Qualifying a Sound Data Acquisition System — SAE J184a

SAE Recommended Practice
Completely revised June 1978

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ϕQUALIFYING A SOUND DATA ACQUISITION SYSTEM—SAE J184a

SAE Recommended Practice

Report of Vehicle Sound Level Committee approved September 1970 and completely revised June 1978. Rationale statement available.

1. Purpose—Various SAE vehicle sound level measurement procedures require use of a sound level meter which meets the Type 1 or Type 2 requirements of American National Standard Specification for Sound Level Meters, S1.4-1971 (R1976), or an alternative system which can be proved to provide equivalent test data. The purpose of this 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 Fig. 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 recommended practice 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.

2. Scope—The scope of the recommended practice 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 a 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 characteristic 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 8 should be consulted for general performance requirements and precautions regarding instrumentation for acoustical measurements.

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).

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 Section 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 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.

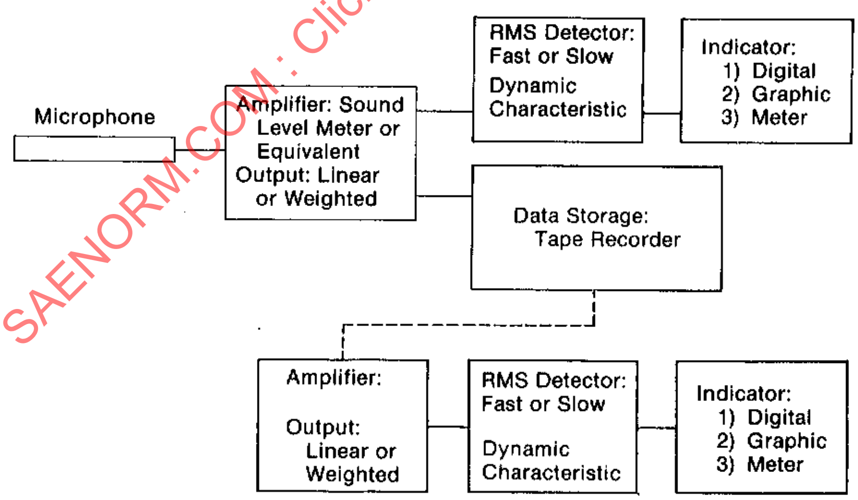


FIG. 1—SOUND DATA ACQUISITION SYSTEM

The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

3.7 Restricted System—Any data acquisition or analysis instrumentation that has a frequency response range that does not meet the pertinent requirements of ANSI S1.4 as specified herein.

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 broadband 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.

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.

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 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.

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 -2.0–0 dB with respect to the reference signal. Overshoot for a continuous 20 dB increasing step change in level shall be between 0 and +1.1 dB.

TABLE 1—SYSTEM FREQUENCY RESPONSE TOLERANCE REQUIREMENTS

Nominal Frequency Hz	A-Weighting Response (dB)	Tolerance[a] in dB Type 1	Type 2
10	-70	±4	—
12.5	-63.4	±3.5	—
16.0	-56.7	±3.0	—
20	-50.5	±2.5	+5.0, -∞
25	-44.7	±2.0	+4.0, -4.5
31.5	-39.4	±1.5	+3.5, -4.0
40	-34.6	±1.5	+3.0, -3.5
50	-30.2	±1.0	±3.0
63	-26.2	±1.0	±3.0
80	-22.5	±1.0	±3.0
100	-19.1	±1.0	±2.5
125	-16.1	±1.0	±2.5
160	-13.4	±1.0	±2.5
200	-10.9	±1.0	±2.5
250	- 8.6	±1.0	±2.5
315	- 6.6	±1.0	±2.0
400	- 4.8	±1.0	±2.0
500	- 3.2	±1.0	±2.0
630	- 1.9	±1.0	±2.0
800	- 0.8	±1.0	±1.5
1000	0	±1.0	±2.0
1250	+ 0.6	±1.0	±2.0
1600	+ 1.0	±1.0	±2.5
2000	+ 1.2	±1.0	±3.0
2500	+ 1.3	±1.0	+4.0, -3.5
3150	+ 1.2	±1.0	+5.0, -4.0
4000	+ 1.0	±1.0	+5.5, -4.5
5000	+ 0.5	±1.5, -2.0	+6.0, -5.0
6300	- 0.1	+1.5, -2.0	+6.5, -5.5
8000	- 1.1	+1.5, -3.0	±6.5
10 000	- 2.5	+2.0, -4.0	+6.5, -∞
12 500	- 4.3	+3.0, -6.0	—
16 000	- 6.6	+3.0, -∞	—
20 000	- 9.3	+3.0, -∞	—

[a]Tolerance limits are deviations allowed from linear or A-weighted system response. Any change to the tolerances of frequency response in ANSI S1.4 will apply.

