GRAS Sound & Vibration
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SysCheck2™

Remote calibration verification in distributed measurements—

Maximize measurement time, minimize setup and maintenance time

GRAS Sound & Vibration
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APPLICATION NOTE

Introduction

Distributed measurement setups come in many different shapes and sizes, and they cover the gamut of acoustic measurement testing applications: from aerospace and automotive, to environmental and relay station monitoring, to high-end audiophile array testing on speakers. The setups themselves can range from microphones that are easily accessible but tens to hundreds of meters (or even kilometers) apart, to measurement stations that are easily accessible but dangerous to access, to measurement locations that are both difficult and dangerous, to setups where the microphones are just plain hard to reach. In all of these cases, one thing is common and binds them all together, the microphones must be calibrated and have those calibrations periodically checked to ensure that the data they provide is good data. And in some cases, the calibration data must be confirmed in tight time frames before measurements are made.

This application note addresses a new way to verify calibration, comply with measurement standards and ensure that you can rely on the data acquired. SysCheck2™ functionality is a new method for accurate remote calibration verification and provides the capability and flexibility to improve the process for all of the scenarios mentioned above.

The following areas will be addressed in this note*:

- What SysCheck2 is—and isn't
- How SysCheck2 works
- How SysCheck2 functionality reduces setup time
- SysCheck2 industry- and situation-specific examples

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* *Editor's note:* What SysCheck2 is—and isn't *and* How SysCheck2 works *are also covered in* The evolution of microphone remote calibration verification—Maximize production line productivity *Application Note. While the concept and functionality are the same, the application is different. Please visit GRASacoustics.com if you would like to also read about production line testing.*

SysCheck2 overview

SysCheck2, introduced in December 2021, is a GRAS-patented technology for verifying measurement chain integrity. This verification tool enables a remote health check on microphones, channel gain and cable integrity. The verifications can be made simultaneously on each SysCheck2-enabled microphone connected to a CCP power module with transducer electronic data sheet (TEDS) support and measurement software. SysCheck2-enabled microphones also provide on demand environmental data (temperature, barometric pressure and humidity).

What it is not and what it is

Tool concepts similar to SysCheck2, such as the older GRAS SysCheck and HBK® charge injection calibration (CIC), are often mistakenly referred to as remote calibration, but that is not entirely accurate. They can confirm, with some accuracy, that the conditions around the microphone in question have not changed enough to require recalibration. SysCheck2, however, is an entirely new generation of remote calibration verification.

Like the older verification technology, SysCheck2 is not a true calibration tool, but the advances in conception and technology result in a remote calibration verification tool that provides a very accurate evaluation of any changes for the entire measurement chain, individually, for each microphone in the setup. This enables SysCheck2 to provide a highly accurate status of the measurement chain and indicate whether conditions in the setup and environment have changed sufficiently to require additional calibrations. Initial calibrations are still required, but afterwards, SysCheck2 can be relied upon to alert users of a change that would necessitate recalibration. This drastically reduces the time difficulty and potential problems (including those resulting from dangerous environments) involved in periodic calibrations. For example, checking calibration by train tracks during peak hours when the trains may be only a minute or so apart.

SysCheck2-enabled microphones are functionally identical to their non-SysCheck2-enabled counterparts (e.g., the SysCheck2-enabled microphone, GRAS 246AE, and the non-SysCheck2-enabled version, GRAS 46AE) until your data acquisition software is set up to enable the verification functionality. This means that the SysCheck2 microphones provide the same level of data quality in their accuracy, precision and reliability as their GRAS non-SysCheck2 counterparts.

How SysCheck2 works

SysCheck2 is a next step in remote calibration verification tools as the signal generation and registration are no longer dependent on potentially costly hardware, thereby removing a point of failure in the system by keeping the functional elements of verification in the microphone itself.

