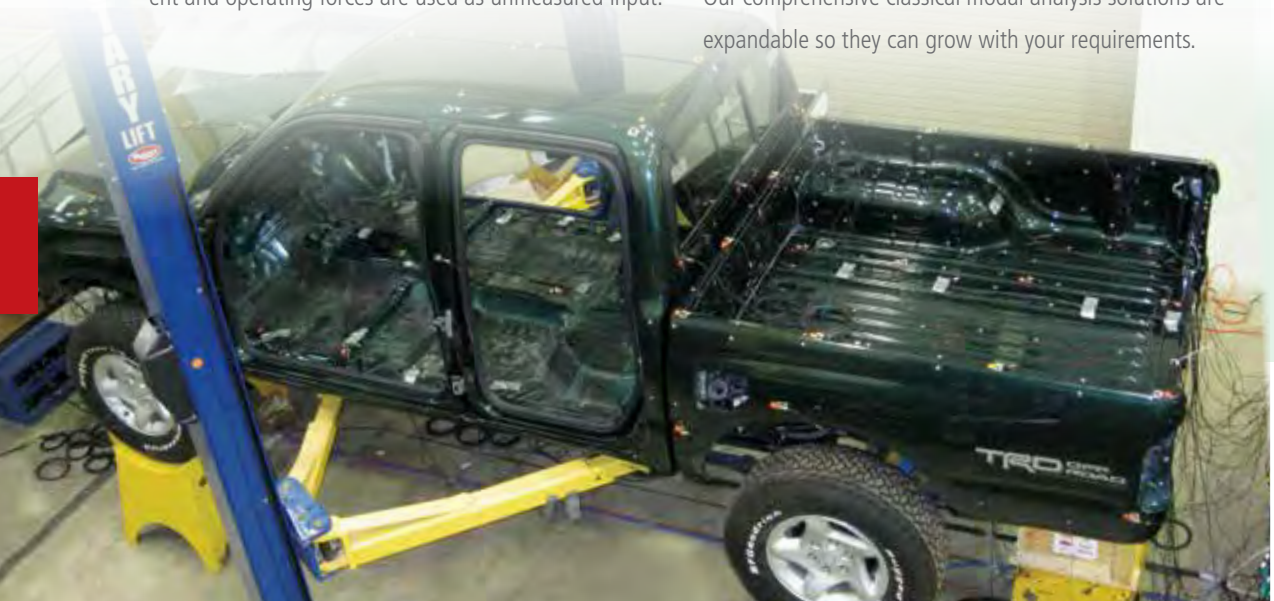
In modal analysis, a mathematical model of a structure's dynamic behaviour is obtained, consisting of a set of modal parameters, each with a mode shape and an associated natural frequency and modal damping value. Experimental modal analysis finds these modal parameters by testing, and it can be performed as classical modal analysis or operational modal analysis.

Classical modal analysis uses measured input forces and output responses from a structure to calculate frequency response functions, while operational modal analysis only measures output responses, as the natural ambient and operating forces are used as unmeasured input.

Classical modal analysis ranges from simple mobility tests with impact hammers to multi-shaker testing of large structures. The results are used in a vast range of applications including:

- Optimising the dynamic properties and behaviour of structures
- Predicting the dynamic behaviour of components and assembled structures
- Predicting responses due to complex excitation
- Predicting effects of structural modifications
- Inclusion of modal damping in Finite Element (FE) models
- Correlation of test models with FE models
- Updating of FE models using test results
- Damage detection and assessment

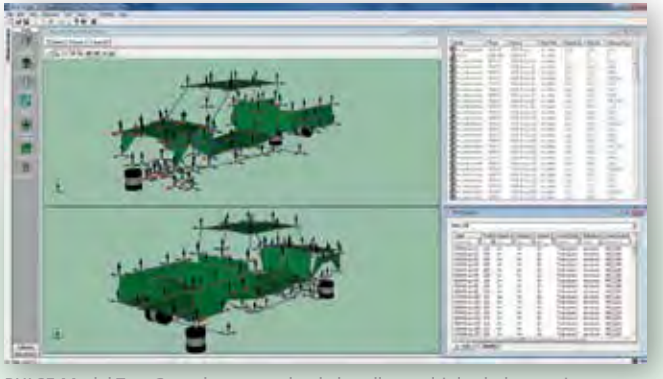
Our comprehensive classical modal analysis solutions are expandable so they can grow with your requirements.



MODAL ANALYSIS – SINGLE REFERENCE

7770-N2, 8720-B, 2 INPUTS, 1 OUTPUT

An entry-level configuration ideal for both impact testing and smaller-size shaker testing. The swift workflow in the dedicated PULSE Modal Test Consultant software guides users step-by-step through the procedure for gathering and validating Frequency Response Functions (FRFs) data sets. Seamless integration with PULSE Reflex Modal Analysis then provides easy and accurate modal parameter estimation, including automated mode selection.



PULSE Modal Test Consultant seamlessly handles multiple shaker testing, providing accurate and reliable FRF data sets for the modal parameter extraction process

MODAL ANALYSIS – SINGLE REFERENCE

7770-N, 8720-B, UNLIMITED INPUTS, 1 OUTPUT

As in the previous configuration, but with more inputs for enhanced shaker testing capabilities and higher data consistency. More DOFs can be easily measured using multiple data sets with roving transducers.

MODAL ANALYSIS – MULTIPLE REFERENCES

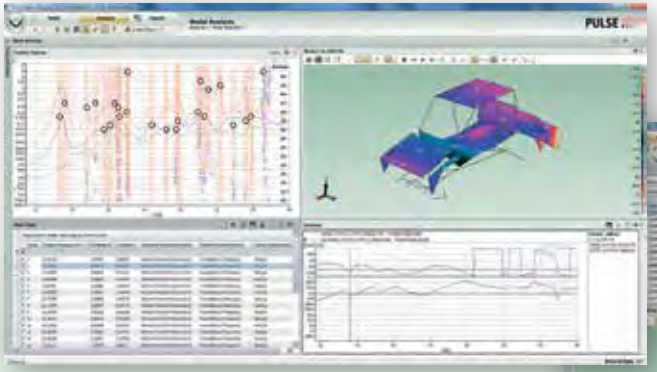
7770-N4, 8720-B, 8721, 4 INPUTS, 1 OUTPUT

A configuration that enables users to solve cases with repeated roots and closely coupled modes by performing impact testing using a triaxial or multiple single axial accelerometers as references. Includes a targeted set of best-in-class mode indicator functions, curve-fitters and validation tools for producing quality results with maximum confidence.

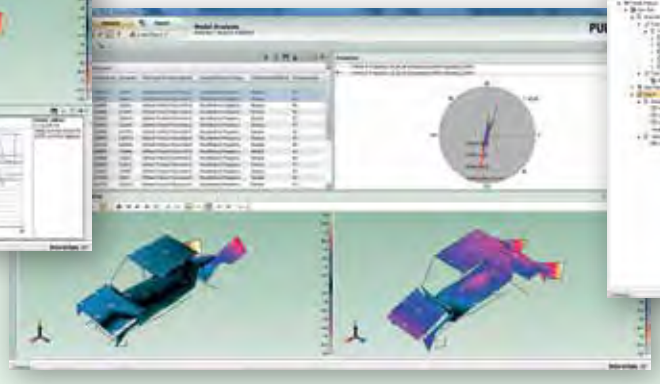
MODAL ANALYSIS – MULTIPLE REFERENCES

7770-N, 8721-B, UNLIMITED INPUTS AND OUTPUTS

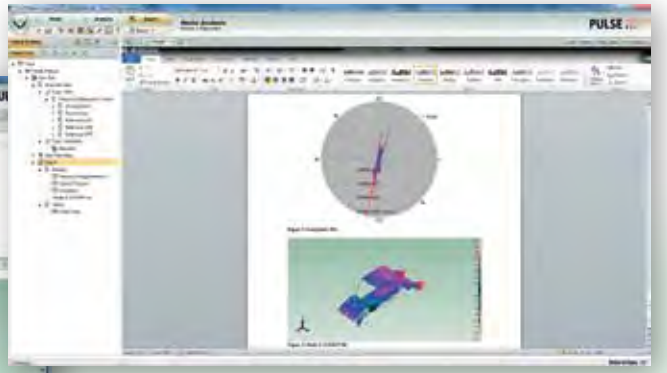
As in the previous configuration, but with the added functionality of performing Multiple-Input Multiple-Output (MIMO) analysis. Ideal for testing large, complex and symmetrical structures, and in demanding situations such as those featuring weakly excited, heavily damped or local modes.



