How to set up a 2-channel Sound System

Can reproduced music in your home actually sound better than live?

What equipment is needed, where to place speakers, and how to get the best sound.
Live music in your room

Can reproduced music in your home actually sound better than live?

Based on the “How to set up a home-theater sound system” article, the basics for setting up a high quality 2-channel sound system for music is covered.

What equipment is needed, where to place speakers, and how to get the best sound.

And busting some of the audio myths that often prevents getting the best performance.

While some of the content may look very technical for some readers – with graphs and hertz and decibels - you can skip those parts, and still get a good introduction on how the experts work with their systems and learn what is important for sound.
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**LIVE MUSIC IN YOUR ROOM**

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Introduction

The joy of listening to music

Listening to music in your home can be entertaining and stimulating, and for many this experience is further enhanced when quality of sound reproduction is very good.

The sense of musicians being in the room, powerful bass with physical impact, details, realism. All this enhances and amplifies the experience.

Perception of sound

We hear sound, and we can feel sound on our body.

Frequency of sound describes the pitch of the tone. Bass tones are low frequency, from around 100-200Hz and down. Young humans can hear higher frequency tones up to around 20KHz.

A frequency response chart shows loudness of sound across the frequency range

How loud the sound has to be to be audible depends on its frequency. Very low bass tones down to and below 20Hz requires quite loud levels to be heard, compared to higher frequencies around 2000-4000Hz.

How well we can hear, and how loud sound we can accept before it is perceived as unpleasant is different from person to person. As we grow older, we tend to lose ability to hear the highest frequencies above 10-15KHz.

If the sound gets very loud, it is perceived as unpleasant. Too loud sound causes damage to hearing. Loudness tolerance is frequency dependent, bass frequencies can be much louder than higher tones.

We can feel sound on our body, mostly at lower frequencies. Feeling the sound requires quite loud volume. This is called tactile feel.
This determines the useful range for sound reproduction. There is a low frequency limit, a high frequency limit, a maximum sound volume limit, and a lower threshold where it is not possible to hear anything below.

**Limits of perception of sound, the area between blue and red lines is the usable range for our music sound system.**

But perception of sound is not only about what we hear. The mechanisms involved are complex, and involves audio memory, memorized properties related to the sound we hear, other sensory inputs like vision.

The brain processes the sound coming in through the ears, and adds and subtracts elements to create what we finally think we hear.

Especially when evaluating audio equipment for sound quality, the disturbances and faults introduced in the perception process causes difficulties for getting reliable listening evaluations. This is why differences in sound that simply does not exist can be heard.

Perception of sound can be seen as a process involving three separate functions:

- **Physiological hearing:** The ear and hearing mechanisms that transforms sound waves into neural information.
- **Psychoacoustics:** The processing of neural sound information into perception of loudness, tone, direction, distance.
- **Interpretation:** The psychological processing of sound elements into meaningful patterns - understand words, recognize instruments, size of acoustic spaces.

The interpretation part involves comparing heard sound to memorized sounds and taking into account other sensory input information such as visual cues. This is what creates trouble for us when we want to compare sound quality of audio equipment. We are notoriously distracted by those other non-audio factors, because we tend to override audio input in favor of what we see and what we expect to hear.
Sound quality

No distortion or bad sounds, voices and instruments appear separated and clear, everything from the very deep bass up to the highest treble is reproduced, and transients and impulses sound powerful and clean.

To achieve a high level of sound quality requires careful attention to selection of equipment and setup of the sound system. This is engineering and science.

The hi-fi world is plagued with myths and misinformation. Some of these myths originate from times when all of the equipment still had very significant defects in sound quality, and continue to live on even after improvements in technology have provided solutions with performance so good that any faults are impossible to hear. Today there is also deliberate misinformation being spread in the marketing of suspect audio products, claiming some sort of magic or new discoveries unknown to science.

The myths and misinformation live on due to the very subjective and inaccurate nature of our perception of sound. When people are told a stone on top of the amplifier improves the sound, they believe it because they can hear it. After reading about Perception of sound, we understand that this experienced difference can be caused by the brain adding elements that is not related to the true sound heard by the ears.

Different parts in the audio system can affect sound performance, in different ways. Some equipment - like DACs - can be made transparent sounding, they do not have any audible faults at all. Other parts - such as loudspeakers - will always set their fingerprints on the sound you hear.

When all faults and contributions and changes added to the original sound is less than threshold of hearing, we call it audibly transparent. Today most of the signal chain can be made audibly transparent. We have lossless computer playback, DACs with distortion and noise figures far below what is possible to hear for a human, the best amplifiers have so little distortion it is also well below this threshold.

But everything is not perfect, everything does not sound the same. Any amplifier pushed beyond its limits will create very audible distortion, a 128K mp3 is audibly different from a lossless original, the YouTube-videos we listen to are compressed with a lossy AAC 125K codec. And some equipment is simply not good enough.

There is also nothing wrong in having far better specifications than strictly necessary. If a DAC has distortion at -120dB, and -80dB may be sufficient, we choose the better version simply to have a better margin and be sure our music signal is never unnecessary compromised.
Different parts in the audio system can affect sound performance, in different ways.

<table>
<thead>
<tr>
<th>Mediocre equipment</th>
<th>Type of fault</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Linear</td>
</tr>
<tr>
<td>Loudspeaker</td>
<td></td>
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<tr>
<td>Amplifier</td>
<td></td>
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<tr>
<td>DA-converter</td>
<td></td>
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<tr>
<td>PC playback</td>
<td></td>
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<tr>
<td>Tape</td>
<td></td>
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<tr>
<td>Vinyl</td>
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<tr>
<td>Room acoustics</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>State of the art</th>
<th>Type of fault</th>
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<tbody>
<tr>
<td></td>
<td>Linear</td>
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<tr>
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<td>Vinyl</td>
<td></td>
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<tr>
<td>Room acoustics</td>
<td></td>
</tr>
</tbody>
</table>

Your personal sound

The artwork comes to play when you want to achieve a specific sound - your personal touch of the music presentation.

But wasn't it meant to be "high fidelity" - as in, exact and true reproduction of the recording. Maybe, in a studio. But at home, you have bought the music for pleasure, and whatever suits your preference to improve the experience is certainly allowed.

You tweak your sound by speaker selection, room acoustics, calibration. Amplifiers, sound processors and playback devices are chosen to have no or as little as possible impact on sound.

This is the future of hi-fi as a hobby. To learn about how to do tweaks that actually works, buy and install new equipment which actually changes and improves the sound.
Requirements

How do you want your sound

How do you want your music presented, how is the sound you want.

If you have never experienced music other than from systems you can find in a typical shop, it would be wise to demo some really capable systems, this can give you some clues about what you should prioritize in your own set-up. Also attending live music performances can bring out aspects of sound that most often are lost in a reproduction system. Remember, something that has not been experienced will not be missed.

You will have to make decisions and compromises to suit the needs of your room and your budget. Interior styling preferences and practicality will also set limits.

Priorities

Consider to prioritize what you believe is important for your listening room:

• How loud?
• Good sound at moderate loudness most important?
• Soundstage - 3D-like reach-out-and-touch or immersive cloud?
• Smooth and soft or rough and direct?
• Low frequency capacity - only subtle or tear-down-the-house?
• Sound coverage for more than one listener?
• Combining 2-channel and multichannel for movies?

These parameters, along with room size and visual appearance considerations, is the foundation for the requirements of the sound equipment.

Room size is important because it takes more sound energy to fill a larger space, which will affect requirements for speakers.

Loudness requirements

How loud do you want to play – that is what defines loudness capacity requirements.

