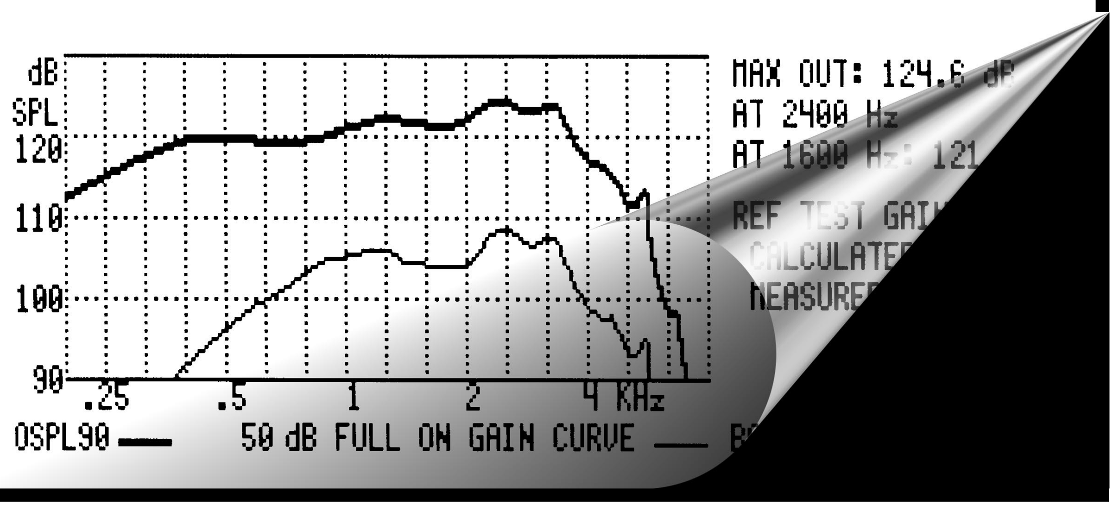
FONIX®

IEC 118-7 WORKBOOK



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CONTENTS

EXERCISES

INTRODUCTION

The IEC Standard, Publication 118-7*, describes a series of electroacoustic tests of hearing aids. People who work with hearing aids use these tests to compare the performance characteristics of individual instruments to the nominal performance characteristics specified by the manufacturer. This instructional workbook is designed to help students and workers become familiar with the theory and practice relating to these tests.

Testing the electroacoustic performance of hearing aids serves two general purposes: 1] to verify that an instrument is functioning properly—according to the manufacturer's specifications; and 2] to verify that an instrument is functioning appropriately—according to the auditory needs of the wearer. The IEC 118-7 standard, and this workbook, address only the first of these purposes. The tests described focus solely on determining whether the performance of a hearing aid is in agreement with factory specifications.

The instructions and exercises in this workbook are based on the assumption that the student already knows how to operate the hearing-aid analyzer, i.e., how to attach a hearing aid to the appropriate coupler, how to adjust the signal level and frequency, how to read the output, gain, and distortion at individual frequencies, and how to run a pure-tone frequency response test. If the analyzer has an automatic IEC test sequence, do not use the automatic sequence with this workbook; run all tests individually (unless instructed otherwise). Find answers to questions in the exercises printed upside down after each question.

The reference text for this workbook is the IEC Standard, Publication 118-7 (1994)*. Citations {in curly brackets} refer to section numbers within that publication. The reader is strongly encouraged to obtain a copy for use with this workbook and for future reference. A second important reference source is the operator's manual of your analyzer.

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*Copies of IEC 118-7 ("Measurement of the performance characteristics of hearing aids for quality inspection purposes"), and all the IEC 118 hearing aid standards, are available from the International Electrotechnical Commission (IEC); 3, Rue de Varembe; PO Box 131 - 1211 Geneva 20; Switzerland; Telex 414121 iec ch; Teletex 228-468 15 102=CEIEC CH; Telefax +41 22 7333843; Tel: (022)7340150; Int. tel: 041-22-7340150.

HEARING AID TYPES

"LINEAR" HEARING AID

A true "linear" hearing aid is a hypothetical device whose gain and frequency response remain the same, regardless of the input signal. Actually, no linear hearing aid exists, because all hearing aids will saturate once the input level is high enough—often at a level within the range encountered by hearing-aid users. Saturation causes large changes in gain, frequency response and distortion, making performance substantially non-linear. However, for the purpose of distinguishing hearing aid types for IEC testing, the term "linear" can be used to describe an instrument whose gain and frequency response remain constant over a wide range of input levels, and whose maximum output is controlled by peak clipping.

AUTOMATIC GAIN CONTROL (AGC) HEARING AID

An "AGC hearing aid" is an instrument whose gain changes automatically, as a function of the level of the signal being amplified. This automatic control of gain is usually designed to reduce the range of output levels as compared to the range of input levels. Such AGC action is called "compression." In general, there are two forms of compression:

- **"Input compression"** — The extent of gain reduction is determined by the level of the input to the hearing aid. "Wide-dynamic-range compression" is a common form of input compression. It is characterized by a low threshold (kneepoint) and a low compression ratio, and it is used to match the dynamic range of ordinary sounds to the reduced dynamic range of the recruiting ear.

- **"Output compression"** — The extent of gain reduction is determined by the level of the output of the hearing aid. "Output-limiting compression" is characterized by a high threshold (kneepoint) and a high compression ratio, and it is used to limit the maximum output of a hearing aid while avoiding the saturation distortion caused by peak clipping.

In IEC 118-7, the only time that you have to differentiate between AGC and non-AGC (linear) hearing aids is in selecting the input level for the "Full-on acoustic gain response curve" {8.3}.