PULSE Reflex Modal Analysis ensures you always have the right curve-fitter at hand with low-order and high-order curve-fitters in the time and frequency domain



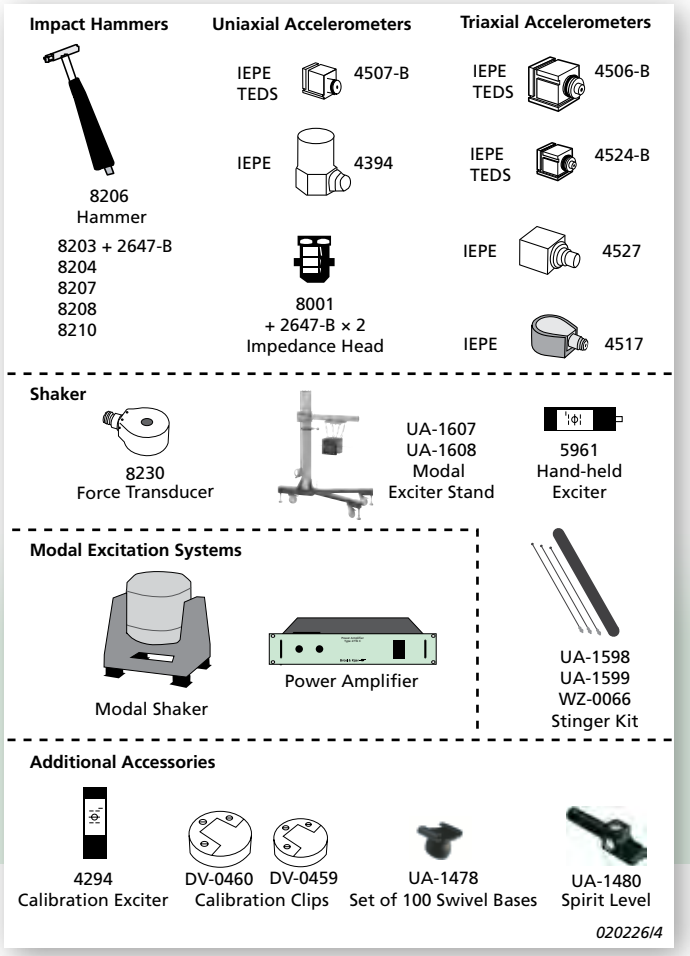
PULSE Reflex Modal Analysis guides you efficiently through measurement validation, parameter estimation setup, mode selection, analysis validation, and reporting



Reports can be prepared in parallel with the analysis process, linking important results as they are produced. High-quality reports are easily to create in Microsoft® Word, Microsoft® Excel® or Microsoft® PowerPoint®

MODAL ANALYSIS – EXCITERS AND TRANSDUCERS

Our solutions cover the entire measurement and analysis chain including accelerometers and force transducers, impact hammers, modal exciter systems, data acquisition front-ends and measurement and analysis software.



IMPACT HAMMER GUIDE

Type	Description	Max force [N, (lbf)]	Overall length [m, (in)]
8203	Force Transducer / Impact Hammer	1250 (281)	0.106 (4.2)
8204	Miniature Impact Hammer	220 (50)	0.122 (4.8)
8206	General Purpose Impact Hammer	220 (50) – 4448 (1000)*	0.22 (8.72)
8207	Heavy Duty Impact Hammer – One pound head	22.2k (5k)	0.30 (11.7)
8208	Heavy Duty Impact Hammer – Three pound head	22.2k (5k)	0.39 (15.2)
8210	Heavy Duty Impact Hammer – Twelve pound head	22.2k (5k)	0.90 (35.3)

*Available in four different versions

EXCITER GUIDE

Type	Description	Max force [N, (lbf)]		Max displacement Pk-Pk [mm, (in)]
		Sine peak	Random RMS	
4808	Permanent Magnetic Vibration Exciter	187 (42)	-	12.7 (0.5)
4809	Vibration Exciter	60 (13.5)	-	8.0 (0.32)
4810	Mini Shaker	10 (2.25)	-	6.0 (0.24)
4824	Modal Exciter	100 (22)	70 (15)	25.4 (1)
4825	Modal Exciter	200 (45)	140 (31)	25.4 (1)
4826	Modal Exciter	400 (90)	280 (63)	25.4 (1)
4827	Modal Exciter	650 (146)	420 (94)	50.8 (2)
4828	Modal Exciter	1000 (225)	650 (146)	50.8 (2)

Note: Table shows selected modal exciters only. Exciters above 1000 N are available.
Modal excitation systems with matching power amplifiers are available.

Shakers and exciters on www.bksv.com

Vibration transducers on www.bksv.com

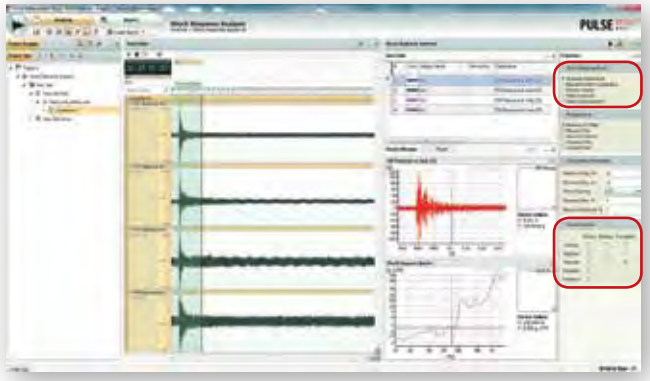
SRS (SHOCK RESPONSE SPECTRUM ANALYSIS)

A single transient shock event such as a pyroshock or a structural impact can damage components in a structural system. Similarly, earthquakes can cause catastrophic failures in bridges and buildings. And with any motion input into a system, the response can be amplified by structural resonances, increasing the damage.

Shock Response Spectrum (SRS) analysis software computes the shock response spectrum from transients in the time domain. It converts motion input to a set of Single Degree of Freedom (SDOF) damped oscillator responses. The response amplitudes of the oscillators are plotted as a function of SDOF frequency to produce the shock response spectrum.

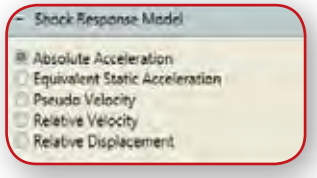
The frequencies are generally logarithmically spaced, typically with 1/n-octave spacing. The amplitudes of the SRS are derived from the individual SDOF responses (at user-defined frequencies) by taking the maximum response either during the primary shock event or during the residual response to the event. Most commonly, the overall maximum response is used, which includes both primary and residual responses – called 'maximax'.

All five of the SRS models mentioned in the ISO 18431 – 4:2007 Standard are available, and with these five SRS models and nine ordinary criteria for amplitude calculation (shock instances), you can configure up to 45 different response types to match your requirements.

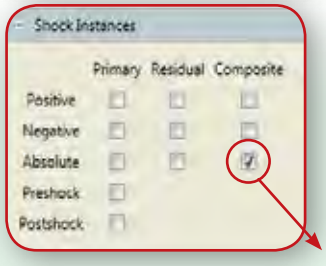


Four time histories (at left) with a SRS for the first time history

Five SRS models



Shock instances



'maximax'

Watch a video about SRS here:

CASE STUDY

DCTA – THE DEPARTMENT OF AEROSPACE SCIENCE AND TECHNOLOGY

The Department of Aerospace Science and Technology (DCTA) is the Brazilian national military research centre for aviation and space flight. DCTA is subordinated to the Brazilian Air Force and coordinates all technical and scientific activities related to the aerospace sector. Noise and vibration testing play a vital role in many phases of operations and DCTA benefits from Brüel & Kjær's complete measurement solutions. They have a large installed base of Brüel & Kjær products ranging from shakers for environmental and structural testing, noise and vibration sensors for a wealth of applications from rugged flight-testing to highly sophisticated laboratory use, multichannel data acquisition and analysis platforms, and an enormous range of noise, vibration and shock software application packages.

DCTA and Brüel & Kjær – A long and fruitful relationship

The Department of Aerospace Science and Technology (DCTA) is the Brazilian national military research centre for aviation and space flight. DCTA is subordinated to the Brazilian Air Force and coordinates all technical and scientific activities related to the aerospace sector in which there are interests by the Ministry of Defence.

DCTA's interests within the world of noise and vibration are multi-fold and they have greatly benefited from a long-term and close relationship with Brüel & Kjær. With operations covering everything from validating equipment for transport, launch and flight-path loading, high quality, efficient testing is vital.

Noise and vibration testing plays a vital role in many phases of operations, and DCTA benefits from the complete measurement solutions offered by Brüel & Kjær. They have a large installed base of Brüel & Kjær products ranging from shakers for environmental and structural testing, noise and vibration sensors for a wealth of applications from rugged flight-testing to highly sophisticated laboratory use, multichannel data acquisition and analysis platforms, and a huge range of noise, vibration and shock software application packages.

The Brüel & Kjær/DCTA relationship goes back many years and, with the LDS and Brüel & Kjær merger at the end of 2008, the relationship has become even stronger. Local Brüel & Kjær expertise, with full service and calibration facilities, further provides the fundament for a long-lasting relationship, providing CTA with high quality, goal-focused, time- and cost-efficient testing solutions.

