Technical Article

What Are the Building Blocks of Bluetooth Speakers?

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Bluetooth® speakers are now fairly common in the marketplace. Many manufacturers offer very basic systems selling for a few dollars to high-end systems selling for hundreds, with varying degrees of audio performance.

The Bluetooth market is highly competitive; hence, you must be very aware of multiple design constraints to develop the right product features at the right cost. These constraints include solution size, component count, cost, efficiency and battery size.

Figure 1 shows the basic blocks inside a Bluetooth speaker:

- **Battery**. Because this is a portable application, the battery is a must-have block.
  - Cost and size constraints mean that this battery must be as cost-effective, small and light as possible.
  - More than likely, you will use the least number of battery cells to achieve the longest play times.
- **Power management**. This block provides the right power levels to the rest of the Bluetooth circuitry.
  - Given the cost and size constraints from the battery, the voltage coming from one or two battery cells would be quite low. You will likely need a boost converter to increase the available voltage to the rest of the system.
  - The power-management block must include a charger to recharge the battery after portable use.
- **Bluetooth system**. This block provides wireless communication to the speaker from a smartphone, tablet or other Bluetooth-enabled products.
  - Bluetooth modules today offer complete solutions for portable audio systems, as they support wireless and wired-in audio natively.
- **Audio**. This block contains all of the electronics to drive the speakers in the system.
  - Because the signal coming from the Bluetooth module has both low-voltage and low-current capabilities, an audio amplifier provides the signal with the necessary higher voltage and current capabilities to drive the drivers in the speaker system.
  - An audio digital-to-analog converter (DAC) may be included in this block to convert the digital audio signal from the Bluetooth module to analog, and to provide additional audio processing in the digital domain to further enrich the customer experience in higher-end systems.

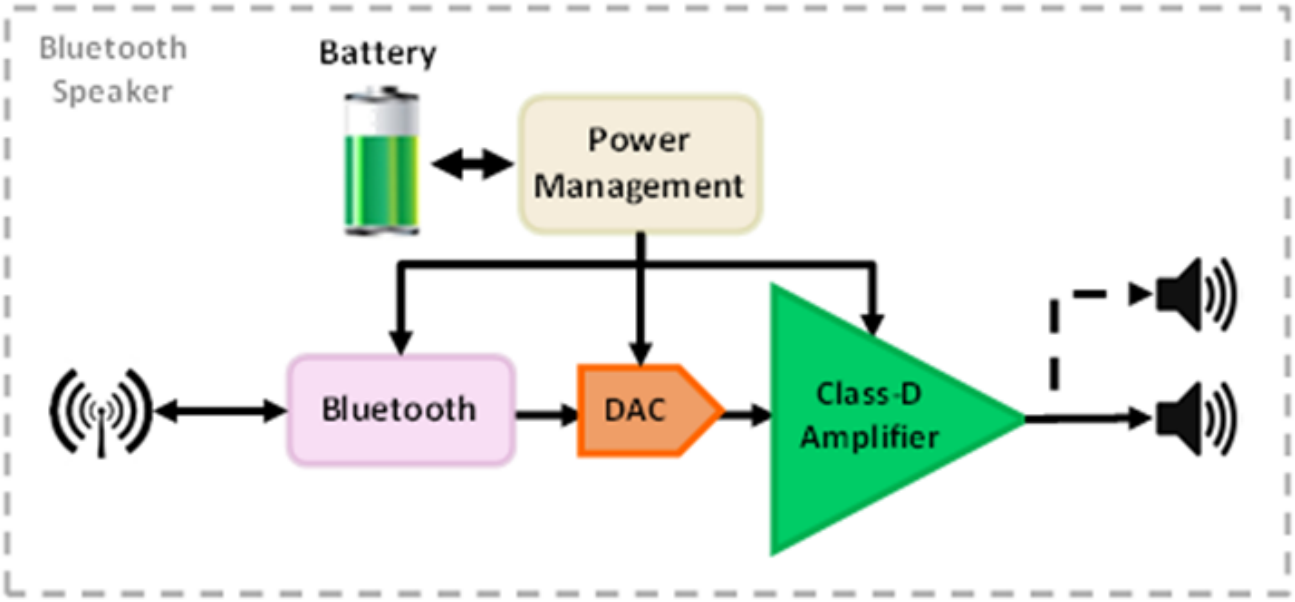

Figure 1. Bluetooth Speaker Block Diagram

Audio Amplifiers: Class-AB vs. Class-D

You have two choices when selecting the best audio amplifier for your Bluetooth speaker systems: Class-AB or Class-D.

