

## Getting Started with Smart® v7: Basic Setup and Measurement

This guide is an introduction to the basic measurement and operational concepts embodied in Rational Acoustics' Smart® v7. While in no way an exhaustive study, this document serves as a starting point for users to familiarize themselves with the fundamentals of Smart's single- and dual-channel capabilities, and provide instruction in the configuration and operation of basic measurement setups.

Regardless of past measurement experience with previous versions of Smart, or other analysis systems, users should take the time to familiarize themselves with the process of ***Configuring Smart v7 for Measurement*** detailed in this document. Unlike previous versions which assumed a simple two-channel I/O, Smart v7 can interface with multiple I/O devices simultaneously, each with multiple input and output channels. Accordingly, Smart v7 makes no assumptions about a user's measurement requirements and upon first run, begins its operation un-configured. As in previous versions however, following initial setup, Smart retains its measurement configuration for subsequent sessions.

*Please note: in the case of the free/public demo version of the software, the Smart measurement configuration is **not** retained from session to session, and must be rebuilt for each new session. Consider it practice.*

This guide assumes a reader with a basic understanding of professional audio equipment and engineering practices. It concludes with a list of recommended additional sources of information where users can further their understanding of these concepts.

*Rational Acoustics LLC is **not** responsible for damage to your equipment resulting from improper use of this product. Be sure that you understand and observe proper input and output levels, impedances and wiring conventions of all system components before attempting any of the measurements described in this document.*

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## Getting Started: Loading and Licensing the Software

To install Smaart v7 on a computer, the user runs the Windows installer (for Windows OS's) or drags the software application bundle into your applications folder (Mac OS's). For full registration and update information, refer to the Smaart Licensing and Installation section of the Rational Acoustics web site:

[http://www.rationalacoustics.com/pages/Smaart\\_Registration\\_FAQs](http://www.rationalacoustics.com/pages/Smaart_Registration_FAQs)

### Recommended Computer Hardware

While Smaart v7 will operate on a wide range of computer hardware configurations, we recommend the following minimum computer configuration for new installations:

#### Windows®

**Operating System:** Microsoft XP, Vista or Windows 7 (32 & 64 - bit)

**CPU:** 2 GHz Dual-Core Intel Processor or faster (or compatible)

**RAM:** 2 GB or greater

**Video:** Graphics processor with 128 M dedicated video RAM, minimum 1024 x 600 pixel display

**Sound Hardware:** Audio Hardware with OS compatible ASIO, Wav/WDM drivers.

#### Macintosh

**Operating System:** Mac OSX 10.5, 10.6, 10.7, or 10.8 (Leopard, Snow Leopard, Lion, Mountain Lion)

**CPU:** 2 GHz Dual-Core Intel Processor or faster (or compatible)

**RAM:** 2 GB or greater

**Video:** Graphics processor with 128 M dedicated video RAM, minimum 1024 x 600 pixel display

**Sound Hardware:** Audio Hardware with OS compatible CoreAudio drivers.

### Registering the Software

Following initial installation, on first run of the software, the user is presented with an activation screen containing that computer's 14-digit "**Machine ID**" and is asked for an "**Activation Code**" to authorize this installation. This Machine ID is a unique code that identifies that computer. Likewise, the Activation Code is a unique code that will only work for the computer with that Machine ID (much the same as SmaartLive v5's PIC).

If the installation is on a computer that is connected to the internet, the user can choose the "Activate Online Now" option to acquire the necessary code and activate the installation. Otherwise, the user should make note of the Machine ID and access Smaart's licensing system at <http://my.RationalAcoustics.com> via another computer to acquire the necessary code to activate this installation.

In either case, the user must enter their Smaart v7 license number (20 alpha-numeric characters: XXXXX-XXXXX-XXXXX-XXXXX), and the password for the user account to which the license is registered. The Smaart v7 license number must be entered exactly as shown, with dashes and capitalization. If the Smaart v7 License has not yet been registered to a user account, the user must first either create a new account and password, or choose an existing account to register it to (i.e. your Smaart v6 license account.) Each license of Smaart v7 allows for two installations of the software. Users may purchase additional installations for any license by contacting Rational Acoustics or authorized representative.

*Note: Smaart software is licensed to a single “user” – defined as either a single person or company. All software installations for a given license must be performed upon computers owned by that user.*

## Fundamental Concepts

Depending upon the application, operating Smaart effectively requires a working understanding of wide range of system measurement concepts and professional audio engineering practices. While it is outside the scope of this document to cover them all, this section highlights a few critical concepts that will significantly assist in understanding Smaart v7's operation and its application.

This document includes an appendices which has a list of recommended additional sources of information where users can further their understanding of these concepts.

### Single-Channel vs. Dual-Channel Measurements

In its essence, Smaart performs two distinct types of measurement: single-channel (signal analysis) and dual-channel (response analysis).

Single channel measurements examine a signal at single point in a system, and could best be described as signal analysis measurements. These operations quantify aspects like signal level and frequency content, and appear in Smaart as Spectrum (RTA and Spectrograph) and SPL measurements. With single-channel, the user acquires a signal via an electrical probe (signal split) or an acoustical probe (microphone), and examines the content of that signal directly. Single-channel methods provide an absolute measurement, and help to answer an engineer's questions like “how much 1 kHz energy is in that signal?” “what is that frequency?” or “what is the SPL at this place in the venue?”.

Dual-channel measurements compare two signals in order to examine the relationship between them. In Smaart's implementations, we compare the input signal of a system (reference) to its corresponding output signal (measurement) to examine what the system is doing to the signals that pass through it. These could best be described as system response measurements, and in Smaart, we rely on dual-channel methods to measure both a system's frequency response (transfer function) and impulse response. Dual-channel methods provide a relative measurement (input vs. output), and help to answer questions like “what is the

crossover frequency in our system” “how much boost/cut?” or “when is the energy from my main speaker arriving at the mic?”

Both types of measurement, single- and dual-channel, are extremely powerful tools for the audio engineer who understands their individual strengths and weaknesses – who understand what they are measuring, and just as importantly, what they are not. Far too often, bad decisions when using an analyzer are the result of engineers confusing/conflating these measurement types.

In Smaart v7, the measurement process begins with the “group” configuration process where we dictate what single-channel (Spectrum) and dual-channel (Response) measurements we wish to use.

### **Time and Frequency Domain Analysis**

A basic understanding of the relative strengths and differences between Time and Frequency Domain analysis is critical to leveraging the measurement power presented in Smaart. As problem solving engineers, the ability to examine a measurement from multiple perspectives (domains) is extremely useful in the process of analyzing a signal or system response. Each of Smaart v7’s primary modes of operation (Real-Time and Impulse Analysis) include both Time and Frequency Domain measurement views.

Time Domain analysis refers examining our signals and system response over time. A time domain plot (amplitude vs. time) of a signal provides a view of the wave form – a critical view for sound editors. A time domain view of a system response (impulse response) shows the signal delay through the system, and whether any late arriving multiples of the signal (reflections / reverberence) are present.

Frequency Domain analysis refers to examining our signals and system responses over frequency. A frequency domain plot (amplitude vs frequency) of a signal provides a view of its spectrum – an extremely helpful view when identifying tonal content or looking for feedback. A frequency domain view of system response (transfer function or frequency response) provides an excellent look at the tonal response of a system as well as its time/phase response by frequency.

In the figure below, an excellent example of the power of utilizing both time and frequency domain views for examining system response is clearly displayed. The Frequency Response measurement depicts a response with a series of linearly spaced dips and peaks in its magnitude trace (lower trace). However that ripple is the symptom - the cause of this ripple can be clearly seen in the Time Domain view of the system response – an obvious second arrival in the impulse response is the source of the comb filter ripple seen in frequency domain.

## Time Domain vs. Freq. Domain

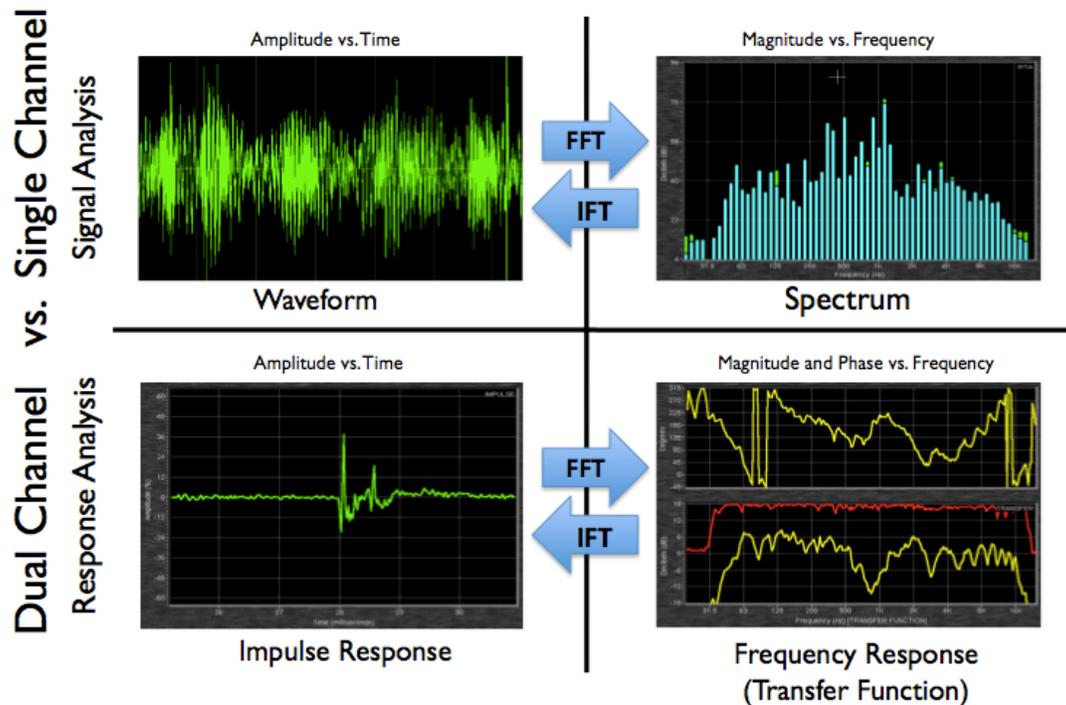


Figure 1: Dual-Channel vs. Single-Channel Measurements in Time Domain vs. Frequency Domain

### FFTs

Smaart uses Fast Fourier Transforms (FFTs) and Inverse Fourier Transforms (IFTs) to translate data between Time domain and Frequency domain views. In effect, an FFT takes a section of a Time domain waveform and provides the frequency content of that selected piece of signal. While a rigorous understanding of this mathematical processes is not required to operate Smaart, it is useful to appreciate the inversely proportional relationship between data in the two domains, where  $\text{Frequency Resolution} = 1 / \text{Time Constant}$  ( $\text{FR} = 1/\text{TC}$ ). In other words, to increase the resolution of spectrum data, one must use larger time slices of the input signal.

Of particular note here is Smaart v7's default FFT setting for Transfer Function measurements, MTW (Multi-Time Window.) Instead of using one FFT of a single fixed length, MTW uses multiple FFTs of decreasing length with increasing frequency. This efficient process provides transfer function data with a consistent resolution of greater than 48<sup>th</sup> octave above 60 Hz with a coherence function that is increasingly sensitive to late reflective data in the higher frequencies. The figure below shows a comparison of the same transfer function measurement made with MTW vs. a single 16k FFT settings. Notice that MTW FFT has better resolution in the LF while the 16k trace has excess resolution in the HF.

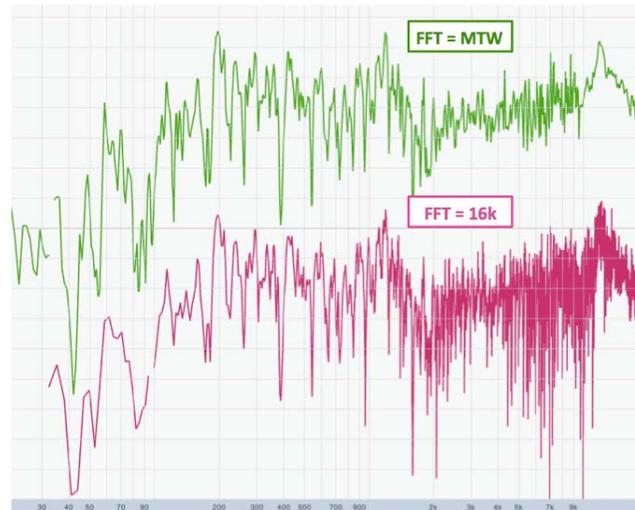


Figure 2: Transfer Functions - MTW vs. Single 16k FFT

For more information on this subject, an in-depth treatment of FFTs can be found in the SmartLive® TechNote “FFT Fundamentals.”

### Smart v7’s Object-Oriented Program Architecture

One of the most powerful aspects of the new Smart v7 platform is its object-oriented program architecture. Effectively, the program is built of many individual code modules that are run as independent, inter-related programs (objects). Data acquisition is handled by the input module(s), single-channel and dual-channel measurements are handled by individual spectrum and response objects, and the graphing and GUI (graphic user interface) are their own separate objects as well.

This architecture creates a measurement environment that easily scalable to a user’s individual requirements. In effect, you can run as many simultaneous single-channel (spectrum) and dual-channel (response) measurements as your PC and audio I/O (Input / Output) hardware will allow.

This also means that Smart’s measurement plots are separate objects from the data they graph. The immediate benefit of this relationship is the user’s ability to change display parameters (smoothing, banding, spectrograph range, coherence blanking, trace color) on the fly without having to recalculate/re-measure the data for the new display parameters.

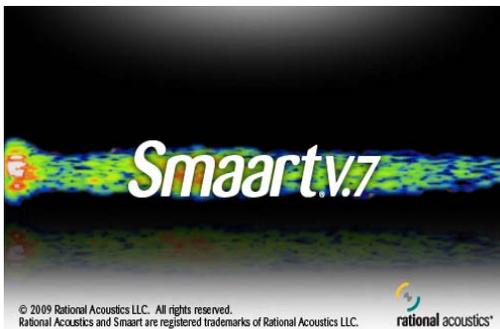
### Configuring Smart v7 for Measurements

The measurement process with Smart v7 begins with the configuration of single-channel (spectrum) and dual-channel (response) measurements. This section details the process and functions involved in configuring the software for measurement.

Unlike previous versions of the software which assumed a simple two-channel I/O, Smart v7 can interface with multiple I/O devices, each with multiple input and output channels. Accordingly, Smart v7 makes no assumptions about a user's I/O capabilities and measurement requirements, and so upon first run, begins its initial operation un-configured. As in previous versions however, following initial setup, Smart retains its measurement configuration for subsequent sessions.

*Note: in the case of the free/public demo version of the software, Smart's measurement configuration is not retained from session to session, and must be rebuilt for each new session.*

Smart v7 is able to acquire input signals from any devices with WAVE, CoreAudio, or ASIO drivers that are recognizable by the computer's Operating System (OS). In fact, it can grab multiple signals from multiple sources **simultaneously**. (Note: only one ASIO source can be accessed at a time)



When Smart v7 starts, the user is presented with this splash screen. While this is displayed, Smart checks to see what I/O devices are available to your OS. It is here that Smart builds its list of input devices, and once a device has been discovered, it will continue to show up for configuration in subsequent runs – even if it is not connected at later start ups.

