

HOW TO

SYSTEM DESIGN FUNDAMENTALS

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Building an audio system doesn't need to be a complex endeavor. By learning the fundamentals of system design you'll easily be able to configure your own system that sounds as great as it looks.

AUDIO BASICS

Sound is simply air vibrations picked up by our ears. High-pitched sounds vibrate at a faster rate, and low-pitched sounds vibrate at a slower rate. Music is nothing more than a mass of complex sounds arranged in a series of complementary tones.

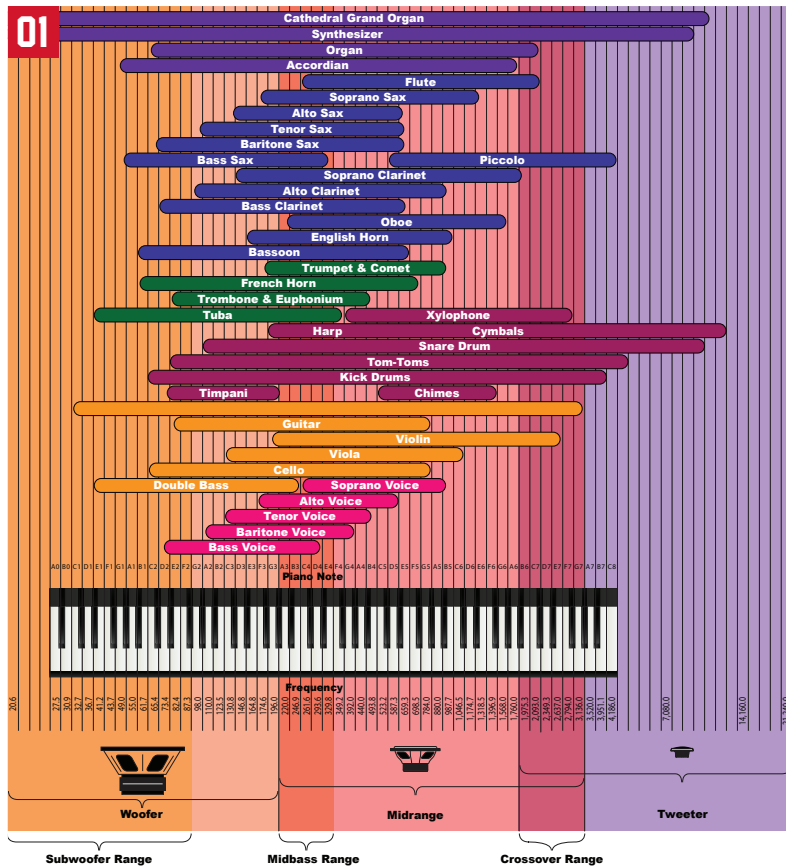


Fig. 01 Illustrates the human hearing range of 20 Hz (Hertz) to 20 kHz (Kilo-Hertz), with lower frequencies appearing on the left side and higher frequencies on the right. We overlaid several musical instruments – including a piano – to illustrate the range of frequencies each instrument is capable of playing.

In its simplest form, there are three types of speakers needed to reproduce the audible frequency range: Tweeters, Midrange, and Woofers. For more complex systems, there are additional Subwoofer and Mid-bass ranges, but for now we're going to keep it simple and stick to three.

High-Frequency Range (2.5kHz to 20kHz)

Tweeters are designed to reproduce the high frequency range, consisting of symbols, synthesizers and higher order harmonics. Since higher frequencies vibrate faster, they produce smaller wavelengths (a 3kHz tone is 4.5 inches / 114 mm long). Their small size allows voice coil and diaphragm components to be compact. However, as wavelengths become shorter, their sound becomes more directional, so a tweeter is the most sensitive speaker to place within the vehicle.

