

AUDIOMETER

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AUDIOMETER

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1. Core Definition

The **audiometer** is a highly specialized electronic instrument designed for the quantitative measurement of auditory sensitivity. Its fundamental purpose is to determine a subject's hearing threshold levels for specific frequencies. This device is the foundational tool in clinical audiology, enabling professionals to assess the minimum intensity required for a person to perceive a pure tone or speech stimulus, thereby providing objective data on the presence and characteristics of hearing loss. Precision and standardization are paramount in audiometry, requiring the instrument to generate stable, predictable acoustic signals across a calibrated range of frequencies and intensities.

The primary output derived from the use of an audiometer is the **audiogram**, a standardized graphical representation of hearing ability. The audiogram plots the hearing threshold level (measured in decibels hearing level, or dB HL) against frequency (measured in Hertz, or Hz). By analyzing the resulting curves for both air conduction and bone conduction, the audiologist can diagnose not only the degree of hearing loss (e.g., mild, moderate, severe) but also its specific type--whether it is conductive (problems in the outer or middle ear), sensorineural (problems in the inner ear or auditory nerve), or mixed.

While commonly associated with clinical diagnostic settings, audiometers are essential across various environments, including educational institutions for screening purposes, research laboratories studying psychoacoustics, and industrial or occupational settings for mandated hearing conservation programs. Regardless of the environment, the integrity of the measurement relies absolutely on the audiometer's adherence to stringent national and international calibration standards, such as those set by the International Organization for Standardization (ISO) or the American National Standards Institute (ANSI).

2. Etymology and Historical Development

The development of the modern audiometer represents a significant evolution from early, non-standardized methods of hearing assessment. Before the advent of electronic measurement, clinicians relied on subjective techniques such as voice tests, watch ticks, or various tuning forks, which provided inconsistent and often unreliable results. The need for an objective, repeatable measure of hearing sensitivity became critical in the late 19th and early 20th centuries, driven by advancements in physics and electronics.

The first recognizable electronic audiometer emerged around the 1920s, notably the Western Electric 1A audiometer. These early devices utilized vacuum tube technology to generate pure tones and control intensity, marking the shift from mechanical to electrical assessment. This technological leap allowed for the precise manipulation of frequency and intensity, essential for creating standardized tests. Crucially, this period saw the initial establishment of a standardized zero reference point (0 dB HL), based on the average hearing threshold of young, healthy listeners, allowing for meaningful comparison of individual hearing ability against population norms.

Further development was significantly accelerated by military requirements, particularly during and after World War II, when large numbers of service personnel required rapid and accurate hearing screening due to noise exposure. This necessity drove innovation toward more portable, robust, and reliable solid-state electronic designs. The late 20th century introduced microprocessor-controlled and computerized audiometers, which automated parts of the testing process, minimized operator error, and facilitated the digital storage and analysis of audiometric data, seamlessly integrating hearing assessment into modern medical informatics.

3. Key Characteristics and Components

A typical diagnostic audiometer is a sophisticated piece of equipment comprising several essential functional units working in harmony to deliver a calibrated acoustic stimulus. The core operation depends on an oscillator circuit, which is responsible for generating the required pure tone frequencies, usually spanning the critical speech range from 125 Hz to 8000 Hz, though specialized units may test up to 20,000 Hz. The stability and purity of these tones are critical to accurate threshold measurement.

Following tone generation, the signal passes through the **attenuator**, an electronic circuit that precisely controls the intensity of the signal. The attenuator allows the operator to adjust the presentation level in discrete steps, typically 5 dB increments, crucial for the standardized bracketing procedures used to identify the true hearing threshold. The accuracy of the attenuator is one of the most critical aspects requiring regular calibration, as any deviation directly compromises the validity of the audiogram.

The final stage involves the **transducers**, which convert the electrical signal into an acoustic signal perceived by the patient. These components are essential for delivering the calibrated sound while ensuring proper acoustic isolation. The patient's response system, usually a simple hand-held button, allows for immediate indication of signal perception, completing the feedback loop necessary for threshold determination.

Oscillator and Frequency Selector: Generates pure tones across the clinically relevant frequency spectrum (e.g., 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, 8000 Hz).

Attenuator: Controls the intensity of the output signal in standardized decibel hearing level (dB

HL) steps, typically ranging from -10 dB HL to 120 dB HL.

Transducers (Air Conduction): Include supra-aural headphones or insert earphones, used to deliver sound to the outer ear canal to test the integrity of the entire auditory pathway.

Transducers (Bone Conduction): A specialized vibrator placed on the mastoid process or forehead, used to bypass the outer and middle ear to directly stimulate the cochlea, assessing sensorineural function.

Microphone and Input Selectors: Necessary for speech audiometry, allowing for the presentation of recorded speech materials or monitored live voice (MLV).

4. Types of Audiometers

Audiometers are categorized based on their complexity, capabilities, and intended use, ranging from simple screening tools to highly comprehensive diagnostic workstations. **Clinical (Diagnostic) Audiometers** represent the highest level of complexity. These instruments are designed for comprehensive audiological evaluation, capable of performing pure tone audiometry, speech audiometry, and numerous specialized tests such as tone decay, ABLB (Alternate Binaural Loudness Balance), and SISI (Short Increment Sensitivity Index). They typically feature two independent channels, allowing for simultaneous presentation of test tones and masking noise, which is essential for accurate monaural testing.

