The Technology Behind the BenQ treVolo Bluetooth Speaker

How and why we developed the world's first portable electrostatic wireless speaker

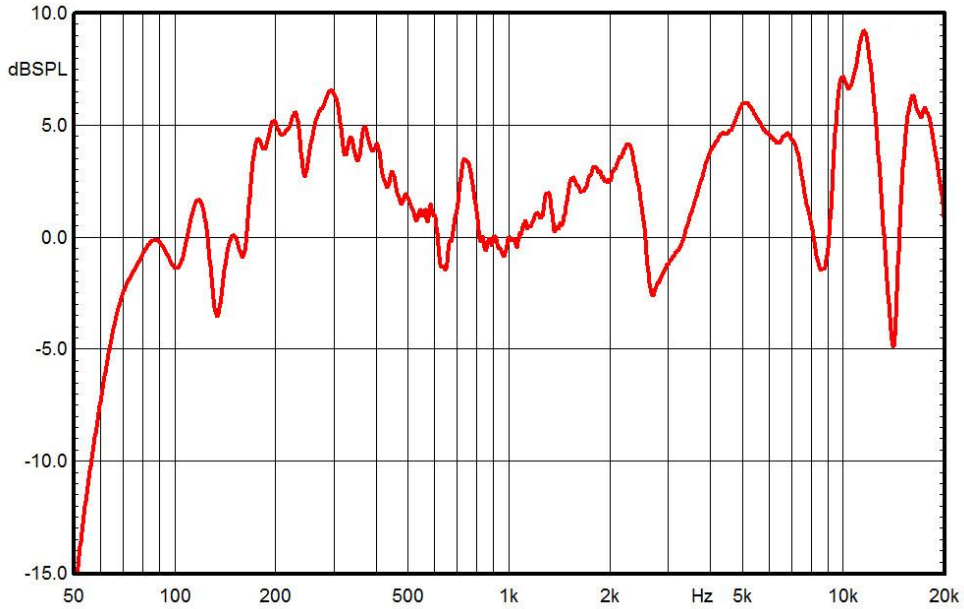
The treVolo is not only BenQ's first audio product, but also the world's first portable wireless speaker to use electrostatic panels. BenQ has been working on developing an affordable and power-efficient electrostatic panel for over two years. Why did we choose such an unusual technology for our first effort? This white paper will explain.

The Problem with Wireless Speakers

Before we created the treVolo, we at BenQ looked at and listened to many wireless speakers. While there were a few we liked, we mostly heard the same problem over and over again: inaccurate midrange and treble reproduction, which made voices, in particular, sound unnatural.

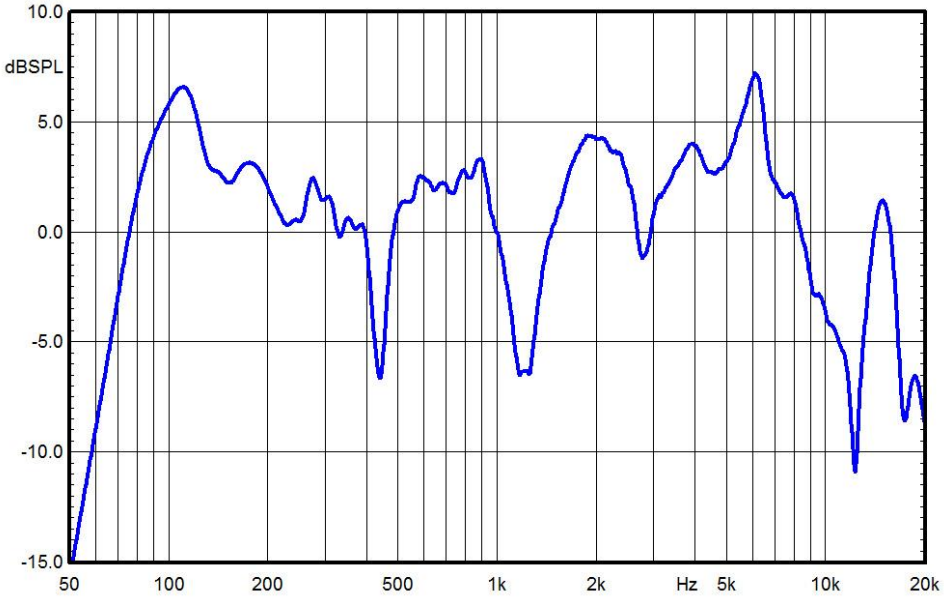
Why were the wireless speakers sounding so bad, when even an inexpensive set of stereo speakers connected to an inexpensive receiver often sounds great? The deeper we looked into the problem, the more we realized it wasn't because these speakers are wireless. It's because of the way they're designed.

