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Qualifying a Sound Data Acquisition System

SAE Recommended Practice
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Submitted for Recognition as
an American National Standard

The Engineering Society For Advancing Mobility Land Sea Air and Space

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HIGHWAY VEHICLE PRACTICE

Submitted for recognition as an American National Standard

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QUALIFYING A SOUND DATA ACQUISITION SYSTEM

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, S1.4-1983, 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.

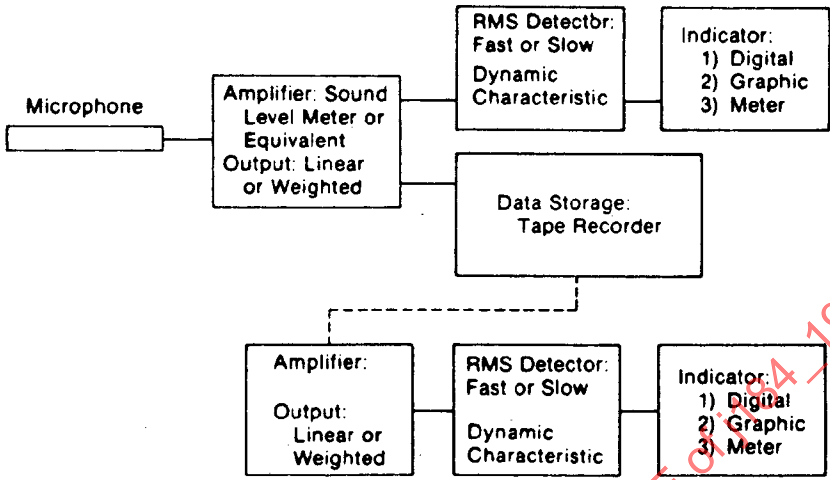


FIG. 1 - SOUND DATA ACQUISITION SYSTEM

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 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 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: 20 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: 20 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: 20 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 paragraph 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.

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: 20 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: 20 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.

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

4.2.2 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:

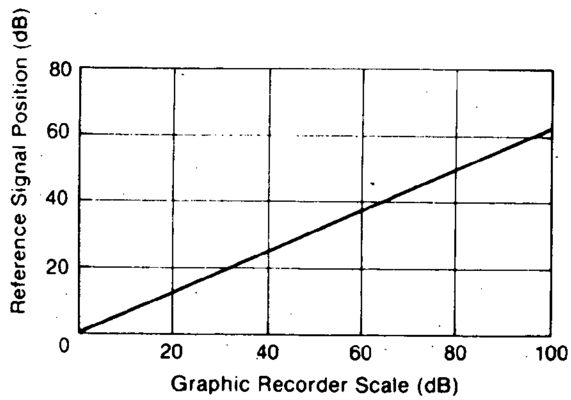
4.3.1 Fast: The system dynamic response is tested with a 1000 Hz signal instantaneously increased by a minimum of 20 dB to the reference signal level for a duration of 200 ms. The maximum indication shall be within -2.0-0 dB with respect to the reference signal. Overshoot for a continuous 20 dB increasing step change in level shall be between 0 and +1.1 dB.

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



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

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 Appendix 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.

5.4.2 Digital: The digital indicator resolution should be at least 0.25 dB. In order to meet the requirements of paragraphs 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 a 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.

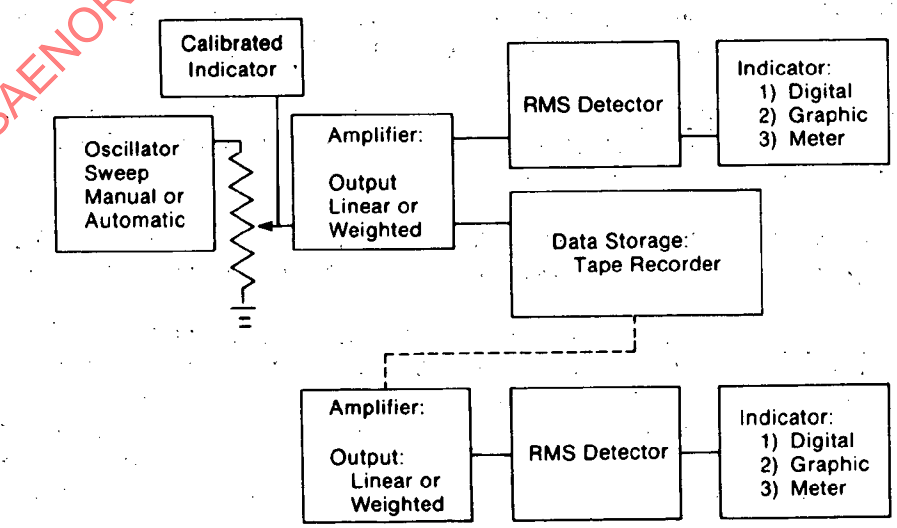


FIG.3 - FREQUENCY RESPONSE QUALIFICATION

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 125 ms	Continuous	1.00	0.0
	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 1 s	Continuous	1.0	0
	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

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.

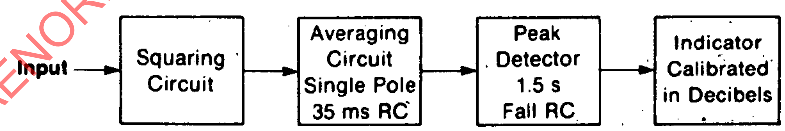


FIG. 6 - IMPULSE DETECTOR/INDICATOR

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.

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.

TABLE 4 - SINGLE BURST RESPONSE

T in ms	Indication dB below Full Scale	Tolerance dB	
		Type 1	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

A3.3 <u>Multiple Burst Response:</u>

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.

