GOLDEN EARS

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Welcome to the Golden Ears

audio eartraining program.

This manual and the accompanying CDs are the product of close to two decades of studio experience as well as recording engineering and production at a number of institutions. The CDs you have purchased, **Volume 1**: *Frequencies*, **Volume 2**: *Effects and Controls* and/or **Volume 3**: *Time Domain — Delay and Reverb Drills*, and **Volume 4**: *Master Frequencies — 1/3 Octave and Dual-Octave Drills* are the cornerstone of the anticipated series of audio eartraining drill sets. Each volume is an independent course, designed to condense years of hands-on experience into a matter of weeks.

As you work your way through the exercises, you'll find yourself hearing recordings in a completely new light. Furthermore, you may expect these CDs to provide years of service as a reference. Long after mastering the exercises, you'll be able to give your ears an occasional "workout" to maintain your valuable skills.

About this manual: Many people have an aversion to reading manuals. However, if you want to start right in with the CDs, go ahead. Simply put on the first CD, play it, and try to figure it out. When you get confused or bored, or just feel like reading something, that's when you should read the manual.

On the other hand, the manual and the CDs are designed to work together. We haven't wasted valuable CD recording time with information that could be better presented in this manual. I've tried to put as much useful material as possible in this manual, so you might want restrain your initial urge to leap right in.

Why develop Golden Ears? The auditory challenges facing today's musicians and recording, mixing, and mastering engineers are really substantial. The performance baseline for audio technology has improved dramatically over the past

twenty years. From the recording studio to the listener's loudspeakers, we have come to expect recordings of superb acoustic instruments, really convincing sampling and synthesis, mega-awesome processing capabilities, and so forth. We now expect audio quality that includes flat frequency response, noiseless and distortionless audio signals, and superb time and spatial resolution. To get these things, we need extremely well-developed critical listening skills.

Golden ears are skilled enough to discern, measure, analyze, and express the physical qualities of musical sounds accurately. Once you have them, you will be able to listen to recordings with more sensitivity and awareness

Golden ears enable us to realize the full potential of our audio systems in the production of recorded music. This CD set provides a crucial tool for developing those ears quickly and easily. It provides a base of auditory experience and knowledge that is essential for working with modern recorded music. Working through these drills and using them as refreshers from time to time will permit you to gain and maintain the equivalent of five to ten years of critical listening experience in a matter of weeks.

As you get good at these drills, you will be able to pinpoint problems rapidly and make useful decisions about how to deal with various audio and musical problems, instead of having to resort to the more traditional "keep turning knobs until something sounds good" approach, with its accompanying hype ("I'm just resetting the critical phase offsets. I'll be with you in a second. There, how's that? Ya gotta love it!"). You will come to know, by ear, how the audio energy is distributed across the spectrum, approximately how loud two sounds are relative to each other, the kinds of signal processing going on, and so on. Almost as important, you will be able to easily detect when others are reduced to random knob-twiddling and hype.

Dave Moulton

Calibrating your system

Calibration consists of a brief sequence of pink noise and five tones. The pink noise will be used for setting playback level, and the tones will be used to confirm the spectrum range of your playback system. The calibration material is at the end of each CD. This way you don't have to listen to it each time you start up.

First, you will set your playback level. It is fairly important not to adjust levels while you are doing the drills (because of the variation in level vs. spectrum at different loudness levels— the so-called Fletcher-Munson curves). You will listen to the pink noise to do this.

Then you will check out the spectrum using the tones. You should probably have all of your tone controls off or set at flat, unless you are really attached to some listening setting that you like an awful lot. Also, if you have a loudness compensation button on your playback preamp or receiver, you should turn it off.

Setting Playback Level Using Pink Noise

The pink noise is played at three different levels. The first level is the "nominal listening level." It will be at the same loudness as the slates and drills when nothing is boosted or cut. You should set the your playback level so it is comfortably medium loud, subject to the considerations of the next two pink noise levels (75 dB SPL might be nice, if you have an SPL meter handy). The second level is 6 dB louder than the nominal listening level and it is about as loud as any of the drills ever get. You should verify that (a) it doesn't cause your speakers or the neighbors any distress and (b) it is comfortable, if somewhat loud. The third level is another 6 dB louder (12 dB above the nominal level), and represents the maximum level

that your playback system will ever need to handle for these drills. You should simply confirm that the system doesn't show signs of distress (bad odors, crackling noises, obvious distortion, etc.) at this level. If it does, you will need to turn down the playback level until it can be reproduced with ease by your system.

Checking the Response of Your System Using the Tones.

The last track on the CD is about 20 seconds long and consists of five sinusoidal tones, in the following order:

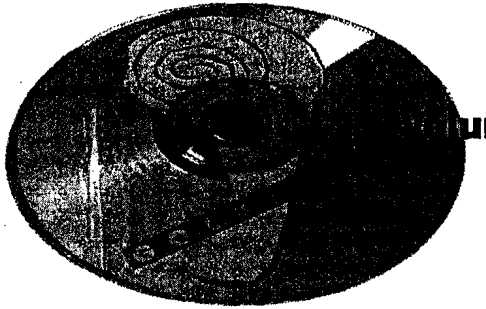
1 KHz
10 KHz
100 Hz
15 KHz
40 Hz

These are at the nominal listening level. Each tone lasts for about five seconds.

You should play back the five tones. If you can't hear 1 KHz, 10 KHz or 100 Hz at the nominal listening level, there is a serious problem with your monitoring system that has to be dealt with before you can proceed. The loudnesses of these tones may sound different to you— so long as the differences are not extreme, you are OK. The 15 KHz and 40 Hz tones represent extremes of the audio spectrum, both for the equipment and for our hearing. Expect them to be significantly softer in level. They may even be inaudible or barely audible. If so, you can proceed, but you should be aware that you may have a little trouble hearing the extremes of the spectrum.

You are now ready to begin the drills.

There are two basic types of drills: sets of examples of changes in loudness of octave bands of the audio spectrum and critical (A/B) comparisons of two versions of a recording.



ume One

Frequencies

The Equalization Drills

The equalization drill sets each consist of ten examples. Each example is about ten seconds long and consists of either pink noise or music. The example begins with the sound played normally. After about three seconds, the sound is altered by boosting or cutting the amplitude of one or more octaves in the spectrum, using a graphic equalizer. After about four seconds of equalized sound, the sound is returned to its normal state. Your task is to identify which octaves of the spectrum were boosted or cut.

To help you, there is a warmup drill preceding the drill set to let you get the "sound" of the various octaves "in your ears." Also, the beginning drill sets restrict the octave ranges being changed into groups called "low" (octaves one through five, 31—500 Hertz), "mid" (octaves four through eight, 250—4000 Hertz), and "high" (octaves six through ten, 1 KHz—16 KHz). This greatly simplifies your decision-making at the beginning.

Doing the Equalization Drills

Calibrate your system (refer to the previous section) and get yourself set on the median plane (equidistant from each speaker). You will find the answers to these exercises at the end of this chapter and answer sheet templates at the end of the manual. Start at the beginning, with Drill Set 1 of the first CD of Volume 1.

• Play the Drill Set, which will include the warmup drill. While listening to the warmup drill, try to memorize the sound of the octaves being boosted. Then listen to the ten examples of the drill set. Guess which octave is being boosted and write it down, expressing it as a center frequency (i.e. "125 Hz").

When you complete the drill set, hit pause on the CD player, and skip back to the beginning of the drill set. The CD will cue up just after the slate for the drill set itself, at Example 1.

• Play the drill set a second time to double check your answers. Pause and skip back again. Now take out the answer sheet that is included in the CD booklet, and play back the drill set a third time, listening while writing down the correct answers on the answer sheet.

• Pause again at the end to score yourself. If you guess the correct octave on an example, give yourself 10 for that example. For each octave "off" you are, take away 1, so that if you guessed 1 KHz (Octave 6) and the right answer was 250 Hz (Octave 4), your score is 8. Total up your scores for all ten examples. A perfect score for a drill set is 100. If you simply wrote down random answers, you should get around 40 points. What I've found is that scores of between 85 and 95 are typical for single octave bands of music being boosted or cut, once you get the hang of it.

• Now go ahead to Drill Set 2. Once again, listen to the warmup drill and play through the ten examples while guessing which octave is boosted. Listen to the examples a second time to reconsider your answers. Then play back the examples while looking at the correct answers and entering them on the answer sheet. Pause and score yourself.

• Go ahead to Drill Set 3 and repeat.

• Quit for the time being. It is counterproductive to work on these exercises when your ears are tired.

• Start your second session by repeating the last drill set of the previous session. Again, do three drill sets, listening to each drill set twice before checking the answers. Always listen to the drill set while you check the correct answers, and write those correct answers down to help you learn to "visualize" in your mind the correct answer related to the sound.

Work through both CDs in Volume 1 this way, repeating the last drill set from the previous session and adding two new drill sets.

Drill Sets **1-3** involve pink noise being boosted in low, middle and high regions

of the audio spectrum.

Drill Sets **4-6** use musical material instead of pink noise, again boosting in low, middle and high regions of the spectrum.

Drill Set **7** will introduce cuts, again starting with pink noise. You will probably find it is easiest to identify the frequency of the octave being cut when it is being brought back in at the end of the example.

Drill Set **13** begins to deal with the entire spectrum, so that your range of possible choices is much larger. If you find yourself getting confused by too many choices, feel free to go back and review any of the first 12 drill sets in order to get your bearings.

Drill Set **5** on the second CD introduces the possibility that a given octave is either boosted or cut. As you do these drills, you must indicate on the answer sheet whether the octave in question is boosted (use a "+") or cut (use a "-"). When you score this or later drill sets where you have to guess whether the octave is boosted or cut, if you guess wrong, take away two more points, so that if you had guessed 1 KHz boosted when in fact 250 Hz was cut, your score would be 6.

• When you have worked your way through both CDs of Volume 1 this way, you should then try CD 1 on random play. Now you will do the drill sets without a warmup and without knowing what the drill set is going to be about. Always listen again while writing down the correct answers.

• When you have become proficient at hearing the drills on CD 1, switch to CD 2 and play it randomly. To provide a little more challenge, try listening only once to the drill set before checking with the correct answers. CD 2 can be played lots of times (probably close to an infinite number— although why you would do that I honestly do not know) before you will know it well enough to be able to remember the answers.

Through all of this, limit your sessions to three or, at the most, four drill sets.

How these drills were made

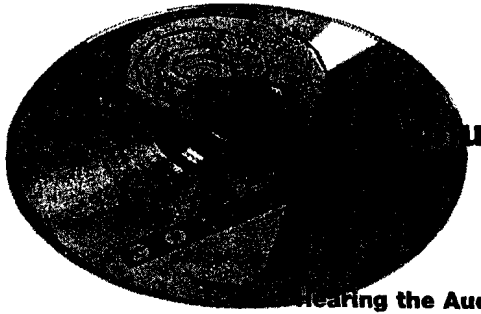
The equalization drills were produced using Pink Noise from an Ivie Pink Noise generator and Compact Disc recordings in a variety of musical styles. Although these drills are pretty close to Fair Use under the copyright law, we have obtained permissions from all owners of the recorded material, and would like to thank them by encouraging you to support them by buying their records. See the credit list for a complete listing of all recordings used.

Both the Pink Noise (in mono) and the recordings (in stereo) were passed through a UREI 10-band graphic equalizer and then recorded directly to hard disk via Digidesign's Pro Tools for editing and assembly. The graphic equalizer was set flat and for each exercise the appropriate octave band was boosted or cut by the appropriate amount (12 dB, or the limit of travel, for Volume 1). In the music recordings, both channels were treated identically.

I determined which band(s) to boost or cut by the use of a random number generator, subject to the following limits: I never did the same thing twice in a row, and I excluded "no change" as a possible answer. Because the selection was random, don't expect that all octave bands must be included in any drill set, or that you can anticipate what we are going to do next. I wasn't trying to fool you or play mind games.

After assembly editing of all the drills and slates, I got bored with the slates and decided to add signal processing to an occasional slate, for amusement. The processing varies from slate to slate and it's there to give you something else to do while improving your mind.