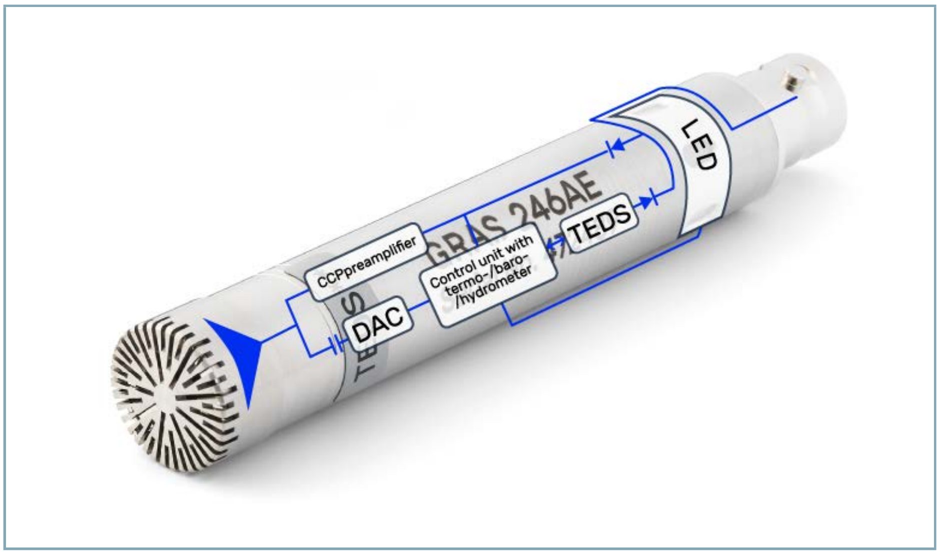

FIGURE 1.
Schematic of SysCheck2 internal components.

Rather than an external signal generator and specialized cabling, SysCheck2 works with CCP-based analyzers that can read and write to TEDS. This will work with a variety of setups. Audio Precision® and Siemens® both offer plug-and-play solutions that will work out of the box. AP's APx 500™ Measurement Software with GRAS 12BA, 12BB or 12BE power modules and an Audio Precision APx series analyzer or with an Audio Precision APx series analyzer with CCP and TEDS read/write capability. Siemens setups require Siemens Simcenter™ Testlab™ Signature Acquisition with a 12Bx or similar power module and analyzer combination with CCP and TEDS read/write capability. However, all features are accessible with a suitable CCP-based power module, analyzer and data acquisition system after setup with the GRAS-supplied software development kit (SDK) or our SDK and an application programming interface (API), depending on your system. Additionally, MATLAB® code is available to directly integrate with custom implementations of data acquisition code via CCP-based GRAS 12Bx power modules and a computer with a suitable sound card. A National Instruments® (NI) demo implementation of the SDK is also available (by request).

Because the functional hardware is built into the microphone itself (Fig 1), no further specialized hardware is needed. Additionally, SysCheck2 has very well-defined coupling of the test signal to the microphone due to a precision coupling capacitor with a guarded signal path from the generator in close proximity. This results in reliable test results over a wide frequency range due to no stray coupling of test signal to preamplifier, polarization voltage or in transmission cable.

Testing the capacitance at medium frequencies (e.g., 250 Hz) can verify the general sensitivity of the microphone. Microphone sensitivity depends on temperature and static pressure; therefore, temperature and static pressure must be accounted for. Each SysCheck2 microphone is equipped with its own internal environmental sensors and ultra-low-power microcontroller and signal generator located in the microphone preamplifier. This signal generator is able to produce a reference signal that can be compared to a reference level measurement in order to determine the measurement chain status. Changes in microphone capsule capacitance, cable integrity, channel gain or the unexpected use of a filter will result in a measurement deviation and will be reflected in a change in the output from the measurement channel (further discussed in the SysCheck2 polarization voltage dependency section, below) and the status of the microphones will be updated in the software status interface, i.e., Go or No-go. Once detected, the problem can be examined and then rectified.

Potential causes for a change in microphone capacitance are:

- Change in temperature
- Change in polarization voltage
- Change in membrane tension
- Damage to the microphone housing or the membrane

NOTE: SysCheck2 can reveal sensitivity change due to temperature, but not influenced by a change in pressure or humidity.

Parameter	Value	
	Accuracy	Range*
Temperature	±2°C/ ±3.6°F	0–65°C/32–149°F
Pressure, static	±1.5 hPa	0–65°C/32–149°F; 300–1100 hPa
Humidity, relative	±4% RH	0–60°C/32–140°F; 0–100%

TABLE 1.
Environment sensor functional parameters.

While temperature is one of the causes of capacitance in the overall measurement chain, it has very little influence on the SysCheck2 generator level. SysCheck2 measurements therefore accurately reflect changes in capacitance, including those caused by changes in temperature.

How SysCheck2 uses polarization voltage to determine status

To determine whether the accuracy for the SysCheck2 check, the 'drift' in polarization voltage and change in sensitivity is compared with the actual SysCheck2 measured level. When performing in-the-field calibrations for a microphone, a sensitivity difference of ±0.3 dB from the original calibration level is typically acceptable. The 0.3 dB change in microphone sensitivity corresponds to approximately 0.08 dB in the SysCheck2 level. This correspondence is shown in Figure 2.