*Note: While an I/O device may show up in Smart's list of configurable devices, it must be connected to your computer at the time of startup to be accessible during program run time.*

### Configuring Audio I/O Devices

While this configuration is not required to use devices in creating and performing measurements, I/O device(s) can be “configured” by the user in the Audio Device Options dialog. This configuration comprises of adjusting Smart's global sample rate and bit depth settings (all devices must use the same settings), and assigning the specific device and its channels “friendly names” - names that help users identify signals and devices as they configure their individual measurements. Additionally, devices can be “ignored”, which hides them from other

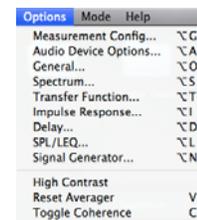


Figure 3: Options Menu  
10 | Page

dialogs within Smart, or removed entirely from the list of devices.

By selecting a device and clicking the “Settings” button, the user is brought to a screen where individual inputs can be calibrated or assigned a Microphone Correction Curve (either provided by the microphone manufacturer or custom made by the user in the form of a tab delimited text file).

The “Audio Device Options” dialogue is accessed via the “Options Menu” or by using the hot key command [Opt + A] (“Hot Keys” are Smart’s built-in, keyboard-based commands).

### Options: Audio I/O dialog

- Users can “ignore” entire devices, temporarily removing them from other device lists in Smart
- User can assign “friendly names” to the devices and individual channels.
- Users can view the status of a loaded device (OK=Connect, N/C=Not Connected)

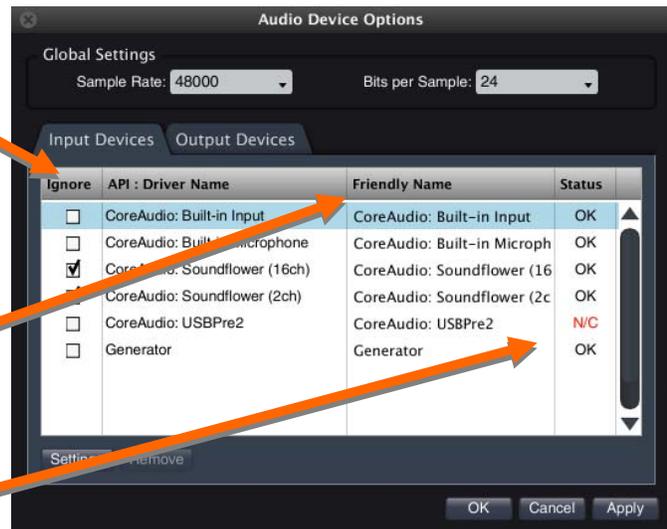


Figure 4: Options – Audio Device Options

*Note: Remember to press [enter] after typing friendly names, or they will not be retained.*

### Configuring Measurement Groups

To perform measurements with Smart v7, a user must construct their measurement configuration. This is accomplished in the “Measurement Config” Options Dialog which is accessed either via “Options Menu”, by using the hot key command [Opt + G], or by clicking on the Measurement Config button located in the measurement controls area of the user interface. Remember, instead of a fixed measurement topology, Smart v7’s object-oriented architecture allows a user to configure as many single-channel (Spectrum) and dual-channel (Response) measurement objects as they wish from the audio I/O channels available. Moreover, these measurements can be run either individually or



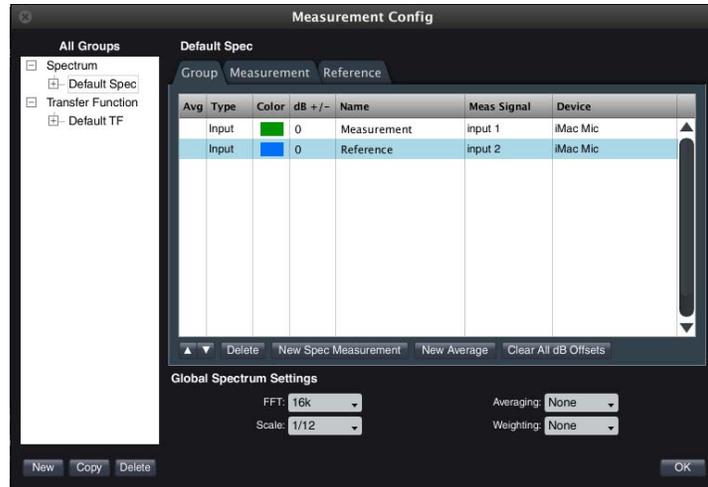
Figure 5: Measurement Config Button

simultaneously, depending upon the user’s requirements.

From the Measurement Config Dialog, a user defines their measurement objects and organizes them into groups.

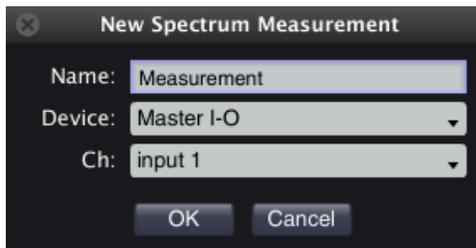
The left side of this dialog is dedicated to a “tree view” of the measurement configuration. Here, one views/creates/copies/deletes Spectrum and Transfer Function groups and views the individual measurements assigned to each.

This tree also acts as the navigation/selector for the “Group Tab View” on the left side of this screen.

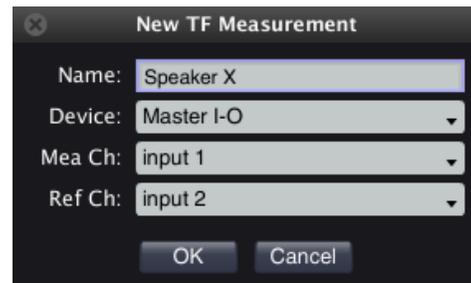


**Figure 6: The Measurement Config Dialog - a powerful interface for configuring, controlling and adapting our measurement system.**

Once a group has been created, a user can select it from the tree and add a measurement to the group by clicking on the “New Spectrum Measurement” or “New TF Measurement” button.



**Figure 7: New Spec Measurement Button - creates a new single-channel measurement.**

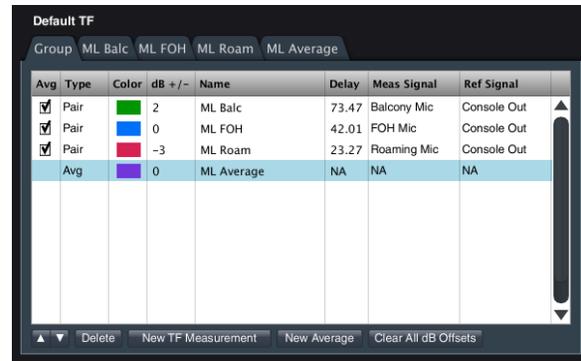


**Figure 8: New TF Measurement - creates a new dual-channel measurement object.**

When configuring a new single-channel measurement within a Spectrum group, the user selects the desired I/O device and input channel. When configuring a new dual-channel measurement within a Transfer Function group, the user selects the desired I/O device and a “measurement” and a “reference” channel for that object. In both cases, the drop-down menus will show “friendly names” for the device and input channels that were configured for that device.

From the “Tab View” section of the Measurement Config dialog, a user can organize each measurement group; adjust the order that each appears in on the main UI, change the selected input signals, set/change the name and color for each trace, and configure live “Average” measurements (using the “New Average” button.) Live Averages are measurements which are calculated from averages of other active measurements in that group.

Each measurement object configured in the Measurement Config dialog is basically a complete Smart measurement engine in itself - each with its own definable set of measurement parameters. Consequently, each object in the group has its own “Tab” in this view where users can address those individual measurement parameters if required. The global and individual control of measurement parameters from within the Measurement Config shall be covered in more detail for each type of measurement later in this document.



**Figure 8: Group Tab View section of the Measurement Config dialog showing live average setup**

*Note: While it is relatively easy to configure and simultaneously run multiple Transfer Function measurements, it is **HIGHLY** recommended that new (and even experienced) users start with simple configurations and build up slowly as they get used to managing multiple simultaneous measurements.*

## The Smart v7 GUI (Graphical User Interface)

This section provides a basic tour of the Smart v7 user interface and reviews its primary navigational tools and concepts. As the feature set and functionality of v7 expands, this will always be an area of continual enhancement, however, the standard layouts, navigation tools and paradigms detailed here will still persist.

### Operation Modes

Smart operates in two distinct measurement modes: Real-Time and Impulse Response. While both modes have the ability to actively measure and display frequency domain and time domain data, the fundamental distinction between these modes is their operational focus. Real-Time mode is designed as an environment for efficiently measuring and capturing spectrum and transfer function measurements –

often in multiples – specifically optimized for in-situ system alignment and mix engineering work. Impulse Response mode is designed to provide a robust and intuitive set of tools for measuring and examining the acoustical response of systems and environments. Smart v7's Impulse Response mode has been significantly expanded from past versions (and will continue to expand) to include much of the functionality from the Smart AcousticTools software package.

### GUI Overviews

The general layout of the GUI for Real-Time and Impulse Response modes:



Figure 10: The Smart v7 Interface - Real-Time Mode

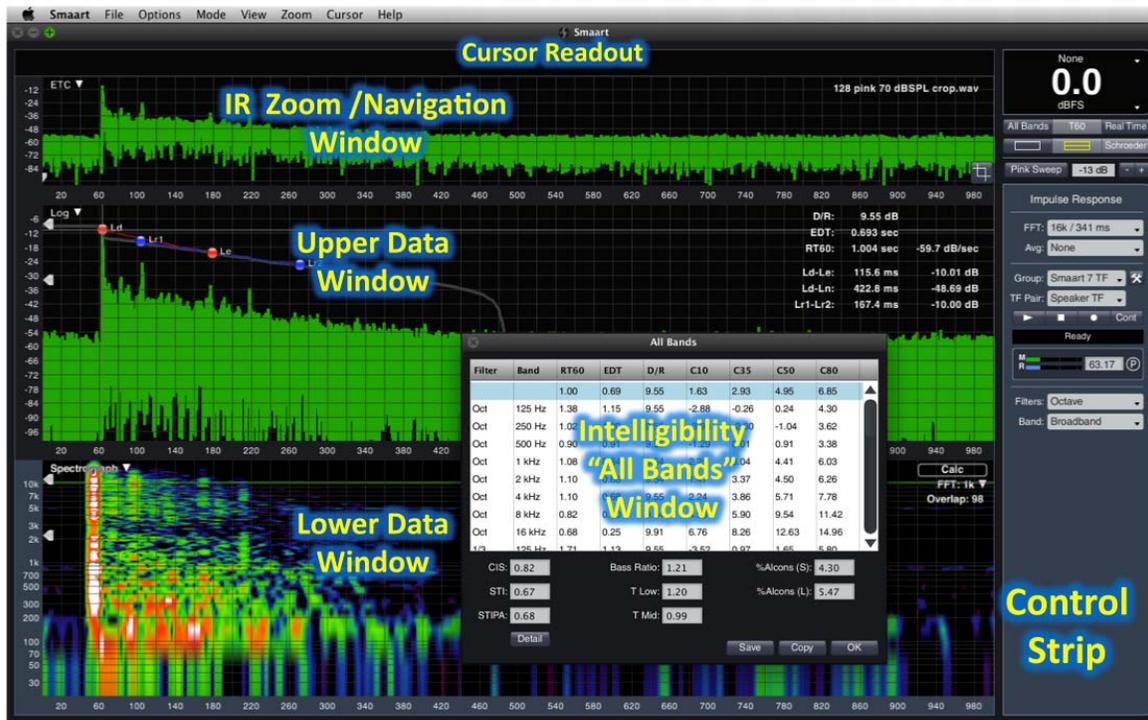


Figure 11: The Smart v7 User Interface - Impulse Analysis Mode

Each mode contains a “Control Strip” on the right side of the interface, and the Real-Time mode includes a Data Storage area on its left side. The majority of each mode’s GUI however is dedicated to the plot area. The uppermost portion of this section is devoted to a cursor read out that displays the coordinates of the mouse cursor in amplitude, frequency or time units, depending on the chart type, when the mouse cursor is positioned over any of the main data plots. The cursor read out can also be configured to display Wavelength or Note ID from the General tab of the Options dialogue.

### Navigation

There are three basic elements in navigating, controlling and configuring Smart v7: GUI via mouse controls, menus/option dialogs, and hotkeys. In most cases, there are multiple ways of controlling the same function – this is particularly important for use cases where one method is preferable over another (e.g. a user operating on a tablet computer where keyboard control are not convenient.) A complete, current listing of the hotkey functions is always available in the software’s help files.

That said, Smart v7’s GUI is built for mouse-based control as its primary interaction mode – either through buttons and data fields in the control strip and data areas, or through “click and drag” controls in the data plot areas. Many of the various controls for each mode will be covered in the specific sections of this document that deal with the specific measurement types. Here however, we will cover the controls that deal specifically with measurement and mode selection, and view control.

### Measurement Selection:

In the data windows for both modes, the user can select the measurement/plot type that is displayed in each window by selecting a drop-down menu from the plot type label in the upper left corner of the plot. Additionally, specific measurement traces can be quickly pulled to the front of the plot from the drop-down menu on the upper-right corner of the plot.

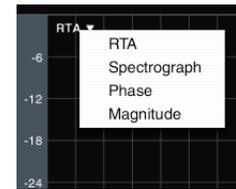


Figure 12: Plot Type Selection for Real-Time Mode, Frequency Domain Data Windows

### Window Layout Selection:

Layout selector buttons in the control strip set the number of data windows (1 or 2) and in the case of Transfer Function displays, toggle display of the optional live impulse response (Live IR) display. When operating with a split display, one of the two main charts is considered the active, or selected chart. If two RTA, Magnitude, or Phase windows are being displayed, each measurement can be assigned to the preferred plot from the appropriate Measurement Config tab. The color of the margins surrounding the plot indicates which of the two is currently selected.



Figure 13: Window Layout Buttons for Real-Time Mode

*Note: The Control Strip and Data Storage areas in the Real Time Mode always correspond with the active data window measurement type.*

Directly above the Window Layout buttons in the Real-Time Mode are two buttons that recall standard, pre-set measurement views. The “Spectrum” button displays a single plot window with “RTA” as the chosen data type. The “Transfer” buttons switches to a two-window display with Phase displayed in the upper window and Magnitude in the lower.

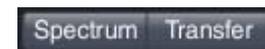


Figure 14: Pre-Set Views

### Mode Selection:

Users can toggle between measurement modes using either the Mode buttons in the control strip, via the “Mode” menu, or by using the [I] and [R] hot keys.

### Zooming:

Users can zoom in *any* of the data windows by using a “rubber band” zoom by either holding [command] + (left button) clicking and dragging, or (right button) clicking and dragging a zoom area on the plot. Frequently-used zoom ranges can be defined in the Zoom Options dialog, and assigned to a hotkey for fast access.

*Note: Clicking on the X (horizontal) or Y (vertical) axis of any data plot will reset its zoom ranges to default.*

## Spectrum Measurements

Smaart’s single-channel Spectrum measurements allow a user to examine the spectral content of audio signals throughout their system. These measurements are extremely useful in many applications, including the location of feedback frequencies in sound reinforcement, noise and sound exposure measurements, cinema system optimization, as well as general signal monitoring tasks.