Most wireless speakers on the market now use so-called "full range" drivers: conventional cone-shaped drivers that are small enough to reproduce high frequencies. Sometimes they're combined with a subwoofer, or with a passive radiator to reinforce the bass. The problem with these drivers is that while their midrange reproduction is sometimes pretty good, their treble reproduction is typically extremely uneven.



Typical response of a full-range cone-type driver. The flatter the red line is, the better. Large peaks and dips in the response make the sound unnatural.

Some wireless speakers attempt to correct this problem by adding a tweeter. However, in almost all cases, a very cheap and harsh-sounding tweeter is used. Compounding this problem is that the crossover circuit that filters the bass frequencies out of the tweeter is very primitive, usually just a single capacitor connected to the tweeter. Typically no crossover filter at all is used for the woofer. The result is that the woofer remains active up into the highest frequencies of sound, where its rough frequency response counteracts any positive benefits of the tweeter.



Typical response of a woofer/tweeter combination in an inexpensive wireless speaker, with only a single capacitor used as the crossover circuit for the woofer and tweeter. Ideally, this line would appear flat.

In our research, the few wireless speakers that sounded good tended to be large, high-priced models that used expensive drivers, bulky speaker enclosures and costly amplifiers. That's fine if you have the money and space for a speaker like that. But our hope when we started this project was to bring higher-quality wireless sound to a broad audience, at a price point of $400 or less.

Fortunately, as we researched different audio technologies, we found a way to accomplish all of our goals … and then some.

The Electrostatic Driver: The Solution for Full-Range Sound

The electrostatic driver is the key to the treVolo's sound quality. For decades, audiophiles have loved the sound quality of electrostatic speakers, manufactured under brand names such as MartinLogan, Quad and Sound-Lab. The reason audiophiles love electrostatics is that they simply sound more natural and spacious than conventional cone- and dome-shaped speaker drivers.

How Electrostatic Drivers Work

An electrostatic speaker uses a thin diaphragm that is driven evenly over its entire surface.

The diaphragm is a sheet of polyester film only a few microns thick, coated with graphite to make it electrically conductive. The film is suspended between two perforated sheets of metal, or grids. A high-voltage source is connected to the end of the diaphragm. The grids are connected to a transformer, which is in turn connected to the amplifier. One of the wires from the transformer is connected to the front grid, and the other to the back grid.

How an electrostatic speaker works. The audio signal from the amplifier feeds the grids through a transformer. The diaphragm is charged from a high voltage source.

When an audio signal from the amplifier reaches the grids, it creates an electrostatic field that fluctuates along with the audio signal. Because the conductive diaphragm suspended between the grids is charged with high voltage, the diaphragm is attracted to one of the grids, in the same way that a balloon sticks to your clothes if you rub the balloon against them to build up a static charge. Then as the polarity of the fluctuating audio signal changes from positive to negative, the diaphragm is attracted to the other grid. The diaphragm thus moves back and forth, which creates sound.

Advantages of Electrostatic Drivers

The main advantage that electrostatic drivers offer over conventional drivers is that the conductive polyester diaphragm has very low mass compared with the cone and dome diaphragms used in conventional speaker drivers. The low mass permits the diaphragm to start moving faster than a relatively heavy cone can, thus allowing it to reproduce high frequencies (treble) more clearly and with a more natural timbre. Low mass also allows the polyester diaphragm to *stop* moving immediately when a musical note ends; instead of continuing to "bounce" back and forth after a musical notes has stopped, the way conventional drivers can.

Most electrostatic drivers are open on both sides so they radiate sound forward and backward. This more closely resembles the sonic radiation patterns of most instruments than a conventional full-range speaker can. Think about a violin, which radiates sound forward and backward with nearly equal intensity. Or a saxophone, a piano or a drum. As occurs with these instruments, the sound from the front of an electrostatic driver reaches your ears directly, while the sound from the rear of the driver reflects off the wall behind and other surfaces to reach your ears. The result—with the instruments or with the electrostatic driver—is a natural sense of ambience.

Electrostatic drivers emit sound freely forward and backward, so they have a more spacious, natural sound. Conventional full-range drivers emit sound only forward; sound coming from the rear of the driver resonates inside the enclosure.

Electrostatic drivers do not use the sealed or ported enclosures typical to most speakers. This configuration offers two advantages. First, there are no box resonances that alter the sound, creating peaks and dips in the frequency response and causing some notes to “ring” after the audio signal has stopped. Second, speaker enclosures tend to contribute non-musical vibrations of their own as their side panels vibrate—but with electrostatic drivers, there is nothing to vibrate but the diaphragm itself.