Mid-Frequency Range (200Hz to 2.5kHz)

Midrange speakers are designed to reproduce this frequency range, consisting primarily of vocals and instruments. This is the most dominant speaker due to the range of frequencies. Placement within the vehicle is more forgiving due to wavelength

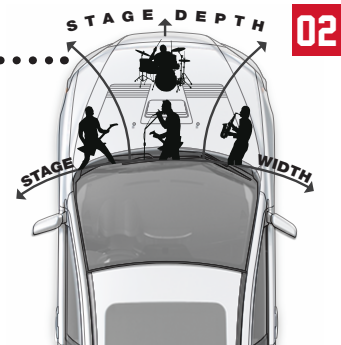
size (a 500Hz tone is 27 inches / 68.6 cm long), but the distance to your ears should be equalized for a proper sound stage, which we'll cover soon.

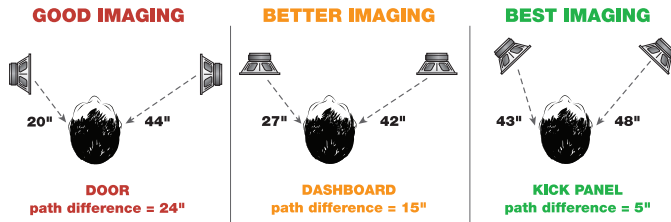
Low-Frequency Range (20Hz to 200Hz)

Woofers are designed to reproduce this frequency range. They have much larger voice coil and cone sizes corresponding to the longer wavelengths they produce. Placement within the vehicle is typically not an issue and perceived to be omnidirectional due to large wavelength size (a 50Hz tone is 270 inches / 6.86 meters long).

MOBILE AUDIO SYSTEMS

With typical car audio systems, our goal is to achieve a sound stage that originates in front of the listener. Sit in the driver's seat and imagine a live concert performing on the vehicle's dash. The sound should originate from across the horizon and reach to the far left and far right of the dash, with the depth ideally reaching far beyond the interior of the vehicle. **Fig. 02** Illustrates the width and depth of a definitive sound stage. Another factor to consider is "imaging" which is the ability to reproduce instruments and vocals in their correct locations on the sound stage. **Fig. 03** illustrates installations and their effect on imaging. If you don't want to physically relocate speakers you can manipulate the localization effect using signal processors like the time delay feature in 3Sixty.3.





03 Coax vs. Component

For the front seats, determine if your vehicle is better apt to support a pair of “coaxial” speakers, where the tweeter is mounted in front of a midrange speaker and installed as one unit, or a “component system” where the midrange and tweeter are separate. Although coaxial speakers are easier to install, component systems typically offer better sound quality. For the rear seating row(s), it’s most practical to utilize coaxial speakers due to space limitations in doors.

Single Amplifier vs. Multiple Dedicated Amplifiers

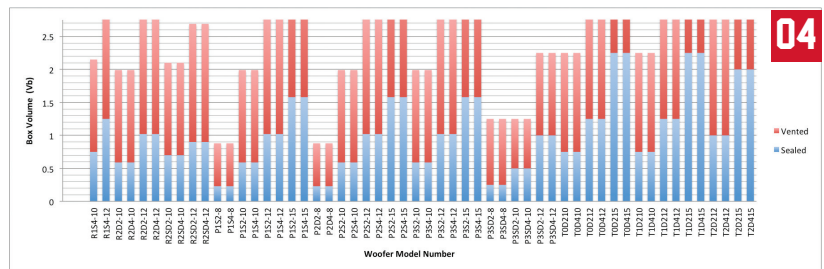
Amplifiers take low audio signal from the source unit and “boost” them up to overcome road noise and make them easier to hear, resulting in better sound clarity. A 3-Channel System uses a 2-channel amplifier with speakers wired to the left and right channels, and a woofer wired in bridged/mono. Note: This type of system requires passive crossovers. A 4-Channel System uses a 4-channel amplifier with front speakers wired to the front channels, and rear speakers wired to the rear to retain fader control. A woofer with a passive crossover can be wired to the front channels to retain constant bass regardless of rear fader control. A 5-Channel System uses a 4-channel amplifier for both front and rear channels to retain fader control, but uses dedicated mono amplifier(s) to power woofer(s). Multiple amplifiers provide better dynamic range (sound quality) and are more versatile, but are costly to implement over single amplifier designs.

