

# Measuring Instrument Combinations

## 1

### Acoustic Measurement

Before starting an acoustic or vibration measurement, three factors must be considered:

- What kind of sound/vibration is to be measured?
- For what purpose?
- Which kind of processing is required (recording, analysis etc.)?

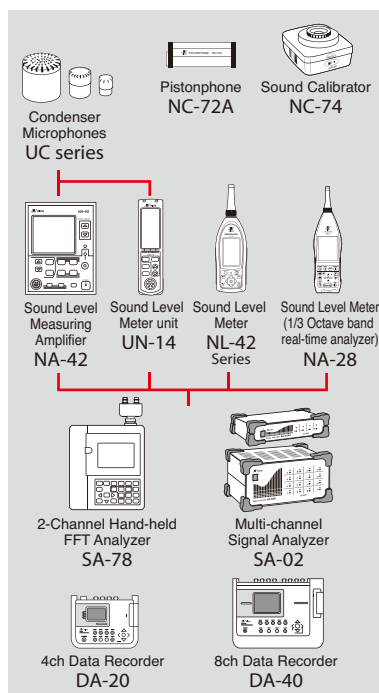
Depending on these factors, the measurement method, type of measuring instrument, and choice of peripheral equipment will differ. Selecting the right combination of products is essential for achieving accurate and reliable results. The following pages are intended to help with the selection of equipment, by describing some representative configurations and showing connection examples.

In acoustic measurements requiring high accuracy, the basic instrument combination consists of a condenser, microphone and preamplifier. To this, other equipment, such as a frequency analyzer and data recorder, is added as needed.

The type of condenser microphone will be determined by factors such as the target sound pressure level, frequency range, and sound field conditions. (See selection examples on page 13.) The general-application Sound Level Measuring Amplifier NA-42 is suitable as an amplifier for these microphones.

Frequency analyzers come in two types: constant-ratio type real-time analyzers and constant-amplitude type FFT analyzers. In the former category, RION offers the Precision Sound Level Meter NA-28 with the 1/3 octave band real-time analyzer function. In the FFT category, there is the 2-Channel Hand-held FFT Analyzer SA-78.

Besides, Multi-Channel Signal Analyzer SA-02 can be used as both 1/1, 1/3, 1/12 Octave Band Analyzer and FFT Analyzer.



## 2

### Calibration of Sound Level Meters and Vibration Meters

#### ● Calibration of sound level meters and similar devices

For overall checking of sound level meters and acoustic measurement systems, RION offers the Sound Calibrator NC-74 (1 kHz, sound pressure level 94 dB), as well as the Pistonphone NC-72A (250 Hz, 114 dB).

#### ● Calibration of vibration meters and similar devices

In order to make it possible for users to easily calibrate vibration meters and vibration accelerometers, RION offers the Calibration Exciter VE-10 (159.2 Hz, acceleration 10 m/s<sup>2</sup>, velocity 10 mm/s, displacement 10 μm).

#### Calibration of sound level meters and similar devices



#### Calibration of vibration meters and similar devices



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## Measuring Instrument Combinations

### 3

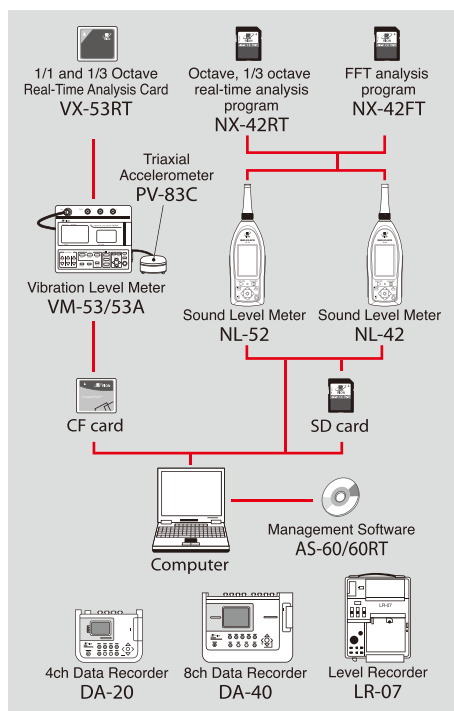
#### Sound Level Meters and Vibration Level Meters in the Field

The basic model lineup for JIS and IEC standard compliant sound level meters is the NL series. For on-site measurements of vibration levels, the Japan Measurement Law and JIS compliant Vibration Level Meters VM-53/53A are suitable. The NL-42 series (SD cards) and the VM-53A series (CF cards) use memory cards to allow long-term recording of vibration level data and calculated data. Data stored on memory cards can be utilized by the dedicated software application AS-60, for level waveform display, editing, further processing, and creating daily and weekly reports.

The NL-42 series supports use of the Octave Band and 1/3 Octave Band Real Time Analysis Program NX-42RT and the FFT Analysis Program NX-42FT. The Data Management Software AS-60 allows playback of real sound files. Analysis data saved with the NX-42RT can be displayed, edited, and processed using the Data Management Software (With Octave and 1/3 Octave Data Management Software) AS-60RT.

The VM-53A allows use of the 1/1 and 1/3 Octave Real-Time Analyzer Card VX-53RT for frequency analysis.

