

# BACH-SP

## The Manual

v. 1.0



**THEORETICA**  
APPLIED PHYSICS

www.theoretica.us



## LEGEND

The text of this PDF document contains many internal and external hyperlinks. It is best to read this manual on an electronic device through Adobe Acrobat or another PDF viewer.

- The text representing internal hyperlinks is shown in **rust-colored font**. Clicking on such hyperlinks will take you to a related part inside the manual.
- The text representing external hyperlinks is shown in **green-colored font**. Clicking on such hyperlinks will launch your default web browser and take you to a related page on the Internet.
- Warnings and potential issues are in **red font**. (We recommend that the user reads all the red text in the manual before extensive use of the BACCH-SP.)





# Contents

<b>1</b>	<b>Introduction</b>	<b>5</b>
1.1	What is the BACCH-SP? . . . . .	5
1.2	Functionality . . . . .	6
1.3	The BACCH-SP Line . . . . .	7
1.4	A Quick Look at the BACCH-SP . . . . .	8
1.5	Setting up the BACCH-SP . . . . .	8
1.5.1	Setting up the <i>Grand</i> model . . . . .	8
1.5.2	Setting up the <i>adio</i> and <i>dio</i> models . . . . .	9
1.5.3	Power . . . . .	9
1.5.4	Passive and Active Cooling . . . . .	9
<b>2</b>	<b>Quick Start &amp; Basic Operation</b>	<b>11</b>
2.1	Turn on the BACCH-SP . . . . .	11
2.2	Select an Input and Output(s) . . . . .	12
2.3	Making and Auditioning a Fixed-Sweet-Spot BACCH <sup>®</sup> Filter . . . . .	13
2.4	Making and Auditioning a Dynamic-Sweet-Spot BACCH <sup>®</sup> Filter with Head Tracking . . . . .	15
2.4.1	Head Tracking with the Webcam . . . . .	15
2.4.2	Head Tracking with the Infrared Camera . . . . .	18
<b>3</b>	<b>Hardware Description</b>	<b>19</b>
3.1	The Front Panel . . . . .	19
3.2	The <i>Grand</i> 's Back Panel and its Connectors . . . . .	20
3.3	The <i>Grand</i> 's Digital I/O Sample Rate LEDs . . . . .	24
3.4	The <i>adio</i> and <i>dio</i> Back Panel . . . . .	25
3.5	The BACCH-BM Binaural Microphone . . . . .	28
3.5.1	Description of Components . . . . .	29
3.5.2	Assembly and Use . . . . .	30
3.6	The Head Tracking Sensors . . . . .	32
3.6.1	The Webcam . . . . .	32
3.6.2	The IR Camera . . . . .	32
3.6.3	The TrackIR Sensor . . . . .	32
<b>4</b>	<b>Operation &amp; Detailed Description</b>	<b>33</b>
4.1	Booting, Restarting and Shutting Down . . . . .	33
4.1.1	Booting . . . . .	33
4.1.2	Restarting and Shutting Down . . . . .	34
4.1.3	Hard Shutdown and Restart . . . . .	34
4.2	The BACCH-SP Wi-Fi Network & the iPad SP-Remote . . . . .	35
4.3	Storing and Syncing the Current Settings . . . . .	35
4.4	Selection of Digital and Analog Inputs and Outputs . . . . .	37
4.4.1	Inputs . . . . .	37





4.4.2	Outputs . . . . .	38
4.5	The Make Filter Page . . . . .	39
4.6	Selecting, Auditioning, and Bypassing BACCH <sup>®</sup> Filters . . . . .	42
4.7	Head Tracking Set Up and Control . . . . .	45
4.8	The Graphic Equalizer (Optional) . . . . .	49
4.9	The Crossover Network (Optional) . . . . .	51
4.10	The Advanced Settings Page . . . . .	53
4.10.1	Analog Preamp Gain Panel . . . . .	53
4.10.2	Audio Engine Panel . . . . .	54
4.10.3	BACCH Filter Designer Engine Panel . . . . .	55
4.10.4	Dolby Tape Noise Reduction Panel . . . . .	57
4.10.5	Thermal Data Panel . . . . .	57
4.10.6	Housekeeping Panel . . . . .	57
4.11	The Binaural Recorder . . . . .	59
4.12	The Test Signal Generator (Optional) . . . . .	61
4.13	The Crosstalk Cancellation (XTC) Plots . . . . .	63
4.14	The Impulse Response (IR) Plots . . . . .	64
4.15	The Internal Audio File Player (IAFP) . . . . .	65
4.16	Internet Connectivity, Technical Support and Remote Updates . . . . .	65
4.17	The Optional BACCH-HP Processing . . . . .	66
<b>5</b>	<b>Troubleshooting</b>	<b>68</b>
5.1	BACCH-SP and iPad not Communicating . . . . .	68
5.2	No Audio . . . . .	69
5.3	Audio Glitches/Dropout and Syncing Issues . . . . .	70
<b>6</b>	<b>BACCH-SP FAQ</b>	<b>71</b>
6.1	What is BACCH <sup>®</sup> 3D Sound? . . . . .	71
6.2	How Does BACCH <sup>®</sup> 3D Sound differ from surround sound? . . . . .	71
6.3	Does BACCH <sup>®</sup> 3D Sound require special loudspeakers? . . . . .	72
6.4	How does BACCH <sup>®</sup> 3D Sound work? . . . . .	72
6.5	What are BACCH <sup>®</sup> Filters? . . . . .	73
6.6	Is BACCH <sup>®</sup> 3D Sound compatible with existing stereo recordings? . . . . .	74
6.7	Is the 3D realism of BACCH <sup>®</sup> 3D Sound the same with all types of stereo recordings? . . . . .	74
6.8	Is BACCH <sup>®</sup> 3D Sound compatible with analog audio? . . . . .	75
6.9	Why call this “BACCH <sup>®</sup> 3D Sound”? . . . . .	75
6.10	Media Coverage . . . . .	76
6.11	Technical Explanation of BACCH <sup>®</sup> Filters . . . . .	76
<b>7</b>	<b>Underlying Technologies and IP</b>	<b>77</b>
7.1	The Theoretica Logo . . . . .	77
7.2	The Theoretica Arpeggio . . . . .	77





8 Technical Specifications

78





# 1 Introduction



The BACCH-SP is a highly sophisticated and unique audiophile-grade audio processor that incorporates technologies that until recently only existed in the laboratory; as such even the savviest audiophile should read at least the first three sections of this manual before any extensive operation of the BACCH-SP.

## 1.1 What is the BACCH-SP?

The BACCH<sup>®</sup> Stereo Purifier (BACCH-SP) is a state-of-the-art, high-definition, digital audio processor that yields highly realistic 3D sound imaging from a pair of stereo loudspeakers. It is conceived, designed, developed and hand-built to exacting standards by [Theoretica Applied Physics](#), in Princeton NJ, USA.

At the heart of the BACCH-SP is BACCH<sup>®</sup> 3D Sound technology from [Princeton University](#), which purifies loudspeaker-based stereo playback from the crosstalk that degrades [the 3D spatial cues that exist in most stereo recordings](#), allowing the listener’s brain to receive the proper psycho-acoustical cues that are needed to perceive the locations of the recorded sound sources realistically in 3D space<sup>1</sup>.

The BACCH-SP is the most advanced digital audio processor for music playback, as it incorporates, for the first time outside the laboratory, a number of advanced technologies that combine to offer what amounts to a virtual reality sound experience for the audiophile. These technologies include:

- Individualized tonally-transparent crosstalk cancellation filters (called [BACCH<sup>®</sup> filters](#)) derived automatically from quick high-resolution calibration (HRTF) measurements made by the listener using the calibrated binaural microphone placed in the listener’s ears.
- Dynamic adjustment of the 3D audio sweet spot through high-spatial-resolution tracking of the listener’s head position using a webcam or 3D infrared camera, and advanced custom-built head recognition and tracking software.
- 64-bit audio processing through a dedicated multi-core computer running custom-built algorithms and optimized convolution engines.
- Wi-Fi-based control of all BACCH-SP functions through an intuitive iPad Remote Controller (called “iPad SP-Remote”) on a dedicated iPad that serves as the sole remote control.

<sup>1</sup>A qualitative description of BACCH<sup>®</sup> 3D Sound is given in Section 6.4. A detailed technical description is given by E.Y. Choueiri in Chapter 5 “Binaural Audio Through Loudspeakers” of the book *Immersive Sound: The Art and Science of Binaural and Multi-Channel Audio*, CRC Press, 2017.





## 1.2 Functionality

The BACCH-SP is foremost a digital audio processor for 3D audio playback but, in addition, has a number of functions that make it a versatile hi-fi component. In particular, the BACCH-SP

- can be used as a digital-to-digital processor, a DAC and/or an ADC<sup>2</sup> thanks to its audiophile-grade digital-to-analog and analog-to-digital converters and its low-jitter internal clock;
- accommodates practically all formats of digital and analog **inputs** and **outputs** (see Table above) and can be used as a switcher to switch between various types of digital and analog inputs and outputs at the touch of a button on the iPad SP-Remote;
- has a versatile digital **crossover network** that can be easily configured to accommodate subwoofers and various bi- and tri-amping options;
- has a 31-band, 1/3-octave 64-bit transparent **graphic equalizer** for compensating for loudspeaker and listening room non-idealities;
- has a **digital volume level control** and a **3-level analog output pre-amplification stage** that allows its analog output to be fed directly into a power amplifier or powered loudspeakers<sup>3</sup>; and
- can be used as a digital binaural recorder along with the supplied high-end binaural microphone. (**BACCH-BM**).



<sup>2</sup>Of the three models in the BACCH-SP line, only the *Grand*, and *adio* models have a DAC and an ADC. The *dio* model is a digital processor with no analog I/O's..

<sup>3</sup>In the case where any of the analog outputs of the BACCH-SP are directly fed into a power amp, the user must be aware that turning the BACCH-SP on or shutting it off without muting the analog inputs or outputs of the amp might produce pops that may be loud enough to damage the loudspeakers.



### 1.3 The BACCH-SP Line

The current BACCH-SP line includes three models: The *Grand* BACCH-SP, the BACCH-SP *adio* and the BACCH-SP *dio*. The *dio* is a digital processor with no analog (DAC or ADC) stages. The various features, options and characteristics of the three models are show in the table below.



*Grand*



*adio / dio.*

The BACCH-SP Line

	The Grand BACCH-SP	BACCH-SP adio	BACCH-SP dio
USB Dig. Audio Input	X	X	X
SPDIF (RCA) dig. I/O	X	X	X
Word clock I/O	X	X	X
SPDIF Optical dig Output	X	X	X
Stereo Analog Balanced XLR I/O	X	X	
Stereo Analog Balanced TRS I/O	X	X	
Stereo Analog unbalanced RCA I/O	X	X	
AES/EBU dig. I/O	X		
AES-3id dig. I/O	X		
SPDIF Optical dig Input	X		
DAC	X (6 chn)	X (2 chn)	
ADC	X (6 chn)	X (2 chn)	
Three-level preamp	X	X	
Webcam Head Tracker	X	X	X
Remote Control iPad	X	X	X
BACCH-BM microphone		X	X
BACCH-BM Pro microphone	X	Optional	Optional
3-band XO network (software)	X	Optional	
InfraRed Head Tracker	X	Optional	Optional
BACCH-HP: 3D audio dSP for headphones (software) with rotational head tracker (hardware)	X	Optional	Optional
64-bit EQ (software)	X	Optional	Optional
3D Audio Analysis Toolkit (test signal generator, XTC and IR measurements) (software)	X	Optional	Optional
Binaural Recorder (software)	X	X	X
Tripod	X	Optional	Optional
Measurements	44.45 cm x 14.6 cm x 51.75 cm	44.45 cm x 8.26 cm x 34.3 cm	44.45 cm x 8.26 cm x 34.3 cm
Weight	18 kg	11 kg	10 kg

This manual applies to all three models, which run the same software and have the same basic functionality, with the exception of the specific model features shown in the table.





## 1.4 A Quick Look at the BACCH-SP

The BACCH-SP has a **single button on the front panel**, with a dim amber LED light at its center (*Grand* model) or above it *adio* and *dio* models). This button, is used to **turn on** the BACCH-SP or to **Force Restart** it in the rare case of a malfunction. All other functions, including normal shut down and restart, are controlled by the iPad SP-Remote.

The back panel has all the connectors including the analog and digital I/O's, and inputs for the head tracker and AC power. The BACCH-SP comes with a dedicated iPad that serves as the sole remote control, a tracking camera<sup>4</sup>, and a binaural microphone (the BACCH-BM Pro for the *Grand* model and the BACCH-BM for the *adio* and *dio* models). As soon as its power cord is plugged in, the BACCH-SP creates its own **dedicated and secure Wi-Fi network** and calls it “BACCH-SP-xxx Network”, where xxx stands for your BACCH-SP's unique serial number. This Wi-Fi network is password protected and is not accessible by any device other than the BACCH-SP and its dedicated iPad. This network remains on as long as AC power is supplied to the SP (i.e. as long as it is connected to a power outlet), even if the unit is shut down. The iPad automatically joins this network when it is turned on and remains on it as long as the network exists (i.e. as long as the BACCH-SP's power cord is plugged in a power outlet).

## 1.5 Setting up the BACCH-SP

### 1.5.1 Setting up the *Grand* model

The *Grand* BACCH-SP can be mounted on a pro-audio rack, placed on a sturdy table or hi-fi equipment shelf, or mounted on top of the recommended three-post SPstand.

**Rack Mounting:** If you intend to have the *Grand* BACCH-SP mounted on a standard pro-audio rack, ask your local dealer for a pair of the custom-made mounting ears that are designed for that purpose. Unscrew the 4 feet off the unit, and store them, before attaching the ears and mounting the unit in the rack. Make sure that at least 1 rack unit space is left free on the top and the bottom of the BACCH-SP to ensure proper passive ventilation.

**Table-top Mounting:** If you prefer to have the unit placed on a table or hi-fi equipment shelf, make sure you leave the 4 feet attached (screwed in) and leave at least 5cm (2 inch) of free space between the top surface of the unit and the next shelf or the bottom surface of the next hi-fi component. Avoid having components that generate excessive heat near the BACCH-SP.

**SPstand Mounting:** A visually impactful, safe, robust and thermally advantageous way to set up the *Grand* BACCH-SP is to mount it on top of the recommended

---

<sup>4</sup>The *Grand* model ships with both a webcam and an infrared camera.





three-post SPstand, which can be ordered from your local dealer. In that case, unscrew the 4 regular feet and screw in the 4 special L-shaped feet that are designed to mate to the top of the SPstand and that come with it. Carefully mate the inner edges of the L-shaped feet to the top outer edges of the SPstand by lowering the BACCH-SP on top of the stand.

### 1.5.2 Setting up the *adio* and *dio* models

The understated but visually stunning chassis<sup>5</sup> of the *adio* and *dio* models is designed to complement most contemporary and period interior designs and deserves to be the visual centerpiece of any high-end or lifestyle audio system.

The *adio* and *dio* models ship with a set of four polished metal cones that easily screw in into the black Delrin mounting feet at the bottom plate the unit to provide effective audio isolation. The cones are then placed over supplied coasters with rubber bottoms that allow the unit to be mounted securely on top of any sturdy flat surface. **By themselves, the Delrin mounting feet do not provide enough friction on most surfaces to prevent the unit from sliding.**

### 1.5.3 Power

The *Grand* BACCH-SP has no voltage settings and accepts all standard household voltage options around the world (from 100V to 220V).

In contrast, **the *adio* and *dio* models REQUIRE SETTING THE VOLTAGE on the back panel of the unit to the local voltage lest damage to the unit occurs.**

Use the supplied AC cord to connect the BACCH-SP to a protected AC power outlet. Like most audiophile-grade hardware the BACCH-SP should be plugged into a power conditioner that protects it from surges and dips in electrical power.



**Required voltage setting for the *adio* and *dio* models.**

### 1.5.4 Passive and Active Cooling

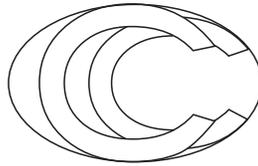
The BACCH-SP's internal components are designed to carry out many demanding functions, including a huge amount of real-time number crunching, without overheating by relying on passive cooling. If overheating occurs, the BACCH-SP goes into active cooling mode where an internal quiet fan kicks in to protect the CPU. Under normal but higher-than-average heat loads the cooling fan may kick in at the lowest of its 4 levels, this is normal and should be inaudible from any practical listening distance from the unit. Hearing the fan from any practical listening distance

<sup>5</sup>The chassis for the *adio* and *dio* models come in either matte black or silver finish. A hand-buffed glossy black or metallic finish is also available as an extra option. The *Grand* model is available in only hand-buffed glossy finish.





is an indication that the BACCH-SP does not have the proper air space around it to insure natural (passive) cooling. In that case, make sure that the BACCH-SP has the proper “breathing space” around it. More on the related topic of thermal data and fan speed monitoring can be found in the subsection describing the Get Thermal Data feature.



---

**End of Section 1.**

---



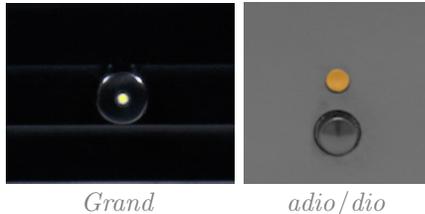


## 2 Quick Start & Basic Operation

In this section we first describe how to quickly start the BACCH-SP, then focus on its most basic and important functionality: making and auditioning BACCH<sup>®</sup> filters. Throughout this section, we often refer to later sections of this manual, where the reader can go to learn in more detail about a hardware or software feature, a button or a setting.

**Warning:** The iPad that ships with the BACCH-SP is a dedicated controller and has a single function: controlling the BACCH-SP. You should never use it for anything else, change its settings, add, update, or remove apps. **You should never update the iPad's operating system.** When the BACCH-SP is plugged online you may get occasional messages on the iPad asking you to update its operating system (iOS). You should cancel these messages and never update the iOS. All software updates to the BACCH-SP and its iPad are done remotely by Theoretica Applied Physics during remote update sessions pre-scheduled with the owner. Any other changes to the software may well result in impairing the BACCH-SP's functionality.

### 2.1 Turn on the BACCH-SP



Make sure the BACCH-SP's Voltage setting is set properly as per Section 1.5.3, and the power cord is connected to a proper power source, then simply depress the **On Button** protruding from the front panel. This lights up the dim amber LED (at the center of the button for the *Grand*, and on top of the button for the *adio* and *dio*) indicating that the BACCH-SP is on<sup>6</sup>. The BACCH-SP will then start its **Booting Process**, which takes from 25 seconds to 75 seconds. (For more detail on the Booting Process see Section 4.1.1).

While the SP is booting up, turn on the iPad (if it is not already on) and choose the TouchOSC app in the iPad's app launcher bar at the bottom of the iPad's screen. This takes you to the main screen of TouchOSC. Tap on the blue "Done" button in the top right corner. This takes you to one of pages of the SP-Remote layout (initially the **I/O page**).

Wait until the single digit near the upper right corner of the screen starts **flickering between "0" and "1"** (see inset picture below). This indicates that the BACCH-SP has finished booting, that it has full two-way communication with the iPad SP-Remote, and that the digital audio processor is functioning normally. (Also, depending on the set-up and the setting on your preamp, you may well hear from your

<sup>6</sup>Another indication that the *Grand* is on is the lit **I/O Sample Rate red LEDs** on its left side panel.



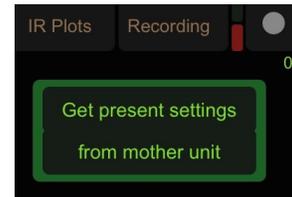


speakers the [Theoretica Arpeggio](#) which announces that the booting process is done and the BACCH-SP is ready.)

The pulsating red LED (which is referred to as the “Intercom” LED in this manual) in the upper right corner of every page (see inset picture above) indicates that the iPad is receiving live data from the BACCH-SP. When any key on the iPad SP remote is tapped, a green (“Data-out”) LED flashes on top of the red one, indicating the iPad is sending a command to the BACCH-SP.

(If after booting, the red “Intercom” LED is not glowing, the iPad and the BACCH-SP are not communicating and you need to refer to Troubleshooting Section 5.1. If the “Intercom” LED is glowing but the “0” and “1” digits are not flickering, the BACCH-SP’s digital audio engine is not running, and you need to refer to Troubleshooting Section 5.2.)

Tap on the square “Get present settings from mother unit” near the upper right corner to get all the settings that were last stored on the SP. (For more detail on the [Booting Process](#) see Section 4.1.1.)

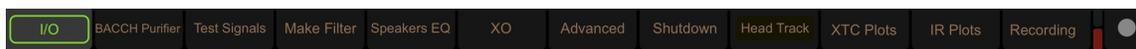


Upper right corner of SP-Remote showing the flickering red (“Intercom”) LED and the alternating 0/1 digits.

## 2.2 Select an Input and Output(s)

Click on the I/O tab to go to the [Inputs/Outputs assignment and control page](#). Choose the desired input and output(s) so that the audio is routed from your chosen audio source, through the BACCH-SP, to your loudspeakers. (See Section 4.4 for more on the available I/O options and their selection.)

Tap on the “Save settings on mother unit” button, in the upper left corner of any page of the SP-Remote to save your I/O selection. (More on [storing the current settings](#) in Section 4.3.)



You are now ready to make your first BACCH<sup>®</sup> filter...





## 2.3 Making and Auditioning a Fixed-Sweet-Spot BACCH<sup>®</sup> Filter



Correct placement of the BACCH-BM mic, blocking entrance to the ear canal.