The Institute of Aeronautics and Space (IAE) (Instituto de Aeronaútica e Espaço) is a division of DCTA and develops projects in the aeronautical, aerospace and defence sectors. IAE is co-responsible for the execution of the Brazilian Space Mission – working on projects such as the VLS-1 Launcher, which is designed to launch small satellites into low earth orbit. IAE also supports the Brazilian Air Force with, for example, flight test capabilities. They also provide launch capabilities for microgravity experiments supporting the VS-30 and VS-40 launchers.

DCTA's impressive range of Brüel & Kjær solutions

Satellite and launcher testing is a multi-disciplinary operation. Environmental vibration/acoustic durability testing is paramount to ensure that structures and equipment can survive a launch; SRS analysis determines shock response properties of structures; modal testing facilitates the understanding and optimisation of dynamic properties of structures; vibration qualification testing provides system and component acceptance testing.

The systems necessary to cover such a diversity of tests range from shakers for environmental and structural testing; flight-tested and laboratory noise and vibration sensors; high-speed, multi-channel data acquisition and analysis platforms, and an enormous range of noise, vibration and shock software application packages.

DCTA has several LDS shakers and controllers for standard vibration testing of electronic equipment. Recently, DCTA purchased the largest LDS shaker on the market, the V994. The V944 shaker was tested in Brüel & Kjær's Royston office in the UK and shipped to Brazil, where it now awaits installation following the completion of DCTA's newest test facility.

With well over 100 channels of PULSE IDA^{e} front-ends (in 17 frames), some 66 channels of LAN-XI data acquisition modules, and a wide range and number of acoustic and vibration sensors to match, DCTA are in a position to carry out all relevant noise and vibration measurement/analysis tasks. Backed by the PULSE applications LabShop, Operational Modal Analysis (OMA), Modal Test, Reflex Shock Response Analysis and PULSE Data Manager, DCTA are in a position to carry out relevant noise and vibration testing and qualification of satellites, space launchers and their components.

Photos courtesy of DCTA

Launcher and satellite noise and vibration testing

The demands placed upon a rocket and its payload are severe during rocket launch. Launchers generate extreme noise and vibration and, at separation stages, pyroshocks cause additional severe loading of the launcher.

Validating equipment for launch is, therefore, not a small task. Testing must be made at all stages of the product – during development to provide qualification of finite element models, during qualification and acceptance testing to validate the design via extensive vibration testing. DCTA provides for the complete on-board measurement and telemetry systems, and can perform dedicated launcher tests such as separation tests, firing tests and transportation tests.

Separation tests using shock response and modal analysis

DCTA (IAE) is tasked with the upcoming separation test of the VGLS-1 Launcher and plans to use an 80-channel PULSE system for shock, PULSE Reflex SRS applications and 60 channels for vibration. PULSE OMA will be used to analyse the pyroshock and the response in additional detail.

PULSE Shock Response Analysis Type 8730 computes the shock response spectrum (SRS) from transients in the time domain in order to determine the damage potential of transient events such as pyroshock.

A transient (shock) event, such as pyroshock or a structural impact, has the potential to damage components in a structural system. Just as with any motion input to a system, the response can be amplified by structural resonances, increasing the damage potential.

DCTA's range of Brüel & Kjær solutions spans the whole measurement chain

The aim of the SRS calculation is to convert motion input to a set of Single Degree of Freedom (SDOF) damped oscillator responses calculated in the time domain. The response amplitudes of the oscillators are plotted as a function of SDOF frequency to produce the shock response spectrum.

PULSE Operational Modal Analysis Type 7760 is an analysis tool for effective modal identification in cases where only the output is known. The software allows you to perform accurate modal identification under operational conditions and in situations where the structure is impossible or difficult to excite using externally applied forces.

Experimental modal analysis is the process of using experimental data to determine the modal parameters (natural frequency, damping ratio, and mode shape) of a structure for the modes in the frequency range of interest. The mode shape is the deflection pattern that represents the relative displacement of all parts of the structure for that particular mode.

Modal parameters are important because they describe the inherent dynamic properties of a structure. The set of modal parameters constitutes a unique set of numbers that can be used for model validation and updating, design verification, benchmarking, troubleshooting, quality control or structural health monitoring.

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

Launcher firing tests using operational modal analysis

During launcher firing tests, OMA is used to validate the excited modes of the launcher during the ignition and burning phases.

Also during the firing test, noise data is obtained to validate/investigate/understand in detail the influence of noise on the thermal protection of the engine, and to correlate with the models for lift-off noise.

Launcher transportation test using vibration durability testing and operational modal analysis

Part of the environmental test program of a launcher is the transportation tests, covering packaging, loading, flight- and road-transport.

PULSE Operational Modal Analysis is used to validate the vibration level and natural excited modes of the launcher throughout these phases.

Component testing using vibration shakers

DCTA (IAE) performs environmental testing services for internal and external customers. Environmental testing is required to verify reliability and flight safety requirements.

DCTA has several LDS shakers and an LDS vibration control system to answer local demands for the different space programs, aerospace and automotive applications it is involved in.

Flight tests using modal analysis

DCTA (IAE) also provides flight test services for the Brazilian Air Force, testing modifications on aircraft and helicopters and re-establishing flight envelopes.

As part of these services, classical and operational modal analysis (OMA) was carried out on a modified and unmodified helicopter during on-ground and in-flight tests.

The tests made it possible to identify any critical modes that would significantly influence the structural and aerodynamic behaviour of the helicopter, with consequential maintenance and safety issues.

Launch telemetry using acoustic and vibration sensors

Brüel & Kjær is working closely with DCTA to deliver a range of sensors and airborne amplifiers to provide critical flight data to their onboard telemetry system for the VLS-1 satellite launch vehicle program.

Missile firing tests using operational modal analysis

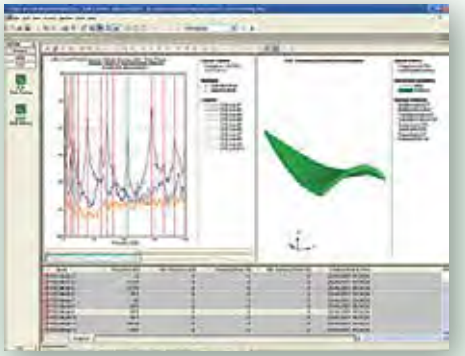
DCTA (IAE) is involved in missile firing tests that are performed on the ground and validated in-flight using OMA. The missile flight profiles are loaded into the shaker controller to verify all environmental conditions of the DCTA-developed missiles during flight.

These tests assist and help design the interface between the missile and the aircraft.

Separation testing

Launcher in support structure before firing test. During the launcher firing test, Brüel & Kjær Type 4956 microphones, Type 2670 preamplifiers, and a PULSE data acquisition system are used to obtain noise data.

PULSE Reflex Shock Response Analysis



PULSE Operational Modal Analysis

OPERATIONAL MODAL

In Operational Modal Analysis (OMA) only the output of a structure is measured, using the ambient and operating forces as unmeasured input. OMA is used instead of classical modal analysis for accurate modal identification under actual operating conditions, and in situations where it is difficult or impossible to artificially excite the structure.

Many civil engineering and mechanical structures are difficult to excite artificially due to their physical size, shape or location. Civil engineering structures are also loaded by ambient forces such as the waves against offshore structures, the wind on buildings, and traffic on bridges, while mechanical structures such as aircraft, vehicles, ships and machinery exhibit self-generated vibrations during operation. In OMA, these forces that would produce erroneous results in classical modal analysis are instead harnessed as input forces.

As OMA can be performed in situ during normal operation, setup time is reduced and downtime can be eliminated. Adding further value, our OMA systems are also scalable, making both hardware and software easy to upgrade. Patents protect the core technology behind our OMA software, including the efficient and powerful Frequency Domain Decomposition (FDD), Enhanced Frequency Domain Decomposition (EFDD) and Curve-fit Frequency Domain Decomposition (CFDD) techniques.

OMA software is available in three versions – Pro, Standard and Light, which differ mainly in the number of techniques they provide.

Calibrator

4294
Calibration Exciter

DV-0460

DV-0459

Calibration
Clips

Miscellaneous

UA-1473 Set of 100 Swivel Bases
UA-1478 Set of 100 Swivel Bases

UA-1480
Spirit Level

2981
Tacho probe

Uniaxial Accelerometers

IEPE
TEDS
4507-B

CHARGE
4393

IEPE
4394

IEPE
TEDS
8344

PR(DC)
457X

Triaxial Accelerometers

IEPE
TEDS
4506-B

CHARGE
4326-A

IEPE
TEDS
4524-B

IEPE
4527

Charge to IEPE Converter 2647-A/B/C

020234/3

Learn more about
Operational modal analysis
on www.bksv.com

ANALYSIS

OPERATIONAL MODAL ANALYSIS LIGHT

7770-N6, 7753, 7760-E, 6 INPUTS

Entry-level configuration based on the efficient and intuitive Frequency Domain Decomposition (FDD) technique for quick and easy identification of natural frequencies and mode shapes. Ideal for small-scale and basic modal testing not requiring damping estimates. More than six DOFs can easily be measured using multiple data sets with roving transducers.

