



SURFACE VEHICLE RECOMMENDED PRACTICE

J184

AUG2014

Issued 1970-09
Stabilized 2014-08

Superseding J184 NOV1998

Qualifying A Sound Data Acquisition System

RATIONALE

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1. **Scope**—Various SAE vehicle sound level measurement procedures require use of a sound level meter which meets the Type 1 or Type 2 requirements of ANSI S1.4-1983 (see 2.1.1.1), or an alternative system which can be proved to provide equivalent test data. The purpose of this SAE Recommended Practice is to provide a procedure for determining if a sound data acquisition system (SDAS) has electro-acoustical performance equivalent to such a meter. By assuring equivalent performance of the test instrumentation, the equivalence of test data is assured.

Two general configurations of sound data acquisition systems will be encompassed (see Figure 1). The first configuration consists of instrument sections which perform as a sound level meter. The second configuration is a system which records data for later processing. The intent of this document is to establish guidelines which permit the test engineer to insure equivalence of sound data acquisition systems to a sound level meter. It requires that the test engineer have a working knowledge of the characteristics of the sound data being measured.

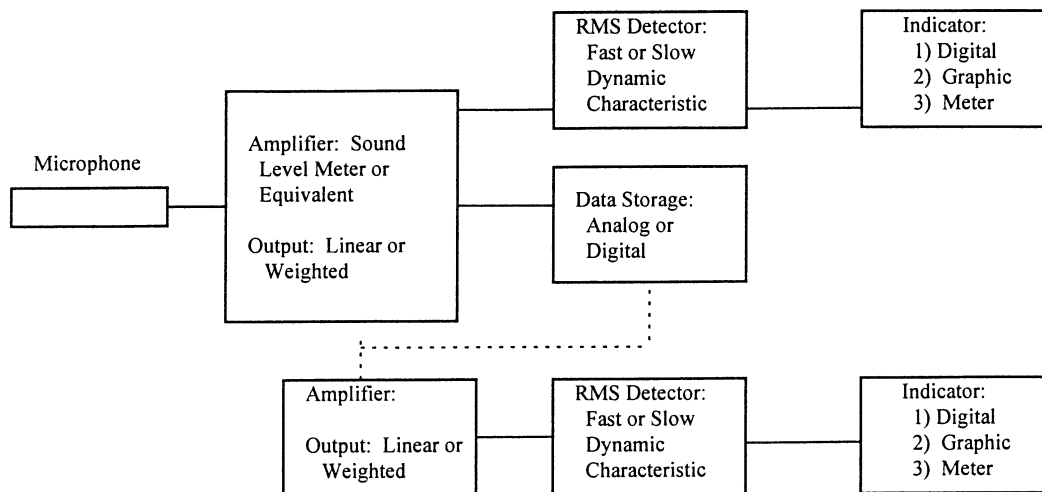


FIGURE 1—SOUND DATA ACQUISITION SYSTEM

The scope of the document includes the system performance requirements for the entire sound measurement system. It provides the methods needed to verify Type 1 or Type 2 instruments. However, it also provides a method to qualify an SDAS that does not meet the requirements in their entirety, but can be used provided knowledge of the test data is obtained and an iterative process is followed in qualifying the SDAS. The system need only be qualified for the dynamic characteristics and weighting mode in which it is to be used. The scope of this document does not include qualification of system components for harmonic distortion, tape recorder wow and flutter, etc. However, these factors must be considered when determining system performance, especially where spectral information is sought. The references in Section 2 should be consulted for general performance requirements and precautions regarding instrumentation for acoustical measurements.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein.

2.1.1 ANSI PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

2.1.1.1 ANSI S1.4-1983 and S1.4A-1985—Specification for Sound Level Meters

2.1.1.2 ANSI S1.11-1986—Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets

2.1.2 IEC PUBLICATION—Available from International Electrotechnical Commission, 3 rue de Verambe, P.O. Box 131, 1211 Geneva 20, Switzerland.

2.1.2.1 IEC publication 651-1993—Sound Level Meters

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE HS 184—Surface Vehicle Sound Measurement Procedures

2.2.2 ANSI PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI S1.1-1986—Acoustical Terminology

2.3 Other Publications

2.3.1 K. Zaveri, "Averaging Time of Level Recorder 2306" and "Fast and Slow Response of Level Recorders 2305/06/07," Bruel & Kjaer, Copenhagen, Denmark, 1975, Technical Review, Issue 2.

2.3.2 P. Hedegaard, "General Accuracy of Sound Level Meter Measurements," Bruel & Kjaer, Copenhagen, Denmark, 1977, Technical Review, Issue 4.

