

**ANSI S2.32-1982  
(ASA 32-1982)**

**Reaffirmed by ANSI  
July 10, 2001**

**Reaffirmed by ANSI  
November 5, 2004**

**Reaffirmed by ANSI  
October 21, 2009**

**Reaffirmed by ANSI  
September 11, 2014**

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Standards Secretariat  
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**AMERICAN NATIONAL STANDARD  
Methods for the Experimental  
Determination of Mechanical Mobility.  
Part II: Measurements Using Single-Point  
Translational Excitation**

**ABSTRACT**

This standard is the second part of a set of five standards covering the experimental determination of mechanical mobility of structures by a variety of methods appropriate for different test situations. Part I of the set (ANSI S2.31-1979) covers basic concepts and definitions as well as instruments used in mobility measurements. The material in Part I is common to most mobility measurement tasks. The present Part II of the set describes measurements in situations where single-point translational excitation with an attached vibration exciter is appropriate.

**Published by the American Institute of Physics for the Acoustical Society of America**

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## FOREWORD

[This Foreword is not a part of American National Standard Method for the Experimental Determination of Mechanical Mobility. Part II: Measurement Using Single-Point Translational Excitation, S2.32-1982 (ASA Catalog No. 32-1982).]

This standard has been developed under the jurisdiction of American National Standards Committee S2 using the American National Standards Institute (ANSI) Standards Committee Procedure. The Acoustical Society of America holds the Secretariat for Committee S2. This standard has been approved for publication by ANSI and by the Acoustical Society of America Committee on Standards (ASACOS).

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Suggestions for improvement of this standard will be welcomed. They should be sent to the Standards Secretariat, Acoustical Society of America, 335 East 45th Street, New York, NY 10017.

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# American National Standard

## Methods for the Experimental Determination of Mechanical Mobility.

### Part II: Measurements Using Single-Point Translational Excitation

## 0 INTRODUCTION

### 0.1 Introduction to the Set of Mobility Measurement Standards

Dynamic characteristics of structures can be determined as a function of frequency from measurements of mobility or of the related frequency response functions called accelerance and dynamic compliance. Each of these frequency response functions are ratios of the motion response of a structure to the exciting force. The magnitude and the phase of these ratios are functions of frequency.

In this set of standards the phrase "mobility measurement" is used in a general sense which includes the determination of mobility, accelerance, and dynamic compliance from the measurements of the exciting force and the motion response of the structure.

Mobility measurements are typically used for:

- (1) Predicting the dynamic response of structures to known or assumed input forces
- (2) Determining structural resonance modes (natural frequencies, mode shapes, and damping ratios)
- (3) Predicting the dynamic interaction of interconnected structures
- (4) Determining dynamic properties (i.e., the complex modulus of elasticity) of materials in pure or composite forms
- (5) Checking the validity and improving the accuracy of mathematical models of structures.

For some applications, a *complete* description of the dynamic characteristics may be required using measurements of translational forces and motions along three mutually perpendicular axes, as well as measurements of moments and rotational motions about these three axes. This set of measurements results in a  $6 \times 6$  mobility matrix for each location of interest. For  $N$  locations on a structure, the system thus has an overall mobility matrix of size  $6N \times 6N$ .

For most practical applications, it is not necessary to know the *entire*  $6N \times 6N$  matrix. Often, it is sufficient to measure the driving-point mobility and a few transfer mobilities by exciting a single point in a single

direction and measuring the translational response motions at key points on the structure. In other applications, only rotational mobilities may be of interest.

In order to simplify the use of standards for the varied mobility measurement tasks encountered in practice, the complete mobility measurement standard will be published as a set of five separate parts:

Part I (ANSI S2.31-1979) covers basic definitions and transducers. The information in Part I is common to most mobility measurement tasks.

Part II (the present document) covers mobility measurements using single-point translational excitation with an attached exciter.

Part III will cover mobility measurements using single-point rotational excitation with an attached exciter. This information is primarily intended for rotor system torsional resonance predictions.