The BACCH<sup>®</sup> filters, which are the heart of the BACCH-SP's 3D imaging capability, are automatically derived by the processor after quick and simple calibration measurements, called HRTF<sup>7</sup> measurements.

To make a fixed-sweet-spot BACCH<sup>®</sup> filter through an HRTF measurement follow these steps:

1. Assemble the **BACCH-BM binaural microphone** (see Section 3.5.2 for more details) and connect them to the mic input (which is labeled ① on the picture of the *Grand's* back panel, and ④ on that of the *audio and dio* models) of the BACCH-SP making sure that all connections and cables labeled red are associated with the Right Input. **It is important to double check that the Left and Right microphone capsules are plugged into the Left and Right mic inputs of the SP because an inverted connection will lead to an incorrect BACCH<sup>®</sup> filter.**
2. Sit in the intended listening position (sweet spot) and place each capsule of the microphone in the intended ear by plugging your ear canal with the ear plug/mic holder, as shown in the picture above.
3. On the **Make Filter page** (described in detail in Section 4.5) select “**Test**” instead of any of the 7 bins available for storing the impulse response (IR) measurements. This will allow you to conduct a quick test to make sure that all connections are correct, and to set the volume of the calibration tones (called “sine sweeps”) to an **acceptable level**.
4. Set the volume on your preamp a bit (about 10 dB) below what is typical for listening to a line-level source in order to insure the safety of your loudspeakers and that the audio sweeps produced by this test and the Make Filter procedure are not too loud.
5. Set the “Speakers Attenuation” rotary dial on that page to about -25 dB as an initial guess. Tap on the “Arm” button to arm the calibration system and



Test showing good sweep level.

<sup>7</sup>HRTF stands for Head-Related Transfer Function, which is a numerical description of how sound waves interact with an individual's head. An HRTF is usually obtained from a series of many acoustic measurements using a test sound (often a “sine sweep”) from a speaker in an anechoic chamber positioned at different locations around the head of a listener wearing in-ear microphones. For making BACCH<sup>®</sup> filters, only two parts of the HRTF series are needed: the measurements made with the sine sweep emitted from each of the two loudspeakers.





after you position your head in the listening position tap on the “Fire” button to trigger the two tone sweeps (one from the left speaker followed by one from the right speaker) that are used for the HRTF measurements.

6. Wait for the end of the tone sweeps and observe which of the three LEDs under “mic level” lights up (after about 3 seconds from the end of the last tone sweep). If the green LED next to “Good” lights up, the volume of the tone sweep is correct and you are all set to go to the next step of the Make Filter procedure. If, instead, the red LED next to “Too low” lights up, the signal-to-noise ratio of the tone level is too low and you need to increase the volume with the “Speakers Attenuation” rotary dial and repeat the test until you get the green “Good” level LED to light up. If the red LED next to “Too low” lights up you need to decrease that level to avoid clipping or distortion. (Typically, the green “Good” LED will light up when the maximum sound pressure meter level displayed on the level meter on that page is between 80 dB and 100 dB SPL.) Once you get to the good level, tap on the “Save settings on mother unit” button to save these changes.
7. Select one of the 7 bins to store your next HRTF measurement, by tapping on that number, make sure that the “With Head Tracking” toggle button is NOT on, and tap on “Arm” then “Fire” to trigger the measurement. In about 2 seconds a voice will announce the beginning of the measurement, which consists of two tone sweeps, one from each speaker and each lasting for 5 seconds. **Avoid making noises when the “RECORDING” LED under that bin number is lit up.** Also, avoid moving your head during the 5-second sweep. After the second tone sweep is recorded, a voice recording will announce that the BACCH<sup>®</sup> measurement is done. You can now remove the microphone from your ears.
8. Immediately after the recording is done, an amber LED will start flashing indicating that the measurement is being processed by the BACCH<sup>®</sup> Filter Designer Engine. You will also see the progress bar under that LED move from 0% to 100% indicating the progress. When the measurement is processed (the processing takes about 2 seconds) the green “Processed” LED will light up to indicate that the job is done and that the new BACCH<sup>®</sup> filter has been loaded in the corresponding bin. Congratulations, you have made your first BACCH<sup>®</sup> 3D Sound filter.
9. Now, to listen to audio through your newly made BACCH<sup>®</sup> filter, switch to the BACCH<sup>®</sup> Purifier page, and select the same bin number you chose to store the HRTF measurement. This will route any audio from the input through the BACCH<sup>®</sup> filter in that bin. Play audio from the input source, sit in the sweet spot (which is the position where you sat during the measurement in Step 7 above) and enjoy BACCH<sup>®</sup> 3D Sound from your speakers.





## 2.4 Making and Auditioning a Dynamic-Sweet-Spot BACCH<sup>®</sup> Filter with Head Tracking

Making a BACCH<sup>®</sup> filter with head tracking allows you to move your head freely during listening while the BACCH-SP's head tracker tracks your head in real time and seamlessly adjusts the 3D audio sweet spot to follow your head as it moves.



There are two options for the head tracking sensor: 1) The **webcam** and 2) the **infrared camera**. These sensors are described in more detail in Section 3.6, respectively, but the main difference between them is that the infrared camera works irrespective of lighting conditions, even in complete darkness, but has a range limited to about 2 meters, while the webcam has a range of more than 5 meters but requires some light on the face of the listener in order to lock in.

### 2.4.1 Head Tracking with the Webcam

1. Plug the webcam into one of the two USB ports on the back panel of the BACCH-SP and place it facing the listener's head at a distance of about 1 to 5 meters. (More on positioning the camera, including streaming the video to the iPad, in Section 4.7. Make sure that the face is illuminated symmetrically so that the head tracking software can recognize it and lock in on it. Avoid back lighting the head and direct light into the camera.
2. Go to the “Head Track” page of the iPad SP-Remote and tap on the “Camera” button in the “Sensor Mode” subpanel. After about 3 seconds the blue LED on the webcam will light up indicating that that the webcam is on and ready.
3. Sit in the listening position and tap on the green “Find Head” button (see picture below). The BACCH-SP will then start searching for your head within the view-range of the camera. This may take a period of 1-20 seconds, during which an LED next to the word “Searching” will blink indicating that the head search procedure is in progress.





4. If your head is found, the green “Head Tracking” LED will light up steadily and the crosshairs will move neat the center of the tracking screen. If the procedure fails to find your head, change the camera’s position and/or orientation and/or lighting on your face and repeat until the procedure succeeds. (For more on head tracking, see Section 4.7.).

5. Select the “0.75 m” Box Size setting. This sets a 75 cm box, centered at the tracked head, outside of which the SP will not look for a head to track. (More on this setting in Section 4.7.)



6. Once head tracking is set, go back to the “Make Filter” page and follow steps 2-5 in Section 2.3 above to set the correct attenuation level (if it has not been set already).

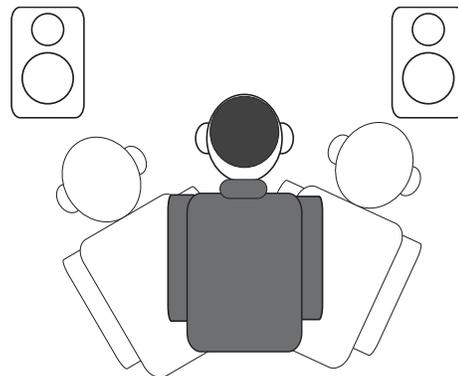


7. Select one of the 7 bins to store your next HRTF measurement, by tapping on that number, then make sure that both the “With Head Tracking” and “Pause before Sweeps” toggle buttons are on (see inset picture). Sit in the center listening position and tap on “Arm” then “Fire” to trigger the measurement sequence. A voice will instruct you where to position your head for each of the three double audio sweeps. Because the “Pause before Sweeps” button is on, the BACCH-SP will stop after each of the three voice instructions and wait for the user to tap on the blinking green “Go” button, which will trigger the pair of audio sweeps. This gives you the time to move your head and check to make sure that your head is still being tracked.

For convenience, the the blinking green “Go” button can be accessed from both the [Make Filter](#) and [Head Track](#) pages. It is best to go to the latter page, after you tap the “Fire” button, so that you can monitor head tracking and insure your head is still being tracked, before you tap the blinking green “Go” button to trigger the audio sweeps.

See the inset figure for the typical positions (Center, Left and Right) of the listener’s head. **Avoid making noises when the “RECORDING” LED under that bin number is lit up.**

8. After the last of the six tone sweeps is recorded, a voice recording will announce that the BACCH<sup>®</sup> measurement is done. You can now remove the microphone from your ears.



Center, Left and Right head positioning during the Make Filter (HRTF measurement) procedure with head tracking.





9. Immediately after the recording is done, an amber LED will start flashing indicating that the measurement is being processed. You will also see the thermometer under that LED move from 0% to 100% indicating the progress. When the measurement is processed (the processing takes about 4 seconds) the green “Processed” LED will light up to indicate that the job is done and that the new BACCH<sup>®</sup> filter has been loaded in the corresponding bin. Congratulations, you have made your first BACCH<sup>®</sup> 3D Sound filter with head tracking.
10. Switch to the [BACCH<sup>®</sup> Purifier page](#) and select the same bin number you chose to store the HRTF measurement. This will route any audio from the input through the BACCH<sup>®</sup> filter in that bin. Note that an LED with the label “HT” under the level meter for that bin is lit, indicating that the BACCH<sup>®</sup> filter in that bin was made with head tracking.
11. Make sure that the “Head Tracking” toggle button near the bottom center of that page is on (see picture below). This insures that live head tracking is enabled and activates a display under that button that dynamically shows the lateral position of your head along with the lateral coordinate. (The coordinate goes from -20 for the extreme left position to +20 for the extreme right position, with 0 indicating the center position.)
12. Play audio from the input source, sit anywhere within the area bounded by the extreme left and right positions chosen during the measurement, and enjoy BACCH<sup>®</sup> 3D Sound from your speakers. As long as your head movements stay within those bounds, your head is tracked by the BACCH-SP and the 3D sound sweet spot is adjusted to seamlessly follow your head.



Head tracking indicator showing, in real time, the detected location of the listener’s head within the extreme left and right limits where the measurements were made.



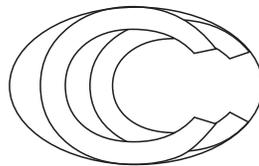


### 2.4.2 Head Tracking with the Infrared Camera

1. Plug the infrared camera into one of the two USB ports on the back panel of the BACCH-SP and place it facing the listener's head at a distance of about 1 to 2 meters. (More on positioning the camera in Section 4.7.)
2. Go to the "Head Tracker" page of the iPad SP-Remote and tap on the "IR Cam" button in the "Sensor Mode" subpanel. After about 9 seconds a faint red light will appear in the left-most lens (see left inset pic). This indicates that the infrared camera is on and ready.
3. Select the "0.75 m" Box Size setting. This sets a 75 cm box, centered at the tracked head, outside of which the SP will not look for a head to track. (More on this setting in Section 4.7.)
4. Sit in the listening position and tap on the green "Find Head" button (see picture below). The BACCH-SP will then immediately search for your head within the view-range of the camera and starts tracking it. If all is set correctly, the green "Head Tracking" LED should light up steadily and the crosshairs (see picture below) should move instantaneously with your head. The crosshairs in the square display show the horizontal (lateral) and vertical (height) positions of your head, and the crosshairs on the right show the depth (forward and backward) position. Adjust the camera's tilt so that crosshairs in the square display is close to the center of the display as shown in the pic below. (For more on head tracking, see Section 4.7.).
5. Once head tracking is set, go back to the "Measure IR" page and follow steps 2-5 of Section 2.3 above to set the correct attenuation level (if it has not been set already), then proceed with Steps 7-12 of Section 2.3 to carry out the HRTF measurements resulting in the head-tracking enabled BACCH<sup>®</sup> filter.



The IR Cam with the red light in the left lens, indicating the camera is on.



\_\_\_\_\_ End of Section 2. \_\_\_\_\_





## 3 Hardware Description

### 3.1 The Front Panel



The front panel of the BACCH-SP is exceedingly simple: It has a single small round button near the center and a single amber LED. This button is used to turn the BACCH-SP on (and therefore is referred to as the “On Button” in this manual) as described in Section 4.1.1. It is not normally used to turn off the BACCH-SP. **Normal shutdown and restart are not done with this button** but rather from the Shutdown/Restart page of the iPad SP-Remote, as described in Section 4.1.2.

This button is also used in the rare cases of a malfunction that cannot be fixed through the procedures described in the [Troubleshooting Section](#). In such cases **Hard Shutdown, or Hard Restart** with this button may be required to restore normal operation as described in Section 4.1.3.

The LED that lights up amber when the BACCH-SP is on is located in the center of the On button for the *Grand* model and above it in the *adio* and *dio* models. The dimness of the amber LED is, by design, in order to reduce visual interference with the surroundings.



### 3.2 The *Grand*'s Back Panel and its Connectors



The back panel has all the connections needed to connect and operate the BACCH-SP. The *Grand* model has all the analog and digital input and output formats and associated connector types needed connect the BACCH-SP to virtually any audio system. While the analog I/O's and the digital outputs can all be used simultaneously, only a single (stereo) digital input should be connected at one time to avoid conflicting clock signals.

**The Back Panel Inputs.** The inputs are located in the top row of the back panel and consist of the following:

- ① **XLR Mic input:** This pair of XLR inputs is used exclusively with the BACCH-BM binaural mic for [HRTF Measurement](#) and [Binaural Recording](#). These inputs apply the 48 V of phantom power required to use the BACCH-BM microphone. Connecting any other load to these powered inputs may damage it.
- ② **Analog Input 1:** Balanced stereo analog audio input on a pair of XLR connectors (for line-level analog sources, e.g. phono stage, tape player, etc.). This input is activated with the button labeled “An In 1 (XLR)” on the [I/O](#) page and requires the “Clock Source” on the [Advanced](#) page to be set to “Internal”.
- ③ **Analog Input 2:** Balanced stereo analog audio input on a pair of TRS connectors (for line-level analog sources, e.g. phono stage, tape player, etc.). This input is activated with the button labeled “An In 2 (TRS)” on the [I/O](#) page and requires the “Clock Source” on the [Advanced](#) page to be set to “Internal”.
- ④ **Analog Input 3:** Unbalanced stereo analog audio input on a pair of RCA connectors (for line-level analog sources, e.g. phono stage, tape player, etc.). This input is activated with the button labeled “An In 3 (RCA)” on the [I/O](#) page and requires the “Clock Source” on the [Advanced](#) page to be set to “Internal”.





- ⑤ **Clock Input:** Digital word clock input on BNC connector for slaving BACCH-SP to an external clock. This requires the “Clock Source” on the [Advanced page](#) to be set to “Word In”.
- ⑥ **AES/EBU Digital Input:** AES/EBU digital stereo audio input on a single XLR connector. This input is activated with the button labeled “Digital In” on the [I/O page](#) and requires the “Clock Source” on the [Advanced page](#) to be set to “Digital In”.
- ⑦ **AES-3id Digital Input:** AES-3id digital stereo audio input on a single BNC connector. This input is activated with the button labeled “Digital In” on the [I/O page](#) and requires the “Clock Source” on the [Advanced page](#) to be set to “Digital In”.
- ⑧ **Optical Digital Input:** S/PDIF digital stereo audio input on a single TOSLINK connector. This input is activated with the button labeled “Digital In” on the [I/O page](#) and requires the “Clock Source” on the [Advanced page](#) to be set to “Digital In”.
- ⑨ **Coaxial Digital Input:** S/PDIF digital stereo audio input on a single RCA connector. This input is activated with the button labeled “Digital In” on the [I/O page](#) and requires the “Clock Source” on the [Advanced page](#) to be set to “Digital In”.
- ⑩ **USB Digital Input:** USB2 digital stereo audio input on a single type-B USB connector (e.g. Computer-based file player). This input is activated with the button labeled “USB In” on the [I/O page](#) and requires the “Clock Source” on the [Advanced page](#) to be set to “Digital In”.

**The Back Panel Outputs.** The outputs are located in the second row from the top of the back panel and consist of the following:

- ⑪ **Analog Output 1:** Balanced stereo analog audio output on XLR connectors (for line-level analog input to preamps, amps, or powered speakers.) This output is activated with the button labeled “An Out1 (XLR)” on the [I/O page](#) and can be assigned to the HF channel on the [XO page](#).
- ⑫ **Analog Output 2:** Balanced stereo analog audio output on TRS connectors (for line-level analog input to preamps, amps, or powered speakers.) This output is activated with the button labeled “An Out2 (TRS)” on the [I/O page](#) and can be assigned to the MF channel on the [XO page](#).
- ⑬ **Analog Output 3:** Unbalanced stereo analog audio output on RCA connectors (for line-level analog input to preamps, amps, or powered speakers.) This output is activated with the button labeled “An Out3 (RCS)” on the [I/O page](#) and can be assigned to the LF channel on the [XO page](#).





- ⑭ **Clock Output:** Digital word clock output on BNC connector for using the BACCH-SP's internal clock as the master clock to other digital devices or processors. If the BACCH-SP's "Clock Source" on the [Advanced page](#) is set to "Internal", the Clock Output will be at a fixed sampling rate of 96 kHz, clocked by the BACCH-SP's internal clock. If the Clock Source on the [Advanced page](#) is set to "Digital In", the BACCH-SP will pass the incoming clock from the Digital Input to the Clock Output. When Clock Output is used, the clock Termination on the [Advanced page](#) should be set to Off. Otherwise, it is better to leave it unless a physical terminator is used.
- ⑮ **AES/EBU Digital Output:** AES/EBU digital stereo audio output on a single XLR connector. This output is activated with the button labeled "Digital Out" on the [I/O page](#). Although it can be assigned to the HF channel on the [XO page](#), the XO should normally be bypassed when using the Digital Output.
- ⑯ **AES-3id Digital Output:** AES-3id digital stereo audio output on a single BNC connector. This output is activated with the button labeled "Digital Out" on the [I/O page](#). Although it can be assigned to the HF channel on the [XO page](#), the XO should normally be bypassed when using the Digital Output.
- ⑰ **Optical Digital Output:** S/PDIF digital stereo audio output on a single Toslink connector. This output is activated with the button labeled "Digital Out" on the [I/O page](#). Although it can be assigned to the HF channel on the [XO page](#), the XO should normally be bypassed when using the Digital Output.
- ⑱ **Coaxial Digital Output:** S/PDIF digital stereo audio output on a single RCA connector. This output is activated with the button labeled "Digital Out" on the [I/O page](#). Although it can be assigned to the HF channel on the [XO page](#), the XO should normally be bypassed when using the Digital Output.
- ⑲ **Headphones Output:** Headphones stereo output on 1/4" TRS connector for connecting headphones to the BACCH-SP's headphones amplifier. **When headphones are used, it is generally necessary to bypass any BACCH® filters by selecting the Bypass button on the BACCH® Purifier page as such filters are not intended for headphones listening**, unless the filters are of the [BACCH-HP type](#), produced using the [optional BACCH-HP filter making and processing software](#) that can be added to the BACCH-SP processor.

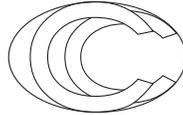


### Non-audio Connections.

②① **Head-Tracker USB Inputs:** A pair of input ports for the Type-A USB connectors of the IR camera or the webcam. **Only one of the sensors should be plugged at one time.**

②② **Network:** Ethernet port for a Cat-5e Ethernet cable with RJ45 connector to connect the BACCH-SP to a local network, and to the Internet for **remote maintenance.**

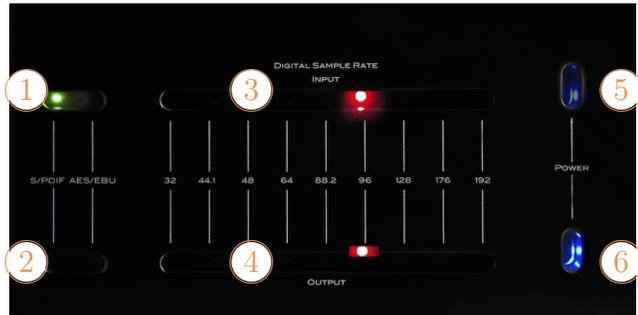
②③ **Power Inlet:** IEC power inlet. It accepts both the 120V/60 Hz and 220V/50 Hz AC power options. No voltage conversion is needed of the *Grand* model. **That is not the case for the *adio* and *dio* models.**





### 3.3 The *Grand*'s Digital I/O Sample Rate LEDs

The left side panel of the *Grand* model has two rows of LED's that display the sampling rate of the digital I/O's, and other LED's that indicate the current status of the internal format conversion hardware.



① **Digital Input Format Conversion Indicator:** Due to the architecture of the BACCH-SP's internal format conversion hardware this green LED will always be in “AES/EBU” position unless the **Toslink (Optical S/PDIF)** input is being used, in which case the LED will be in the “S/PDIF” position.

② **Digital Output Format Conversion Indicator:** Due to the architecture of the BACCH-SP's internal format conversion hardware, this green LED will always stay in the “AES/EBU” position no matter what digital output is being used.

③ **Digital Input Sampling Rate Indicator:** This row of red LED's indicate the sampling rate for the digital input in use, which could be AES/EBU, AES-3id, S/PDIF coax or optical. (The USB input is not included.) If no such digital input is connected, these LEDs alternate continuously with a ticker-tape effect (that is normal).

④ **Digital Output Sampling Rate Indicator:** This row of red LED's indicate the sampling rate for the digital output in use, which could be AES/EBU, AES-3id, S/PDIF coax or optical. If no such digital output is connected, these LEDs alternate continuously with a ticker-tape effect (that is normal).

