Sound Reinforcement for Designers
Detailed Course Outline

Listen, Measure, Predict

"Listen, measure, predict... it's the mantra of the sound system designer." Sound system design is a three-legged stool. It combines several disciplines that are equally important to the process. We need to train our ear-brain system to listen critically to loudspeakers and rooms. We need to measure to understand what we are listening to. Measurement provides an objective reference for the subjective process of listening. It teaches us what is "good" or "bad" regarding sound reinforcement. Ultimately we will use this understanding to design sound systems - predicting at the drawing board how a loudspeaker will perform in a given acoustic environment.

This overview lesson establishes the link between listening, measuring and predicting, and how they form a circular approach to the sound system design process.   pb

Three video clips covering these topics.

1. Introduction
2. A System Design Process
3. On-Site Evaluation
4. Measurements
5. The Room Impulse Response - RIR
6. Sculpting the RIR
7. Listen-Measure-Predict
8. Listening by Convolution
9. Classical Methods vs. Room Modeling
10. Listening by Auralization
11. The Most Important Tools Is YOU!
12. Conclusion

Sound Fields in Enclosed Spaces

Rooms are like snowflakes. There are no two alike. Yet, we need a common verbiage and set of definitions for the sound fields that develop within them.

The acoustic environment that the loudspeaker is placed into has as much to do with how it sounds as the loudspeaker itself. Subtract the room out of the equation and all loudspeakers are intelligible. Add it back in, and only some of them are. This lesson is a crash course in room acoustics, but presented in relevance to sound system design. It forms a language useful for describing the influence of the room on the listening process. It defines the "ingredients" that ultimately determine the sound quality of a system.

Three video clips covering these topics.

1. It's About Time
2. Room Acoustics
3. The Impulse Response
4. Post-Processing the RIR

5. Absorption
6. Scattering
7. Wave Behavior
8. The Direct Field
9. Early Reflections
10. Late Reflections
11. Reverberation
12. Conclusion

Acoustic Measures

For most humans, the listening process is so natural that we do not consider its complexities and subtleties. It is largely subjective, since the human ear/brain system is neither calibrated nor consistent. Yet there are times when we must quantify what is being heard. In the past century a number of "measures" for room evaluation have been developed. In recent years they have been Standardized and are supported by all the mainstream acoustics measurement programs. These measures add an objective element to the subjective process of listening.

"I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be."

[Lord Kelvin, PLA, vol. 1, "Electrical Units of Measurement", 1883-05-03]

Three video clips covering these topics.

1. Introduction
2. Schroeder Integration
3. Decay Time Measures
4. Early-Decay Time - EDT
5. Clarity
6. Measurement Software
7. Conclusion

Software Tools for System Designers

I've always been a sort of instrumentation junkie. It began with the purchase of a $12,000 TEF analyzer in the 1980's. Since then I have owned about every major acoustics measurement platform that has been developed. One thing I have learned on this journey is that it is not about the platform - it's about the data. Ultimately what all the platforms are doing is collecting the Room Impulse Response (RIR). They all give you the same RIR if used correctly.

In this lesson, I'll show you how to get the RIR without even taking a computer into the space. This frees you to think, wander and listen. When you find a spot for which you want the RIR, you make a simple recording, which later can be processed into the RIR. Your measurement software of choice will not be able to distinguish it from one that it has collected. I have used this process to measure rooms all over the world, from the Taj Mahal in India, to the Sydney Opera House, to the Smithsonian Institution.

The tools presented here are either free or dirt cheap. The site time required is minimal. You can now efficiently measure every space. - pb

Three video clips covering these topics.

1. Acoustic Measurement Platform
2. Wave Editor
3. Software Convolver
4. Scoring the RIR
5. RIRs from Sweep Recordings
6. Practice Makes Perfect!

Loudspeaker Directivity

By nature most people gravitate to the on-axis position to listen to a loudspeaker. Some might even wander a bit left and right to assess the coverage. Sound system designers need to consider the sound coming from the loudspeaker at all angles, as this is what ultimately determines the direct-to-reverberant sound ratio at a listener position.