The slate for each track actually appears at the end of the warmup drill, so that you may listen 'blind' to each track.



ume One

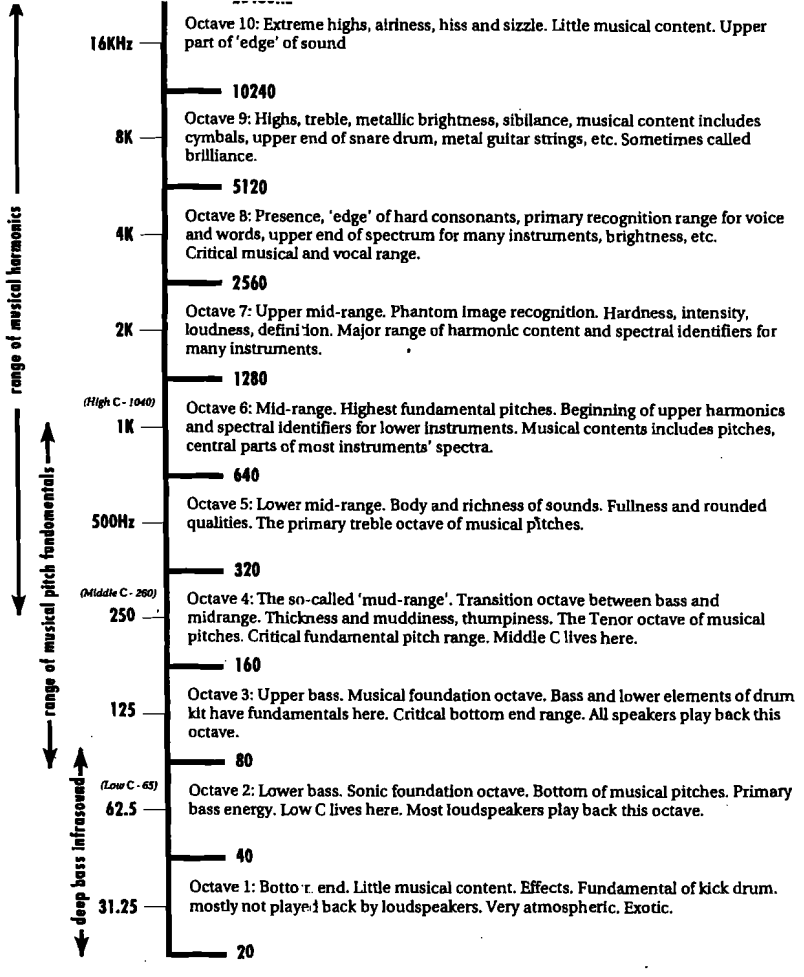
earing the Audio Spectrum

Perfect pitch is a highly developed auditory memory that allows you to identify a given pitch by ear alone. A few people have that memory capability naturally. Most of us can learn it, if we want to. The Golden Ears course does something related to perfect pitch training, in that it teaches and develops your memory for regions of the audible spectrum. Where the musician with perfect pitch can say "That note is an E-flat," you will be able to say, "The treble is boosted by 3 dB at 2.5 KHz" This latter ability turns out to be extremely useful. In essence, it gives you the ability to tune your audio system or recording studio, which can be thought of as a musical instrument.

You will learn to identify the qualities of frequencies throughout the audible spectrum, using pink noise and musical examples. This ability is developed gradually. In Volume 1, you will learn the sound of each of the ten octaves in the spectrum. These are the raw materials of frequency out of which we build music, and each one has its own particular characteristics, quality, and musical significance. In recording, handling these octaves is one of our primary tasks.

On the following page:

The Ten Octaves of the Audio Spectrum. Given both in terms of the ISO center frequencies (on left) and boundary frequencies. Each octave has its own particular qualities, musically, acoustically and psychoacoustically...



Some insights about these octave ranges:

- Various musical functions exist in various different ranges. Octaves 2-5 contain the musical fundamental pitches. Octaves above those contain the overtones that are central to defining timbre for musical sounds.

- Overall apparent loudness is very much a function of how these octaves are treated. This is particularly true for octave 7, which contains the frequencies our ears are most sensitive to.

Later on, we are going to release additional materials you can use to learn to identify (to 3 dB accuracy) the magnitude of a change in level of any octave of the spectrum. This skill will then be extended to 1/3 octave resolution.

Another useful direction we will also offer allows you to practice hearing two different octaves of the spectrum modified simultaneously. When you have mastered this, you will have acquired the fundamental ability to mentally scan the audible spectrum and "hear out" spectral elements by ear. You will begin to be able to hear and identify full equalization curves, not to mention the harmonic structures of individual musical sounds. Finally, you can work on drills involving three spectral regions modified simultaneously!

Volume 1, Disc 1 (Frequencies)

This is the first CD in the Golden Ears Audio Ear Training series of recordings. Drills on this CD involve identifying one-octave bands of pink noise or recorded music that have been boosted or cut using a conventional graphic equalizer. The first 12 drill sets involve only a portion of the audio spectrum, making it easy for you to concentrate on learning the sound of a particular portion of the spectrum. Drill sets 13 and 14 involve the entire audio spectrum.

Answers are given below. I recommend that you go back and re-listen to drills you have done while observing the answers to help you "internalize" the sounds of the various octaves of the spectrum. Please note that Track Cue points occur after the identifying slates and warm-up drills, so that you may select drills at random to test your hearing ability as it develops.

All of us at KIQ Productions gratefully acknowledge and thank the various record companies that have allowed us to use their recorded materials. We urge you to support these companies and buy their records.

Credits

Created and produced by David Moulton
Engineer: Robin Coxe-Yeldham. Assistants: Bill Lee and Dan Ricci
Rights to recorded material granted by:

Boston Skyline Records, Boston, MA
SOL Records, 51 Maxfield Street, West Roxbury, MA 02131 Tel. 617-327-6470
JVC Records, Los Angeles, CA

Drill Set 1 *Lowest five one-octave bands of Pink Noise boosted 12 dB*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	500 Hz	63 Hz	500 Hz	31 Hz	250 Hz	125 Hz	500 Hz	125 Hz	250 Hz	500 Hz

Drill Set 2 *Middle five one-octave bands of Pink Noise boosted 12 dB*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	4 KHz	2 KHz	250 Hz	500 Hz	250 Hz	500 Hz	1 KHz	4 KHz	500 Hz	2 KHz

Drill Set 3 *Highest five one-octave bands of Pink Noise boosted 12 dB*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	1 KHz	8 KHz	2 KHz	8 KHz	4 KHz	8 KHz	1 KHz	16 KHz	2 KHz	1 KHz

Drill Set 4 *(Music: Tom Coster: "Gotcha!!," JVC 2015-2, Band 1.)*
Lowest five one-octave bands of Music boosted 12 dB

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	63 Hz	250 Hz	500 Hz	31 Hz	500 Hz	63 Hz	125 Hz	63 Hz	500 Hz	250 Hz

Drill Set 5 *(Music: Signs of Life: "Signs of Life," SOL Records, Track 1)*
Middle five one-octave bands of Music boosted 12 dB

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	250 Hz	1 KHz	250 Hz	500 Hz	250 Hz	4 KHz	250 Hz	2 KHz	250 Hz	4 KHz

Drill Set 6 *(Music: Alex Acuña and the Unknowns: "Thinking of You," JVC JM-2006-2, Band 1)*
Highest five one-octave bands of Music boosted 12 dB.

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	4 KHz	16 KHz	1 KHz	4 KHz	1 KHz	8 KHz	2 KHz	8 KHz	4 KHz	16 KHz

Drill Set 7

Format: *Lowest five one-octave bands of Pink Noise cut 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	500 Hz	63 Hz	500 Hz	31 Hz	125 Hz	500 Hz	125 Hz	31 Hz	250 Hz	63 Hz

Drill Set 8

Format: *Middle five one-octave bands of Pink Noise cut 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	500 Hz	1 KHz	250 Hz	500 Hz	4 KHz	500 Hz	1 KHz	250 Hz	2 KHz	4 KHz

Drill Set 9

Format: *Highest five one-octave bands of Pink Noise cut 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	4 KHz	16 KHz	1 KHz	2 KHz	4 KHz	8 KHz	1 KHz	16 KHz	8 KHz	16 KHz

Drill Set 10 *(Music: "The Very Best of TRACKS, 1969-1974," BSD 111, Band 1)*

Format: *Lowest five one-octave bands of Music cut 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	250 Hz	63 Hz	500 Hz	63 Hz	125 Hz	250 Hz	125 Hz	250 Hz	63 Hz	500 Hz

Drill Set 11 *(Music: Kevyn Lettau: "Simple Life," JVC 2016-2, Band 1)*

Format: *Middle five one-octave bands of Music cut 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	500 Hz	2 KHz	1 KHz	4 KHz	250 Hz	500 Hz	250 Hz	1 KHz	500 Hz	250 Hz

Drill Set 12 *(Music: Bruno Råberg: "Pentimento," BSD 115, Band 1)*

Format: *Highest five one-octave bands of Music cut 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	8 KHz	16 KHz	4 KHz	8 KHz	2 KHz	4 KHz	16 KHz	4 KHz	2 KHz	4 KHz

Drill Set 13

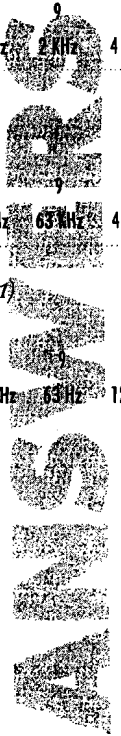
Format: *All ten one-octave bands of Pink Noise boosted 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	31 Hz	16 KHz	1 KHz	2 KHz	63 Hz	4 KHz	31 Hz	4 KHz	63 KHz	4 KHz

Drill Set 14 *(Music: Don Crusin, "Don Crusin," JVC JMI 2010-2, Band 1)*

Format: *All ten one-octave bands of Music boosted 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	16 KHz	4 KHz	63 Hz	500 Hz	8 KHz	4 KHz	500 Hz	16 KHz	63 Hz	125 Hz



Volume 1, Disc 2 (Frequencies contd.)

This is the second CD in the Golden Ears Audio Ear Training series of recordings. Drills on this CD involve identifying one-octave bands of pink noise or recorded music that have been boosted or cut using a conventional graphic equalizer. The first four drill sets each are restricted to either boosting or cutting. The remaining ten sets involve a mixture of boosting and cutting octaves across the entire audio spectrum.

Answers are given below. I recommend that you go back and re-listen to drills you have done while observing the answers to help you "internalize" the sounds of the various octaves of the spectrum. Please note that Track Cue points occur after the identifying slates and warm-up drills, so that you may select drills at random to test your hearing ability as it develops.

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JVC Records, Los Angeles, CA

Drill Set 1

Format: *All ten one-octave bands of Pink Noise boosted 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	16 KHz	125 Hz	8 kHz	125 Hz	500 Hz	16 KHz	4 KHz	31 Hz	250 Hz	31 Hz

Drill Set 2 *(Music: "The Very Best of TRACKS, 1969-1974," BSD 111, Band 2)*

Format: *All ten one-octave bands of Music boosted 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	2 KHz	125 Hz	63 Hz	250 Hz	2 KHz	63 Hz	250 Hz	2 KHz	31 Hz	2 KHz

Drill Set 3

Format: *All ten one-octave bands of Pink Noise cut 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	1 KHz	63 Hz	500 Hz	2 KHz	4 KHz	63 Hz	250 Hz	4 KHz	63 Hz	2 KHz

Drill Set 4 *(Music: Alex Acuña and the Unknowns: "Thinking of You," JVC JML 2006-2, Band 2)*

Format: *All ten one-octave bands of Music cut 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	16 KHz	125 Hz	16 KHz	4 KHz	63 Hz	2 KHz	250 Hz	31 Hz	1 KHz	2 KHz

Drill Set 5

Format: *All ten one-octave bands of Pink Noise boosted (+) or cut (-) 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	+31Hz	+63Hz	–500Hz	+31Hz	–16KHz	+31Hz	–125Hz	+4KHz	–31Hz	–250Hz

Drill Set 6

Format: *All ten one-octave bands of Pink Noise boosted (+) or cut (-) 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	–8KHz	+4KHz	+63Hz	+500Hz	+4KHz	–8KHz	+500Hz	+1KHz	–31Hz	–250Hz

Drill Set 7

Format: *All ten one-octave bands of Pink Noise boosted (+) or cut (-) 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	+16KHz	–16KHz	–31Hz	–4KHz	+500Hz	+8KHz	–4KHz	–63Hz	+2KHz	–4KHz

Drill Set 8 *(Music: Signs of Life: "Signs of Life," SOL Records, Track 2)*

Format: *All ten one-octave bands of Music boosted (+) or cut (-) 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	+8KHz	–4KHz	–500Hz	–2KHz	+16KHz	–16KHz	–250Hz	+63Hz	–31Hz	–8KHz

Drill Set 9 *(Music: Bruno Råberg: "Pentimento," BSD 115, Band 2)*

Format: *All ten one-octave bands of Music boosted (+) or cut (-) 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	+125Hz	+250Hz	–500Hz	+250Hz	–125Hz	+500Hz	+125Hz	–63Hz	–500Hz	–250Hz

Drill Set 10 *(Music: Tom Coster: "Gotcha!!," JVC 2015-2, Band 2.)*

Format: *All ten one-octave bands of Music boosted (+) or cut (-) 12 dB.*

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	+125Hz	+16KHz	–250Hz	+31Hz	+16KHz	–1KHz	–4KHz	+500Hz	+2KHz	+125Hz

Drill Set 11 *(Music: Trio Sonata: "Encore!", BSD 114, Band 1)*

Format: All ten one-octave bands of Music boosted (+) or cut (-) 12 dB.