TABLE 2—SYSTEM LINEARITY REQUIREMENTS

Type 1	within ±0.5 dB	22.4–11 200 Hz
Type 2	within ±0.5 dB	63–2000 Hz
	within ±1.0 dB	22.4–11 200 Hz

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 -3.0– -5.0 dB with respect to the reference signal. Overshoot for a continuous 20 dB increasing step change in level shall be 0–+1.6 dB.

4.3.3 Reference Signal—The above 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. (Refer to Fig. 2.)

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

Current standards do not specify Impulse Response or *Fast* and *Slow* decay times. These topics are covered in Appendices A.2 and A.3.

4.4 RMS Accuracy—The Sound Data Acquisition System RMS conversion must be within ±0.5 dB of the true RMS value for all signals with crest factors up to and including 10 dB. For test method see Appendix A.4.

4.5 Dynamic Range—The Sound Data Acquisition System dynamic range is governed by three factors, the data signal crest factor, the data signal amplitude range, and the system signal-to-noise ratio. The system signal-to-noise ratio must be at least 15 dB to insure that inherent instrument noise does not contribute more than 0.2 dB to the measured level. The system selected for measurement must have a total dynamic range that at least equals the sum of these three factors. Any bandpass filtering or weighting of the data after recording may require a wider dynamic range of the Sound Data Acquisition System. The system noise floor including that of the filter must be 15 dB below the minimum filtered data signal value.

5. Component Requirements

5.1 Microphone—If a microphone is used which has not been provided as a component of a Type 1 or Type 2 sound level meter, it must meet the microphone characteristics described in ANSI S1.4.

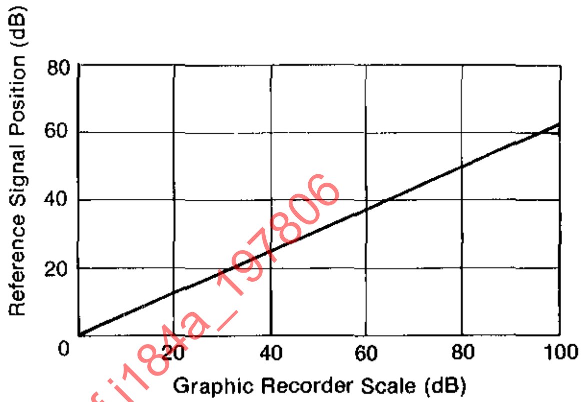
5.2 Magnetic Tape Recorders—Generally, wow and flutter requirements will be met if the tape recorder meets the other requirements of this standard in the data acquisition environment.

5.2.1 The brand and type of tape used for data acquisition must be tested with the system recorder to qualify overall recorder performance.

5.3 RMS Converter—Ideally, the RMS converter should control the dynamic response of the Sound Data Acquisition System in the *Fast* and *Slow* modes. Practically, the characteristics of the indicating instrument (meter or graphic recorder) may influence the dynamic response. When the RMS converter controls the dynamic response, the single pole filter time constants selected should be 125 ms for *Fast* and 1 s for *Slow*. (See Section A.1.)

5.4 RMS Indicator Requirements—The indicating instrument shall comply with Section 4, System Performance Requirements. Ideally, the dynamic response of the indicator should be an order of magnitude faster than the RMS converter dynamic response. In some cases, the dynamic response of the indicator and converter are of the same order of magnitude. When this occurs, the measurement results from the following three types of indicators may differ.

5.4.1 Graphic—The reference signal for the dynamic response test should be positioned at a point as close as practical as that determined from Fig. 2 for the scale being used. It is suggested that a 20 dB step function be used.



For indicators scaled linearly in dB, such as graphic level recorders, the reference signal can be positioned at 63% of full scale as indicated above.

FIG. 2—REFERENCE SIGNAL POSITION

5.4.2 Digital—The digital indicator resolution should be at least 0.25 dB. In order to meet the requirements of Sections 4.3.1 and 4.3.2, for noise of a transient nature, a *Hold* circuit should be incorporated.

5.4.3 Meter—If a meter is used as the readout indicator, the scale shall be graduated in 1 dB steps over a range of at least 15 dB.

6. Test Procedures—The entire system, except the microphone, must be used in the final qualification procedures. All components must be terminated with the correct impedance, including all connecting cables used to collect data. It may be desirable to check individual instruments, such as tape recorders, before performing the test.