When turning up the volume it often sounds “loud” because the sound is distorted and compressed. This happens if the speakers and the amplifiers are not capable of delivering sufficient sound pressure level, and thus will distort the sound. And this will be the case for most traditional hi-fi-style speakers - they simply do not have enough sound pressure capacity.

Room acoustics will also affect perceived loudness. A room with insufficient damping will sound louder, because it actually is, with the same volume setting. Smaller rooms also tend to be louder, because they have more early reflections.

To be able to reproduce sound at reference level is often used as a requirement for theater sound. For music there is no such standard, but for realistic reproduction the theater requirements for 105dB from each main speaker is barely enough.

A good system will also sound better at reduced loudness levels.
Typical music playback sound pressure levels

<table>
<thead>
<tr>
<th></th>
<th>Sound exposure (dB SPL-C)</th>
<th>Max peak (dB SPL-Z peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic instruments, classical, jazz at realistic live levels</td>
<td>90dB</td>
<td>110dB</td>
</tr>
<tr>
<td>Electronica/dub/rock nice and loud</td>
<td>100dB</td>
<td>120dB</td>
</tr>
<tr>
<td>Moderate volume for a late night listening session (-30dB)</td>
<td>60dB</td>
<td>80dB</td>
</tr>
</tbody>
</table>

For playing music at 90dB we see that peak sound pressure level is 110dB - around 20dB louder. This is important, capacity must be dimensioned for this peak levels for clean sound without distortion.

Sound pressure levels logged from listening position, Ane Brun – The Light From One, played at 0dB master volume.

Red line is peak level - this defines capacity requirements, black line is dB(Z) - this is the perceived loudness

Panda Dub, master volume starts at 0dB then increased to +6dB. Loud and powerful for a short listening session.
Sound character

Does it sound smooth and nice, or is it open and direct, perhaps leaning towards more hard and dynamic. But can you have it all - smooth and nice - and open and dynamic, at the same time.

Depends. Most traditional hi-fi speakers sound more smooth and nice than accurate and realistic. Many professional-style speakers with horn loaded high-frequency drivers can give you better dynamics, but some times at the cost of a more hard and forward sound character. But the best speakers can give you more of everything - smooth and dynamic at the same time. Key parameters are capacity and sound radiation pattern.

This character of sound will be determined by the speakers, but you will also be able to make adjustments with acoustics and calibration.

If you are on a budget, some compromise may be necessary, but certainly it is possible to have it all, and even better. A system with full dynamic capacity and high resolution may at first sound unfamiliar, because it does not quite sound like "speakers" anymore, and that is exactly the point - it sounds realistic.

Soundstage

Placement of sounds and instruments and how they appear is a result of the loudspeakers radiation pattern and room acoustics, and a few other - more complex - aspects of the loudspeakers performance.

Once you have chosen your speakers, the baseline for soundstage and how the sound is presented is determined, and changing the room can only get you so far. Make sure the speakers you choose are able to produce the soundstage you want.

Room acoustics does matter, and tweaking the room can change things in a preferred direction, but if you start out with speakers born with a "wrong" type of sound, it is a lot harder to fix afterwards by rebuilding you room, and perhaps if you choose the more suitable speaker it is not necessary to do much to the room at all.

Planar dipole magnestatic speakers - narrow and precise vertical radiation, no sound sideways - instruments in your room.
Traditional multi-way small direct radiator speaker - point source, wide forward radiation which transforms to omnidirectional for lower frequencies - a precise window right in to the recorded event.

Getting the bass right

For music you can choose to not have subwoofers, only left and right full-range speakers.

The subwoofers are responsible for reproduction of the lowest frequencies. But a good bass-system properly calibrated will also improve overall bass quality. With a bass-system it will be much easier to get smooth bass response and enough capacity to enjoy music at live sound levels.

Low frequency limit

If you never play loud, 30Hz low frequency extension is enough, and you can get by with a physically very small bass-system, and get excellent bass performance.

For realistic live music levels, you should aim for extension down to below 20Hz, and capacity for around 120dB. Achieving this requires a serious bass-system, it will definitely be visible in you room.

This has to do with our perception of sound - to be able to hear very low frequencies requires quite loud sound. So if you never play very loud, there is no need to be able to reproduce the very lowest frequencies. We can see this from the picture in the Perception of sound chapter.

But what if the music does not contain much below say 40Hz - which is the case for most music. Why 20Hz.

Music contains impulse-like sounds, such a drums, and impulses are by nature short in duration in time, but also very wide distributed across the frequency range. If the loudspeakers cut off the lowest frequencies, this will make the impulse sound different because something is removed, and it will also be smeared in time because the impulse response is compromised due to the roll-off.

Not all recordings have all the drums and instruments recorded full range, many are filtered. But for those who are full-range, the difference is more impactful and realistic and dry bass with extension down to below 20Hz.
For traditional music – rock, classical, jazz – many will find extension down to around 30Hz flat with decent capacity is enough. Electronica, EDM, dub, dubstep and also newer pop music can contain lower frequencies, all the way down to below 20Hz.

In a spectrogram we can see the frequency distribution of the music as time travels along the horizontal axis.

**How to interpret the spectrogram charts:**

*Frequency up along the vertical axis, time travels along the horizontal axis. Frequency scale is 0 to 200Hz, time range 20 s.*

**How this relates to music signals:**

*Bass transient: Short in time, wide frequency span
Very low frequency sound
Too low frequency is only noise*
Let us have a look at some real music examples, and see what is actually present at very low frequencies.

*Flashbulb - Near The Woods.*

Solid content down to 16Hz. The impulses (bass-drum) are short in time duration but spreads across a wide frequency range.

And confirmed by analyzing frequency spectrum from playback - the red graph shows peak level.
Some jazz - Vestbo Trio. Drums down to 20Hz.

Pop music - Selena Gomes. Bass-drop down to 10Hz.
Lorde - White Teeth Teens. Certainly looks like some serious deep bass to me.

Malia & Boris Blank - Turners Ship. Good level down to 16Hz.
Classical : Voices Of Music - La Folia. Artists stomping on the scene creates content all the way down, and good level to around 25Hz.

So it certainly looks like deep bass is present in music. And being able to reproduce that properly will have very significant impact on the listening experience.

Combining 2-channel and multichannel movie

If you already have the multichannel system for movies, just connect the music source and enjoy.

Differences between 2-channel and multichannel that affects sound are mostly acoustically related:

• Multichannel has different requirements for room acoustic properties due to all the speakers spread around the room.
• Media room often has a big screen on the front wall which will limit possibilities for front wall acoustic treatment – although main speakers does not radiate much sound in this direction, it will affect reflections coming from sound reflected from other surfaces that eventually hits the front wall.
• Placement of main speakers can be somewhat restricted in a media/theater room.
• Movie sound requires more powerful subwoofers with extension well below 20Hz.
• Multichannel system enables listening to multichannel music.