DIRECTIONAL HEARING AID

A "directional hearing aid" is an instrument whose microphone sensitivity changes as a function of the direction from which sound arrives at the input. IEC 118-7 specifies that the "...manufacturer and purchaser should use acoustic test boxes of the same make and type to secure identical measurement conditions" {3.2, Note 3}. Because of this restriction, we will not use directional hearing aids with this workbook.

Exercise: ***Choose hearing aids for testing:*** *Consult published specification sheets of hearing aids available in your dispensary to list the model-numbers for several so-called "linear" (peak-clipping) and "AGC" instruments. These should not be directional hearing aids. Be sure that at least one instrument is linear, with mild gain and a wide frequency range, at least one has moderate gain, at least one has high gain, at least one has wide-dynamic-range (input) compression, at least one has output-limiting compression, and at least one is equipped with an induction coil (telecoil) input. Also, at least one hearing aid should be a behind-the-ear (BTE) type and one an in-the-ear (ITE, ITC, or CIC) type. You will use the listed instruments for practice in later exercises. (Note: Be sure the IEC 118-7 manufacturer's specifications are available for each aid you choose.)*

List:

THE TESTING SYSTEM

The testing system includes both the test equipment (the hearing-aid analyzer) and the test environment (the room in which testing is done). Specific requirements for the test equipment and the test environment are given in the IEC 118-7 standard. These requirements are paraphrased below, with references to the appropriate sections of the standard given in brackets.

Stray signals {6.1}:	Stray electric fields or magnetic fields, mechanical vibrations, and noise in the test space (sound chamber) must be low enough so that test results are not altered by more than 0.5 dB.
Sound source {6.2}:	Amplitude — must be accurate to ± 1.5 dB between 200 and 2000 Hz; to ± 2.5 dB between 2000 and 5000 Hz.
	Frequency — must be within 2% of the value indicated.
	Total harmonic distortion — for frequency response and full-on gain curves must be ≤ 2% up to 70 dB SPL, ≤ 3% up to 90 dB SPL; for harmonic distortion test, ≤ 0.5% up to 70 dB SPL.
Coupler types {6.3}:	Couplers (2cm^3) must be those described in IEC Publication 126—"IEC Reference Coupler for the Measurement of Hearing Aids Using Earphones Coupled to the Ear by Means of Ear Inserts".
SPL measurement system {6.4}:	Calibration must be accurate to ± 0.5% at a specified frequency.
	Coupler microphone — must have equal sensitivity within ± 1 dB between 200 and 2000 Hz, and within ± 1.5 dB between 2000 and 5000 Hz, re the sensitivity at 1000 Hz.
	Total harmonic distortion — between 200 and 5000 Hz, must be $<$1% for up to 130 dB SPL; $<$3% for 130-145 dB SPL.
	Internal noise — must be at least 10 dB below lowest measured level.

	Rms indication — the indicated SPL must be within ± 0.5 dB of true rms for sinusoidal signals.
Battery current {8.5}:	Accuracy must be to 5%.
Ambient conditions {7.3.4}:	Temperature: 23° C ± 5° Relative humidity: 40% - 80% Atmospheric pressure: 101.3 (+5/-20) kPa
Graph displays and printouts {8.1}:	Vertical axis: linear, in decibels (dB); horizontal axis: logarithmic frequency (Hz). Ratio of vertical to horizontal axes (aspect ratio) must be 50 decibels per decade frequency.

Exercise: ***Check the analyzer specifications:*** *In the operator's manual of your hearing aid analyzer, find the section giving technical specifications. Do the specifications meet the IEC requirements? Where do they fall short? How can these shortcomings affect measurements?*

Notes:

Exercise: ***Calibrate the analyzer microphone(s):*** *If possible, have your instructor, technician, or teaching assistant help you check, and if necessary, adjust the calibration of the microphone(s) used with your analyzer.*

Notes:

Exercise: ***Check for stray sound in the test space:*** *The standard suggests the following method for checking the influence of stray signals {6.1}. Use the wide-range, mild-gain, linear hearing aid you previously chose for testing. With the gain (volume) control set to full-on, run a frequency response curve using a 50-dB-SPL input signal. Print or store the results. Now turn off the test signal and run a second curve. At every frequency between 200 and 5000 Hz, the second curve should be at least 10 dB lower in level than the first. If this is true, then the stray sound in the test space is low enough so as not to have influenced the first curve by more than 0.5 dB.*

Other than stray sound in the test space, what are other sources of noise that could interfere with the test results?

Internal noise of the hearing aid; internal noise of the test-system microphone.

Notes:

Exercise: ***Check the aspect ratio of graph printouts:*** *The standard aspect ratio is 50 dB per decade, meaning that a length on the vertical axis corresponding to 50 decibels should equal a length on the horizontal axis corresponding to a decade (a ten-fold change) in frequency. Do the graphs you obtained in the previous exercise meet the standard aspect ratio? Why is it important that all hearing aid response curves use the same aspect ratio?*

So everybody can judge each hearing aid with the same visual frame of reference. It's easy to emphasize or de-emphasize features of a response curve by manipulating the aspect ratio.

BASIC DEFINITIONS

Section {4} of the 118-7 standard explains some of the terms used in the standard. Other terms are defined in IEC Publications 118-0 (Measurement of Electroacoustical Characteristics), 118-1 (Hearing Aids with Induction Pick-up Coil Input) and 118-2 (Hearing Aids with Automatic Gain Control). Additional definitions are given below for the purpose of instruction.

ACOUSTIC GAIN (also called "coupler gain" or, simply, "gain") — The difference, in dB, between the output SPL and the input SPL. In standard tests, "gain" refers to the output SPL measured in the coupler, minus the input SPL measured at the test point.