For recording of sound level and vibration level data, RION level recorder LR-07 is useful. Sound pressure waveform and vibration acceleration waveform information can be recorded using a data recorder (4-channel type: DA-20, 8-channel type: DA-40), allowing for later analysis with waveform processing software.



### 4

#### Sound Level Monitoring

Aircraft noise, factory noise and other types of noise that have an influence on the living environment require constant level monitoring in order to devise efficient countermeasures. For short-term monitoring, the Sound Level Meter NL-42 series along with the level recorder LR-07 and a suitable all-weather windscreen is a convenient arrangement (Figure 1).

For constant monitoring on a long-term basis, a system built around the Environmental Sound Monitor NA-37 is optimal. Such a system can use the public telephone network or another suitable online link to send data to a monitoring facility. The optional Aircraft Noise Identifier Unit AN-37 provides the capability of determining sound incident direction while the Environmental Noise Data Processing Software AS-50PA1 handles the obtained data.

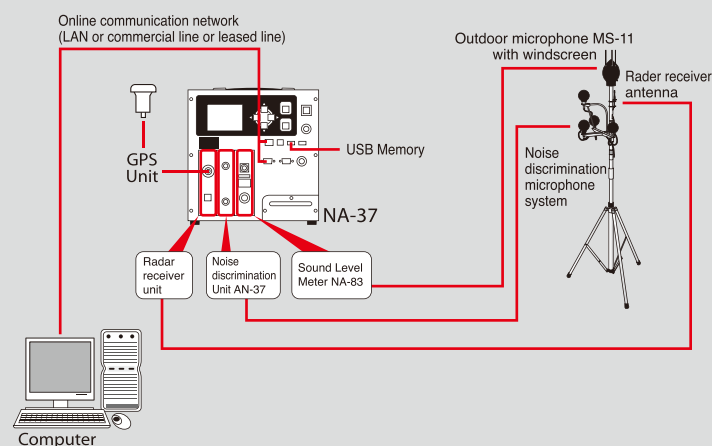
The Aircraft Noise Processing Program NX-37C and Aircraft Noise Data Processing Software AS-50PA2 including support for ground-level sound events\* are also available. Environmental Noise Data Processing Software AS-40PA1 is also available that allows to process the collected data of environmental noise (Figure 2).

\* Ground-level sound event refers to noise produced by aircraft on the ground, within the airport area. This includes noise from take-off and landing, taxiing, engine trial runs, APU etc.

Figure 1



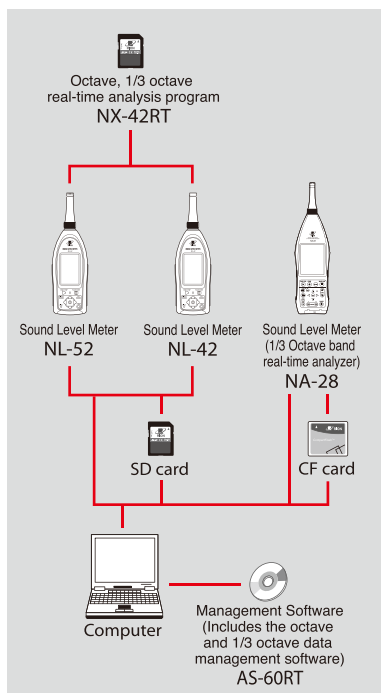
Figure 2



## 5

### Noise Measurement at Working Places

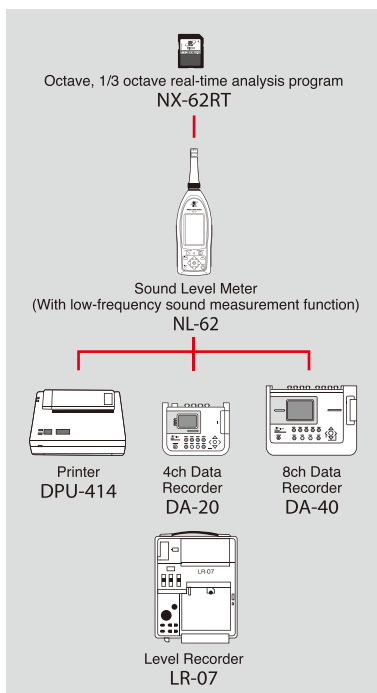
The measurement of sound exposure levels is an important prerequisite for protecting personnel working in an environment with high sound level from hearing damage. Regulations to control generation of noise at work places have come into force in many countries. For instance, The Noise Prevention Guideline issued by the Japanese Labor Ministry (currently the Health, Labor and Welfare Ministry) in 1992 provides the framework for measurement and evaluation of equivalent continuous sound pressure levels. The Sound Level Meter NL-42 series is suitable for such measurements. When the NL-42 series is used, the results can be stored on a SD card and later exported to a spreadsheet application for easy processing. The Octave Band and 1/3 Octave Band Real Time Analysis Program NX-42RT can also be used to analyze the frequency ranges that are critical for noise countermeasures. The Sound Level Meter NA-28 with the 1/3 octave band real-time analyzer function is also a highly useful tool. Analysis data saved with the NX-42RT and NA-28 can be displayed, edited, and processed using the Data Management Software (With Octave and 1/3 Octave Data Management Software) AS-60RT.