6.1 System Frequency Response—The test oscillator amplitude frequency response shall be verified flat (±0.2 dB with a previously calibrated indicator). Corrections for deviation in oscillator output will be used to adjust the system frequency response. The microphone frequency response corrections must be added to obtain the total system frequency response.

6.1.1 Linear System Response—The system frequency response must be checked with the above calibrated oscillator. (See Fig. 3.) The check shall be performed at a level which is 5 dB below full scale (to allow for the tolerance in Table 1) and at least 15 dB above the system noise floor.

6.1.2 A-Weighted Systems Response—When an A-weighted frequency response is measured, the system internal signal gain, immediately after the A-weighting network, may be increased by 20 dB for the frequency response verification below 100 Hz and an additional 20 dB for verification below 30 Hz. (See Fig. 4.)

6.1.3 If other weighting networks are used, the procedure in Section 6.1.2 should be followed with the appropriate modifications.

6.2 RMS Detector Performance Test—Two methods of testing the RMS detector are outlined in the Appendix A.4. Either of the methods may be used to test the RMS detector.

6.3 System Noise Check—The complete system electronic noise floor should be measured with the microphone removed and replaced with the manufacturer's recommended impedance. In some test environments, it may be advisable to also measure the system noise floor with the microphone in place, but acoustically isolated from the sound source and at the actual measurement location during a representative test sequence.

7. General Comments

7.1 Environmental Responses—Care should be taken to ensure that the instrumentation is operated in an acceptable environment. Refer to the

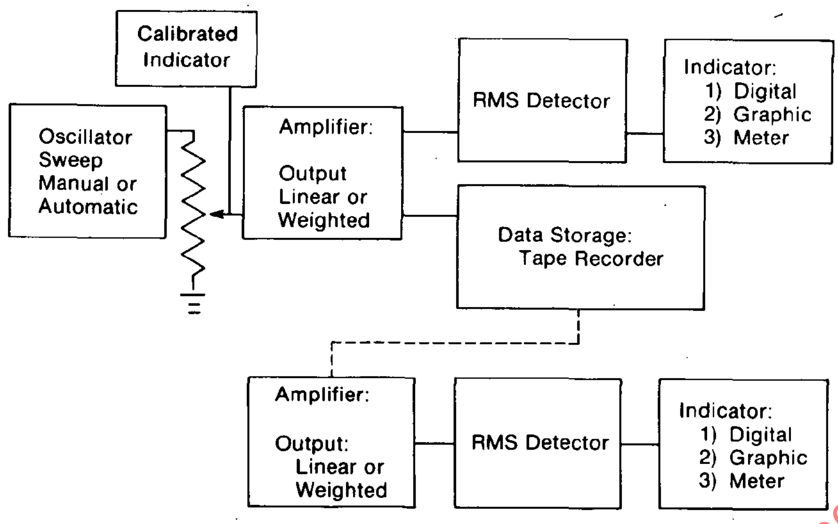


FIG. 3–FREQUENCY RESPONSE QUALIFICATION

manufacturer's specifications for the effect of temperature, humidity, atmospheric pressure, vibration, and magnetic and electrostatic fields on each component piece of equipment. ANSI S1.4 lists the required tolerances for which manufacturer data is not available.

7.2 **Dynamic Characteristic and Time Constant**–The combined effects of circuit electronics and indicator ballistic properties on sound data can be termed *Dynamic Characteristic*. These parameters can vary widely and still meet the requirements of ANSI S1.4 for *Fast* and *Slow*. In an effort to minimize variables in sound level meters, the dynamic performance characteristics must be understood. Appendix A.1 deals with the system dynamic characteristics in terms of a single pole RC filter with a precise time constant.

New standards are moving in the direction of specifying ideal dynamic performance in terms of a single pole RC filter. It is realized that introduction of the meter ballistics complicates duplication of a single pole RC filter performance. However, single pole RC filter performance is a practical reality if a maximum RMS hold circuit is introduced between the averaging circuit and the indicator for transient sounds. For sound with constant level containing little fluctuation, the meter ballistic properties do not affect the measured value.

7.3 **Windscreens**–The spectrum of sound being measured and, to a lesser extent, the angle of incidence of source to microphone have an effect on the accuracy of Sound Data Acquisition Systems which utilize a windscreen. The windscreen can significantly alter the signal between 1000 Hz and 4000 Hz. Windscreen corrections on data may be provided by the manufacturer or by *on-off* comparison measurements using live data. Wind induced noise is often insignificant on weighted data, particularly with the wind speed limitation imposed in SAE sound level measurement procedures.