There is no need to buy additional amplifiers, DACs or processors for a separate 2-channel system if you intend to use the same main front speakers.
## Requirements

### Requirements for 2-channel music sound reproduction

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>Specification / Suggested alternatives</th>
<th>How to achieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How loud</td>
<td>120dB (peak) / 100dB (peak)</td>
<td>Speakers and amplifiers must meet SPL requirement</td>
</tr>
<tr>
<td>3</td>
<td>Sound quality</td>
<td>Perfect signal to the speakers</td>
<td>Choose audibly transparent equipment</td>
</tr>
<tr>
<td>4</td>
<td>Bass-system</td>
<td>Max SPL 120dB, extension below 20Hz / 100dB, extension 30Hz</td>
<td>Add subwoofers with sufficient capacity</td>
</tr>
<tr>
<td>5</td>
<td>Sound character</td>
<td>Open and dynamic / soft and pleasant / open and dynamic and soft and pleasant</td>
<td>Choose speakers according to preference</td>
</tr>
<tr>
<td>6</td>
<td>Soundstage</td>
<td>Big concert hall / dry studio / musicians in your room / you in the concert hall</td>
<td>Speaker radiation pattern and room acoustics</td>
</tr>
</tbody>
</table>

### Detailed technical requirements for "audibly transparent"

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>Specification / Suggested alternatives</th>
<th>How to achieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Distortion</td>
<td>&lt; -80dB</td>
<td>Use equipment that meets requirement</td>
</tr>
<tr>
<td>2.2</td>
<td>Noise</td>
<td>&lt; -100dB</td>
<td>Use equipment that meets requirement</td>
</tr>
</tbody>
</table>

### Detailed technical requirements for standalone DSP

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>Specification / Suggested alternatives</th>
<th>How to achieve</th>
</tr>
</thead>
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<tr>
<td>2.1</td>
<td>Distortion</td>
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<td>2.2</td>
<td>Noise</td>
<td>&lt; -120dB</td>
<td>Use equipment that meets requirement</td>
</tr>
</tbody>
</table>

### Detailed functional requirements to support bass-system

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>Specification / Suggested alternatives</th>
<th>How to achieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Delay adjustment for main speakers</td>
<td>Minimum 15ms/5m delay capacity.</td>
<td>Install processor with adjustable delay processing for mains.</td>
</tr>
<tr>
<td>3.2</td>
<td>Crossover for bass-system</td>
<td>Adjustable 40Hz - 200Hz 2. order or 4. order</td>
<td>Install processor with subwoofer output.</td>
</tr>
</tbody>
</table>
Equipment

Overview

You need a source to play your music from, a digital processor (DSP) to process the sound, amplifiers and speakers.

The speakers are the most important and demanding to choose.

<table>
<thead>
<tr>
<th>Equipment Overview</th>
<th>What it does</th>
<th>How it affects sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Source: CD-player, streamer, computer</td>
<td>Play music</td>
<td>Only important for functionality</td>
</tr>
<tr>
<td>Analog Source: Vinyl, tape</td>
<td>Play obsolete music</td>
<td>Quality of a vinyl player or tape machine affects sound</td>
</tr>
<tr>
<td>Option: Stereo Amplifier</td>
<td>Volume control, drives the speakers</td>
<td>Lack of processing capabilities will affect sound</td>
</tr>
<tr>
<td>Option: AV-Receiver</td>
<td>Sound processing, volume control, drives the speakers</td>
<td>Set-up and processing options will affect sound</td>
</tr>
<tr>
<td>Option: DSP – digital signal processor</td>
<td>Sound processing</td>
<td>Processing options will affect sound</td>
</tr>
<tr>
<td>Option: DAC</td>
<td>Converts digital signals to analog</td>
<td>None, unless it is defective</td>
</tr>
<tr>
<td>Option: Power amplifiers</td>
<td>Drives the speakers</td>
<td>Make sure there is enough power</td>
</tr>
<tr>
<td>Loudspeakers</td>
<td>Makes the sound</td>
<td>The most important for sound quality</td>
</tr>
</tbody>
</table>

Loudspeakers in the 2-channel music room

<table>
<thead>
<tr>
<th>Notation</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>Front left main speaker.</td>
</tr>
<tr>
<td>R</td>
<td>Front right main speaker.</td>
</tr>
<tr>
<td>Sub</td>
<td>Subwoofer, one or several, plays the lowest frequencies that gives the sound weight and impact.</td>
</tr>
</tbody>
</table>
Sound equipment for 2-channel system – the AV-receiver option and 2 small subwoofers

A full 7.1 system - still great for 2-channel music, and full surround for movies
Source

You can use a laptop computer to play digital content of any music file format from disc, and also stream content from the net. Just install the media player software of your preference, configure, done. When set up properly this computer has no influence on sound quality, it just passes the digital signal to the DAC or processor. Use the HDMI output and HD-audio pass-through.

Other sources, such as media streamers and CD players can also be connected to your DAC or processor.

A media player built for the purpose of playing and streaming music can be a good solution, easier to set up and user-friendly functionality.

Vintage gear like vinyl players and tape machines has seen an upturn in popularity recent years, there is something about the physical media and the tweaking and care those machines require, that many people find appealing. Those will require analog inputs on you processor/DAC.

As the format of media content is constantly changing, this is a part of your system that is likely to need replacement later on.

AV-Receiver

The AV-Receiver is a very good choice also for a dedicated music system. Good value for money, and all the processing and functionality needed in one box.

A typical AV-Receiver has 5 or 7 power amplifiers for speakers, processing capability for all digital sound formats, and automatic calibration and room correction setup.

Processing for digital crossover with adjustable delay for bass system integration is an important feature for the music system.

Receivers from the major brands all get you a lot for the money, and even the smaller budget-models will give good performance. The differences among brands and price range will be functionality, amplifier power, room correction capability, and connections.

AV-processor/AV-receiver for music room:

- Many channels and support for Dolby Atmos, Auro3D, DTS:X is not necessary
- Check recommended impedance if using the AVR to power the speakers, many can not drive 4 ohm speakers
- Consider AV-processor with no power amplifiers
- HDMI input and output
- Pre-out connectors for option to add external power amplifier

DAC

Converts digital signal to analog. A standalone DAC is only necessary if you do not have an amplifier or processor with digital inputs.

Choose one that has the functionality you need, and can support the inputs you need, both for hardware connections from your digital players and data stream formats. Reasonably good DACs have been transparent sounding the last decades.
DSP

Processes the sound and converts digital signals to analog. If you choose to place a standalone DSP after the volume control it needs to have very good performance to avoid potential noise and distortion problems.

You need DSP processing for the bass-system, for crossover and delay adjustment on main speakers.

A computer used as media player can also do the DSP functions in software players like JRiver.

Power amplifiers

Power amplifiers for main speakers must be powerful enough to ensure no distortion.

Integrated amplifiers and AV-receivers include power amplifiers. Enthusiasts usually prefer external power amplifiers for more flexibility, increased performance and freedom to select.

If you use an AV-receiver and requirements estimate that more than around 50W on main front channels are needed, it may be worth looking for external amplifiers, to make sure there is enough headroom. Reliability may also be an issue – the typical receiver will quickly run very hot if pushed to the limit, which will increase risk of failure significantly.

Many higher performance subwoofers does not have the amplifier built-in. Typical power requirements are high, 500W-2000W, which means a professional style PA-amplifier is what to get. They are often noisy due to fans used for cooling, so it might be a good idea to place those amplifiers in a different room.

Professional amplifiers is a good alternative for main speakers as well, if more power than around 200W is needed. But be aware that not all amplifiers are sonically transparent sounding with “perfect sound”, some pro amplifiers can have quite high distortion levels.

Main speakers

The speakers are the most important for good sound.

Dynamics must meet sound pressure requirements, while bass extension below 60 or 80Hz is not needed if the lower bass is handled by the subwoofers.

Woofer size is a very good indicator for sound pressure capability of a speaker. This is because the output will be displacement limited at the lowest frequencies, 60 – 100Hz, it does not matter what sensitivity and power handling a speaker has if there is not enough capacity to move air, the sound will be compressed and distorted.