## 6

### Low-Frequency Sound Measurement

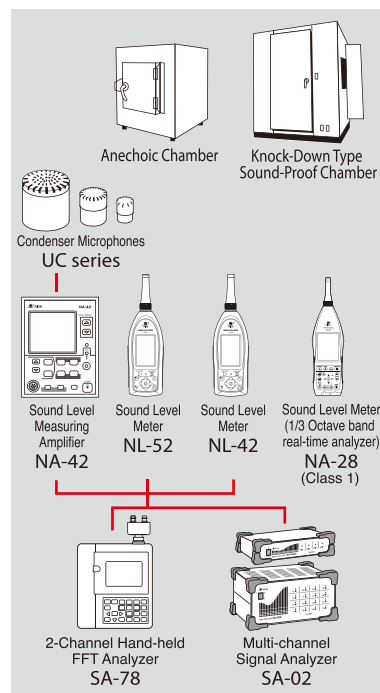
So-called infrasound in the range below the human hearing threshold, from 1 Hz to about 20 Hz, can have a physiological impact on humans if sound pressure levels are very high. It can also cause other unwanted effects such as window rattling and develop into an environmental problem. To measure sound in this range, the Sound Level Meter NL-62 + NX-62RT which provides G characteristics as defined by ISO 7196 and 1/3 octave band analysis can be used. By connecting the Level Recorder LR-07 or a Data Recorder (DA-20 with 4 channels or DA-40 with 8 channels), the level changes and sound pressure signal condition can be recorded, and the Printer DPU-414 allows printout of measurement results.



## 7

### Quality Management Based on Sound and Vibrations

Measuring the noise level and vibrations produced by machinery and other equipment can often provide valuable data for quality control. Depending on the characteristics of the measurement target, UC series microphones or PV series accelerometers are used as sensors connected to equipment such as the Sound Level Meter Unit UN-14, Vibration Meter VM-83 or Charge Amplifier UV-15/16. When only the sound or vibration Level is to be measured, the NL-42 series, NA-42, or VM-83 with comparator function are suitable. For purposes such as detection of abnormal noise, frequency analysis must also be performed. In such cases, the Multi-channel Signal Analyzer SA-02 series, the Sound Level Meter NA-28 (with 1/3 octave band analysis function) is useful. For judging a product to be defective or non-defective in the manufacturing process, Multi-Channel Signal Analyzer SA-02 series with software CAT-SA02-CMP03, or 2-Channel Hand-held FFT Analyzer SA-78 with software CAT-CMP7802 are useful.



## Measuring Instrument Combinations

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#### Sound-Proof Chambers, Anechoic Chambers, Echo Chambers

When performing acoustic measurements, special conditions must often be established, such as low-noise environment, semi-free sound field, free sound field, or diffuse sound field.

##### ● Low-noise environment

Using a sound-proof chamber or box, when the sound level emitted by equipment is low, ambient noise can influence a measurement. To prevent this, place the measurement target in a sound-proof chamber or box. In some cases, using an anechoic chamber or box where the influence of reflections is minimized can also be useful.

For acoustic power level measurements according to the sound pressure method or for measuring the sound insulation characteristics of building materials, a semi-free sound field, free sound field, or diffuse sound field must be realized, according to standard stipulations. This can be achieved by using suitable RION products.

##### ● Semi-free sound field

Using a semi-anechoic chamber  
Except for the floor, all surfaces of such chambers are specially treated for sound absorption to minimize the influence of reflections.

##### ● Free sound field

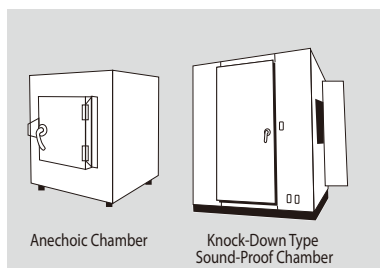
Using an anechoic chamber  
All surfaces including the floor of such chambers are specially treated for sound absorption to minimize the influence of reflections.

##### ● Diffuse sound field

Using an echo chamber or type I test chamber  
For sound insulation measurements, JIS prescribes the use of a so-called Type I chamber which provides an environment with uniform energy distribution.

##### ● Insulation measurement environment

Using a type II test chamber  
This refers to a cuboid test chamber with specially adjusted reverberation times for specific frequencies.



### 9

#### Measurement of Sound Insulation and other Performance Parameters of Buildings

The acoustic properties of dividing walls, floor slabs, and other building elements are usually measured and evaluated according to the JIS specifications or methods recommended by the Architectural Institute of Japan, as listed below.

##### ● ISO 140-1

Acoustics - Measurement of sound insulation in buildings and of building elements - Part 1: Requirements for laboratory test facilities with suppressed flanking transmission

##### ● ISO 140-3

Acoustics - Measurement of sound insulation in buildings and of building elements - Part 3: Laboratory measurements of airborne sound insulation of building elements

##### ● ISO 140-4

Acoustics - Measurement of sound insulation in buildings and of building elements - Part 4: Field measurements of airborne sound insulation between rooms

##### ● ISO 140-7

Acoustics - Measurement of sound insulation in buildings and of building elements - Part 7: Field measurements of impact sound insulation of floors

##### ● ISO 140-8

Acoustics - Measurement of sound insulation in buildings and of building elements - Part 8: Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a heavyweight standard floor