Data from Smaart’s Spectrum measurements are viewable as a standard RTA (Real Time Analyzer) plots, or graphed over time in a three-dimensional (level vs. frequency vs. time) Spectrograph plot.

## Spectrum Controls

Once configured, individual Spectrum measurements appear as elements in the Spectrum control strip. Here, the user can choose which measurements to actively run , monitor the input level of the signal, and show/hide the trace.

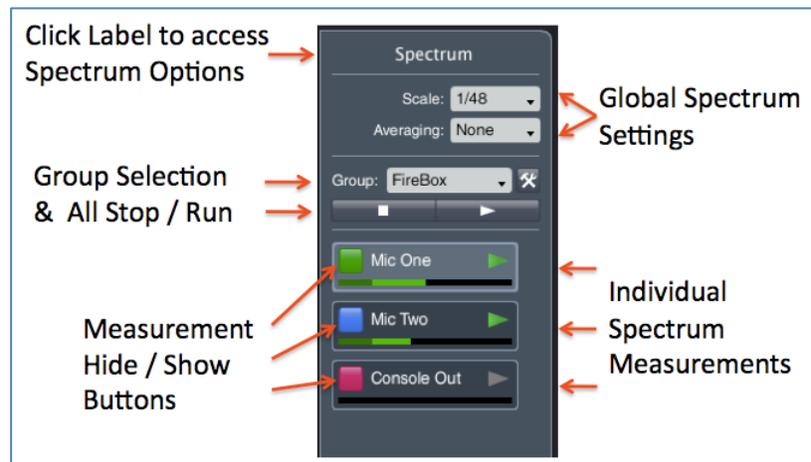


Figure 15: Spectrum Control Strip

## Global Spectrum Settings:

By default, all Spectrum objects use the same global, user-configurable measurement and display parameters (FFT, Averaging, Weighting and Scale). The global Scale and Averaging settings can be adjusted directly from the Spectrum Control Strip, while all global settings can be addressed in the Measurement Config dialog.

Moreover, Averaging and Weighting can set separately for each measurement (if desired) in the individual measurement’s tab in the Measurement Config controls.



Figure 16: Global Spectrum Settings from Measurement Config

## RTA

The real-time analyzer, or RTA, is a familiar tool to audio professionals. By adjusting the scale and averaging, a user is able refine their measurement’s resolution and responsiveness to fit the task at hand.

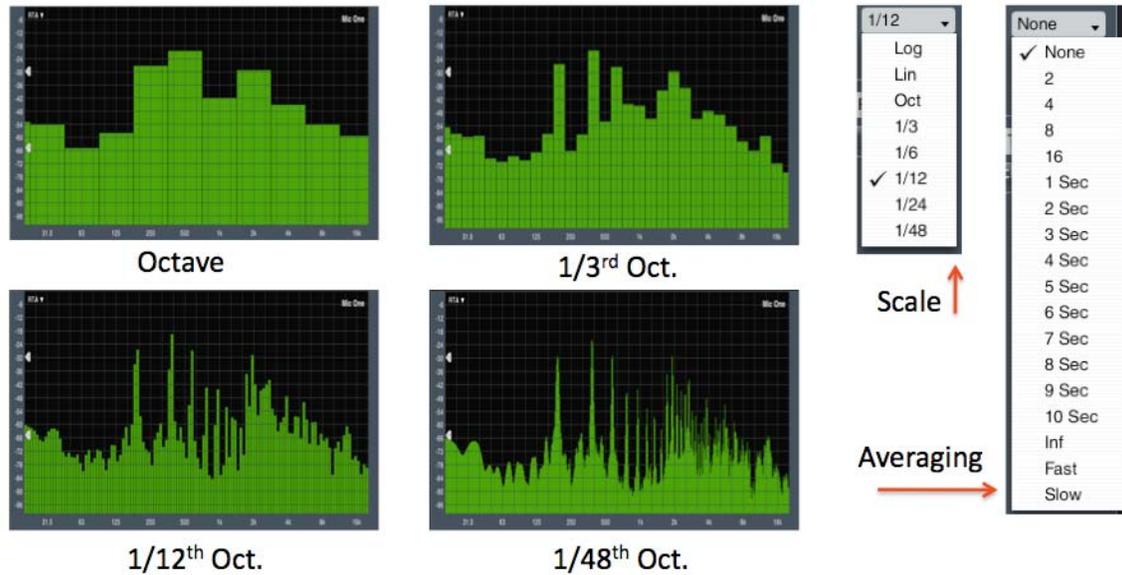


Figure 17: Spectrum RTA - Scale and Averaging Adjust

### Spectrograph

While the RTA has historically been, by far, the most commonly used view of a Spectrum for professional audio engineers, another way of displaying this data is extremely illuminating and has been commonly applied for years in the fields of voice recognition, vibration analysis and underwater acoustics (on submarines). Smart's Spectrograph display (or Spectrogram, as it is more generally known) is a plot of a signal's spectrum over time. This hybrid display graphs a continuous series of Spectrum measurements with frequency on one axis, time on another, and level indicated by the trace color.

In Smart, this graph is fundamentally governed by setting the threshold level at which data begins to appear on the graph. When a frequency band in the spectrum is over the lower threshold, it shows up on the plot, starting with a dark blue color at lower levels, and transitioning through green, yellow,

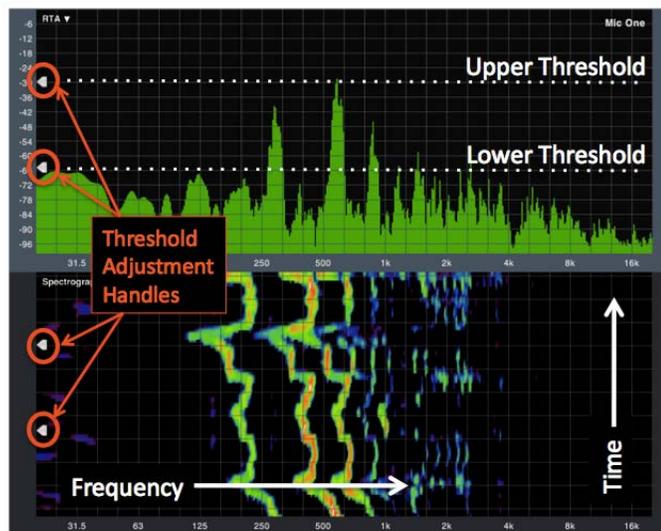


Figure 18: Spectrograph Thresholds

orange and red with higher level – eventually showing up as white if the level reaches or exceeds the upper threshold.

The key to creating a useful spectrograph is in setting the dynamic range for the display – in setting the thresholds for showing / hiding the spectral data. Set the range too wide and the display loses definition, and important features may get lost. Set it too narrow or the lower threshold too high and data might get missed altogether.

One of the powerful new features in Smaart v7 is the Threshold Adjustment Handles that are available on the left axis of RTA and Spectrograph plots. With these controls, a user can adjust spectrograph thresholds dynamically – *without having to reacquire the data*.

Moreover, Smaart v7's spectrograph retains a history of the last “x” slices (spectrum measurements), and a user can scroll the display back through older data in the history if it has passed off of the display. A user can access and adjust the size of this history file, as well as the display width for each slice, in the Spectrum Options dialog.

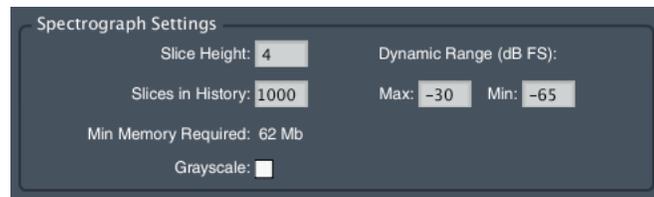


Figure 19: Spectrograph Settings in Spectrum Options

*Note: Smaart only graphs data from the “active” spectrum measurement – even if multiple single-channel measurements are running simultaneously.*

### Application Examples

What follows are two examples of spectrum measurements used in common, “real world” applications. The first uses both RTA and Spectrograph for examining frequency content – specifically, in identifying feedback frequencies. The second uses the spectrograph to examine interaction patterns (comb filtering) that are caused by direct sound interacting reflections with near boundaries.

### Feedback Identification:

In this example, a vocal microphone is routed through a simple sound system. For our Spectrum measurement we acquire the output signal of the mixing console.

The vocal mic gain is raised until we get feedback.

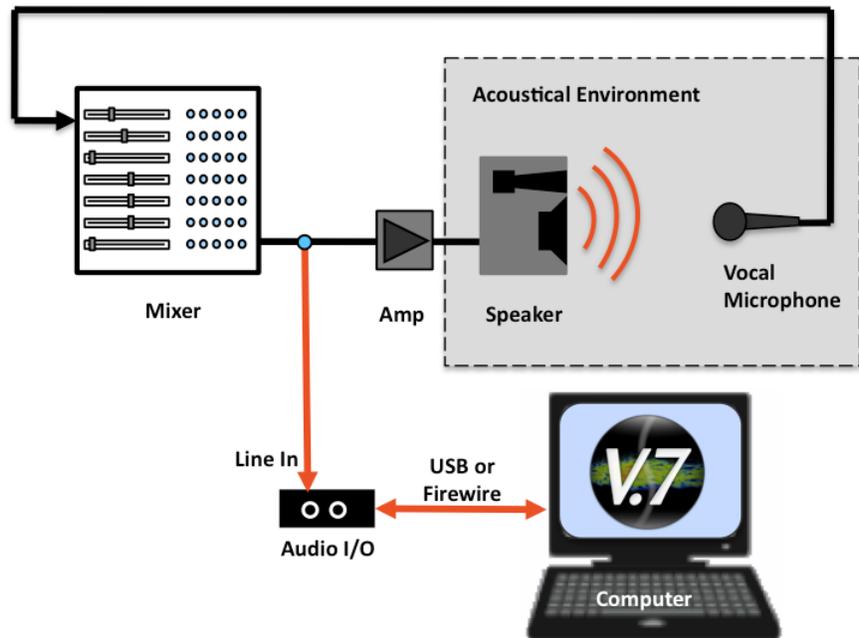
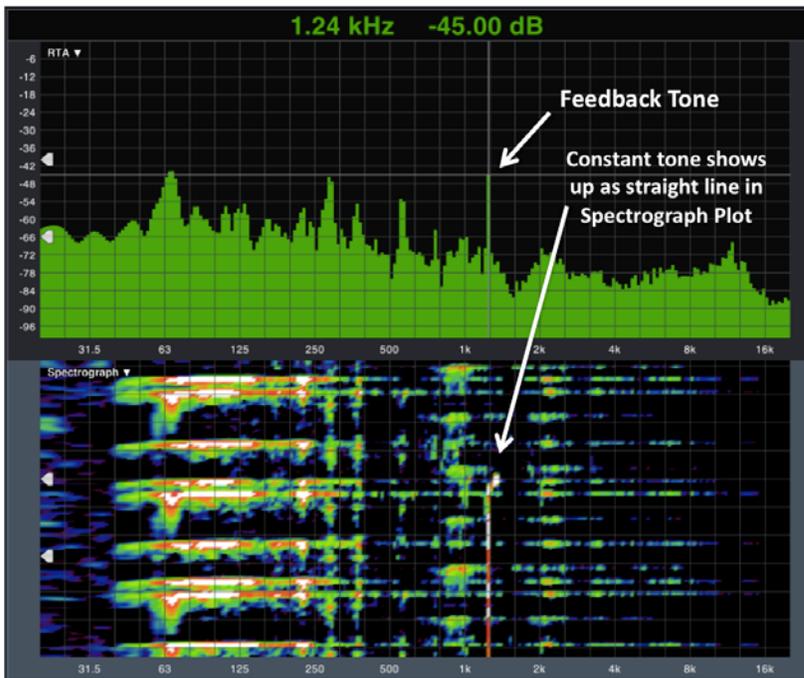


Figure 20: System Configuration for Monitoring Feedback



The feedback tone can be identified as a vertical bar at 1.24 kHz in the RTA display. However, because there is also other signal going through the system at the same time as the feedback, it is easier to distinguish the vertical line of the constant feedback tone in the Spectrograph plot.

Figure 21: Feedback Displayed in RTA and Spectrograph Plots

### Examining Interaction Patterns with Spectrograph:

The following is a simple technique that uses the Spectrograph for examining coverage and interaction patterns in loudspeaker systems. Simply put, the user

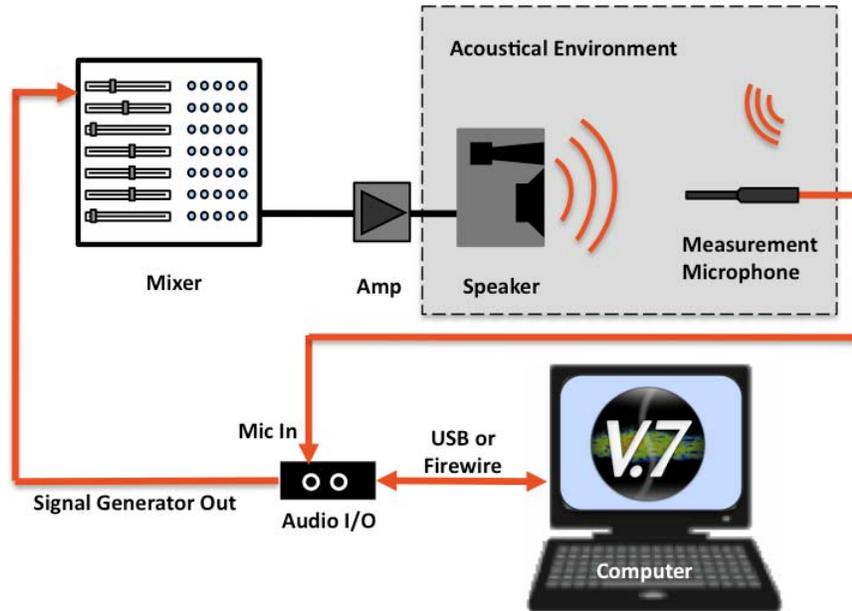


Figure 23: System Configuration for Interaction Study

excites the system with pink noise – which should produce a relatively constant level/color at all frequencies on a spectrograph plot – and then moves the measurement mic through the listening environment. Level variations from interactions, like the audible comb filtering caused by reflections, can be seen as interaction patterns on the spectrograph plot of the mic signal. Adjusting the dynamic range helps to better highlight the interaction patterns.