OPERATIONAL MODAL ANALYSIS STANDARD

7770-N, 7753, 7760-C, UNLIMITED INPUTS

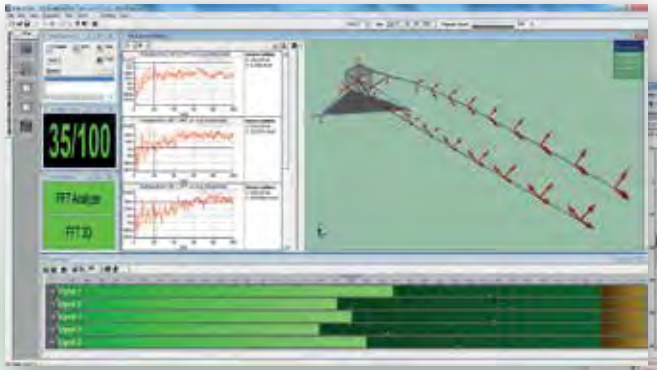
Standard configuration including the three frequency-domain techniques FDD, Enhanced FDD (EFDD) and Curve-fit FDD (CFDD). In addition to mode shape identification, the EFFD and CFDD techniques determine damping and give an improved natural frequency estimation with a minimum of additional user interaction. Includes automatic detection and removal of harmonic components.

OPERATIONAL MODAL ANALYSIS PRO

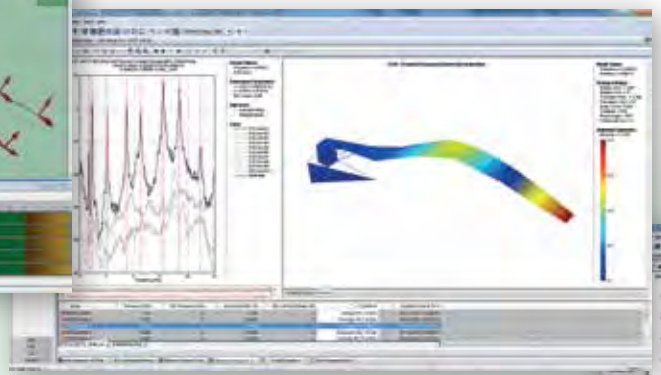
7770-N, 7753, 7760-A, BZ-8527, UNLIMITED INPUTS

State-of-the-art configuration with the most powerful and accurate techniques available today, including three frequency-domain techniques (FDD, EFDD and CFDD) and three unbiased time-domain techniques based on Stochastic Subspace Identification (SSI). The crystal-clear SSI stabilisation diagrams and automatic mode estimation make modal parameter estimation straightforward and robust. The configuration offers the best possible validation by comparing the results of the different techniques with each other.

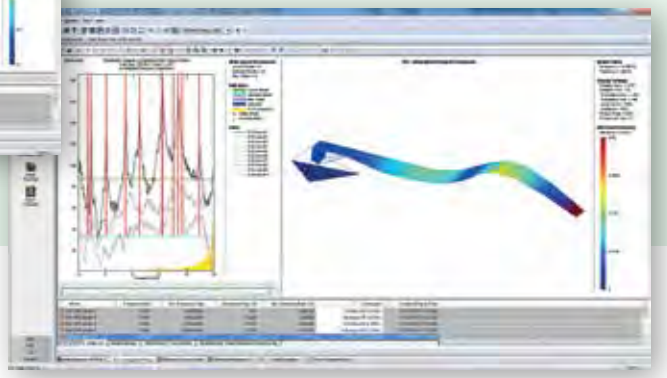
With the BZ-8527 Batch Processing Option for OMA Pro, it is possible to perform SSI analysis on a large amount of time files without user interaction. The configuration is ideal for demanding large-scale modal testing.



PULSE Modal Test Consultant is used for geometry creation, geometry-driven data acquisition, measurement validation and seamless transfer of data to the OMA software for modal parameter estimation



The peak-picking method used in the three FDD techniques lets you manually extract the modes using a fast snap-to-peak facility. Automated mode estimation is also supported



A special implementation of the SSI techniques produces crystal clear stabilisation diagrams for easy selection (manual or automatic) of stable modes


Picture Courtesy of Rolls-Royce Plc

OPERATING DEFLECTION

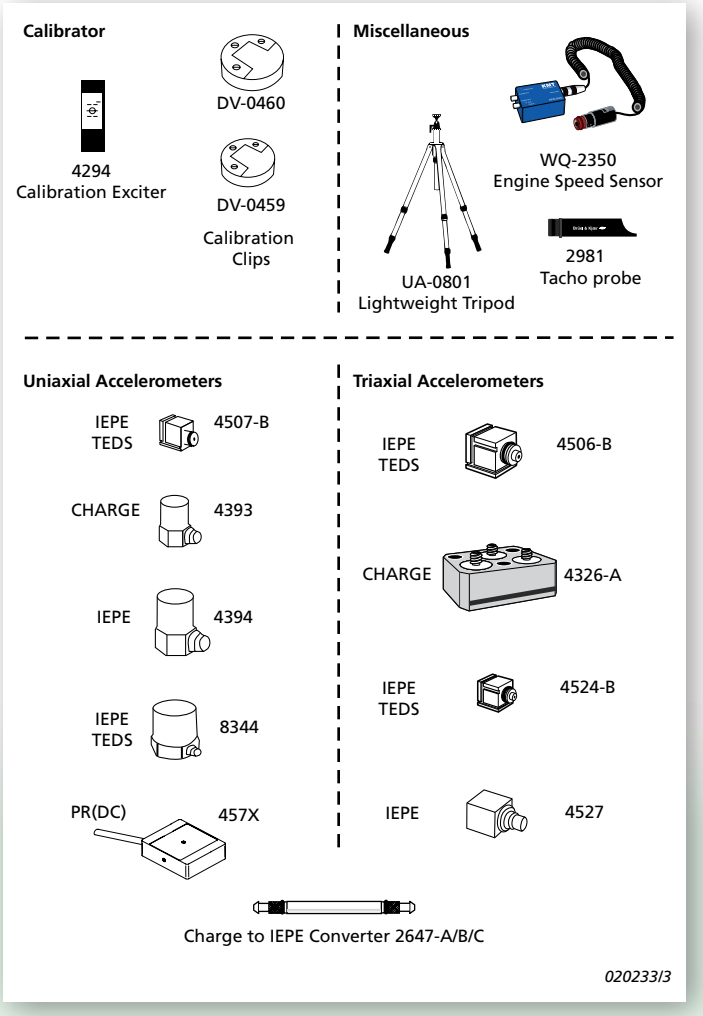
Operating Deflection Shapes (ODS) analysis determines the vibration patterns of a structure under given operating conditions. The vibration patterns are shown as animated geometric models of the structure that display a combination of the forcing function acting on the structure and the dynamic properties of the structure.

The forcing function depends on the operating conditions, which for machinery can be influenced by factors such as engine speed, load, pressure, temperature and flow. For civil engineering structures, ambient forces from wind, waves and traffic might also apply.

ODS analysis can be divided into three types:

- Time ODS – where the vibration pattern for an analysed frequency range is determined as a function of time
- Spectral ODS – where the vibration pattern is determined for specific frequency or order components
- Run-up/down ODS – where the vibration pattern is determined for specific order components as a function of rotational speed

Our scalable ODS systems provide complete guidance throughout setup, measurement, validation and animation for each ODS type, and allow analysis in real-time or during post-processing of time histories.



Learn more about
Operating deflection shapes analysis
on www.bksv.com

SHAPES

TIME AND SPECTRAL ODS

7770-N2, 7765-A, 2 INPUTS

Entry-level configuration especially suited for spectral ODS using multiple data sets. Applicable for:

- Stable machine speed
- Analysing lower and/or well-separated spectral components

Order Analysis Type 7702 option is recommended in cases of slight instability and for analysing higher and close spectral components, in order to eliminate smearing.

TIME AND SPECTRAL ODS

7770-N, 7765-A, UNLIMITED INPUTS

This configuration allows simultaneous response measurements in more DOFs, offering additional advantages such as:

- Shorter test time
- Higher data consistency
- Time ODS in multiple DOFs

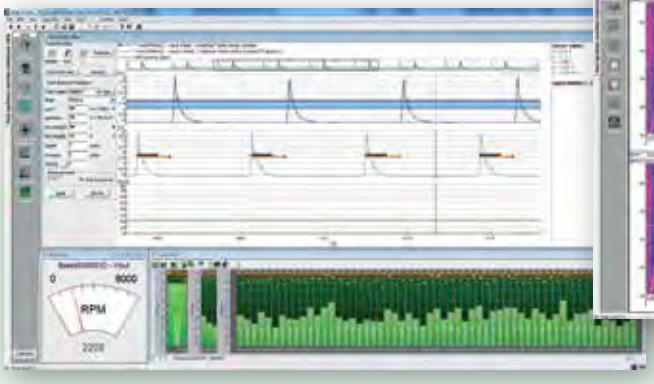
See comments on Order Analysis Type 7702.