An electrostatic driver can effectively cover a much broader range of sound than a conventional cone or dome driver can. In the case of the electrostatic drivers used in the treVolo, the range is from the lower midrange up to the highest treble frequencies. Because of this wide range, the crossover circuits that filter the bass out of the electrostatic drivers and the high frequencies out of the treVolo’s woofers can be set to a lower frequency. With typical two-way wireless speakers, the crossover occurs at about 3 kilohertz—right in the region where the human ear is more sensitive, and where reproduction errors are most audible.

Precise Bass from Dual Woofers and Dual Passive Radiators

The principle weakness of electrostatic drivers is that the diaphragm cannot travel very far between the grids. Thus, it cannot move enough air to reproduce bass notes, unless the diaphragm is extremely large. This is why most electrostatic speakers, including the treVolo, use conventional cone woofers to reproduce bass.

In the case of the treVolo, there are two woofers, both high-quality, high-excursion 2.5-inch drivers with compact neodymium magnets. The two woofers fire forward, through the center grille of the treVolo. The small size of the woofers and the power of the neodymium magnets assures tight, responsive bass with none of the booming or ringing heard in many wireless speakers. The compact, rigid enclosure that holds the woofers also helps prevent the vibration and resonance that plagues so many wireless speakers, especially larger models with plastic enclosures.

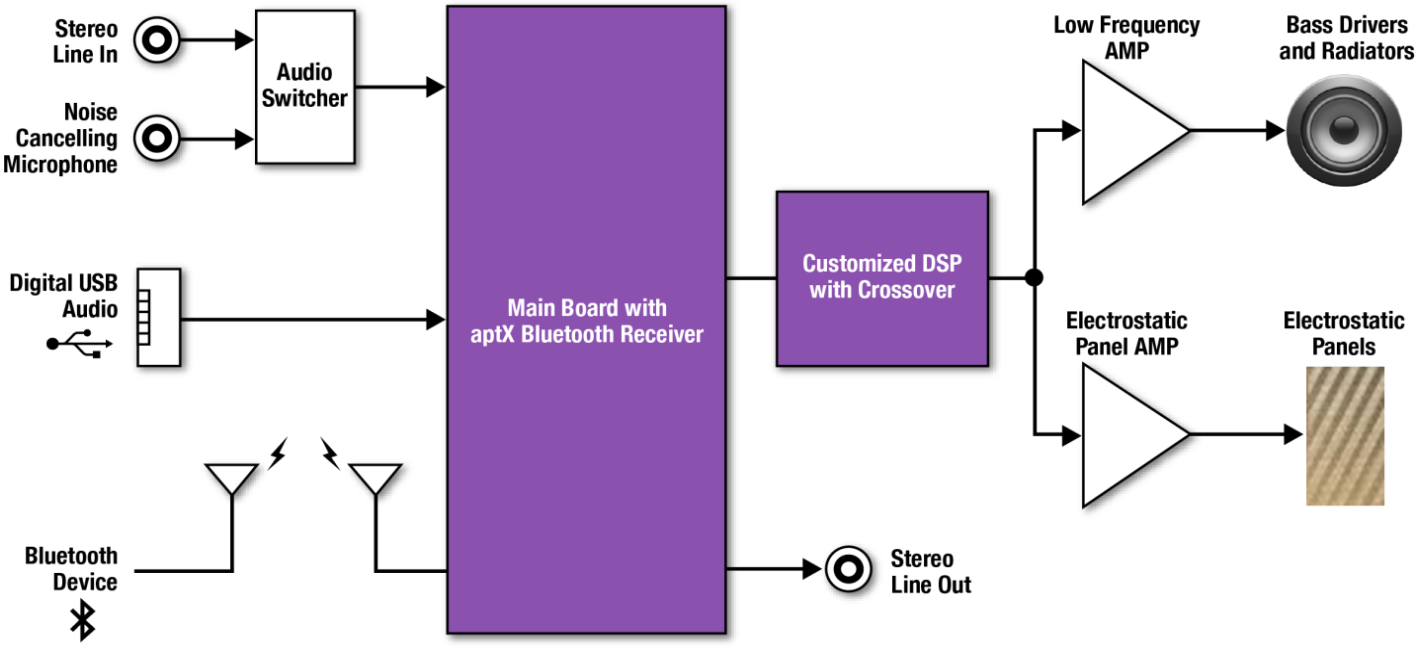
The treVolo uses dual 2.5” woofers and large passive radiators to generate crisp, accurate bass. These drivers operate on a separate amplification system than the electrostatic panels and are controlled via the DSP for smooth transitions from low to high frequencies.

The bass reproduction of the treVolo's woofers is reinforced through the use of two long-throw passive radiators mounted in the sides of the central enclosure. These passive radiators are tuned through precise addition of mass to their diaphragms, so their resonant frequency is lowered into a range of audio frequencies below what the woofers can cover on their own. Thus, the passive radiators pick up where the woofers leave off, extending the treVolo's bass response down below 60 Hz and giving the compact speaker a satisfying, full sound.