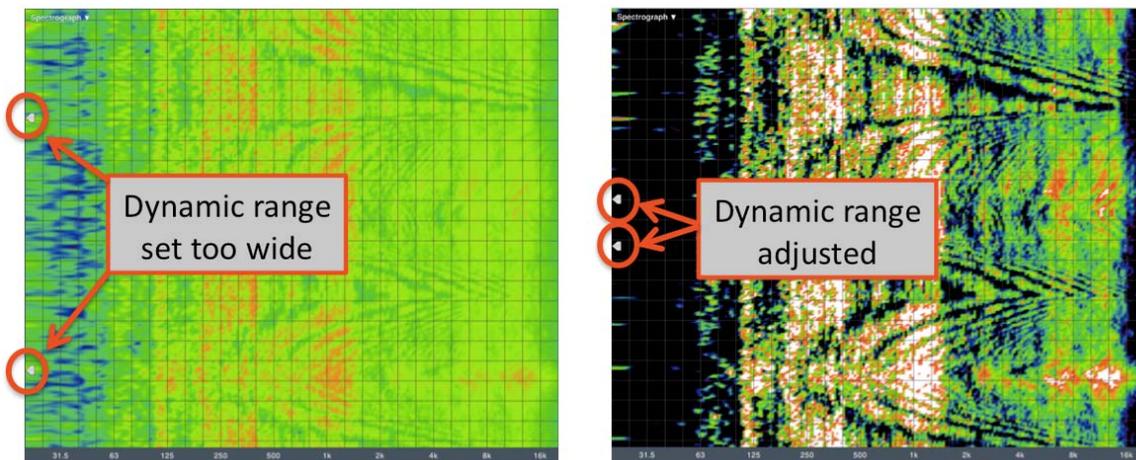


Figure 22: Comb Filter Interaction Patterns Viewed in the Spectrograph Plot | Page

## Transfer Function Measurements

*Transfer Function* is a dual-channel measurement that determines a system's frequency response by comparing its input signal (reference) to its output signal (measurement). This measurement shows the difference between those two signals in both magnitude and phase and represents the processing behavior of the system as a function of frequency.

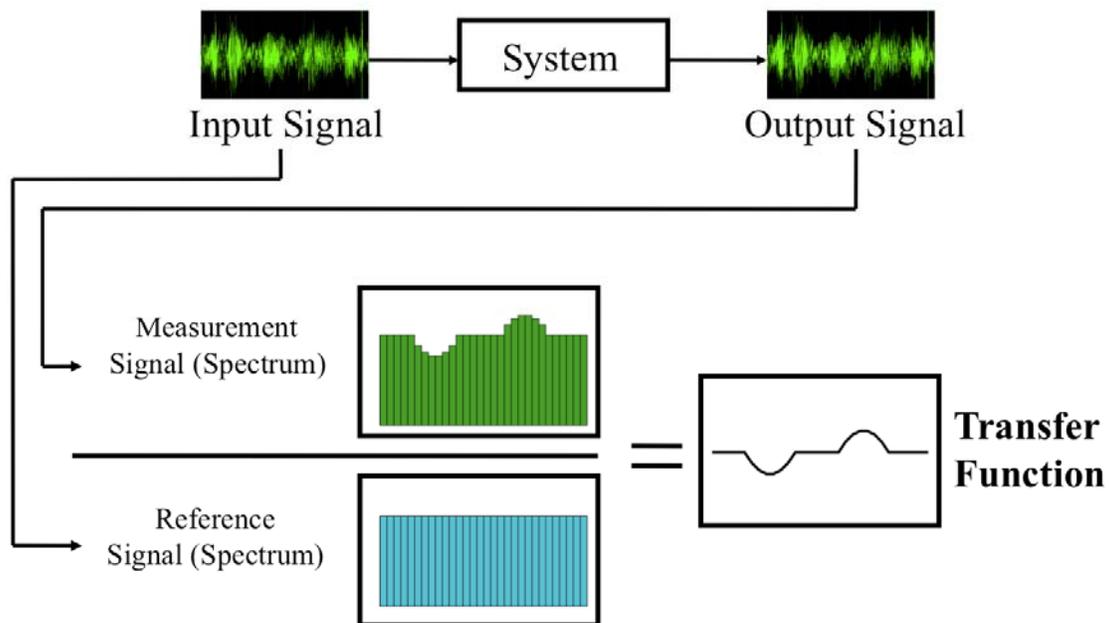


Figure 24: Transfer Function

Smaart's Transfer Function measurement allows a user to examine the frequency response of various components of their sound system, both electrical (EQ's, mixers, processors) and electro-acoustical (loudspeakers, their environment and their drive electronics). These measurements are extremely useful in many applications, including loudspeaker design, equipment evaluation, equalization and system optimization.

Data from Smaart's Transfer Function measurements are viewable as four separate traces, on three separate plots/windows: magnitude response and coherence (same window), phase, and live IR (time domain plot).

### Magnitude

The Magnitude window shows both the Magnitude portion of the transfer function (frequency response), and the Coherence trace (see below). In the magnitude plot, gain and loss show up as deviation from the center 0 dB line.

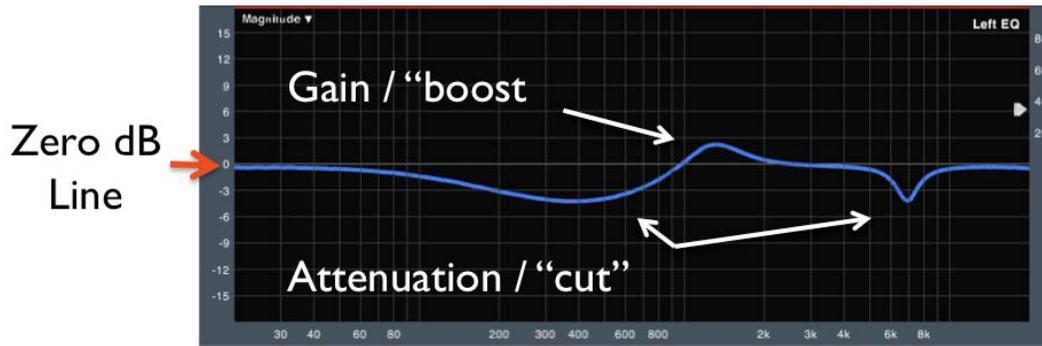


Figure 25: Transfer Function Magnitude Trace

The user can click and drag a magnitude trace up and down to move it vertically on the plot.

### Phase

The Phase plot displays the Phase portion of the Transfer Function measurement. This plot shows the difference (in degrees) between the reference and measurement signals, and provides an indication of overall relative timing by frequency, phase shift due to filtering and system polarity. The phase plot is “circular” through 360° – the top of the plot (180°) is the same place as the bottom of the plot (-180°). The phase trace below shows a continuous trace that leaves the bottom of the plot and continues on from the top.



Figure 26: Transfer Function Phase Trace

The user can click and drag a phase trace vertically to change the position of the 0° point. Regardless of the position of 0°, the phase trace always displays a range of 360° in its standard, “wrapped” display format.

### Coherence

The Coherence trace displays the stability of the Transfer Function data over the given series of measurements/averages, and is expressed as a percentage from 0 (bad coh. – inconsistent data) to 100% (highly consistent data.) If the Transfer Function’s averager is set to “instantaneous”, Coherence is not calculated.

The Coherence trace is plotted using the upper ½ of the Magnitude window by default, but it can be configured to only occupy ¼ of the window height.

There are three general causes of reduced coherence. First, a problem with the measurement system – most commonly, not having the measurement delay set properly (see below). Second, environmental noise causing measurement contamination – loss of signal-to-noise. And third, excess reverberance / drop of Direct-to-Reverb ratio in the measurement system. On an ongoing basis, the Coherence trace provides an excellent indication of system intelligibility, and is a good source of feedback on system/measurement quality.

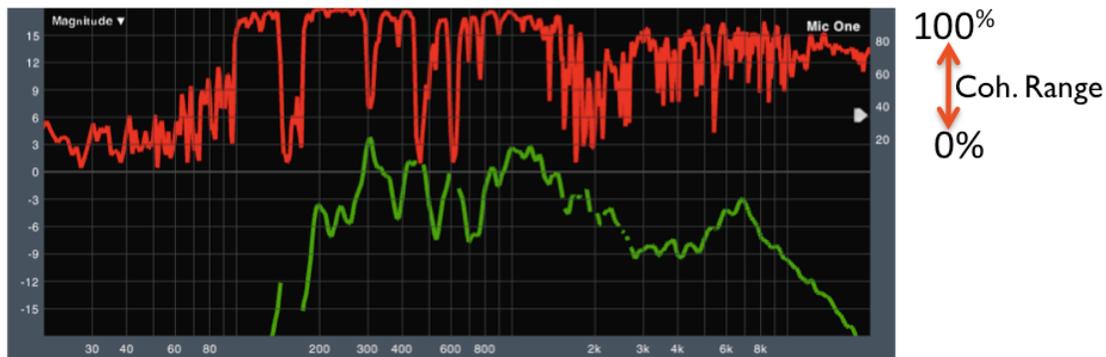


Figure 27: Transfer Function - Coherence Trace

Smaart utilizes a blanking function that will hide Transfer Function data from the plot at frequencies where Coherence is below a set blanking threshold. The user can set this in Transfer Function options, or use the adjustment handle on the magnitude plot (next to the coherence scale in the upper right).

### Transfer Function Controls

Like Spectrum, all Transfer function measurements by default use the same “Global TF Settings” for FFT, Averaging, Smoothing, etc, - unless they are set to ignore those settings in the measurement’s individual tab in the Measurement Config.

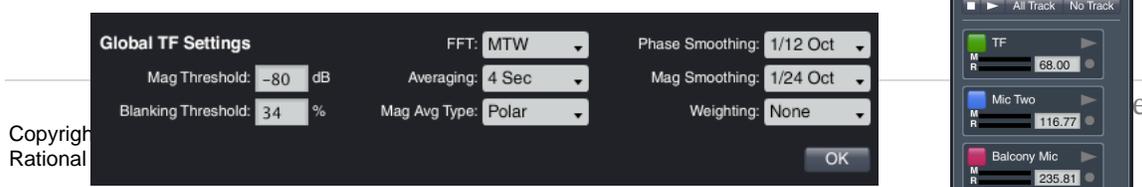


Figure 28: Transfer Function Controls

### Averaging:

Averaging a measurement stabilizes the measurement and helps reject uncorrelated noise. The Smaart v7 uses a standard FIFO (First In, First Out) for the lower levels of averaging (2, 4, 8, 16) and then switches to accumulators above that (1 sec, 2 sec, etc). These accumulators provide significant improvements in stability over past larger FIFO's and are preferred for acoustic measurements.

### Smoothing

Smaart v7 includes new “Fractional Octave” smoothing algorithms for reducing the ripple in TF traces and aiding in viewing the general trends of the data curves.

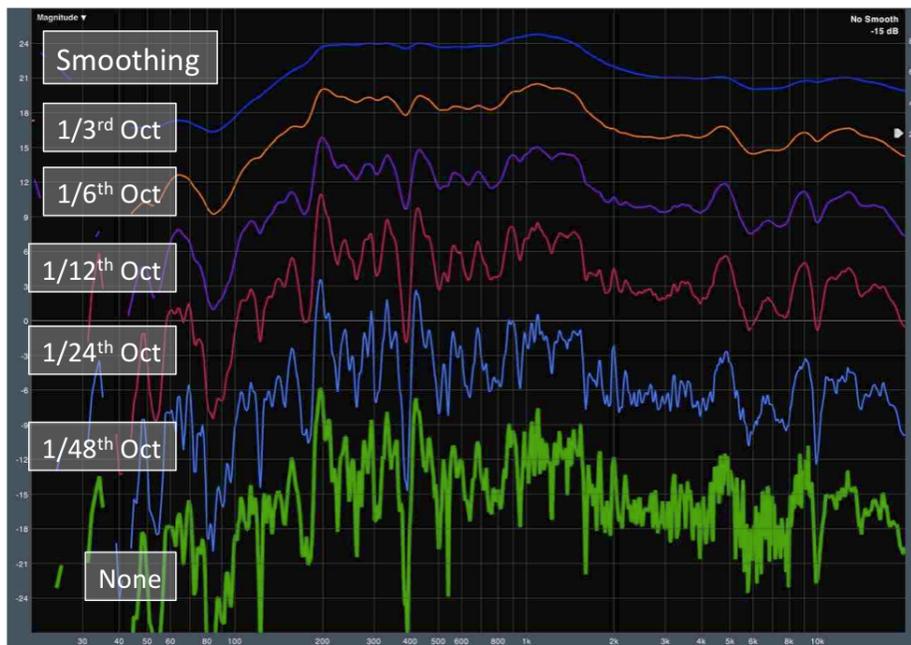


Figure 29: Smoothing

### Live IR

The Transfer Function can be viewed as a “Live IR”. This display shows the Impulse Response in a linear scale, time domain view with the TF measurement delay time located at the center of the screen. Live IR settings can be adjusted in the Transfer Function Options dialog .

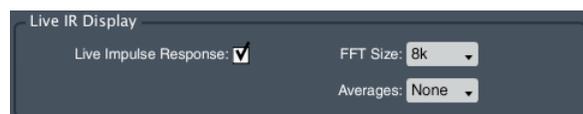


Figure 30: Live IR Settings

The “Live IR” measurement can be displayed in a Linear (default), Log or ETC view – selectable via a drop-down menu located in the top-left corner of the plot.

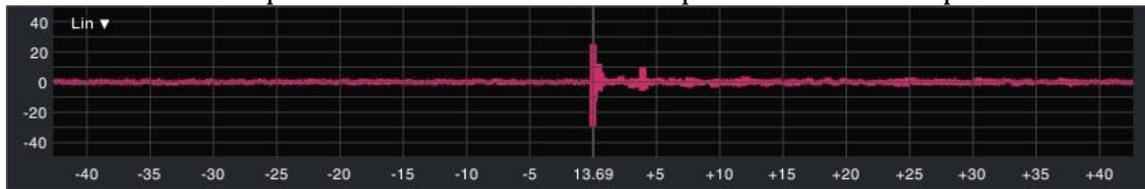


Figure 31: Live IR Window: Linear View

### Delay Locator / Delay Tracking

Transfer Function is calculated by comparing the signal on input to a system to its corresponding output signal. Most times, there is some delay through the system, often the result of latency in the processing, signal delay and acoustic propagation time. Each transfer function object has a measurement delay that can be used to delay the input/reference signal to its output/measurement signal. Accordingly, Smaart has a built-in “Delay Locator” function that



Figure 32: TF Control Object

performs an impulse response measurement, and returns the time associated with the tallest peak – normally the delay time associated with the arrival of the direct sound. For each measurement object, this function can be called with the “Find” button in its individual measurement control.