2.3.3 C. G. Wahrmann and J. T. Brock, "On the Averaging Time of RMS Measurements," Bruel & Kjaer, Copenhagen, Denmark, 1975, Technical Review, Issues 2 and 3.

2.3.4 Arnold P.G. Peterson and Ervin E. Gross, Jr., "Handbook of Noise Measurements," 7th Edition, General Radio Company, West Concord, MA, 1972.

2.3.5 R. B. Randall, "Frequency Analysis," Bruel & Kjaer, Copenhagen, Denmark, 1987.

3. Definitions

- 3.1 Data Signal Range**—Twenty times the logarithm (to base 10) of the ratio of highest RMS signal amplitude to lowest RMS signal amplitude for a specific test condition; unit is decibel (dB).
- 3.2 Dynamic Range**—Twenty times the logarithm (to base 10) of the ratio of the instrumentation system maximum signal amplitude to system noise floor amplitude; unit is decibel (dB).
- 3.3 Frequency Response**—Twenty times the logarithm (to base 10) of the ratio of output signal amplitude to input signal amplitude over a specified frequency range as a function of signal frequency; unit is decibel (dB). For a complete sound data acquisition system, it is the indicated sound level minus the sound pressure level at the microphone.
- 3.4 Full Scale**—The maximum undistorted signal level for each instrument.
- 3.4.1 Full scale for an amplifier is the maximum output signal level. Input full scale can change with amplifier gain.
- 3.4.2 Full scale for a tape recorder is the maximum signal amplitude defined in 3.6.
- 3.4.3 Full scale for an indicating instrument is defined as the input voltage for maximum indication.
- 3.4.4 Full scale for any system component is the maximum output signal level which allows for undistorted signals defined in this recommended practice.
- 3.5 Indicator**—A device used to provide a visual display of signal amplitude.
- 3.5.1 DIGITAL—A numeric or alpha-numeric display of the measured signal amplitude.
- 3.5.2 GRAPHIC—A trace recording of the measured signal amplitude on a scaled chart.
- 3.5.3 METER—Electrically driven needle or other device (possibly digital) which deflects over a calibrated scale as a function of the measured signal amplitude.
- 3.6 Maximum Signal Amplitude**—The signal amplitude below which the harmonic distortion is less than 3% over the operating frequency range.
- 3.7 Restricted System**—Any data acquisition or analysis instrumentation that meets the requirements as specified herein, but only over a limited frequency range.
- 3.8 Signal Crest Factor**—Twenty times the logarithm (to base 10) of the ratio of the peak signal amplitude to the RMS signal amplitude; unit is decibel (dB).
- 3.9 Signal-to-Noise Ratio**—Twenty times the logarithm (to base 10) of the ratio of the data signal amplitude to system noise floor amplitude; unit is decibel (dB).
- 3.10 System Noise Floor**—The broad band electrical noise inherent in instrument circuits with proper input/output terminations.
- 3.11 Test Apparatus**—Equipment used for qualifying, but not part of the Sound Data Acquisition System.
- 3.12 Digital Signal Processing Terminology**—Additional terminology referring to digital systems can be found in Appendix E of ANSI S1.11-1986.

4. System Performance Requirements

4.1 Frequency Response (Amplitude)—The continuous frequency response (linear or A-weighted) of a Type 1 or Type 2 Sound Data Acquisition System shall meet the tolerances in Table 1.

TABLE 1—SYSTEM TOLERANCE LIMITS AND FREQUENCY RESPONSE WEIGHTING FOR A-WEIGHTING

Nominal Frequency Hz	A-Weighting Response (dB)	Tolerance Limits on Response in dB	Tolerance Limits on Response in dB
		Type 1	Type 2
10	−70.4	±4	+5.0, −∞
12.5	−63.4	±3.5	+5.0, −∞
16	−56.7	±3.0	+5.0, −∞
20	−50.5	±2.5	±3.0
25	−44.7	±2.0	±3.0
31.5	−39.4	±1.5	±3.0
40	−34.6	±1.5	±2.0
50	−30.2	±1.0	±2.0
63	−26.2	±1.0	±2.0
80	−22.5	±1.0	±2.0
100	−19.1	±1.0	±1.5
125	−16.1	±1.0	±1.5
160	−13.4	±1.0	±1.5
200	−10.9	±1.0	±1.5
250	−8.6	±1.0	±1.5
315	−6.6	±1.0	±1.5
400	−4.8	±1.0	±1.5
500	−3.2	±1.0	±1.5
630	−1.9	±1.0	±1.5
800	−0.8	±1.0	±1.5
1000	+0	±1.0	±1.5
1250	+0.6	±1.0	±1.5
1600	+1	±1.0	±2
2000	+1.2	±1.0	±2
2500	+1.3	±1.0	±2.5
3150	+1.2	±1.0	±2.5
4000	+1	±1.0	±3
5000	+0.5	±1.5	±3.5
6300	−0.1	+1.5, −2.0	±4.5
8000	−1.1	+1.5, −3.0	±5.0
10 000	−2.5	+2.0, −4.0	+5.0, −∞
12 500	−4.3	+3.0, −6.0	+5.0, −∞
16 000	−6.6	+3.0, −∞	+5.0, −∞
20 000	−9.3	+3.0, −∞	+5.0, −∞