COMPRESSION RATIO — In an AGC hearing aid, the change in input SPL which causes a 1-dB change in output SPL (technically: $\Delta I/\Delta O$). This is a measure of the degree of compression.

CONTROLLING MICROPHONE — See "Monitoring Microphone."

EQUIVALENT INPUT NOISE {8.7} — The output level of the noise generated by the hearing aid, minus the gain of the aid.

FREQUENCY RESPONSE — A set of output levels generated as a function of frequency for a fixed input level. Sometimes, frequency response is expressed in terms of "gain", by subtracting the input level from each measured output level.

FULL-ON POSITION —"Full-on" means the gain (volume) control of the hearing aid is at its maximum position.

GAIN CONTROL —"Gain control" is the technical term for what is commonly called "volume control."

HARMONIC — An integral multiple of a given frequency. For example, the first harmonic of a frequency is the frequency itself; the second harmonic of a frequency is twice the frequency; the third harmonic of a frequency is three times the frequency; etc.

HARMONIC DISTORTION — An instrument exhibits "harmonic distortion" when the instrument produces harmonics in the output signal that are not present in the input signal. Basically, the test for percent total harmonic distortion (%THD) measures the power produced in the output of a hearing aid at frequencies equal to the second and higher harmonics of the input signal, as compared to the power produced by the hearing aid at the frequency of the input signal.

INPUT SOUND PRESSURE LEVEL ("input SPL") — In IEC 118-7, the "input sound pressure level" (also called "input level") is the SPL within 5-10 mm of the inlet of the hearing-aid microphone. This level is determined by the monitoring or controlling microphone of the analyzer.

KNEEPOINT ("threshold") — The input SPL at which a compression circuit begins to reduce the gain.

MONITORING MICROPHONE (also called "controlling microphone" or "leveling microphone") — A microphone that is used to monitor the sound pressure level of the test signal for the purpose of maintaining the specified input sound pressure level.

NOMINAL REFERENCE TEST GAIN {4.4} — The gain of the hearing aid which, for a 60-dB-SPL input signal at the reference test frequency, produces an output SPL that is 15 dB below the nominal reference $OSPL_{90}$. When this gain is not at least 7 dB below the full-on gain for a 60-dB-SPL input at the reference test frequency, then the nominal reference test gain becomes the full-on gain minus 7 dB.

$OSPL_{90}$ {8.2} — A frequency response curve showing output SPL as a function of frequency with the gain (volume) control set for full-on and an input SPL of 90 dB.

OUTPUT SOUND PRESSURE LEVEL ("output SPL") — The SPL measured by the coupler microphone (also called "output level").

PRESSURE METHOD — A measurement method which uses a pressure-calibrated monitoring microphone to control the SPL near the sound inlet of the hearing aid microphone {4.1}

REFERENCE TEST FREQUENCY — The frequency at which several of the standard tests are done, normally 1600 Hz; or 2500 Hz if so specified.

RMS ("root-mean-square") — The overall, long-term power level of a signal. (The square-root of the mean of the squares of several samples of a signal over a specified time period.)

SOUND PRESSURE LEVEL (SPL) — The designation "dB SPL" means that the decibel level given is a comparison between an observed sound pressure and a specified reference sound pressure. The reference sound pressure for dB SPL is 20 micropascals (μPa). This sound pressure—corresponding to 0 dB SPL—is close to the minimum audible field pressure at 2000 Hz. Saying "dB SPL" is equivalent to saying "dB re 20 μPa." Technically,

$$\text{dB SPL} = 20 \log_{10}(\text{observed sound pressure} \div 20\ \mu\text{Pa})$$

PREPARING TO TEST

SETTING THE TRIMMERS OR PROGRAMMING ON THE HEARING AID IN PREPARATION FOR TESTING

See Section {7.3} of the 118-7 standard for the “Normal operating conditions for a hearing aid.” In general, set all trimmers or programming to give the widest possible frequency range (except where stated otherwise), the highest possible maximum gain, and the highest possible maximum output.

CHOOSING THE CORRECT COUPLER

Follow the instructions in your analyzer operator’s manual for attaching hearing aids to the various coupler configurations.

- BTE instruments: Use the coupler containing the earmold simulator (labeled “HA-2” with FONIX equipment), with the cone-shaped and tubal extensions attached.

- ITE, ITC, and CIC instruments: Use the direct access coupler (labeled “HA-1” with FONIX equipment). Although IEC 118-7 doesn’t mention vents, vents should be sealed for 2cc-coupler tests. To be sure that the seal is good, seal vents at the outer vent opening (on the faceplate).

- Body instruments: Use the coupler containing the earmold simulator (labeled “HA-2” with FONIX equipment), without the cone-shaped and tubal extensions attached.

PRELIMINARY PRACTICE

LEVELING THE TEST EQUIPMENT

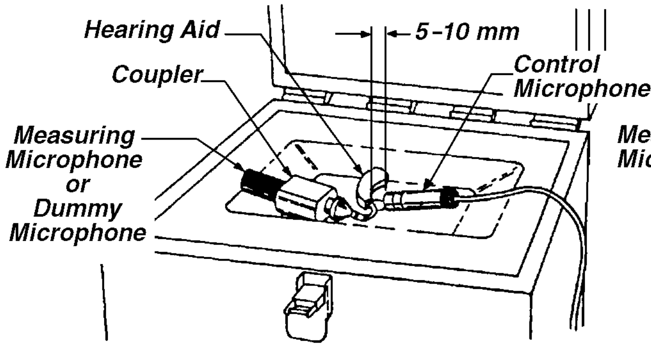
"Leveling" is the procedure that adjusts the electrical drive to the loudspeaker so that each frequency is presented at a predetermined level during testing. With analyzers that use separate microphones for leveling and for measuring, leveling is often done automatically, at the time of testing {7.2.2}. With analyzers that use the same microphone both for leveling and for measuring, leveling is done before testing {7.2.3}.