⑤ **Digital Input Format Conversion Switch and LED:** This recessed black radio button (that can be reached using a screwdriver) can be used to turn on or off the digital input format conversion hardware inside the BACCH-SP. The blue LED indicates whether this switch is on or off. **When it is off, the BACCH-SP cannot accept any digital input.** Turning it off is an option when one is using the analog inputs (or the BACCH-SP's internal player) and one wishes to suppress the LED lights for visual reasons.

⑥ **Digital Output Format Conversion Switch and LED:** This recessed black radio button (that can be reached using a screwdriver) can be used to turn on or off the digital output format conversion hardware inside the BACCH-SP. The blue LED indicates whether this switch is on or off. **When it is off, the BACCH-SP cannot send out any digital output.** Turning it off is an option when one is using the analog outputs and one wishes to suppress the LED lights for visual reasons.





### 3.4 The *adio* and *dio* Back Panel



The back panel of the *adio* and *dio* models has all the connections needed to connect and operate the BACCH-SP. The *adio* and the *dio* have the same connections, except the *dio* has no analog section, therefore connectors 5-10 do not exist on its back panel. While the analog I/O and the digital outputs can all be used simultaneously, only a single (stereo) digital input should be connected at one time to avoid conflicting clock signals.

- ① **Coaxial Digital Input:** S/PDIF digital stereo audio input on a single RCA connector. This input is activated with the button labeled “Digital In” on the **I/O** page and requires the “Clock Source” on the **Advanced** page to be set to “Digital In”.
- ② **USB Digital Input:** USB2 digital stereo audio input on a single type-B USB connector (e.g. Computer-based file player). This input is activated with the button labeled “USB In” on the **I/O** page and requires the “Clock Source” on the **Advanced** page to be set to “Digital In”.
- ③ **Clock Input:** Digital word clock input on BNC connector for slaving BACCH-SP to an external clock. This requires the “Clock Source” on the **Advanced** page to be set to “Word In”. e.g. phono stage, tape player, etc.).
- ④ **XLR Mic input:** This pair of XLR inputs is used exclusively with the BACCH-BM binaural mic for **HRTF Measurement** and **Binaural Recording**. These inputs apply the 48 V of phantom power required to use the BACCH-BM microphone. Connecting any other load to these powered inputs may damage it.
- ⑤ **Analog Output 1:** Balanced stereo analog audio output on XLR connectors (for line-level analog input to preamps, amps, or powered speakers.) This output is activated with the button labeled “An Out1 (XLR)” on the **I/O** page and can be assigned to the HF channel on the **XO** page.
- ⑥ **Analog Output 2:** Balanced stereo analog audio output on TRS connectors (for line-level analog input to preamps, amps, or powered speakers.) This output is activated with the button labeled “An Out2 (TRS)” on the **I/O** page and can be assigned to the MF channel on the **XO** page.





- ⑦ **Analog Output 3:** Unbalanced stereo analog audio output on RCA connectors (for line-level analog input to preamps, amps, or powered speakers.) This output is activated with the button labeled “An Out3 (RCS)” on the **I/O** page and can be assigned to the LF channel on the **XO** page.
- ⑧ **Analog Input 1:** Balanced stereo analog audio input on a pair of XLR connectors (for line-level analog sources, e.g. phono stage, tape player, etc.). This input is activated with the button labeled “An In 1 (XLR)” on the **I/O** page and requires the “Clock Source” on the **Advanced page** to be set to “Internal”.
- ⑨ **Analog Input 2:** Balanced stereo analog audio input on a pair of TRS connectors (for line-level analog sources, e.g. phono stage, tape player, etc.). This input is activated with the button labeled “An In 2 (TRS)” on the **I/O** page and requires the “Clock Source” on the **Advanced page** to be set to “Internal”.
- ⑩ **Analog Input 3:** Unbalanced stereo analog audio input on a pair of RCA connectors (for line-level analog sources, e.g. phono stage, tape player, etc.). This input is activated with the button labeled “An In 3 (RCA)” on the **I/O** page and requires the “Clock Source” on the **Advanced page** to be set to “Internal”.
- ⑪ **Coaxial Digital Output:** S/PDIF digital stereo audio output on a single RCA connector. This output is activated with the button labeled “Digital Out” on the **I/O** page. Although it can be assigned to the HF channel on the **XO** page, the XO should normally be bypassed when using the Digital Output.
- ⑫ **Optical Digital Output:** S/PDIF digital stereo audio output on a single TOSLINK connector. This output is activated with the button labeled “Digital Out” on the **I/O** page. Although it can be assigned to the HF channel on the **XO** page, the XO should normally be bypassed when using the Digital Output.
- ⑬ **Clock Output:** Digital word clock output on BNC connector for using the BACCH-SP’s internal clock as the master clock to other digital devices or processors. If the BACCH-SP’s “Clock Source” on the **Advanced page** is set to “Internal”, the Clock Output will be at a fixed sampling rate of 96 kHz, clocked by the BACCH-SP’s internal clock. If the Clock Source on the **Advanced page** is set to “Digital In”, the BACCH-SP will pass the incoming clock from the Digital Input to the Clock Output. When Clock Output is used, the clock Termination on the **Advanced page** should be set to Off. Otherwise, it is better to leave it On unless a physical terminator is used.
- ⑭ **Headphones Output:** Headphones stereo output on 1/4” TRS connector for connecting headphones to the BACCH-SP’s headphones amplifier.





When headphones are used, it is generally necessary to bypass any BACCH® filters by selecting the Bypass button on the BACCH® Purifier page as such filters are not intended for headphones listening, unless the filters are of the BACCH-HP type, produced using the optional BACCH-HP filter making and processing software that can added to the BACCH-SP processor.

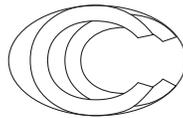
**15 Power Inlet:** IEC power inlet. **BEFORE CONNECTING POWER MAINS, USER MUST CHECK AND INSURE THAT THE VOLTAGE SELECTOR, LABELED 17 IN THE FIGURE ABOVE, IS SET TO THE APPROPRIATE VOLTAGE, OR DAMAGE MAY OCCUR.**

**16 Protection Fuse:** Changable 2 A/ 250 V “slow blow” fuse.

**17 Voltage Selector:** Manual selector for selecting correct voltage. This selector can be turned using a regular screwdriver and **must be set to the correct voltage before connecting the power mains to 15 OR DAMAGE MAY OCCUR.**

**18 Network:** Ethernet port for a Cat-5e Ethernet cable with RJ45 connector to connect the BACCH-SP to a local network, and to the Internet for **remote maintenance.**

**19 Head-Tracker USB Inputs:** A pair of input ports for the Type-A USB connectors of the IR camera **or** the webcam. **Only one of the sensors should be plugged at one time.**





### 3.5 The BACCH-BM Binaural Microphone



The BACCH-BM binaural microphone is a high-quality, hand-assembled, stereo-matched, and individually calibrated and equalized microphone used primarily for the in-ear acoustic measurements needed to make BACCH<sup>®</sup> filters. It can also be used as a state-of-the-art binaural recording microphone with or without the BACCH-SP.

The microphone comes in two versions:

- **The BACCH-BM** comes as standard with the *adio* and *dio* models.
- **The BACCH-BM Pro** comes as standard with the *Grand* model, and is available as an upgrade option with the *adio* and *dio* models. It differs from the regular BACCH-BM by the smaller size of its capsules (whose diameter is about 1/3 that of the regular version), its frequency extension (which goes up to 30 kHz), and the fact that the capsules are gold plated. Otherwise, the two versions have the same characteristics, **specifications**, and performance.

For making BACCH<sup>®</sup> filters, the two versions are equivalent and give the same results. The BACCH-BM Pro has an advantage in making high-definition binaural recording due to its larger frequency extension (30 kHz). The two versions come in the same packaging, which include the same accessories. They are visually differentiated by the fact the regular BACCH-BM has a white Y wire junction (labeled ④) in the





[picture above](#)) while the BACCH-BM Pro has a black Y wire junction (as the one shown in that [picture](#)).

### 3.5.1 Description of Components

The BACCH-BM package has the following components:

- ① **The BACCH-BM microphone capsules:** These two capsules are the audio sensors of the binaural microphone. Each capsule is encapsulated in a 3D-printed white enclosure that protects it and provides support for it. At the other end this enclosure is a small protruding pin that serves to hold in place the removable and washable earbud (a number of which are supplied in the package) and prevents it from slipping off the enclosure when it is pulled out of the ear canal.
- ② **The 5-pin XLR Connector:** This XLR5 connector houses the high-precision analog signal conditioning circuit for the BACCH-BM, and allows it to operate on the 48 V phantom power that is supplied by the BACCH-SP Microphone Inputs (item ① of Section 3.2, or item ④ of Section 3.4).
- ③ **Y Wire Junction:** This 3D-printed Y wire junction is white for the BACCH-BM (which comes standard with the *audio* and *dio* models) and black (as in the [picture above](#)) for the BACCH-BM Pro (which comes standard with the *Grand* model).
- ④ **Dual XLR Adapter:** This XLR5 female to dual-XLR3 male Y-cable adapter allows the BACCH-BM to plug into the BACCH-SP's Microphone Inputs (item ① of Section 3.2, or item ④ of Section 3.4).
- ⑤ **BACCH-BM Case:** This durable case comes with both the regular and Pro versions of the BACCH-BM microphone and houses all the components shown in the [picture above](#).
- ⑥ **Calibration Card:** This laminated card displays the individualized microphone calibration, including the [technical specifications](#), frequency responses, and equalization curves. Each card displays the serial number of the individual microphone in the package.

Not shown in the [picture](#) are the following items included in the BACCH-BM package:

1. **A set of washable white rubber earbuds** which allow inserting and holding the mic capsules in the entrance of the ear canal. The BACCH-BM comes with a small pouch containing 20 such earbuds of medium size (which fit most human ears), while the BACCH-BM Pro comes with a set of three pouches (for three sizes: small, medium and large) containing 20 earbuds each. **Used earbuds should not be shared between individuals unless thoroughly cleaned with rubbing alcohol and left to dry for 3 minutes.**





2. **A USB stick** (included in the BACCH-BM case) containing the individual free-field equalization filter of the BACCH-BM required to flatten its response and match the gain between the two capsules. The filter is given as an impulse response (IR) (at 96kHz) in the standard .wav format, as well as in the proprietary .bac format used internally by the BACCH-SP. **This filter has already been loaded in the BACCH-SP and is automatically used by the processor whenever the mic signal is used. The USB stick should NOT be inserted in the USB ports of the BACCH-SP.** It is included here, in case the BACCH-BM is used for binaural recording with a recording system other than the BACCH-SP<sup>8</sup>.
3. **A cable-shirt clip** (included in the BACCH-BM case) which holds the mic cable and which is clipped to the listener's shirt to mechanically isolate the microphone during HRTF measurements.
4. **A 5-conductor balanced extension cable** which is used between the 5-pin male XLR Connector (2) and the XLR5 female connector of the Dual XLR Adapter (4) as an extension to allow the user to sit in the sweet spot with the BACCH-BM connected to the BACCH-SP.

### 3.5.2 Assembly and Use

To assemble the BACCH-BM follow these steps:

1. Hook up the 5-conductor balanced extension cable between the between the 5-pin male XLR Connector (2) and the XLR5 female connector of the Dual XLR Adapter (4).
2. Plug the two male XLR connectors at the end pf Dual XLR Adapter (4) into the BACCH-SP's Microphone Inputs (item (1) of Section 3.2, or item (4) of Section 3.4).
3. **With clean and dry fingers**, mount one of the clean earbuds to the back of each of the microphone capsules by first inserting the small plug protruding from the white capsule enclosure into the earbud and pushing on the screen-capped tip of the capsule, so that the bottom of that screen cap is flush with the earbud, as shown in the inset pictures on the right.

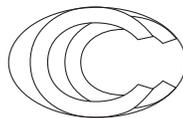


Proper mounting of the BACCH-BM (Pro) microphone capsule in an earbud.

<sup>8</sup>In that case, the filter should be loaded in the recording system as an impulse response to be convolved with the mic signal using a standard stereo convolution plugin (for more information on the use of the BACCH-BM with recording systems other then the BACCH-SP, contact [Theoretica's Technical Support](#).



4. Insert the sheathed microphone cable, just below the **Y wire Junction** (4), into the cable-shirt clip as shown in the inset picture, then attach the clip to your shirt in order to mechanically isolate the microphone capsules from the rest of the assembly.
5. Place the earbud-mounted capsule that is connected to the wire marked with a red tape into the right ear, so that the earbud plugs the entrance to the ear canal, as shown in the inset picture. Place the other capsule, the same way, in the left ear.
6. You are now ready to use the BACCH-BM for **making BACCH® filters** or for **binaural recording**,





## 3.6 The Head Tracking Sensors

### 3.6.1 The Webcam



The BACCH-SP ships with a Logitech C920 webcam for use as a sensor for head tracking. The camera plugs into the Head-Tracker USB Inputs (item [20](#) of Section [3.2](#), or item [19](#) of Section [3.4](#)) and is controlled from the [Head Tracker](#) page. The webcam-based head tracker can track a head that 5 meters or more from the camera but requires some light on the face of the listener in order to lock in.

Make sure that the face is illuminated symmetrically so that the head tracking software can recognize it and lock in on it. Avoid back lighting the head and direct light into the camera.

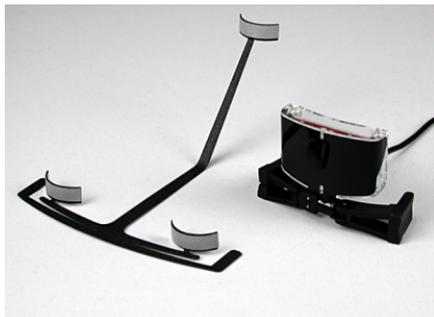
### 3.6.2 The IR Camera

The optional IR camera can be used for head tracking irrespective of lighting conditions, even in complete darkness, but has a range limited to about 2 meters only. It works with incandescent light, fluorescent light, natural light and no light but its ability to track the head suffers if light sources with string infrared light (such as some halogen lamps) radiate directly into the camera.



Like the webcam, the IR camera plugs into the Head-Tracker USB Inputs (item [20](#) of Section [3.2](#), or item [19](#) of Section [3.4](#)) and is controlled from the [Head Tracker](#) page.

### 3.6.3 The TrackIR Sensor



The optional TrackIR sensor is for tracking head rotation with the optional [BACCH-HP 3D headphones package](#). It consists of an IR emitter/receiver unit that plugs into the Head-Tracker USB Inputs (item [20](#) of Section [3.2](#), or item [19](#) of Section [3.4](#)), and a passive reflector that is mounted on the headphones with a clip.

\_\_\_\_\_ **End of Section 3.**



## 4 Operation & Detailed Description

### 4.1 Booting, Restarting and Shutting Down

**Warning:** In the case where any of the analog outputs of the BACCH-SP (*Grand* and *adio*) are directly fed into a power amp, the user must be aware that turning the BACCH-SP on or shutting it off without muting the analog inputs or outputs of the amp (or shutting off the amp) might produce pops that may be loud enough to damage the loudspeakers.

#### 4.1.1 Booting

1. Make sure the SP's power cord is connected to a proper power source and simply depress the **On button** protruding from the front panel<sup>9</sup>. This lights up the dim amber LED (at the center of the button for the *Grand*, and on top of the button for the *adio* and *dio*) indicating that the BACCH-SP is on<sup>10</sup>. The BACCH-SP will then start its **Booting Process**, which takes from 25 to 75 seconds.
2. While the SP is booting up, turn on the iPad and choose the TouchOSC app in the iPad's app launcher bar at the bottom of the iPad's screen. This takes you to the main screen of TouchOSC. **Do not tap on or change any of the settings.** Tap on the blue "Done" button in the top right corner. This takes you to one of pages of the iPad SP-Remote layout (initially the I/O page).
3. Wait until the small rectangular red LED (which is referred to as the "Intercom" LED in this manual) near the top right corner is glowing steadily. The single digit in the upper right corner of the screen (see **inset picture** in Section 2.1) starts flickering between "0" and "1". This indicates that the BACCH-SP has finished booting, that it has full two-way communication with the iPad SP-Remote, and that the digital audio processor is functioning normally. (Also, depending on the set-up and the setting on your preamp, you may well hear from your speakers the **Theoretica Arpeggio** which announces that the booting process is done and the BACCH-SP is ready.)

The pulsating red ("Intercom") LED in the upper right corner of every page indicates that the iPad has an active two-way communication link with the BACCH-SP. When any key on the iPad SP remote is tapped, a green LED flashes on top of the red one, indicating the iPad is sending a command to the BACCH-SP.

(If after booting, the Intercom LED is not glowing, the iPad and the BACCH-SP are not communicating and you need to refer to Troubleshooting Section 5.1.

<sup>9</sup>For the *Grand* model, the On button must be held down until it is flush with that panel for about 2 seconds then released.

<sup>10</sup>Another indication that the *Grand* is on is the lit **I/O Sample Rate red LEDs** on its left side panel. There are no such LEDs on the *adio* and *dio*.





If the Intercom LED is glowing but the “0” and “1” digits are not flickering, the BACCH-SP’s digital audio engine is not running, and you need to refer to Troubleshooting Section 5.2.)

4. Tap on the square “Get present settings from mother unit” near the upper right corner to get all the settings that were last stored on the SP. (For more detail on the [Booting Process](#) see Section 4.1.1.)

#### 4.1.2 Restarting and Shutting Down



Shutting down and restarting the BACCH-SP are done from the “Shut-down” page. First check that the Intercom LED is glowing red to make sure that the BACCH-SP and the iPad SP-remote are communicating correctly, then tap the Shut down or Restart but-

ton. Immediately after this action, the Intercom LED should go off, indicating that the BACCH-SP has stopped communicating with the iPad SP-Remote as it goes through its own shutdown or restart procedure. In the case of shutdown, the BACCH-SP will completely shut down after a period of about 25-75 seconds, at the end of which the dim amber LED on the front panel of the BACCH-SP (and, in the case of the *Grand* model, the [I/O Sample Rate red LEDs](#) on the left side panel, which indicate the I/O sampling rates) go off.

In the case of Restart, the BACCH-SP will go through a shut-down and start cycle by itself, during which the dim amber LED on the front panel of the BACCH-SP will remain on. During that cycle the iPad SP-Remote and the BACCH-SP cannot communicate. At the end of the cycle, the Intercom LED in the top right corner of every page on the iPad SP-Remote start glowing red (as shown in Fig 1), indicating that the BACCH-SP is now communicating with the iPad SP-Remote and is ready for normal operation.

#### 4.1.3 Hard Shutdown and Restart

In the rare cases where the BACCH-SP becomes unresponsive, and none of the Troubleshooting schemes in Section 5 work or apply, you would need to Hard Shutdown the unit. To do so, depress the On button and keep it depressed until the BACCH-SP shuts down (the amber LED light goes off, and in the case of the *Grandmode*, the side I/O LEDs go off). Wait a few seconds, then you can restart the unit as usual with the On button.

**Note that after a “Hard Shutdown” the boot up procedure may take a bit longer than usual as the BACCH-SP goes through an internal check and restore procedure.**

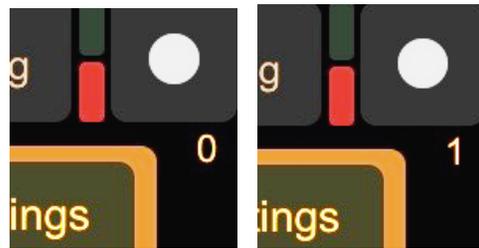




## 4.2 The BACCH-SP Wi-Fi Network & the iPad SP-Remote

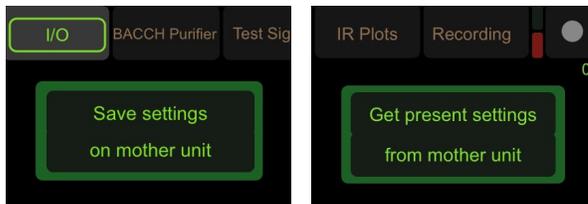
As soon as the BACCH-SP is plugged in a power outlet it sets its own dedicated and secure Wi-Fi network with the name “BACCH-SP PUX Network”, where x represents the serial number of your unit. This network is dedicated to the communication between the SP and the iPad, and remains on as long as the unit is plugged in a power outlet, even if the BACCH-SP is turned off. The iPad SP-Remote software runs on the iPad as a layout under the TouchOSC app v.1.9.3. **Updating this app, the iOS, or any other software on the dedicated iPad should be avoided in order to insure full functionality of the BACCH-SP.** (More on Internet connectivity and the iPad software in Section 4.16.)

The range of communication between the iPad and the mother unit is typically at least 7 meters but may be less if there are large physical obstacles, or walls, between the iPad and the BACCH-SP or if there is significant radio frequency interference in the radio band used by the BACCH-SP (which can be either 2.4 or 5 GHz depending on the environment).



Before controlling the BACCH-SP with the iPad SP-Remote make sure that Intrecom LED is glowing red and the single digit in the upper right corner of the screen (see the two inset pictures) is flickering between “0” and “1”, which indicate that the BACCH-SP has full two-way communication with the iPad SP-Remote, and that the digital audio processor is functioning normally.

## 4.3 Storing and Syncing the Current Settings



Tapping on the “Save settings on mother unit” button, in the upper left corner of any page of the SP-Remote (left inset picture) will save the current settings permanently until they are changed. **Any changes to the settings on the iPad’s SP-Remote will be made instantaneously on the mother unit but are not stored in memory until the “Save settings on mother unit” button is tapped.** If the BACCH-SP is restarted, all the settings made since the last time the “Save settings on mother unit” button was tapped will be lost and the unit will boot up to the previously stored settings. The only exception is after taking the HRTF measurements for making a BACCH<sup>®</sup> filter, when the BACCH-SP automatically stores all its current settings.