##### ● ISO 717-1

Acoustics - Rating of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation

##### ● ISO 717-2

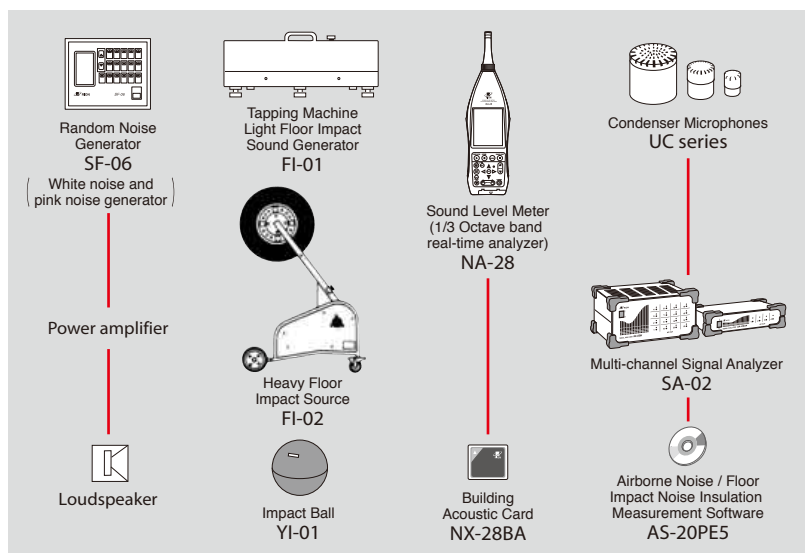
Acoustics - Rating of sound insulation in buildings and of building elements - Part 2: Impact sound insulation

##### ● Architectural Institute of Japan, recommended measurement standards

- Measurement of sound pressure level differences in actual buildings
- Measurement of internal/external sound pressure level differences in actual buildings
- Measurement of impact sound level in actual buildings
- Measurement of external noise at actual buildings for design of sound-proofing
- Measurement of internal noise at actual buildings

To create the white noise or pink noise required for these measurements, the Random Noise Generator SF-06 is used. Suitable impact sound sources are the Tapping Machine FI-01 (Light Floor Impact Sound Generator), the Bang Machine FI-02 (Heavy Floor Impact Source, impact force characteristics 1), and the Impact Ball YI-01.

For evaluation complying with the standard stipulations, frequency analysis must also be performed. The required measurement results are reliably obtained with the Precision Sound Level Meter NA-28 with 1/3 octave band analyzer function) in combination with the Building Acoustic Card NX-28BA. Rion also offers the Multi-Channel Signal Analyzer SA-02 series and the Airborne/Floor Impact Sound Insulation Measurement Software AS-20PE5.

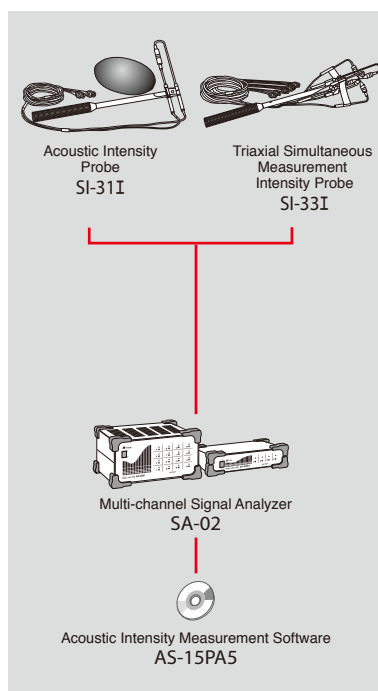


# 10

## Acoustic Intensity

Acoustic intensity is defined as the sound energy coming from a specific direction. By measuring acoustic intensity, it is possible to assess the acoustic power level of a sound source or measure the sound insulation performance of materials without having to use an anechoic chamber or other special equipment. It also is useful when examining from which part of the sound source a given noise emanates or which part of a material allows sound to pass through, and allows visualization of the results.

For acoustic intensity measurement, the Acoustic Intensity Probe SI-31I is connected to a Multi-Channel Signal Analyzer of the SA-02 series, and the Acoustic Intensity Measurement Software AS-15PA5 is used. By choosing the 3-Axis Simultaneous Measurement Intensity Probe SI-33I, results for a three-dimensional grid can be obtained in a single operation.