Quad-Amplified Electronics with Three-Channel Digital Signal Processing

The treVolo incorporates an electronics design that is similar in concept to those used for the most technically advanced professional studio monitors and high-end consumer audio systems now available.

Each driver in the treVolo is powered by its own amplifier channel. The unit contains two stereo Class D amplifiers: one for the electrostatic drivers, and one for the woofers. Because the crossover filters are implemented in the treVolo's internal DSP chip, no passive crossover components are connected between the amplifiers and the drivers. This arrangement assures maximum control over the drivers by the amplifiers. It also makes the most of the amplifiers' power, because there are no passive crossover components to soak up the amplifiers' energy. (Note that there are a few passive components connected between the woofer amp and the woofers, but these are small-value components used solely for filtering the high-frequency energy from the output of the Class D amplifier, and they have no effect on audio frequencies.)



Because a separate amplifier channel is devoted to each driver in the treVolo, all of the crossover and EQ functions can be implemented in DSP, instead of using passive components.

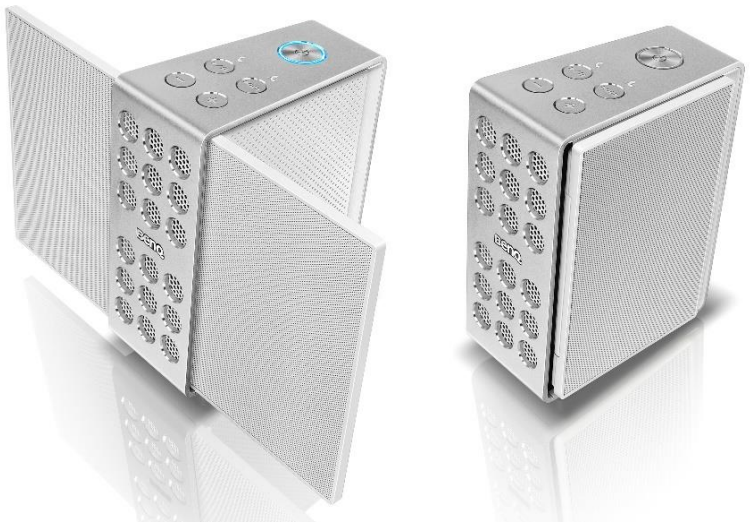
Because each driver has its own separate amplifier, the drivers' responses were specifically tailored by using digital signal processing (DSP) technology instead of power-wasting, imprecise passive components. The DSP used in the treVolo is a three-channel design created specifically for 2.1-channel devices such as the treVolo. The DSP provides one channel each for the electrostatic panels, and a single channel for both woofers. The controls for these channels are optimized for their purpose—i.e., the controls for the ".1" bass channel are optimized for the tuning of bass response.

This three-channel DSP allowed us to achieve an adjustment accuracy of 0.1 dB and 1 Hz in the treVolo's crossover and EQ filters. The crossover that filters the bass out of the electrostatic panels and the midrange and treble out of the woofers is executed entirely through DSP, so that our engineers could achieve exactly the response curves they wanted without having to compromise.

We also used this three-channel DSP to create the treVolo's three listening modes. The Pure mode has minimal DSP processing, while the Warm and Vivid modes use DSP-based filtering to optimize the treVolo's response for different types of music and different listening tastes. Because these modes were created in DSP, we were able to experiment with numerous different settings to find the ones our engineering team agreed delivered the most useful and musically valuable options.

Innovative Portable Design

The treVolo may be the first electrostatic speaker created for portable use (although there have been a few electrostatic headphones). Surprisingly, though, the electrostatic panels offer considerable advantages when it comes to portability. The panels themselves are only a few millimeters thick, and they require no enclosure behind them. Thus, we were able to engineer the panels so they fold flat against the treVolo's sides. The resulting size is just less than 7" tall, 3" wide, and about 5" deep, small enough to fit easily into a suitcase or even a backpack.



The ultra-thin electrostatic panels fold against the sides of the treVolo for easy portability.

A rechargeable battery capable of powering the unit for 12 hours of typical use makes it easy to carry the treVolo around the house, over to a friend's house or even on a weekend getaway without having to worry about charging it.

Conclusion

The BenQ treVolo offers many performance advantages over typical wireless speakers.

- Electrostatic drivers for clearer, more natural midrange and treble and a more spacious sound
- Small, high-output woofers for precise, accurate bass
- Precision-tuned passive radiators for deeper bass response
- Quad-amplified design allowing all crossovers and EQ functions to be implemented in DSP for superior sound quality and efficiency
- Compact, folding design and 12-hour rechargeable battery for easy portability.

If you would like to know more about the BenQ treVolo wireless speaker, please visit www.BenQtreVolo.com.