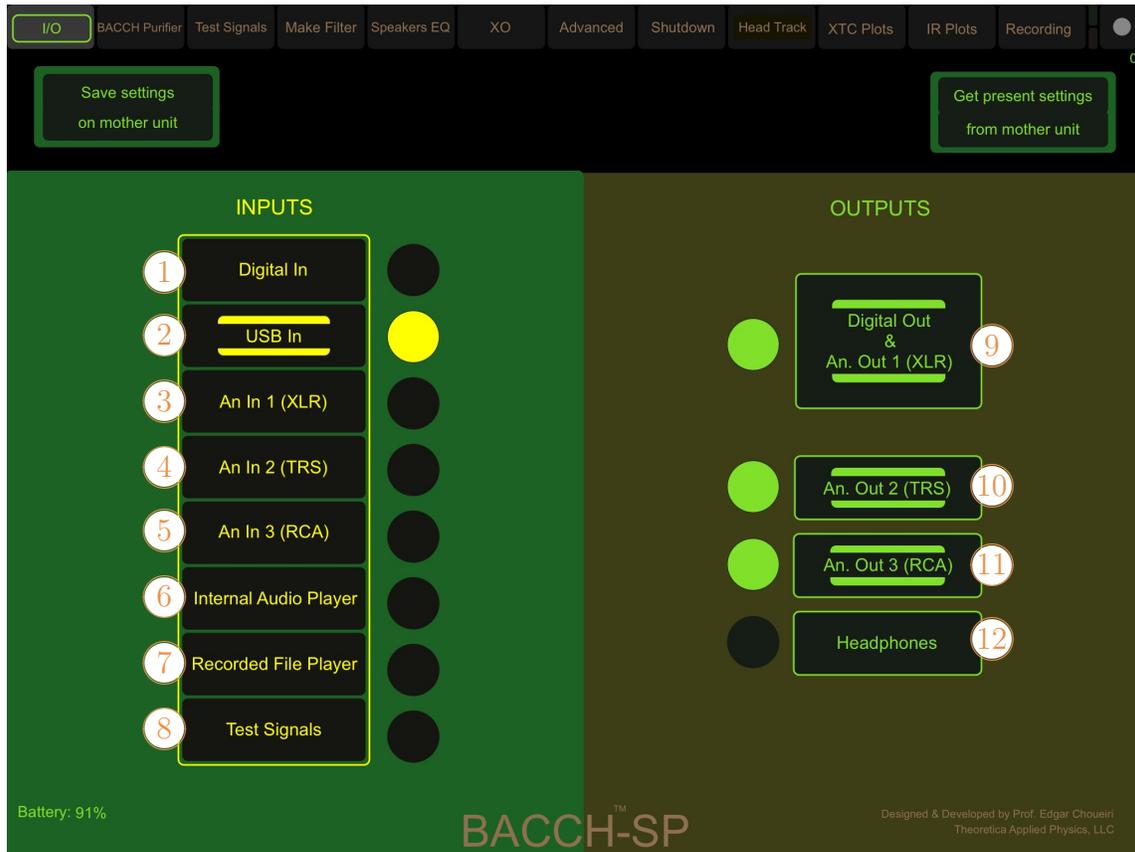


Tapping on the “Get present settings from mother unit” button (right inset picture) will not recall the previously stored settings but will simply refresh the settings appearing on the iPad’s SP-Remote with their present values. This is useful to sync the settings on the iPad with those dialed in the mother unit after a loss of communication between the two, or after the TouchOSC or the iPad have been restarted.





## 4.4 Selection of Digital and Analog Inputs and Outputs



The BACCH-SP is also a versatile input and output switcher that allows switching between various digital and analog inputs and outputs. The switching is easily done from the “I/O” page of the iPad SP-Remote, shown in the figure above. The round LEDs light up next to each input or output button to indicate which I/O is selected. While any of the 4 output options can be activated simultaneously, only a single input of the eight inputs can be selected at a given time. **Therefore only one of the eight round yellow LEDs should be lit at one time. Having more than one of these LEDs lit is indicative of an incomplete bin switch due to a drop of communication between the iPad and the mother unit. In such a case, you should switch out of the desired input then switch back to it to insure that only its LED is lit.**

Moreover, it is important to remember, as stated in the hardware description of Sections 3.2 and 3.2, that **only a single (stereo) digital input should be connected at one time to avoid conflicting clock signals.**

### 4.4.1 Inputs

- ① **Digital In:** This radio button is for all digital inputs except USB. **In order to allow the SP to lock to the clock of the incoming digital signal and adapt its sampling rate to that of the incoming audio, the “Digital In” setting must be selected for the Clock Source on the Advanced, page unless the SP is slaved to**





an external clock, in which case the Clock Source should be set to “Word In”.

- ② **USB In:** This radio button is for the USB audio input.
- ③ **An In 1 (XLR):** This radio button is for the XLR stereo analog input (which is available on the *Grand* and *adio* models only).
- ④ **An In 2 (TRS):** This radio button is for the TRS stereo analog input (which is available on the *Grand* and *adio* models only).
- ⑤ **An In 3 (RCA):** This radio button is for the RCA stereo analog input (which is available on the *Grand* and *adio* models only).
- ⑥ **Internal Audio Player:** This radio button is for the BACCH-SP’s **Internal Audio File Player (IAFP)**, which comes pre-loaded with a large collection of **Binuaral+ music albums, courtesy of the Chesky Records label**. The player is described in Section 4.15. **When this input is selected, the Clock Source setting on the Advanced page must be set to “Internal”.**
- ⑦ **Recorded File Player:** This radio button is for playing audio files recorded with the BACCH-SP internal **Binaural Recorder**, described in Section 4.11. **When this input is selected, the Clock Source setting on the Advanced page must be set to “Internal”.**
- ⑧ **Test Signals:** This radio button is for playing audio files recorded with the BACCH-SP internal **Binaural Recorder**, described in Section 4.11. **When this input is selected, the Clock Source setting on the Advanced page must be set to “Internal”.**

#### 4.4.2 Outputs

- ⑨ **Digital Out & An Out 1 (XLR):** This button is for all digital outputs *and* the XLR stereo analog output (the latter is available on the *Grand* and *adio* models only).
- ⑩ **An Out 2 (TRS):** This button is for the TRS stereo analog output, which is available on the *Grand* and *adio* models only.
- ⑪ **An Out 3 (RCA):** This button is for the RCA stereo analog output, which is available on the *Grand* and *adio* models only.
- ⑫ **Headphones:** This button is for the stereo output of the headphones analog amplifier. **When headphones are used, it is generally necessary to bypass any BACCH<sup>®</sup> filters by selecting the Bypass button on the BACCH<sup>®</sup> Purifier page as such filters are not intended for headphones listening, unless the filters are of the BACCH-HP type, produced using the optional BACCH-HP filter making and processing software that can added to the BACCH-SP processor.**





## 4.5 The Make Filter Page



The methods for creating BACCH<sup>®</sup> filters, **with** or **without** head tracking, were described in Sections 2.4 and 2.3 respectively. Here we focus on describing the controls on the Make Filter page, which are used during the filter making (HRTF measurement) process.

- ① **Arm:** This button arms the BACCH-SP for making the HRTF measurements required for the automatic filter making process. Specifically, it activates the microphones, whose signal levels can then be seen in ⑫ and allows the ‘Fire button ⑩) to be activated.
- ② **With Head Tracking:** If this button is on, the HRTF measurement process initiated by tapping the Fire Button ⑩) will yield a BACCH<sup>®</sup> filter with head tracking enabled.
- ③ **Pause before Sweeps:** If this button is on, the HRTF measurement process initiated by tapping the Fire button ⑩) will pause before emitting each pair of sine sweeps from the speakers, in order to give the user the time to position his head in the intended position for the measurement. During that





pause the Go button **Go button** (4) will flash green until it is tapped, which will trigger the next pair of sine sweeps.

(4) **Go** During an HRTF measurement with the “Pause before Sweeps” button on, this Go button will flash green during the pause between the sine sweeps, until it is tapped. When tapped it will trigger the next pair of sine sweeps.

(5) **Test:** This radio button will set the HRTF measurement to be in test mode. An HRTF measurement done in test mode will not produce a BACCH<sup>®</sup> filter. Such a test measurement is used to make sure that the signal level of the sine sweep emitted by the speakers (controlled by (11)), as recorded by the BACCH-BM, is neither too high (which may cause clipping) nor too low (which may lead a low signal-to-noise ratio). A Good level corresponds to a sound pressure level (SPL) between 85 and 95 dB, as shown at the **Microphone Level Meter** (12).

(6) **Mic level indicator:** One of the 3 LEDs in this indicator will light up at the end of an HRTF measurement to indicate whether the mic level during the sweep was too high (which may cause clipping), too low (which may lead a low signal-to-noise ratio) or “Good”. It is advisable to do test measurement to ensure that the mic level is “Good” before proceeding to make a BACCH<sup>®</sup> filter.

(7) **Bin Selector:** This set of radio buttons allows selecting the bin in which the BACCH<sup>®</sup> filter resulting from the HRTF measurement will be stored. The BACCH<sup>®</sup> filter in that bin would then be available for use by selecting it using a **similar bin selector on the BACCH<sup>®</sup> Purifier page**. The small round red LEDs on top of each bin number indicate which of the bins is currently selected and serves to confirm a bin switch when such a switch is made. **Only one of these LEDs should be lit at one time. Having more then one of these LEDs lit is indicative of an incomplete bin switch due to a drop of communication between the iPad and the mother unit. In such a case, you should switch out of the desired bin then switch back to it to insure that only its LED is lit.**

(8) **Recording Indicator:** The recording indicator LED, corresponding to the selected bin, will light up red when the BACCH-SP is recording the response of the sine sweeps at the BACCH-BM microphone in the ears of the listener. **when this recording indicator LED is on, it is important not move the head or make sounds, as that may compromise the performance of the resulting BACCH<sup>®</sup> filter.**

(9) **Measurement Processing Progress Bar:** This progress bar shows the progress of the **BACCH<sup>®</sup> Filter Designer Engine** in processing the HRTF measurement just taken. It starts moving shortly after the the last sine sweep is emitted and recorded and reaches 100% in a couple of seconds for a



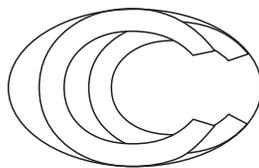


measurement without head tracking, or 3 seconds for one with head tracking. At the end of the Make Filter process, i.e. after the Progress Bar reaches the 100% end, the BACCH-SP executes an auto-save command that saves all current settings to memory. If the BACCH-SP is restarted before another

**⑩ Fire:** The Fire button is only activated when the **Arm button ①** is on. When tapped, the Fire button will trigger the sequence of voice messages and sine sweeps for the HRTF measurement.

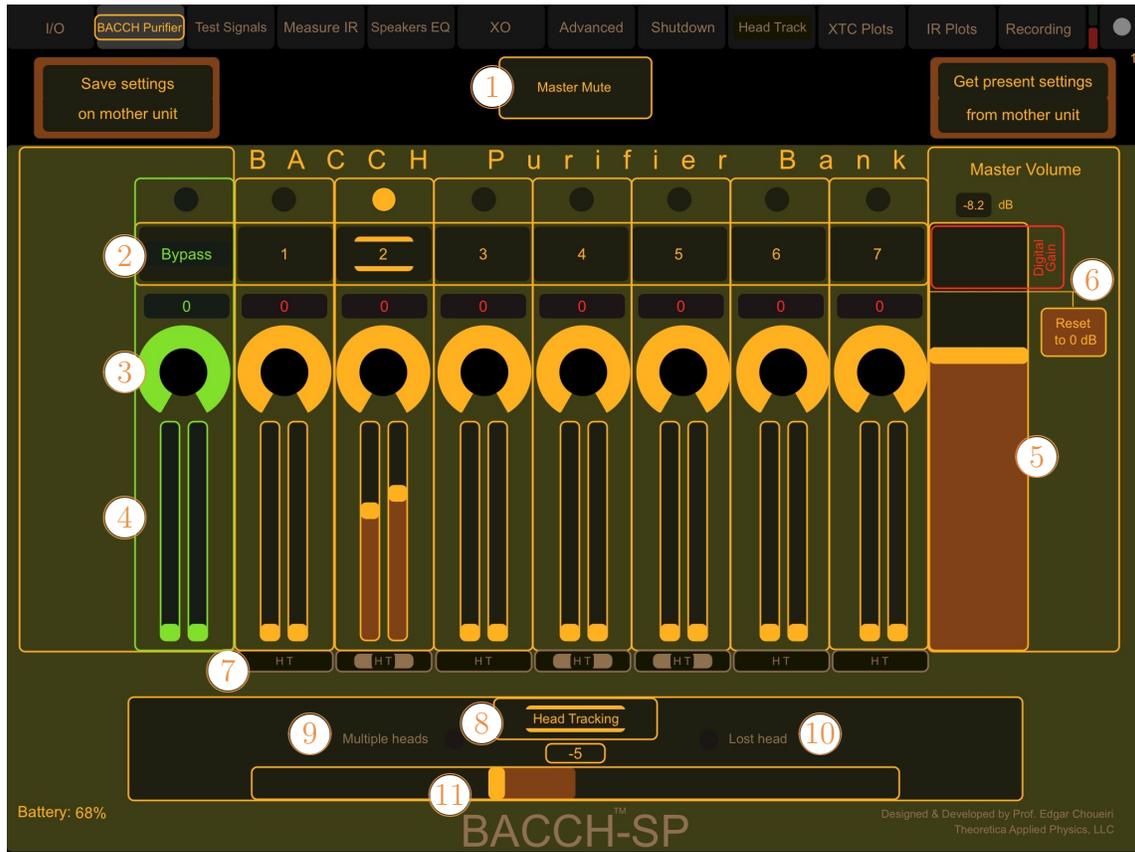
**⑪ Attenuation Dial:** This attenuation dial controls the level of the sine sweeps emitted during the HRTF measurement. It is used typically used during a **test HRTF measurement ⑤** to set the correct level and **should not be changed during an actual measurement.**

**⑫ Microphone Level Meter:** This level meter shows the level of the signal recorded at the BACCH-BM microphone in the ears of the user. It is calibrated to give an accurate measure of the sound pressure level (SPL) in dB. Ideally, during the sine sweep, the signal level should be between 85 and 95 dB.





## 4.6 Selecting, Auditioning, and Bypassing BACCH<sup>®</sup> Filters



Selecting, auditioning, and bypassing BACCH<sup>®</sup> filters are done through the BACCH<sup>®</sup> Purifier Page, which offers the following controls:

- ① **Master Mute:** This button mutes the audio from all the outputs of the BACCH-SP.
- ② **Bin Selector:** This set of radio buttons allows selecting a BACCH<sup>®</sup> filter from one of the seven available bins. The Bypass position corresponds to unprocessed audio, i.e. to the signal not undergoing any BACCH<sup>®</sup> filtering. To switch between bins, simply tap on the number of the desired bin. To bypass, tap on the word "Bypass". The small round yellow LEDs on top of each bin number indicate which of the bins is active and serves to confirm a bin switch when such a switch is made. **Only one of these LEDs should be lit at one time. Having more than one of these LEDs lit is indicative of an incomplete bin switch due to a drop of communication between the iPad and the mother unit. In such a case, you should switch out of the desired bin then switch back to it to insure that only its LED is lit.**
- ③ **Individual Bin Attenuation Dials:** These attenuation dials allow attenuating the audio coming out of each bin. They are useful to match the levels between two or more bins for comparing the audio between them, when the





BACCH<sup>®</sup> filters in those bins have different level (due to different dynamic range loss). Since regular BACCH<sup>®</sup> filters have no dynamic range loss, the audio through them would have the same level (which is also the same level for the “Bypass bin”) these dials should generally be left at a zero attenuation unless one makes an **irregular BACCH<sup>®</sup> filter** (discussed in Section 4.10.3), which would have finite dynamic range loss, and would thus require bins containing regular BACCH<sup>®</sup> filters to be attenuated for a matched comparison with the irregular filter.

④ **Individual Bin Level Meters:** These level meters give a visual measure of the audio level in the activated bin, prior to attenuation (i.e. upstream of the attenuation dial). A level meter is only active if its bin is selected through the **Bin Selector** ② and audio is coming from the **selected input source**. It is not affected by the **the Master Mute button** ①, or the **the Master Volume slider** ⑤,

⑤ **Master Volume Slider:** This slider controls the volume of the audio coming out of the `hyperref[LbOutputsSelec]`selected outputs. It should generally be used as an attenuator (from 0 dB FS) but can be used to boost the audio (digital amplification) if the slider is raised into the red-framed range marked “Digital Gain”, where the output signal can be boosted by up to 10 dB. **This additional digital boost should be used judiciously. Some audiophile recordings have enough headroom to allow raising the slider above 0 dB, but doing so for many popular music recordings may well lead to clipping as many commercial recordings are mastered to have the average and peak levels of the audio too close to 0 dB FS to allow a digital boost.** Lowering the volume slider too far (below 20-30 dB) would incur, as in the case of any digital attenuation, a dynamic range loss that may become audible if the attenuation is excessive. Therefore, if getting normal sound pressure level at the listening position requires lowering the Master Volume slider too far, it is better to use analog attenuation, which is in the case of the *Grand* and *adio* models can be done through the 3-level **Analog Gain switcher**.

⑥ **Volume Reset Button:** When tapped this button quickly resets the Master Volume slider to 0 dB FS.

⑦ **Head-Tracking Indicators:** These indicators will light up around the letters “HT” if the associated bins contain a BACCH<sup>®</sup> filter with head tracking, i.e. one made with the **Head Tracking button** turned on on the **Make Filter page**. These bins are referred to as “HT-enabled bins”.

⑧ **Head-Tracking Button:** This button activates or de-activates head tracking. Its effect applies only if the **selected bin** is an “HT bin” (i.e. contains a BACCH<sup>®</sup> filter made following the **procedure for making BACCH<sup>®</sup> filters with head tracking** described in Section 2.4. When this button is on for an HT bin, and **head tracking** is set correctly, the **head location indicator** ⑪ moves





to show the instantaneous lateral (left-right) location of the tracked listener's head. When the button is off for an HT bin, head tracking is de-activated and the BACCH-SP defaults to the central BACCH<sup>®</sup>filter, which assumes that the non-tracked listener is most likely sitting at the location where the center HRTF measurement was made (see figure at the bottom of Page 16).

⑨ **Multiple Heads LED Indicator:** This indicator works only when using the infra-red (IR) sensor for head tracking, and lights up when there are more than one head in the *view range of that sensor*.

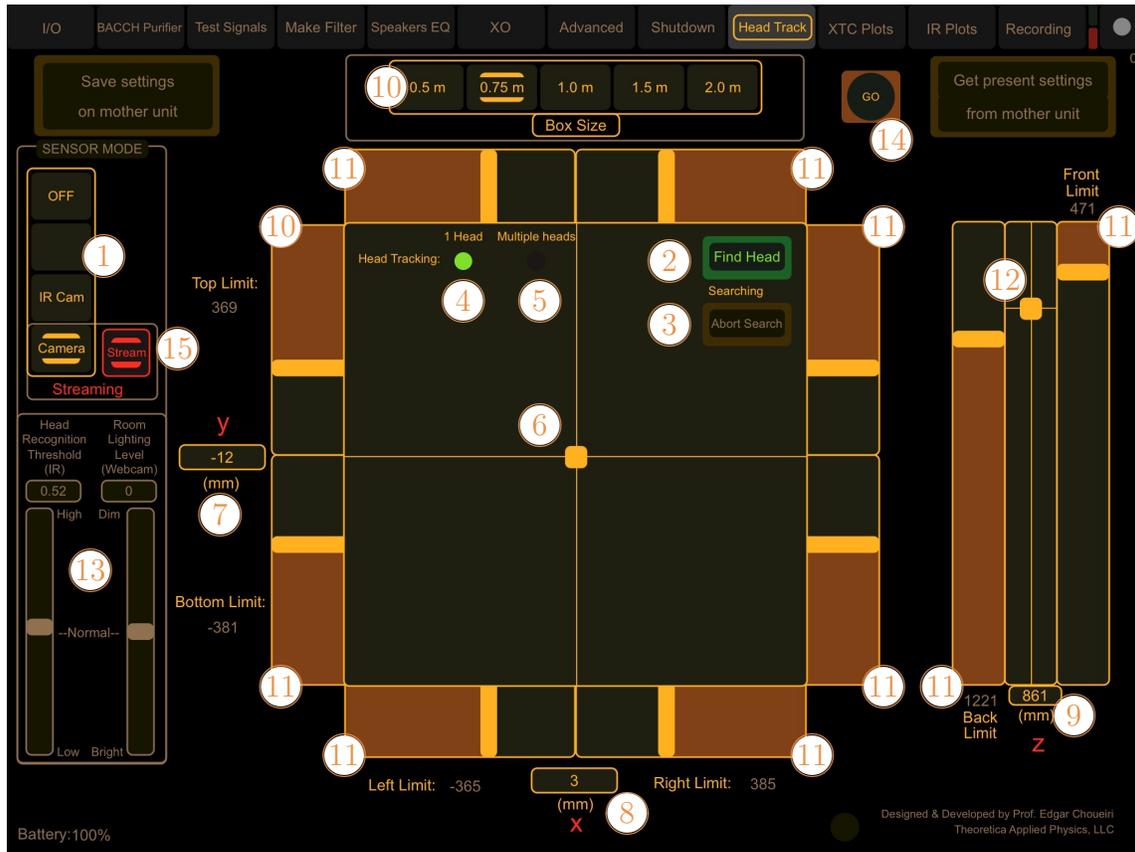
⑩ **Lost Head LED Indicator:** This indicator lights up when the BACCH-SP head tracking system finds no head to track.