Rule-of-thumb for woofer size and output requirements:

<table>
<thead>
<tr>
<th>Woofer size</th>
<th>Recommended use</th>
</tr>
</thead>
<tbody>
<tr>
<td>6”</td>
<td>6” or smaller are really out of fashion..</td>
</tr>
<tr>
<td>8”</td>
<td>Still too small</td>
</tr>
<tr>
<td>12”, 2x8”</td>
<td>Small room &gt;80Hz</td>
</tr>
<tr>
<td>15”, 2x12”, or even more..</td>
<td>Medium room &gt;60Hz and small room with high fun-factor</td>
</tr>
</tbody>
</table>

Also note that there are no miracle speakers out there that magically delivers more, because all speakers have to follow the same physical laws. Actually, this table is valid for very good speakers designed with limited low frequency extension (>60Hz), good displacement linearity and powerful, efficient motor system.
Directivity – how the speaker radiates sound in the 3-dimensional space – is important for soundstage.

If realistic reproduction at live concert levels is the goal, you should avoid the old-fashioned hi-fi speaker with dome tweeter and small woofers. The dome tweeter has no directivity control, and does not have the required dynamic capacity. Two small 6.5” woofers in a box designed to have bass down to 30 to 40Hz will never have the capacity required for realistic lower midrange reproduction.

Reasonably high efficiency is required to reproduce the full dynamics of music at live sound levels. Sensitivity is specified as dB/1m/2.83V, or dB/1m/1W. Higher value for higher efficiency, typical hi-fi speakers are in the 84-88dB range, and can never play loud even with unlimited power put into them because they will reach power compression or simply burn out. Some full-range horn loaded systems can have sensitivity at more than 100dB.

A sensitivity difference of 6dB means four times power difference – a 90dB speaker requires 400W to play equally loud as a 96dB sensitive speaker with 100W.

**Speaker radiation should cover a reasonably wide area and not send sound in to walls**

Example main loudspeakers specification:

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<thead>
<tr>
<th>2-channel main speakers requirements</th>
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<tbody>
<tr>
<td><strong>Frequency range</strong></td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td><strong>Woofe size</strong></td>
</tr>
<tr>
<td><strong>Directivity</strong></td>
</tr>
</tbody>
</table>
Speakers can be compared by looking at frequency response and polar charts, and sensitivity. A smooth frequency response in the required range 80Hz - 20KHz is desired. Polar plots show off-axis response, this should be smooth and not fall off at high frequencies inside the angle of the seating area.

However, technical specifications with response plots will not tell you how the speaker sounds. You must listen to it. Reading measurements correctly also requires quite a lot of expertise. What looks like a fault in one measurement may actually be deliberately designed in to achieve a desired type of sound, or counteract a problem.

For larger and medium sized rooms it is recommended to choose speakers with larger bass drivers to get more headroom in the important mid-bass and upper bass range, this is where much of the impact and energy will be in both music and movies. Such speakers are typically bass reflex enclosures equipped with one or two 12” to 18” bass drivers.

If you never play very loud, it can also be worthwhile to look at planar dipole speakers of the electrostatic or magnetstatic type.

**Subwoofers and bass-systems**

A bass-system is several subwoofers put together into one system.

Your chosen requirements for low frequency cut-off and maximum loudness level determines what subwoofers you should get.

You need to ensure there is enough output capacity, and have a reasonably flat frequency response down to the cut-off.

Practical incarnations of subwoofers tend to have different sound characteristics, due to different priorities in each design, here is an attempt to describe briefly the typical consequences of different approaches:

<table>
<thead>
<tr>
<th>Subwoofer type</th>
<th>+</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small sealed low-cost</td>
<td>Cheap.</td>
<td>Boomy, no impact and punch. Best to turn it off, as it will not contribute in any positive way to the overall sound experience.</td>
</tr>
<tr>
<td>Sealed with long-excision driver</td>
<td>The best for very low frequency extension, small size, easy to design.</td>
<td>Lacking in dynamics and impact, often sounds kind of soft and rounded.</td>
</tr>
<tr>
<td>Ported with large motor driver</td>
<td>More output capacity, more impact and punch.</td>
<td>Port compression limits low frequency output, larger than sealed.</td>
</tr>
<tr>
<td>Horn</td>
<td>Great impact and punch, dry and powerful bass, high output capacity.</td>
<td>Limited usable bandwidth, very large, can be affected by resonances.</td>
</tr>
<tr>
<td>Compact Horn Subwoofer</td>
<td>Great impact and punch, dry and powerful bass, small compared to performance.</td>
<td>Difficult and advanced to design, expensive to build.</td>
</tr>
</tbody>
</table>

Location of subwoofers significantly affects the response. By placing several subwoofers at different locations it is usually possible to get a reasonably smooth frequency response, across most of the room. Most subwoofers also employ some sort of DSP with equalizer, with manual or in some cases automatic setup.

Two or more subwoofers should be used, and the largest improvements can be seen going from one up to around four – adding even more does not necessarily give improvements comparable to the extra effort.
Relevant subwoofer specifications can be difficult to find, as most hi-fi and home-theater subwoofers are unspecified – it is not possible to see the output capability from the data provided. However, there is often a good correlation between subwoofer size, design type, and output:

<table>
<thead>
<tr>
<th>Subwoofer typical performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type and size</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Sealed with 12” driver</td>
</tr>
<tr>
<td>Sealed with 18” driver</td>
</tr>
<tr>
<td>Reflex box with 12” driver</td>
</tr>
<tr>
<td>Large (200l) reflex box with 18” driver</td>
</tr>
<tr>
<td>Horn 500l</td>
</tr>
</tbody>
</table>

_System with small bass-system, 2x S6-14 subwoofers._
A larger bass-system, 4 compact horn units stacked.
Placing speakers and listening position

Listening position - speakers

Placement of speakers and listening position has huge impact on sound, and you should use some time on this to get the best possible result.

Start by placing main speakers and listening position in an equidistant triangle. The angle between the speakers is 60 degrees, and the distance between you and each speaker is the same as the distance between the speakers.

Placing the speakers at some distance from side walls can be preferable, especially for smaller speakers with lesser radiation control. Some distance between the speakers and the front wall is good, this often improves soundstage depth.

For the listening position, try to avoid the middle of the room or close to the back wall – these locations tend to have the worst uneven bass response. Close to the back wall there will also be early reflections from the wall behind your head.

In a home theater or media room the options for speakers and seating placement are limited by the fact that when the screen is placed, all other items just have to follow. If you have a dedicated music room, this limitation does not exist, and speakers and listening position can be located more freely to achieve the best sound.
2-channel speaker placement guide:

Distance from listening position to each speaker equals distance between speakers.

Here we observe some distance from speakers to front wall (good), side walls are very close to speakers (bad), listening position is off-center lengthwise (good) and at some distance from back wall (good).

The speakers-listening position triangle can be moved and rotated in the room, and you can make it smaller to get more distance between speakers and walls.

The best listening position is precisely located on the center-line between the main speakers, because this location is where it is possible to experience the magic three-dimensional sound stage. As described in the chapter about main speakers, better speakers with controlled directivity is the clue to get better sound for other locations around the room. The other seats will not achieve magic imaging, but tonal balance and a sense of music filling the room is possible.

What happens if you do not sit in the middle between the main front speakers? Imaging will be compromised, so that the virtual location of sounds tends to be imprecise and move towards the nearest speaker. Room acoustics and speaker radiation pattern has significance for how far off center you can move before it gets very bad, but it is not possible to achieve a precise soundstage in center and at the same time similar sound across a wide area.

Placement of speakers affect frequency response, mainly from midrange and down in to the bass range. You want a placement with smooth response from around 100Hz and up. Below that is not important because the bass-system takes over, which makes it easier to find a good placement where imaging and frequency response is good.
Alternative placement by rotating the speakers:

Less distance from speakers to front wall (bad), better distance to side walls (good), listening position quite close to back wall (bad).

After finding the best placement, you can adjust the sound further by making adjustments to speaker angling. This will affect soundstage - point speakers towards listener to get more precise imaging, point more outwards to create larger and more diffuse sound.