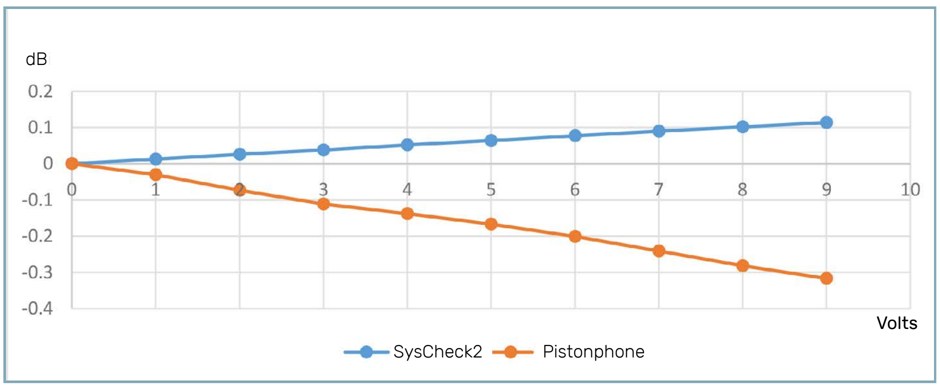

FIGURE 2.
Effect of the loss in polarization voltage on microphone output.

The status displayed by the microphones is determined by the selected Acceptance Level and Difference to SysCheck2 Level (DSL) (Table 2).

* *The environmental sensor has an operational range of -40 to 85°C /-40 to 185°F, but the listed accuracy is only valid in the corresponding range given in Table 1.*

Acceptance Level (dB)	DSL	
	Go	No-go
0.3	DSL <= 0.08	DSL > 0.08
0.5	DSL <= 0.13	DSL > 0.13
0.8	DSL <= 0.21	DSL > 0.21

TABLE 2. *Acceptance level parameters.*

NOTE: If the microphone is calibrated to -25.5dBV/Pa @ 23°C, the sensitivity correction of 246AE microphone @ 35°C is -0.01*(35-23) dB = -0.12 dB, the sensitivity @ 35°C will be -25.5+(-0.12) dB V/Pa = -25.62 dB V/Pa.

SysCheck2 functional details of determining the acceptance level

In the simple case where environmental conditions have not changed, a check with SysCheck2 @250 Hz before and after measurement will ensure that the sensitivity of a ½″ microphone has not changed more than approximately four times the SysCheck2-measured change in decibels. In other words, if the measured SysCheck2 result has changed 0.05 dB, the microphone sensitivity is expected to be within 4*0.05 dB, ±0.2 dB. Since the change can originate from different things, such as change in membrane tension, change in microphone component integrity or change of charge, the sign of the change cannot be determined.

If temperature, ambient pressure, and humidity has changed, the sensitivity of the microphone capsule might also have changed. Initially when the reference SysCheck2 measurement was made the temperature, ambient pressure and humidity could be read from the microphone and stored together with the measurement. With these parameters, the measurements can be corrected with the microphone's environment coefficients as specified in the data sheet.

NOTE: No environmental correction is made automatically. For example, the validation with SysCheck2 corrected for temperature verifies that the microphone is working correctly, but since the sensitivity might have changed, the microphone sensitivity will need to be corrected for temperature. The environmental coefficients of the microphone sets can be found on their data sheets.

To avoid ambient noise disturbing the SysCheck2 verification, the ambient noise level measured in the band containing 250Hz must be below 65 dBSPL for a 246AE and 85 dBSPL for a 246AO.

NOTES:

- Using a 1/3 octave narrow band measurement the noise level of 60 dB during test, will typically influence less than 0.2 dB.
- If the microphone is calibrated to -25.5 dB V/Pa @ 23 °C, the sensitivity correction of 246AE microphone @ 35 °C is -0.01*(35 – 23) dB = -0.12 dB, the sensitivity @ 35 °C will be -25.5+(- 0.12) dB V/Pa = -25.62 dB V/Pa.

What SysCheck2 can detect

In the evaluation of measurement chain health, SysCheck2 can detect microphone sensitivity or channel gain changes greater than 0.3 dB. Additionally, the microphone acquires data on local environmental conditions, including temperature, pressure and humidity.

SysCheck2 status indicators

Status 1—Represents a state where the microphone and measurement chain indicate zero faults. The system is unchanged from the initial check and measurements can be performed.

Status 2—Indicates that a deviation in the measurement chain has been detected. The measurement chain needs to be checked and an acoustic calibration is required.