⑪ **Head Location Indicator:** This dynamic indicator shows the instantaneous lateral (left-right) location of the tracked listener's head, if the *Head-Tracking Button* is on and if the selected bin is an "HT bin" (i.e. one that contains a BACCH<sup>®</sup> filter made following the *procedure for making BACCH<sup>®</sup> filters with head tracking* described in Section 2.4.





## 4.7 Head Tracking Set Up and Control



The Head Track page shown above is where all the controls for head tracking reside. These controls allow selecting a sensor, triggering a Head Search process to find the listener’s head in the sensor’s field of view, and lock on it, and controls for monitoring head tracking and setting up a virtual box (centered on the listener’s head) within which to track the head (any heads outside of this box will not be tracked). Once the head tracking parameters have been set and the BACCH-SP is tracking the listener’s head, the user can proceed to **make BACCH<sup>®</sup> filters**. **If the head tracking settings are changed, or the sensor is moved, the head-tracking parameters of BACCH<sup>®</sup> filters in HT-enabled bins, may not be valid anymore, and such filters must be remade following the procedure in Section 2.4.**

① **Sensor Mode:** This radio button allows selecting a sensor type for head tracking. The “Off” setting turns off the sensor; “IR Cam” turns on the **infrared camera** and “Camera” turns on the **webcam**. The “Stream” button, which works for the webcam only, and which allows streaming the camera’s video to the iPad for helping to point the camera, is described separately in the entry for ⑮ further below.

② **Find Head:** **This green button works only for the webcam sensor.** After pointing the webcam towards the head of the listener to be tracked, sitting in





the intended sweet spot and tapping this button will trigger the head search process, which will cause the BACCH-SP to scan the camera's view field for a human head. During this process, which takes a maximum of 30 seconds, a small round yellow LED will flash next to the word "Searching" below the button to indicate that the head search process is in progress. During this head search process the listener should look straight towards the camera. If the process is successful, the Head Tracker will lock on the face of the listener, the yellow LED will stop flashing, the green **1-head Head Tracking indicator LED** (4) will light up, and the crosshairs (6) will start following the head. If after 30 seconds no lock occurs, the yellow LED will stop flashing, the green **1-head Head Tracking indicator LED** (4) will not light up and the crosshairs will not be responsive to the listener's head movement. In that case, the camera needs to be repointed (the "Streaming to iPad" utility can be used to aid on that task) and/or the lighting to be adjusted so that the head is lit more uniformly with no little or light going to the camera as described in Section ??).

(3) **Abort Search:** This button works only for the webcam sensor. Tapping on this button will abort the Head Search process that is started by tapping the **Find Head button** (2).

(4) **1-head Tracking Indicator:** This small red LED indicator lights up whenever the BACCH-SP has locked in on a head and is tracking it.

(5) **Multiple Heads Indicator:** This small red LED indicator, which works only for the IR sensor, lights up when the IR sensor detects more than one head in its view field.

(6)  **$x - y$  Crosshairs:** During head tracking these crosshairs move to dynamically show the instantaneous location of the tracked head. The corresponding  $x$  (lateral) and  $y$  (height) coordinates are displayed in real time in the numerical fields labeled (7) and (8), as measured in mm from the center of the **Head Tracking Box**.

(7) **Instantaneous  $x$  Value:** The number in this field is the instantaneous  $x$  (lateral) coordinate of the tracked head as measured in mm from the center of the **Head Tracking Box**.

(8) **Instantaneous  $y$  Value:** The number in this field is the instantaneous  $y$  (height) coordinate of the tracked head as measured in mm from the center of the **Head Tracking Box**.

(9) **Instantaneous  $z$  Value:** The number in this field is the instantaneous  $z$  (depth) coordinate of the tracked head as measured in mm from the head tracking sensor.

(10) **Head Tracking Box Size:** This radio button selector allows selecting the size of the Head Tracking Box, which is a virtual box, centered on the





listener's head, within which to track the head. Any heads outside of this box will not be tracked. The settings are 0.5, 0.75, 1.0, 1.5 and 2.0 meters. For a given setting, say 0.75 m, the Head Tracking Box is set to have a width and height (and, in the case of the IR cam, the depth) all set to 75 cm. This setting should be made after the head tracker has locked on a head. The box frame sliders

**11 Manual Box Size Sliders:** These  $x$ ,  $y$  and  $z$  sliders allow setting the size of the virtual Head Tracking Box manually, but they are best left to be set automatically by selecting the Box size from the [Head Tracking Box Size selector](#) **10**.

**12 Depth Location Crosshairs:** These crosshairs show the instantaneous location (depth,  $z$ ) of the tracked head from the sensor. This head coordinate is not used by the BACCH-SP to adjust 3D imaging. Only the lateral coordinate  $x$  is used for that purpose.

**13 Image Controls:** There are two sliders in the control sub-panel.

- The first slider labeled “Head Recognition Threshold (IR)” **works only for the IR sensor** and is used to raise or lower the threshold for what the Head Tracking algorithm considers a human head. A high value (above 0.5) raises that threshold and is useful in the rare circumstances when there are objects in the view field of the IR sensor that resemble a 3D human head. Such objects will be excluded from head tracking if the threshold is high enough. Lowering the threshold can sometimes aid in recognizing a head whose 3D features are altered by hair or a worn hat. Normally, this slide should be left at the Normal setting (0.5).
- The second slider labeled “Room Lighting Level (Webcam)” **works only for the webcam** and is used to compensate for strong or dim lighting in the room. Raising this slider above the zero value (Normal) will aid in detecting a head in dim lighting. Lowering it helps in bright lighting. Since the webcam-based Head Tracking algorithm has automatic brightness control, this slider has limited effect and is seldom used except in situations where the lighting is extremely dim or bright.

**14 Go:** This button has the same function as the [Go button](#) on the [Make Filter Page](#) described on page 40. During an HRTF measurement with the “Pause before Sweeps” button on, this Go button will flash green during the pause between the sine sweeps, until it is tapped. When tapped it will trigger the next pair of sine sweeps. It appears on both the [Make Filter](#) and [Head Track](#). It is on the latter page in order to make it convenient to trigger the sine sweep while monitoring head tracking to insure that the sine sweeps are





not triggered at a time when head tracking is not working or the head tracker has lost the head.

**15 Stream:** The streaming function works only for the webcam sensor. This button streams the video from the webcam to the iPad so that the user can see what the camera is seeing. This can be quite helpful to set and point the camera when setting up head tracking. To use the video streaming function, follow these steps:

1. Set the camera in the desired location and point it as best as you can towards the head of the intended listener sitting in the sweet spot.
2. Sit in the sweet spot and tap the the Stream button (15). The word "Streaming" under that button will starts flashing in red.
3. Flip out of the TouchOSC app on the iPad and launch the VLC app, located in the iPad dock.
4. In the VLC app tap the small white cone icon in the upper left corner. This will bring up a menu of functions.
5. Tap on the "Network Stream" item in that menu. This will bring up the Network Streaming page.
6. Tap on the item labeled "BACCH-SP Cam" on that page. This will open up a small square display in the lower left corner. Tap on that display to enlarge it to full screen.
7. You should now see a live streaming of the webcam's video with a latency of about 2 seconds.
8. You can now use this live display to adjust the camera position and pointing, and to adjust the lighting so that the face of the listener is roughly in the center of the display. You may or may not see the green crosshairs indicating that the head has been locked on and is being tracked. Either way, proceed to the next step.
9. Go back to the Head Track page in the TouchOSC app and tap on the Find Head button (2).
10. Wait for the head search process to find the head and lock on it, as described in the description of the Find Head button (2) above.
11. After the head is found and head tracking starts, choose a box size setting (10) to set the virtual box to the desired size (the 0.75 m size is a good typical setting.)
12. Head tracking is now all set. You can proceed to making HT-enabled BACCH<sup>®</sup> filters.

**Note:** If the head tracking settings are changed, or the sensor is moved, the head-tracking parameters of BACCH<sup>®</sup> filters in HT-enabled bins, may not be valid anymore, and such filters must be remade following the procedure in Section 2.4.





## 4.8 The Graphic Equalizer (Optional)



The BACCH-SP has an optional double-precision (64-bit), 31-band, 1/3-octave digital graphic equalizer that allows equalizing the output audio (on all outputs) to compensate for room modes and/or speakers's coloration. This equalizer, while very accurate, is not meant as an automated room correction function that automatically adjusts to meet a set target frequency response. It is a manual equalizer that is used to equalize the sound by adjusting the 31 sliders on the intuitive graphical interface shown above.

① **Preset Selector:** This radio button selector allows storing and recalling up to 5 dialed equalization curves as presets. To store an equalization curve in a preset, simply tap the preset number on the selector, dial the curve using the sliders ③, then tap the **Save Settings on mother unit** button located in the upper left corner of every SP-Remote page. To recall (and apply) the stored curve in a preset, simply tap that preset number.

② **Activate:** This button activate or deactivates the equalizer (all presets).

③ **EQ Curve interface:** You dial an EQ curve for a given preset by moving the sliders on this interface. Note that if you move any of the 31 band sliders above 0 dB by a certain amount, say  $x$  dB, the BACCH-SP will automatically





apply an attenuation of  $x$  dB to the audio to avoid clipping. This corresponds to a dynamic range loss of  $x$  dB displayed at ⑤.

④ **Flatten:** Tapping on this button will immediately flatten the EQ curve in the active preset, by zeroing all the 31 band sliders.

⑤ **Dynamic Range Loss Value:** The value of dynamic range loss due a dialed equalization curve having one, or more, sliders set above 0 dB, is displayed here to remind the user that the audio for this preset is automatically attenuated by that amount.





## 4.9 The Crossover Network (Optional)

The screenshot displays the 'CROSSOVER NETWORK' settings page. At the top, there are navigation tabs: I/O, BACCH Purifier, Test Signals, Make Filter, Speakers EQ, XO (selected), Advanced, Shutdown, Head Track, XTC Plots, IR Plots, and Recording. Below these are two buttons: 'Save settings on mother unit' and 'Get present settings from mother unit'. The main area is divided into three rows of settings:

- Row 1 (Bypass):** A radio button labeled '1 Bypass' is selected. Below it, a frequency range from 20 Hz to 22 kHz is shown with the text '(An Out 1 = An Out 2 = An Out 3 = Dig Out)'.
- Row 2 (2-Band XO):** A radio button labeled '2 2-Band XO' is selected. It shows an 'XO1' frequency slider set to 118 Hz (labeled '3') and two output bands: 'LF (An Out 3)' and 'HF (An Out 1 & Dig Out)'.
- Row 3 (3-Band XO):** A radio button labeled '4 3-Band XO' is selected. It shows an 'XO1' frequency slider set to 162 Hz (labeled '5') and an 'XO2' frequency slider set to 1632 Hz (labeled '6'). The output bands are 'LF (An Out 3)', 'MF (An Out 2)', and 'HF (An Out 1 & Dig Out)'.
- Row 4 (Sanders):** A radio button labeled '7 Sanders' is selected. It shows an 'XO1' frequency slider set to 50 Hz (labeled '8') and a 'Fixed XO2 (172 or 228 Hz)' (labeled '9'). The output bands are 'LF (An Out 3)', 'MF (An Out 2)', and 'HF (An Out 1 & Dig Out)'.

Below the crossover settings are three attenuation sliders and filter order selectors:

- LF Band Attenuation:** A slider set to -12.9 dB (labeled '10'). Below it is an 'XO1 Filter Order' selector with '8th' and '4th' options (labeled '11').
- MF Band Attenuation:** A slider set to -10.4 dB (labeled '12'). Below it is an 'XO2 Filter Order' selector with '8th' and '4th' options (labeled '13').
- HF Band Attenuation:** A slider set to 0 dB (labeled '14').

The bottom of the screen shows 'Battery: 88%' on the left, 'BACCH-SP' in the center, and 'Designed & Developed by Prof. Edgar Choueiri, Theoretica Applied Physics, LLC' on the right.

The BACCH-SP Grand and audio models have an optional versatile, powerful and accurate 64-bit digital crossover (XO) network that is easily configurable from the page shown above. It can be configured as a 2-band or 3-band XO network, with variable XO frequencies, individual band attenuation, and Linkwitz-Riley filters with selectable (4th/8th) order.

- ① **Bypass:** This radio button bypasses the XO network altogether. At this setting all of the the BACCH-SP's analog outputs (as well as the digital output) receive the same full-band audio signal.
- ② **2-Band XO:** At this setting the BACCH-SP splits the processed audio into a high-frequency (HF) band, which it sends to its **An Out 1 (XLR) and Digital Out outputs**, and a low-frequency (LF) band, which it sends to its **An Out 3 (RCA) output**. This allows using a bi-amped speakers system, such as one with subwoofers.
- ③ **2-Band XO Frequency:** This slider allows changing the 2-band XO frequency between 50 and 5000 Hz.
- ④ **3-Band XO:** At this setting the BACCH-SP splits the processed audio into a high-frequency (HF) band, which it sends to its **An Out 1 (XLR) and**





**Digital Out outputs**, a medium-frequency (MF) band, which it sends to its **An Out 2 (TRS) output**, and a low-frequency (LF) band, which it sends to its **An Out 3 (RCA) output**. This allows using a tri-amped speakers system.

⑤ **3-Band XO Frequency 1:** This slider allows changing the first 3-band XO frequency, separating the LF and MF bands, between 50 and 5000 Hz.

⑥ **3-Band XO Frequency 2:** This slider allows changing the second 3-band XO frequency, separating the MF and HF bands, between 200 and 18,000 Hz.

⑦ **Custom XO:** This setting is reserved for custom XO configurations that are programmed by Theoretica by request of the user who wishes to configure the BACCH-SP for a more complex or particular playback system than is possible with a regular XO network<sup>11</sup>. For inquiries about the design and implementation of custom XO networks, contact [Theoretica's Technical Support](#).

⑧ **Custom XO Frequency 1:** This first Custom XO frequency, separating the LF and MF bands, can be pre-programmed to be controlled by a slider like shown in the picture above, or to be a fixed value as in ⑨.

⑨ **Custom XO Frequency 2:** This second Custom XO frequency, separating the MF and HF bands, can be pre-programmed to be a slider like ⑧ or a fixed value as shown in the picture above.

⑩ **LF Band Attenuation:** Controls the attenuation of the LF band of the XO network. It has no effect when the XO network is in **Bypass mode**.

⑪ **Order of XO Filter 1:** Allows switching the order of the first XO filter between 4th order (a slope of 24dB/Octave) and 8th order (a slope of 48dB/Octave). It has no effect when the XO network is in **Bypass mode**.

⑫ **MF Band Attenuation:** Controls the attenuation of the MF band of the XO network. It has no effect when the XO network is in **Bypass mode** or **2-Band mode**.

⑬ **Order of XO Filter 2:** Same as ⑪ but for the second XO filter. It has no effect when the XO network is in **Bypass mode** or **2-Band mode**.

⑭ **HF Band Attenuation:** Controls the attenuation of the HF band of the XO network. It has no effect when the XO network is in **Bypass mode**.

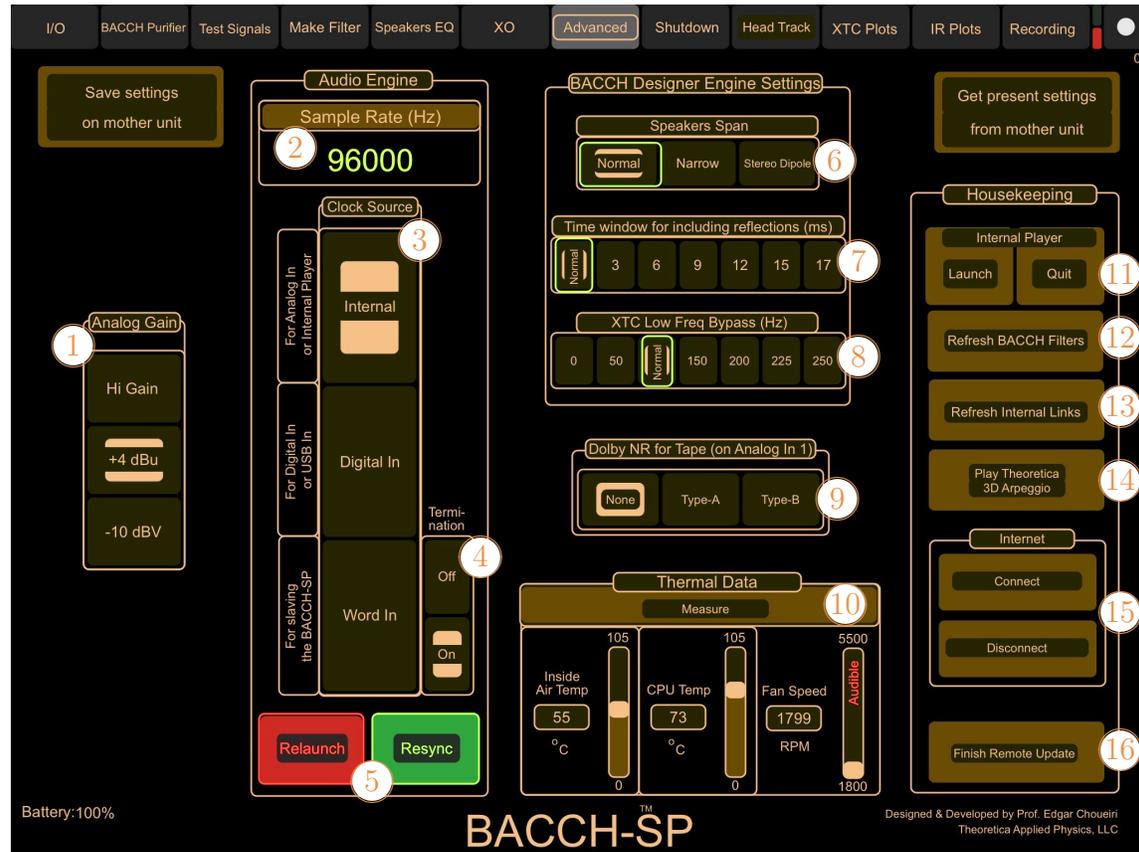
---

<sup>11</sup>Examples are multiple horn systems and hybrid electrostatic-dynamic speakers systems, which might require frequency-dependent amplitude and phase equalization and driver time alignment for each of the three bands in the XO. The example shown in the picture above is a custom XO network for the [Sanders M10 hybrid electrostatic-dynamic speakers](#), which require an XO with specific frequency-dependent equalization that is applied by the pre-configured outboard processor that ships with those speakers. The BACCH-SP's custom XO can replace such a processor, thus eliminating the additional A/D and D/A conversion of that processor.





## 4.10 The Advanced Settings Page



The Advanced page consists of 6 panels that contain a number of controls, settings, and housekeeping functions that are useful for configuring the BACCH-SP, adapting it to particular situations and monitoring its performance.

### 4.10.1 Analog Preamp Gain Panel

① **Analog Gain:** This three-setting radio button selector, allows setting the gain on the preamp at the BACCH-SP's (*Grand* and *adio* models) analog outputs. This integrated analog preamp is useful for adapting the BACCH-SP's analog outputs to the inputs of your amp(s), thus often eliminating the need for an outboard preamplifier<sup>12</sup>. The medium (default) setting “+4 dBu” is a good starting point for most amps and playback configurations. If the playback sound pressure level (sound volume) is too high at the listening position when the **Master Volume** slider is near 0 dB FS, the Analog Gain should be set to its lowest setting of -10 dBV. In the opposite case, when the sound is too low at

<sup>12</sup>**Warning:** In the case where any of the analog outputs of the BACCH-SP (*Grand* and *adio*) are directly fed into a power amp, the user must be aware that turning the BACCH-SP on or shutting it off without muting the analog inputs or outputs of the amp (or shutting off the amp) might produce pops that may be loud enough to damage the loudspeakers.





the listening position with the **Master Volume slider** near 0 dB FS, the Analog Gain should be set to the “Hi Gain” setting.

#### 4.10.2 Audio Engine Panel

② **Sampling Rate:** The current sampling rate (SR) at which the BACCH-SP is operating is displayed here in green. While this display will change automatically to instantaneously reflect any changes to the SR, the brown button labelled “Sample Rate (Hz)” can be used anytime to query the mother unit for the SR in case the iPad was not in communication with the SP during the SR change.

③ **Clock Source:** This 3-setting radio button selector is used to set the clock source for the BACCH-SP to one of the following three settings:

- **Internal:** This setting sets the clock source to be the BACCH-SP’s internal clock, which is fixed at 96,000 Hz, and should be selected whenever the **selected input** is the **Internal Audio File Player**, or any of the **three analog inputs**.
- **Digital In:** At this setting the BACCH-SP extracts its clock signal from the active digital input. This setting should be selected whenever the **selected input** is any of the **Digital Inputs**, including the the USB input.
- **Word In:** At this setting the BACCH-SP is slaved to an external clock signal coming through the **Digital word clock input**. This setting should be selected whenever the **selected input** is any of the **Digital Inputs**, including the **the USB input** and the desired digital clocking is supplied by an external master clock. **When such an external clock is used, all digital processors in the signal path, including the BACCH-SP, should be slaved to that same master clock..**

④ **Clock Termination:** This switch controls the termination of the BNC clock signal path. It should be in the On position, If a **Digital** or **USB** input is selected, an external master clock is used, and the BACCH-SP is the last digital processor in the digital clock’s signal path. When the termination is turned On, an internal 75 Ohm resistor is activated to terminate the clock path at the **Digital word clock outputs**, which is equivalent to placing a physical external BNC terminator at that output.

⑤ **Audio Engine Resync and Relaunch:**

- **Resync:** Tapping this green Rsync button will cause the BACCH-SP to pause its audio processing engine for about 1 second and attempt to resync it with the selected clock signal. Such a esync might resolve **audio glitches/dropout issues** as described in Troubleshooting Section 5.3.





