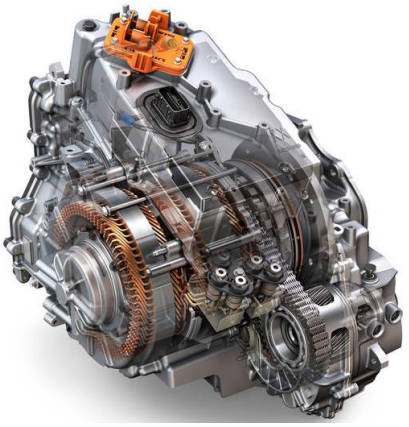
PLATO – Powertrain NVH Testing Using Microphones



Overview

PLATO is a multi-channel hardware/software system solution designed specifically for measuring noise/vibration ("NVH") signatures of rotating machines, including automotive power transmission assemblies.

PLATO systems provide precision order-locked analysis, using a shaft speed reference signal to synchronise data acquisition. When operating with test machines, data capture & processing can be automated and synchronised to test machine schedules as part of an in-process or end-of-line quality assurance check.

Analyses include:

- expected order (spectra, order-tracks) with comparisons against self-taught or user-input reference levels
- unexpected ("ghost") order grading

The same PLATO software used for testing also provides in-depth interactive graphing / reporting when not in test mode.

The goals for any such system include:

- diagnosis of product faults
- test results that correlate well with subjective assessments of the product in-service e.g. in-vehicle

To achieve these goals, many PLATO systems opt to measure vibration (linear or rotational), but some product testing can benefit from measuring (((((((**radiated noise**)))))))

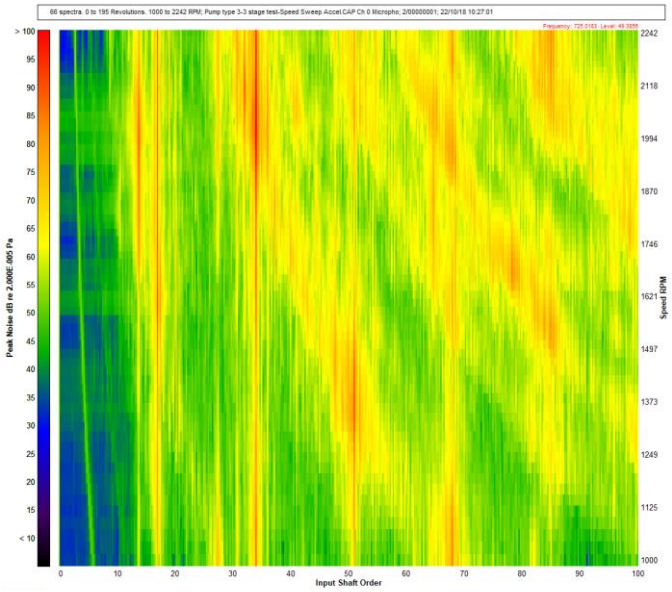
Should you measure radiated noise?

Measuring radiated noise (as opposed to vibration) is typically best suited to products that:

- include large radiating surfaces
- are known to transmit noise through airborne paths to assessors when in-service e.g., passengers within a vehicle.

In these circumstances, measuring radiated noise has been shown to provide a route to high levels of correlation to subjective assessments of noise inside vehicles, **BUT…**

care must be taken to ensure the noise results are repeatable and meaningful.



Typical Radiated noise order domain spectrogram for speed sweep on gear-based transmission

Acoustic enclosures

Radiated noise measurements are only successful if the acoustic space in which the measurements are made is:

- of sufficiently **low background noise** level
- can be controlled to remain **acoustically consistent**

Background noise levels in the 45-50dBA range are typically required to allow product noise-to-background noise ratios to be high enough for meaningful measurements to take place. Test machine motors should be positioned outside the enclosure and the enclosure should not be used for storage (acoustic reflections are required to stay consistent).

The above typically requires an acoustic enclosure (or "noise haven") to be employed, which must:

- be easy for the product to enter/leave
- not provide any gaps through which factory noise can enter the testing space

See NVH International's Design Aid (**DA403**) for more details on acoustic enclosures for powertrain radiated noise measurement.

Typical acoustic enclosure for measurement of radiated noise in the presence of high and variable background noise levels e.g., factory shopfloors

Microphones

Microphone type

Typical free-field array microphone

Free-field microphones are typically used for powertrain noise measurements. Array style (electret) microphones are cost-effective, so make the deployment of multiple microphones per system viable (see details on spatial averaging below).

