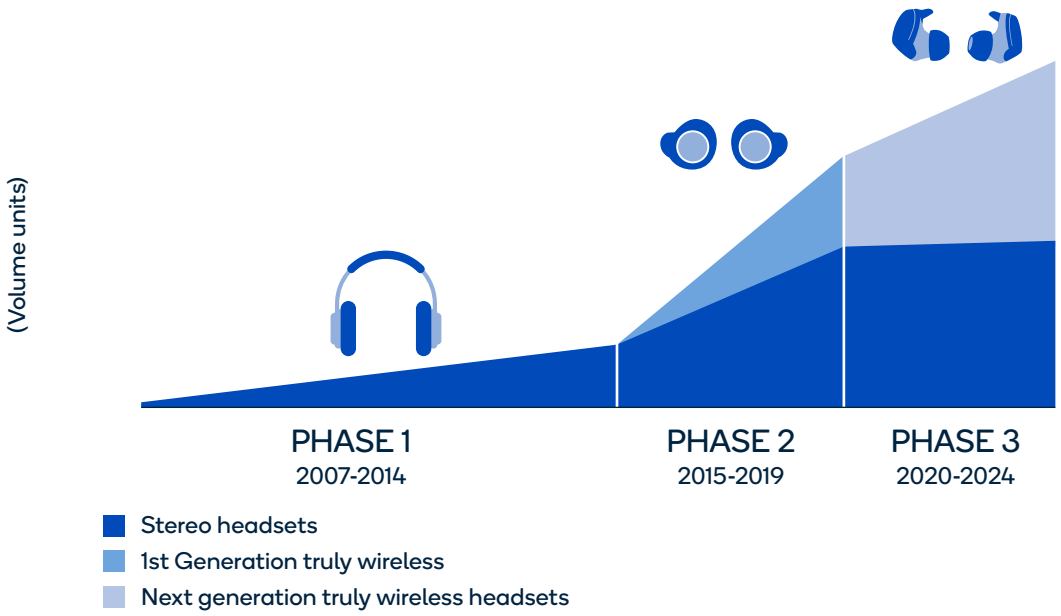
Qualcomm

The evolution of true wireless technology

Introduction: The age of total wireless freedom

Look around on your daily commute or the next time you are out for a walk or run. You will probably notice more people than ever with wireless earbuds nestled in their ears, enjoying their favorite music or listening to the latest podcast. Since the first truly wireless earbuds were launched over six years ago, there has been substantial growth in this category—with busy lifestyles driving demand for total wireless freedom, portability, and extended battery life. Since we first developed Qualcomm TrueWireless™ Stereo, we have continued to make advancements in the technology to help our customers deliver major breakthroughs in the truly wireless earbud category. Now that consumers have embraced truly wireless freedom, they are demanding much more from these devices, including all-day wear and comfort, seamless user experiences, and dependable connectivity.

Growth of truly wireless category



Wireless earbuds and headsets are connected to mobile phones using Bluetooth. Bluetooth is supported on virtually all mobile phones and is designed to work over short distances removing the need for wires. It shares the 2.4 GHz ISM band with Wi-Fi and other unlicensed radio applications and Bluetooth devices use frequency hopping across 80 channels to help minimize the effects of interference with other devices. Bluetooth is continuously being developed—and our Bluetooth Audio SoCs have been key in helping to deliver high quality audio for a wide range of mobile phone and headset combinations.

The first wave of truly wireless devices were designed for voice calls and music streaming; however, use cases have evolved since then demanding that the latest generation of earbuds deliver richer consumer experiences with features including hearing enhancement, Active Noise Cancellation, ambient leak-through of sound for situational awareness, and integrated Voice Assistants. A further development challenge for manufacturers is meeting consumer demand for ultra-small form factor earbuds that can be used for many hours at a time while balancing the need for increased processing power to meet the demands of these more sophisticated use cases. Next generation truly wireless headsets in both premium and entry/mid tiers need to support this growing range of features and applications and continue to deliver customer satisfaction with seamless wireless connections.

The truly wireless earbud challenge

In terms of consumer experience and ease of use, there are three key challenges with connecting wireless earbuds to mobile phones using standard operating systems and Bluetooth connectivity:

1. Bluetooth address management

The consumer needs to see a single pair of earbuds show up as paired or connected in their list of Bluetooth devices on their mobile phone. For a seamless user experience, this needs to be taken care of behind the scenes with no need for user intervention. Each Bluetooth device has a unique Bluetooth address, and native mobile phone operating systems are designed to use a single Bluetooth address when connecting to a third-party wireless audio device such as a headset or speaker. By appearing to have a single Bluetooth address, earbud pairs can connect to any mobile phone without using a proprietary protocol handled by an app or the operating system on the phone.