# 11

## Acoustic Power Level

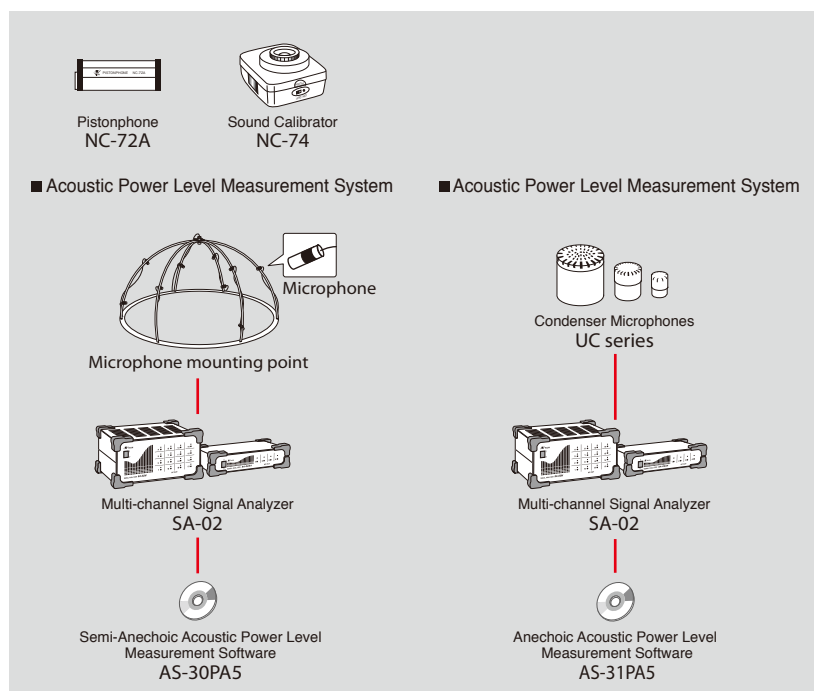
Even if emitting noise of the same energy level, the actual ambient noise level in the vicinity of mechanical or electrical machinery, office equipment etc. will differ, depending on various conditions. When predicting expected noise levels associated with installation or removal of a given piece of equipment, or when assessing the equipment as a single noise source, it is important to determine the acoustic power level which represents the acoustic energy produced by the equipment per unit of time. The basic components that are required when configuring a system to measure the acoustic power level of a sound source are suitable microphones and preamplifiers, a Multi-Channel Signal Analyzer of the SA-02 series, and acoustic power level measurement software.

- Acoustic power level measurement system using a hemi-anechoic chamber
  - ISO 3745
  - ISO 3744

Calculates the acoustic power level according to the stipulations of the respective standard.

- Acoustic power level measurement system using a reverberation chamber, wide-band)
  - ISO 3741

Calculates the acoustic power level according to the stipulations of the respective standard.





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#### Sound quality evaluation

In conventional sound evaluation measurements, frequency weighting using the "A" characteristics is commonly used for measurements intended to express the noise level. However, sound quality is increasingly gaining recognition as an aspect that is significant in evaluating the sound emitted by various kinds of products. Consequently, various parameters expressing sound quality such as loudness, roughness, and sharpness have come to be widely recognized as useful for evaluating sound. To measure these parameters, a system consisting of microphone and preamplifier, Multi-Channel Signal Analyzer of the SA-02 series, and sound quality evaluation software is suitable.

##### ● Loudness

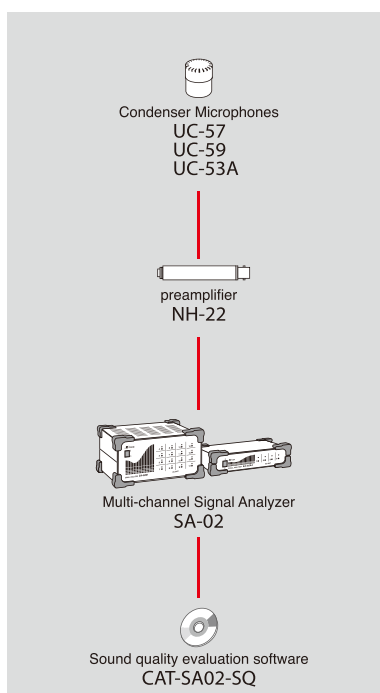
Loudness is an aspect that expresses the subjective volume of a sound as perceived by human hearing. ISO 532 defines the standard method which is used to calculate loudness as an evaluation parameter.

##### ● Sharpness

Sharpness is an evaluation parameter that expresses the sharp metallic quality of sound in the high frequency range.

##### ● Roughness

Roughness is an aesthetic evaluation parameter that expresses the perceived roughness dependent on modulation frequency, modulation rate, and sound pressure level changes.



### 13

#### Pure tone evaluation

The Tonal Audibility Calculation Program (Excel macro) can be used for pure tone evaluation.

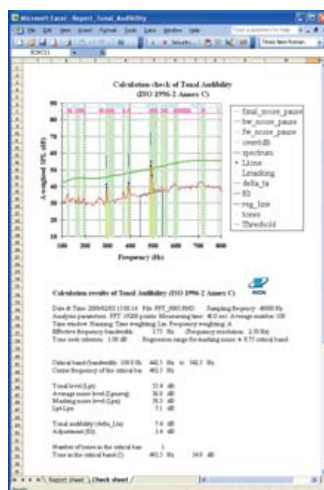
ISO 1996-2:2007- Annex C

##### ● Assessing the audibility of tones in noise

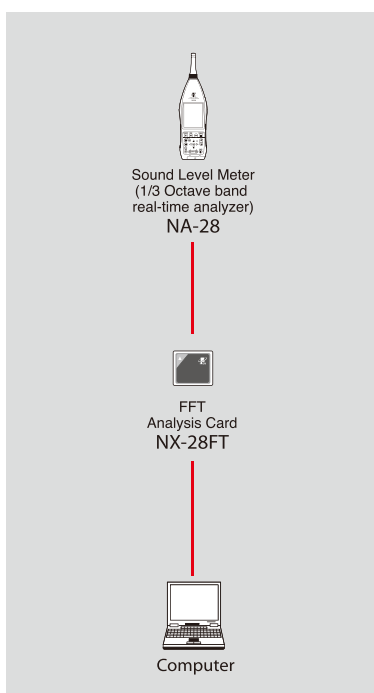
The aim of the objective method is to assess the prominence of tones in the same way as average listeners based on the psychoacoustic concept of critical bands.