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	–500Hz	+4KHz	–125Hz	+1KHz	+125Hz	–8KHz	–250Hz	+16KHz	+1KHz	–4KHz

Drill Set 12 *(Music: "The Very Best of TRACKS, 1969-1974," BSD 111, Band 4)*

Format: All ten one-octave bands of Music boosted (+) or cut (-) 12 dB.

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	+500Hz	+125Hz	+1KHz	–500Hz	+8KHz	–125Hz	–500Hz	+2KHz	+63Hz	–8KHz

Drill Set 13 *(Music: Seymour Hayden: "Scarlatti by Hayden", BSD 112, Band 1)*

Format: All ten one-octave bands of Music boosted (+) or cut (-) 12 dB.

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	+125Hz	–125Hz	+250Hz	+125Hz	–500Hz	+4KHz	+500Hz	–31Hz	+8KHz	+63Hz

Drill Set 14 *(Music: Don Grusin, "Don Grusin," JVC JMI 2010–2, Band 8)*

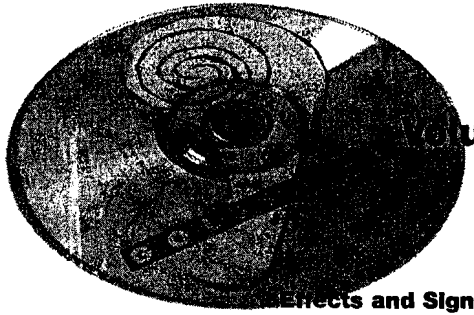
Format: All ten one–octave bands of Music boosted (+) or cut (-) 12 dB.

Example #	1	2	3	4	5	6	7	8	9	10
Answers:	–8KHz	–125Hz	–500Hz	+1KHz	–16KHz	–31Hz	–2KHz	+250Hz	+125Hz	–63Hz

A word about blank answer sheets.

At the back of the book you'll find all the blank answer sheets for the various exercises and drills contained on the CDs. In order to keep this manual to practical proportions we've only provided a handful of each format, so we advise you to rush to Xerox machine and make fistfuls of copies of each type of blank so you won't run out in the course of the program.

If you do run short, fax us at 213/650-2468 and we'll fax or mail some new masters to you.



ume Two

ffects and Signal Processing

The A/B Drills

Each A/B drill set consists of five examples. Each example is a pair of recorded excerpts of music. The first recording (A) is the "reference" and the second (B) is a clone of the first with some sort of signal processing or audio anomaly added. Your task is to identify the signal processing applied to the B recording.

To assist you, we have limited the number of possibilities to a menu of 31 possible signal processing changes, grouped into six families: amplitude change, distortion, compression, equalization, stereophony and time-delay/reverberation. Also, we have included "no change" as an additional answer, just to keep you honest. Instead of a warmup drill, the first half of CD 3 demonstrates all of these effects for you. The balance of CD 3 and all of CD 4 are A/B drills.

The A/B drills are an effort to instill critical listening paranoia in you and to teach you how to hear and identify small differences between two versions of the same recording. This is an absolutely essential skill for certain aspects of record production work. Trust me! You don't want to be the one to explain that you didn't notice that the reverb return on the right channel dropped out in the middle of the third song and that because you didn't notice it you went ahead and OK'd it for a production run of 5,000 CDs. Such explanations are upsetting for all concerned and it is better for your basic life quality if you don't have to be involved in many such explanations, particularly as the person who has to do the explaining!

Doing the Drills

• Calibrate your system. Answer sheet templates are at the end of this chapter and answer sheet templates at the end of the manual.

• Listen to the demonstration examples on CD 1 of Volume 2. There are thirty-one of them, in six families. Go over them until you are quite sure you can hear the differences described. You will probably find some of them quite easy, while others will be a little harder. Devote an entire listening session just to the demonstration examples. It will take between 45 minutes and an hour.

• Then, in your next session, cue up Drill Set 1 on CD 1 (beginning with Track 8). Listen to the five A/B examples. For each example, guess both which family of signal processing was used, and which specific menu item it was. On some examples, only one channel is changed. Guess which channel (note that it doesn't have to be the same as the channel used in the demonstration examples).

• After you have completed the five examples, put the CD player in Pause and skip back to Track 8 (Example 1) again. Listen again to reconsider your answers. Skip back and listen a third time, this time writing down the correct answers. At the end of the drill set, hit pause, and score yourself.

• If you guess everything correctly, including left or right channel, give yourself 20 for the example. If you get the channel wrong but have everything else right, give yourself 15. If you guess the right family of effects but have miss the menu item, give yourself 10. Otherwise, it's the big zippo for you. A perfect score for a drill set is 100. If you guess randomly, you should probably get about 7 points. Typical scores are between 45 and 70.

After you have scored yourself, go back and check out the stuff you got wrong. Listen to the A and B version until you can easily pick out the difference.

• Skip ahead to Track 13, the beginning of Drill Set 2. Listen to the five examples, listen again to check your answers, listen a third time while looking at and writing down the correct answers, score yourself if you like, and resolve the examples you didn't get right.

Two drill sets (ten examples) are enough for any given session.

• Work through the six drill sets on CD 1 and the 12 drill sets on CD 2 of Volume 2. Then, use the random function on CD 2 to really challenge yourself. Each example has its own track number. Press random and then play; listen to the A and B versions, hit pause, and check the track number on the CD player. Look up the answer. If you didn't get it right, go back over the example until you can hear it. Repeat up to ten times each session.

How These Drills Were Made

The A/B drills were created by recording an excerpt to hard disk from a commercial recording about thirty seconds long. This recording (the A version) is cloned and then passed through one of the thirty-odd signal processing possibilities we have included, and then recorded as a second hard disk sound file. This modified clone is then named "B" and assembled with the slates and "A" to create each example in the drill set. Each example uses different music.

Selection of the signal processing was done in two stages, both random. First, the family of change type was selected, including the possibility of "no change." Then, within each family, a particular change was selected. In the case where the selection involved only one of two channels, selection of Left or Right was also random. The only limit I applied was not to allow two "no changes" in a row.

I continued the practice of adding signal processing to the slates, just as a fun kind of distractor. These have no relationship to the actual examples themselves.

Hearing Amplitude

The ability to hear a signal as being louder or softer seems obvious, but given that the louder sound usually seems to sound better, it is essential to know when loudness is the only difference between two signals. That way, you neither fool yourself nor get fooled by some crazed or unethical salesperson. Another possibility I've included here is the gradual change in level. In these examples, the B version starts out identically to the A version, but gradually changes level during the example.

Hearing Distortion

You will learn to recognize THD (Total Harmonic Distortion) in recorded music, in the 10-30% range (pretty gross) and in the 1-10% range (mild). You will probably be surprised to find out that perception of distortion is significantly affected by the music being played, and also by the extent to which harmonic distortion is dependent on level. You also will learn that terms like "10% distortion" are pretty much meaningless on dynamically changing signals, and what we mean to say is something like "the loudest peaks of the recording are probably generating distortion products that are only 20 dB (10% of the amplitude) softer than the peaks themselves."

Hearing Compression

You will learn to recognize the effect of compression on a variety of different signals, and to identify fast and slow compressor release times. This is a fairly difficult area, and probably warrants significant study by itself (another future project). The "musical" impact of compression is a highly variable one, where very slight changes result in dramatically different effects.

Hearing Equalization

You will learn to recognize equalization problems, on either or both channels. This is, of course, related to the spectrum analysis drills you have been doing. For these drills we used on-console equalization rather than a graphic equalizer, and we set controls in ways that we found musically relevant. The details of the individual settings are given in the answer sheets.

Hearing the Stereo Field

You will learn to recognize anomalies in the stereo image consistently (reverse image, mono summation, polarity reversal, and pseudo-stereo). These develop your ability to identify the important and all too frequent errors that appear in our final product: the stereophonic mix. Confidence that you can reliably catch and fix these problems is invaluable.

I generated pseudo-stereo for these examples by using a 10-band graphic equalizer with alternating octaves boosted and cut and the settings of the two channels reversed. The resulting phase shift results in a "phasey" kind of stereo spaciousness.

Hearing Time Domain

You will learn to recognize channel-to-channel time differences over the 1—50 ms. range, and to recognize gated and ungated reverb.

Volume 2, Disc 1 (Effects & Processing)

This is the third CD in the Golden Ears Audio Ear Training series of recordings. Drills on this CD involve identifying signal processing used to change a recording. The first half of the CD involves examples of 31 different possible signal-processing changes used in these examples. The remainder of the CD consists of drill sets of five examples each.

Answers are given below. I recommend that you go back and re-listen to drills you have done while observing the answers to help you "internalize" the sounds of the various octaves of the spectrum. Please note that Track Cue points occur after the identifying slates and warm-up drills, so that you may select drills at random to test your hearing ability as it develops.

All of us at KIQ Productions gratefully acknowledge and thank the various record companies that have allowed us to use their recorded materials. We urge you to support these companies and buy their records.

Credits

Created and produced by David Moulton
Engineer: Robin Coxe-Yeldham.
Assistants: Bill Lee and Dan Ricci
Rights to recorded material granted by:

Boston Skyline Records, Boston, MA
SOL Records, 51 Maxfield Street, West Roxbury, MA 02131 Tel. 617-327-6470
JVC Records, Los Angeles, CA

Examples	Family	Specific Change	Music
Track 1		Introduction	
Track 2	Amplitude	3 dB louder	12
	Amplitude	3 db softer	1
	Amplitude	3 dB atten during sample	11
	Amplitude	3 db boost during sample	5
Track 3	Distortion	gross (10-30%) overload distortion ("clipping")	3
	Distortion	slight (1-3%) overload distortion ("clipping")	14
Track 4	Compression	compression, fast release	13
	Compression	compression, slow release	6
Track 5	Equalization	high frequencies cut	9
	Equalization	high frequencies boosted	14
	Equalization	L or R channel lows boosted 6 dB	10
	Equalization	L or R channel lows cut 6 dB	2
	Equalization	L or R channel lows & highs cut 6 dB	4
	Equalization	mid frequencies boosted 6 dB	7
	Equalization	mid frequencies cut 6 dB	8
	Equalization	L or R channel lows boosted & highs cut 6 dB	12
	Equalization	L or R ch. mids & highs cut 6 dB	1
	Equalization	L or R channel mids boosted & opposite channel highs cut 6 dB	11

Examples	Family	Specific Change	Music
Track 6	Stereo	stereo to mono	5
	Stereo	mono to pseudo-stereo	3
	Stereo	stereo reversed	14
	Stereo	one channel reversed polarity	13
Track 7	Time-delay/Reverb	reverb added	6
	Time-delay/Reverb	reverb deleted	9
	Time-delay/Reverb	gated reverb added	4
	Time-delay/Reverb	gated reverb deleted	9
	Time-delay/Reverb	1 ms. time delay L or R ch.	2
	Time-delay/Reverb	5 ms. time delay L or R ch.	15
	Time-delay/Reverb	15 ms. time delay L ar R ch.	7
	Time-delay/Reverb	30 ms. time delay L or R ch.	8
	Time-delay/Reverb	50 ms. time delay L or R ch.	14
Drill Set 1			
Track 8, Ex 1	Amplitude	3 db softer	12
Track 9, Ex 2	Distortion	slight (1-3%) overload distortion ("clipping")	3
Track 10, Ex 3	Compression	compression, slow release	13
Track 11, Ex 4	Stereo	stereo reversed	14
Track 12, Ex 5	Distortion	gross (10-30%) overload distortion ("clipping")	5