RUN-UP/DOWN ODS

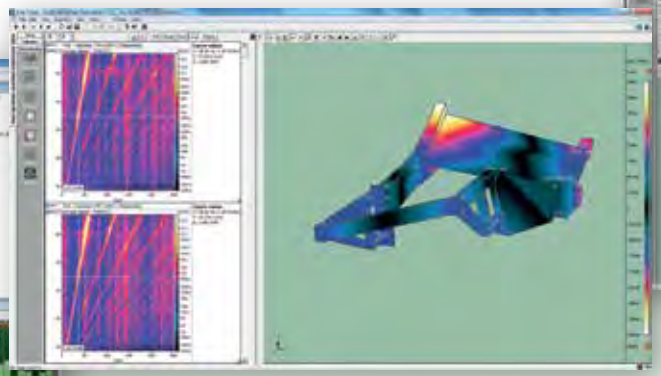
7770-N, 7702-N, 7765-B, UNLIMITED INPUTS

State-of-the-art configuration with the full range of ODS techniques: Time ODS, spectral ODS (frequency- or order-based) and run-up/down ODS analysis. Supports analysis of stationary, quasi-stationary and transient signals.

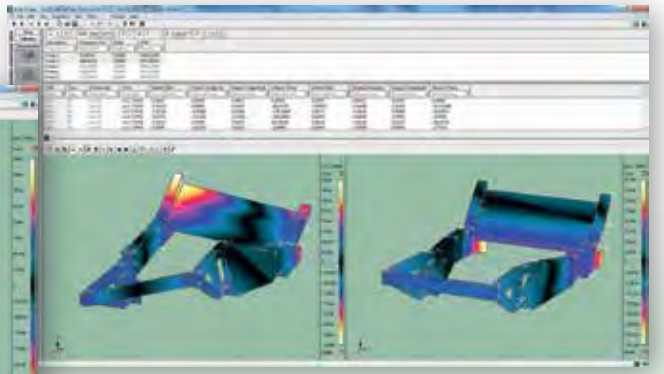
The configuration is ideal for advanced large-scale ODS analysis.



The ODS Test Consultant incorporates time-saving tools to give maximum data reliability in the shortest possible test time. One example is the Graphical Tacho Setup for straightforward tacho detection.



Run-up/down ODS analysis allows determination of the vibration pattern for frequency and order components versus RPM. Contour plots are available for easy detection and separation of orders and structural resonances.



The shapes can be saved in a table in terms of acceleration, velocity and displacement. Different animation types and views are supported including side-by-side, overlaid and difference animation.

TEST-FEA INTEGRATION

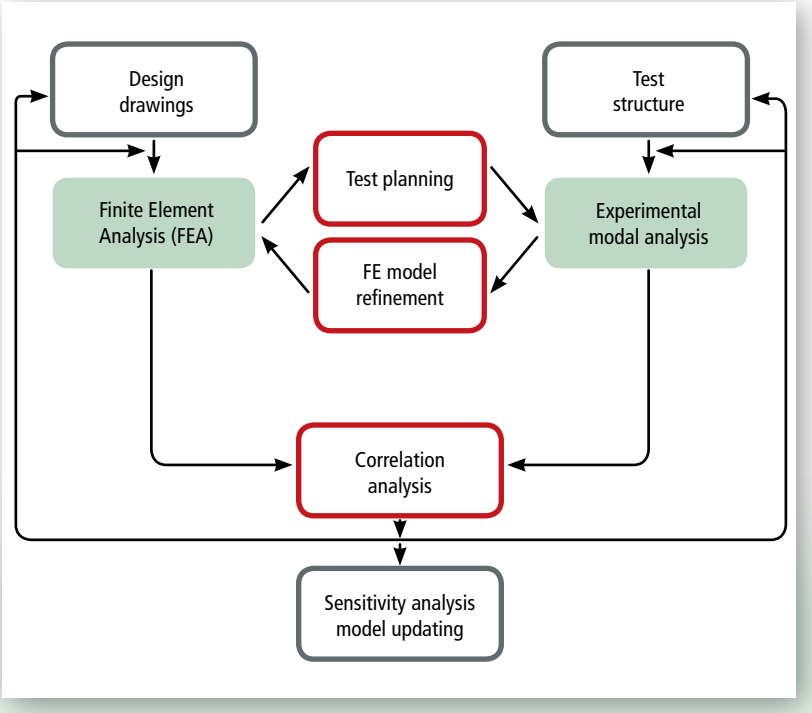
Integrating testing and Finite Element Analysis (FEA) helps to cut development costs, reduces the amount of physical prototypes, and shortens the time from concept to production – all by optimising strategies for testing structures and improving the development of Finite Element (FE) models. Using baseline FE models you can optimise your structural tests early in a project and then improve these FE models with the enhanced results.

PULSE Reflex offers powerful tools to gain better confidence in the test and simulation results and to improve essential engineering judgment skills, benefitting test engineers, analysts and management.

With our PULSE Reflex Finite Element Interfaces software you can import FE models into PULSE Reflex Modal Analysis for performing test planning (pre-test analysis) and test validation.

Using PULSE Reflex Correlation Analysis you can perform a complete correlation analysis of two modal models to identify shortcomings in modal tests and any areas of insufficient modeling quality in FE models. This helps to easily design optimal test conditions and evaluate different modeling strategies.

Learn more about
Test-FEA integration
on www.bksv.com



A schematic overview of test-FEA integration

TEST PLANNING AND VALIDATION

8700, 8718, 8719, 8720/21

Using PULSE Reflex Finite Element Interfaces and PULSE Reflex Modal Analysis enables:

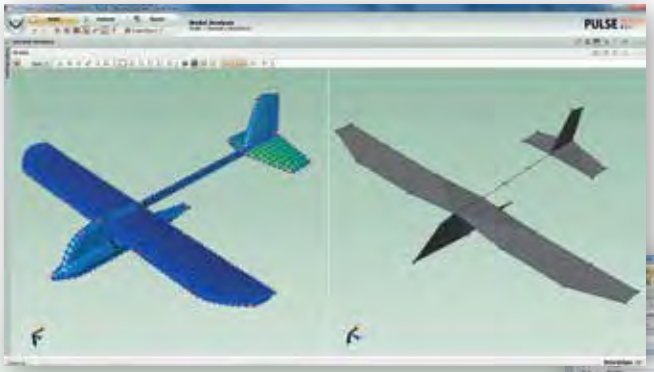
- Import and visualisation of FE models from leading programs like Nastran®, Ansys®, Abaqus® or as UFF files
- Animation of FE models to investigate frequency range of interest, mode density, mode order, critical modes, etc.
- Animation of FE models to select optimal excitation and response points and directions for modal testing
- Decimation of FE models to accurate test models for modal testing
- Comparison of modal test results with FEA results

MODEL CORRELATION

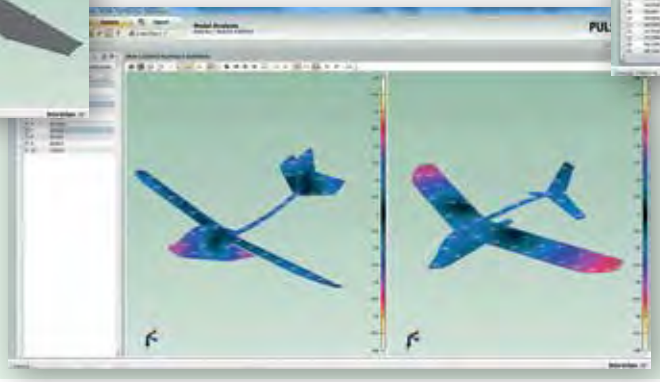
8700, 8718, 8719, 8722

Using PULSE Reflex Finite Element Interfaces and PULSE Reflex Correlation Analysis allows you to perform a complete visual and numerical correlation analysis of two modal models (test vs. FE, test vs. test or FE vs. FE) including:

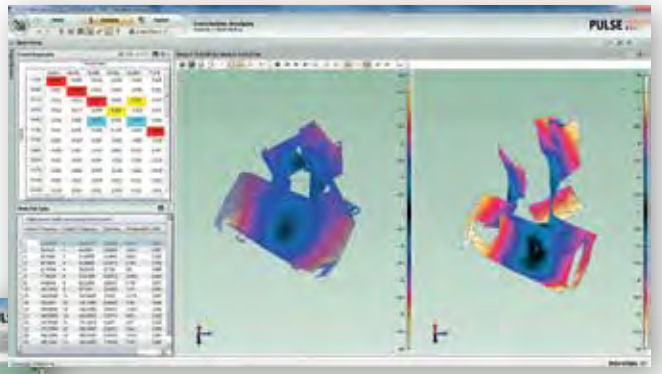
- Geometry alignment and DOF mapping between models
- Comparison of models based on mode table values and mode shape animations
- Mode shape correlations based on AutoMAC, CrossMAC, AutoOrthogonality and CrossOrthogonality calculations
- Mode pairing based on frequency, damping and mode shape correlations



PULSE Reflex Modal Analysis: Decimation of an FE model to a test model by selecting points on the FE model.