Changing distance between speakers will also affect soundstage. If you experience loss of clarity and imaging in center, try to move the speakers closer together. If the stereo image seems narrow, try moving the speakers further apart, increasing the angle between them.

What works best for speaker angling and width depends on the speakers and the room. Try, listen, experiment.

**Subwoofer placement**

Subwoofer location affects the low frequency response, and the actual response is a result of room dimensions but also wall flex and damping, and any windows and openings. The best placement depends on room acoustic properties, practical and interior considerations, number of subwoofers available and subwoofer size.

Moving subwoofers around to fix bass problems is not very rewarding. It is better to just place them up front behind the main speakers, a couple at the back wall if you have 4 or more, and rely on DSP to fix it.
Especially with large bass-systems with several large subwoofers there will be very limited options for placement. Often the bass-system is custom designed to the room, and will only fit in one location. That is fine, if the response is not that great to begin with, it can be fixed with DSP later.

One subwoofer is rather hopeless, but if that's what is available, try placing it somewhere between the front speakers along the front wall, asymmetric.

If you have followed the advice in this guide, you have at least two subwoofers. If you have good bass absorption on the back wall it may work well to place them in the front left and right corners. Often it is possible to get a better response by moving them away from the corners, somewhere in between the front speakers. If practical due to interior issues, a placement further back along the side walls towards the back wall can also give better results.

If you have 4 subwoofers, place them in the corners, two up front and two at the back. The idea is to place subwoofers on opposite locations from boundaries, to be able to fill in nulls, or holes, in the frequency response.

It is best to place subwoofer units symmetric left-right. Although bass frequencies can not be localized, the subwoofer units can, because they will always radiate some sound above the crossover frequency. If you are stuck with asymmetric layout with all subwoofers on one side wall, set crossover to 60Hz or lower, this will usually fix the localization issue.

**Bass and listening position**

Bass is affected by the location of the listening position. How much the bass response changes throughout the room depends on the bass system, size and shape of the room, rigidity of walls, any openings, doors and windows. Close to boundaries the bass is often strong - perhaps too strong - and in the middle of the room the bass is weaker.

A better bass response can sometimes be achieved by moving the listening position.

A better solution is to fix the bass with a bass system consisting of several subwoofer units, calibrated to create a uniform and smooth response across the whole room.

*2 subwoofers up front:*

*Bass is weak at the listening position, stronger along the back wall, and very strong near the front wall.*
4 subwoofers calibrated for uniform sound field:

Strong and precise bass at the listening position, bass is much more similar across the room.

Different room - 2 subwoofers up front:

Decent bass at the listening position, weak bass if moving forward, very strong and resonating bass near the front wall.
Room Acoustics

Overview

The acoustics of your room is very important for the sound, some will say the most significant factor.

Reasonably good sound can not be achieved without taking care of acoustics, this is not something you can choose to ignore.

Good room acoustics means reasonably low reverberation and control of reflections. We know how an empty concrete-wall hall sound like – lots of echo, and it may be difficult to understand what a person says. Not the sound we want in our music listening room.

There are products available today that can fix room acoustics, such as absorbers and diffusors. However, they tend to be expensive, large and visually obtrusive. Especially if the room also functions as a normal living room, there are aesthetic concerns that will limit placement of such items.

I will describe acoustic treatment as a 4-stage process:

1. Reverberation control - Placing sufficient absorption material inside the room.
2. Remove early reflections - Reflected sound, from walls, ceiling, floor, should be removed.
3. Remove room mode resonances and boundary interference - Affects lower frequencies, difficult to remove.
4. Adjust later reflections - To achieve desired soundstage.

Make a plan

Starting out with some acoustic panels and moving them around to see if the good sound magically materializes will not work.

Make a complete plan for acoustic treatment, stick to it, and make adjustments afterwards if the result is not like expected.

The plan can be as simple as adding 2 ceiling panels, or something more elaborate.

• Practical and budget limitations will dictate what you can do
• Set a realistic goal for what you want to achieve
• Consider speaker sound radiation pattern – different speakers require different acoustics
• Furniture, windows, openings are all part of the room acoustics
• Generally, more absorption to fix one problem unfortunately does not automatically give a better overall result – a complete solution for the whole room is required
• Knowledge is required, this is acoustic engineering and not magic, and yes, it is possible to predict what will be achieved

Ceiling absorbers

Adding ceiling absorption gives huge improvements to a normal untreated room, and rarely has any major negative side effects.

Cover most of the ceiling surface, you can leave some space between clouds or panels, you can use 20cm thick absorbers like the ones in Room2 here, or 5cm acoustic panels as a still very good compromise.
Acoustic panels can be mounted hanging down suspended at a small distance from the ceiling, with distance in between the panels. It will be very effective, as the tiles will absorb sound both from the room directly and from the ceiling, reflected.

**Suspended acoustic ceiling panels**

**Add a bass-system**

A decent bass system with DSP (digital sound processor) can in most cases fix all major bass issues.

You will get more smooth and even bass response, remove all boom and resonances, get improved tactile feel and be able to hear and feel all the bass down to the deepest tones.

When this is set up properly, the overall sound quality will improve – the sound is better and more balanced and neutral with the bass system enabled.

The alternative of using bass absorption is not practical in most rooms, because of the size required to make it work down to the lowest frequencies.
Acoustic measurements

To be able to see what is going on you need acoustic measurements.

The purpose of measurements is to get information that can be used to make adjustments to the sound – moving speakers, subwoofer calibration, placement of acoustic treatment.

The equipment needed for measuring does not cost much, it is not very difficult to set up, and REW measurement software is free.

The difficult part is to be able to do proper measurements and then analyze them afterwards. This requires knowledge. You need to know what to measure, how to measure it, and what the various graphs and plots mean.

You can try to get someone to do measurements for you – a professional or a friend. The problem is quality control – it is difficult to know if the person you are hiring actually has the required knowledge. I recommend learning to do this yourself, and if you decide to hire, look for someone who works in the pro world with studios and studio acoustics.

The frequency response shows how loud the sound is at different frequencies. This is the first you look at to verify quality of sound reproduction, ideally it should be smooth, but not necessarily flat, often a tilted curve is preferred. Frequency response determines perception of tonal balance.

---

**Frequency response measurement of a loudspeaker in free field.**
What happens in time is equally important, and more difficult to understand. A decay plot shows how the sound dies out across the frequency range, the ideal is fast decay with same decay rate across the whole frequency range. The frequency response of the decay has impact on perceived tonal balance.

Decay shows frequency response at time intervals, giving a good understanding of how the sound behaves in time across the frequency range.

Early reflections can be identified by looking at the time impulse response. The ideal is a curve that dies immediately and has no reflection peaks. The first 0-5ms is determined solely by the speaker itself, then later on the reflections from surfaces and objects in the room takes over.

IR measured in-room at listening position. Red and green graphs compare two different speakers.
The frequency spectrogram shows how the sound begins and decays across the frequency range.

Reduce reverberation

Reverberation should be around 0.2 to 0.4 seconds, depending on size of the room – less reverb in smaller rooms. This is achieved by placing absorbent material in the room, such as furniture, and acoustic absorbers.

A good way to achieve this is to add absorption in the ceiling, as described for Ceiling absorbers.

In a small room there is not sufficient diffuse sound energy to create a true reverberant sound field. Strictly speaking the contribution from the room is decaying resonances - the sound dies too soon to be distributed evenly throughout the space. At higher frequencies it will appear more like a diffuse reverberant field because the resonances are so many and close together, at lower frequencies these resonances are fewer and separated, causing coloration of the sound rather than spaced sound.