7.4 A-weighting the signal before recording for later processing can reduce the need for unnecessary wide dynamic range because dominating low frequency data will be attenuated.

7.5 A rationale for the development of this recommended practice is contained in SAE HS 184.

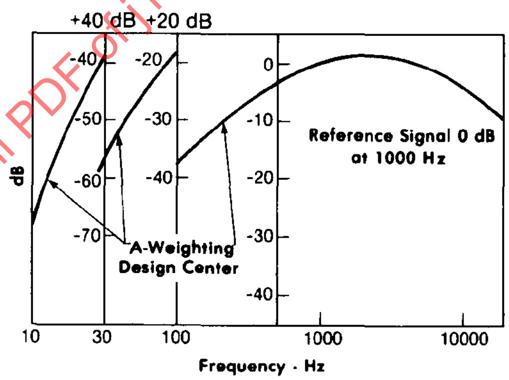


FIG. 4–STEP INCREASES IN SYSTEM INTERNAL SIGNAL TO KEEP A-WEIGHTING RESPONSE VERIFICATION ABOVE SYSTEM ELECTRONIC NOISE FLOOR

8. References

8.1 Consolidated Revision of IEC Publications 123 and 179: "Sound Level Meters", Draft: June 1976, Section 7–10.

8.2 ANSI S1.4-1971 (R1976), Specification for Sound Level Meters, American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

8.3 K. Zavert, "Averaging Time of RMS Measurements, Fast Slow Simulation", Bruel & Kjaer, Copenhagen, Denmark, 1975, Technical Review, Issue 2.

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

8.5 ANSI S1.1-1960, Acoustical Terminology, American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

8.6 W. J. Webster and J. W. Farenacci, "Use of Graphic Level Recorders as Indicating Instruments", Bureau of Noise, New York State Department of Environmental Conservation, South Wolf Road, Albany, NY 12201.

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

8.8 ANSI S1.11-1966 (R1976), Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

8.9 SAE HS 184.

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

APPENDIX

The following sections are intended to provide information for further verification of the system dynamic characteristic. These supplement the requirements of ANSI S1.4 and are intended for better characterization of the SDAS.

A1. System Dynamic Characteristic—The single point specification for dynamic characteristics of Sections 4.3.1 and 4.3.2 is broad enough to allow significant variations between systems in measurement of transient data. To alleviate this potential problem, this recommended practice is suggesting that a simple first order system be adopted as the model for system response. The following suggested model does not intend to supersede the previous requirements, but to provide a model such that evaluation of all transient data will be made on a uniform basis. The single tone burst response specification of Sections 4.3.1 and 4.3.2 meets the design center values of the model at the tone burst lengths specified.

Fig. 5 is a block diagram of an RMS detector and indicator. The dynamic response to step changes in level is defined by the equations:

$$e_o = e_{in}\,(1-e^{-T/RC})^{1/2} \quad \text{for increasing signal levels}$$

$$e_o = e_{in}\,(e^{-T/RC})^{1/2} \quad \text{for decreasing signal levels}$$

e_o and e_{in} in volts

T—Time from beginning of step change

RC—Electrical time constant of the circuit

It is suggested that RC be selected as 0.125 s for *Fast* and 1 s for *Slow* (as shown in Table 3) and that these time constants determine the system dynamic response. This requires the indicator response to be approximately ten times faster than the averaging constant.

A2. Dynamic Characteristic Decay Performance—The indicator decay for *Fast* from an indication 4.0 dB below full scale shall be at least 10 dB in 0.5 s when the signal is removed. Under the same test conditions, the indicator decay for *Slow* will be at least 10 dB in 3.0 s.

A3. Impulse Mode—Fig. 6 is a block diagram of an impulse detector indicator.

A3.1 Frequency Response—When a continuous test signal is applied, the indication in impulse mode shall be the same as the indication in *Fast* and *Slow* within 0.1 dB between 31.5 Hz and 8 kHz.

A3.2 Single Burst Response

A3.2.1 The tone burst indications in Table 4 shall be met for a single sinusoidal burst with a frequency of 2 kHz and a duration T.

TABLE 4—SINGLE BURST RESPONSE

T in ms	Indication dB below Full Scale	Tolerance dB Type 1	Tolerance dB Type 2
continuous	0	Ref	Ref
20	- 3.6	±1.5	±2.0
5	- 8.8	±2.0	±3.0
2	-12.6	±2.0	No test

A3.2.2 When the burst duration is held constant at 2 ms and the input amplitude is increased by 10 dB, the indication must increase by 10 dB ±1 dB.