- **Relaunch:** Tapping this red Relaunch button will cause the BACCH-SP to stop and relaunch its audio processing engine, which takes about 5-7 seconds. This is a more drastic measure that may be called upon for addressing specific issues as described in the Troubleshooting Section 5.

### 4.10.3 BACCH Filter Designer Engine Panel

This panel contains controls that allow changing the settings for the BACCH Filter Designer Engine (BFDE) that produces BACCH<sup>®</sup> filters from HRTF measurements. At the end of the HRTF measurement procedure, the BFDE is automatically launched and processes the measurement into a BACCH<sup>®</sup> filter subject to three types of advanced settings that can be changed by the user to address particular circumstances that require departing from a regular BACCH<sup>®</sup> filter. A *regular BACCH<sup>®</sup> filter is defined as one produced with the three settings in these panel set to “Normal”*. These three Normal settings are framed in green to make it easier for the user to see any departure from a regular BACCH<sup>®</sup> filter setting. For most listening situations, these settings should be left in the “Normal” position. **Changing these settings does not cause any changes to the BACCH<sup>®</sup> filters already produced and stored in the seven BACCH purifier bins. These settings are applied when the BFDE crunches the next HRTF measurement taken.**

⑥ **Speakers Span:** This radio button selector allows applying an equalization (to the next BACCH<sup>®</sup> filter produced by the BFDE) that compensates for the bass roll-off that may occur to the mono component of the input signal (i.e. the part of the stereo signal that exists equally in both left and right channels, such as the lead singer in some pop music recordings.) when the speakers span angle (the angle between the speakers as sustained from the position of the listener) is narrow<sup>13</sup>.

- **Normal.** In normal listening situations, where the the speakers and the listener’s positions are configured in the so-called “stereo triangle” configuration, i.e. where the speakers and the listener’s head are each located at one apex of an equilateral triangle (thus a speakers span angle of  $\pm 30$  degrees), there will be no such bass roll-off to the center image and no need for compensation. For such normal listening geometries this radio button should be left in the “Normal” position. This setting applies to speakers

<sup>13</sup>This bass roll-off, which occurs only when the speakers span is narrow (less than  $\pm 20$  degrees) and only to the mono component of the stereo signal is due to the fact that a mono signal presents a singularity for crosstalk cancellation. In fact, **with a purely monaural signal BACCH<sup>®</sup> filtering should be bypassed**. Such a singularity, which can happen in a mixed multi-stem studio recording does not happen acoustically in real life (or in a real acoustic recordings done with a main stereo mic pickup) since it is practically impossible to have a sound that has 100% correlation at the left and right ears (mics).





span angles larger than  $\pm 30$  degrees and down to speakers span angles of about  $\pm 25$  degrees.

- **Narrow.** For speakers span angles between  $\pm 25$  and  $\pm 10$  degrees, this setting will produce BACCH<sup>®</sup> filters that have a built-in equalization that compensates for the bass roll-off that occurs to the mono component of the input signal. This equalization is only needed if, both, the speakers span is narrow *and* the mono component of the input signal is pronounced (such as the lead singer in a pop music recording). For programs that do not have a strong mono component, or acoustic recordings of sources in real spaces, such equalization is not needed but would not have any adverse effects if applied **except for a dynamic range loss (DRL) of about 3 dB<sup>14</sup>**. The actual DRL is **displayed on the corresponding XTC Plot**.
- **Dipole.** For speakers span angles lower than  $\pm 10$  degrees, which is seldom the case in high-end audio, this setting will produce BACCH<sup>®</sup> filters that have a more aggressive built-in equalization that compensates for the stronger bass roll-off that occurs to the mono component of the input signal in such closely spaced speakers configurations. A BACCH<sup>®</sup> filter produced with this setting will incur a dynamic range loss (DRL) of about 6 dB. The actual DRL is **displayed on the corresponding XTC Plot**.

⑦ **Time Window for Including Reflections:** A BACCH<sup>®</sup> filter is produced by the BFDE from an HRTF measurement after applying a time window to the impulse response, to control the amount of room reflections included in the filter design. The longer the window, the more the resulting BACCH<sup>®</sup> filter can compensate for these reflections and, generally, the higher is the resulting **crossstalk cancellation (XTC) level**. However, depending on the strength and location of the reflections, an excessively long time window can cause an audible smearing to the impulse response. A regular BACCH<sup>®</sup> filter is produced with the shortest window (about 2 ms), whose button setting is marked “Normal” on this radio button selector and is framed in green. Such a short window is called an anechoic window as it only captures the direct sound part of the impulse response in making the filter. **At the Normal setting, the resulting BACCH<sup>®</sup> filter is the purest and has no time artifacts. Increasing the time window beyond 9 ms should be done judiciously and the sound through the resulting BACCH<sup>®</sup> filters should be compared to the bypassed sound to make sure that it is free from any audible artifacts caused by the inclusion of strong room reflections in the design of the filter.** For more on **room reflections and 3D sound imaging** see Section 6.3.

⑧ **XTC Low Frequency Bypass:** This radio button selector allows setting the crossover frequency below which the resulting BACCH<sup>®</sup> filter does not cause any crosstalk cancellation (XTC). **It is generally best to leave this setting**

<sup>14</sup>Audio processed through BACCH<sup>®</sup> filter having a dynamic range loss of  $x$  dB is heard about  $x$  dB lower in volume than the same audio through the **Bypass** button





at the “Normal” position, which corresponds to 94 Hz, since sound localization is not effective below that frequency. A frequency higher than the normal setting is only justified if the bass output at and below that frequency is assigned to a single (mono) transducer, which is seldom the case in high-end audio. **Note that depending on the room dimensions and the location of the speakers and listener, the bass response below the selected XTC Low Frequency Bypass may sound different than the bass response when the BACCH<sup>®</sup> filter is bypassed.** This is due to the way the BACCH<sup>®</sup> filter treats the bypassed bass-part of the signal. **The bass response below the selected XTC Low Frequency Bypass should be dialed to be flat (by ear or by measurement) as a function of the room dimensions and the playback geometry.**

#### 4.10.4 Dolby Tape Noise Reduction Panel

⑨ **Dolby NR for Tape:** This radio button selector allows applying a double-precision digital implementation of Dolby Analog Tape Noise reduction to the audio coming from the **Analog In 1 (XLR) input**. This is done when an analog tape machine connected to that input and is playing a tape that was coded with either Dolby A (professional) or Dolby B (consumer) tape noise reduction.

#### 4.10.5 Thermal Data Panel

⑩ **Thermal Data:** Tapping on this button queries thermocouples and fan speed sensors inside the BACCH-SP and, after a delay of about 2 seconds, displays the results in this panel. An “Inside Air Temperature” below 80 °C and “CPU Temperature” below 100 °C are indicative of normal operation. If the BACCH-SP is subjected to excessive heat, or has its aeration slots blocked, these temperature indicators will rise and an ultra-low-noise internal fan will kick in to protect the CPU. The fan will remain practically inaudible from more than 1 m from the unit, as long as the fan speed, shown in that panel, remains below 4000 rpm.

#### 4.10.6 Housekeeping Panel

The housekeeping panel contains the following buttons:

⑪ **Launch/Quit Internal Player:** These two buttons allow launching and quitting the **Internal Audio File Player (IAFP)**. Note that this player is automatically launched whenever the **Internal Audio File Player input** is selected as an input on the **I/O page**.

⑫ **Refresh BACCH Filters:** **This button is used in advanced technical situations only** when a BACCH<sup>®</sup> filter is transferred to the BACCH-SP via





the network. Tapping on this button will reload all the stored or transferred BACCH<sup>®</sup> filters into their respective bins.

**13 Refresh Internal Links:** This button is used in advanced technical situations only when a the internal configuration of the BACCH-SP has been altered by a technician. Tapping on this button will refresh refresh the internal links inside the BACCH-SP after such an alteration.

**14 Play Theoretica 3D Arpeggio:** Tapping this button will trigger the playback of the **Theoretica 3D Arpeggio**, which is a 7-second binaural recording of an arpeggio played on an ancient lyre (see Section 7.2). This is useful for quickly mapping the 3D soundstage through the selected BACCH<sup>®</sup> filter to give a quick sense of the performance of the filter. (The same arpeggio is also played by the BACCH-SP at the end of the **boot-up sequence** is a chime to signal that the BACCH-SP is ready for operation.)

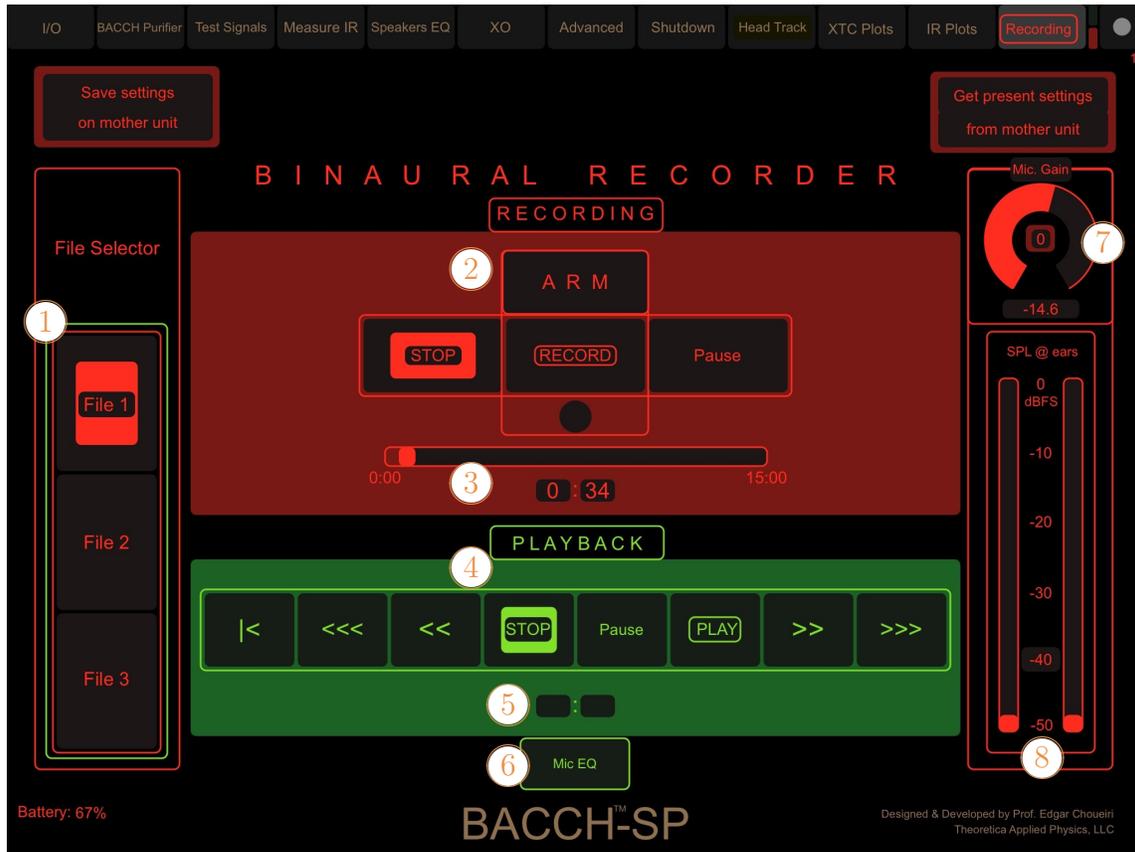
**15 Connect/Disconnect Internet:** When a live Ethernet cable is plugged into the BACCH-SP, the unit goes online automatically and becomes accessible through the Internet to Theoretica's tech support team, who can service the unit, update its software and run tests that may help identify and resolve issues encountered by the user. The unit can be taken offline by either unplugging the Ethernet cable, or tapping the Disconnect button in this sub-panel. Tapping the Connect button, with the live Ethernet cable plugged in, will bring the unit online. **The user should be aware that when the BACCH-SP is online and a camera is plugged in, Theoretica's tech support has visual access to the camera's view field. BY HAVING THE UNIT ONLINE AND THE CAMERA CONNECTED, THE USER IS IMPLICITLY CONSENTING TO GRANT THEORETICA'S TECH SUPPORT PERSONNEL VISUAL ACCESS TO THE CAMERA'S VIEW FIELD.** For more on **connectivity and remote updates**, see Section 4.16.

**16 Finish Remote Update:** This button is tapped by the user at the end of the **Remote Update Sequence** to finish the remote update as described in Section 4.16.





## 4.11 The Binaural Recorder



The Binaural Recorder allows the user to use the **BACCH-BM microphone** to record audio on the BACCH-SP and play it back immediately. To record, **assemble the microphone** and insert it in your ears or the ears of the person with whose head you wish to make a binaural recording then use the simple controls on the Binaural Recording page, shown above, to record audio to the selected file and play it back. **To hear the playback of recorded files, the “Recorded File Player” input should be selected on the I/O page.**

The Binaural Recorder can record up to three files each limited to a duration of 15 minutes. This limit is to avoid filling the BACCH-SP’s solid-state drive (SSD) by mistake. The Binaural Recorder is meant more as a demo feature to illustrate the spatial accuracy of BACCH-filtered binaural audio<sup>15</sup> rather than as a tool for making extensive recordings. For extensive recordings the BACCH-BM microphone can be used with any stereo recording system that has XLR inputs for a pair of microphones and can supply them with 48 V phantom power.

<sup>15</sup>An effective demonstration of the spatial accuracy with which the BACCH-SP can reproduce binaural audio is to have the subject sit in the sweet spot and wear the BACCH-BM microphone and have another person go around him speaking or making sounds to map the 3D sound stage while recording the sounds through the Binaural Recorder. The subject then plays back the recorded file after removing the BACCH-BM and gets to judge the spatial accuracy of the reproduced audio.

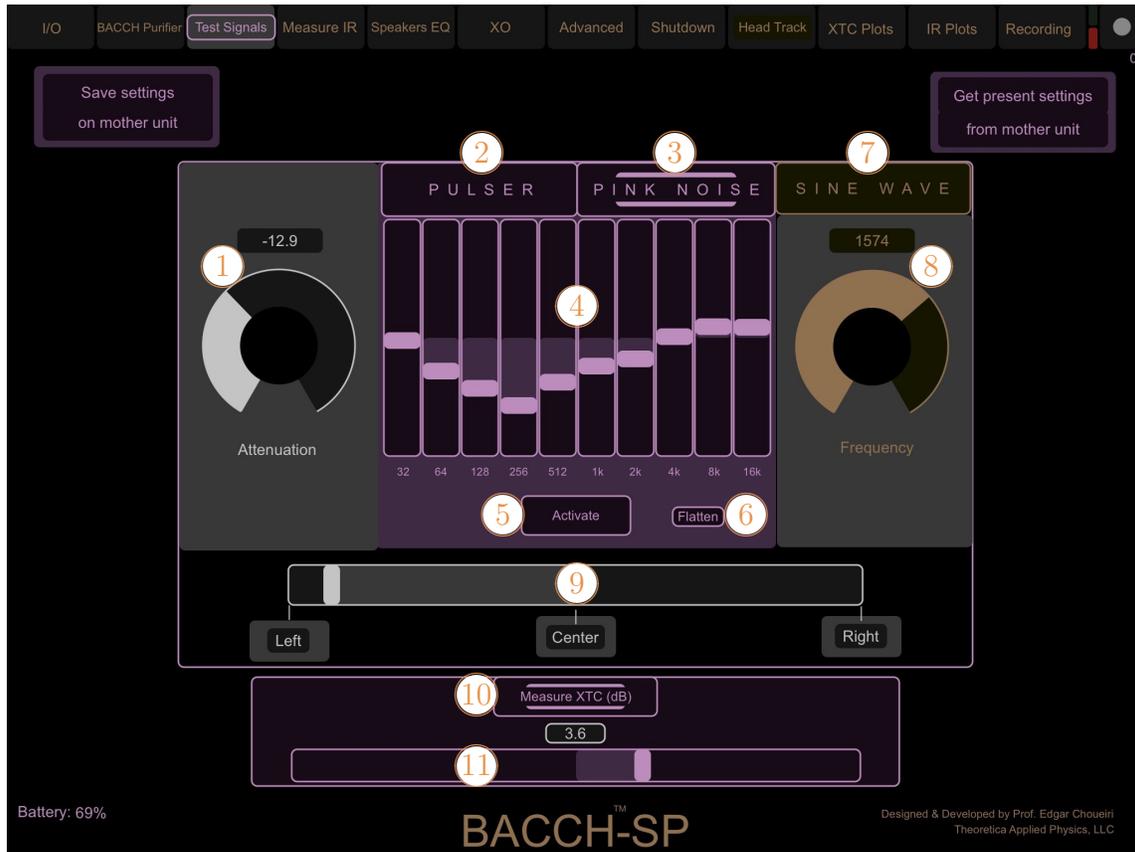




- ① **File Selector:** Allows selecting one of three files for recording and playback. Each file is limited to 15 minutes of recording time.
- ② **Record Transport:** The “Arm” button turns on the mic input, and arms the recorder, which is activated by the “Record” button and paused by the “Pause” button.
- ③ **Recording Progress Bar:** Shows the time progress of the recording activity.
- ④ **Playback Transport:** This radio button selector contains the typical controls for a recording playback system, much like the playback transport of a tape machine.
- ⑤ **Playback Time:** Shows the time progress of the playback activity.
- ⑥ **Mic EQ:** Activating this radio button applies a special equalization (called diffuse field equalization) to the recorded binaural audio during playback, which makes the tonal balance of the binaural audio more natural when played back through speakers.
- ⑦ **Mic Level Control:** This dial allows controlling the gain/attenuation of the mic signal. Tapping the small “0” button at the center of the dial sets the gain/attenuation to 0 dB.
- ⑧ **Mic Level Meter:** This calibrated level meter gives an accurate measure of the sound pressure level (SPL) as measured by the BACCH-BM microphone at the entrance of the ear canals.



## 4.12 The Test Signal Generator (Optional)



The Test Signal Generator allows producing test signals (pulses, pink noise and sine waves) that can be used for diagnostics by a technician or technically-minded user. This functionality is not necessary for operating the BACCH-SP. **To use these test signals as input to the processing inside the BACCH-SP the “Test Signals” input should be selected on the I/O page.**

- ① **Attenuation:** This dial attenuates all signals generated by the Test Signal Generator.
- ② **Pulser:** This button activates a harmonically rich pulse.
- ③ **Pulser:** This button activates a generator of correlated pink noise.
- ④ **Equalizer:** This is a 10-band (full-octave) graphic equalizer that can be used to filter (band shape) the pulser and pink noise signals.
- ⑤ **Equalizer Activation:** This button activates the equalizer. When it is off, the signal is passed through unequalized (full band),
- ⑥ **Flatten:** Tapping on this button will quickly reset all the sliders of the graphic equalizer ⑤ to the center position.





- ⑦ **Pulser:** This button activates a sine wave generator.
- ⑧ **Frequency:** This dial sets the sine wave frequency.
- ⑨ **Panner:** This slider allows panning the test signal between the left and right channels.
- ⑩ **Measure XTC:** This button activates the real-time crosstalk cancellation (XTC) measurement system. This system is superseded by the XTC measurements shown in the [XTC plots](#), which are more accurate as they are based on the [HRTF measurements](#), and show the whole XTC spectrum over the entire audio band. The real-time XTC measurement can sometimes be insightful to evaluate relative XTC performance at various frequencies<sup>16</sup> and between various head locations. To use it, follow these steps:

1. Assemble and wear the [BACCH-BM microphone](#) as described in Section [3.5.2](#).
2. Sit in the desired position where you wish to make an instantaneous XTC measurement.
3. Go to the [Make Filter page](#) and turn on the microphones with the [Arm button](#).
4. Go back to the [The Test Signal Generator](#) and activate the XTC measurement with button ⑩.
5. Turn on the pink noise generator ③ (for a wide band XTC measurement) or the sine wave generator ⑦ for a single frequency XTC measurement).
6. Pan the sound to extreme left using the panner ⑨ to measure the Left-side XTC, or the extreme right to measure the Right-side XTC. The instantaneously measured XTC level is displayed in dB in the XTC field and graphically by the horizontally moving bar in the XTC level meter ⑪ below that field.
7. After you are done taken XTC measurements, make sure to turn off the measurement system with the button ⑪ and the microphones with the [Arm button](#) on the [Make Filter page](#).

- ⑪ **XTC Level Meter:** The horizontally moving bar in this XTC level meter gives a visual indication of the instantaneous XTC level measured by the procedure described above. The corresponding XTC level in dB is displayed in the field above this level meter.