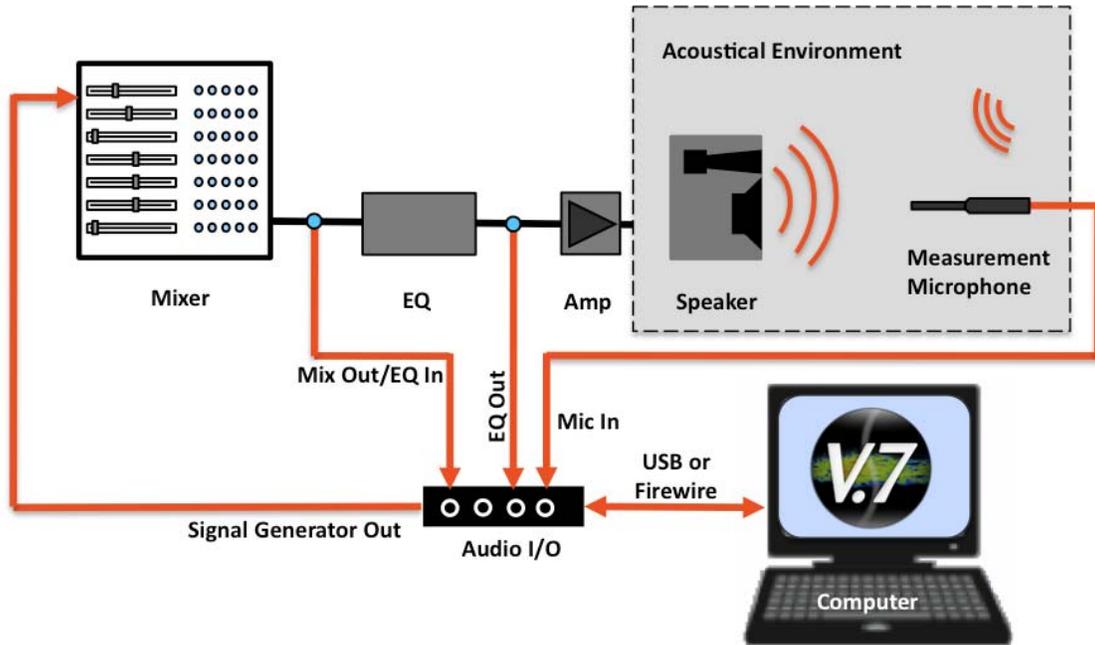
Alternatively, the user can choose to have an individual measurement object continuously track the measurement delay (using the same basic function as Live IR) by pressing the “Track” button or indicator light located in the measurement’s individual control.

*Note: The “Track” function does consume some processor resources, so if your measurement delay is not changing (the mic or speaker is not actively moving,) it is probably best to turn track off once the measurement delay has been acquired.*

### Application Example: Setting an Equalizer for a Loudspeaker

In this example, an engineer measures the Transfer Function of a loudspeaker, and then adjusts an equalizer to “flatten” its overall response. Here, the user has a multi-channel I/O, so measurements of the Equalizer (Mix Out compared to EQ Out) and complete loudspeaker system (Mix Out compared to Microphone) can be performed simultaneously. This example could also be accomplished performing those measurements individually/sequentially.

This example uses the following hardware configuration.



**Measurement Config**

Default TF

Group	Mic One	EQ					
Avg	Type	Color	dB +/-	Name	Delay	Meas Signal	Ref Signal
Pair	0	Mic One	37.10	Mic One	Console Out	Console Out	
Pair	0	EQ	3.15	EQ Out	Console Out	Console Out	

Set up with a measurement of the total system ("Mic One") and the Equalizer ("EQ")

Adjust EQ measurement Tab to use a small average, no smoothing, and graph "inverted"

**Measurement Config - EQ Tab**

TF: EQ

Measurement Settings:

- Delay: 3.15
- Phase Smoothing: 1/24 Oct
- Averaging: 8
- Phase Smoothing: None
- Mag Smoothing: None
- Weighting: None
- Inverted

Global TF Settings:

- Mag Threshold: -80 dB
- Averaging: 4
- Phase Smoothing: 1/24 Oct
- Blanking Threshold: 34 %
- Mag Avg Type: Polar
- Mag Smoothing: 1/48 Oct
- Weighting: None

Settings:

- Device: PreSonus FIREBOX
- Sample Rate: 48000
- Meas Ch: EQ Out
- Bit Depth: 24
- Ref Ch: Console Out
- Configure Device

Figure 33: Transfer Function - Sample Configuration

This configuration produces the following initial measurements.

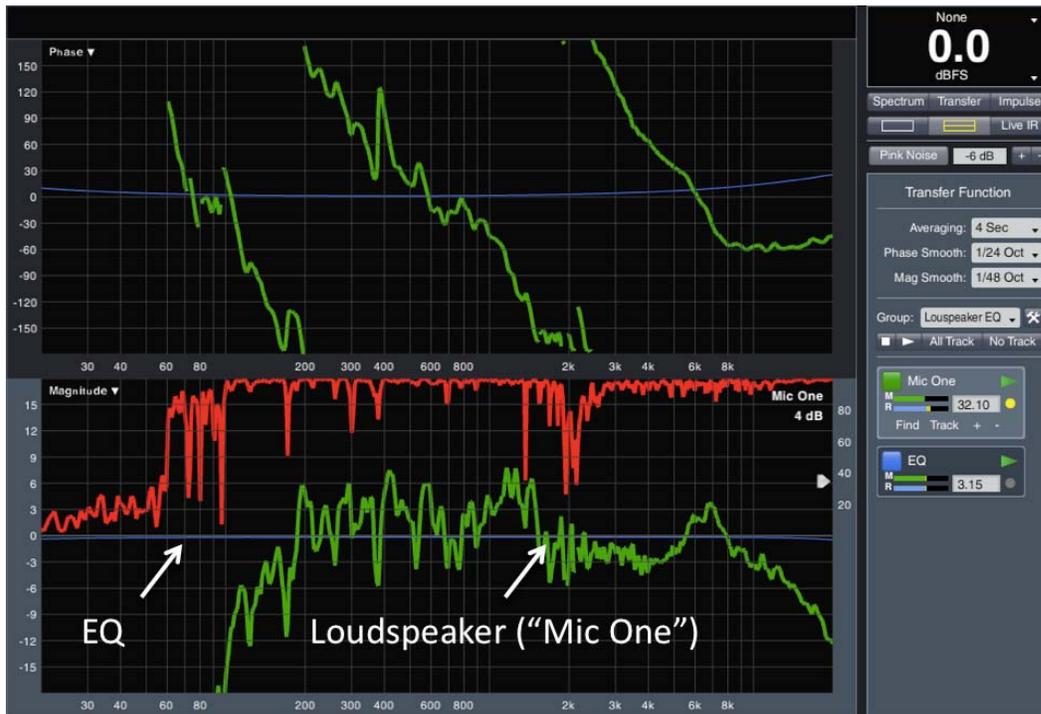


Figure 34: Initial Transfer Function Measurement - Loudspeaker and EQ

Next we capture the loudspeaker response trace, adjust the EQ and view the results in the active “Mic One” measurement of the total system. Note that the EQ measurement has been set to graph inverted, so we can lay the EQ directly over the stored response trace. This helps with refining filter width and frequency.

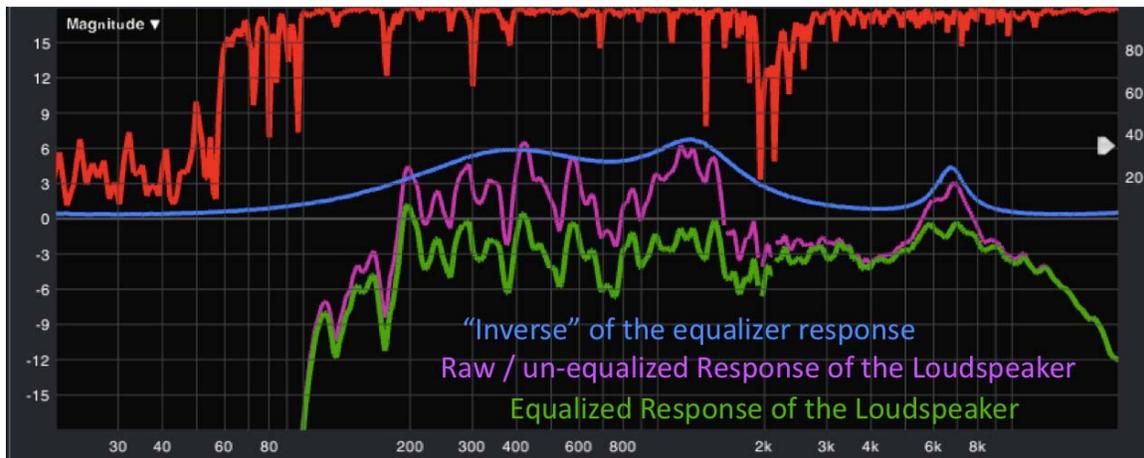


Figure 35: Transfer Function Measurement - Initial Speaker Response (Stored), EQ Trace (inverted) and Equalized Speaker

## Data Management

Data traces are “captured” into and manipulated from the Data Storage Strip located on the left side of the Real-Time GUI. There are separate Data Strips for Spectrum (RTA) data and Transfer Function data, with the Storage Strip that corresponds to the active data window type displayed (same as with the control strip.)

Traces captured to the Data Strip are written to a dedicated file in Smart for retention between subsequent shutdowns and startups. Users wishing to remove data from a register can simply highlight and delete the file. Users can also choose to write any trace permanently to a user accessible file by selecting the desired data register and choosing the “Save” (or “Save Many”) function in the Trace “Info” or “More” areas. Users will be prompted to choose the destination folder for the data file.

Users can load saved Smart .ref, .srf or .trf data - created from any version of Smart (past or present)- by selecting the “Load” function under “More”, and then selecting the file from its stored location. Entire folders of traces can be reloaded into Smart if needed. Smart cannot read data stored as .rgp (reference group files).



Figure 36: Data Storage Strip

*Note: Smart v7 data is now saved in separate formats for Spectrum (.srf) and Transfer Function (.trf) data. This is done as a convenience so that users can quickly determine the saved data type. (Old .ref files did not designate which type of data in their file extension.)*

To capture a trace, simply click the “Capture” button (or use the [spacebar] hot key), name the data (or use the default auto-name), and the new captured data register will appear in the Data Strip. Information about the captured data and control over its display parameters can be found in the “Trace Info” dialog – accessible via the “Info” button. Alternatively, for basic trace information, placing the mouse cursor over a data register will show a data “tool-tip” with information about that captured data. Right-clicking a trace will display a menu containing common trace function such as “Info” and “Delete”. Data in the strip can be reorganized via a simple drag-and-drop reordering, and for further organization, data “folders” can be created by choosing the “New Folder” option also located via the “More” button.



Figure 37: Data Info and Control Dialog

When performing multiple live measurements, the user can choose the “Capture All” button to capture data from all active measurements simultaneously. The resulting captured data traces will be placed into a newly created data folder in the strip.

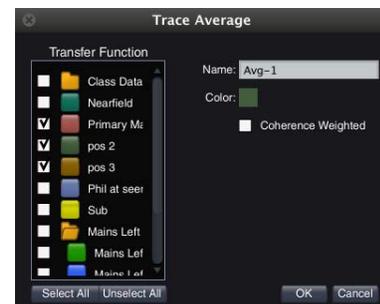


Figure 38: Trace Averaging Dialog

To average stored data traces, access the “Trace Average” dialog via the “More” button. This will place the averaged trace in the next open register.

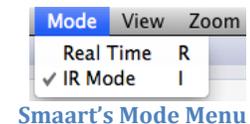
*Note: The trace averaging function can only average traces stored with the same FFT measurement settings.*

## A Note Regarding Operation Modes

Smaart operates in two distinct measurement modes: Real-Time (R-T) and Impulse Response (IR). While both modes have the ability to actively measure and display frequency domain and time domain data, the fundamental distinction between these modes is their operational focus. Real-Time mode is designed as an environment for efficiently measuring and capturing spectrum and transfer function measurements – often in multiples – and for continuously monitoring the effect of changes made to our systems as we adjust them. R-T Mode is specifically optimized for the ongoing flow of work that is encountered over the course of in-situ system alignment and mix engineering work. Impulse Response mode, by contrast, is designed with a more “post-process,” “measure then analyze” work flow in mind. While it can be operated as a “continuous” measurement engine, most often IR mode is employed to first capture (or import) individual, high resolution Impulse Response measurements of our electro-acoustical systems, and then subsequently analyze/dissect/evaluate those measurements in detail over time.

### Switching Between Measurement Modes in Smaart

There are a few ways for a user to switch between Smaart’s two operational modes. A user can select/change mode from Smaart’s menu bar via the “Mode” drop-down list. These can also be selected via the hot keys “I” and “R” (as denoted in the Mode menu).



**Mode Toggle Button**

Smaart’s operating modes can also be called via the Mode toggle button in the view control area on the right side of the interface. When in R-T Mode, this button is labeled “Impulse” – when in IR Mode, it is labeled “Real-Time”.

A final way to switch modes is by recalling a measurement view – either standard or user-defined. By recalling a view, part of its definition is the operational mode, so recalling a view necessarily requires that Smaart switch to the mode included in its definition. By pressing the “Spectrum” or “Transfer” buttons in the view control area, these views are defined as R-T mode, so pressing these buttons in IR Mode will cause a switch of modes.

## Impulse Response Mode

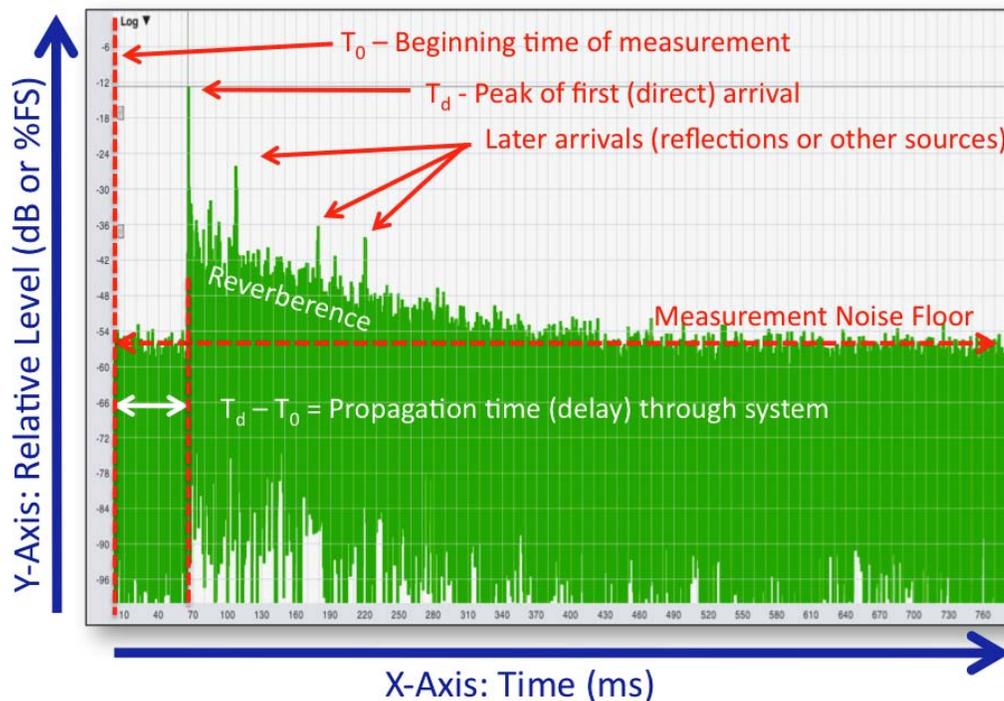
Impulse Response (IR) Mode provides a robust and intuitive set of tools for measuring, examining and evaluating the acoustical response of systems and environments. In this mode, we can also analyze previous IR measurements or other time-domain information that have been stored in standard .wav or .aiff (MAC) audio file format.

### The Impulse Response Measurement

An Impulse Response is the Time Domain view of the response of a system. It is displayed as (relative) level vs. time, and shows what happened to the signals passing through the system in time. It is an invaluable tool for examining how our systems are affecting our signals in time, for determining the relative arrivals of various elements/energies in our systems, and in the case of electro-acoustic systems, for examining and evaluating reverberant behavior and its impact on speech transmission and intelligibility. The IR Response presents a complete and detailed record of the frequency and level response of the measured system, and therefore Smaart's Impulse Response Mode is equipped with many tools for extracting that information and multiple methods of viewing/examining the results.