A3.3 Multiple Burst Response

A3.3.1 The following indications of Table 5 shall be met for continuous sequence of sinusoidal bursts having a frequency of 2 kHz and a duration of 5 ms and a repetition frequency F.

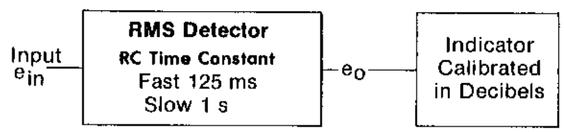


FIG. 5—RMS DETECTOR INDICATOR

TABLE 3—DYNAMIC PERFORMANCE TO INCREASING STEP INPUT CHANGES

Averaging Time	Duration of Step Change, ms	Response Referred to Continuous Signal e_o	dB
Fast	Continuous	1.00	0.0
125 ms	200	0.89	- 1.0
	100	0.74	- 2.6
	50	0.57	- 4.8
	20	0.38	- 8.3
	5	0.20	-14.1
Slow	Continuous	1.0	0
1 s	2000	0.93	- 0.6
	1000	0.80	- 2.0
	500	0.63	- 4.0
	200	0.43	- 7.4
	50	0.22	-13.1

TABLE 5—MULTIPLE BURST RESPONSE

F in Hz	Indication dB below Full Scale	Tolerance dB Type 1	Tolerance dB Type 2
continuous	0	Ref	Ref
100	- 2.7	±1.0	±1.0
20	- 7.6	±2.0	±2.0
2	- 8.8	±2.0	±3.0

A3.3.2 When the repetition rate is held at 2 Hz, and the input amplitude is increased by 5.0 dB, the indication must increase by 5.0 dB.

A3.4 Impulse Decay Performance

A3.4.1 When the continuous signal is suddenly decreased to zero, the indication must decrease by 4 dB in 3 ±0.5 s for Type 1 and 3 ±1.0 s for Type 2.

A4. RMS Detector Tests

A4.1 RMS Detector Test Method 1—Connect the equipment as shown in Fig. 7. The R value shall be 1% or less than the Detector Indicator System (DIS) input impedance. The DIS input may be applied through a suitable network replacing the microphone, or in series with the microphone if acoustic pickup can be made negligible. Perform the tests indicated in Table 6.

For each test, the sine wave generator level and the DIS gain controls for the required indicated value. Adjust the noise generator average RMS value

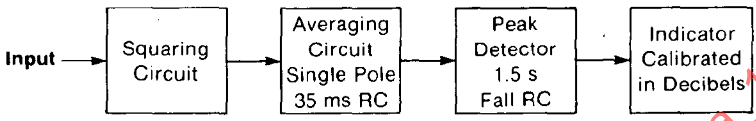


FIG. 6—IMPULSE DETECTOR/INDICATOR

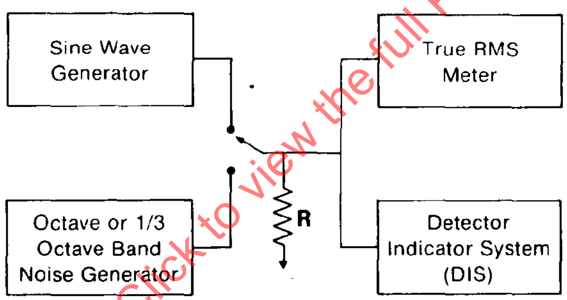


FIG. 7—RMS DETECTOR TEST METHOD 1

TABLE 6—RMS DETECTOR TEST REQUIREMENTS

	Frequency Hz	Input	Indicated Value dB Below Full Scale	Function	Averaging Time
Test 1	1000 Hz	Sine Wave	- 1.0	Set	Fast
	1000 Hz Band	Noise	- 1.0±0.5	Read	Fast
Test 2	1000 Hz	Sine Wave	-10.0	Set	Fast
	1000 Hz Band	Noise	-10.0±0.5	Read	Fast
Test 3	6300 Hz	Sine Wave	- 1.0	Set	Fast
	6300 Hz Band	Noise	- 1.0±0.5	Read	Fast
Test 4	6300 Hz	Sine Wave	-10.0	Set	Fast
	6300 Hz Band	Noise	-10.0±0.5	Read	Fast
Test 5	63 Hz	Sine Wave	- 1.0	Set	Slow
	63 Hz Band	Noise	- 1.0±0.5	Read	Slow
Test 6	63 Hz	Sine Wave	-10.0	Set	Slow
	63 Hz Band	Noise	-10.0±0.5	Read	Slow