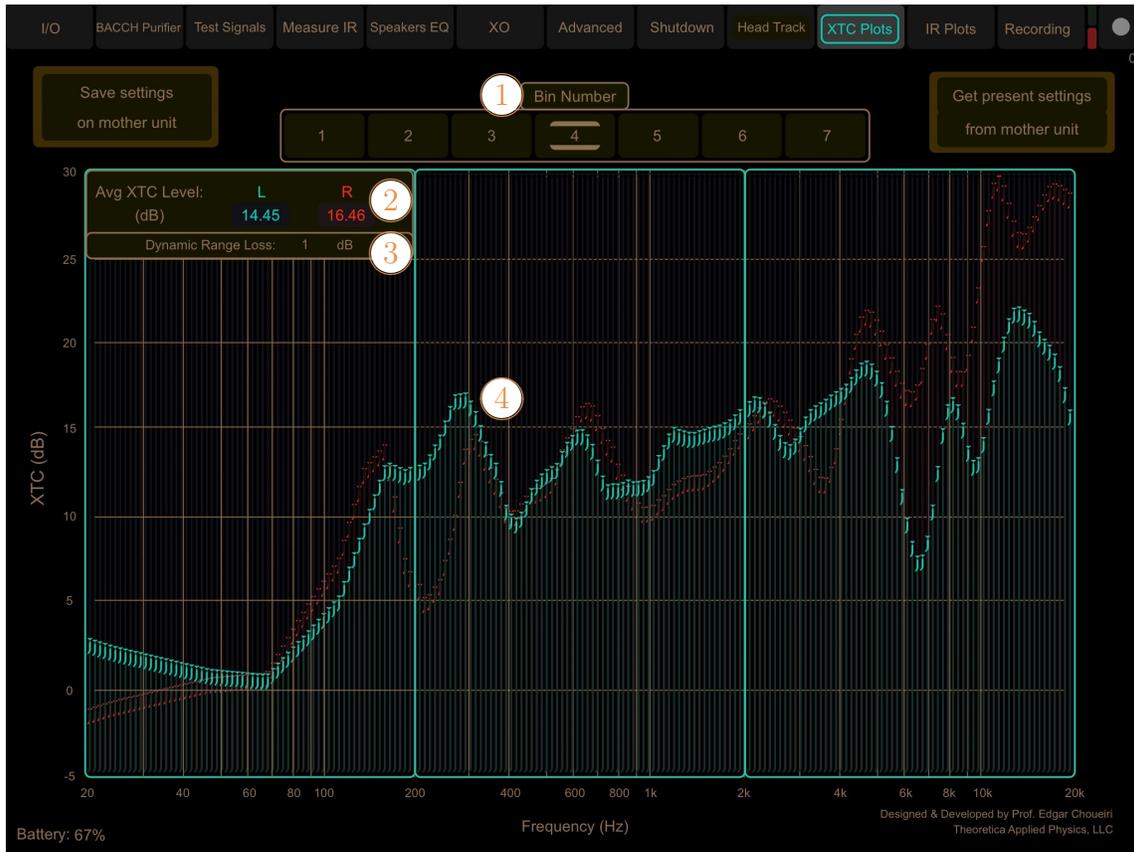
---

<sup>16</sup>Since these real-time measurements, unlike the more perceptually-accurate HRTF-based XTC measurements displayed in the [XTC plots](#) discussed in Section [4.13](#) are not time-windowed, they include the effects of reflections that are too late to degrade imaging and therefore represent only the minimum estimate of the perceptually achievable XTC.





### 4.13 The Crosstalk Cancellation (XTC) Plots



At the end of an HRTF-measurement, after the [Measurement Processing Progress Bar](#) shows that the measurement has been processed loaded and in the selected bin, the BACCH-SP carries out a very accurate calculation of the resulting XTC spectrum using the HRTF measurements and a time window that is set by the selector labeled [Time Window for Including Reflections](#) on the [Advanced page](#). The calculated XTC spectrum for each bin is displayed in the plot for that bin on the XTC Plots page shown in the above picture.

① **Bin Number:** This radio button bar allows displaying the XTC spectrum plot for the desired bin.

② **Average XTC Level:** The average XTC level for the selected bin is displayed (in dB) in these two fields: in blue for the Left-side XTC, and in red for the Right-side XTC.

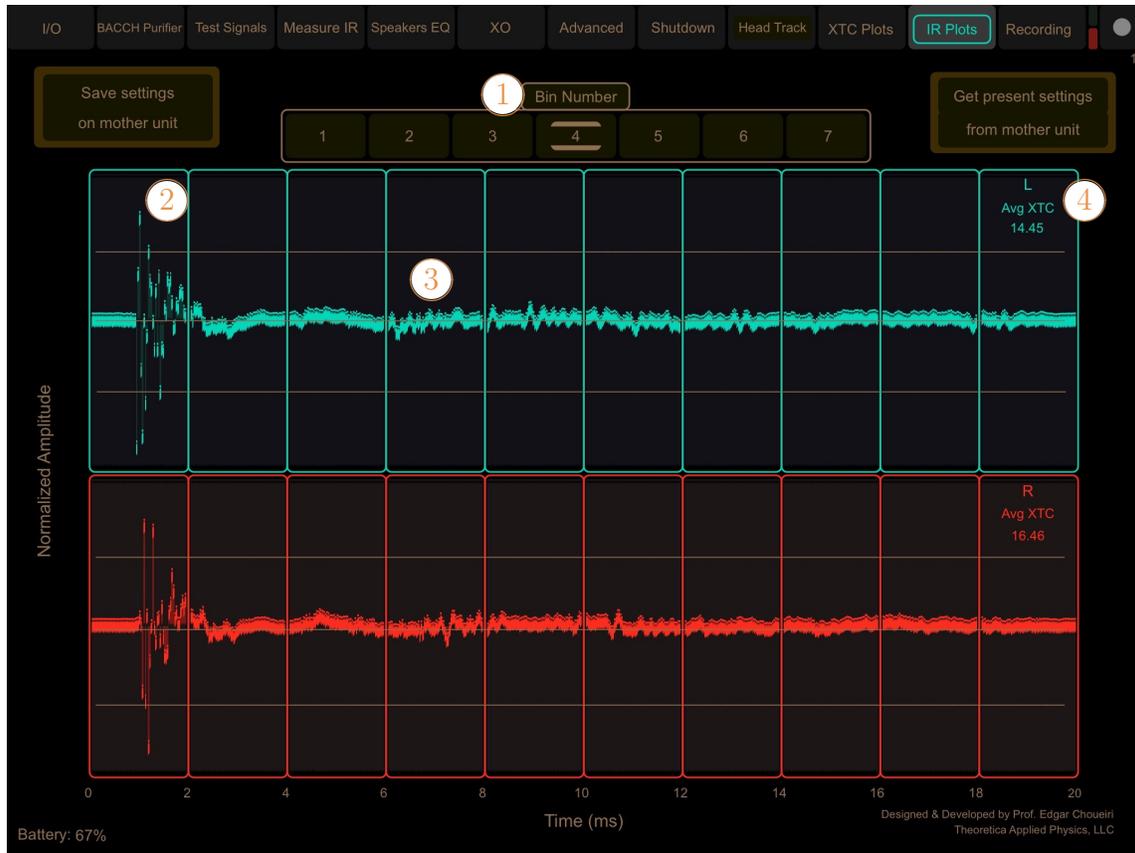
③ **Dynamic Range Loss:** This field displays the value of the dynamic range loss (in dB) corresponding to the BACCH<sup>®</sup> filter in the selected bin. For Regular BACCH<sup>®</sup> filters (defined in [Section 4.10.3](#)) this dynamic range is zero or 1 dB but can go up to about 3 dB if the [Speaker Span](#) setting is “Narrow”, and up to about 6 dB if that setting is in “Dipole”.





- ④ **Average XTC Level:** The curves of the Left-sided (in blue) and Right-sided (in red) XTC spectra are shown in this display.

#### 4.14 The Impulse Response (IR) Plots



At the end of an HRTF-measurement, after the **Measurement Processing Progress Bar** shows that the measurement has been processed loaded and in the selected bin, the BACCH-SP displays the resulting measured impulse response (IR) in a plot corresponding to the selected bin on the IR Plots page shown in the above picture. The blue and red curves represent the left and right IRs respectively.

- ① **Bin Number:** This radio button bar allows displaying the IR plot for the desired bin.
- ② **Direct Sound:** This part of the impulse response represents the direct sound that reaches the ears of the listeners directly from the speakers.
- ③ **Reflected Sound:** Structure in this part of the impulse response curve represents sound reflected off nearby surfaces (walls, ceiling, floor, table, etc.) located on a path between speakers and ears that is less than 7 meters.
- ④ **XTC Level:** The average XTC level, the same as that **displayed on the corresponding XTC plot**, for the selected bin is displayed here (in dB).





## 4.15 The Internal Audio File Player (IAFP)

The BACCH-SP has an internal audio file player (IAFP) that can be selected as the audio source using **button ④** on the **I/O page**. The BACCH-SP can be configured for two IAFP options:

1. **The Default IAFP Option:** The default IAFP does not require a special account and is operated using Apple's Remote iPad app included on the iPad. It comes loaded with the Chesky Records Binaural+ album series.
2. **The Roon Option:** Roon Core or RoonBridge, which are installed in the BACCH-SP and can be activated remotely by Theoretica's technical support by request from the user. The user can then access Roon from the iPad, to play files from a local NAS drive (connected to the same local network as the BACCH-SP's ethernet connection), a mounted USB drive, or streamed through Tidal and/or Qobuz (the user can login to his Tidal and/or Qobuz accounts from the iPad).

## 4.16 Internet Connectivity, Technical Support and Remote Updates

When a live Ethernet cable is plugged into the BACCH-SP, the unit goes online automatically and becomes accessible through the Internet to Theoretica's tech support team, who can service the unit, update its software and run tests that may help identify and resolve issues encountered by the user. The unit can be taken offline by either unplugging the Ethernet cable, or tapping the **Disconnect button** in the Internet subpanel of the **Advanced page**. **The user should be aware that when the "Remote Access for Tech Support" is activated and a camera is plugged in, Theoretica's tech support has visual access to the camera's view field. BY ALLOWING "REMOTE ACCESS FOR TECH SUPPORT" AND HAVING THE CAMERA CONNECTED, THE USER IS IMPLICITLY CONSENTING TO GRANT THEORETICA'S TECH SUPPORT PERSONNEL VISUAL ACCESS TO THE CAMERA'S VIEW FIELD.**

Theoretica Applied Physics often releases updates to the BACCH-SP software. These updates, which add new functionality, improve performance and fix issues, are done remotely via the Internet. First, the user receives an email message from either Theoretica or its dealer/representative, informing him of the availability of the update, and request a time for the user to have his SP online for remote access. **Since most remote software updates do not require the camera to be connected and the user is advised to disconnect the camera before granting Theoretica access to update the BACCH-SP's software.** At the agreed upon time, Theoretica will remotely access the unit, carry out the software update then send the following email message to the user, with instructions how to finish the update on the user's end by uploading the latest SP-Remote layout to the iPad:

Theoretica Applied Physics has recently updated some of the software on BACCH-SP SN: PUXX via the Internet. This major update contains performance improvements to the BACCH-SP.





For the update to take effect, please execute the following simple steps on your BACCH-SP's iPad:

1. Go to TouchOSC on your iPad.
2. Tap the small white circle in the upper right hand corner of any page of the old BACCH-SP Remote GUI. This will take you the TouchOSC settings window (labeled simply "TouchOSC").
3. Under "Layout" you should see the name of the present layout, v x.xx, (and others that may have been uploaded previously). Tap on the name of the present layout in that list (y.yy). This will take you to the "Layout" window.
4. In that "Layout" window, tap on the field labeled "Add" near the top of the window. This will take you to a window titled "Add Layout".
5. In that "Add Layout window" you should see a list of one or more hosts under "Found Hosts". At least one of them is called "BACCH-SP". Tap on that "BACCH-SP" field. This will upload the latest layout (v y.yy) to your iPad and return you to the "Layout" window.
6. In the "Layout" window, in a list titled "iPad", you should now see the name of the new layout "BACCH-SP Remote y.yy" in the list of names. Tap on the name of this latest layout to select it. You will then automatically be taken back to the "TouchOSC" window.
7. Tap on "Done" in the upper hand corner of that window and you will be taken to the first page (I/O) of the new layout.
8. Tap on the "Get Present settings from mother unit" button near the upper right corner to get the latest settings from the SP uploaded to the GUI.
9. Tap on the "Advanced" tab and in that page tap on the button "Finish Remote Update" located in the lower right corner.

This completes the upload. You can now resume using your SP and iPad remote as usual.

**PLEASE NOTE that this update will overwrite your previous settings and filters. Please make sure to reset these settings as desired before you proceed using your SP to make new filters.**

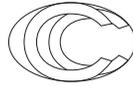
## 4.17 The Optional BACCH-HP Processing

BACCH-HP is a recently-patented advanced 3D headphones technology developed at Princeton University, which can be added remotely as an option to the BACCH-SP, and which adds the capability of making BACCH-HP filters (following a procedure that is very much like that for [making BACCH filters](#)) that would allow the user to experience essentially the same sound through headphones as that experienced when





listening to the same BACCH-filtered speakers used to make the BACCH-HP filters. To inquire about adding BACCH-HP processing to BACCH-SP, contact [Theoretica's Technical Support](#).



————— **End of Section 4.** —————

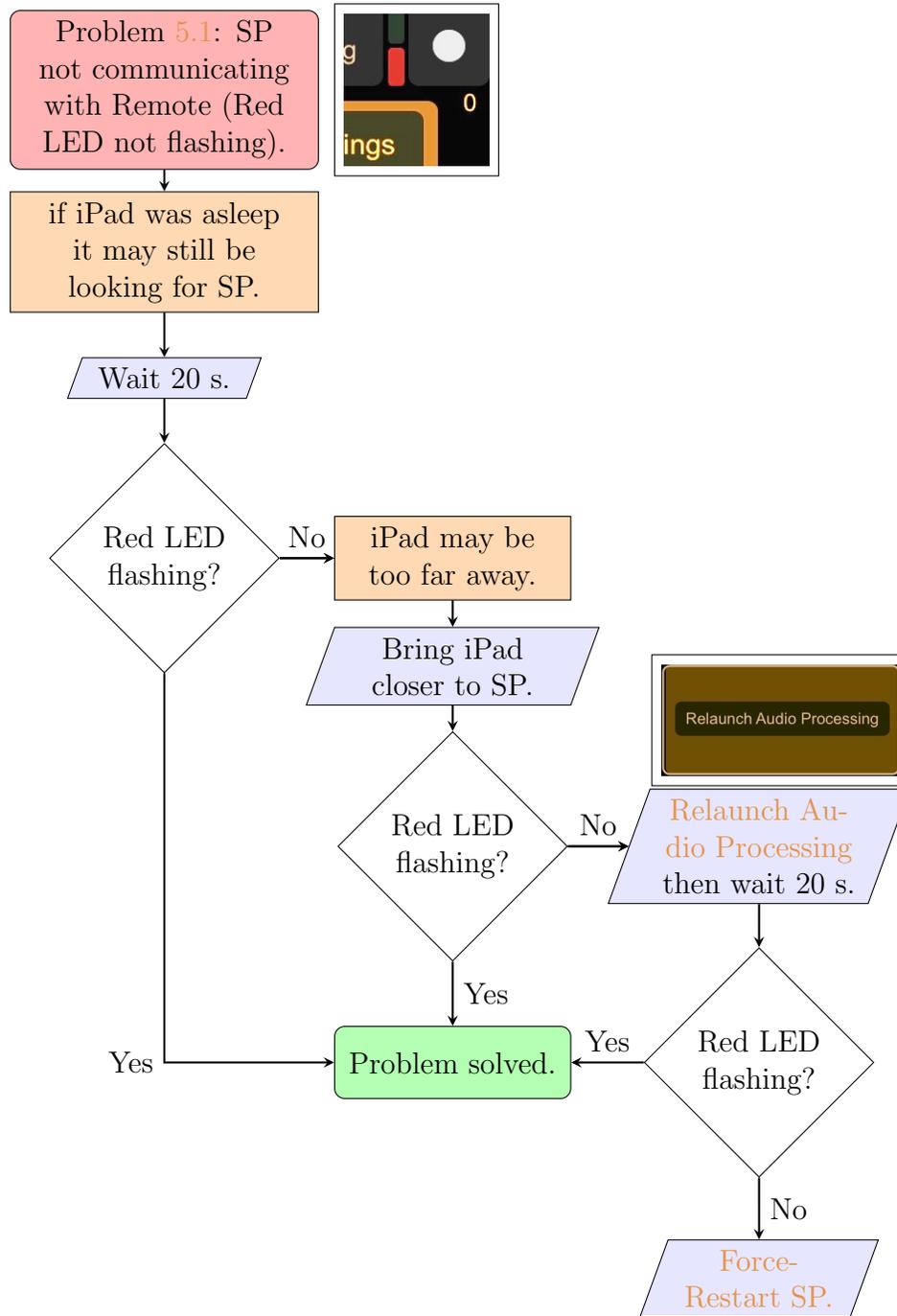




## 5 Troubleshooting

### 5.1 BACCH-SP and iPad not Communicating

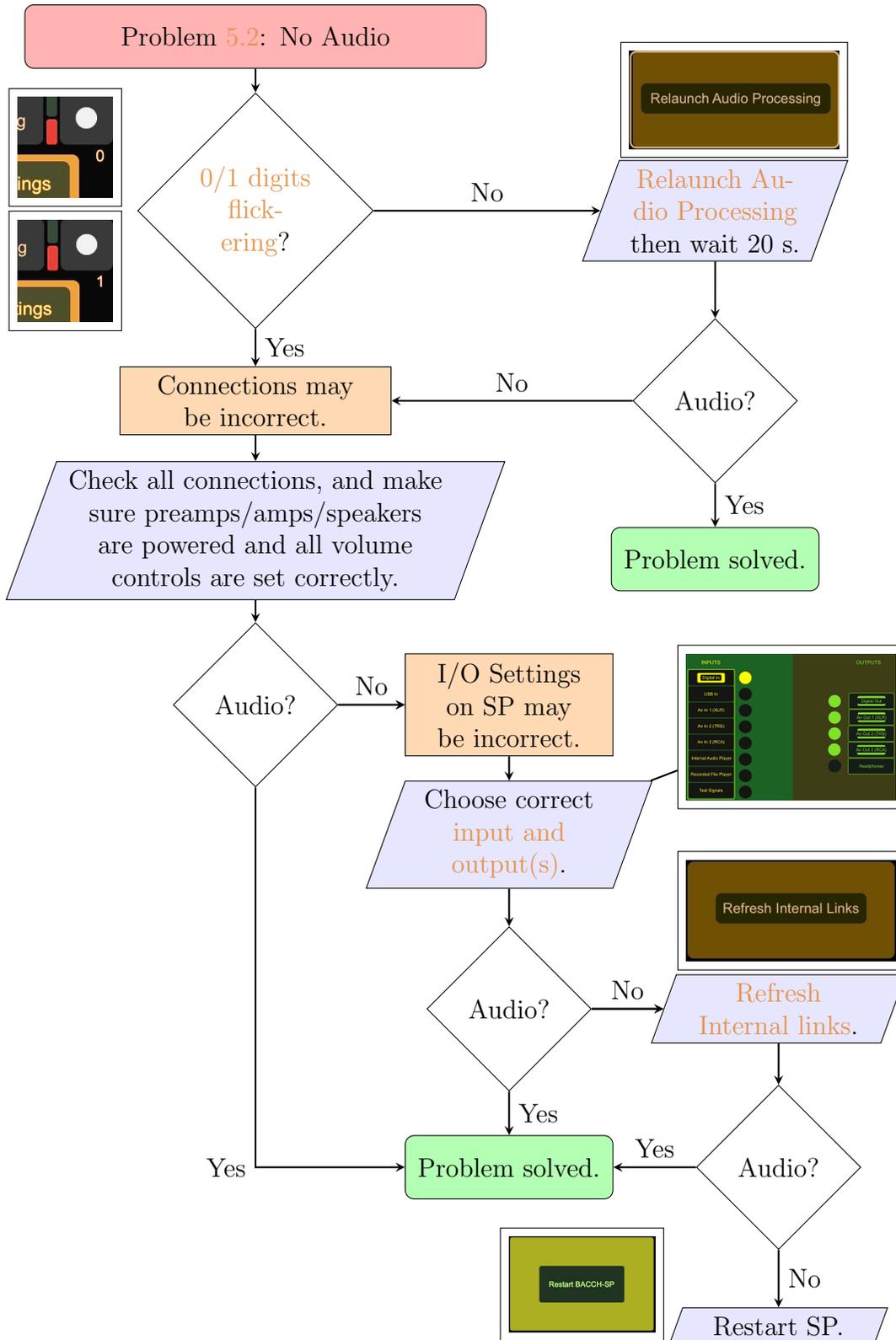
If the red LED in the upper right corner of any iPad SP-Remote page is not flashing, the iPad and the BACCH-SP are not communicating. Follow the steps in the flowchart below to fix the problem.