TABLE 5 - MULTIPLE BURST RESPONSE

F in Hz	Indication dB below Full Scale	Tolerance dB	
		Type 1	Type 2
Continuous	0	Ref	Ref
100	- 2.7	±1.8	±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 <u>Impulse Decay Performance:</u>

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 to equal the sine wave generator RMS value as indicated on the True RMS meter. The DIS average reading must be within ±0.5 dB of the sine wave reading.

Use C or Flat weighting in Tests 3-6. If neither C nor Flat is provided, signals should be connected to the linear electronics section of the DIS between the weighting networks and the detection system.

If A or B weighting must be used for the tests, the 63 Hz tests should be modified. Set the sine wave frequency as shown in Table 7.

For tests 5 and 6, the average meter deflection may be determined by averaging 50 instantaneous deflection readings taken at least 2 s apart.

Alternately, if provided, use a longer averaging time. The meter fluctuations must be less than ±0.25 dB using this method.

The 1/3 octave or octave bands of noise should be derived from a gaussian noise source that is pink over the range from at least 20 Hz-20 000 Hz, within ±1 dB. The filters must meet the Class II or III requirements of American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.11-1966 (R 1976). Pink means a spectrum level downward slope of 10 dB/decade applied to gaussian random noise. Above 20 kHz, the slope must fall at this rate or faster.

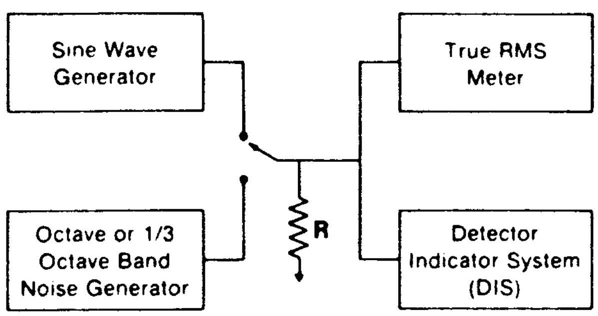


FIG. 7 - RMS DETECTOR TEST METHOD 1

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	Road	Fast
Test 2	1000 Hz	Sine Wave	- 10.0	Set	Fast
	1000 Hz Band	Noise	- 10.0 ± 0.5	Road	Fast
Test 3	6300 Hz	Sine Wave	- 1.0	Set	Fast
	6300 Hz Band	Noise	- 1.0 ± 0.5	Road	Fast
Test 4	6300 Hz	Sine Wave	- 10.0	Set	Fast
	6300 Hz Band	Noise	- 10.0 ± 0.5	Road	Fast
Test 5	63 Hz	Sine Wave	- 1.0	Set	Slow
	63 Hz Band	Noise	- 1.0 ± 0.5	Road	Slow
Test 6	63 Hz	Sine Wave	- 10.0	Set	Slow
	63 Hz Band	Noise	- 10.0 ± 0.5	Road	Slow

TABLE 7 - FREQUENCY CORRECTION FOR 63 Hz TEST

Weighting	Octave	1/3 Octave
A	67.4 Hz	63.6 Hz
B	64.9 Hz	63.4 Hz

A4.2 RMS Detector Test Method: The RMS accuracy is tested by comparing the indication for a reference sine wave to a continuous sequence of rectangular pulses and a sequence of tone bursts. The reference sine wave frequency shall be 2 kHz. The rectangular test pulses shall have durations of 200 μs and rise times of less than 10 μs. The tone burst test signal shall consist of an integer number of sine waves (2 kHz) starting and ending at zero crossing. The repetition frequency shall be 40 Hz.

The reference sine wave and the test signals shall have identical RMS values. The signals are compared using a weighting network prior to the reference meter identical to the sound level meter weighting within the tolerances of Table 1. The C-weighting characteristic or Flat shall be used. If the instrument has only A- or B-weighting, test with tone bursts only.

The test signal is connected to the electrical input of the sound level meter. The test is performed in Slow dynamic characteristic, or in Fast if Slow is not available.

Both positive and negative going pulses are used in the rectangular pulse test. The test shall be performed at 1 dB below the upper limit of the specified measuring range and at intervals of 10 dB below this level down to the lowest level that produces an indication of more than 3 dB on the indicator.

A4.2.1 Rectangular Pulse Test: Apply the 2000 Hz sine wave reference signal by switching to Reference as shown in Fig. 8. Adjust the sine wave reference signal level until the SDAS indicator is 1 dB below the upper limit of the specified measuring range. Note the indication of the reference RMS meter.

Apply the appropriate rectangular pulse sequence as shown in Table 8 by switching to Pulse. Adjust the pulse generator amplitude for the same indication on the reference RMS meter. The SDAS indication must be within the limits shown in Table 7.

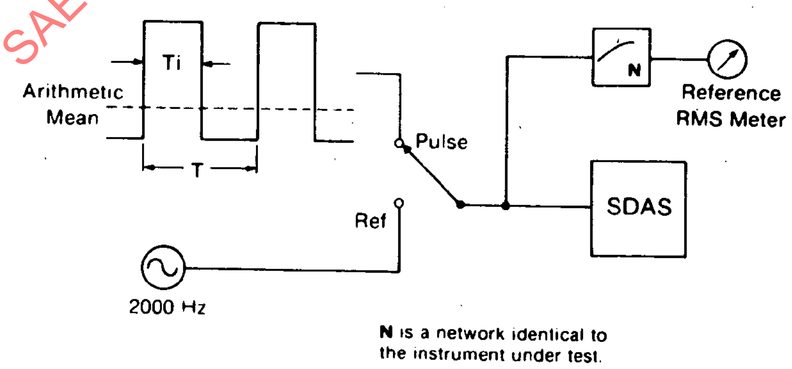


FIG.8 - RECTANGULAR PULSE TEST