Remove reflections

Reflections from surfaces such as walls will cause the sound to be less clear, and sometimes attain a hard character. Speech intelligibility will be compromised, and individual sound sources does not appear with the proper sense of physical dimension and lacks precise location in the sound field.

Reflecting surfaces are where you can trace a reflective path from your listening position back to a speaker, either through single reflection – typically sidewall, or multiple, such as sidewall-back-front. Sound reflects like light – entry and exit angle on reflecting surface is the same.
First reflection points are where you can see the reflection of the speaker from the listening position.

1. reflection from L, R main front speakers on sidewalls

But we need to consider radiation pattern. Front left speaker, seen from listening position, radiation in blue - for high frequencies the sidewall, floor or ceiling does not exist.
We turn around and see that there is a first reflection point on the back wall. From above, we see the speaker radiates high frequency sound into back wall and part of the right sidewall.

At lower frequencies the speaker becomes increasingly omnidirectional, now there are reflections on the left wall and floor for midrange frequencies.

If you have chosen speakers with good directivity control, it may not be necessary to do much with the side walls, but the back wall should be damped, and this is more important if the back wall is close to the listening area.

This is the reflection pattern for one speaker - left main front. All other speakers will also have reflections. This is where a surround system is very different from 2-channel stereo - there are more speakers and many more reflections.
Direct sound and 1. reflections from walls for L, C, SR, SBR speakers

Subwoofers work at low frequencies only, they have boundary interference with all surfaces inside the room, but no reflections that can be easily removed by using a thin panel.

Acoustic panels are good for reflection control. 50mm thick panels on a reflective surface will absorb sound from midrange and up. For better, wider frequency range absorption rock-wool or fiber glass standard building insulation in 20cm thickness will work better.

Reflection points on walls and ceiling can be treated with such absorption. Thickness and size determines frequency range for which the absorption is efficient, and as we see from the speaker radiation pictures there is no point in adding thin high-frequency absorption to the sidewalls or front wall, thicker and larger is needed to work at lower frequencies.

Usually the floor reflection is left untreated, it is not practical to place acoustic damping on the floor where people are walking.

If the reflecting surface is at some distance from the listening position, you can choose to use diffusion instead of absorption to treat the reflection.

It is not desirable to remove all reflections, if you use too much damping it will sound unnatural and dull. Leave some space untreated, and consider using acoustic diffusors which spread the sound reflection evenly back in to the room.
Room modes and boundary interference

At lower frequencies, typically around 200Hz and below, the response will be dominated by boundary interference – reflections from the surfaces around the speakers and reflections around the listener. Boundary interference is what causes most of the irregularities and deep cancellations on the frequency response.

Room modes can also be troublesome in many rooms - waves that resonates between the rooms acoustic boundaries – between walls, between floor and ceiling, there are also circular modes. These resonances are worse if the walls are very rigid, such as concrete walls.

At lower frequencies there are also reflections from the front wall and ceiling, wavelengths are large and we call them boundary interference.
It is possible to fix this even in smaller rooms, but large constructions covering whole walls are required. This may not be practical in your room, or you simply will not put in the required effort.

A proper bass-system system with several subwoofers will make a huge improvement in the lower bass range. Multiple sound sources will even out the response. Good subwoofers also has digital sound processing, so that it is possible to adjust the frequency response and level out peaks.

Adding proper 40cm or more acoustic absorption on the back wall will improve the bass significantly, especially at higher bass frequencies.

Installing a bass system large enough to act like a large sound source from floor to ceiling will improve the response.

Signal processing room correction software can reduce the effects of boundary interference close to the speaker. This is achieved using time corrective filters, and must not be confused with equalizing, which only corrects the frequency response.

How to deal with boundary interference:

- Move speakers
- Move listening position
- Use multiple subwoofers
- Use equalizer
- Large acoustic damping constructions
- Use time-domain corrective room correction.

In a small room the acoustic behavior changes with frequency. At low frequencies discrete boundary interference reflections causes dips and peaks affecting larger parts of the frequency curve, at high frequencies the reflections appear diffuse.

Since absorption at low frequencies requires very much damping - thick and covering whole surfaces, the result is too much high frequency damping, and the room will sound very dull. By using more diffusion at higher frequencies, it is possible to achieve a much more balanced sound. In a small room it is a good approach to try to get as much low frequency absorption as possible, and as much diffusion as possible at higher frequencies.
A frequency-dependent strategy for acoustic treatment - absorb lower frequencies, diffuse higher frequencies

Adjust later reflections
Adding diffusors or changing the surface of absorbents can bring back some life to the room and actually improve the sound.
Sense of room from the recording, placement and presence of sound objects up front can be affected.
The idea is to preserve a gap very early in time where reflections are eliminated, and then add some reflections just a little higher in level a little later in time.
This can be done by adding diffusors on the back wall. Speaker radiation pattern, room size, room acoustics before making changes, will all affect the impact on sound from changing the reflection pattern.

Don't forget the seats
If your seating is leather, then put some blankets over the backs and pillows on seats not in use, because the leather surface will cause early reflections due to the relatively close distance to the listeners ears.

Soundproofing
Acoustic treatment inside the room has no effect on the sound level outside. To significantly reduce the sound level outside, very extensive construction work has to be done.
Some improvement can be achieved by covering walls and ceiling with an extra layer of drywall panel, but this will not enable you to have a live concert while others are sleeping in a nearby room.

Loudspeaker radiation matters
Better speakers with controlled directivity will be less affected by room acoustic properties, and can give reasonably good results with less acoustic treatment. This makes it easier to get a nice aesthetic appeal, and will also lower the total cost.

Effects of furniture
All items placed inside a room affects its acoustic properties. Sofas, chairs, bookshelves, curtains, carpets will contribute to lower the reverberation by absorption, change reflections and change boundary conditions.
A puff in front of the speaker functions as an acoustic absorber, and fits nicely in as part of the interior.

**Tactile response and bass**

A reason for turning up the volume louder once you reach a level where all instruments and details can be easily heard is the tactile feel of the sound acting on your body - this sense of powerful sound.

Tactile feel is determined by sound field properties - not only sound pressure, but also particle velocity and sound intensity.

Tactile properties affects how the bass is perceived, a system with proper tactile response will also sound better at reasonable listening levels.

The sound source affects tactile feel - a larger source is better. This is one of the reasons you can experience nice punch on a live concert - the loudspeaker system is physically large. Horns tend to have better tactile feel than small sealed subwoofers.

Room boundary reflections destroy tactile feel, this is the other reason you experience much better punch in the bass at an outdoor live concert - there are no significant reflections at low frequencies.

To preserve as much tactile feel as possible in a small room it is necessary to consider both the sound source and acoustics. Larger subwoofers systems and good acoustic damping works better. When setting up a multiple subwoofer system it is important to account for sound field properties, in a bad case it is possible to end up removing all tactile feel if you use only sound pressure measurement for adjustments.
Acoustics plan for the living room

- Suspended acoustic ceiling absorber clouds - or:
- Replace the ordinary ceiling with acoustic ceiling panels
- Consider acoustic panels on side walls if reasonable due to interior design considerations
- Acoustic panels on 1. reflection part of the back wall surface
- Multiple subwoofers properly set up with DSP to deal with low bass resonances and modes
- Consider acoustic properties when choosing seating – leather must be covered with blankets.

Acoustic treatment without doing extensive construction work
Acoustics plan for dedicated media room

- 20cm damping with slats on ceiling
- 40cm or more damping with slats on back wall
- 20cm damping with slats on front wall
- Subwoofer system on front wall, large to create plane wave
- Consider 20cm damping on side walls near speakers
- Consider acoustic diffusors at back for more and proper diffusion
- Consider acoustic properties when choosing seating – leather must be covered with blankets.