Examples	Family	Specific Change	Music
Drill Set 2			
Track 13, Ex 1	Stereo	one channel reversed polarity	11
Track 14, Ex 2		no change	1
Track 15, Ex 3	Equalization	L channel lows (200 Hz.) boosted & highs (10 K Hz.) cut 6 dB	7
Track 16, Ex 4	Equalization	high frequencies (10 KHz.) cut	6
Track 17, Ex 5	Distortion	slight (1-3%) overload distortion ("clipping")	9
Drill Set 3			
Track 18, Ex 1	Amplitude	3 dB louder	4
Track 19, Ex 2	Stereo	mono to pseudo-stereo	9
Track 20, Ex 3	Distortion	gross (10-30%) overload distortion ("clipping")	15
Track 21, Ex 4	Equalization	L channel lows boosted 6 dB @ 150 Hz.	2
Track 22, Ex 5	Equalization	mid frequencies boosted 6 dB @ 1.5 KHz.	8
Drill Set 4			
Track 23, Ex 1	Equalization	R channel lows boosted 6 dB @ 100 Hz.	2
Track 24, Ex 2	Compression	compression, slow release	15
Track 25, Ex 3	Stereo	one channel reversed polarity	9
Track 26, Ex 4	Amplitude	3 dB louder	4
Track 27, Ex 5	Equalization	mid frequencies boosted 6 dB @ 1.5 KHz.	9

Examples	Family	Specific Change	Music
Drill Set 5			
Track 28, Ex 1		no change	1
Track 29, Ex 2	Equalization	high frequencies cut 6 dB @ 10 KHz.	12
Track 30, Ex 3	Equalization	high frequencies boosted 6 dB @ 10 KHz.	9
Track 31, Ex 4	Stereo	one channel reversed polarity	4
Track 32, Ex 5	Compression	compression, slow release	2
Drill Set 6			
Track 33, Ex 1	Amplitude	3 db boost during sample	8
Track 34, Ex 2	Time delay/Reverb	reverb added	14
Track 35, Ex 3	Amplitude	3 db boost during sample	13
Track 36, Ex 4	Compression	compression, slow release	6
Track 37, Ex 5	Amplitude	3 db softer	7
Track 38	Calibration Data		

(Contd...)

Music Credits:

1	Alex Acuña and the Unknowns: "Thinking of You," JVC JMI 2006-2, JVC Records
2	Oscar Castro-Neves: "Brazilion Scandals", JVC 2018-2, JVC Records
3	Tom Coster: "Gotcha!!," JVC 2015-2, JVC Records
4	Frank Gambale: "Note Worker", JMID 2001, JVC Records
5	Don Grusin, "Don Grusin," JVC JMI 2010-2, JVC Records
6	Kevyn Lettau: "Simple Life," JVC 2016-2, JVC Records
7	Special EFX: "Play", JVC 2017-2, JVC Records, JVC Records
8	Sadao Watanabe, "Morning Island", JMI 2013-2, JVC Records
9	Signs of Life: "Signs of Life," SOL Records
10	Fifth Estate: "Ding Dong! The Witch is Back!", BSD 116, Boston Skyline Records
11	Seymour Hayden: "Scorlatti by Hayden", Boston Skyline Records
12	Bruno Råberg: "Pentimento," BSD 115, Boston Skyline Records
13	"The Very Best of TRACKS, 1969-1974," BSD 111, Boston Skyline Records
14	Trio Sonata, BSD 110, Boston Skyline Records
15	Trio Sonata: "Encore!", BSD 114, Boston Skyline Records

Volume 2, Disc 2 (Effects & Processing)

This is the fourth CD in the Golden Ears Audio Ear Training series of recordings. Drills on this CD involve identifying signal processing used to change a recording.

Answers are given below. I recommend that you go back and re-listen to drills you have done while observing the answers to help you "internalize" the sounds of the various octaves of the spectrum. Please note that Track Cue points occur after the identifying slates and warm-up drills, so that you may select drills at random to test your hearing ability as it develops.

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SOL Records, 51 Maxfield Street, West Roxbury, MA 02131 Tel. 617-327-6470
JVC Records, Los Angeles, CA

Examples	Family	Specific Change	Music
Track 1		Introduction	
Drill Set 1			
Track 2, Ex 1	Amplitude	3 db softer	5
Track 3, Ex 2	Equalization	R ch. lows cut 6 dB @ 200 Hz.	15
Track 4, Ex 3	Compression	compression, fast release	11
Track 5, Ex 4	Time delay/Reverb	15 ms. time delay R channel	3
Track 6, Ex 5	Distortion	slight (1-3%) overload distortion ("clipping")	7
Drill Set 2			
Track 7, Ex 1	Equalization	R ch. lows cut 6 dB @ 200 Hz.	6
Track 8, Ex 2	Distortion	gross (10-30%) overload distortion ("clipping"),	13
Track 9, Ex 3	Stereo	one channel reversed polarity	14
Track 10, Ex 4	Stereo	stereo reversed	8
Track 11, Ex 5	Time delay/Reverb	5 ms. time delay R ch.	2
Drill Set 3			
Track 12, Ex 1	Amplitude	3 db softer	4
Track 13, Ex 2		no change	9
Track 14, Ex 3	Distortion	gross (10-30%) overload distortion ("clipping"),	12
Track 15, Ex 4	Amplitude	3 dB attenuation during sample	1
Track 16, Ex 5	Equalization	mid frequencies cut 6 dB (@ 2KHz.)	5

Examples	Family	Specific Change	Music
Drill Set 4			
Track 17, Ex 1	Amplitude	3 dB louder	15
Track 18, Ex 2	Compression	compression, fast release	11
Track 19, Ex 3		no change	3
Track 20, Ex 4	Compression	compression, slow release	7
Track 21, Ex 5	Stereo	one channel reversed polarity	6
Drill Set 5			
Track 22, Ex 1	Stereo	mono to pseudo-stereo	13
Track 23, Ex 2	Compression	compression, fast release	14
Track 24, Ex 3	Equalization	L ch. lows (200 Hz.) boosted & highs (8 KHz.) cut 6 dB	8
Track 25, Ex 4	Time-delay/Reverb	gated reverb added	2
Track 26, Ex 5	Equalization	L ch. lows boosted 6 d8 @ 200 Hz.	4
Drill Set 6			
Track 27, Ex 1	Distortion	gross (10-30%) overload distortian ("clipping"),	9
Track 28, Ex 2		no chonge	12
Track 29, Ex 3	Stere	stereo to mona	1
Track 30, Ex 4	Amplitud	3 dB louder	5
Track 31, Ex 5	Time-delay/Reverb	reverb added	15

Examples	Family	Specific Change	Music
Drill Set 7			
Track 32, Ex 1	Amplitude	3 dB louder	3
Track 33, Ex 2		no change	11
Track 34, Ex 3	Equilization	mid frequencies cut 6 dB @ 1 KHz.	7
Track 35, Ex 4	Compression	compression, fast release	6
Track 36, Ex 5	Amplitude	3 db softer	13
Drill Set 8			
Track 37, Ex 1	Amplitude	3 db boost during sample	14
Track 38, Ex 2	Distortion	slight (1-3%) overload distortion ("clipping")	8
Track 39, Ex 3	Time-delay/Reverb	15 ms. time delay R ch.	2
Track 40, Ex 4	Stereo	stereo reversed	4
Track 41, Ex 5	Compression	compression, slow release	9
Drill Set 9			
Track 42, Ex 1	Distortion	gross (10-30%) overload distortion ("clipping"),	12
Track 43, Ex 2	Distortion	slight (1-3%) overload distortion ("clipping")	1
Track 44, Ex 3	Stereo	stereo to mono	5
Track 45, Ex 4	Equalization	L ch. mids (1K) boosted & R ch. highs (10K) cut 6 dB	15
Track 46, Ex 5	Distortion	slight (1-3%) overload distortion ("clipping")	5

Examples	Family	Specific Change	Music
Drill Set 10			
Track 47, Ex 1	Amplitude	3 dB louder	11
Track 48, Ex 2	Equalization	R ch. lows boosted 6 dB @ 200 Hz.	7
Track 49, Ex 3	Distortion	slight (1-3%) overload distortion ("clipping")	6
Track 50, Ex 4	Amplitude	3 dB louder	13
Track 51, Ex 5	Amplitude	3 db boost during sample	14
Drill Set 11			
Track 52, Ex 1	Equalization	high frequencies cut 6 dB @ 8 KHz.	8
Track 53, Ex 2	Time-delay/Reverb	15 ms. time delay L ch.	2
Track 54, Ex 3	Equalization	mid frequencies cut 6 dB @ 2 KHz.	4
Track 55, Ex 4	Equalization	R ch. lows boosted 6 dB @ 100 Hz.	9
Track 56, Ex 5	Stereo	stereo reversed	12
Drill Set 12			
Track 57, Ex 1		no change	1
Track 58, Ex 2	Distortion	slight (1-3%) overload distortion ("clipping")	5
Track 59, Ex 3	Stereo	mono to pseudo-stereo	3
Track 60, Ex 4	Time-delay/Reverb	50 ms. time delay R ch.	7
Track 61, Ex 5	Amplitude	3 dB attenuation during sample	6
Track 62	Calibration Data		

Music Credits:

1 Alex Acuña and the Unknowns: "Thinking of You," JVC JMI 2006-2, JVC Records
2 Oscar Castro-Neves: "Brazilian Scandals", JVC 201B-2, JVC Records
3 Tom Coster: "Gotcha!!," JVC 2015-2, JVC Records
4 Frank Gambale: "Note Worker", JMID 2001, JVC Records
5 Dan Grusin, "Don Grusin," JVC JMI 2010-2, JVC Records
6 Kevyn Lettau: "Simple Life," JVC 2016-2, JVC Records
7 Special EFX: "Play", JVC 2017-2, JVC Records, JVC Records
8 Sadao Watanabe, "Morning Island", JMI 2013-2, JVC Records
9 Signs of Life: "Signs of Life," SOL Records
10 Fifth Estate: "Ding Dong! The Witch is Back!", BSD 116, Bostan Skyline Records
11 Seymour Hayden: "Scarlatti by Hayden", Boston Skyline Records
12 Bruno Råberg: "Pentimento," BSD 115, Boston Skyline Records
13 "The Very Best of TRACKS, 1969-1974," BSD 111,-Boston Skyline Records
14 Trio Sonata, BSD 110, Boston Skyline Records
15 Trio Sonata: "Encore!", BSD 114, Boston Skyline Records

Problems, Suggestions and Comments

Over the years there have been several routine comments that students have made about the drills that I would like to discuss in order to ease your mind.

1. "The equalization drills can be tough to hear, especially octaves 1 and 10."

The equalization drills involve all ten octaves of the audio spectrum. Because the examples are chosen at random, the octave centered at 31 Hertz is often involved. What you will soon discover is that most loudspeakers don't do much below 40 Hertz and most recorded music doesn't have much energy down there either. So, such examples are hard (impossible, sometimes) to hear. In keeping with the realities of the real world, that's life. Remember to guess!

2. "The slates are really annoying."

Comments (including some remarkably rude ones), suggest that my slates are a distraction, particularly with the A/B drills. There is a reason: auditory memory fades quickly, and the drills become much easier (too much so, in fact) if the transition from A to B is very quick. Again, real life doesn't work that way: the problems usually occur while two people are talking to you while you eat a hamburger in the doorway of the studio while an automated mix is being made. That's when you need to be able to hear the aforementioned reverb return drop out. So, the slate is intended to serve as a buffer, a distractor, between the two examples.

3. "It's really hard to hear the stereo examples!"

Many of the A/B drills that involve stereo/mono, polarity reversal, change on one channel only, etc. are mainly audible along the median plane and barely audible anywhere else in the room. This is an important lesson to learn. If you sit off to the side of the median plane, you are going to be in trouble.

The median plane (as taught in high school geometry—it had to come in handy sometime) consists of all points equidistant from each speaker. Anything more than a couple of inches off the median plane will do grievous damage to the stereo illusion, particularly for critical listening and stereo audio mixing.

As an audio pro, learn to fight for a seat on the median plane: your career may depend it!

4. "What is The Secret to acing these drills in nothing flat?"

Frankly, I think intuitive guessing (snap off the answer quickly, without thought, as soon as you hear the stimulus) works pretty well, particularly as you gain experience. When pink noise is the signal source, characterizing the octave bands (2 kHz as a leaky steam fitting, 63 Hz as a distant jet engine, for instance) works pretty well. However, this labeling technique has its dangers when you get into program material, because your pet noise characterizations may not align with the instrumental timbres you are listening to. Over the long run, I personally have tried to memorize a sense of "highness" or "lowness" for each octave band, and found this works quite well in real life. If you have a sense of the "sound" of an octave band (and the sound of its absence) firmly fixed in your ear-memory, it is quick work to move into the equalization realm to fix problems during recording sessions.