Part IV will cover measurements of the entire mobility matrix using attached exciters. This will include the translational, rotational, and combination terms required for the  $6 \times 6$  matrix for each location on the structure.

Part V will cover mobility measurements using impact excitation.

NOTE: At the time when Part II was published, Parts III, IV, and V were in preparation.

Mechanical mobility is defined as the frequency response function formed by the ratio of the phasor of the response velocity to the phasor of the applied force. If the response is measured with an accelerometer, conversion to velocity is required to obtain the mobility. Alternatively, the ratio of acceleration to force, called accelerance, may be used to characterize a structure. In still other cases, dynamic compliance, the ratio of displacement to force, may be used.

NOTE: Historically, frequency response functions of structures have often been expressed in terms of the *reciprocal* of one of the above-named dynamic characteristics. The arithmetic reciprocal of mechanical mobility has often been called mechanical impedance. It should be noted, however, that this is misleading because the arithmetic reciprocal of mobility does not, in general, represent any of the elements of the impedance matrix of a structure. This point is elaborated upon in Appendix B of ANSI S2.31-1979.

## 0.2 Introduction to Part II of the Set (ANSI S2.32-1982)

For many applications of mechanical mobility data, it is sufficient to determine the driving-point mobility and a few transfer mobilities by exciting the structure at a single location, in a single direction, and measuring the translational response motions at key points on the structure. The translational excitation force may be applied either by vibration exciters attached to the structure under test or by devices that are not attached.

Categorization of excitation devices as attached or unattached has significance in terms of the practicality of relocating the excitation point. It is much easier, for example, to change the location of an impulse applied by an instrumented hammer than it is to relocate an attached vibration exciter to a new point on the structure. Both methods of excitation have applications to which they are best suited. The present Part II of the complete set of mobility measurement standards treats measurements using a single attached exciter; measurements made by impact excitation without the use of attached exciters are treated in Part V.

## 1 PURPOSE AND SCOPE

### 1.1 Purpose

The purpose of this standard is to describe recommended procedures for measuring mechanical mobility and other frequency response functions of structures such as buildings, machines, and vehicles using a single translational vibration exciter attached to the structure under test for the duration of the measurement.

### 1.2 Scope

The scope of this standard includes measurement of mobility, accelerance, or dynamic compliance, either as a driving-point measurement, or as a transfer measurement. It also applies to the determination of the arithmetic reciprocals of those ratios such as free effective mass. Although excitation is applied at a single point, there is no limit on the number of points at which simultaneous measurements of the motion response may be made. Multiple response measurements are required, for example, for modal analyses.

## 2 DEFINITIONS

Definitions of terms used in this standard conform to those given in ANSI S1.1-1960 and S2.31-1979 and

in ISO Standard 2041-1975. Definitions of certain terms pertaining to digital data analysis are found in ISO Draft International Standard DIS 4865-1979. For convenience, the most important definitions used in this standard are given below.

### 2.1 Frequency Response Function

Frequency-dependent ratio of the motion response phasor to the phasor of the excitation force.

NOTES:

(1) In order of preference, motion response may be expressed in terms of either velocity, acceleration, or displacement. The corresponding frequency response function designations are mobility, accelerance, and dynamic compliance, respectively.

(2) Phasors are defined in Appendix C of ANSI S2.31-1979.

### 2.2 Driving-Point Mobility, $Y_{jj}$

The ratio, in (m/s)/N, of the velocity phasor at point  $j$  to the phasor of the excitation force applied at the same point with unconstrained motion response at all other points unconstrained, i.e., free of any dynamic restraining force.

NOTE: The term "point" designates a location and a direction. The term "coordinate" has also been used with the same meaning as "point."

### 2.3 Transfer Mobility, $Y_{ij}$

The ratio, in (m/s)/N, of the velocity phasor at point  $i$  to the excitation force phasor at point  $j$  with the motion response at all points other than  $j$  unconstrained.

### 2.4 Frequency Range of Interest

The range, in hertz, from the lowest frequency to the highest frequency at which mobility data are to be obtained in a given test series.