Building a room from scratch - use the opportunity to fix acoustics properly

Acoustic treatment built into the wall - absorption at low frequencies, diffusion and scattering at high frequencies.

Slat-covered absorbents can be made more efficient for lower frequencies and more reflective for higher frequencies by adding much more slats and vary width of slats rather than gap - fixed gap width 5-10mm, slat width 30mm and more.
40cm back wall absorption

5cm side wall absorption for midrange and up

20cm ceiling and front wall absorption

Front/side/ceiling: Absorb only upper bass >100Hz, removes boundary interference for main speakers

Back: Absorb all bass, thicker absorption
Controlled directivity speakers

Bass system with stacked units for large radiating source eliminates boundary interference

Speaker shape spreads sound

Absorbers with slats covered with fabric looks like clean wall
Acoustics plan for dedicated 2-channel music room - the Room2

- 4 large ceiling cloud absorbers
- 20cm damping with slats on front wall
- Side wall absorbers 20cm thick
- Subwoofer system on front wall, different configurations possible
- Poly diffusors and hard surfaces at back
- 2 small puff absorbers on floor
- Acoustic table
View towards front wall:
Absorption on early reflection surfaces and boundary reflections from front wall

View to back:
Poly diffusors and hard surfaces
Calibration

Calibration means to adjust all settings for speakers and sound so that level, distance and frequency range is reasonably correct for the speakers, and for 2-channel this means getting the integration between the bass system and main speakers right. The goal is to achieve a smooth frequency response and proper time impulse response.

The settings are adjusted on the DSP or AV-receiver.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Affects</th>
<th>How to adjust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speaker distance</td>
<td>For 2-channel: subwoofer integration</td>
<td>Distance adjustment on AV-receiver, delay on DSP</td>
</tr>
<tr>
<td>Speaker level</td>
<td>Balance between speakers, playback sound level calibration</td>
<td>Trim level adjustment on DSP or AV-receiver, trim level on amplifiers</td>
</tr>
<tr>
<td>Frequency response</td>
<td>Tonal balance, perceived sound quality</td>
<td>Equalizer in AV-receiver, DSP with equalizer, equalizer and crossover frequency on subwoofers, speaker selection, speaker location, room acoustics</td>
</tr>
<tr>
<td>Crossover frequencies and distance for subwoofer</td>
<td>Subwoofer integration, punch and clarity in bass</td>
<td>Crossover frequency and distance settings/delay on DSP or AV-receiver</td>
</tr>
</tbody>
</table>

Target frequency response

A correct frequency response of the system is required for good and balanced sound.

Unfortunately there is no simple answer to how this correct curve looks like.

The best target depends on the speakers, room acoustics, preference and the source material playing.

Experience with sound reproduction have learned us how the response should be to give a perceptually neutral and good sounding balance to the sound; a tilted in-room response so that bass is louder and higher tones are softer.

Flat anechoic on-axis response from the speakers means that the direct sound – the sound from the speakers without room contribution – is flat. The room contribution will add more at lower frequencies and less at higher, so that the overall response measured at the listening position will be tilted downwards. How large the tilt is, depends on room acoustics, size of the room and loudspeaker radiation pattern.

Generally, smaller rooms have a larger tilt, more damped rooms have less tilt.

It is important to note that this tilted response is not a result of personal preference to make it sound “better but not neutral” - the tilted curve is the neutral sound.

There should be no large holes or peaks on the response, this would indicate a problem with speakers or room acoustics. Generally, the smoother the better, part from the desired tilt.

The reasons behind the tilted response lies in how we perceive sound. Perception of tonal balance is more weighted towards the direct sound from the speaker – before any room contribution is added. The human hearing operates in both time and frequency, something that is very easy to forget when working with frequency response measurements.
At lower frequencies the room gain is a result of boundary conditions, and it is not possible to separate the room contribution from the speaker sound.

**Example typical frequency response with tilt**

The perceived tonal balance is a result of the direct sound and decay. If the decay is not linear across the frequency range, this will color the tonal balance. Speaker radiation affects the frequency balance of the decay, wider radiation at some frequencies will increase decay in this range, and this is often compensated for in the voicing of the speakers. They seem to measure wrong on-axis, but when placed in a room the result is a flat and smooth response. This means it will not necessarily give good results to simply equalize the frequency response to flat.

Bass-lift means to add a little lift in the bass. This is a customization from a strictly neutral response, and is chosen according to personal preference – some like no lift, some like much. Choosing gain and step frequencies is part of the tweaking process here, and what works will depend on the bass system and room acoustics.

The combined target correction curve is often referred to as House-curve.

**Target correction curve with 6dB bass-lift**
In-room smoothed response with tilt and bass-lift

Tweaking the frequency response requires acoustic measurement equipment and a proper equalizer. Some room correction systems can improve the response by automatic adjustment, but if the correction is not optimized for a tilted response that matches your room and speakers, the result will not be good.

Luckily, it turns out that good, reasonably linear speakers in a reasonably good room will give a decent frequency response, with flat on-axis direct sound, and tilted in-room total response. Then the only adjustment required is the bass-lift which is done on the bass-system/subwoofers.

Tone controls on newer AV-processors and AV-receivers can be used to create a tilted response.

For program-material adjustments the bass level can be adjusted with the sub output trim level.

Music recordings have huge differences in tonal balance - some due to artistic choice and type of instruments and music, some due to preference, and the monitoring system in the studio was not necessarily neutral as we understand the term today. Typically, productions from the 80's sound brighter with less bass, and new productions have a tonal balance with much more bass and is more suited for systems with a flat response.

If similar tonal balance for all music is a requirement, then you will have to adjust the target according to each recording - a rather hopeless approach. But you can use the bass trim level, and tone controls, to make adjustments to recordings you find to be too far off, and for the most accept that differences in tonal balance is part of the artistic expression and as so does not need any further tweaking.

Checking L, R speakers calibration for 3 seats using pink noise. Frequency response is smooth and shows the desired gradual tilt, approx. 10dB down at 20KHz from 20Hz. All 3 seats show very good consistency. No eq above 120Hz, no room correction, just decent speakers in a decent room.
Response near-field at 1m (red) compared to listening position at 2.6m (blue).

The near-field has mostly direct sound at high frequencies, but bass is still affected by room boundaries. At 2.6m we observe a tilted shape.

Level calibration

For 2-channel music it is strictly not necessary to calibrate level, this is only for convenience so that you have a fixed reference for master volume. Actual loudness for the same master volume setting can vary as much as more than 20dB between different music recordings.

However, it is convenient to know you are not exceeding the capacity of the system, as you can determine at what master volume setting the amplifiers will clip for a 0dBFS input signal.

An AV-receiver with automatic set-up will usually find usable values for speaker trim levels, so that main speakers and surrounds are balanced, and reference level is reasonably correct.

You will of course adjust the master volume setting to your preference when listening, regardless of what the master volume setting displays.

Currently it seems the most widely used method for level calibration for movie systems is to use the Dolby -20dB RMS Pink Noise signal. The adjustment is done by playing the pink noise signal and adjusting the level of speakers using a
RMS sound pressure level meter. This method ensures your system will be calibrated to the same standard as all others using the Dolby signal as reference. This signal has full frequency range and will result in a much more accurate calibration than a typical AV-receiver which uses narrow-band noise.

<table>
<thead>
<tr>
<th>Dolby Pink Noise -20dB RMS calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loudspeaker</td>
</tr>
<tr>
<td>Main L/R</td>
</tr>
</tbody>
</table>

The calibration can be done at lower level as well, just subtract the master volume setting from the measured level, master at -10dB means 75dB on the measured SPL.