In any case, leveling must account for all items present in the test chamber at the time of testing. In other words, the complete hearing-aid/coupler/microphone apparatus (or equivalent) must be in place during leveling. With a single-microphone system, the Equivalent Substitution Method is used (see below), and leveling must be re-done whenever a change is made that could affect the acoustics of the measuring system, such as when changing the type of hearing aid from ITE to BTE.

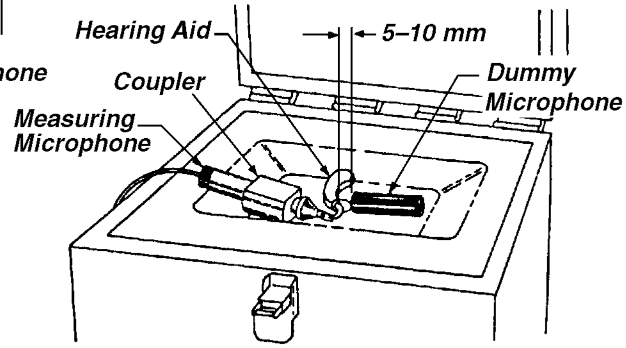
EQUIVALENT SUBSTITUTION METHOD (single-microphone systems only)

Single microphone analyzers must use the "Equivalent Substitution Method" for leveling, described in Section {7.2.3} of the standard. For the Equivalent Substitution Method, you must have a "dummy microphone" (or microphone substitute) that has the same physical dimensions as the actual microphone. During leveling, the dummy microphone takes the place of the measuring microphone inside the coupler (see figure A on the next page). The measuring microphone is instead placed near the opening of the hearing aid microphone. The center of the diaphragm of the measuring microphone should be within 5-10 mm of the opening of the hearing aid microphone. (The diaphragm of the measuring microphone is just behind the grille.) During testing (figure B), the positions of the dummy microphone and the measuring microphone are reversed.

Exercise: ***Set up for leveling:*** *Using a BTE hearing aid, practice setting up for leveling. Have the instructor verify that you have achieved the correct set-up, as illustrated in the figure (A) on the next page.*



(A)



(B)

If you have a single-microphone system, now reverse the positions of the dummy microphone and the measuring microphone, as illustrated in the figure (B) above. Now have the instructor verify that you have the correct set-up for testing.

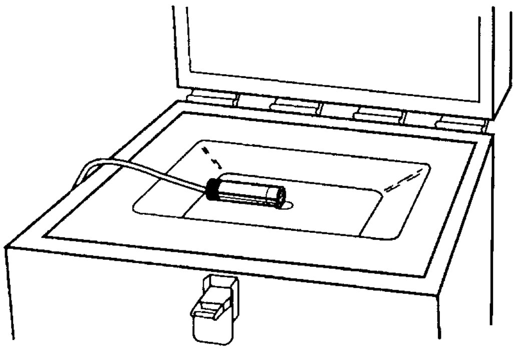
Repeat the exercise using an ITE-, ITC-, or CIC-type hearing aid.

LEVELING CHECK

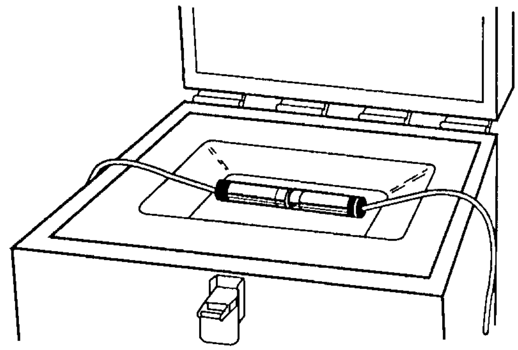
It's a good idea to check the functioning of your leveling/testing system from time to time, by running a "leveled" frequency response test without a hearing aid and coupler present. The result is the frequency response of the testing system. The output level should be the same as the input level at every frequency, within ± 1.5 dB between 200 and 2000 Hz, and within ± 2.5 dB between 2000 and 5000 Hz.

Exercise: ***Run a leveling check:***

1] Place the measuring microphone at the reference position in the sound chamber, as illustrated in the figure (A) on the next page. Do not use a hearing aid or a coupler. With dual-microphone systems, place the leveling microphone facing, and within 5-10 mm of the measuring microphone, as illustrated in the figure (B) on the next page.



(A)



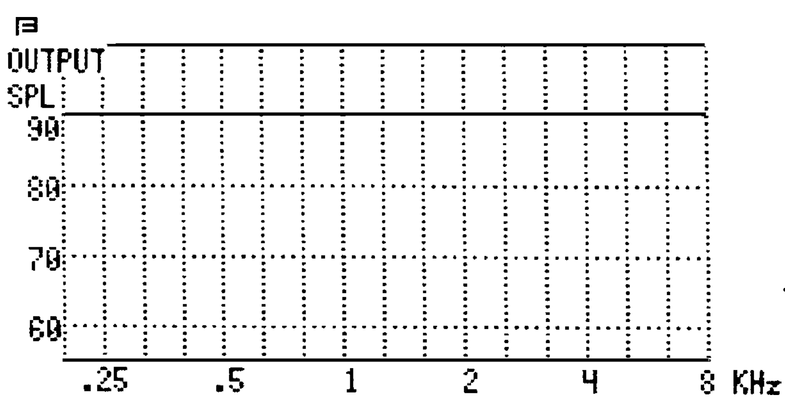
(B)

2] With a single-microphone system, "level" the system at this time. Otherwise, proceed to the next step.