- 4.1.1 A Restricted System (linear or weighted) shall meet the tolerances in the continuous frequency range from 1/6 octave above to 1/6 octave below the range specified. For measured data, the total sound level of all bands outside the Restricted range shall be at least 15 dB lower than the overall measured level.
- 4.1.2 When other weighting networks are used, the frequency response and tolerance of the respective network as specified in ANSI S1.4-1983 shall apply.

- 4.1.3 Data recorded using a Restricted System shall be designated by type, weighting, dynamic characteristic, and frequency response. For example: Type 1, A, Fast, 100 Hz - 4 kHz.

4.2 Linearity

- 4.2.1 SYSTEM LINEARITY—For a single range attenuator setting, the linearity error for measurements over the data signal range shall not exceed the tolerances indicated in Table 2, unless limited by a Restricted system.

TABLE 2—SYSTEM LINEARITY REQUIREMENTS

Type 1	within ± 0.7 dB	31.5 to 8000 Hz
	within ± 1.0 dB	20 to 12 500 Hz
Type 2	within ± 1.0 dB	31.5 to 8000 Hz
	within ± 1.5 dB	20 to 12 500 Hz

- 4.2.2 RANGE ATTENUATOR LINEARITY—All settings of the sensitivity range control, either manual or automatic, shall introduce errors less than those specified in Table 2 for a sine wave with respect to a reference signal. If more than one sensitivity range is provided, it is recommended that the ranges be at 10 dB increments.

4.3 Dynamic Characteristic

- 4.3.1 FAST—The system dynamic response is tested with a 1000 Hz signal instantaneously increased by a minimum of 20 dB to the reference signal level for a duration of 200 ms. The maximum indication shall be within -2.0 to 0 dB with respect to the reference signal for a Type 1 system and within -3.0 to 0 dB for a Type 2 system. Overshoot for a continuous 20 dB increasing step change in level shall be between 0 and $+1.1$ dB for both Type 1 and Type 2.
- 4.3.2 SLOW—The system dynamic response is tested with a 1000 Hz signal, instantaneously increased by a minimum of 20 dB to the reference signal level for a duration of 500 ms. The maximum indication will be within -3.1 to -5.1 dB with respect to the reference signal for Type 1 and within -2.1 to -6.1 for Type 2. Overshoot for a continuous 20 dB increasing step change in level shall be 0 to $+1.6$ dB for both Type 1 and Type 2.
- 4.3.3 IMPULSE—The system dynamic response is tested with a 1000 Hz signal, instantaneously increased by a minimum of 20 dB to the reference signal level for a duration of 20 ms. The maximum indication will be within -5.1 to -2.1 dB with respect to the reference signal for Type 1 and within -5.6 to -1.6 dB for Type 2.
- 4.3.4 REFERENCE SIGNAL—The previous requirements apply for a reference signal 4.0 dB below full scale, on a logarithmically scaled indicator. For scales which are linear in dB, such as a graphic level recorder, 63% of maximum indicator deflection corresponds to 4.0 dB below full scale on a logarithmically scaled indicator.

CAUTION—Significant sound level reading variations are possible between systems measuring the same sound even though the system performs within the limits specified in 4.3.1, 4.3.2, and 4.3.3. The dynamic response performance is a function of the indicator ballistics and the detector averaging time which may differ between instruments. Since 4.3.1, 4.3.2, and 4.3.3 do not specify ideal design center circuit performance, a dynamic response model based on a single pole filter is suggested in Section A.1. Ideally, the dynamic response of the indicator should be an order of magnitude faster than the RMS detector dynamic response.

Fast and Slow decay times and additional performance tests for impulse are covered in Sections A.2 and A.3.