For the A/B drills, I think you have to hang loose, and let the answers come to you. (How's that for pseudo-Zen?) You do this by relaxing, letting yourself notice that

there is a difference, and then intuitively guessing what the difference is (the most terrifying thing about these drills is that often you can't hear a difference at first). Sure, you'll be wrong a lot, but the trick is to notice that there is a difference. Once you can do that, the rest is fairly easy. Remember, there is no way that you can learn and know all the differences in your mind beforehand by brute intellectual force.

The drills all involve self-scoring, if you care to indulge. Keep in mind that this is not a competition, and just because you score in the high 90's doesn't mean that you have better hearing than some other poor schlumpf. What it means is that you are more effectively recognizing and articulating what you are hearing than you were when you were scoring in the low 80's. So, the drills aren't tests, and the strictly optional scoring is for your own information and critical evaluation.

History of These Drills

I started giving these ear training drills to individual students and small classes in my own recording studio in the early 1970s. The method is based on traditional musical ear training methods that were inflicted on me in music school (Juilliard), but with as much of the terror removed as possible. (Some music schools used to treat ear training as a rite of passage, an initiation-by-humiliation ritual.)

As some of you may know, in traditional music ear-training, students practice hearing and identifying intervals, chords, melodies, rhythms and counterpoint. "Taking dictation" (Gulp!— I still cringe in fear, just thinking about it!) meant listening to the teacher play something and writing it down by ear. The beginning part of this training was simply identifying intervals and chords. It is from that basic practice that I developed these drills. I've found that the terror part of ear-training is not only unnecessary, but actually counterproductive, and that by being friendly and supportive about it my students (that's you, now) progress quickly and enthusiastically.

So, when you do the drills in Volume 1 you will be doing the equivalent of identifying intervals and chords: you will be learning to identify regions of the audio spectrum. Volume 2 includes drills to help you learn to discern signal-processing (I call them A/B drills), and after that there will be increasingly challenging spectrum drills, to a point where you should be able to hear and identify complete equalization settings by ear. That's right, you should be able to listen to an equalizer switched in and out on a recording and describe how the equalizer is set, in terms of frequencies and the amount of boost or cut, by ear alone!

These drills have evolved somewhat over the years, and have achieved a certain amount of renown. National Public Radio has used them as part of the training for their production and engineering personnel, and I have used them in a variety of college programs, including the Music Production and Engineering program at Berklee and the Tonmeister Studies program at the State University of New York, College at Fredonia. In addition, they have been used by faculty at UCLA, New York University, the Danish Acoustical Institute, and NBC. At present, I am developing a full course in critical listening based on these drills for Emerson College in Boston.

There are other people also working on critical listening skills for music and audio. Alton Everest and Tom Rossing have released some excellent auditory demonstration recordings. Their recordings are intended to demonstrate the audible effect of various signal processing operations and psychoacoustic effects. Andresj Miskiewicz, currently at Northeastern University in Boston and formerly at the Chopin Academy in Warsaw, Poland, has developed a wonderful and very powerful curriculum that he calls Auditory Solfege. This is an active ear-training curriculum (you need a teacher and a fair amount of hardware to do it) for recording engineers that involves an elaborate array of exercises and training. After three years of study, you can hear and identify just about everything! Will Moylan, at the University of Massachusetts at Lowell, has developed an auditory skills course that

involves analytical listening and notation of recorded sounds that is generally related to the "taking dictation" part of conventional music ear-training. Check out his book, The Art of Recording: The Creative Resources of Music Production and Audio.

My drills are a series of exercises intended to help you learn how to identify sound characteristics under a wide variety of circumstances, by ear alone. Through practice on drills of increasing levels of difficulty, they allow you to develop hearing skills and the ability to describe sounds to a point fairly close to the limits of auditory discrimination for frequency and amplitude. They are designed for home use, and to be extremely user-friendly. All you really need is a CD player and moderately decent speakers or headphones. After you've gone through and mastered the drills in Volumes 1 and 2, you should be able to describe the response curve of any given system, as well as the control settings on an equalizer, the amount of delay on a time-delay line, and the settings on a compressor or noise gate. Further, you should be able to pick out most regular signal processing with considerable confidence.

This audio ear-training can be fun, in a weird kind of way. You will find that it can easily arouse your competitive instincts, and you may come to delight in impressing your friends at parties with your new-found high-tech vocabulary, as in, "The zither seems to be down two dB at 750 Hz and there's about 4% Total Harmonic Distortion on the second harmony bagpipe track. Oh, and by the way, the mid-range driver on the left speaker is wired out of polarity." However, audio ear training is much more than a game. You really cannot expect to make professional quality music without such skills. Intelligent hearing (AKA Golden Ears) is a basic tool you should have in your bag of audio goodies (next to the red Sharpie, the Etymotic Ear Plugs and the Tylenol).

Objectives of this study

The Ear as an Acoustical Test Measurement Instrument

The human auditory system is a remarkable sensory system, capable of observations and discrimination that equal or exceed all but the most elaborate testing equipment we've been able to build to measure sound. Therefore, it is possible for us to use our hearing as a test instrument, once we figure out how to articulate what it is we are hearing. The ability to accurately describe the physical nature of what we are hearing is a primary objective of the Golden Ears Drills.

Ear Training and Learning

There is also a higher-level "Zen of learning" aspect to all ear-training. Musical sound is generally perceived in the right hemisphere of the brain as "spatial" or holistic patterns, and as such is not generally available to the "verbal" left brain for conscious verbalized description. This is part of the difficulty with ear-training. Although the actual act of perception is fairly easy, it exists in a realm of our consciousness that doesn't have words.

(If you are curious about this right brain/left brain business, check out Tom Blakeslee's excellent book for normal people, The Right Brain.)

Nonetheless, you can certainly learn to describe what you hear, and the ability to effectively articulate audio issues is priceless in our field. The clumsy, inarticulate conversation that takes place among musicians, engineers, and producers, such as "Can you like, make, the guitar a little fluffier, y'know what I mean?" seriously interferes with their creative efforts.

Being Able to Speak Accurately About What You Hear

As you become fluent at this, you will be able to easily note many things about a recording, quickly and apparently effortlessly. You will be able to "hear through" the recording much better, identifying signal processing, level problems, etc. with little trouble.

How Good Can Your Ears Get?

A couple of years ago, a colleague of mine, who likes to complain that he is going deaf in one ear and can't hear anything high in the other, knocked the proposed CBS Copycode scheme (which was allegedly inaudible) right out of the ballpark by identifying it 100% of the time in controlled double-blind tests conducted by the National Bureau of Standards. Once he astounded me by identifying, by brand and model, the side microphone I had used in a middle-side stereo recording I was playing for him, and noting (correctly, as I found out to my chagrin) that it was not functioning to spec! And yes, he has done these drills!

When you get the hang of doing these drills, the stuff you can hear will seem equally magical to others, and your ability to quickly and surely arrive at the sound you need will seem remarkable to them. To you, it will be obvious and intuitive. You will have Golden Ears.

A Few Warnings

The Challenge

Try not to lose self-confidence when working on your Golden Ears. It can be a slow process of learning, and you may occasionally get stuck and feel like you aren't progressing. Stick to it and pace yourself. Just as when you learned to ride a bicycle, you learn this stuff through repeated failures.

Also, I think it is really important to go over this stuff with the answers in hand repeatedly until you are sure you actually can consciously identify the sounds we are studying. You will often get lost, will not be able to hear a change, or will hear something else (a boost in EQ will of course make something louder— the trick is to know that it wasn't just louder, but louder at a specific part of the spectrum). You will get frustrated and tired sometimes. Keep the faith! It's like learning to ride a bicycle!

Getting Lower Scores While You Are Getting Better

The nature of the drills is such that as you progress, the drills get harder. If you bother to score yourself, you may notice that your scores keep getting worse. Don't be discouraged. To use a golf analogy, the drills start out as all Par 3 and progress to being all Par 6! Don't expect to be getting Par 3 scores on Par 6 exercises!

If you need a quick ego boost as you get mired down in some of the more advanced stuff, go back and try the earlier, easier drills. For instance, after you've been trying to guess that B has attenuated 3 dB during the example, you will find that pink noise boosted 12 dB in one octave band is really disgustingly easy.

About Monitors

There is no such thing as a perfect monitoring environment. Because these exercises utilize the entire audible spectrum, weaknesses in your monitoring system will be exposed. This is exacerbated by the fact that you are performing extremely critical listening. The solution here is to simply do your ear training, accepting and compensating in your mind for the apparent frequency response deficiencies introduced by your monitors. In fact, the audio recordings you produce or listen to will be played on countless different systems, many of which are probably inferior to your monitoring set-up. Learning to compensate mentally for deficiencies in the monitoring space is part of training your Golden Ears.

Changing Ears

As you start this drill work, you will notice that your perception of sounds changes. For a while, it may be a little disconcerting, and you should be mentally prepared for this. As you begin to internalize the audible spectrum, you will start hearing everything in terms of octaves. You roll down the car window at seventy (er, fifty-five, I know, I know) and hear Octave 2 (63 Hz) instead of wind buffeting. You tune in a sports event and instead of crowd roar you hear Octave 5 (500 Hz). Instead of a light metallic edge on an acoustic guitar you hear Octave 9 (8 kHz)!

Also, the A/B drills will make you so paranoid about each little nuance that you will start listening to just the spaces between the sounds. For a while, you will find you stop hearing the music and instead hear only the reverb, the sonic detailing, the delays, the release trails and attack pumping of compressors. Whew!

This goes away, sort of, after you have acquired and internalized these Golden Ear skills, so that your original musical focus and subjective enjoyment comes back. But you will also have an added dimension, a hearing acuity that allows you to hear your way into and through the sounds in a way that you never could

before, forever altering your sense of what sound is and can be.

Tarnished Ears?

Do not panic if you find you can not hear above 19,995 Hz Lots of students have come to me in terror because they can't hear some high frequency and are sure their career is over! In fact, the half-octave bout 15 kHz isn't terribly significant musically and isn't played back by all that many audio systems.

We often refer to the audible spectrum as 20 Hz to 20 kHz, but those stated limits are really just convenient values for us to remember. A more functional definition of the useful audible spectrum for music recording might be 40 Hz to 15 kHz In addition, the fact that you are in the audio engineering field at all suggests you have had above average exposure to sound at loud levels (in the studio, attending/working concerts, etc.). So it is possible that you may even have slightly reduced acuity at some frequencies. Additionally, we aren't all born equal. Women, in my experience, seem to have greater sensitivity to high frequencies and to harmonic distortion than men. Individual variances between people are significant as well. Don't worry! Knowing more specifics about what you can and cannot hear will improve your critical listening skills. You can be sure that many of the engineers whose work has sold millions of records have done it with hearing that is physiologically far from perfect. The colleague I mentioned above is a classic example.

Tired Ears

Ah, yes. Tired ears are also tired brains. And when you are tired, you can't hear very well, in a critical listening sense. You can't do these drills for very long, just as you can't expect to work totally creatively and productively for sixteen hours at a stretch. The perceptual job is just too tough, and you've got to accept the limitations of your own particular attention span.

How do you know when you are tired? When louds don't seem loud anymore, and you feel the urge to really crank it up to give you a little shot of adrenaline. We all like to crank it up, of course, but I suggest that you limit it to the occasional recreational abuse, at home. Don't do it as a professional practice.

Another sign that you're getting tired is when you begin to get confused, bored, or impatient, which is nature's way of telling you it's time to stop. Work on this stuff only for as long as you can really focus on it.

In Closing...

As your experience develops, your confidence in recording, mixing, production, and listening sessions will go way up. That's because you can not only hear, but also describe what you hear in physical quantities, saying "the toms are boosted 6 dB at 250 Hertz" instead of "the toms sound tubby," or "the piccolo is down 3 dB at 500 Hertz," instead of "I think the piccolo sounds thin"

This business is really about sound, and this is the best doorway into sound that I know. So don't let the Audio Devils get you. May the Force be with you, and remember, if you can't hear it, it's probably 31 Hertz being cut! Good luck!