Microphone powering and conditioning

NVH International also supplies the MC-103 range of multi-channel powering/ conditioning modules that can accept any number of microphones.

A user-configurable high-pass filter can be applied to each output to remove energy at frequencies below those of interest for analysis. The filtered signal is then amplified to optimise the use of ADC-ranges on attached data acquisition hardware.

4-channel microphone powering/conditioning module

Is a single, close microphone, OK?

The short answer is “no”. Many specifiers of radiated noise measurement systems believe that a single microphone positioned as close as possible to the product under test is all that is required to make meaningful measurements. Reasons why you should not use a single, close microphone include:

- The microphone measures noise mainly emitted from the closest part of the product under test and may not capture all the significant energy that can be radiated from the remainder of the product.
- The microphone would be operating in the acoustic "near field" and become part of the noise field circulating close to the product from local "sources" to "sinks". Part of the noise it measures will then not radiate away from the product.
- Close microphones are more likely to be damaged or sprayed with oil.
- Close microphones require a mechanism to position them for measurement and remove them during product loading and unloading. The positioning mechanism adds cost and potential for unreliability.
- The noise measured by a close microphone is very dependent on the exact position of the microphone. A different microphone position gives a different result. Which one should be believed? Which one is "correct"?
- Correlation with in-vehicle noise is likely to be difficult.

Multiple, close microphone?

Using multiple, close microphones can provide better results than a single, close microphone, but such systems tend to generate more problems with damage and reliability of the positioning systems. The problems associated with the microphones being in the acoustic near field also remain.

Multiple, remote microphones

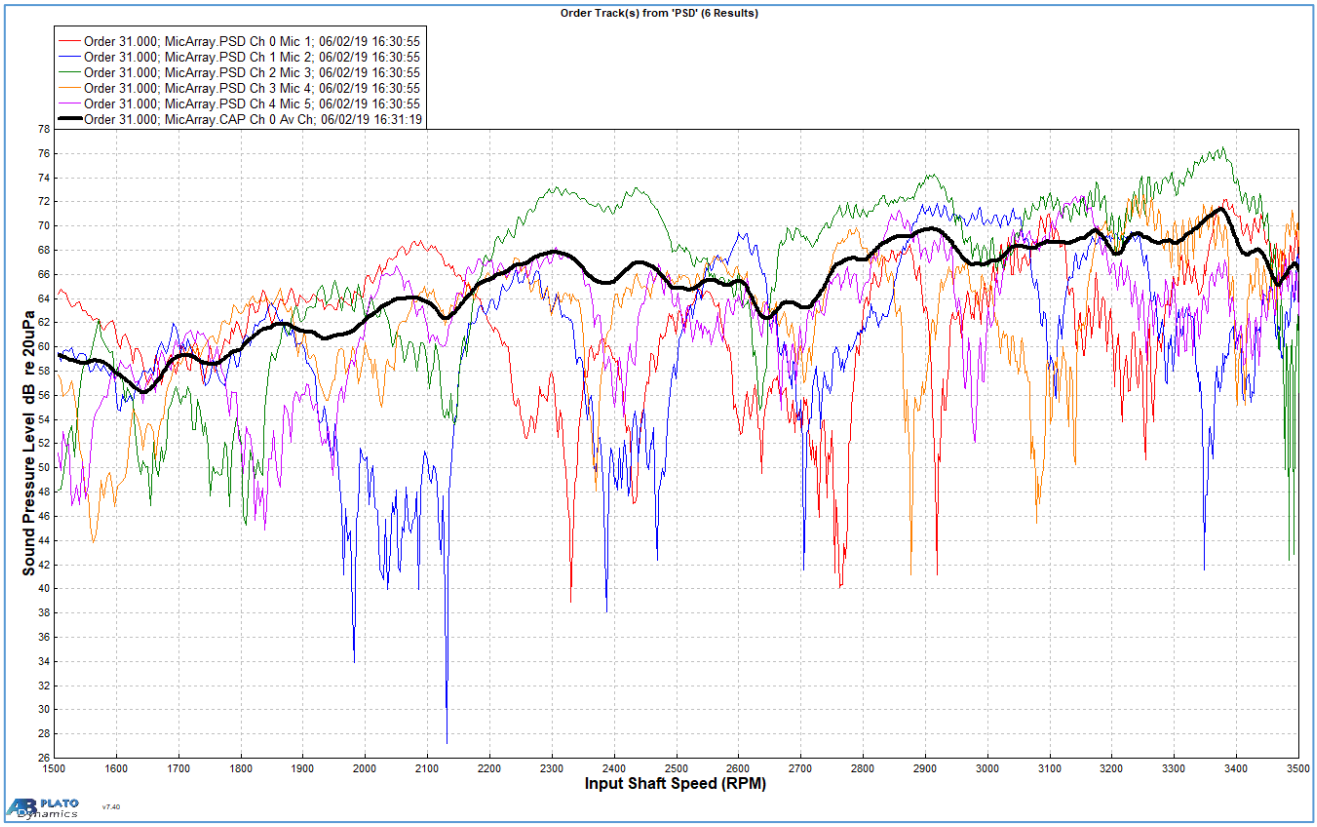
Multiple, remote microphones capture noise radiating from most of the surfaces of the product under test using a combination of direct and reflected sound. Multiple, remote microphones are:

- Easy to install (see NVH International's Design Aid **DA402** for more details on microphone mounting systems).
- Positioning/retraction mechanisms are not required, hence reduced cost and greater reliability.
- Reduced chance of damage or oil spray contamination.
- Total microphone cost is higher but is compensated by lack of need for retraction mechanism, less chance of damage to microphones and reduced servicing costs.

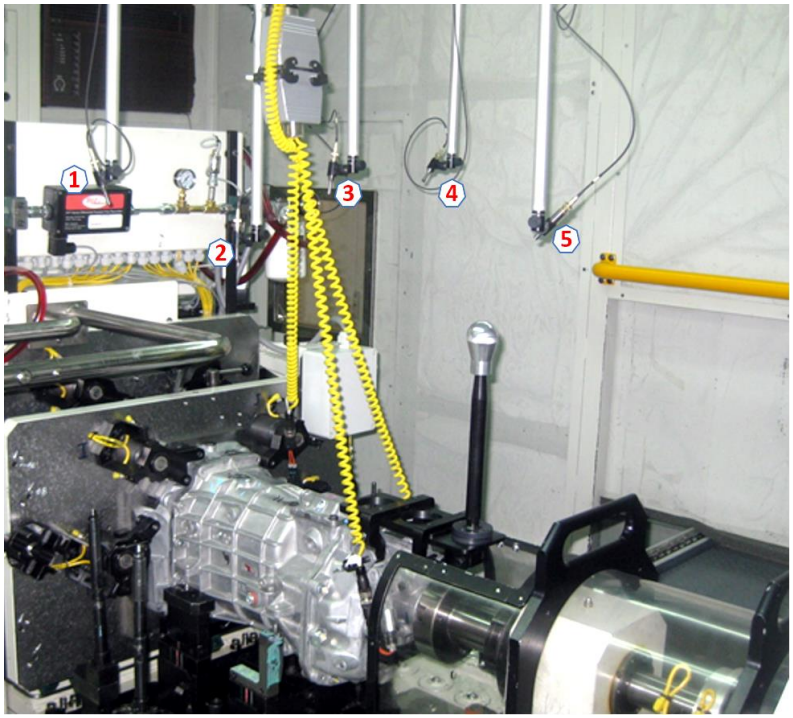
Spatial averaging

When measuring inside a closed space, an individual microphone's response is heavily influenced by the pattern of standing waves that is inevitably set-up within the space. Small changes in temperature and atmospheric pressure then dramatically change the response, despite the position of the microphone being unchanged. (Single microphones can give a frequency dependent spread of results up to 20dB merely because of air temperature changes).

Spatial averaging over an array of microphones greatly reduces these effects and provides a **significantly more repeatable** measure of the total acoustic output of the product under test. Five (5) or six (6) microphones are the preferred configuration with the minimum recommended number being three (3).



Gear-mesh fundamental order-tracks from speed sweep for five (5) microphones (**red**, **blue**, **green**, **orange**, **pink**) with inter-channel (spatial) average overlaid (**black**)



Five (5) microphone array noise testing of 7-speed manual transmission

NVH International has implemented many successful end-of-line NVH measurement and analysis systems that measure radiated noise.

The example system shown here positions five (5) microphones approximately 1m from the transmission under test so they do not interfere with the transmission load/unload procedure.