## 5.2 No Audio

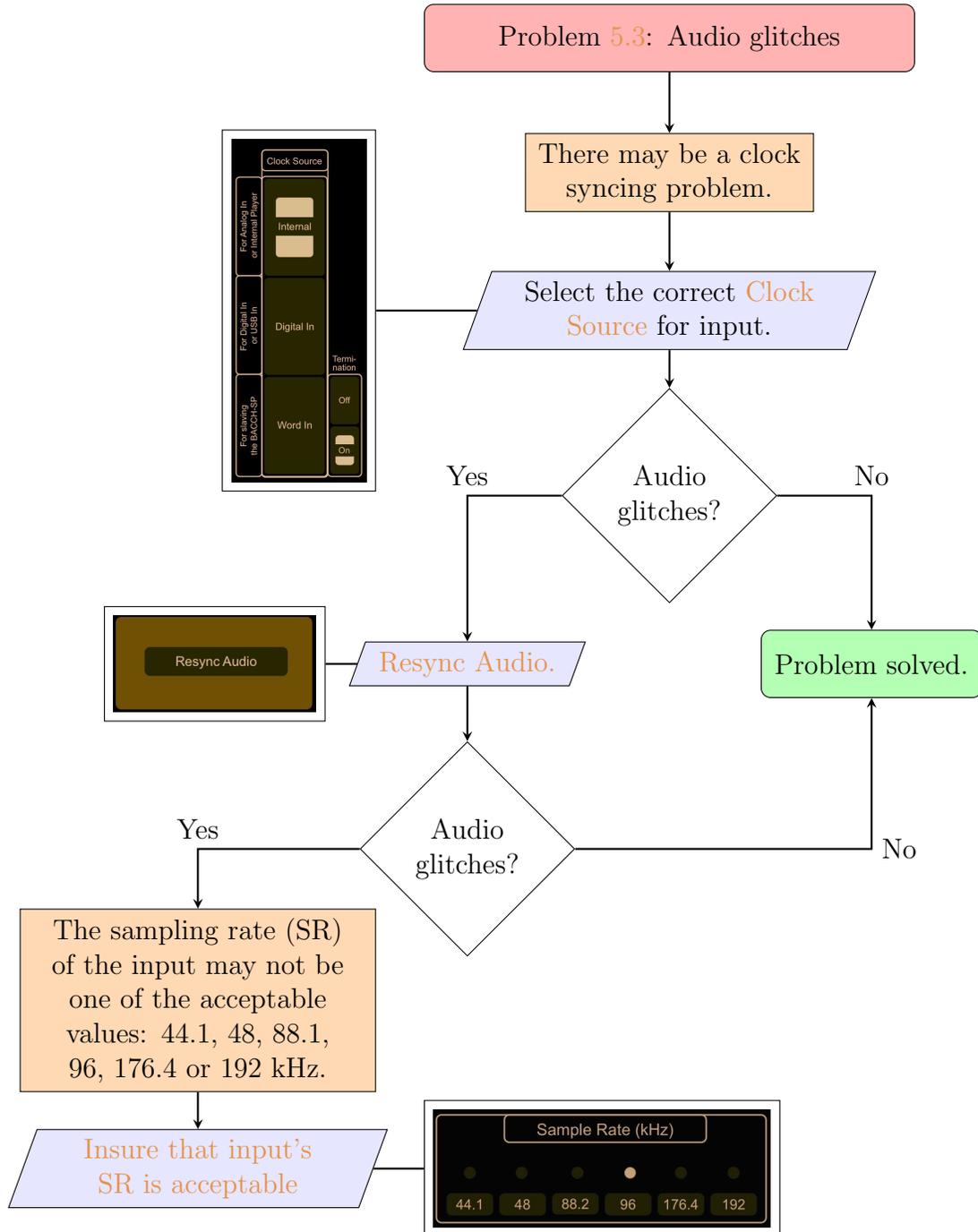
Follow the steps in the flowchart below to fix the problem of no audio.





### 5.3 Audio Glitches/Dropout and Syncing Issues

If you hear glitches (e.g. dropouts, clicking, screeches, ...) in the audio, follow the steps in the flowchart below to fix the problem.





## 6 BACCH-SP FAQ

### 6.1 What is BACCH<sup>®</sup> 3D Sound?

BACCH<sup>®</sup> 3D Sound is a recent breakthrough audio technology (licensed by Princeton University) that yields unprecedented spatial realism in loudspeakers-based audio playback allowing the listener to hear, through only two loudspeakers, a truly 3D reproduction of a recorded soundfield with uncanny accuracy and detail, and with a level of high tonal and spatial fidelity that is simply unapproachable by even the most expensive and advanced existing high-end audio systems.

BACCH<sup>®</sup> 3D Sound relies on canceling out an undesired artifact (called crosstalk) that occurs whenever stereo sound is played through loudspeakers, thus allowing the 3D cues which the brain needs to hear in 3D, and which exist in abundance in practically all well-made stereo recordings, to naturally reach the brain of the listener.

### 6.2 How Does BACCH<sup>®</sup> 3D Sound differ from surround sound?

BACCH<sup>®</sup> 3D Sound has nothing to do with surround sound. Surround sound, which was originally conceived to make the sound of movies more spectacular, does not (and cannot) attempt to reproduce a true 3D soundfield. What 5.1 or 7.1 surround sound aims to do is provide some degree of sound envelopment for the listener by surrounding the listener with five, seven, or more loudspeakers. For serious music listening of music recorded in real acoustic spaces, audio played through a surround sound system can at best give a sense of simulated hall ambiance but cannot offer an accurate 3D representation of the soundfield.

In contrast, BACCH<sup>®</sup> 3D Sound's primary goal is accurate 3D soundfield reproduction. It gives the listener the same 3D audio perspective as that of the ideal listener in the original recording venue<sup>17</sup>. Soundstage “depth” and “width”, concepts often used liberally in hi-end audio literature to describe an essentially flat image (relative to that in BACCH<sup>®</sup> 3D Sound), become literal terms in BACCH<sup>®</sup> 3D Sound. **If, for instance, in the original soundfield a fly circles the head of the ideal listener during the recording, a listener of that recording played back through the two loudspeakers of a BACCH<sup>®</sup> 3D Sound system will hear, simply and naturally, the same fly circling his or her own head.** If, in contrast, the same recording is played through standard stereo or surround sound systems the fly will be perceived to be inside the loudspeakers or, through the artifice of the phantom image, in the limited vertical plane between the loudspeakers.

---

<sup>17</sup>By the “ideal listener in the recording venue” we mean the actual main stereo recording microphones, or the left and right channels of the stereo master recording, which represent the left and right ear of the ideal listener in the original soundfield.





### 6.3 Does BACCH<sup>®</sup> 3D Sound require special loudspeakers?

BACCH<sup>®</sup> 3D Sound will greatly enhance the spatial fidelity of sound reproduction through any loudspeakers. Loudspeakers that have high sound directivity<sup>18</sup> will give the best and most accurate 3D imaging in a room with little or no sound treatment, as room reflections, which degrade the imaging, are minimized by such loudspeakers.

However, even loudspeakers with low directivity (i.e. omni-directional loudspeakers) will give a spectacularly wide soundstage with BACCH<sup>®</sup> 3D Sound in a typical listening room. With increasing loudspeaker directivity the image's depth and 3D imaging approach the depth and spatial characteristics of the original soundfield.

An ongoing investigation of <sup>19</sup>at the 3D3A Lab, has shown that dipole speaker designs, electrostatic speakers, as well as speakers with horns and waveguides offer significant advantages in 3D imaging with BACCH<sup>®</sup> 3D Sound as they increase the ratio of direct to reflected sound.

Abating room reflections with physical room treatment (i.e. using sound absorbers on sound-reflective surfaces) in a listening room is always beneficial to any audiophile-grade sound system. For BACCH<sup>®</sup> 3D Sound the effect of sound treatment is equivalent to using loudspeakers with high directivity. The more directive the loudspeakers are, the less sound treatment is needed for BACCH<sup>®</sup> 3D Sound to produce a full and accurate 3D sound image.

Therefore, in a reflective untreated listening room, directive loudspeakers are more desirable. In a well treated listening room with sound-absorbing surfaces, any loudspeakers, even omnidirectional ones, will produce an excellent 3D image.

### 6.4 How does BACCH<sup>®</sup> 3D Sound work?

Imagine a musician who stands on the extreme right of the stage of a concert hall and plays a single note. A listener sitting in the audience in front of stage center perceives the sound source to be at the correct location because his brain can quickly process certain audio cues received by the ears. The sound is heard by the right ear first and after a short time delay (called ITD) is heard by the left ear. Furthermore there is a difference in sound level between the two ears (called ILD) due to the sound having travelled a little longer to reach the right ear, and the presence of the listener's head in the way. The ILD and ITD are the two most important types of cues for locating sound in 3D and are to a good extent preserved by most stereophonic technique<sup>20</sup>.

When the stereo recording is played through the two loudspeakers of a standard stereo system, the ILD and ITD cues are largely corrupted because of an important and fundamental problem: the sound recorded on the left channel, which is *intended only for the left ear*, is heard by *both* ears. The same applies to the sound on the right channel. Consequently, an audiophile listening to that recording on standard

---

<sup>18</sup>Sound directivity is the extent to which loudspeakers beam the sound towards the listener instead of broadcasting it in all directions around the room.

<sup>19</sup>speakers directivity

<sup>20</sup>They are most accurately preserved if the recording is made with a dummy head (see Q&A 6.7).





stereo system will not correctly perceive the musician to be standing on the extreme right of the stage but rather at the location of the right speaker.

Consequently the perceived soundstage is mostly confined to an essentially flat and relatively limited region between the two loudspeakers irrespective of the quality and cost of the hardware in the standard stereo system - the 3D image is greatly compromised<sup>21</sup>.

In order to insure the correct transmission of the ILD and ITD cues to the brain of the audiophile, the sound from the left loudspeaker to the right ear, and that reaching the left ear from the right loudspeaker (called “crosstalk”) should be cancelled.

The technique of crosstalk cancellation (XTC) has been known for some time and can be applied by filtering the recorded sound through an XTC filter before feeding it to the speaker. This can easily be done digitally. However, until recently, XTC filters have had a detrimental effect on the sound as they inherently add a strong spectral coloration to the processed signal (i.e. they severely change the tonal character of the sound). This is why XTC had not been widely adopted by stereo manufacturers and audiophiles. (See the detailed discussion on XTC-induced sound coloration in the technical paper).

BACCH<sup>®</sup> 3D Sound is based on a breakthrough in XTC filter design, that allows producing *optimized* XTC filters, called BACCH<sup>®</sup> footnoteBACCH<sup>®</sup> stands for “Band-Assembled Crosstalk Cancellation Hierarchy” - a name that represents the mathematical filter design method and pays tribute to the great composer with a similar sounding name. filters, that add no coloration to the sound for a listener in the sweet spot . Not only do BACCH<sup>®</sup> filters *purify* the sound from crosstalk, but they also purify it from aberrations by the playback hardware in both the frequency and time domains.

The result is a 3D soundstage with a striking level of spatial and tonal fidelity never experienced before by audiophiles<sup>22</sup>.

## 6.5 What are BACCH<sup>®</sup> Filters?

There are two types of BACCH<sup>®</sup> filters. The individualized BACCH<sup>®</sup> filter (sometimes called i-BACCH<sup>®</sup>) is custom-made using *in-situ* acoustic measurements of the audiophile’s entire listening chain, including his hi-fi hardware, loudspeakers, head, torso and ears. It is designed by sending special test tones through the hi-fi chain and recording the sound with miniature microphones placed at the entrance of the audiophile’s ear canals as he is sitting in a sweet spot of his choice. It takes about one minute to do this measurement. The BACCH-SP produces individualized BACCH<sup>®</sup> filters.

The universal BACCH<sup>®</sup> filter (called u-BACCH<sup>®</sup>) is the same as i-BACCH<sup>®</sup>

<sup>21</sup>Aside from greatly compromising the 3D image, standard stereo (and even more, surround sound), inherently suffers from the problem of comb filtering, which significantly alters the tonal content of sound, and which is due to the interference of sound waves emanating from more than one speaker.

<sup>22</sup>See the video Ref [1] made by the Star Ledger newspaper of an audiophile from the NJ audio society experiencing BACCH<sup>®</sup> 3D Sound for the first time.





linebreak except a special dummy head, having microphones in its ears, is used to make the measurements instead of the audiophile's own head and ears. A u-BACCH<sup>®</sup> filter yields a bit less accurate 3D image than i-BACCH<sup>®</sup> when used by the audiophile himself to listen to his hi-fi system, but is more compatible with other listeners (who do not have i-BACCH<sup>®</sup> filters designed for them). Since the dummy head was designed to represent the sound diffraction characteristics of an "average" human head, the difference between the sound through the two types of filters is subtle but perceivable by a discerning audiophile.

## 6.6 Is BACCH<sup>®</sup> 3D Sound compatible with existing stereo recordings?

Yes. Unlike other 3D audio techniques (see Q&A ??), all of which require non-stereophonic recording techniques and coding, and many more than two loudspeakers for playback, BACCH<sup>®</sup> 3D Sound is fully compatible with all existing stereo recordings, and requires a single pair of loudspeakers.

In fact, virtually all stereo recordings contain 3D cues that are corrupted by standard stereo playback (see discussion in Q&A 6.4). BACCH<sup>®</sup> 3D Sound simply allows these 3D cues to reach the brain of the listener. Therefore an audiophile can delight in re-listening to his existing collection of recordings through BACCH<sup>®</sup> 3D Sound and discover the striking spatial and tonal fidelity that was missing or marred by standard stereo playback.

## 6.7 Is the 3D realism of BACCH<sup>®</sup> 3D Sound the same with all types of stereo recordings?

The stereophonic recording technique that is most accurate at spatially representing an acoustic sound field is, incontestably, the so-called "binaural" recording method<sup>23</sup>, which uses a dummy head with high-quality microphone in its ears<sup>24</sup>. Until the recent advent of BACCH<sup>®</sup> 3D Sound, the only way for an audiophile to experience the spectacular 3D realism of binaural audio was through headphones. Many such recordings exist commercially, and more have recently been made thanks to the iPod revolution.

BACCH<sup>®</sup> 3D Sound shines at reproducing binaural recordings through two loudspeakers and gives an uncannily accurate 3D reproduction that is far more stable and realistic than that obtained by playing binaural recordings through headphones<sup>25</sup>.

<sup>23</sup>The accuracy is due to the fact that binaural audio preserves not only the correct ILD and ITD cues discussed in Q&A 6.4, but also contains so-called "spectral cues," which are the effects the torso, head and ears have on the frequency response and which the brain uses, in addition to ILD and ITD cues, to locate sound, especially at higher frequencies.

<sup>24</sup>The spatial accuracy of dummy head recording is only surpassed by recordings made with microphones placed in the listener's own ears - alas, a rare commodity that would have benefits upon playback for only that listener.

<sup>25</sup>This is because binaural playback through headphones or earphones is very prone to head internalization of sound (which means that the sound is perceived to be inside the head) and





All other stereophonic recordings fall on a spectrum ranging from recordings that highly preserve natural ILD and ITD cues (these include most well-made recordings of “acoustic music” such as most classical and jazz music recordings) to recordings that contain artificially constructed sounds with extreme and unnatural ILD and ITD cues (such as the pan-potted sounds on recordings from the early days of stereo). For stereo recordings that are at or near the first end of this spectrum, BACCH<sup>®</sup> 3D Sound offers the same uncanny 3D realism as for binaural recordings<sup>26</sup>. At the other end of the spectrum, the sound image would be an artificial one and the presence of extreme ILD and ITD values would, not surprisingly, lead to often spectacular sound images perceived to be located in extreme right or left stage, very near the ears of the listener or even sometimes inside of his head (whereas with standard stereo the same extreme recording would yield a mostly flat image restricted to a portion of the vertical plane between the two loudspeakers).

Many of well-made popular music recordings over the past two decades have been recorded and mastered by engineers who understand natural sound localization and construct mostly natural-like stereo images, albeit artificially, using realistic ILD and ITD values. Such recordings would give a rich and highly enjoyable 3D soundstage when reproduced through BACCH<sup>®</sup> 3D Sound.

## 6.8 Is BACCH<sup>®</sup> 3D Sound compatible with analog audio?

Yes. The BACCH-SP Sound processor accommodates (balanced or unbalanced) stereo analog inputs and outputs. Since the BACCH<sup>®</sup> filter is a digital one and must be applied in the digital domain, the input analog signal is converted to a high-resolution using audiophile-grade A/D converters inside the processor. The processed digital signal can then be sent out as a digital signal (e.g. for an outboard converter or a digital speaker) or converted to analog using an audiophile-grade D/A converter inside the processor.

## 6.9 Why call this “BACCH<sup>®</sup> 3D Sound”?

The word “stereo” was always associated with three-dimensional objects or effects until its later use, in the 1950s, in the word stereophony, which, ironically, is now a term that does not invoke true three-dimensional sound in the popular mind<sup>27</sup>. In fact, the earliest use of “stereo”, which comes from the word Greek *στερεός*, (stereos) which means solid, goes back to the 16<sup>th</sup> century when the term stereometry

---

requires, in order to avoid this problem, an excellent match between the geometric features of the head of the listener and those of the dummy head with which the recording was made (this problem has been recently surmounted by the Smyth headphones technology <http://www.smyth-research.com/>). BACCH<sup>®</sup> 3D Sound does not suffer from this problem as the sound is played back through loudspeakers far from the listener’s ears.

<sup>26</sup>The 3D realism is the same although the ability of reproducing a sound source at a location that accurately corresponds to the original location is relatively decreased due to the absence of spectral cues.

<sup>27</sup>Despite the tendency of some audiophiles and audio reviewers for describing the sound from certain hi-fi components as “three-dimensional” or “holographic”.





was coined to denote the measurement of solid or three-dimensional objects. This was followed by stereographic (17th c.), stereotype (18th c.), stereoscope (19th c.) (a viewer for producing 3D images), and stereophonic (circa 1950). Stereophonic sound, alas, remained a poor approximation of 3D audio until the recent advent of BACCH<sup>®</sup> 3D Sound, which restores to the word stereo its original 16th century 3D connotation.

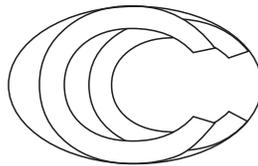
The epithet “pure” in “BACCH<sup>®</sup> Stereo Purifier” refers to the purifying action of the BACCH<sup>®</sup> filters, which are at the heart of BACCH<sup>®</sup> 3D Sound. A BACCH<sup>®</sup> filter “purifies” the sound from crosstalk for playback on loudspeakers, without adding coloration, and purifies it also from the detrimental effects of spatial comb filtering and non-idealities of the listening room, the loudspeakers and the playback chain.

## 6.10 Media Coverage

[Media coverage and reviews](#)

## 6.11 Technical Explanation of BACCH<sup>®</sup> Filters

A detailed technical description and analysis of optimal crosstalk cancellation, and BACCH<sup>®</sup> Filters is given by E.Y. Choueiri in Chapter 5 “Binaural Audio Through Loudspeakers” of the book *Immersive Sound: The Art and Science of Binaural and Multi-Channel Audio*, CRC Press, 2017.





## 7 Underlying Technologies and IP

BACCH<sup>®</sup> is a registered trademark of Princeton University.

**The BACCH<sup>®</sup> Patent:** US Patent under PCT/US2011/50181 (and equivalent patents worldwide) [Spectrally uncolored optimal crosstalk cancellation for audio through loudspeakers](#). Licensed to Theoretica by Princeton University.

**The BACCH<sup>®</sup>HP Patent:** US Patent No. 9,560,464 (and equivalent patents worldwide) [System and method for producing head-externalized 3D audio through headphones](#). Licensed to Theoretica by Princeton University.

**The Head Tracking Patent:** US Patent No. 6,243,476 [Method and apparatus for producing binaural audio for a moving listener](#) Licensed exclusively to Theoretica by MIT Media Labs.

**The Visage Head Tracking SDK:** Head tracking uses [Visage SDK HeadTrack](#) licensed to Theoretica by [Visage Technologies](#).

**The Theoretica IP:** The BACCH-SP relies on a number of technologies and algorithms that are the intellectual property of Theoretica. These include various components for user interfaces, measurement procedures and signal processing, as well as algorithms for optimized convolution with variable FIR filters, and IR smoothing, thresholding and interpolation.

### 7.1 The Theoretica Logo



The lyre player in the Theoretica logo is reproduced from an ancient Greek black-figure [pan-Athenaic amphora](#) painted by the [Princeton Painter](#) circa 530 BC. The amphora is the property of [Theoretica Applied Physics](#).

### 7.2 The Theoretica Arpeggio

The Theoretica 3D Arpeggio, heard by tapping the “Play Theoretica 3D Arpeggio” button on the [Advanced Settings page](#) was created by permission of the composer, [Michael Levy](#), using an audio excerpt from “Hymn to Hermes” played by the composer on a replica ancient Greek lyre. From the album [The Ancient Greek Lyre](#).

Play Theoretica  
3D Arpeggio





## 8 Technical Specifications

Frequency response @ 96 kHz	-0.5 dB: 7 - 45,000 Hz
Sampling Rates	44.1, 48, 96, 88.2 176.4, 192 kHz
Crosstalk	< -110 dB
Word clock level	1 - 5.6 V <sub>pp</sub>
Word Clock BNC connection with termination Off	10 kOhm
Word Clock BNC connection with termination On	75 Ohms
Audio processing word size	64 bit
<b>Grand and audio Analog Stage:</b>	
Total Harmonic Distortion Plus Noise	< 0.0015 %
Input impedance for An In 1 (XLR)	10 kOhm
Input impedance for An In 2 (TRS)	10 kOhm
Input impedance for An In 3 (RCA)	470 kOhm
Output impedance	75 Ohm
Analog preamp output level Setting 1	+19 dBu
Analog preamp output level Setting 2	+13 dBu
Analog preamp output level Setting 3	+2 dBV
<b>BACCH-BM Binaural Microphone:</b>	
Polar pattern (out-of-ear)	Omnidirectional
Microphone capsule	
BACCH-BM Pro	Gold-plated electret condenser
BACCH-BM	Electret condenser
Mic capsule dimensions	
BACCH-BM Pro	2.5 mm (d) × 3.2 mm (h)
BACCH-BM Pro in enclosure	5.6 mm (d) × 11.7 mm (h)
BACCH-BM	6 mm(d) × 3.5 mm (h)
BACCH-BM in enclosure	8.2 mm (d) × 12.2 mm (h)
Phantom power	+48 V
Frequency range (+/- 1 dB, w/ EQ)	
BACCH-BM Pro	20 - 30,000 Hz
BACCH-BM	20 - 20,000 Hz
Sensitivity @-35 dB re. 1 V/Pa (±3 dB)	17.8 mV/Pa
Equivalent noise level	27 dB(A)
Signal-to Noise ratio re. 1 kHz @ 1 Pa (94 dB SPL)	67 dB
<b>Dimensions:</b>	
<i>Grand</i> model	44.45 × 14.6 × 51.75 cm (17.5 × 5.7 × 20.4 inches)
<i>audio</i> and <i>dio</i> models	44.45 × 8.26 × 34.3 cm (17.5 × 3.25 × 13.5 inches)
<b>Weight:</b>	
<i>Grand</i> model	18 kg (39.7 lbs)
<i>audio</i> and <i>dio</i> models	10 kg (22 lbs)