*Impulse Response derives its name from the fact that it represents what one would get out of the system if one input a single, perfect impulse (all frequencies simultaneously at equal level) into the system.*

### Impulse Response Measurement Example



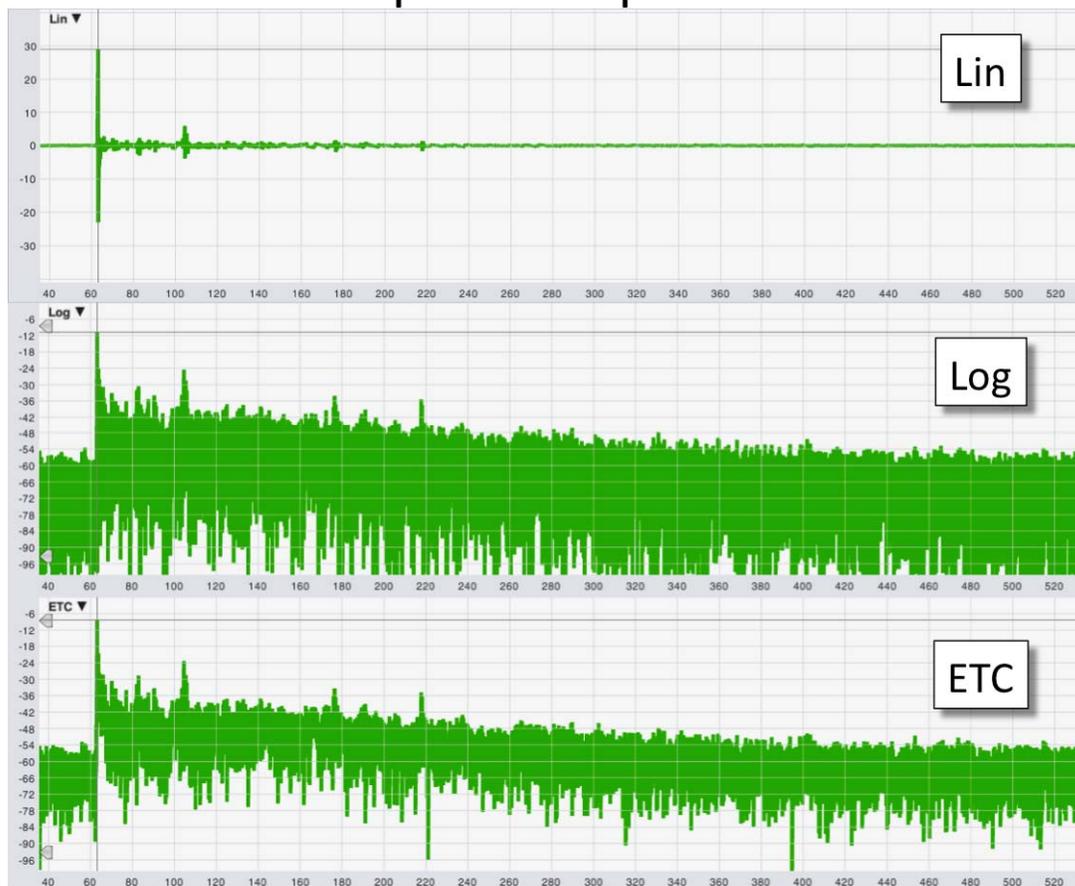
### Impulse Response Views

Smaart offers three standard Time Domain views for displaying the Impulse Response: Lin, Log and ETC. Wherever an Impulse Response is available, the operator is given the ability to select between these views via a drop-down menu in the upper left corner of the display.



IR View Select

## Three Impulse Response Views



Three Impulse Response Views

The illustration above shows an impulse response displayed using Smaart's three standard views: Lin, Log and ETC. The most notable differences between these three views can be summed up as follows:

#### **Lin**

As its name implies, the Lin view displays the IR on a linear scale. A benefit of this view is that both the positive and negative parts of the IR Oscillogram

are shown in their corresponding orientation (+ up, - down), so the application of a polarity inversion (an electrical swapping of + and -) can readily be seen as an inversion of the Lin impulse response - basically, it gets flipped upside-down. The downside of the linear scale view is that it is much harder to see lower energy, later arrivals (reflections/reverberance).

### Linear View of IR Shows Polarity Reversal



### Polarity Reversal Shown in Linear View

## Log & ETC

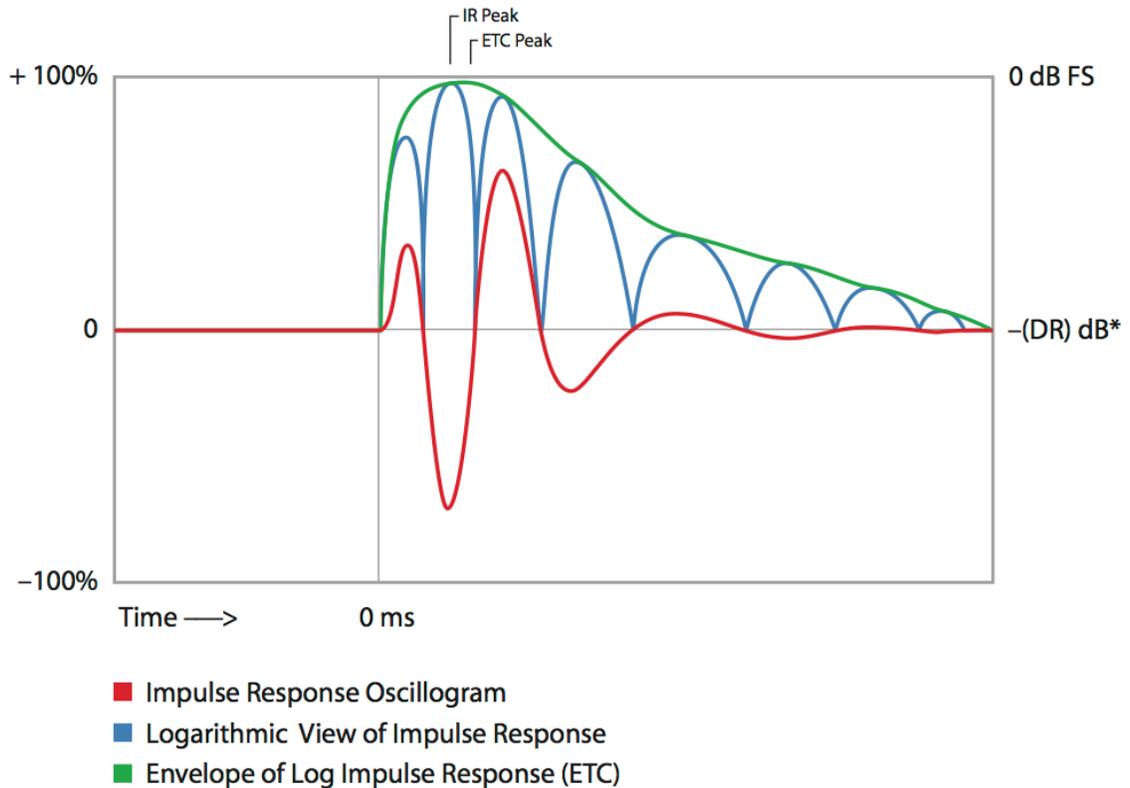
If a user is interested in examining the reverb structure of a system, display views like Log or ETC, which use logarithmic vertical scales, are preferred. This effect can readily be seen in the illustration “Three Impulse Response Views” above.

Please note however, Log and ETC’s logarithmic vertical scale (dB) have no negative-going portion, and therefore are not particularly useful for spotting polarity reversals.

## What is the ETC, and how does it differ from the Log view of the IR?

ETC stands for **E**nergy **T**ime **C**urve (or alternately, **E**nvelope **T**ime **C**urve), and represents the magnitude of the IR energy arrival over time with the phase information ignored. Using the illustration below, we start by examining the Lin view where we can readily see the +/- swings of the IR oscillogram. These are indicative of the phase response of the system varying through 360° over the response. When we translate the IR to a Log view, we see that the negative going parts of the linear oscillogram are now shown as positive-going peaks, and the places where the Lin view crosses the 0 line, moving from + to - (or vice versa), the Log view shows a magnitude at minimum (a dip). The interesting issue here is, that minimum does not necessarily represent zero energy. It could represent energy that has a relative phase of 90° or 270°. The ETC therefore shows a logarithmic-scaled view of only the magnitude of the IR, effectively ignoring the phase information in the display.

So what is it useful for? The ETC is generally a much easier logarithmically-scaled IR view to read. Particularly when measuring systems with little to no HF energy.



\* "DR" = Max. Dynamic Range (given bits/sample).

### Three Views of an IR: Lin, Log and ETC

#### IR Mode User Interface

With the version 7.4 release, the Impulse Response Mode user interface has been significantly reconfigured/updated/enhanced. The most obvious changes to GUI for this mode are due to the addition of intelligibility and RT measurement capabilities, the desire to utilize more "in-plot" controls, and of course, a need to more closely follow the GUI layout used in the Real-Time Mode.



Impulse Response Mode: User Interface

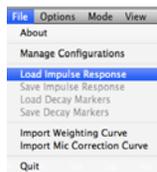
In general, using the IR Mode involves a process that follows three distinct steps: Acquisition, Preparation, Analysis.

### IR Mode Data Acquisition: Impulse Response Measurement Controls

In IR Mode, a user can perform an Impulse Response measurement by choosing any Response Measurement they currently have configured ("Group" and "TF Pair"), setting the measurement parameters ("FFT", and "Avg"), verifying signals via meters, and pressing the measurement start. 

A user can choose to run the measurement in a continuous mode, by depressing the  button prior to pressing start.

IR mode can also be used as a simple audio recorder to capture signals from the "Meas" input of a selected TF Pair by first depressing the "record" button , and then using the start button to begin and end the recording.



Alternatively, the user can choose to load a stored file via the "File" menu. Once the user has captured or loaded an impulse response measurement, the name of the measurement shows up in the upper right of the IR Mode "Nav" window, and they can use the viewing tools below to edit and analyze it.

### Setting IR Measurement Parameters and Maximizing Dynamic Range

If the only piece of information one is looking for is the arrival time of the direct sound, setting measurement parameters is a relatively easy proposition. Just make sure that you have the proper measurement and reference signals, that they are of sufficient level, and that your IR measurement's Time Constant (TC) is at least three times (3x) the length of the delay you are trying to measure.

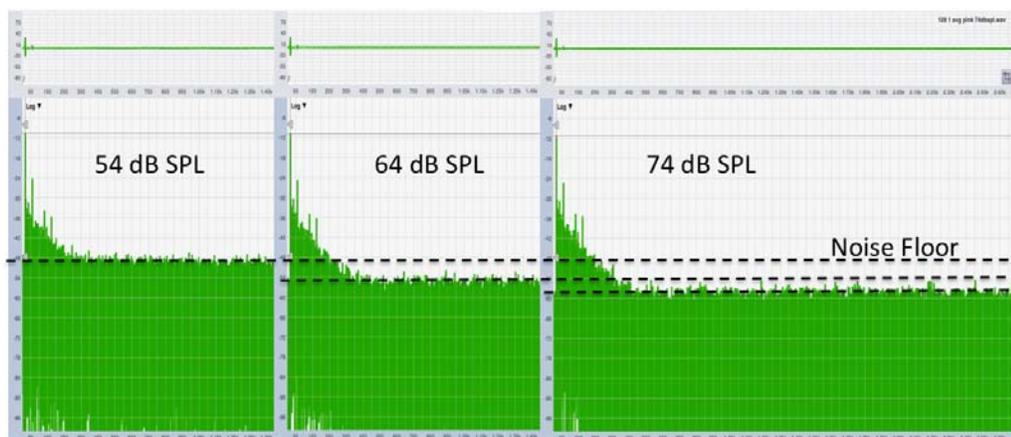
More often however, user making measurement in IR Mode are interested in acquiring a detailed measurement of the entire reverberant/acoustic response of a system. As such, setting the measurement parameters becomes an issue of maximizing the dynamic range of the measurement – an issue of dropping the noise floor and exposing as much of the reverberant structure as possible.

In this case, there are a few ways, often used in combination, to do this. They include: measuring louder, using averaging, measuring with longer TC's, and choosing a appropriate measurement stimulus.

#### Measure Louder

One of the simplest ways to increase your measurement's signal to noise ratio (S/N) is to measure louder. Simply put, to raise the system output level vs. the environment's ambient noise level. Notice in the figure below, as the measurement's acoustic level increases, the noise floor drops, exposing more of the reverberant decay. However, it is useful to note that this effect has the most impact when increasing from lower system output levels that much closer to the environment's ambient noise level.

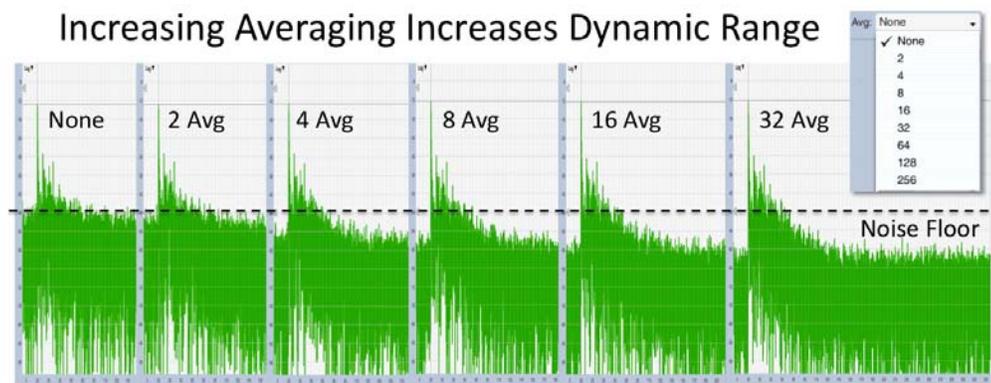
#### Measuring at Progressively Louder SPL Levels



#### Measure Louder for Increased Dynamic Range

### Use Averaging

As noted earlier in this document, averaging multiple measurements together suppresses the impact of uncorrelated noise, thereby dropping the noise floor of the IR.