##### ● Target sounds

Steady and varying tones, narrow-band noise, low frequency tones



Tonal Audibility Calculation Program



### 14

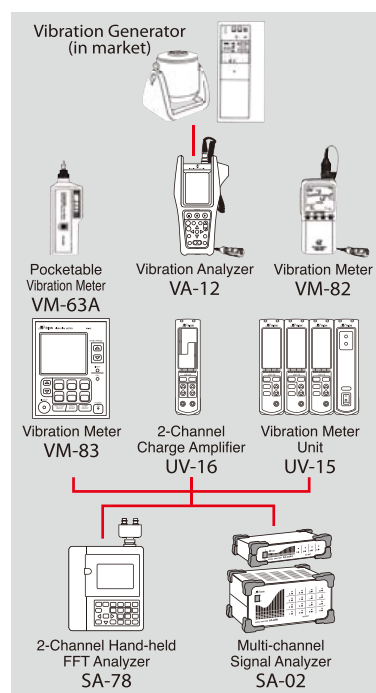
#### Measurement of Mechanical Vibrations

Vibration measurements are most commonly carried out using PV series piezoelectric accelerometers as the sensor providing the input signal. Because there will be considerable differences in the magnitude of vibrations, depending on the measurement object, RION offers a wide range of accelerometers with different sensitivity levels and dimensions. Velocity information can be obtained by integrating the acceleration figures. Velocity can then be converted to displacement by further integration.

The RION product lineup in the category of portable vibration meters includes the Pocketable Vibration Meter VM-63A, the Vibration Meter VM-82, and the Vibration Analyzer VA-12 with built-in FFT analysis function. In the larger stationary type unit category, RION offers. The Vibration Meter VM-83, which also supports servo accelerometers, and the UV series charge amplifiers, such as the UV-15 and UV-16, which support a multi-channel configuration for simultaneous measurement.

For vibration analysis, suitable RION products include the Vibration Analyzer VA-12, the 2-Channel Compact FFT Analyzer SA-78, the Multi-Channel Signal Analyzer SA-02 series for FFT analysis.

When measuring vibration characteristics of machine parts and facilities, a vibration source is commonly used. Various types of containing, different output levels, are available to match the size of the object under test.



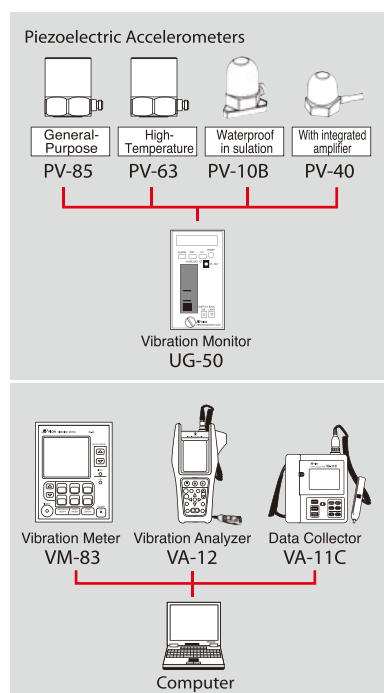
# 15

## Vibration Monitoring

Vibration monitoring is an important tool for detecting symptoms of impending problems in machinery and for implementing preventive maintenance. In the semiconductor industry and other sectors that require high accuracy manufacturing, vibration monitoring helps to improve yield and facilitates quality control. There are two basic patterns for vibration monitoring: continuous monitoring where vibration levels are automatically monitored on an ongoing basis and an alarm is triggered when a certain level is exceeded, and periodic monitoring at regular intervals combined with trend analysis designed to assess and manage the condition of the equipment.

RION offers a range of vibration accelerometers suitable for constant monitoring including general-purpose, high-temperature, water-proof and insulated types, and accelerometers with integrated preamplifiers. The Vibration Monitor UG-50 is suitable for such applications and offers the capability to output an alarm signal.

The Vibration Analyzer VA-12/11C and the Vibration Meter VM-83 can be connected to a computer for configuring a constant monitoring system.



# 16

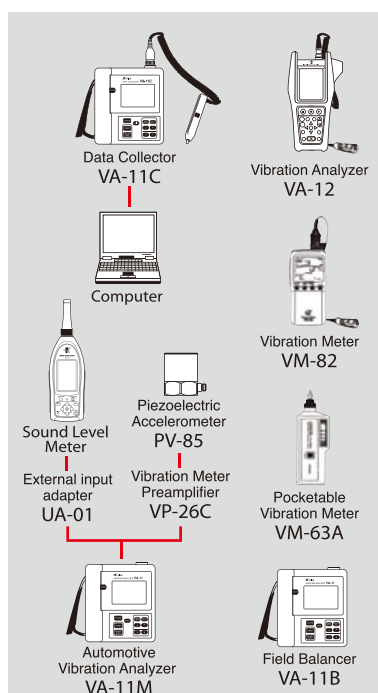
## Industrial Machinery Equipment Diagnosis

All machines use either rotation, reciprocal movement, impact, or some other form of motion to achieve their purpose. If a problem occurs somewhere, unwanted vibration will increase. Normally, simple diagnosis is carried out on a regular schedule to establish the normal/abnormal status of equipment. When a problem is detected, precision diagnosis is performed to obtain in-depth knowledge about the condition.