3] Using a 90 dB SPL signal, run a pure-tone frequency response in this configuration.

The resulting measurement is the frequency response of the measuring system itself. The measured levels at each frequency should be very nearly the same as the signal level, 90 dB SPL. (An example is shown below.) Does your measured frequency response conform to the IEC 118-7 requirements? (Assume the measuring microphone is completely accurate.)

Should be within ±1.5 dB between 200 and 2000 Hz, and within ±2.5 dB between 2000 and 5000 Hz.



PRACTICE WITH IEC TEST PROCEDURES

OUTPUT SOUND PRESSURE LEVEL FOR 90 dB INPUT SPL ($OSPL_{90}$)

The $OSPL_{90}$ test uses an input level of 90 dB SPL, with the gain control in the full-on position. IEC 118-7 uses 90 dB SPL, full-on, because most hearing aids will be saturated (at their maximum possible output) under those conditions.

Exercise: ***Measure an $OSPL_{90}$ frequency response curve:***

Instructions:

1] Set the trim controls and gain control of one of the instruments on your list for the broadest and most powerful response.

2] Level the analyzer (if necessary).

3] Set the input level for 90 dB SPL.

4] Run a pure-tone frequency response.

FULL-ON ACOUSTIC GAIN RESPONSE CURVE

The "full-on acoustic gain response curve" is a gain-versus-frequency curve generated with the gain (volume) control set to full-on. The manufacturer must specify an input SPL based on the following criteria: If, using a 60 dB input SPL, the output at any frequency between 200 and 5000 Hz is within less than 5 dB of the $OSPL_{90}$ curve, then a 50 dB input SPL shall be used. Also, if an AGC instrument does not allow the AGC circuit to be disabled, then a 50 dB input SPL shall be used. Otherwise, a 60 dB input SPL shall be used.

Exercise: ***Choose the input (source) level for specifying nominal full-on gain:*** *Using one high-gain, one moderate-gain, and one mild-gain "linear" instrument from your list, determine by the procedure given below whether to use a 50-dB-SPL or a 60-dB-SPL input level to measure the full-on gain for each. (Note: For actual quality inspections,* *always use the input SPL specified by the manufacturer.)*

<u>Procedure</u>:

1] Run an $OSPL_{90}$ curve (90-dB-SPL input, full-on).

2] Run another SPL curve at full-on, but this time using a 60-dB-SPL input level.

3] Compare the two curves: if the 60-dB curve is separated from the 90-dB curve by less than 5 dB at any frequency between 200 and 5000 Hz, then you must use an input level of 50 dB SPL for full-on gain measurements. Otherwise, you must use 60 dB SPL. Exception: Always use 50 dB SPL for AGC instruments which do not allow the AGC to be disabled.

Do your results agree with the input levels specified for full-on gain by the manufacturers?

Exercise: ***Measure the full-on acoustic gain response curve:***

1] If available, choose a hearing aid whose specified input level for full-on gain is 50 dB SPL. (Otherwise, use an instrument for which 60 dB is specified.)

2] Set the trimmers to the nominal settings as described in the "Preparing to Test" section of this workbook, and set the gain (volume) control to full-on.

3] Set the analyzer to display the response in terms of "Gain" (output SPL minus input SPL). If your analyzer can display only output SPL, you will need to subtract the input SPL from all curve values.

4] Run two frequency response curves, one using a 50 dB input SPL and one using a 60 dB input SPL.

Was there a difference between the results for the two input levels? Why? Why not? If yes, under what conditions would there be no difference? If not, under what conditions would there be a difference?

The reason 50 dB SPL was specified is that testing with a higher input level could result in saturation at some frequencies. The results for 60 dB SPL, therefore, could disagree with the 50-dB-SPL results. If there was no difference between the results for the two levels, then saturation was not affecting the measurement.

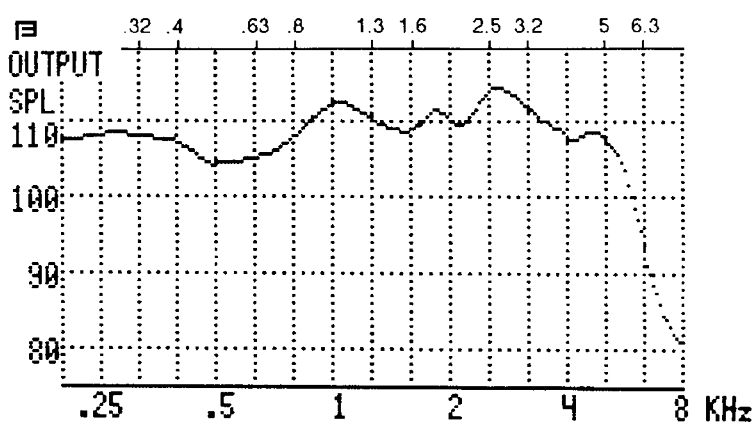
BASIC FREQUENCY RESPONSE CURVE AT NOMINAL REFERENCE TEST GAIN SETTING *{4.4}*

The purpose of testing hearing aid performance at the "nominal reference test gain" setting is that hearing aids are normally used with the gain control (volume control) set back from full-on to some degree. To simulate this real-use condition, the IEC 118-7 standard states that for an input SPL of 60 dB at the reference test frequency, the gain of the hearing aid shall be set back to *at least* 7 dB below the full-on gain. Conditions permitting, the gain is to be set back even more, to the point that the output SPL in the coupler is 15 dB below the $OSPL_{90}$ value. If a 7-dB set-back already results in an output less than or equal to 15 dB below the $OSPL_{90}$ value, then no further set-back is required. The acoustic gain corresponding to this output level is the "nominal reference test gain."