PULSE Reflex Modal Analysis: Animation of FEA modes provides useful information for setting up and performing modal tests.



PULSE Reflex Correlation Analysis: Complete model correlation of test and FEA results.

PRODUCTION TESTING

Protecting brand value increasingly requires living up to the quality expectations of customers, and whether it is an automotive or a telecom/audio product, manufacturers must constantly enhance production tests.

Brüel & Kjær's core competencies in sound and vibration is based on more than 70 years of experience within the design and production of equipment for measuring sound and vibration.

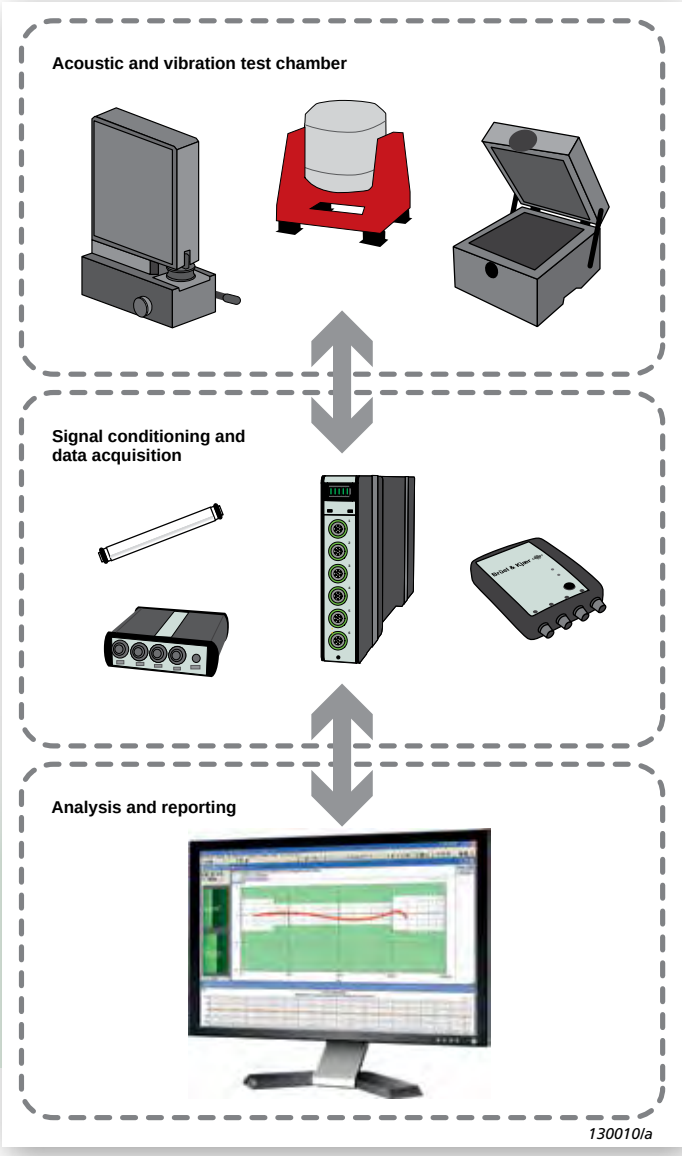
Applying our knowledge and systems to production testing gives a competitive advantage to products, at the same time as helping to save costs.

Brüel & Kjær has production test solutions that can be applied for:

- ► Incoming component inspection
- ► In-line production testing
- ► End-of-line production testing

We supply complete systems covering the complete range of vibration and acoustic production testing, from a single test station to fully serviced complete plant systems and turnkey services.

Our comprehensive range includes all of the necessary components including microphones, accelerometers, preamplifiers, couplers, front-ends, databases and report generators.



A typical customised production test system based on standard system components

PRODUCTION QUALITY TESTING FOR WORLDWIDE MANUFACTURING

With component production facilities around the world contributing to the manufacture of precise measurement equipment, Brüel & Kjær needs detailed and strictly centralised control of production test targets. When a new system was called for to maintain our R&D targets in production by tracking and analysing test outcomes around the world, we decided to build our own.

The key challenge for our R&D department is maintaining and meeting targets during the actual production of equipment. This is especially critical for high-value electronic components and assemblies such as we make. While go/no go testing is important to give a fast pass or fail, high value assemblies cannot be simply rejected and it is necessary to 'drill down' into the results to analyse the reasons for any failures to meet designated specifications. Equally, documenting the consistency of effective production is a vital part of modern manufacturing. In sum, data is everything, and time is short.

Remote manufacturing

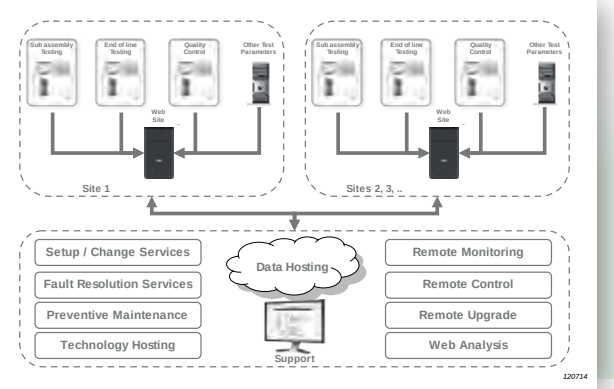
In the modern business climate, remote manufacturing is widespread, and Brüel & Kjær is no exception. Consequently, we need a system that monitors, analyses and responds to product and component quality issues quickly, covering assembly plants in multiple locations around the world.

With our primary R&D expertise and infrastructure located in our Denmark headquarters, we need a testing service that has infrastructure at the various assembly plants, while delivering results remotely to test engineers located elsewhere. Test engineers need to track production quality expressed in terms of numerical values that govern whether or not the tested unit has met expected targets.

The bottom line is that the test should ensure components, circuit boards and finished products roll off the production lines around the world, including at subsidiary companies and suppliers, with a specified level of quality commensurate with our demanding and precise standards, in order to retain our leading market position. All while minimising any reduction in the rate of production.

Searching for a solution

We set out to find an objective, automated test solution capable of assessing the electroacoustic quality of products, allowing those that do not meet the appropriate level of quality to be rejected.



"With this system we have oversight at headquarters through the remote connections. We want full control, especially on production sites... If something needs to be changed, we do it from headquarters and then push it to their systems."

Jesper Bo Vedel,
Manager of Test Engineering,
Brüel & Kjær

Requirements were:

- *Production sites around the world*
- *Full oversight from headquarters*
- *Complete central target control*
- *No possibility of local adjustment*

We needed a test engine to make this possible and looked at the market to get one. However, as the ones available did not offer everything we wanted, we decided to make our own.

Our experts in production testing and measurement innovation are used to creating systems like this, and a custom solution was able to provide the entire package – not just instrumentation but design, domain expertise, software and operating services.

Brüel & Kjær's large global support network enables us to draw on our extensive service experience and established resources throughout the world. Consequently, the system allows us to track test results from sub-suppliers in Thailand, China, Japan, Taiwan, other locations in Denmark, France and the US, and headquarters in Nærum, Denmark.

Data management

A database manager helps to set up all measurements, control instruments, and save data in a database. Data is carried on a server that is local to the manufacturing location and backed up every night. Rather than permanent monitoring, it records the tests permanently for later analysis. This all takes place at Brüel & Kjær's Class-A data centre in Melbourne, Australia, which has more than 20 years of remote management experience with our noise monitoring solution customers – who include many of the world's airports. All test data is collated, securely stored and maintained, and is accessible 24/7 to authorised users of the system. The system can operate on multiple production lines across multiple locations, providing a single entry point for monitoring production testing.

"Confidence, and the ability to see the quality are what we want. With this system we have so much visibility that we feel very safe – and we trust it to deliver"

Torben Bjørn,
Vice President of Operations, Brüel & Kjær

System benefits

- *Consistent level of test quality across the products*
- *Full visibility of remote manufacturing quality*
- *Shows long-term trends and issues early to enable action before they affect production*
- *Delivers trustworthy results checked by experts at HQ*
- *Continuous quality improvements*
- *Flexibility and mobility of production lines*
- *Focus on constant cost reduction*
- *Less expensive global travel*
- *Less dependence on operator skill level*
- *Cross-functional data sharing*
- *Secure data hosting*

VIBRATION TEST AND CONTROL

Ensuring reliability and durability requires accurate replication of real-life vibration conditions during R&D and production operations. Testing strategies include accelerated lifetime testing, accelerated stress testing, durability testing, lifecycle testing, package testing, and squeak and rattle detection.

From mobile phone sub-assemblies through to complete satellite systems, our comprehensive solutions cover applications throughout the entire spectrum of vibration testing – covering payloads up to 6000 kg, with force ranges from 9 N to 289 kN.