If you have calibrated measurement equipment with a real-time spectrum analyzer you can verify the level and also check the frequency response at the same time.

Note that the Dolby pink noise signal does not have a RMS value of -20dB, it is closer to -18dB. The standard calibration in AV-receivers use a narrow-band -20dB RMS signal, which means an AV-receiver calibration will usually end up around 2dB hot compared to using the Dolby signal.

**Room correction**

Most modern AV-receivers have some kind of room correction – a digital processing filter making adjustments to the sound trying to minimize effects of room acoustics and speaker response.

The result of an automatic room correction will depend on how the correction system is implemented, speakers radiation pattern and frequency response, and room acoustics. If the correction equalizes to a flat target frequency response, the end result will most likely be too bright sounding.

If you find it difficult to achieve a perceived neutral frequency balance with the room correction, it is always possible to turn it off.

I recommend getting a real room correction system if this is something you desire very much. Such a system should let you customize the target frequency response and how corrections for reflections are done. Note that using an equalizer, whether manually set or automatic, is not the same as time corrective room correction.

If you use computer-based playback there are software-based solutions with very high performance available. Audiolense is one example, highly regarded by many audio enthusiasts.
Manual setup on AV-receiver

If you decide to not use the receivers built-in room correction, you can now do manual adjustments to get the best sound.

After running the automatic set-up on the receiver, I recommend checking and tweaking the settings:

- Set level and distance for L, R to same
- Set subwoofer crossover frequency to suitable value
- Set subwoofer distance for best impulse response combined with L, R
- Disable room correction

Verify and adjust the trim levels if necessary, as described above in 'Level calibration'.

Note that if you change level or distance settings this will render the room correction configuration faulty, as the calculated filters were made using the automatically configured values.

If your speakers have a reasonably flat anechoic on-axis frequency response, and your room has reasonable acoustics, the system may now have a good frequency response – one with flat direct sound from the speakers, and a total in-room response slightly tilted downward with increasing frequency.

Some crude adjustments on frequency response can be done if the processor/DSP has a graphic equalizer. On many AV-receivers this equalizer can only be used when room correction is disabled. Measurements are required to make useful adjustments, as it is difficult and unreliable to do it without actually seeing the effects.

Subwoofer calibration

Proper calibration of the bass-system system is required for good seamlessly integrated sound in the lower frequencies, from lower midrange and down.

An AV-receiver usually has an additional subwoofer trim level that can be used to set different bass level for different sources, or to change the level if a recording has too soft or too much bass. For this to work properly, the subwoofer system has to be set up with the right frequency response, so that the overall response is reasonably smooth and matches desired target response for different subwoofer level settings.

It is recommended to use acoustic measurements as an aid in the set-up process, it is very difficult to get it right without seeing the actual response and effects of adjustments. But ordinary acoustic measurements do not show a complete picture of how sound is perceived at bass frequencies, so listening evaluation is still necessary.

When using a DSP with parametric equalizer, be careful not to add much gain at holes in the response, focus on taking down peaks by adjusting q, center frequency and gain on filters.

If you have chosen a target response with bass-lift, the shape of this curve is implemented in the bass-system DSP.
Subwoofer calibration steps:

1. Place subwoofers in the four corners of the room, if you have proper 40cm damping on the back wall you can try all subwoofers along front wall.
2. Adjust bass-system DSP equalizer, delay, phase so that frequency response of subwoofers alone is reasonably smooth, and matches target shape.
3. Never time-align 4 corner-placed subwoofers to the listening position, try adding 2ms delay on the front right and back right units.
4. Choose crossover frequency - often higher than usually recommended - try 120Hz. No proper DSP for delay on mains? Asymmetric placement? Try a lower frequency, 60Hz.
5. Time align subwoofers and main speakers by setting Subwoofer Distance or add delay to main speakers, remember to add delay of DSP and additional acoustic group delay in subwoofers and low pass filters - in total this may end up being several meters more than the physical distance to the subwoofers.
6. Limited processing capability? No delay for mains? Only 2 subwoofers? Better results can often be achieved by moving the subwoofers back towards the listening position, away from the front wall corners.
7. Using an AV-receiver? Do not run mains as "large"/full-frequency range, do not use “Direct” or “Pure Direct” mode as this will usually disable the processing you have carefully tuned to get the best seamless subwoofer integration.

* Bass-system eq adjustment on this 40Hz peak improves decay significantly. Use eq to take down peaks with notch filters and adjust broadband shape to target with shelf filters. Leave the holes, they can only be filled by moving or adding subwoofer units.*

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Measurements

To be able to do a proper calibration where you check the frequency response it is necessary to measure using a microphone and acoustic measurement software.

I recommend a calibrated acoustic measurement microphone, a professional USB I/O device, and REW room acoustic measurement software, you run it on a standard laptop computer.

With measurement capability in place, you can now see the effects of tweaking the configuration settings and changes in room acoustics.

Getting the subwoofer system properly integrated is now possible, as you can see what is happening with the combined response when you make adjustments, and you can set delay on main speakers to get the timing right.

If you do not want to put in the required effort to find out how this works, you can try to find a friend or enthusiast in the neighborhood to help you out with some basic measurements. A competent dealer may also be able to help, but be prepared to pay for the service.

See Room Acoustics - Acoustic measurements for more on acoustic measurements.

*Microphone placed at main listening position, ready for measurement*
Further improvements

Learning more
This article covers basic principles for getting the best sound, it does not go in to detail on technical terms and theory. A place to start for more information and to learn more, can be to search the net for terms and subjects mentioned.

The How to set up a home-theater sound system article:
www.kvalsvoll.com/Articles/HowtosetupaHomeTheaterSoundSystem.htm

The Audio Calculator for speaker sensitivity and power requirements:
www.kvalsvoll.com/Articles/AudioCalculators.htm

Kvålsvoll Design web pages has informative articles and product presentations:
www.kvalsvoll.com

Better sound
Improvements to sound can be done by doing changes to your system:

1. Calibration and setup
2. Room acoustics and placement
3. Loudspeakers
4. Amplifiers

How to proceed depends on what you want to improve.

Louder and cleaner at high sound pressure levels:

• Better loudspeakers with increased sensitivity
• Improving room acoustics will make it sound cleaner and more dynamic
• Install more powerful amplifiers

Cleaner, more defined sound:

• Improve room acoustics
• Better loudspeakers
• Work on calibration and setup

Better bass with more impact and punch at low frequencies, less boom:

• Install capable bass-system with multiple subwoofers
• Work on calibration to get more even response and perhaps lift the low end quite a bit
• Install acoustic treatment for low frequency control
• Relocate subwoofers to get more impact
About the Author

I run the Norwegian registered company Kvålsvoll Design AS.

I like to create things, I like to work on engineering challenges as well as shape and visual appearance. I also enjoy working on abstractions like systems and concepts. This forms the foundation of Kvålsvoll Design.

I am an engineer in cybernetics and electronics. I have started several companies, and I have designed, built and tested complex cybernetic systems involving advanced dynamic control algorithms.

In 2012-2013 I started designing loudspeaker systems for home entertainment. Development is based on my expertise on simulation and dynamic systems. I have also learned a lot about how we perceive sound, which is of vital importance for defining proper requirements for sound system design.

The development of audio solutions in Kvålsvoll Design has lead to several new technologies for sound reproduction, such as the Compact Horn subwoofers, controlled directivity waveguide horns, very-high-slope crossover networks.

Acknowledging the importance of set-up and calibration, a new method for subwoofer calibration has been developed, which accounts for sound-field intensity for better tactile feel. This is new, and Kvålsvoll Design is so far the only company using this method.

Thank you for reading,

Øyvind Kvålsvoll