Another way of stating the above is that the "target" nominal reference test gain is equal to the $OSPL_{90}$ value at the reference test frequency, minus 75 dB. But if the full-on gain, using an input of 60 dB SPL at the reference test frequency, is already less than the target value plus 7 dB, then the nominal reference test gain becomes the full-on gain minus 7 dB. (See "Basic Definitions" in this workbook, for more.) Step-by-step instructions for practice are given in the two exercises that follow.

Note: IEC 118-7 allows a tolerance range of ± 1 dB around the standard value, for setting the gain (volume) control to the reference test position {8.4}.

Exercise: ***Calculate the "nominal reference test gain":*** *For the hearing aid whose $OSPL_{90}$ curve appears below, calculate the nominal reference test gain. Assume the reference test frequency is 1600 Hz. (Note: For actual quality inspections, always use the nominal reference test gain specified by the manufacturer.)*



<u>Instructions</u>:

Read and record the $OSPL_{90}$ value at the reference test gain frequency (1600 Hz).

109 dB SPL

The following may seem complicated, so read through it slowly. Consider three separate hypothetical cases, all three corresponding to the above $OSPL_{90}$ value. For all three cases, consider that the gain control is still set to full-on after measuring the $OSPL_{90}$—but the input signal is now lowered to 60 dB SPL and the frequency is set to 1600 Hz. The hearing aid analyzer is set to display "gain":

(a): Imagine that the value displayed for full-on gain is 30 dB. What would be the "nominal reference test gain? (Hint: First calculate the $OSPL_{90}$ value minus 75 dB; this is the target value. The gain must be set back a <u>minimum</u> of 7 dB.)

The target value is (109 - 75) dB, = 34 dB. The full-on gain of 30 dB is already less than the target value plus 7 dB; therefore, the nominal reference test gain would become the full-on gain minus 7 dB; 30 dB - 7 dB = 23 dB.

(b): Imagine that the value displayed for full-on gain is 38 dB. What would be the nominal reference test gain?

The full-on gain is still less than the target value plus 7 dB; therefore, the nominal reference test gain would still be the full-on gain minus 7 dB; In this case, 38 dB - 7 dB = 31 dB.

(c): Imagine that the value displayed for full-on gain is 44 dB. What would be the nominal reference test gain?

The full-on gain is not less than the target value plus 7 dB; therefore, the nominal reference test gain is the original target value, 34 dB.

Exercise: ***Generate a nominal reference test gain frequency response curve:***

Instructions:

1] Using a high-power hearing aid from your list, calculate the target nominal reference test gain. [Hint: Set the controls of the hearing aid to the nominal settings, run an $OSPL_{90}$ curve, read the output SPL at the designated reference test frequency—1600 Hz unless otherwise specified—and subtract 75 dB.] (Note: For actual quality inspections, always use the nominal reference test gain specified by the manufacturer.)

2] Set the analyzer to display gain for an input of 60 dB SPL at the reference test frequency; do not yet change the position of the gain control (leave it at full-on).

3] Subtract the target nominal reference test gain from the displayed full-on value.

displayed full-on gain_ _ _ _ _

minus target gain_ _ _ _ _

"N" = _ _ _ _ _dB

4] If "N" is less than 7 dB, you must set the gain control back so that the displayed gain equals the full-on gain minus 7 dB (± 1 dB). If "N" is equal to or greater than 7 dB, set the gain control back so that the displayed gain is equal to the target gain (± 1 dB).

(Note: The displayed gain may change once you remove your hand from the volume control and close the lid of the test chamber. Therefore, wait until the lid is closed before deciding whether you have achieved the desired gain.)

5] Once you have achieved the nominal reference test gain position of the gain (volume) control, run a frequency response curve (output SPL versus frequency) using a 60-dB-SPL input signal. This is the "basic frequency response curve."

6] Repeat the above exercise using a low-power hearing aid from your list.

TOTAL HARMONIC DISTORTION *{8.6}*

Measuring the percent total harmonic distortion (%THD) is normally straightforward with a hearing aid analyzer. Typically, all that is required is setting the gain control to the nominal reference test position, presenting the test signal specified by the manufacturer, and then reading the %THD value shown by the analyzer.

The test signal for measuring total harmonic distortion is a 70-dB-SPL pure tone set to the frequency specified by the manufacturer. The specified frequency must be a one-third octave frequency between 400 and 1600 Hz (inclusive).

Exercise: ***Read the total harmonic distortion:***

Instructions:

1] Using a hearing aid from your list, set its controls to the nominal settings.

2] Set the gain control to the nominal reference test position specified by the manufacturer. (Hint: Present a 60-dB-SPL tone at the reference test frequency and set the gain control so that the displayed gain matches the published value.)

3] Set the analyzer to read total harmonic distortion for a 70-dB-SPL signal at the distortion test frequency specified by the manufacturer.

4] Read the total harmonic distortion displayed by the analyzer and compare to the manufacturer's specifications.

Food for thought:

What are some possible causes, other than actual distortion produced by the hearing aid, that could cause erroneous, excessively high distortion readings?

Extraneous noise, either in the test space or produced by the hearing aid.

What experiment could eliminate extraneous noise as a possible cause for excessively high distortion readings?

With most hearing aids, increasing the signal level will increase the distortion, and vice-versa. If you raise the signal level and the distortion reading goes down, then extraneous noise is likely the cause of the erroneous reading. And vice-versa: if you lower the signal level and the distortion reading goes up, then extraneous noise is likely the cause of the erroneous reading.