The unbeatable performance of our systems combines with their versatility to make them highly efficient for R&D and production testing. All shakers offer the widest achievable range of test levels.

Our technical experience is frequently in demand to tailor customer-specific solutions for the most exacting requirements, in markets including aerospace, automotive, space, defence, electronics and machinery production.

Global support, service and training is part of our unique appeal, and draws on both our unrivalled experience and global coverage. On-site service and maintenance contracts are offered globally for all vibration test system configurations.

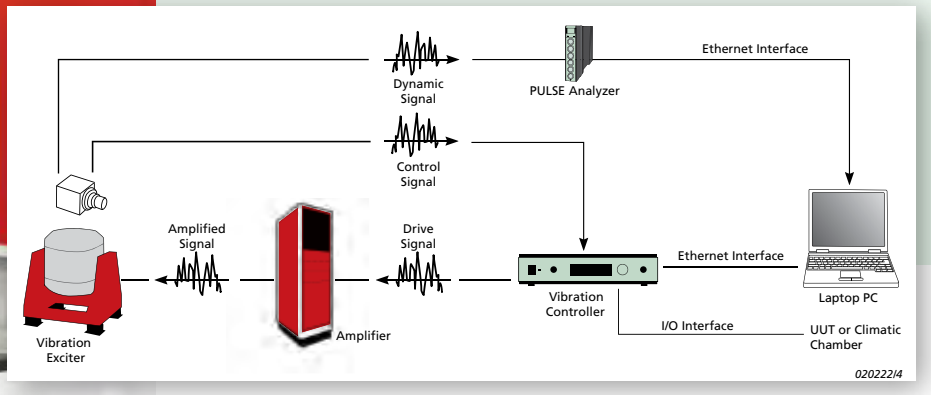
The range we offer includes vibration controllers, LDS shakers, slip-tables and energy-efficient amplifiers, giving us all of the components we need to meet virtually any test requirement in the world today. This allows you to acquire all your measurement and testing components from one supplier, and to enjoy all the benefits of capability, scale and resilience that we offer.

VIBRATION CONTROLLERS

VC-LAN AND LASER/COMET

Multi-point control of complex structures with an intuitive user interface to support workflows from basic tests like sine, random and shock, up to advanced system tests for the most challenging scenarios.

- Automated reporting
- Waveform recording and replication
- Resonance search track and dwell



Scan here to learn more about vibration test systems:

PERMANENT-MAGNET SHAKERS

V101-V455

PEAK FORCE RATINGS FROM 9 N TO 489 N

- Modal and structural analysis
- Electronic assembly test
- Calibration systems

Efficient armature design allows for delivery of impressive peak forces and acceleration over a very wide frequency range.

AIR-COOLED ELECTRO-DYNAMIC SHAKERS

V555-V780

PEAK FORCE RATINGS FROM 667 N TO 5115 N

- Automotive component testing
- Aerospace component testing
- Electronic assembly testing
- Structural testing and analysis
- Vibration stress testing under varied environmental conditions
- In-house test and calibration facilities

With a combination of a wide frequency range, high force and high acceleration, this range of air-cooled shaker systems delivers excellent all-round capabilities for testing all types of components and smaller assemblies.

AIR-COOLED HIGH FORCE ELECTRODYNAMIC SHAKERS

V830-V8

PEAK FORCE RATINGS FROM 8.9 kN TO 60 kN

- Automotive parts and systems – qualification testing
- Electronic assembly, computer equipment testing
- Avionics and military hardware testing
- Satellite component testing
- Product and package testing
- General stress screening

The industry standard for automotive, military and electronic testing. Full versatility and capability as demanded for research and development, product qualification and stress screening.

WATER-COOLED VERY HIGH FORCE ELECTRODYNAMIC SHAKERS

V9-V994

PEAK FORCE RATINGS FROM 89 kN TO 289 kN

- High-force, long-duration automotive testing
- Space, avionics and military hardware testing
- Low-frequency and shock pulse testing
- Product and package testing
- 3-axis testing of complete satellite systems
- Multi-shaker, multi-axis application
- Suitable for cleanroom environments

WORLDWIDE SERVICE

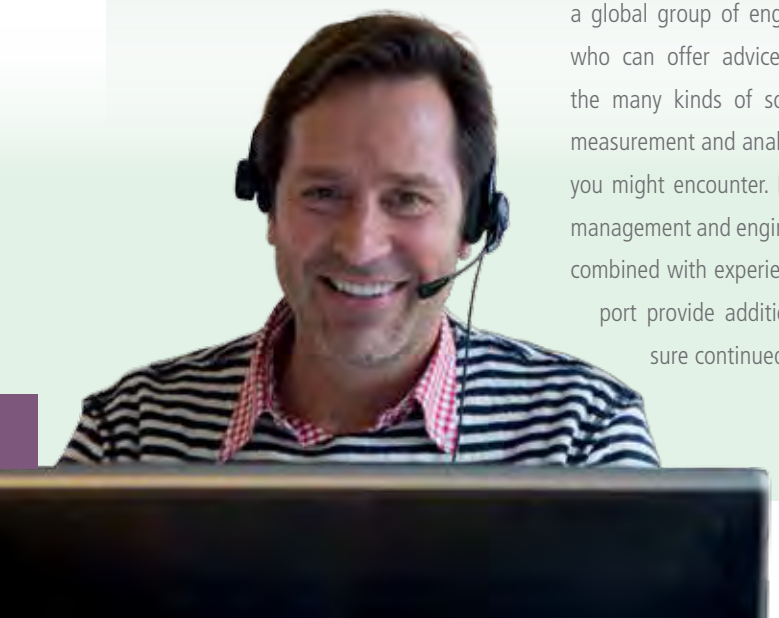
To provide you with the best customer service we continuously expand our offerings and improve our internal processes – ensuring the same 'best-in-class' standards around the globe.

A single point of contact speeds up your enquiries by connecting you to the right person the very first time, and our multilingual Global Customer Care organisation will be eager to assist you in any way. They submit your requests for service, track your orders end-to-end, and proactively inform you about the status and delivery schedule. And if you need technical support, they will route you to a dedicated contact.

Equipment calibration and repair is expertly carried out in one of Brüel & Kjær's accredited calibration centres. Our Global Product Care team is regularly trained and certified to perform calibrations and repairs of instrumentation, in order to maintain the same high standards that new equipment enjoys.

Knowledgeable Global Field Service engineers will be at your disposal for on-site field services including installation, system configuration, fault resolution, calibration and preventative maintenance of entire systems. A range of services reduces the risk of faults occurring during use.

Your local support team is backed by a global group of engineering specialists who can offer advice and solutions for the many kinds of sound and vibration measurement and analysis challenges that you might encounter. Professional project management and engineering test services combined with experienced technical support provide additional value and ensure continued smooth operation.



360-DEGREE SERVICES

1 Installation to get you up and running

Our skilled engineers will not leave you until you are up and running. From software to comprehensive systems, their expertise will save you time.

2 Training – efficiency from the start

Get instruction from the people who know the Brüel & Kjær products best. We offer extensive national and international training programmes that give you the opportunity to improve and increase your capabilities.

3 Support – help is always at hand

If you need help, just call our hotline during normal working hours to talk to experienced Brüel & Kjær engineering support teams.

4 Software updates and revisions

Ensure you are always up-to-date with a Software Maintenance and Support Agreement that grants holders exclusive access to licensed software products including tested version upgrades, updates, and patches.

5 Expert calibration

Planned, regular calibration assures measurement data quality and validity. We offer a comprehensive range of calibration services including accredited calibration, traceable calibration, and verification – performed at your site or in our laboratories.

6 Hardware maintenance – no unpleasant surprises

Under the maintenance scheme we test your instruments according to their original specifications and bring them up to standard.

7 Repair – authorised service staff and original parts

Our highly skilled service engineers use original equipment and spare parts to ensure repair quality and to extend your product's working life, on-site or in our workshop.

8 Rental – a realistic option

For short-term projects, or when your instrumentation is being repaired, why not rent from us? This means you can always say yes to sound and vibration measurement opportunities.

AND SUPPORT

IF YOU USE PULSE, YOU MIGHT:

- Like to benefit from new Microsoft® improvements to stay on track with latest technology
- Need support on a regular basis, such as when the system is installed, when a new version is released or when a new operator takes over
- Experience Microsoft® updates that bring the risk of PULSE not functioning properly and need help to fix it
- Want to constantly improve efficiency by taking advantage of the enhancements and improvements to the features and functionality of PULSE
- Need to reduce the cost of ownership and manage the life-cycle of your system
- Enjoy the peace of mind of knowing your agreement is active
- Gain exclusive access to attractive offers and receive invitations to join seminars and user days

Brüel & Kjær's Software Maintenance and Support Agreement is designed to cover all of the above.

SOFTWARE MAINTENANCE AND SUPPORT AGREEMENT

Keeping pace with evolving business requirements means that you need to ensure your PULSE system remains up-to-date. The Brüel & Kjær Software Maintenance and Support Agreement keeps your PULSE system at the forefront of this evolution and provides access to expert technical user-support when you need it.