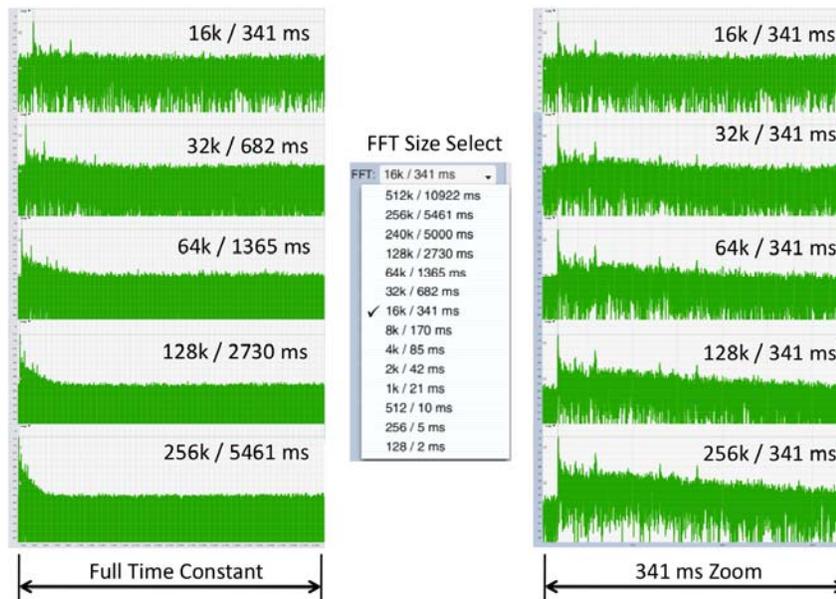


Increase Averaging for Increased Dynamic Range

### Increase the Measurement Time Constant

Increasing the measurement TC beyond the basic 3x rule stated above has a dramatic effect on the dynamic range of the resulting IR measurement. For this reason, if a user is specifically interested in exposing as much of the reverberant field as possible, it is suggested that the user employ a measurement TC of 5x the last arrival in the reverberant field.

## Impulse Response Measurement vs. Choice of FFT/TC Size



Effects of Increasing FFT Size / Time Constant

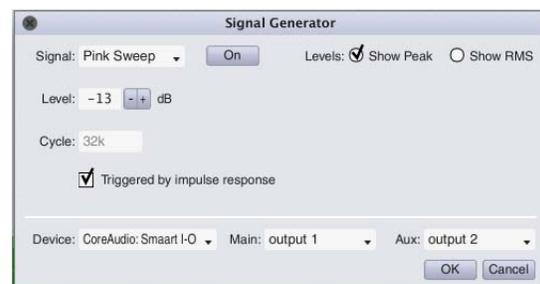
The illustration above shows a series of measurements made on the same system using increasing TC's. The left column shows the full measurement while the right shows the same measurements zoomed to the first 341 ms to give an "apples-to-apples" comparison of the effect of increasing TC on measurement dynamic range.

### Choice of Stimulus Signal

While complex stimulus signals like random pink noise can be used quite effectively to make these measurements. An additional reduction of noise floor can be obtained through the use of a log swept sine wave or specifically set pseudo-random pink noise. While the setup details for using the pseudo-random noise are beyond the scope of this doc, the settings for using the swept sine in IR mode are relatively straight forward.

In the signal generator settings (which can be accessed via the options menu, or via the [Opt+N] hot key), choose "Pink Sweep" as the source signal and then check the "Triggered by impulse response" option box in the lower

left. Also, make sure the device and channel for the noise generator



Generate Pink Sweep

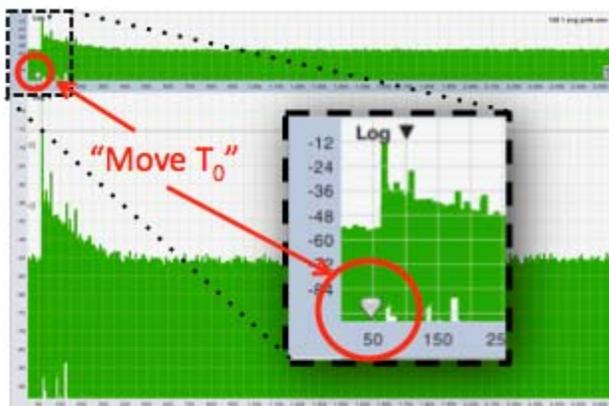
output are properly assigned. With these settings in place, the generator will output the required sine wave sweep for the measurement when the user presses the measurement start. 

### IR Mode “Nav” Window and Editing Your IR Data

The top data plot of the IR mode GUI is a window displaying the entire impulse response measurement in either Lin, Log or ETC view (user selectable). This “Nav” window is used for selecting the time domain zoom for the lower data windows, as well as for selecting and cropping the size of the active measurement.

As in Real-Time mode, right Click and drag to choose your zoom window, and click on the data axis to clear the zoom.

A user begins by acquiring data as described above, either by performing a measurement, making a recording or by loading a file, an Impulse Response measurement. The next step in the process then is to “prep” the raw data:

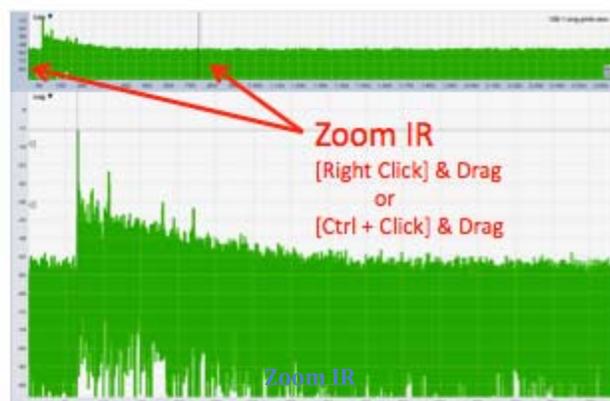


Sometimes it is necessary for a user to move the  $T_0$  (the beginning of the measurement record) to add some extra delay prior to the initial arrival times of the impulse measurement. By using the fact that mathematically, Impulse response measurements are inherently circular (the end of the record is effectively the beginning), a user can grab the  $T_0$  marker on the lower left of the

Nav window, and simply slide the IR's  $T_0$  to the right. This control then takes data from the end of the measurement record, and brings it to the beginning.

Quite often (for reasons demonstrated above) this initial measurement/file/recording can be significantly larger than needed for analysis.

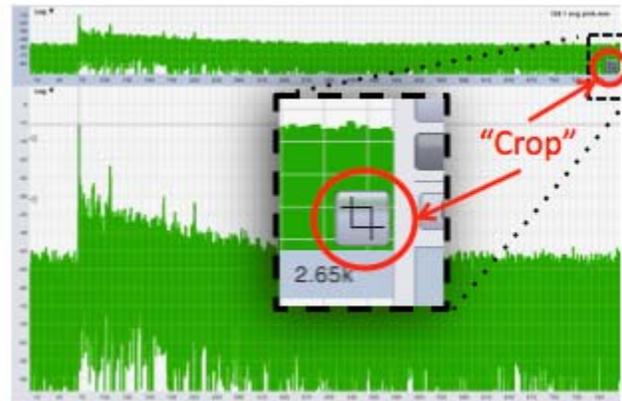
In this case, the user first uses the “Zoom” function for the Nav



window to select the file range of interest.

Then, after selecting the desired range for the data, the user can then choose to “crop” the data to the zoomed range.

Note: the crop function does not discard the unused portion of the measurement/file/recording. It simply limits the size of the actively used portion of the data. The crop button acts as a toggle. If the user wishes to “un-do” the current crop, they can simply press the crop button once again to bring back the full measurement.

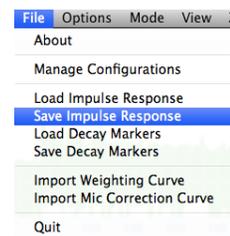


Crop IR

### Saving Your IR Data

If a user wishes to save the current measurement, or if a user wishes to make the current “crop” permanent, they must then save the IR measurement with the crop engaged.

Smaart IR Mode data is stored in standard .wav or .aiff (MAC) audio file format.



Save IR

*Note: Once a user has acquired and prepped their IR mode data, it is generally advisable to Save the impulse response at that point.*

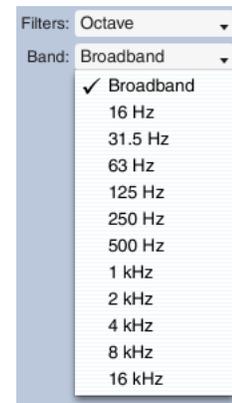
### Viewing and Analyzing Your IR Measurement

As previously stated, the IR measurement contains a complete record of the system response over time. This data can be explored, viewed and analyzed many ways with the tools contained in the IR mode.

The IR mode interface has either one or two (user selectable via the data window control buttons  located in the IR control strip) for displaying various views/zooms/ranges of the active IR data. As detailed above, the user can choose the ranges of the data being viewed in these windows via Smaart’s standard [Right Click + drag] zooming function. These zooms can be activated from any of the UI’s plot windows, and can be undone by simply clicking on any of the plot borders.

## Filtering Your Data with Octave and 1/3<sup>rd</sup> Octave Filters

It is often of interest to analyze the response of systems over specific frequency ranges instead of simply viewing the basic “broadband” response. Users can view specific frequency ranges of the active IR data via the application of user-selectable octave and 1/3<sup>rd</sup> octave filters. Control for selecting these filters is located at the bottom the IR mode control strip.



Octave Filters

Note: application of these filters only applies to the information being displayed in the lower data windows, is not permanent, and does not affect the current active IR data (as indicated in the Nav window.)

## Viewing and Calculating Reverberant Decay

For plot windows displaying either Log or ETC views of the IR data, Smart IR mode provides a few tools for the user to analyze and estimate the rate of reverberant decay (e.g.  $T_{60}$ ) for the environment being measured. This is often coupled with the filtering function described above for calculating reverberant decay by octave.

The two primary tools for analyzing reverberant decay in Smart are the Schroeder curve and the “ $T_{60}$ ” markers. These can be displayed in a Log or ETC plot view by toggling their respective control buttons   in the IR control strip.

### Schroeder Reverse Integration Curve:

Developed as a clear and repeatable way of showing the rate of decay of a reverberant field, the Schroeder curve simply integrates (adds up) the energy of a system in reverse, starting from the end of the IR time record (indicated in Smart by the  $L_n$  marker) back to the beginning of the record ( $T_0$ ). Most standard calculations of reverberant decay are based on this curve, as are Smart’s automatic placement of its  $T_{60}$  markers. Please note: changing the placement of the  $L_n$  marker can significantly affect the calculation of this curve, as it will change the integration start point.

### $T_{60}$ Reverberant Decay Markers:

The  $T_{60}$  button displays markers that are used in Smart to calculate different reverberant decay metrics. When initially activated, markers positions for all frequency bands – broadband, octave, and 1/3<sup>rd</sup> oct - are automatically calculated, and the relevant markers for the current view are shown. Users may, as they require, adjust the positions of any of the markers from their initial default positions by clicking and dragging them on the plot, and all metrics that use that marker’s position will subsequently be recalculated.

The  $L_n$  marker is calculated from a proprietary method of estimating the point in time and level in the IR where the reverberant decay meets the noise floor. All of Smaart's other  $T_{60}$  markers are calculated from the Schroeder curve as follows:

- $L_d$  (Level of Direct) – located at the peak of the Schroeder curve.
- $L_{r1}$  (Upper Level of Reverb) – located 5dB down from  $L_d$
- $L_e$  (Level for calc of Early decay time) – located 10dB down from  $L_d$
- $L_{r2}$  (Lower Level of Reverb) – located as far down the curve as possible from  $L_{r1}$  (preferably 30dB down) but still 10dB above  $L_n$

When the T markers are shown, lines on the plot connect  $L_d$  to  $L_e$  (red) to indicate the slope of EDT (Early Decay Time), and  $L_{r1}$  to  $L_{r2}$  (blue) to indicate the slope of reverberant field's decay.

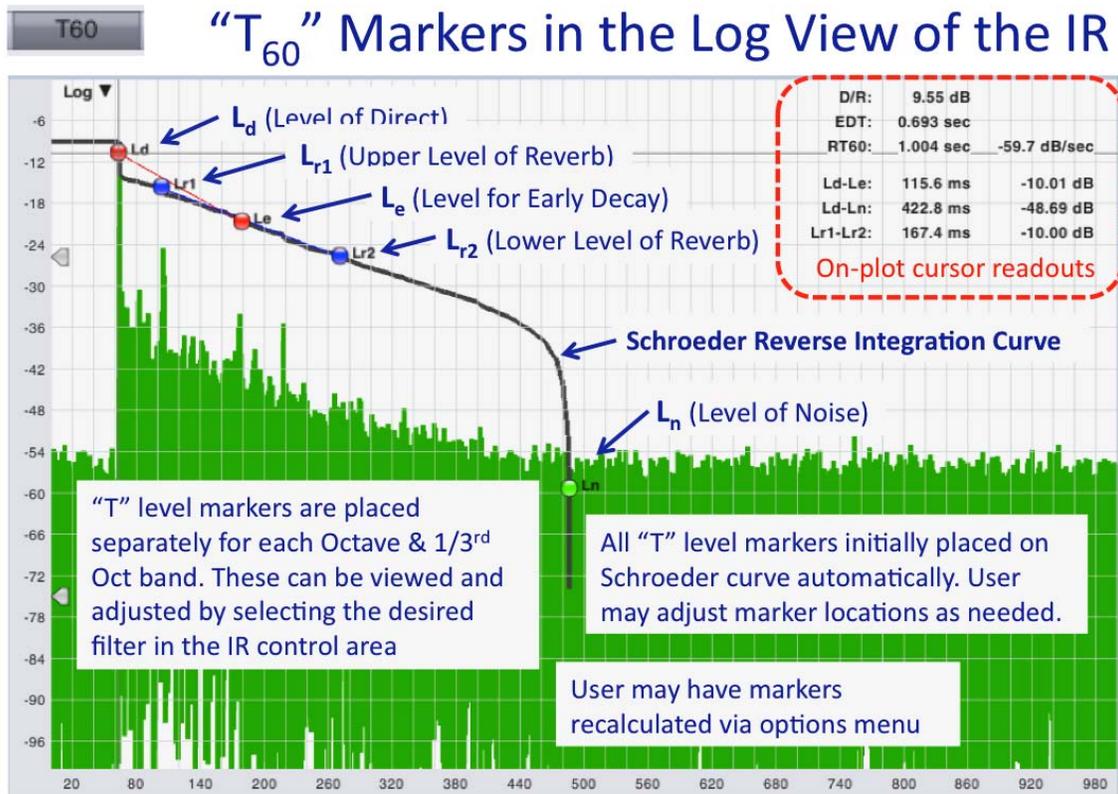
*Note: changing the active IR data by either cropping/un-cropping or moving  $T_0$  will trigger a complete recalculation of the Schroeder curve and all T markers.*

### On-Screen Cursor Readout

When the  $T_{60}$  markers are actively displayed, an on-screen readout of certain cursor metrics are also displayed on the plot in the upper right corner. These are:

- D/R – Direct to Reverberant energy ratio. Calculated as the ratio in dB of the sum of the energy in the IR from ( $L_d$  to  $L_e$ ) vs that of ( $L_e$  to  $L_n$ )
- EDT – Early Decay Time. Calculated as the difference in time in sec between  $L_d$  and  $L_e$
- RT60 – Calculated as the slope between  $L_{r1}$  and  $L_{r2}$  and normalized to 60dB of decay. Shown in sec ( $T_{60}$ ) and -dB/sec (decay rate slope)
- $L_d-L_e$  - Calculated in sec and dB
- $L_d-L_n$  - Calculated in sec and dB (overall indicator of dynamic range)
- $L_{r1}-L_{r2}$  - Calculated in sec and dB

All calculated reverberant decay times, for all Octave and 1/3<sup>rd</sup> Octave bands, can be viewed in the All Bands Table described intelligibility measurement section below.