BATTERY CURRENT

Not all hearing aid analyzers are equipped to test battery current. With those that are, you must use a battery simulation device that fits in the battery drawer of the aid and plugs into the analyzer. Settings on the analyzer let you select the battery simulation that corresponds to the battery type specified by the hearing-aid manufacturer.

Exercise: ***Read the battery current:***

Instructions:

1] Install the appropriate battery simulator in the battery compartment of one of the hearing aids on your list.

2] Set the trimmers for IEC testing, and set the gain control for the nominal reference test position specified by the manufacturer.

3] Apply a 60-dB-SPL signal at the reference test frequency.

4] Read the battery current.

INTERNAL NOISE GENERATED IN THE HEARING AID (EQUIVALENT INPUT NOISE) *{8.7}*

The equivalent input noise (EIN) is a "figure of merit" that answers the following question: Assume, hypothetically, that the hearing aid your are testing has *no* internal noise, even though it actually has some. What signal SPL would you have to apply at the input of the hearing aid to generate the output SPL that you *actually* measure with no signal applied?

The EIN is arrived at by setting the gain control to the nominal reference test position, measuring the “rms” output level with no input signal present, and then subtracting the nominal reference test gain. (Output SPL, minus gain, equals equivalent input SPL.) The only complication is that one of the qualities of noise is that its level fluctuates continually. Consequently, when determining the rms noise output level, the measuring device must use circuitry equipped to estimate “true rms” over a specified time period. In running the automatic IEC test sequence, the analyzer uses such circuitry to arrive at a valid estimate of the EIN. When attempting to determine the EIN manually, i.e., from outside the automated test sequence, you can roughly estimate the EIN level by taking the average of several manual readings. This is precisely what you will do in the next exercise.

Exercise: ***Estimate the equivalent input noise:***

Instructions

(Note: It is important to have a noise-free test environment for this procedure.)

1] Using one of the hearing aids on your list, set the trimmers for IEC testing, and set the gain control for the nominal reference test position specified by the manufacturer.

2] Turn the test signal off.

3] With no signal present, record several successive samples of the output SPL. Take at least five or six samples: The greater the number of samples, the more accurate the estimate of the typical EIN will be.

4] Add all the sample output SPLs and divide by the total number of samples taken. This gives you the average noise output SPL.

5] Subtract the nominal reference test gain from the average noise output SPL. This is your estimate of the EIN.

6] Try the above procedure for at least one other type of hearing aid.

Food for thought:

Can you think of why a compression aid might show a higher EIN, even if the quality of the circuitry is as good as a linear hearing aid with similar nominal gain and output characteristics?

When no input signal is present, the compression circuitry can increase the gain, and therefore the noise output SPL. When an input signal is present, the gain of the hearing aid will go down, along with at least a portion of the internal noise. Taken together, these conditions will increase the EIN estimate.

TELECOIL (INDUCTION PICK-UP) SENSITIVITY *{8.8}*

Not all hearing aid analyzers are equipped to test telecoil performance. With those that are, you must use a special signal coil (either built in or external to the analyzer). This coil will generate a magnetic field of 10 milliamperes per meter (mA/m), as specified in section {8.8} of the standard. The gain control should be set to full-on for this measurement, with other controls at the same nominal settings as for other tests. The hearing aid must be placed within the magnetic field and then oriented (rotated, stood on-end, etc.) so as to achieve the maximum possible output. The standard says the observed output is to be "expressed as the output SPL at a magnetic field strength of 1 mA/m." This means that for linear hearing aids, the nominal pick-up coil sensitivity is equal to the observed output minus 20 dB. Unfortunately, it is not clear how this characteristic is to be expressed when AGC is active.

Exercise: ***Measure the telecoil sensitivity:*** *From your hearing aid list, use any instrument having a telecoil (preferably a linear instrument).*

Instructions:

1] Choose a test environment that is free from extraneous magnetic fields. Do not place the signal-generating coil on a metallic surface, or near a video monitor, fluorescent light, electrical appliance or motor.

2] Set the magnetic signal level for 10 mA/m (this setting may be automatic) and set the frequency to the nominal reference test frequency.

3] Prepare the hearing aid for testing (set the trim controls, attach the coupler, level, etc.).

4] Set the hearing aid switch to the "T" position.

5] Set the gain control to the full-on position.

6] While observing the output level on the analyzer, find the physical orientation of the hearing aid about the test point that gives the maximum output reading. (For most BTEs, the hearing aid has to be placed perpendicular to the signal-generating coil to achieve the maximum telecoil output.)

7] Record the maximum output reading and subtract 20 dB.

Food for thought:

Why do you suppose the output level changes as the orientation of the aid changes?

Magnetic fields generally are directional. Maximum current is induced into the coil of the hearing when that coil has the same orientation as the signal-generating coil.

Why do we subtract 20 dB (for linear instruments) in complying with expressing the pick-up coil sensitivity in terms of 1 mA/m?

We measure at 10 mA/m. IEC says to express this in terms of 1 mA/m. The number of decibels difference between the two is: $20 \log_{10}$ (1 mA/m ÷ 10 mA/m), equals -20 dB.

Why is the above 20-dB rule not necessarily applicable to AGC instruments?

The above rule assumes the gain is the same for both the 10- and 1-mA/m input conditions. With AGC, the gain can change with varying input conditions.