Dave Moulton, Groton, MA

PS: *We'd really like to hear from you about these drills. We're open to suggestions, improvements, etc., and would just like to talk to anybody that has bothered to read this far! . Thanks again for your interest.*

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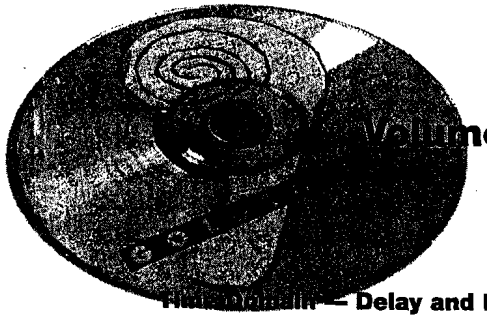
Or call us at:	213/650-2467 (Fax: 213/650-2468)
Or Email to:	kiq@soho.ios.com

Acknowledgments

I'd like to thank a bunch of people for their support. In the beginning, at Dondisound Studios, Greg Becker and Tom Swift gave me a tremendous amount of help. Too many wonderful students to mention by name at SUNY/Fredonia suffered through early versions and gave me much help and guidance (it used to be a weekly ritual— ear training at 6 PM every Monday for the Tonmeister students). At National Public Radio, Skip Pizzi, Neil Muncy, Paul Blakemore, Curt Wittig, Elaine Salazar, Dave Glasser, and Terry Skelton all provided great help and support. At Berklee, I'd like to specially thank Tony Dibartolo, Mark Wolinski, Mark Hutchins, Robin Coxe-Yeldham, Wayne Wadhams, Carl Beatty, and Mitch Benoff, not to mention Alex Hodge and Peter Alhadeff. At Home and Studio Recording Magazine, thanks to Nick Batzdorf for encouraging me to go ahead with this project. And especially, thanks to my wife June, who used to do these drills on the sly out in the office while I was doing classes in the control room at Dondisound, and who has listened to more pink noise than anyone should ever reasonably have to! Thanks again to all of you!

About the author

Dave Moulton has degrees in music from Bard College and the Juilliard School of Music. He has taught music, audio, and acoustics at a variety of colleges, including the State University of New York, College at Fredonia and Berklee College of Music, where he has served as Chair of the Music Production and Engineering Department. He is currently on the faculty at both the University of Massachusetts at Lowell and Emerson College in Boston. During the 1970s he owned and operated Dondisound Studios, a commercial recording facility in upstate New York. He has been active in acoustics and loudspeaker design and shares in several patents pertaining to loudspeakers. He is currently a writer for Recording Magazine, and is completing a book on music recording. Dave is active as a composer and recording engineer.



Delay and Reverb drills

Volume 3 of the Golden Ears Ear Training Drills is devoted to the development of your ability to discriminate time intervals. Specifically, the first CD in the volume focuses on the perception and identification of short delay times, while the second CD focuses on the perception and identification of predelay and reverberation decay times.

There are a couple of very important things to know about our perception of time in sound. The most important thing is that 50 milliseconds (which represents a frequency of 20 Hz.), represents a very important discrimination boundary for us. Multiple events occurring more than 50 ms. apart in time are perceived as separate events, while multiple events occurring less than 50 ms. apart in time are fused into a "single" event, perceptually. So the range of delays between about 30 and 70 ms. is one of the most important ranges to learn to hear. Interestingly, this threshold defines the lowest sinusoidal frequencies we hear, as well as the boundary between perceived still frames and moving pictures (it's no coincidence that the lowest viable frame rate for film is 24 frames per second!).

The second thing to know is that the onset of the precedence, or Haas, effect (where the sound appears to come from the earlier sound source) is about .7 milliseconds. Delays shorter than that are perceived as coming from a point between the two sound sources while delays longer than that are perceived to come from the earlier source, sort of. In practice, delays between .7 and 15 ms. give various localization senses depending on speaker placement, room size, etc.

Finally, you should know that these localization phenomena become timbral phenomena when you sum the delays with the undelayed signal in mono. This difference represents, to me, one of the most fascinating and revealing paradoxes about our listening system. Have fun twisting your mind around trying to understand it!

The reverb drills are designed to help you recognize and identify reverb onset

and decay times, and to be able to predict the emotional and musical impact various times will have on different styles of music.

The amount of predelay determines something about the impact of a sound. The sound "Kaboom" can be thought of as "Boom" with 100 ms. predelay. The secondary punch of the onset of reverb adds great emotional intensity and force to sounds. How much is good? It depends on the music, its tempo, and mood. I've chosen a range (0 - 100 ms.) that straddles the 50 ms. threshold described above. After you've done these drills, you'll have a pretty good handle on your "predelay value system."

Reverb time describes "how long it takes sound to die away." More importantly, sounds that take a long time to die away are "louder longer," which is to say they are more easily heard under the direct or dry sounds while the music is going on. At the same time, different reverberance times have different emotional qualities, and your ability to predict these for any given music are going to make production work much, much easier. I've chosen a range that covers the generally useful range of reverb times: .3 seconds to 5 seconds.

Doing the Delay Drills

As you've done with previous drill sets, get yourself set on the median plane, with answer sheet and pencil at hand and audio system levels set. Start at the beginning, which is a series of demonstration recordings. Play the demonstrations, listening carefully to the impact and sound character of the different delays. There are 35 different delay times, ranging from 0 to 170 milliseconds. These are demonstrated three times: first with a kick drum sound, second with Pink Noise, and finally with a brief phrase of vocal music. As the decay times increase from 0 to 1 ms., the sound will pan from center toward the earlier speaker. From 1 to 20 ms., the sound will hover about the earlier speaker, but will be ambiguous and

change its location with each different delay. Between 20 and 50 ms., the sound will "pull apart" into two separate sounds: the original undelayed sound and its audible echo.

One interesting thing to note and keep in mind is that 30 ms. delay equals one video frame of delay, 60 ms equals 2 frames, etc. If you are working with film sound, learning to recognize these delays is particularly useful.

Take a break, then listen to the demos again in mono. In mono, you will hear the delays manifested as a pitch (this is known as "comb filtering") that gets lower as the delay gets longer. At 50 ms. the delay is so long that the pitch is below audio, and you will hear a clangorous quality on sustained sounds.

I suggest you play the demos over a number of times, listening to them in the background while you are doing other things to get them in your ears. When you feel pretty confident you understand and can hear the various delays in the demonstrations, then go ahead to the drills.

You can start doing the drills either by listening to them while looking at the answers or by guessing the answers. There are four kick drum drills, three Pink Noise Drills, and ten music drills. I recommend you do up to three drills in any given session, but no more unless you're feeling really sharp. These things are tiring, and wear you out in a hurry.

After you take a drill you can score yourself. If you guess the correct delay on an example, give yourself 10 for that example. For each delay interval "off" you are, take away 1, so that if you guessed 10 ms. and the right answer was 20 ms., your score is 7. Total up your scores for all ten examples. A perfect score for a drill set is 100. If you simply wrote down random answers, you should get around 20 points. I expect you should be getting scores of between 70 and 85 once you get the hang of it. In case you hadn't already figured it out, I don't think scores are very important, except as a way for you to chart your progress.

After you've done all the drills, use the random function on your CD player to permit you take these drills over and over. If you get to the point where you have actually memorized all of the drills, you certainly won't need my help anymore!

Once again, remember to limit your study sessions to three or at most four drill sets.

How The Delay Drills Were Made

The delay drills were produced using a truncated kick drum sample, Pink Noise from an Ivie Pink Noise generator, and Compact Disc recordings in a variety of musical styles. Although these drills are pretty close to Fair Use under the copyright law, we have obtained permissions from all owners of the commercially recorded material, and would like to thank them by encouraging you to support them by buying their records. See the credit list for a complete listing of all recordings used.

All examples for all drill sets were recorded onto two channels of an Alesis ADAT recorder. Using the BRC controller, delay offsets for one channel or the other were created as the recordings were recorded to hard disk via Digidesign's Pro Tools for editing and assembly.

I determined delays and channels by the use of a random number generator, with the following limit: I never repeated a delay. I did, however, include No Delay as a possibility. So don't try to anticipate what is going to come next. I wasn't trying to fool you or play mind games.

The slate for each track actually appears at the end of the identifying slate so that you may listen 'blind' to each track.

Doing the Reverb Drills

As above, get yourself set on the median plane, with answer sheet and pencil at hand, and audio system levels set. Start at the beginning, which is a series of

demonstration recordings. Play the demonstrations, listening carefully to the impact and sound character of the different predelay and reverb times. There are six different predelay times, ranging from 0 to 100 milliseconds, and eight different reverb decay times, ranging from .3 seconds to 5 seconds. These are demonstrated three times: first with a kick drum sound, second with a drum machine loop, and finally with a brief phrase of piano music. Each reverb time is demonstrated with all six predelay possibilities.

As with the delay demos, you can listen to the demos repeatedly, and I recommend that you listen to them in the background while you are doing other stuff to get them comfortably in your ears.

You can start doing the drills either by listening to them while looking at the answers or by guessing the answers. There are four kick drum drills, three drum kit Drills, and seven music drills. I recommend you do up to three drills in any given session, but no more unless you're feeling really sharp. These things are tiring and wear you out in a hurry.

After you take a drill you can score yourself. If you guess the correct predelay on an example, give yourself 5; if you correctly guess reverb time, give yourself another 5 for that example. For each predelay interval or reverb time "off" you are, take away 1, so that if you guessed 40 ms. predelay and 1.5 seconds reverb time and the right answer was 20 ms. predelay and 2.5 seconds reverb time, your score is 7. Total up your scores for all ten examples. A perfect score for a drill set is 100. If you simply wrote down random answers, you should get around 20 points. I expect you should be getting scores of between 70 and 85 once you get the hang of it.

After you've done all the drills, use the random function on your CD player to permit you take these drills over and over. If you get to the point where you have actually memorized all of the drills, you are probably way beyond my help!

Once again, remember to limit your sessions to three or, at the most, four drill sets.

How The Reverb Drills Were Made

The reverb drills were produced using a truncated kick drum sample, some drum loops from a Yamaha keyboard, and Compact Disc recordings in a variety of musical styles. Although these drills are pretty close to Fair Use under the copyright law, we have obtained permissions from all owners of the commercially recorded material, and would like to thank them by encouraging you to support them by buying their records. See the credit list for a complete listing of all recordings used.

All examples for all drill sets were recorded onto a hard disk recorder using Digidesign's Pro Tools. They were then sent through a Lexicon NuVerb (using a modified Medium Hall Program with 50% wet mix) and recorded onto DAT. They were subsequently transferred back to Pro Tools for editing and assembly. The commercial recording segments were chosen to minimize the amount of reverb inherent in the recordings. Due to the NuVerb wet/dry mix proportions, such reverb is effectively masked.

I determined predelays and reverb times by the use of a random number generator, with the following limit: I never repeated a setting. So don't try to anticipate what is coming next. I wasn't trying to fool you or play mind games.

The slate for each track actually appears at the end of the identifying slate so that you may listen 'blind' to each track.

Credits:

Written, Produced, and Engineered by:

David Moulton, David Moulton Professional Services, Groton, MA.

Mastered by:

Laurie Flannery, Northeastern Digital Recording, Southborough, MA.

Volume 3 Answers for Delay Time Drills.
All times are in milliseconds. Blank answer sheets in back of book.