In contrast, **Screening Audiometers** are generally portable, single-channel devices intended for rapid testing of populations to identify individuals potentially needing full diagnostic evaluation. These devices limit testing to a small number of key frequencies (e.g., 500, 1000, 2000, 4000 Hz) at fixed intensity levels (e.g., 20 dB HL or 25 dB HL). They are widely used in public health programs, schools, and industrial occupational health clinics where time efficiency and ease of operation are prioritized over detailed diagnosis.

A significant subset of diagnostic devices are specialized **Speech Audiometers**, which focus exclusively on measuring a person's ability to understand spoken language. While standard audiometers can perform basic speech tests, dedicated speech audiometers offer superior stimulus control, including inputs for recorded speech material (which ensures standardization across patients) and precise control over masking noise crucial for determining the Speech Recognition Threshold (SRT) and the Word Recognition Score (WRS). These measurements are vital for determining communication abilities and predicting hearing aid benefit.

5. Operational Procedures

The operation of an audiometer follows standardized protocols, primarily the modified Hughson-Westlake procedure, which ensures that threshold determination is reliable, minimizing false positive or false negative responses. Before testing commences, the audiometer must be

biologically or electroacoustically checked for calibration, and the patient must be seated in a sound-attenuating booth to eliminate ambient noise that could compromise the validity of low-intensity measurements. Clear, unambiguous instructions must be given to the patient, ensuring they understand their task is to signal even the faintest audible sound.

The process of determining the threshold for a specific frequency involves a structured bracketing technique, designed to converge upon the softest sound the patient can hear reliably. This iterative process is crucial for distinguishing genuine auditory perception from guesswork or expectation.

Starting Frequency and Intensity: Testing typically begins at 1000 Hz, as it is a highly reliable frequency, presented at an intensity level clearly audible to the patient (e.g., 30 dB HL).

The "Down 10, Up 5" Strategy: If the patient responds to the initial tone, the intensity is decreased by 10 dB until a non-response occurs. Once a non-response is noted, the intensity is increased by 5 dB until a response is secured again.

Threshold Identification: This bracketing procedure (down 10 dB, up 5 dB) is repeated at the non-response/response boundary. The threshold is defined as the lowest intensity level at which the patient correctly responds to the stimulus at least two out of three times at that level.

Frequency Progression: After the 1000 Hz threshold is established, the audiologist proceeds to test 2000 Hz, 4000 Hz, and 8000 Hz, followed by 500 Hz, 250 Hz, and potentially 125 Hz.

Masking Implementation: If the signal presented to the test ear is loud enough to potentially cross over the skull (via bone conduction) to the non-test ear and stimulate it (a phenomenon called inter-aural attenuation), **masking noise** (usually narrow-band noise centered around the test frequency) must be introduced to the non-test ear to keep it preoccupied, ensuring the measured threshold belongs exclusively to the ear being evaluated.

6. Significance and Impact

The audiometer's significance lies in its role as the indispensable diagnostic tool for managing auditory health across the lifespan. By generating the audiogram, it provides the quantitative data necessary for accurate medical diagnosis, allowing otolaryngologists and audiologists to differentiate between medically treatable conditions (like otitis media, which causes conductive loss) and permanent conditions (like presbycusis, which causes sensorineural loss). This distinction is fundamental to determining the appropriate course of action, be it surgery, medication, or hearing rehabilitation.

In the realm of rehabilitation, audiometric results directly dictate the parameters for effective hearing aid fitting. Modern digital hearing aids are programmed based specifically on the patient's thresholds at various frequencies, allowing for precise, customized amplification that compensates for the unique configuration of their hearing loss. Without the frequency-specific detail provided by the audiometer, effective programming would be impossible, leading to poor sound quality and

rejection of the device by the user.

Furthermore, the audiometer plays a crucial public health and regulatory role. It is central to occupational audiology, ensuring compliance with legal standards set by bodies like the Occupational Safety and Health Administration (OSHA). Regular audiometric testing allows employers to monitor the effectiveness of noise control measures and protective equipment, identifying workers experiencing a standard threshold shift--an early indicator of noise-induced hearing damage--before it becomes a permanent and disabling condition.

7. Calibration and Quality Control

Due to the critical dependence on standardized measurements, the integrity of the audiometer is maintained through rigorous and regular calibration procedures. Calibration verifies that the sound pressure level (SPL) delivered by the transducers for a given frequency and intensity setting accurately matches the defined acoustic standards (0 dB HL). Without accurate calibration, all subsequent audiograms generated by the device are unreliable and potentially misleading, leading to diagnostic error.

Calibration is typically performed at two levels: the daily biological check and the annual electroacoustic calibration. The **biological check** involves a trained operator testing their own hearing or that of a known reference listener daily to confirm that the thresholds measured are consistent with previous results. This quick check helps identify sudden equipment failures, such as cracked headphone diaphragms or cable faults.

The more intensive **electroacoustic calibration** must be performed annually by certified technicians using specialized equipment, including acoustic couplers, sound level meters, and voltmeters. This process verifies transducer output levels, attenuator linearity, frequency accuracy, and harmonic distortion across the entire operational range, ensuring strict adherence to ANSI S3.6 or equivalent international standards. Failure to maintain this calibration voids the reliability of clinical data, potentially leading to incorrect prescription of amplification or flawed litigation regarding hearing impairment compensation.

Further Reading

[Audiometer \(Wikipedia\)](#)

[American Speech-Language-Hearing Association \(ASHA\) - Pure-Tone Audiometry](#)

[National Center for Biotechnology Information \(NCBI\) - Basic Audiometric Evaluation](#)