In this lesson I will describe loudspeaker directivity, from how it is measured, to how it is presented, to how it is used by the sound system designer. Terms like "Q" and "DI" will become part of your system design language. Once you know the required directivity for a design approach, you can wade through the makes and models of loudspeakers in the marketplace that qualify. - pb

Four video clips covering these topics.

1. Introduction
2. Sound Power
3. Sound Intensity
4. Sound Pressure
5. A Reference Case
6. Growing and Shaping the Sphere
7. Directivity Index and Directivity Factor
8. Directivity at a Point
9. Spherical Loudspeaker Data
10. Rated Coverage Angles
11. Data Presentation

Large Room Acoustics

This is the lesson where it all comes together. We've learned about loudspeaker directivity. We've learned about the sound fields that it produces in an enclosed space. We are now ready to predict the direct-to-reverberant ratio for a listen in the room. This is the single most important step of the design process, as it allows us to evaluate system performance at the drawing board.

The concepts may seem cumbersome at first, but you will find that they are actually quite intuitive. You will be able to walk into a room and by listening alone, know how to improve the intelligibility or clarity of the system. By crunching some numbers, you can determine which variables to wiggle to make the system work. - pb

Three video clips covering these topics.

1. Overview
2. Distance Variables and Initial Assumptions
3. What is a Large Room?
4. Hopkins-Stryker
5. A More Useful Form
6. The Equation in Motion - LD
7. The Reverberant Field Level
8. Critical Distance
9. Intelligent Compromise

Speech Intelligibility

Ironically, a sound system can sound good for music and be unintelligible. It can sound bad for music, and be highly intelligible. The reasons why are not necessarily intuitive. They must be learned.

If you want to really set yourself apart from the competition, learn how to design intelligible sound systems. As most eventually learn by experience, there is more to it than simply hanging some loudspeakers in a room. In this lesson you will learn what factors are important regarding speech intelligibility, and even how to measure it. - pb

Two video clips covering these topics.

1. Introduction
2. Speech System Requirements
3. Speech Intelligibility Measures
4. The Room Impulse Response and STI
5. Hand-Held Instruments
6. Conclusion

Putting it all together

We've covered many principles and practices. Let's walk through the whole process of determining the direct-to-reverberant ratio at a listener position. This lesson shows how to put some numbers to the listening process, and effectively "connect the dots" between room acoustics, loudspeaker directivity and the listener.

Ultimately you want to know how far you can cut into a reverberant field with a given loudspeaker directivity, while accounting for the effect of using multiple loudspeakers in the space. The included calculation program will allow you to create countless scenarios that will form your understanding of why systems work, or why they don't.

Three video clips covering these topics.

1. Intelligibility Calculator
2. The Objective
3. A Walk Through the Equation - LD
4. A Walk Through the Equation - LR
5. Changing the Variables

6. The Signal-to-Noise Ratio
7. Conclusion

An Acoustical Site Survey

The site survey provides the "Listen" and "Measure" parts to our mantra - Listen, Measure, Predict. But taking loudspeakers into a room to evaluate it takes time, and costs money. I've spent a lot of years refining the process so that I can get in and out with minimal gear, and have the data I need to initiate the design process. In this lesson I will go step-by-step, describing the gear and procedures used to quickly and accurately evaluate a room. This will provide arrows for your quiver. You can decide which to use on a case-by-case basis. - pb

Three video clips covering these topics.

1. Introduction
2. Sound Sources
3. Microphones
4. A Backup Plan
5. Site Overview
6. Direct-to-Reverberant Demonstration
7. Measurement Position Selection
8. Placing the Microphone
9. The Data
10. STI-PA Measurements
11. Advanced Techniques
12. Going Out With A Bang

Merging Measurement and Design

Room acoustics predictions can be fickle. What "should" happen and what "does" happen are often two very different things. The accuracy of performance predictions can be greatly improved by refining the model using some measured data. In this course I've presented methods that dramatically speed up the room measurement process. The same efficiency increase can be realized in the modeling process, once you establish a meaningful hierarchy for your efforts.

In this lesson I will go through the whole process for an actual space, using measured data to build a meaningful room model that can be used to try your design ideas. pb

Three video clips covering these topics.

1. Overview
2. 3D Surface Model
3. Places Source and Listeners
4. Refine the Model From Measured Data
5. Design the System
6. Conclusion

Final Exam