WHAT'S INCLUDED

Tested to work with Microsoft® Windows® – keep PULSE secure and reliable

We ensure your PULSE application remains secure and reliable with each Microsoft® update by continuously testing our products on the latest versions of the Microsoft® Windows® operating system, including all critical updates.

Upgrade – benefit from the newest technology

Our development department constantly improves the functionality and user-interface of PULSE, spending thousands of hours improving our software based on customer feedback. With a valid Software Maintenance and Support Agreement you will benefit from these very latest developments.

Exclusive access to hotline

Your local Brüel & Kjær support team is committed to helping you when technical expertise is required. The hotline is backed up by our global team of skilled product specialists and application engineers. With an agreement you will receive support, and be our service and support organisation's highest priority.

Unify the versions of PULSE software – become more flexible

If you have more than one PULSE system, it is likely that they are different versions. This gives you less flexibility and/or higher cost, as operators need to know how to use different programs and interfaces. With the Software Maintenance and Support Agreement, all versions will be updated to the latest version.

Receive attractive offers during the year

With a Software Maintenance and Support Agreement you will receive attractive offers made especially for agreement holders, giving you substantial savings during the year.

ONE-YEAR AGREEMENT PROGRAMME

The Software Maintenance and Support Agreement (M1), entitles you to receive priority technical user-support for the current software version and any version released within 12 months, as well as direct and immediate access to all software updates and revisions issued by Brüel & Kjær for licenced products.

MULTI-YEAR RENEWAL PROGRAMME

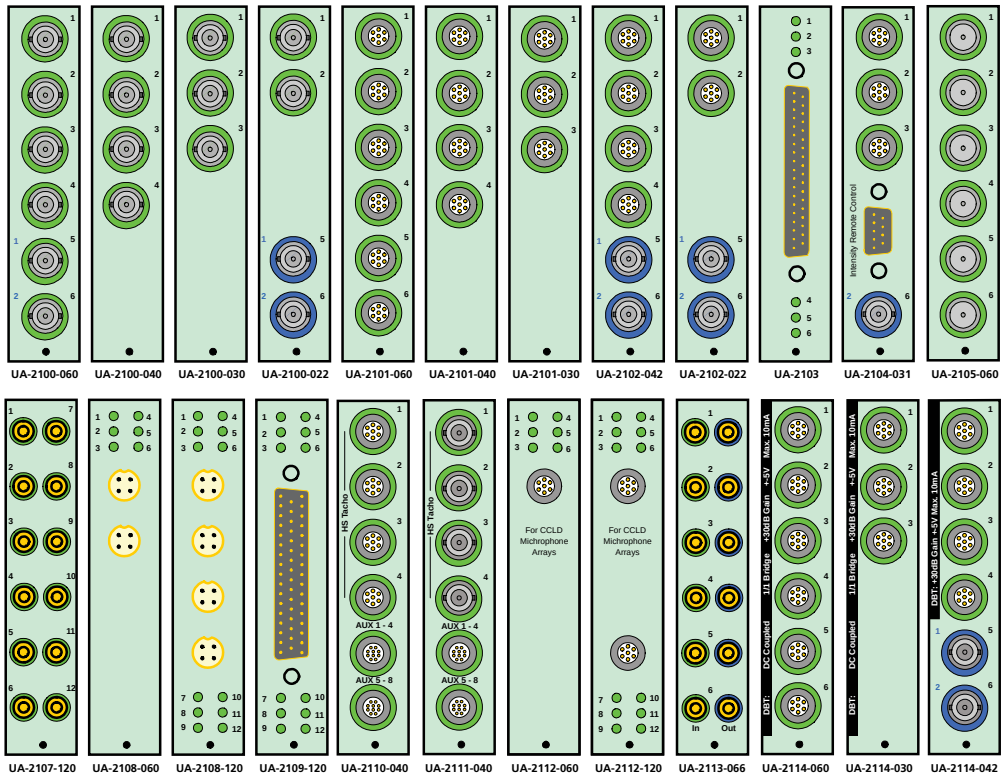
Besides all the agreement benefits, the multi-year version of M1 gives ongoing compatibility with the latest Microsoft® operating systems and unifies software versions, always keeping you up-to-date. Additionally, our calibration service (including collection and delivery) can be bundled into the agreement for improved data quality and cost savings.

PULSE HARDWARE

a Constant Current Line Drive for CCLD (DeltaTron)/ICP®/IEPE accelerometers or microphone preamplifier
b Via CCLD Converter Type 2646 or the range of Charge to CCLD Converters Type 2647
c UA-2105-060 requires a Type 2647-A, -B, -C, or -D per channel

Input Type	Product Name	Type No.	Input Channels	Front Panel	Generator Output Channels	Frequency Range	Front Panel Connectors			
							Included	Optional		
Direct CCLD[a] Mic. Preamp. (0 or 200V polarization voltage) Charge[b]	3-ch. Input Module LAN-XI 102.4 kHz (Mic, CCLD, V)	3052-A-030	3		-	0 Hz to 102.4 kHz	BNC: UA-2100-030	LEMO: UA-2101-030	SOUND INT: UA-2104-031	DBT: UA-2114-03
	4-ch. Input Module LAN-XI 51.2 kHz (Mic, CCLD, V)	3050-A-040	4		-		BNC: UA-2100-040	LEMO: UA-2101-040		SOUND INT: UA-2104-031
	6-ch. Input Module LAN-XI 51.2 kHz (Mic, CCLD, V)	3050-A-060	6		-		BNC: UA-2100-060	LEMO: UA-2101-060	SOUND INT: UA-2104-031	CHARGE AMP: UA-2105-060[c] / SUB-D: UA-2103
								TRIAX: UA-2108-060	6CH ARRAY: UA-2112-060	MONITOR: UA-2113-066 / DBT: UA-2114-060
	4-ch. Input Module/HS Tacho + 8 ch. LAN-XI 51.2 kHz (Mic, CCLD, V, HS Tacho, Aux)	3056-A-040	4+8		-	0 Hz to 51.2 kHz	Aux BNC: UA-2111-040	Aux LEMO: UA-2110-040		SOUND INT: UA-2104-031
	Generator, 4/2-ch. Input/Output Module LAN-XI 51.2 kHz (Mic, CCLD, V)	3160-A-042	4		2		BNC: UA-2100-060	LEMO/BNC: UA-2102-042		SOUND INT: UA-2104-031 / DBT: UA-2114-042
	Generator, 2/2-ch. Input/Output Module LAN-XI 51.2 kHz (MIc, CCLD, V)	3160-A-022	2		2		BNC: UA-2100-022	LEMO/BNC: UA-2102-022		
Direct CCLD[a] Charge[b]	12-ch. Input Module LAN-XI 25.6 kHz (CCLD, V)	3053-B-120	12		-	0 Hz to 25.6 kHz	SMB: UA-2107-120	TRIAX: UA-2108-120		12CH ARRAY: UA-2112-120
Battery Module										
	Battery Module	2831-A	-		The battery module is a rechargeable Li-Ion battery with an output voltage of 14.8 V and a capacity of 6400 mAh. On the front, 5 LED status indicators show the remaining capacity.					
LAN-XI Frames										
	5-module LAN-XI Front-end Frame Type 3660-C	3660-C-000	Houses up to 4/3 input/ output modules + 1/2 batteries		Mains (90-264 V AC, 47 – 63 Hz) or DC powered (10 – 32 V). Phase and sample-synchronous measurement with other PULSE front-ends including IDA[e]. Plug-and-play modules can be removed for field measurements using a single module, or swapped for calibration or repair. Modules can be locked or screwed in place. Operation is silent as long as the temperature of the unit is within safety limits. If the maximum operating temperature is reached, cooling fans start. Their SPL is < 30dB at 1m.					
	11-module LAN-XI Front-end Frame Type 3660-D	3660-D-000	Houses up to 10/9 input/ output modules + 1/2 batteries							

PULSE HARDWARE



Interchangeable front panels

LAN-XI frame rear view

Single LAN-XI module – rear view

3660-C

5-module LAN-XI Front-end Frame

3660-D

11-module LAN-XI Front-end Frame

3052

3-ch input
100 kHz

3050

4/6-ch input
50 kHz

3053

12-ch input
25 kHz

3056

4-ch input
50 kHz
HS Tacho
Aux inputs

3160

2/4-ch input
2-ch output
50 kHz

2831

Battery
module

UA-2203	Blank Module for LAN-XI Mainframe
UA-2204-A	19" Mounting Kit for 3660-D Frame
ZG-0469-001	Charger for Li-Ion battery Type 2831
ZG-0858	Auto Charger for 2831 LAN-XI Battery

UL-1018	SD-card 16 GB Micro, requires BZ-7848-A (NOTAR)
UL-0252	10-Port 10/100/1000 Managed Gigabit Switch with Maximum PoE (8-ports)

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