Standard vs. Compact Amps

Depending upon your vehicle type and space will determine what size of amplifier is used. Most cars, trucks and SUVs have ample room for installing traditional amplifiers. However single cab trucks and sub-compact cars (think SMART car) are limited in space and may benefit from compact amplifiers. Electrically sensitive vehicles like hybrid/electric cars may also benefit from the “current sipping” advantages of compact amps. Rockford Fosgate’s newer lines of compact Punch/Power series amps are perfect since they require little space and current. Keep in mind their dynamic output is lower than traditional amps.

Woofer Size

Typical car audio woofers range in size from 8” to 15”. Determining what size and how many to use is up to you. It’s easy as measuring the maximum Height, Width & Depth available (or space you want to sacrifice) for woofers. Use our Woofer BoxWizard at www.rockfordfosgate.com/rfttech to determine the amount of cubic feet/liters available. One or two woofers are adequate for most systems. The charts in **Fig. 04** illustrate the amount of airspace needed for Rockford Fosgate woofers.



Rockford Fosgate Sealed Enclosures

Woofer Size	8”	10”	12”	15”
Vb (Cubic Feet)	0.23 – 0.50	0.50 – 0.75	0.75 – 1.25	1.58 – 3.0
Vb (Liters)	6.5 – 14	14 – 21.2	21.2 – 35.4	44.7 – 85

Rockford Fosgate Vented Enclosures

Woofer Size	8”	10”	12”	15”
Vb (Cubic Feet)	0.65 – 1.0	0.75 – 1.50	1.75 – 2.0	2.5 – 3.5
Vb (Liters)	18.4 – 28.3	21.2 – 42.5	49.5 – 56.6	70.8 – 99

Power vs. Loudness

How loud you design a system is of personal preference, and low frequencies are the primary factor of how loud a system plays. Loudness is defined as a psycho-physical sensation perceived by the human ear/brain, whereas SPL (Sound Pressure Level) is a logarithmic quantity measured with test equipment. An amplitude change of 1 dB is the minimum detectable sound adjustment perceived by ear, with 3 dB being the most recognizable change. An increase of power and/or woofers used in a system equates to more “loudness”. Typical vehicle electrical systems can only support around 500 to 600 watts of amplifier power, so keep this in mind when building your system. The chart in **Fig. 05** illustrates how power, woofer cone area and loudness relate to SPL.

To Equalize or Not

If the built-in equalizer on the radio provides adequate tone control, then there’s no need for an additional equalizer. However, if you desire more customization of the audio signal, a signal processor with more control over the sound like the 3Sixty.3 may be needed for your desired taste.

Decibel Increase	+3 dB	+6 dB	+10 dB
Perceived loudness by human hearing	1.23 times louder	1.5 times louder	Twice as loud
Watts needed if using same woofers	2 times the power	4 times the power	10 times the power
Cone area required using same power	2 Woofers	4 Woofers	10 Woofers

Matching Amplifiers to Speakers

Once you determine the type and quantity of speakers needed for your system, how much “amplifier power” should you buy? Look at the speaker’s RMS power handling (sometimes labeled “Pe”) and sensitivity ratings (labeled “Sensitivity” or “SPL”), then use the chart below in **Fig. 06** for the minimum and maximum power needed. Remember to abide by amplifier impedance recommendations and divide your power output by the number of speakers. For example, if an amplifier channel produces 100 Watts, but you have two speakers connected to that channel, each speaker will “see” 50 Watts within the same frequency range.