Class-AB audio amplifiers are linear amplifiers that generate no electromagnetic interference (EMI) and do not require many external electronic components. They are highly inefficient, however, and require substantial passive or even active thermal management in the form of heat sinks and fans.

On the other hand, Class-D audio amplifiers are highly efficient switching amplifiers that need very little thermal management; but they do require output inductors that are not exempt from EMI concerns.

Play Time, Battery and Efficiency Considerations: System Design Trade-offs

A portable system poses an interesting design challenge: how to keep costs down while adopting a necessary (and potentially expensive) battery, which may comprise one or many individual cells with different battery chemistries.

As I stated, Class-AB audio amplifiers do not generate EMI and do not require many external electronic components; as such, you would think that they would be ideal for a cost-constrained system like a Bluetooth speaker.

But their very low efficiency means that, in a Bluetooth speaker, the charge from the battery backup will be mostly wasted as heat. This low efficiency comes at a very high cost, as a system that uses a Class-AB amplifier will require additional battery cells to fulfill this requirement.

Class-D amplifiers' high efficiency makes them ideal for portable audio systems; their high efficiency means that a very low-cell-count battery (even from a single battery cell if selecting the right chemistry) can power a Bluetooth speaker system. This reduces total system cost significantly, as well as weight and size.

Music and Idle-power Losses: Not Every Class-D Audio Amplifier Is Created Equal

Audio systems are marketed by power and peak-power ratings that may not reflect how audio systems are typically used as customers do not typically listen to music at very high power in a typical home-audio system, and even less so in a portable application like a Bluetooth speaker.

For Bluetooth speakers, the main specification customers must be aware of is play time, as it lists the typical use of the system.

As I made the case for Class-D amplifiers' high efficiency in Bluetooth speaker systems, you should be aware that efficiency is not the only factor when maximizing play time. Obvious additional factors include the power consumption of all of the system blocks when the system is active and shut down; other not-so-obvious considerations include idle power losses in the audio amplifier itself.

A typical music waveform, like the one shown in Figure 2, has some amplitude variability. Note the proportion of "loud" music (high amplitude) to "quiet" music (low amplitude). This waveform shows that audio systems playing typical music will remain most of the time in the "quiet" music range; hence the audio amplifier outputs low-power sound most of the time.

Figure 2. Typical Music Waveform

Previous-generation Class-D amplifier solutions like TI's popular TPA3110D2 and most of the Class-D amplifiers in the market are not efficiency-optimized for low-output power levels. As you can see in Figure 3, the supply current in last-generation Class-D amplifiers remains constant even when the output power level is low or even zero. This constant current wastes battery charge; it shortens play time and increases battery cell count and system cost.