## 3 OVERALL CONFIGURATION OF THE MEASUREMENT SYSTEM

Individual components of the system used for mobility measurements under this standard shall be selected to suit each particular application. However, all such systems shall include certain basic components arranged as shown in Fig. 1. Requirements for the characteristics and usage of those components are given in the following sections.



**Documents**

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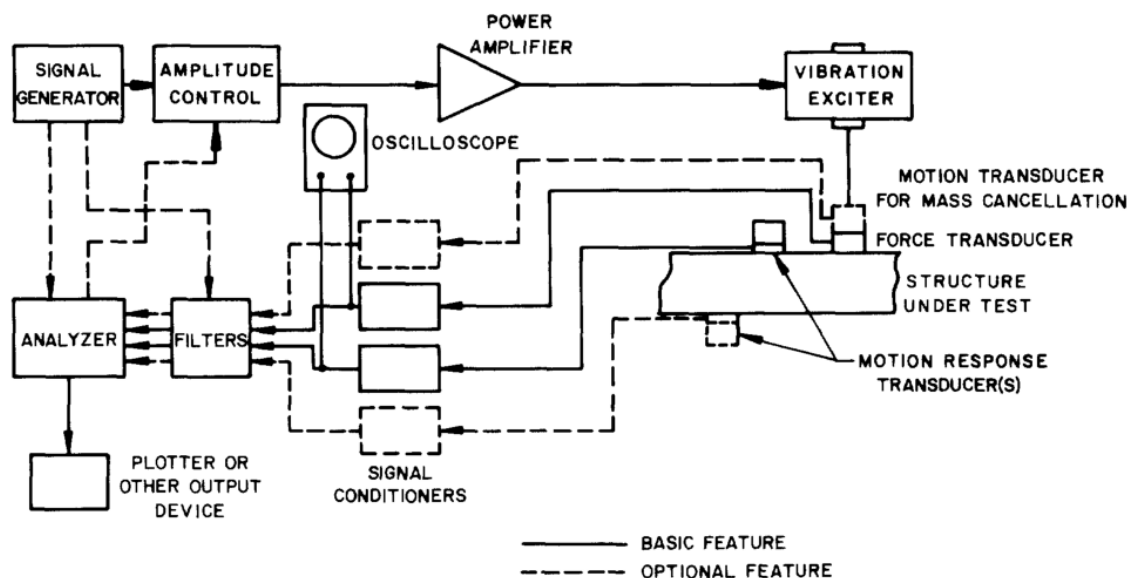


FIG. 1. Block diagram of mobility measurement system.

#### 4 SUSPENSION OF THE STRUCTURE UNDER TEST

Mobility measurements are performed on structures either in an ungrounded condition (freely suspended) or in a grounded condition (attached to one or more supports), depending on the objective of the test.

##### 4.1 Grounded Measurements

The support of the test structure shall be representative of its support in typical applications unless otherwise specified. A description of the support shall be included in the test report.

##### 4.2 Ungrounded Measurements

A compliant suspension of the structure shall be used. The magnitudes of all elements of the driving-point mobility matrix of the suspension, at its point(s) of attachment to the structure under test, should be at least ten times greater than the magnitudes of the corresponding elements of the mobility matrix of the structure at the same attachment point(s).

In the absence of quantitative information, design of the suspension is largely a matter of judgment. As a minimum requirement, all resonance frequencies of the rigid-body modes of the suspended structure shall be less than half the lowest frequency of interest.

Items commonly used to provide compliant suspension include shock cords and resilient pads of material such as foam and rubber. Since those suspension items have mass as well as compliance, care must be taken to ensure that the frequencies of the suspension resonances are well away from the modal frequencies of the test structure itself. The masses of any suspension components such as hooks and turnbuckles located close to the structure under test shall also be less than 1/10th of the free effective mass of the structure at each frequency of interest.

Preliminary testing should be performed to identify locations for the attachment of the suspension with the minimum possible effect on the intended measurements. Suspension near nodal points of the structure under test will minimize the interaction of the suspension system with the structure. Suspension cables should run normal to the direction of excitation, if practical.

NOTE: Of particular concern is any added damping of the structure's modes due to the suspension.