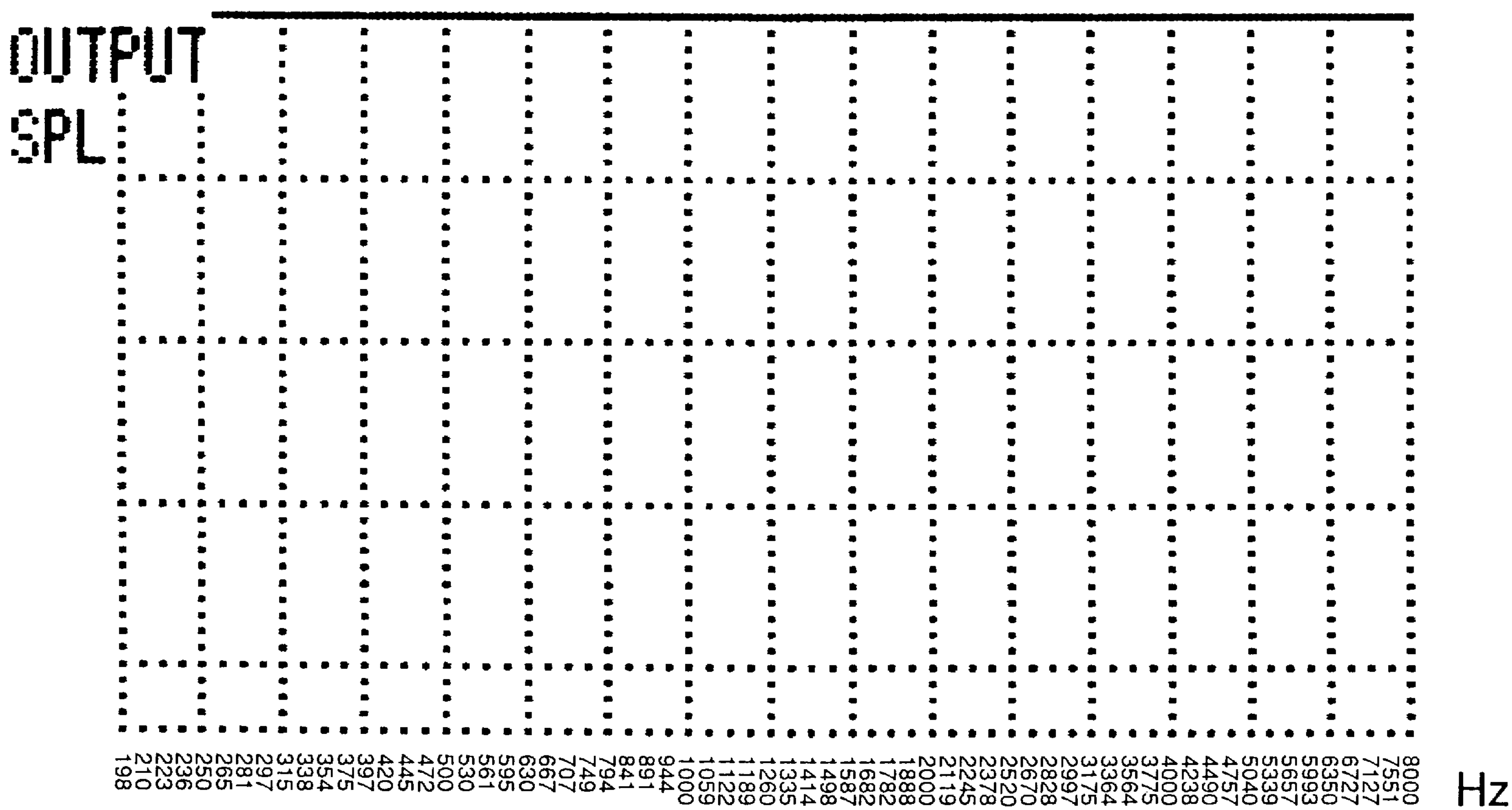
SUMMARY OF IEC 118-7 NOMINAL CHARACTERISTICS {5}

CHARACTERISTIC	TEST CONDITIONS
$OSPL_{90}$	Input level 90 dB SPL; gain control full-on.
Full-on gain at the reference test frequency	Input level specified by the manufacturer—normally 60 dB SPL—but 50 dB SPL if full-on response curve is less than 5 dB from $OSPL_{90}$ curve at any frequency between 200 and 5000 Hz, or if AGC cannot be disabled; gain control full-on.
Full-on acoustic gain frequency response curve	Same conditions as nominal full-on gain at the reference test frequency.
Basic frequency response curve	Input level 60 dB SPL; gain control at reference test gain position specified by the manufacturer.
Battery current	Input level 60 dB SPL at reference test frequency specified by the manufacturer; gain control at reference test position specified by the manufacturer.
Total harmonic distortion	Input level at 70 dB SPL at one-third octave frequency between 400 and 1600 Hz; frequency specified by the manufacturer; gain control at reference test position specified by the manufacturer.
Equivalent input noise level	No input signal; gain control at reference test position specified by the manufacturer.
Maximum pick-up coil sensitivity if applicable)	Input level 10 mA/m at reference test frequency; gain control full-on; output expressed in terms of 1-mA/m input.

Exercise: ***Run a complete IEC 118-7 test sequence*** *(manually)*: *Using each of four varied types of hearing aids from your list, run all the tests listed in the table on the previous page. Do not use the automatic IEC test sequence in your analyzer; run the tests individually, as you did in the earlier practice exercises, except, in all cases use the manufacturer's specified values for: input level for full-on gain, reference test frequency, and nominal reference test position of the gain control.*

Compare your results to the manufacturers' published specifications. Do the results match the specified characteristics? If not, which characteristics do not match? Decide whether the instrument in question is functioning normally.

Now, following the instructions in the operator's manual, use the automatic IEC 118-7 test sequence in your analyzer to generate a separate set of test results for each instrument. Do these results match your earlier results? If not, figure out why you have a discrepancy.



Appendix—graph scale with ¹⁄₁₂-octave frrequencies