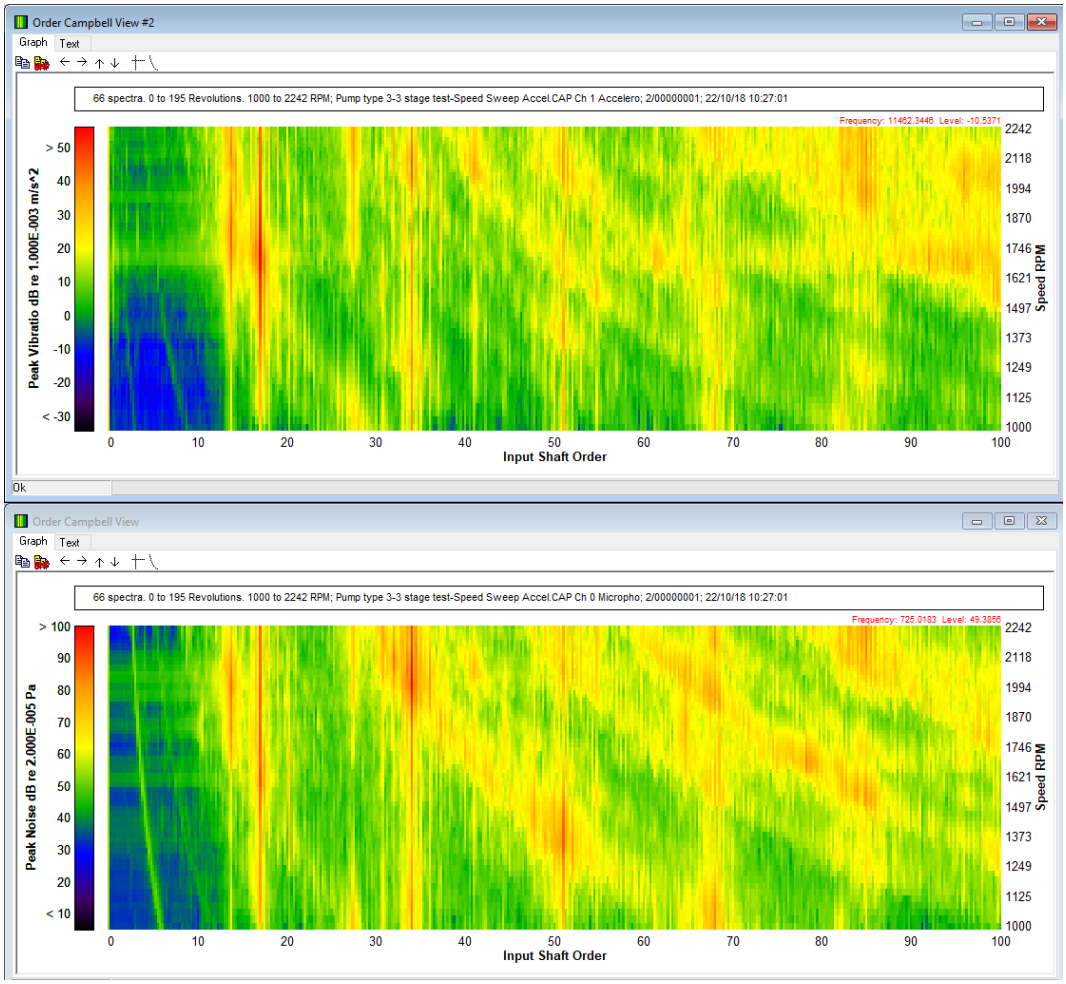
Each microphone is positioned with a clear line-of-sight to the product under test.

The test takes place inside an acoustic enclosure with the test machine's motors outside the acoustic test space. The test machine's input/output driveshafts then pass through acoustic tunnels to ensure background noise levels are kept to a minimum.

Noise or vibration?

It is often very difficult to predict whether noise or vibration results from a test will provide the best data to achieve the system goals.

Both noise and vibration results will contain the same key features – as can be seen in these spectrograms obtained simultaneously from the same test- but the details of each feature e.g. each salient order-track, will be different.