For example, if a woofer is rated to handle 100 Watts RMS, the formula (100W x 0.30 = 30W) would result in our speaker needing 30 Watts minimum. The maximum would be equivalent to the woofer RMS power handling, which would be 100 Watts. If a midrange or tweeter is rated to handle 50 Watts RMS, the formula (50W x 0.20 = 10W) would result in our speaker needing 10 Watts minimum. The maximum would be equivalent to the midrange or tweeter RMS power handling, which would be 50 Watts.

Suggested Power	Subwoofers	Midrange/Tweeters
Minimum Watts	30% of Speaker RMS	20% of Speaker RMS
Maximum Watts	100% of Speaker RMS	100% of Speaker RMS

MARINE AUDIO SYSTEMS

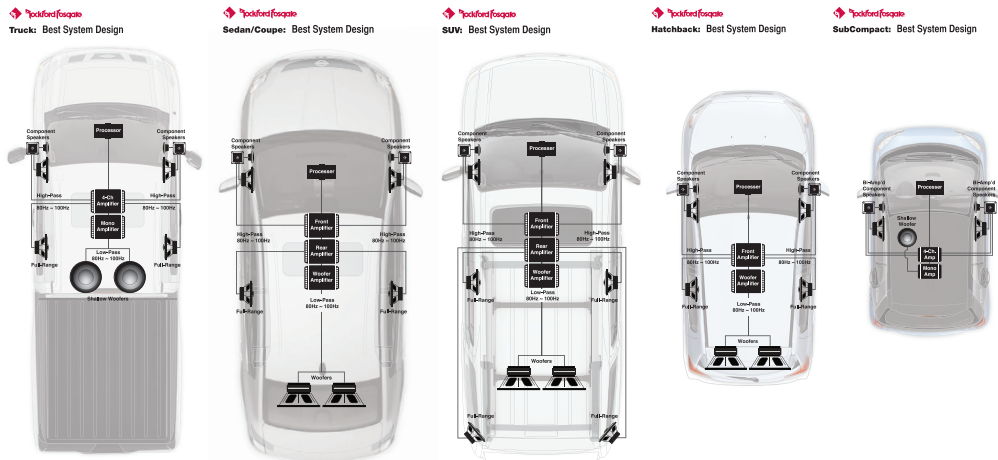
Rockford Fosgate continues to expand its product line for marine audio systems. However, in watercraft installations, system design is less about imaging/staging and more about convenience. Speakers are typically placed in direct path of listeners in the boat. This is common because most boats are “open air” with nothing to reflect sound. The exception is the woofer, as it’s usually placed to “boundary load” under the bow or in a compartment where low frequencies can reverberate to emphasize bass. An experiment you can try at home to illustrate this effect is to place a woofer enclosure in the middle of a room and listen to it. Now move the enclosure under a coffee/kitchen table and listen to the result. Low frequency waves reflecting off the table give the impression that it’s louder.

MOTORSPORTS AUDIO SYSTEMS

Rockford Fosgate also continues its development of application specific products, like the recent release of compact Punch and Power series amplifiers. In motorcycle, golf cart, and ATV/UTV, or side-by-side installations, system design is also less about imaging/staging and more about convenience. The compact size and efficient power supply requirements make the compact Punch and Power amplifiers perfect for use in current limited installations.

EXAMPLE SYSTEM DESIGNS

You can download good/better/best system designs from our RFTECH Knowledge Base. Enter Answer ID “11” in the search box or use the QR Code.



SUMMARY

Audio systems don’t have to be complicated, and simplifying the goal can reduce headaches when building one. Keep the system basic using just three ranges of speakers (low/mid/high). Optimize the front using component speakers, and if rear speakers are needed, stick to coaxial types. For bass, measure available space and work backwards to determine what size and quantity of woofers can be used, with one or two being adequate in most systems. Of course there are several opinions on what’s “best”, but these guidelines will help narrow your choices. Rockford Fosgate offers three product lines under PRIME, PUNCH and POWER series to meet your system needs. Refer to the Buyer’s Guide section of this magazine for more info.