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 1	Kick Drum									
Correct Delay	30	2.5	2	50	1.2	100	50	0	3	20
Delayed Channel	R	R	L	R	L	R	L		L	L
DRILL SET 2	Kick Drum									
Correct Delay	0.3	25	0.5	50	2.5	85	25	12	8	85
Delayed Channel	R	L	L	R	L	L	R	R	L	L
DRILL SET 3	Kick Drum									
Correct Delay	25	20	1	0.2	0.1	8	0	50	1.2	7
Delayed Channel	L	L	R	L	R	L		L	R	L
DRILL SET 4	Kick Drum									
Correct Delay	8	40	85	1	0.5	2	100	120	20	25
Delayed Channel	L	L	L	L	R	R	R	R	L	R
DRILL SET 5	Pink Noise									
Correct Delay	0	5	50	85	1.2	50	0.7	25	5	0.8
Delayed Channel		L	R	R	L	R	R	L	R	L
DRILL SET 6	Pink Noise									
Correct Delay	1.2	40	60	0.2	5	0.9	1.2	0.7	12	2
Delayed Channel	L	R	L	L	L	L	R	R	L	R
DRILL SET 7	Pink Noise									
Correct Delay	10	30	10	0.3	100	0.6	60	3	60	2
Delayed Channel	R	R	R	R	R	R	L	R	R	R

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 8	Mixed Music Examples from Credit List									
Correct Delay	0.1	12	50	25	100	30	85	15	10	20
Delayed Channel	L	L	L	R	L	L	R	R	L	L
DRILL SET 9	Mixed Music Examples from Credit List									
Correct Delay	2.5	0.3	25	5	3	20	0	6	0.5	25
Delayed Channel	R	R	L	R	R	R		R	L	L
DRILL SET 10	Mixed Music Examples from Credit List									
Correct Delay	0.7	0.8	6	120	40	0	2.5	120	0.1	50
Delayed Channel	R	L	L	R	L		L	R	R	R
DRILL SET 11	Mixed Music Examples from Credit List									
Correct Delay	3	4	140	7	5	1.2	70	100	0.1	4
Delayed Channel	R	L	R	R	L	L	R	L	R	R
DRILL SET 12	Mixed Music Examples from Credit List									
Correct Delay	3	0.4	20	0.3	0	0.2	8	70	50	30
Delayed Channel	L	R	R	R		L	R	R	R	L
DRILL SET 13	Mixed Music Examples from Credit List									
Correct Delay	2	8	3	40	3	5	85	15	12	0.2
Delayed Channel	R	L	R	R	L	R	L	R	R	R
DRILL SET 14	Mixed Music Examples from Credit List									
Correct Delay	7	0.3	1	120	0.6	5	2	0.1	7	30
Delayed Channel	R	L	L	R	L	L	L	R	L	L

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 15	Mixed Music Examples from Credit List									
Correct Delay	0.6	30	25	7	3	0.3	1.2	0.8	25	10
Delayed Channel	R	R	R	R	R	L	L	L	L	L
DRILL SET 16	Mixed Music Examples from Credit List									
Correct Delay	0.1	30	0.8	85	0.9	20	1.5	1.2	0.2	60
Delayed Channel	L	L	L	R	R	R	L	L	L	L
DRILL SET 17	Mixed Music Examples from Credit List									
Correct Delay	2	0.7	4	1.2	40	3	0.8	85	6	0.7
Delayed Channel	R	L	L	R	L	R	R	R	R	R

Volume 3 Answers for Predelay/Reverb time Drills.
Predelay times are in milliseconds. reverb times are in seconds.

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 1	Kick Drum									
Correct Predelay	80	60	100	60	0	80	20	0	30	80
Correct Reverb	3	1.5	1	1.5	1	0.3	1	3	0.5	2
DRILL SET 2	Kick Drum									
Correct Predelay	80	40	60	0	20	80	80	40	60	40
Correct Reverb	0.75	1	2	5	1.5	0.75	5	3	0.3	5

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 3	Kick Drum									
Correct Predelay	80	100	60	0	20	40	80	100	40	60
Correct Reverb	0.5	0.75	3	1	0.5	0.75	5	2	3	1
DRILL SET 4	Kick Drum									
Correct Predelay	100	0	0	60	100	0	40	80	0	0
Correct Reverb	1	2	0.3	2	0.3	2	5	2	1.5	1
DRILL SET 5	Drum Kit									
Correct Predelay	20	100	0	0	20	80	0	60	0	100
Correct Reverb	0.3	0.75	1	0.5	0.3	5	5	1	1	0.3
DRILL SET 6	Drum Kit									
Correct Predelay	20	60	80	20	40	100	80	20	40	0
Correct Reverb	2	1.5	0.75	0.5	0.75	0.3	5	0.5	3	1.5
DRILL SET 7	Drum Kit									
Correct Predelay	60	40	0	0	60	40	80	0	0	20
Correct Reverb	1	0.5	0.75	5	5	0.75	2	0.3	0.75	3
DRILL SET 8	Drum Kit									
Correct Predelay	100	40	40	40	60	80	100	0	40	80
Correct Reverb	1	5	0.3	0.5	1	0.3	0.3	0.75	2	3
DRILL SET 9	Mixed Music Examples from Credit List									
Correct Predelay	80	100	20	0	20	60	20	100	40	80
Correct Reverb	1.5	2	1	0.75	3	0.3	0.75	5	0.3	0.75

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 10	**Mixed Music Examples from Credit List**									
Correct Predelay	80	40	40	0	20	60	60	80	60	20
Correct Reverb	0.5	2	1	0.75	0.5	3	1.5	0.3	3	3
DRILL SET 11	**Mixed Music Examples from Credit List**									
Correct Predelay	0	100	80	100	100	60	60	60	100	0
Correct Reverb	0.75	1	1	1	0.3	0.5	2	1	0.75	0.75
DRILL SET 12	**Mixed Music Examples from Credit List**									
Correct Predelay	60	20	20	60	100	80	0	100	20	0
Correct Reverb	0.3	3	5	1	1	2	2	1	3	1
DRILL SET 13	**Mixed Music Examples from Credit List**									
Correct Predelay	0	20	80	0	100	60	20	0	60	100
Correct Reverb	0.75	2	0.75	2	2	3	5	5	5	5
DRILL SET 14	**Mixed Music Examples from Credit List**									
Correct Predelay	0	80	80	0	20	0	80	20	0	100
Correct Reverb	0.75	0.3	0.75	0.5	3	0.75	0.75	0.3	2	5

ANSWERS

Volume Four

Master Frequencies — Octave and Dual Octave Drills

Volume 4 of the Golden Ears Ear Training Drills is devoted to the development of your ability to discriminate frequency bands to a sophisticated level. The first CD in the volume focuses on the perception and identification of bands centered about each 1/3 octave of the audio spectrum, while the second CD focuses on the simultaneous perception and identification of two separate octave bands.

1/3 of an octave is roughly equal to the "critical band" of our hearing mechanism, which defines the region within which we can detect only a single sinusoidal tone, so it represents a useful limit of discrimination. If you wish to develop your ability to memorize narrower frequency bands, you are going to have to start working on perfect pitch, which is a different process altogether, one that has comparatively little bearing on audio. Think of it this way: once you can reliably identify any 1/3 octave of the frequency spectrum, you have achieved just about all the spectral sensibility you are ever going to need!

Identifying two octaves at once is a fairly high-level cognitive task, and requires the developed mental ability to consciously "scan," or break into component parts, the audio spectrum. This is the skill you need to be able to equalize sound and predict the sound of any given equalization effectively. When you can successfully hear and identify two octaves at a time, you can easily manage all the various equalization tasks. From there on, it's a matter of refinement, and you probably never can get this skill as finely refined as you'd like. I know I'm still trying to get better, and I've been doing these things since 1970!

Doing the Drills

As you've done with previous drill sets, get yourself set on the median plane with answer sheet and pencil at hand and audio system levels set. Start at the beginning, which is a series of demonstration recordings. Play the demonstrations, listening carefully to the impact and sound character of the different frequency

bands. For the 1/3-Octave drills, there are 27 separate bands that I've arbitrarily separated into groups of low (31 to 315 Hz.), mid (315 to 1250 Hz.) and high (1.6 kHz. to 16 kHz.). These are demonstrated twice: first with pink noise and second with music. For the dual-octave drills, I've simply prepared a demonstration of typical combinations to help you get the idea. It would take entirely too long to demo all possible combinations to be useful.

I suggest you play the demos over a number of times, listening to them in the background while you are doing other things to get them in your ears. When you feel pretty confident you understand and can hear all the frequencies in the demonstrations, then go ahead to the drills.

You can start doing the drills either by listening to them while looking at the answers or by guessing the answers.

For the 1/3 octave drills, the first six drills are pink noise and music drills for low, mid, and high frequency ranges. These are followed by three broadband pink noise and four broadband music drills. For the dual-octave drills, there are three pink noise and seven music drills.

I recommend you do up to three drills in any given session, but no more unless you're feeling really sharp. These things are tiring, and wear you out in a hurry.

After you take a drill you can score yourself.

For the 1/3 octave drills, if you guess the correct 1/3 octave on an example, give yourself 10 for that example. For each 1/3 octave "off" you are, take away .33, so that if you guessed 400 Hz. and the right answer was 1,000 Hz., your score is 8.7. (I apologize for inflicting decimals on you!) If you guess boost or cut incorrectly, take away 2. Total up your scores for all ten examples. A perfect score for a drill set is 100. If you simply wrote down random answers, you should get around 40 points. I expect you should be getting scores of between 75 and 90 once you get the hang of it.

For the dual-octave drills, give yourself 5 for each octave band you guess correctly. Take away 2 for incorrectly guessing boost or cut. Take away 1 for each octave "off" you are. Give yourself the "best possible" score, and never give yourself a negative score. A perfect score is 100. If you guessed randomly, you should get around 40 points. I expect you should get between 70 and 85.

In case you hadn't already figured it out, I don't think scores are very important, except as a way for you to chart your progress.

After you've done all the drills, use the random function on your CD player to permit you take these drills over and over. If you get to the point where you have actually memorized all of the drills, you certainly won't need my help anymore!

Once again, remember to limit your study sessions to three or at most four drill sets.

How The Drills Were Made

Pink Noise and Music examples were recorded using Digidesign Sound Designer II. Using the Waves Q10 parametric equalizer working on a loop, I switched the appropriate frequency bands in and out while recording the loop to DAT. For the 1/3 octave drills, I set the Q at 7, and for the dual-octave drills I set the Q at 4. These give bandwidths slightly wider than 1/3 and one octave respectively, and mercifully make the examples easier to hear.

I then transferred the DAT recordings to Digidesign Pro Tools for editing and assembly, and after that was done created a master DAT from the Pro Tools file.

I determined frequencies and boost/cut by the use of a random number generator, with the following limits:

– for the 1/3 octave drills; I never repeated a setting and I never used No Change.

– for the dual-octave drills, I always treated two octaves, I never boosted and cut the same octave, and I never boosted one octave and cut an adjacent one. So, don't

try to anticipate what is coming next. I wasn't trying to fool you or play mind games.

The slate for each track actually appears at the end of the identifying slate so that you may listen 'blind' to each track.

Good Luck!

Credits:

Written, Produced and Engineered by:

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Mastered by:

Laurie Flannery, Northeastern Digital Recording, Southborough, MA.

Volume 4 Answers for 1/3-octave Drills. Answers with no sign have been boosted. Answers with a minus (-) sign have been cut. The number refers to the center frequency of the 1/3 octave band.

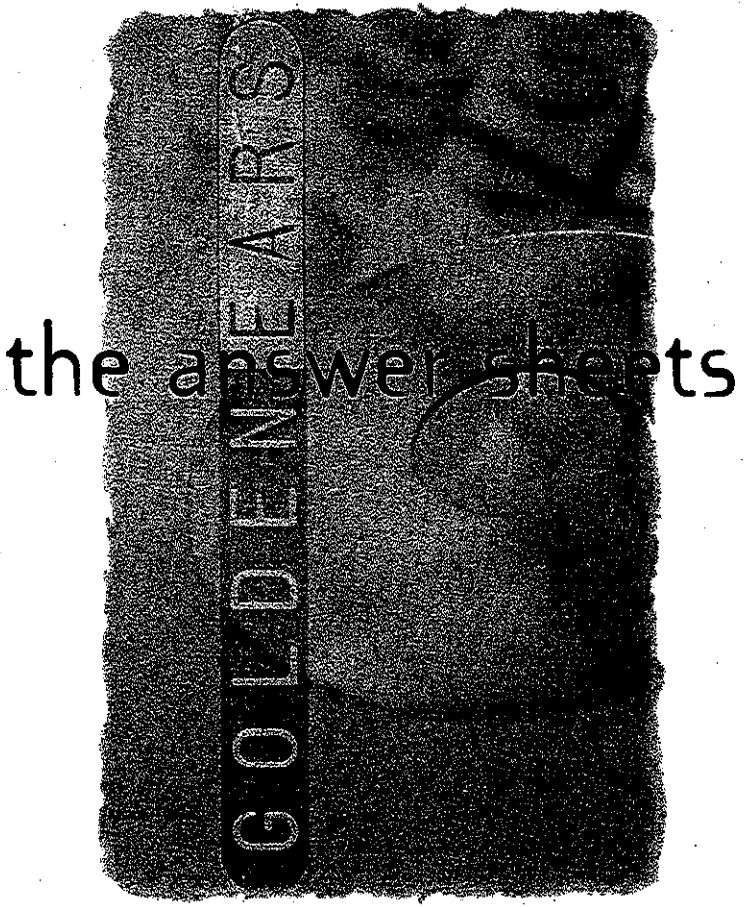
Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 1	Pink Noise, Low Frequencies									
correct answer:	-100	200	-250	40	-80	-315	160	-200	-80	50
DRILL SET 2	Pink Noise, Mid Frequencies									
correct answer:	2.5K	1.6K	-800	800	-1K	2K	-500	1K	-315	-2.5K
DRILL SET 3	Pink Noise, High Frequencies									
correct answer:	8K	-5K	-12.5K	-2K	-3.15K	6.3K	1.6K	10K	-3.15K	2K
DRILL SET 4	Music (Tom Coster), Low Frequencies									
correct answer:	-40	-160	-63	250	40	-100	-200	315	50	125
DRILL SET 5	Music (Signs of Life), Mid Frequencies									
correct answer:	800	400	1.25K	-800	630	1K	-630	500	1.6K	-1K
DRILL SET 6	Music (Alex Acuña), High Frequencies									
correct answer:	-2.5K	-2K	6.3K	3.15K	-4K	8K	-12.5K	-3.15K	-10K	16K
DRILL SET 7	Broadband Pink Noise									
correct answer:	500	250	31	-40	1K	-31	400	-630	-12.5K	63