Products suitable for simple diagnosis include the General-Purpose Vibration Meter VM-82 and the Pocketable Vibration Meter VM-63A. These allow checking multiple pieces of machinery within a short time, using simple procedures.

For precision diagnosis, the Vibration Analyzer VA-12 and Data Collector VA-11C with built-in FFT analysis function are well suited.

Other equipment includes the Field Balancer VA-11B which has an integrated FFT analyzer and can perform balancing functions in the field, and the Automotive Vibration Analyzer VA-11M.



# 17

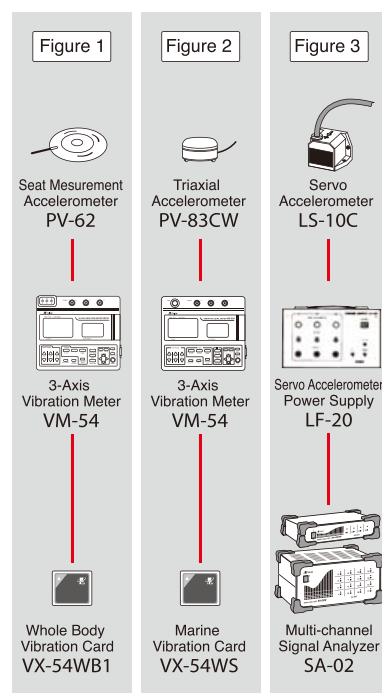
## Whole-Body Vibration Measurement

Vibrations are transmitted to the human body via the feet when standing, via the posterior when seated, and via the back when leaning on a backrest.

The influence of such vibrations on humans can be evaluated under many aspects including vibration perception, comfort, health hazards, and motion sickness. ISO 2631 specifies many different frequency compensation circuits for judging vibration depending on direction as well as rotational vibration. ISO 2631 compliant measurements can be made by using the 3-Axis Vibration Meter VM-54 combined with the Whole Body Vibration Card VX-54WB/VX-54WB1 or Marine Vibration Card VX-54WS.

For measurement of seat vibrations and evaluation of ride quality, the Seat Measurement Accelerometer PV-62 is mounted to the measurement target and connected to the 3-Channel Preamplifier VP-80, as shown in (Figure 1).

For evaluation of buildings and ride quality in ships, vibration measurement can also be carried out with the Accelerometer PV-83CW (supplied with VX-54WS), as shown in (Figure 2). When making motion sickness related measurements, the frequency range from 0.1 to 0.5 Hz is relevant. A suitable measurement setup consists of the Servo Accelerometer LS-10C for detecting vibrations, connected to Multi-Channel Analyzer SA-02 via the Servo Accelerometer Power Supply LF-20 (Figure 3).



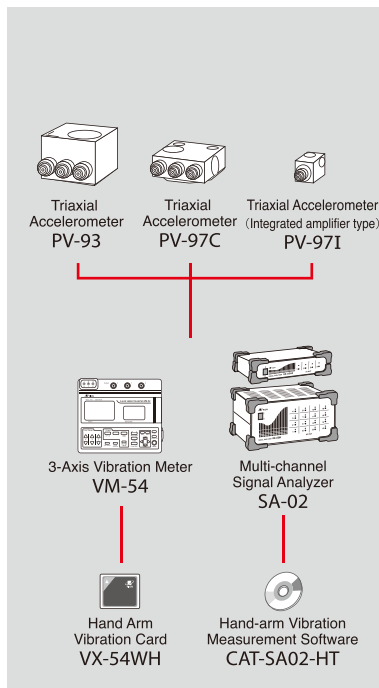
## Measuring Instrument Combinations

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#### Hand-arm Vibration Measurement

In the work environment, hand-arm vibration leading to an ailment called Raynaud's disease can pose a serious problem. This kind of vibration-related ailment, where blood circulation in the hand and fingers decreases causing them to appear white, is often due to the use of chain saws, rock drilling machines and other hand-held or hand-guided power tools that produce vibrations. ISO 5349 compliant quantitative evaluation of such vibrations is possible by using the 3-Axis Vibration Meter VM-54 together with the Hand-Arm Vibration Card VX-54WH.

To devise measures for preventing such vibrations, the vibration exposure can be determined by a Triaxial vibration component measurement performed on the handle of the tool in question. For this purpose, the Triaxial Accelerometer PV-93/97C/97I or multiple single-axis accelerometers PV-90B/90I are combined with the 3-Channel Preamplifier VP-80 and connected to the VM-54 in which the Hand-Arm Vibration Card VX-54WH has been installed. It is also possible to measure the hand-arm vibration using the Multi-Channel Signal Analyzer SA-02 series with the software CAT-SA02-HT.