In addition to any status indications set up in the analysis software, the microphones also have built-in RGB LED lights that can be set to display visual cues to the health of the measurement chain and can be used for the easy identification of specific microphones.

The deviation could:

- Derive from a detected instability in the measurement chain.
- Result from a background noise event that is too high.
- Indicate that the check result falls outside of the acceptable uncertainty window.

Depending on the expected level of accuracy required for the measurement to be performed, an acoustic calibration is suggested.

The proof of concept and scenario testing

The Acceptance Level selected in the acquisition software has a noticeable effect in the level of deviation required to return a No-go. The threshold can be set to 0.3, 0.5 or 0.8 dB.

To test the effects of different types of damage, 40 microphones were subjected to a variety of abuse and tested as if they were placed on a production line.

All units had an initial calibration and SysCheck2 level measured and then saved. Thereafter, all microphones were stressed and abused, far beyond what is normally reasonable for a laboratory microphone. The abuse included or simulated:

- Being dropped on the floor (mechanical impulse stress)
- Subjecting the microphone to overheating conditions (very high heat outside the specifications (180°C for 60 min) , which is very unsuitable for the electrical components
- Touching diaphragm with fingers
- Puncturing the diaphragm with pinhole dot
- Slicing the diaphragm with razor blade (flange).

Measurements were also made to observe how SysCheck2 behaved with dirt and water on the membrane, which is something that realistically occurs on production lines.

Figure 3 is a graph of the results. It is clear that there is linear correlation of SysCheck2 level change and the microphone's sensitivity change. The correlation is, however, affected by the type of error. Importantly, the loss of polarization voltage (most commonly, a source of error that can occur in harsh environments for prepolarized microphones), correlates well with the Ideal Acceptance level-DSL intersection line (Fig. 3), and is therefore extremely useful in a SysCheck2 verification.

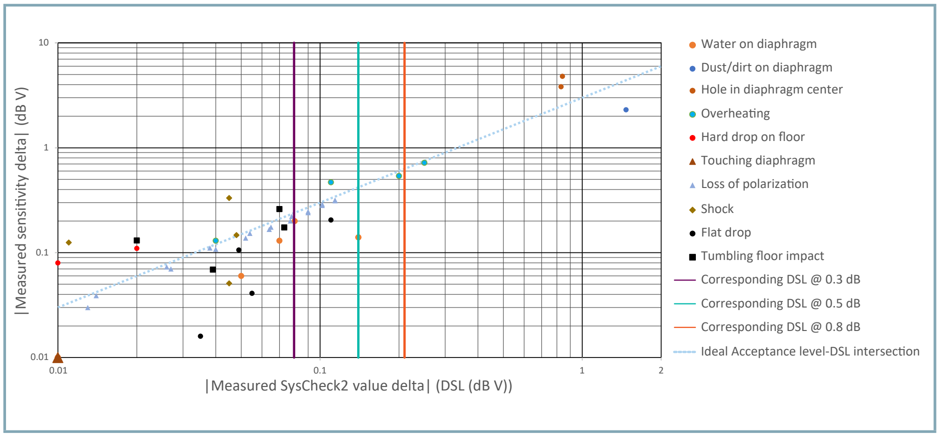

FIGURE 3.
Graph showing the relation between deviation in sensitivity for the set acceptance level and the SysCheck2 DSL in determining the status of the microphone. Results to the left of the relevant DSL are considered a Go for the corresponding Acceptance level.

Challenges in an aerospace measurement scenario

The general procedure outlined in the following scenario is:

1. Setup measurement and connect microphones as usual.
2. Establish measurement reference signal.
3. Prior to measurement (within the allotted time stipulated by the standard), run SysCheck2 check to compare initial reference signal to the current signal and get the environmental data for potential corrections.
4. A status will be displayed in your data acquisition software according to your setup.
5. Measure.

Calibration challenges in the aerospace industry share many of the characteristics with other industries, but also have some unique acoustic measurements challenges. Often the DUT is a larger structure, requiring a substantial separation of sensors, even over a geographical area to assess environmental impacts or consisting of large microphone arrays with many channels to identify noise sources of the DUT.

Many of the tests are performed outdoors, where temperature and other environmental parameters can change over the course of the day or based on changes in weather conditions. Because of this, it is critical in many cases that the calibration is known to be valid and environmental conditions known within a short time frame before the measurement. The measurement system must be ready to perform when the aircraft is performing a fly-over or a jet engine is running because testing is a time- and resource-intensive endeavor. Missing a measurement window is not an option.