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 8	Broadband Pink Noise									
correct answer:	-160	8K	12.5K	-160	2K	160	500	1K	-250	400
DRILL SET 9	Broadband Pink Noise									
correct answer:	800	-400	-125	-12.5K	-1K	-400	-16K	-80	400	-250
DRILL SET 10	Broadband Music (Tracks)									
correct answer:	-250	200	63	125	-100	-800	-1.6K	-160	1.25K	3.15K
DRILL SET 11	Broadband Music (Kevyn Lettau)									
correct answer:	-4K	-3.15K	-10K	-50	80	2.5K	31	-500	-31	6.3K
DRILL SET 12	Broadband Music (Pentimento)									
correct answer:	315	630	1K	-12.5K	5K	-160	200	500	63	-50
DRILL SET 13	Broadband Music (Don Grusin)									
correct answer:	-31	-16K	-125	-400	100	-315	200	-12.5K	-3.15K	125
DRILL SET 14	Broadband Music (Scarlatti by Hayden)									
correct answer:	500	125	-6.3K	1.6K	40	16K	-315	1.25K	-800	80

Volume 4 Answers for dual-octave drills. Answers with no sign have been boosted. Answers with a minus (-) sign have been cut. Numbers refer to the center frequencies of the octave bands.

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 1	Pink Noise									
correct answer:	–500	–8K	–8K	16K	4K	–8K	–16K	1K	–16K	8K
correct answer:	–63	31	–500	125	1K	–63	–4K	–63	–1K	–2K
DRILL SET 2	Pink Noise									
correct answer:	16K	500	–16K	–16K	16K	250	–16K	2K	–500	–1K
correct answer:	500	–125	2K	31	–4K	125	–31	–250	–250	125
DRILL SET 3	Pink Noise									
correct answer:	–16K	2K	–63	–4K	63	–1K	–8K	1K	–8K	1K
correct answer:	500	–63	–31	31	31	250	–1K	500	–500	125
DRILL SET 4	Music (Kevyn Lettau)									
correct answer:	1K	–8K	–500	–4K	4K	–1K	–8K	–8K	1K	4K
correct answer:	–63	–63	125	–1K	2K	250	63	2K	–125	–125
DRILL SET 5	Music (Don Grusin)									
correct answer:	–16K	–8K	16K	4K	–16K	250	–16K	–1K	16K	–2K
correct answer:	63	500	–500	1K	–250	31	–4K	–1K	–63	–250
DRILL SET 6	Music (Pentimento)									
correct answer:	500	4K	16K	–4K	–1K	–16K	8K	4K	1K	–2K
correct answer:	–125	–125	–2K	63	–63	125	–63	–31	–250	500

Ex. #	1	2	3	4	5	6	7	8	9	10
DRILL SET 7	Music (Scarlatti by Hayden)									
correct answer:	1K	–500	1K	4K	1K	–250	–4K	16K	–1K	4K
correct answer:	–31	125	31	1K	–250	–125	500	63	–31	2K
DRILL SET 8	Music (Tracks)									
correct answer:	2K	250	1K	125	250	–16K	4K	8K	–2K	8K
correct answer:	63	–63	–31	31	63	–125	125	125	125	1K
DRILL SET	9Music (Tom Coster)									
correct answer:	–2K	1K	–16K	250	2K	–2K	2K	–16K	250	4K
correct answer:	–500	125	125	–31	250	–500	–250	–2K	125	1K
DRILL SET 10	Music (Trio Sonata)									
correct answer:	16K	–250	–8K	2K	16K	–2K	16K	–8K	8K	1K
correct answer:	4K	63	–31	125	–1K	500	125	–1K	1K	–63
DRILL SET 11	Music (Signs of Life)									
correct answer:	4K	–500	–1K	16K	–1K	4K	16K	–2K	–8K	2K
correct answer:	63	125	63	–1K	125	–31	–63	500	–125	–125
DRILL SET 12	Music (Watanabe)									
correct answer:	16K	–4K	1K	–16K	–8K	–250	–8K	4K	1K	–4K
correct answer:	63	–63	–63	–8K	–1K	63	1K	–63	–63	–1K



Golden Ears Volume 1, Frequencies answer sheets

Drill: Boost or Cut Pink Noise or Music 12 dB

Instructions

After a warmup demo, you will hear 10 examples of pink noise or music being boosted or cut in 1-octave bands by 12 dB. You guess which octave is being boosted or cut. Answer in the row labeled "Your answer."

Enter the correct answer in the next row. Score according to instructions.

Add your scores up for Total.

Be sure to indicate whether each example is boosted or cut, as well as which octave is involved.

The following pages are templates—you should make many Xerox copies before you start...

Reference guide to octaves and frequencies:

Octave	1	2	3	4	5	6	7	8	9	10
Ctr. Freq.	32	63	125	250	500	1000	2000	4000	8000	16000
Range	20-40	40-80	80-160	160-320	320-640	640-1.25K	1.25-2.5K	2.5-5K	5-10K	10-20K

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Volume 2, Effects & Processing — A/B drills **reference guide**

Score 10 points for each correct family
Score 10 points for each correct identification of A/B difference
Take 5 points off for guessing the wrong channel

FAMILY	ACTUAL A/B CHANGE
Amplitude	3 dB louder
Amplitude	3 db softer
Amplitude	3 dB attenuation during sample
Amplitude	3 db boost during sample
Distortion	gross (10-30%) overload dist.
Distortion	slight (1-3%) overload distortion
Compression	compression, fast release
Compression	compression, slow release
Time-delay/Reverb	reverb added
Time-delay/Reverb	reverb deleted
Time-delay/Reverb	gated reverb added
Time-delay/Reverb	gated reverb deleted
Time-delay/Reverb	1 ms. time delay L or R ch.
Time-delay/Reverb	5 ms. time delay L or R ch.
Time-delay/Reverb	15 ms. time delay L or R ch.
Time-delay/Reverb	30 ms. time delay L or R ch.
Time-delay/Reverb	50 ms. time delay L or R ch.

FAMILY	ACTUAL A/B CHANGE
Equalization	high frequencies cut
Equalization	high frequencies boosted
Equalization	L or R channel lows boosted 6 dB
Equalization	L or R channel lows cut 6 dB
Equalization	L or R channel lows & highs cut 6 dB
Equalization	mid frequencies boosted 6 dB
Equalization	mid frequencies cut 6 dB
Equalization	L or R channel lows boosted & highs cut 6 dB
Equalization	L or R ch. mids & highs cut 6 dB
Equalization	L or R channel mids boosted & opposite channel highs cut 6 dB
Stereo	stereo to mono
Stereo	mono to pseudo-stereo
Stereo	stereo reversed

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

*Name*____________________________

Track	Guessed family	Guessed specific change	Correct family	Correct specific change	Score
				Total score:	

Volume 3 Drill Answer Sheets

Drill: Delay Left or Right Channel by between 0 and 170 milliseconds.

Instructions

You will hear 10 examples of Kick Drum, Pink Noise or Stereophonic Music with either Left or Right channel being delayed by up to 170 ms.

You guess the amount of delay and which channel is delayed.
Answer in the row labeled "Your ans."
Enter the correct answer in the next row.
Score according to instructions.
Add your scores up for Total.

You should also do these drills with the channels summed to mono, and just guess the amount of delay.

As always, you'll need lots of these answer sheets so copy freely...

Reference guide to delay times used, in milliseconds

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	1.2	1.5	2	2.5	3	4	5	6	7
8	10	12	15	20	25	30	40	50	60
85	100	120	140	170					

Drill Set# ________

Example #	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ________

Example #	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ________

Example #	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ________

Example #	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ________

Example #	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ________

Example #	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ________

Example #	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ________

Example #	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Volume 3 Answer Sheet for Predelay and Reverb Drills.

Predelays from 0-100 ms. and Reverb decay times from .3 to 5 seconds.

Instructions

You will hear 10 examples of Kick Drum, Drum Kit (machine) or Stereophonic Music with reverb added.

You guess the predelay and and reverb times.
Answer in the row labeled "Your ans."
Enter the correct answer in the next row.
Score according to instructions.
Add your scores up for Total.

Reference guide to times used:
predelay (in milliseconds) and reverb decay (in seconds)

Predelay	0	20	40	60	80	100				
Reverb decay,	0.3	0.5	0.75	1	1.2	1.5	2	2.5	3	5

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Predelay											
Reverb time											
Correct predelay											
Correct reverb time											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Predelay											
Reverb time											
Correct predelay											
Correct reverb time											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Predelay											
Reverb time											
Correct predelay											
Correct reverb time											Total score:
Score:											

Volume 3 - Predelay and reverb times

Drill Set# __________

Example#	1	2	3	4	5	6	7	8	9	10	
Predelay											
Reverb time											
Correct predelay											
Correct reverb time											Total score:
Score:											

Drill Set# __________

Example#	1	2	3	4	5	6	7	8	9	10	
Predelay											
Reverb time											
Correct predelay											
Correct reverb time											Total score:
Score:											

Drill Set# __________

Example#	1	2	3	4	5	6	7	8	9	10	
Predelay											
Reverb time											
Correct predelay											
Correct reverb time											Total score:
Score:											

Volume 4 Answer Sheet for 1/3-octave drills

Boost or Cut Pink Noise or Music by 15 dB

Instructions

You will hear 10 examples of Pink Noise or Music being boosted or cut in 1/3-octave bands by 15 dB. You guess which 1/3 octave band is being boosted or cut.
Answer in the row labeled "Your ans."
Enter the correct answer in the next row.
Score according to instructions.
Add your scores up for Total.
Be sure to indicate whether each example is boosted or cut, as well as which 1/3 octave is involved.

Reference guide to octaves and frequencies.

Note that the 25 Hz. and 20 kHz. bands are never used in the drills.

Octave Range	1	2	3	4	5	6	7	8	9	10
Center Freq.		50	100	200	400	800	1600	3150	6300	12500
Range		44-56	89-111	178-222	356-445	712-890	1.4-1.8K	2.8-3.6K	5.6-7.1K	11-14K
Center Freq.	32	63	125	250	500	1000	2000	4000	8000	16000
Range	28-36	56-71	111-142	222-280	445-561	890-1100	1.8-2.2K	3.6-4.5K	7.1-8.9K	14-18K
Center Freq.	40	80	160	315	630	1250	2500	5000	10000	
Range	36-44	71-89	142-178	280-356	561-712	1.1-1.4K	2.2-2.8K	4.5-5.6K	8.9-11.1	

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer:											
Correct answer:											Total score:
Score:											

Golden Ears Ear Training Drill Answer Sheet for dual octave Drills

Boost or Cut Pink Noise or Music 12 dB in 2 simultaneous bands.

Instructions:

You will hear 10 examples of Pink Noise or Music being boosted or cut in two simultaneous 1-octave bands by 12 dB.

You guess which octaves are being boosted and/or cut.
Answer in the rows labeled "Your ans."
Enter the correct answers in the next two rows.
Score according to instructions.
Add your scores up for Total.

Be sure to indicate whether each example is boosted or cut, as well as which octave is involved.

Reference guide to octaves and frequencies

Octave	1	2	3	4	5	6	7	8	9	10
Ctr. Freq.	32	63	125	250	500	1000	2000	4000	8000	16000
Range	20-40	40-80	80-160	160-320	320-640	640-1.25K	1.25-2.5K	2.5-5K	5-10K	10-20K

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer A											
Your answer B											
Correct answer A											
Correct answer B											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer A											
Your answer B											
Correct answer A											
Correct answer B											Total score:
Score:											

Drill Set# ______

Example#	1	2	3	4	5	6	7	8	9	10	
Your answer A											
Your answer B											
Correct answer A											
Correct answer B											Total score:
Score:											