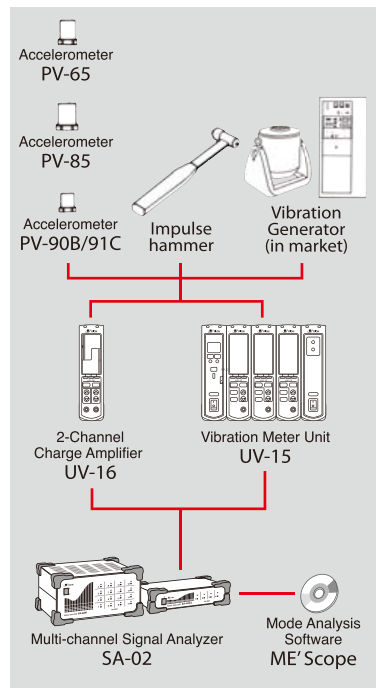
### 19

#### Mode Analysis

Analyzing the state and type of vibrations occurring in objects is an important approach that helps to detect early signs of problems, prevent breakdowns, and reduce the emission of noise. Test mode analysis is a method that uses vibration modes for creating models of vibration patterns. It is especially useful in exploring causes and countermeasures for resonance phenomena and other vibration and noise related problems.

An impulse hammer is used to create a controlled impact, and the resulting vibrations are measured in 3 directions on the entire surface, using suitable accelerometers such as the PV-90B/91C. A Multi-Channel Analyzer of the SA-02 series and the Mode Analysis Software ME Scope are then employed to perform the mode analysis. A large number of transfer function peaks can provide information about normal mode vibration frequency, mode shape, attenuation coefficient and other mode parameters.

Separate structure change simulation software makes it possible to study anticipated vibration mode changes that will result from physical changes to the machinery or the supporting structure. External force response analysis is also possible.



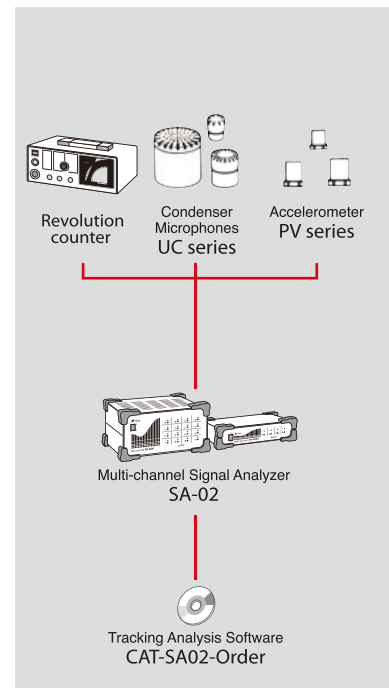
### 20

#### Tracking Analysis System

Nearly all kinds of rotating machinery such as car engines and electric motors produce vibrations that depend on their revolution speed and gear ratio. Such vibrations then become the source of noise which contains predominantly frequency components resulting from the vibrations.

Because the revolution speed of rotating machinery changes over time, it is effective to perform frequency analysis in sync with the changing revolution speed. This process is called tracking analysis. There are several types of tracking analysis, as described below.

- **Harmonics ratio analysis**  
Using the basic rotation speed as the fundamental, the higher-order harmonics components (2nd order, 3rd order...) are analyzed according to the rotation speed change.
- **RPM tracking analysis**  
This is a special form of harmonics ratio analysis, where the level change at one frequency or harmonic is plotted on a graph pegged to the rotation speed change.
- **Mode circle**  
Another form of harmonics ratio analysis, where the amplitude and phase change at one frequency or harmonic according to the rotation speed change is plotted on a coordinate system.
- **Spectrum map**  
The change in spectral pattern when the rotation speed is changed is plotted continuously and the level change is analyzed in a macro reference frame.
- **Campbell diagram**  
The rpm dependent spectral change is plotted on a graph where the amplitude value is represented by the diameter of a circle.



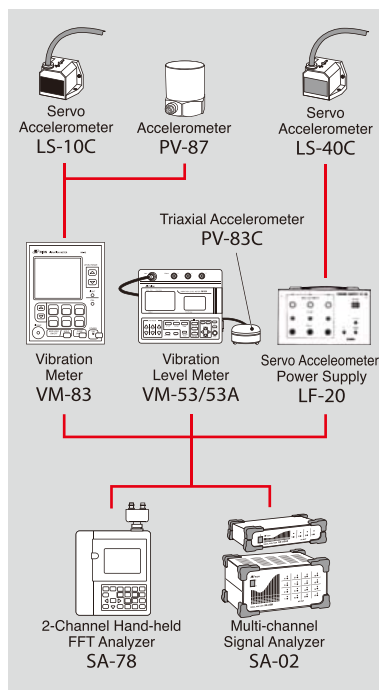


# 21

## Measurement of Low-Frequency Microvibrations

Low-level, low-frequency vibrations must be measured in various instances, such as when measuring minute floor vibrations to assess the occupation comfort of a building, checking for microvibrations in a clean room for semiconductor manufacturing or testing the efficiency of vibration damping systems for precision machinery. The Servo Accelerometer LS-10C/40C, Vibration Level Meter VM-53/53A or the high-output accelerometer PV-87 in combination with the Vibration Meter VM-83 are suitable for such purposes. It is also possible to perform frequency analysis and evaluation with the Multi-Channel Signal Analyzer SA-02 series, 2-Channel Compact FFT Analyzer SA-78.

The evaluation of floor vibrations uses the floor response waveform for determining vibration frequency, displacement, velocity, acceleration and attenuation constants. These are then compared to reference curves for actual evaluation. For testing the efficiency of vibration damping systems, sensors are mounted on the floor and to the mounting bed of the object under test.



# 22

## Vibration measurement with sound level meter

By connecting a vibration sensor to the sound level meter, measurement of vibrations becomes possible.