In the aerospace industry there can be no compromises with quality, and the integrity and accuracy of all measurements are of highest importance. It is therefore important that the test setup consisting of front end, (long) cables and sensors are validated and data integrity is confirmed.

Traditionally, microphone validations used a calibrator, physically applying a 1000 Hz tone to each individual microphone. This is time consuming and as the performance of the system might differ slightly based on the environmental conditions, you will have a limited insight of the overall performance at the time of test. Therefore, in many cases the background noise is measured and if the data seems plausible, the test is initiated. Installation and validation of the system, including long cables and remote sensors, are usually much more time consuming than the test itself.

SysCheck2-enabled microphones change the scenario, saving time and ensuring accurate data.

Using SysCheck2 microphones to acquire data from a flyover, the test team sets up for the measurement as normal, positioning each microphone according to requirements and performing the initial calibration. Once done, the operator can set the reference check for all microphones present in the field, simultaneously with a single click. Each microphone's measured value is stored in the microphone's TEDS as a reference value. With 30 minutes to go before the flyover, the operator verifies the measurement chain with one more click and again saves the calibration and environmental data. The temperature had dropped since the initial calibration, but the environmental data can be used for corrections during post-processing.

The advantages of using a SysCheck2-enabled microphone compared to a traditional microphone for distributed measurement in demanding applications such as in the aerospace industry are many:

- Shorter installation and validation time
- Stored calibration verification data prior to each test
- Stored environmental data prior to each test
- Fast identification of any malfunctions at any channel
- Environmental compensation possibilities during post processing
- More reliable measurement data

Challenges in a dangerous measurement scenario

The general procedure outlined in the following scenario is:

1. Setup measurement and connect microphones as usual.
2. Establish measurement reference signal.
3. Monitor
4. Periodically run SysCheck2 checks to compare the initial reference signal to the current signal and get the environmental data for potential corrections.
5. A status will be displayed in your data acquisition software according to your setup.
6. Continue monitoring.

In real-world situations, microphones can be placed along rails used by high-speed and commuter trains, on the façades of buildings to measure city noise, spaced out along long suspended spans to monitor bridges or placed close to rapidly revolving machines. Because we place the health of the operator above measurement accuracy, or because climbing on a bridge pillar is unpractical, it is problematic to verify these microphone positions as often as needed, even if they are exposed to harsh environmental conditions.

Traditionally, in order to verify the calibration and environmental data for these microphones, special safety requirements, including added protective apparatus and potential delays to train or commuter, or machinery operation schedules must be incurred to assure the safety of the operator. The time and travel to locations must be accounted for and all incorporated into the required calibration schedule.

SysCheck2-enabled microphones avoid the pitfalls associated with verifying measurement microphones in potentially dangerous and difficult locations.

Using SysCheck2-enabled microphones to verify the microphones placed on the suspension cables of a suspension bridge, the setup team makes the initial placement and calibration for the measurement microphones. Back at the monitoring hub, the operator can make a full simultaneous remote verification of the entire measurement chain that uses SysCheck2 microphones. At regularly scheduled intervals, the operator can verify the measurement chain against the initial reference check without leaving their desk; thus, preventing the unnecessary exposure of any operators to risk while still being able to check the health of microphones, channel gain and cable integrity.

As an added benefit, SysCheck2-enabled microphones provide on-demand environmental data (temperature, barometric pressure, and relative humidity). Having access to this data at the exact location of the microphone allows microphone sensitivity correction, if needed.

The advantages of using a SysCheck2-enabled microphone for measurement where a calibration is unpractical or dangerous are many:

- Remote verification of the measurement chain health before and after each test
- Simultaneous verification of all channels
- Ability to read and store environmental data captured at the exact location of the microphone
- Enabling accurate environmental compensation during post processing
- Easy visual assessment of microphone location via RGB LEDs on the microphone preamplifier body

Conclusion

Calibration is a vital passage in the acoustic measurement procedure. It is time consuming, can only be performed by trained technician, and calibration cannot be avoided. Furthermore, calibration in dangerous environments adds additional required skill sets and needs for the calibration technician.

Previous remote verification tools have not been accurate enough to effectively detect when a measurement system needed to be re-calibrated. The only alternatives were to incur greater cost for more manpower in time-sensitive measurement scenarios or take more time in non-time-sensitive situations, or calibrate “often enough” and find the best balance between potentially dangerous or time intensive calibrations. The accuracy of SysCheck2 verification can quickly flag a measurement chain that deviates and can be performed by an untrained operator as part of a measurement procedure. This allows to minimize required personnel, time spent calibrating and, importantly, decrease the risk incurred by operators.