"T" Markers in the Log View of an IR Plot

### Intelligibility Measurements and the All Bands Table

As part of IR mode Smart, includes the ability to calculate a full compliment of standard Intelligibility metrics. As a rule, these metrics seek to estimate the relative intelligibility of the measured system based on measurements of specific critical requirements for understanding spoken word in an environment. In general, these metrics fall in to two different categories for their methodology: comparisons of early to late (direct to reverberant, beneficial to detrimental) energy, and measures of loss of modulation (critical to the transmission of speech).

It is outside the scope of this document to describe the full derivation, relevance or justification for these metrics, however a basic list of the intelligibility measures

All Bands								
Filter	Band	RT60	EDT	D/R	C10	C35	C50	C80
		1.00	0.69	9.55	1.63	2.93	4.95	6.85
Oct	125 Hz	1.38	1.15	9.55	-2.88	-0.26	0.24	4.30
Oct	250 Hz	1.02	1.00	9.55	-3.96	-2.30	-1.04	3.62
Oct	500 Hz	0.90	0.91	9.55	-1.29	0.01	0.91	3.38
Oct	1 kHz	1.08	0.84	9.54	2.25	3.04	4.41	6.03
Oct	2 kHz	1.10	0.88	9.54	1.47	3.37	4.50	6.26
Oct	4 kHz	1.10	0.68	9.55	2.24	3.86	5.71	7.78
Oct	8 kHz	0.82	0.30	9.54	4.56	5.90	9.54	11.42
Oct	16 kHz	0.68	0.25	9.91	6.76	8.26	12.63	14.96
1/3	125 Hz	1.71	1.13	9.55	-3.52	0.97	1.65	5.80

CIS: 0.82      Bass Ratio: 1.21      %Alcons (S): 4.30  
 STI: 0.67      T Low: 1.20      %Alcons (L): 5.47  
 STIPA: 0.68      T Mid: 0.99

contained in Smart and shown in the All Bands Table are as follows:

**Clarity (C10, C35, C50, C80)**

**%Alcons (L and S)**

**CIS**

**STI / STIPA**

**Bass Ratio**

**T Low**

**T Mid**

#### [All Bands Table](#)

***For more complete description of these intelligibility metrics,  
please refer to the help files contained in the Smaart program!***

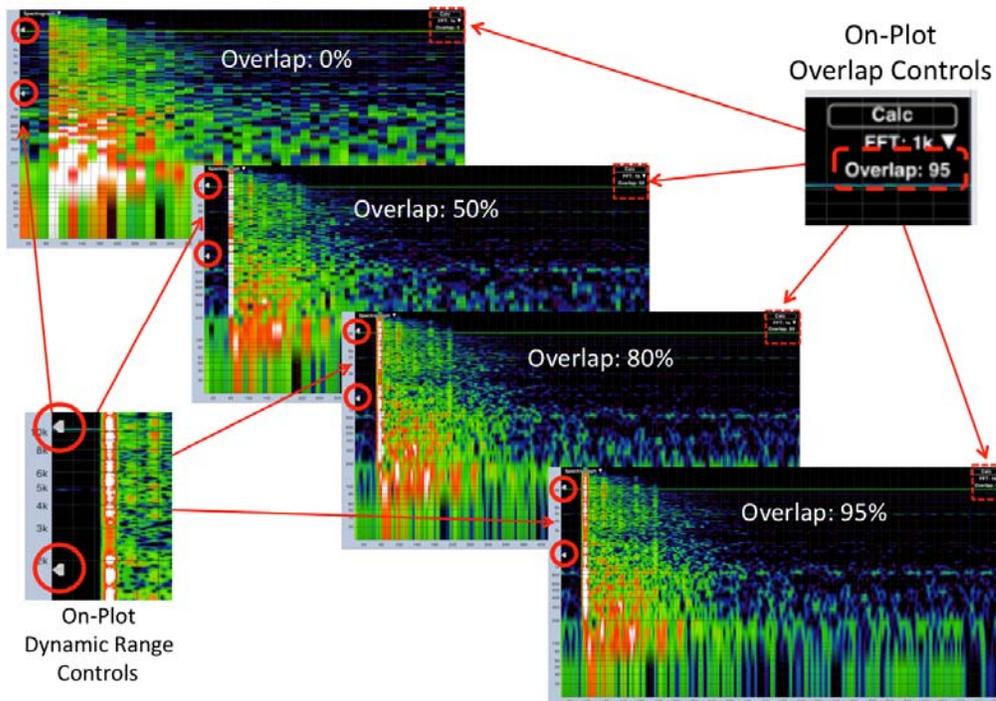
#### **Spectrograph View of IR**

The IR measurement contains a full set of response data for a system, and the Spectrograph allows a user to process the IR to examine this frequency vs. level vs. time information in graphic detail.

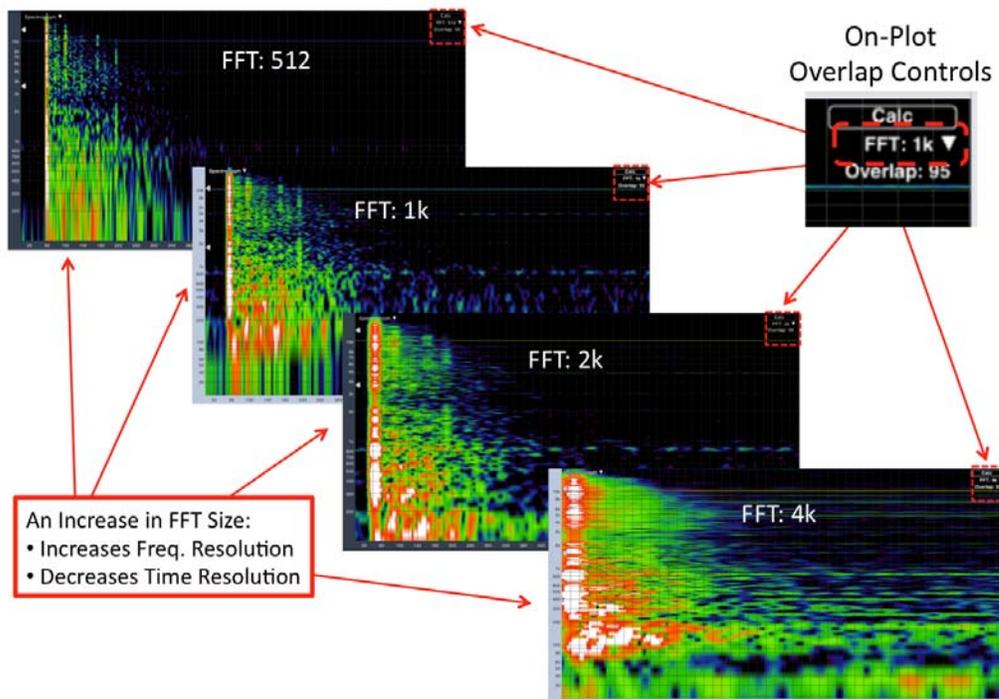
Most of the relevant Spectrograph controls for the processing and view control are located in the upper right corner of the plot. Initially, a user must press the “Calc” to generate display information. However, as long as the active IR data remains unchanged (no change to cropping,  $T_0$  or frequency filtering ) the display will recalculate automatically when you vary the FFT size and overlap parameters.

The following illustrations show the impact of varying the Overlap and FFT.

## IR Spectrograph: Varying Overlap



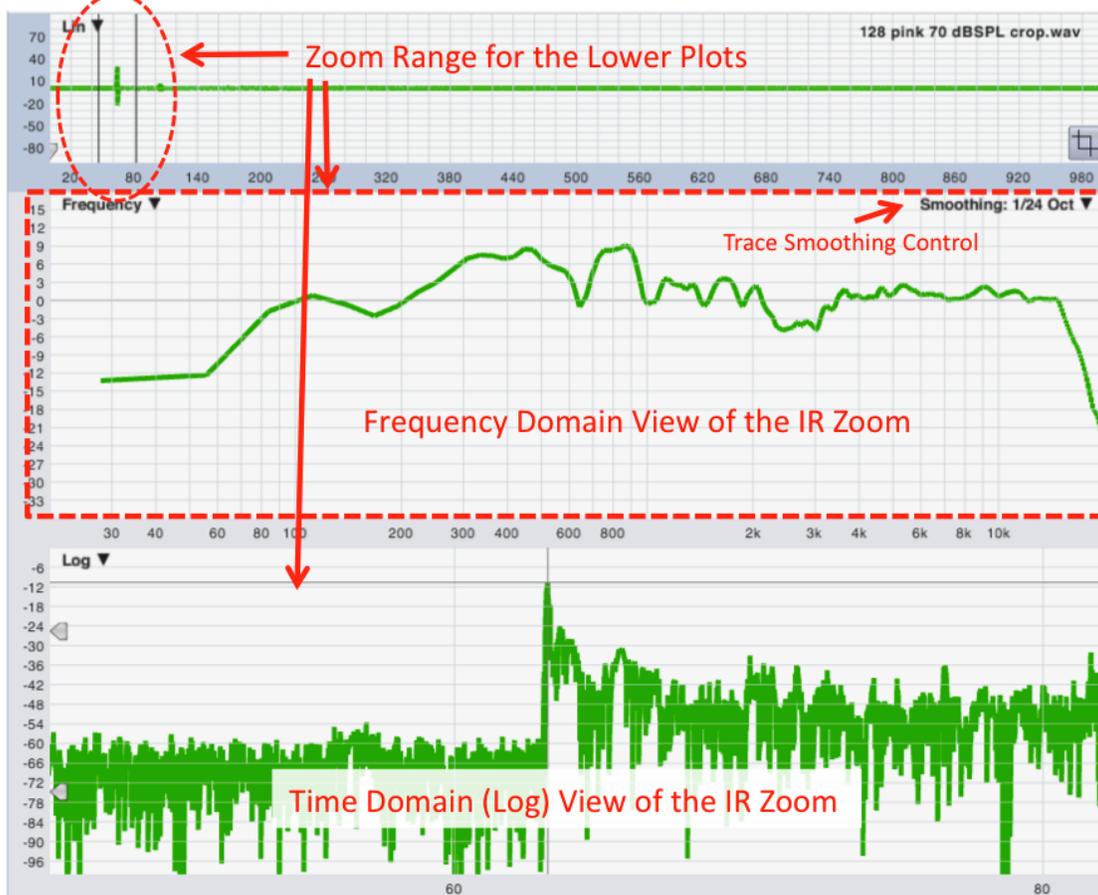
## IR Spectrograph: Varying FFT Size



### Frequency View of IR

One final view of the Impulse Response offered by Smart is the Frequency view. This plot type displays the Frequency Domain view of the current zoom window, and is an excellent tool for examining the frequency content of a specific range of an IR plot. Additionally, the controls for smoothing this trace have now been located in the upper right of the plot.

## Frequency View of an IR (Zoomed)



Frequency View of an IR Zoom

## Appendices

### Hot Keys (Accelerator Keys)

A complete, up to date listing of Smaart's Accelerator Keys is always contained in the Software's Help files. Go ahead, use them. No one is watching. We won't tell.

<b>General Measurement Controls</b>	
[G]	Signal Generator On/Off (Toggle)
[O]	Selected Measurement On/Off
[Cmd/Ctrl] + [O]	All On (run all live measurements of selected type)
[Cmd/Ctrl] + [Alt] + [O]	All Off (stop all live measurements of selected type)
[V]	Reseed Averages
<b>Delay Controls</b>	
[D]	Track Delay (toggles Delay Tracking for selected Transfer Function measurement)
[Cmd/Ctrl] + [D]	All Track (turn on Delay Tracking for all active Transfer Function measurements)
[L]	Find Delay (for selected Transfer Function measurement)
[Cmd/Ctrl] + [L]	Find All Delays (find delays for all active Transfer Function measurements)
[,<]	Increment Delay (for selected Transfer Function measurement)
[.>]	Decrement Delay (for selected Transfer Function measurement)
<b>Data Storage and File Operations</b>	
[Space]	Capture Trace (captures the front trace on the selected graph into new storage slot)
[Shift] + [Space]	Capture All (captures all active measurements on the selected graph into a new folder object)
[Cmd/Ctrl] + [Shift] + [Space]	Recapture (captures the front trace on the selected graph into the selected storage slot, replacing it's previous contents)
[Cmd/Ctrl] + [S]	Save to File (.wav or .srf/trf depending on the operating mode)
[Del]	Removes the selected static trace storage slot
[Cmd/Ctrl] + [Shift] + [Del]	Removes <i>all</i> selected static trace storage slot
[Cmd/Ctrl] + [C]	Copy to ASCII (copies the selected static trace to the Operating System clipboard in ASCII text format)
<b>Display Controls</b>	
[C]	Toggle Coherence Trace (Transfer Function measurements only)
[I]	IR Analysis Mode
[M]	Switch Preferred Plot
[R]	Real-Time Mode
[S]	Spectrum
[T]	Transfer Function
[Cmd/Ctrl] + [I]	Live IR (Show/Hide)
[Y]	Clear Y Offset (Selected)
[Cmd/Ctrl] + [Y]	Clear Y Offset (All)
[Z]	Cycle Z Order (Forward)
[Shift] + [Z]	Cycle Z Order (Back)
[+]	Zoom In Y
[-]	Zoom Out Y
[Cmd/Ctrl] + [+]	Zoom In X/Y
[Cmd/Ctrl] + [-]	Zoom Out X/Y
[Cmd/Ctrl] + [Alt] + [+]	Zoom In X
[Cmd/Ctrl] + [Alt] + [-]	Zoom Out X
↑	Scroll Up*
↓	Scroll Down*
←	Pan Left
→	Pan Right
[Cmd/Ctrl] + ↑	Move Front Trace Up (moves the front trace upward on the selected graph by 1 dB)
[Cmd/Ctrl] + ↓	Move Front Trace Down (moves the front trace downward on the selected graph by 1 dB)

\*Or roll "roll" the (wrapped) Phase display.

[Cmd/Ctrl] means press the [Ctrl] key on a Windows computer or the [Cmd] key (sometimes called the Apple Key or "flower" key) on a Macintosh computer. The Alt key on a Windows system maps to the Option key on

### Self-Help: Where to go for Answers

Ultimately, the user, as engineer and operator, is responsible for answering their own specific application questions. In order to assist in this process, Rational Acoustics suggests the following sources:

1. Use the HELP FILES in the software – a lot of very helpful information about Smaart’s functions and features is there, and it is fully searchable.
2. The Smaart user forums at RationalAcoustics.com
3. Smaart Training sessions
4. Previously published Smaart and SmaartLive Manuals and Technical Notes – these can be found on the Rational Acoustics web site at: [http://www.rationalacoustics.com/pages/New\\_Documentarium](http://www.rationalacoustics.com/pages/New_Documentarium)
5. The “Recommended Reading” sources cited in the last section of this document.
6. Or even contact Rational Acoustics directly via email (preferred) or phone.

Training session information and contact information for Rational Acoustics and authorized representatives can be found at <http://rationalacoustics.com>.

### Recommended Reading

McCarthy, Bob. **Sound Systems: Design and Optimization, Second Edition**. Oxford, UK: Focal Press, 2009

Davis, Don & Patronis, Eugene, Jr. **Sound System Engineering, Third Edition**. Oxford, UK: Focal Press, 2006

Davis, G. & Jones, R. **Yamaha Sound Reinforcement Handbook, Second Edition**. Milwaukee: Hal Leonard, 1989.

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