Five (5) Product casing **vibration** (upper graph) and radiated **noise** (lower graph) acquired simultaneously

+44 1225 970315
sales@nvhint.com
Eastern House, 15-16 Silver Street
Bradford-On-Avon, UK, BA15 1JZ
www.nvhint.com

Front-end hardware

PLATO currently uses front-end hardware from **National Instruments** (“NI”), including:

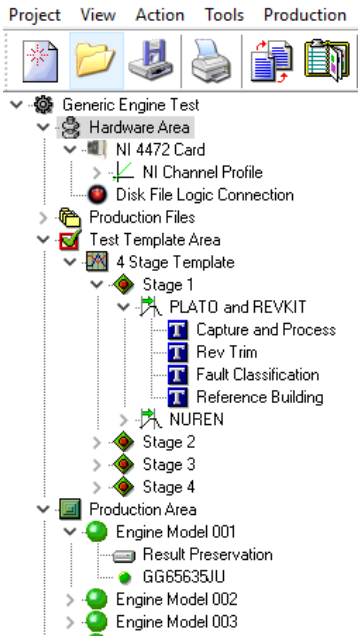
- Standalone PXIe-chassis with **PXI-4492/4497** for a total of eight (8) or sixteen (16) analogue measurement channels
- **204.8kHz** sample rate per channel

- Portable CompactDAQ (cDAQ) chassis with **9250** modules (2-channels per module) or **9234** modules (4-channels per module) providing channel count options: 4, 8, 12 … 32
- **102.4kHz** sample rate per channel (9250 modules)
- **51.2kHz** sample rate per channel (9234 modules)

- Portable **USB-4432** for five (5) measurement channels
- **102.4kHz** sample rate per channel

All **PLATO** supported NI solutions include 24-bit, fully anti-aliased sampling, with the option (software set per channel) to AC-couple and provide power to ICP-sensors.

Highly configurable software



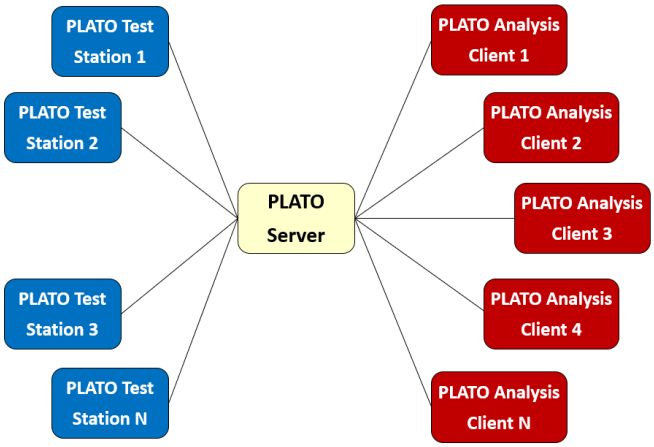
PLATO is PC-based and runs on a *Microsoft Windows* ™ platform. Highly configurable software projects (using an intuitive tree structure) allow testing resources to be configured and multi-stranded NVH test procedures to be defined.

Once defined, the project tree can be password protected to only allow access to those competent of making changes.

Much use is made of testing templates. These allow similar products under test to be tested in similar ways, yet with flexibility to allow each product model definition to override default settings. Adding new product types is then a very straightforward exercise.

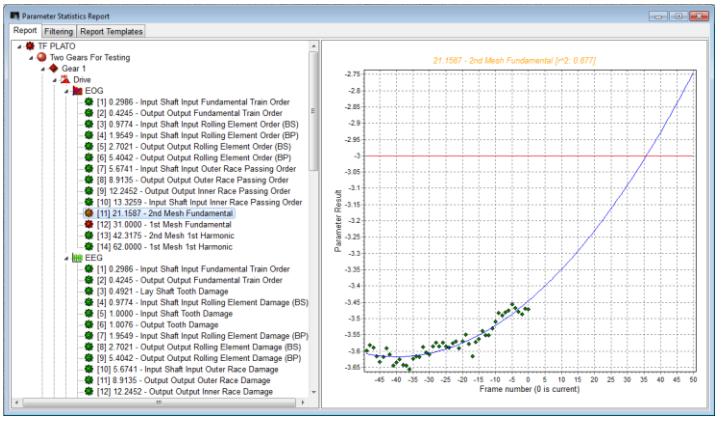
Once a test has been completed, salient summary results are stored in state-of-the-art databases, so they can be viewed locally or via a network connection. At the same time, options exist to store "raw" (detailed) results, facilitating further in-depth (off-line) analysis.

Plato-SERVER



All PLATO test stations can be networked to a SQL-server based central repository called Plato-SERVER which then, via PLATO Analysis Client ("PAC") software running on individual's PCs/laptops, provides access to summary results, raw and processed data files and production reports/trends etc.

Plato-SERVER and PAC-software are available **free-of-charge**.



Release Date: 19-MAY-2022

Document No. PS-408

Issue No. 02

+44 1225 970315
sales@nvhint.com
Eastern House, 15-16 Silver Street
Bradford-On-Avon, UK, BA15 1JZ
www.nvhint.com