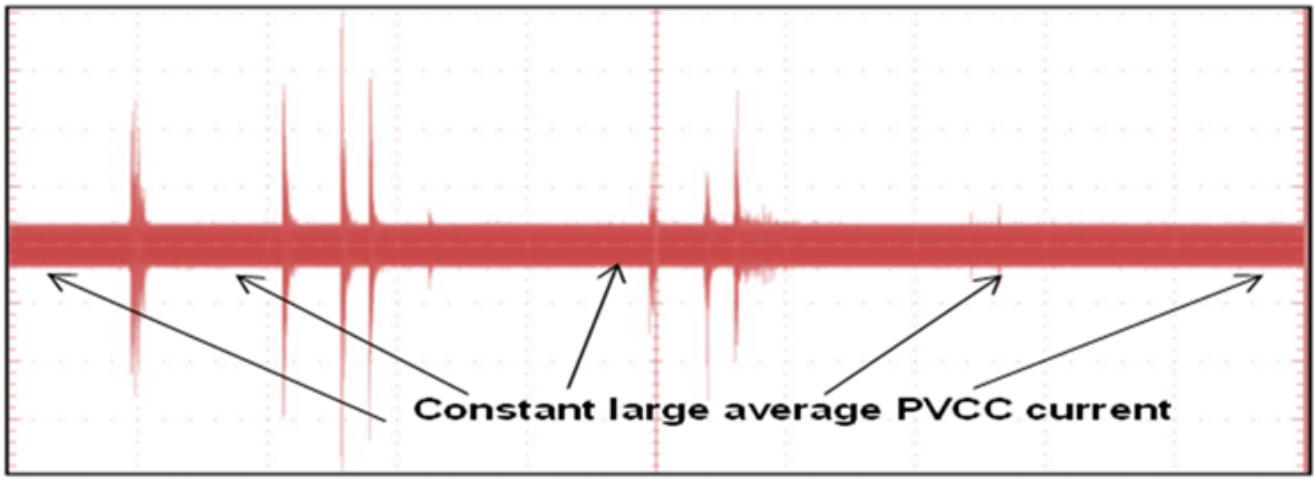

Figure 3. Last Generation Class-D Amp

Next-generation Class-D amplifiers like the TPA3128D2 use a novel hybrid modulation mode to minimize idle power losses and maximize power savings. Notice how in Figure 4, the supply current to the amplifier decreases dramatically when the output power level is low; this power savings elongates play time, thus decreasing battery cell count and system cost.

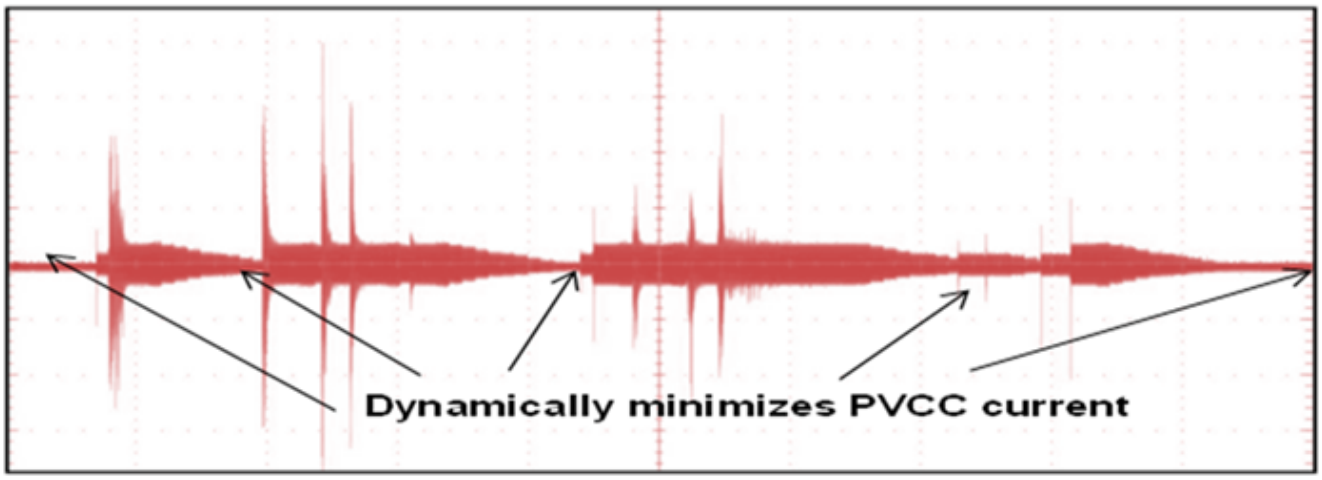

Figure 4. TPA3128D2 performance

You can easily take full advantage of this new feature and its derived cost savings by migrating from the TPA3110D2 to the TPA3128D2, as both solutions are pin-to-pin compatible for easy redesign.

Have you designed a Bluetooth speaker system? If so, what specifications were most important to you? Log in and leave a comment below.

Additional Resources

- If you're considering designing a portable speaker, purchase the TPA3128D2 evaluation module.
- Check out the TI Audio landing page for audio subsystem diagrams, device recommendations and suggested design considerations.
- Read this application note which shows tests results that prove the performance improvements by the new features of TPA3128D2
- Watch this short video where I discuss the benefits of TPA3128D2.

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