2. Ensuring robustness of the Bluetooth connection to the earbuds

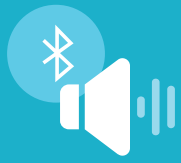
Thanks to advancements in Bluetooth technology, consumers have become accustomed to glitch-free wireless audio and have the same expectations for their truly wireless earbuds. The ISM band (Industrial, Scientific and Medical frequency band) is very congested so minimizing the bandwidth used by truly wireless headsets is important. The audio quality can be affected by interference from other devices, so it is also important to implement measures to reduce interference such as switching the connection or sharing information between earbuds.

3. Allowing all user behavior, including the use of one earbud and switching earbuds

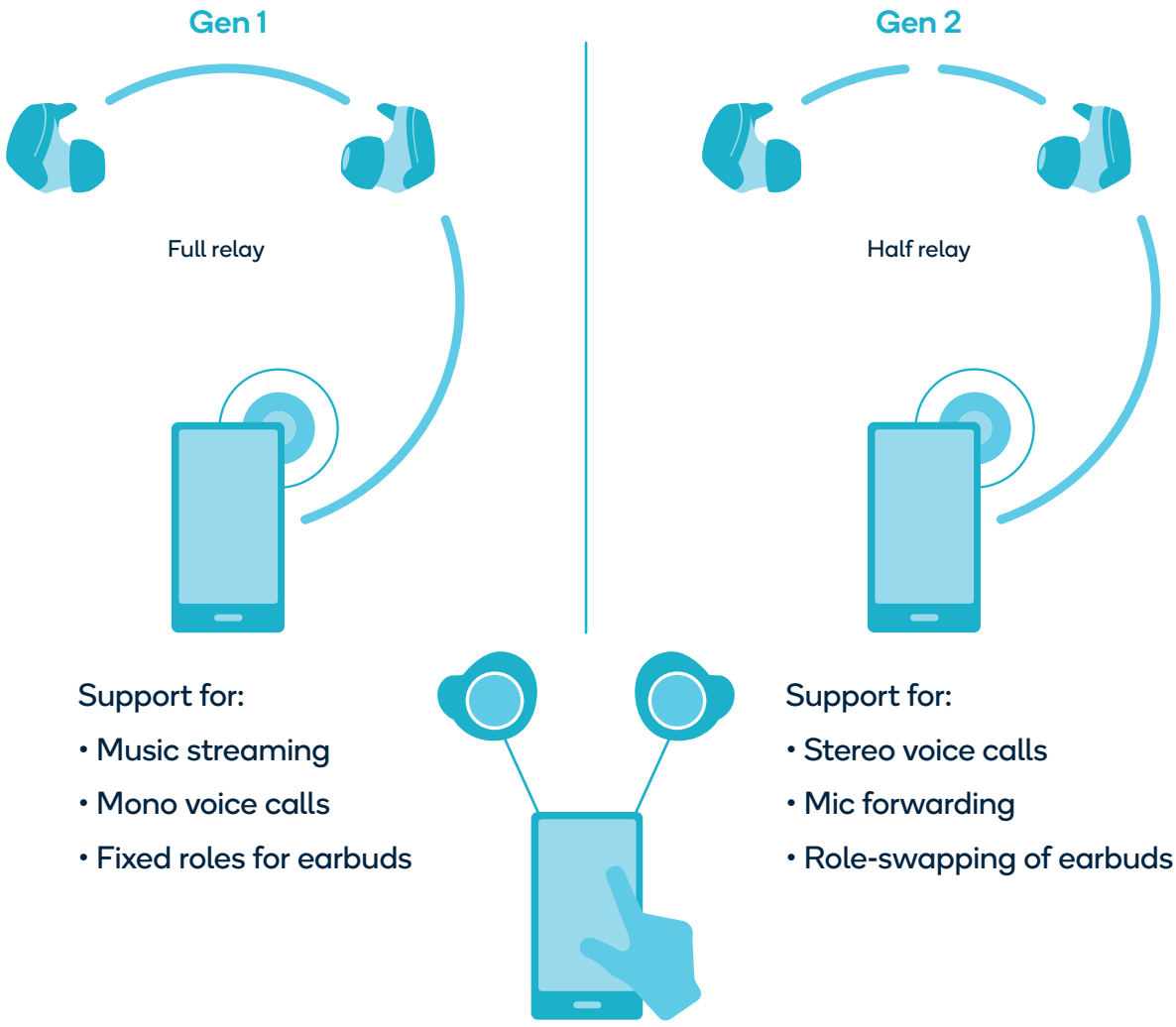
With separate wireless earbuds users can wear both or either one of the earbuds, swapping between any combination without interrupting music playback or a voice call. This includes behaviour such as removing one earbud to talk with someone nearby, then putting it down and walking away while expecting to hear audio or continue a call on the remaining earbud. Users may also want to charge one earbud and then switch to the fully charged earbud. If a user loses one earbud, then it would be preferred to buy a single replacement earbud rather than pay for a new pair.

The evolution of Qualcomm TrueWireless™ technology

Since Qualcomm TrueWireless Stereo was first developed various techniques have also been introduced to help overcome the difficulties in connecting truly wireless earbuds to mobile phones using a single Bluetooth address.

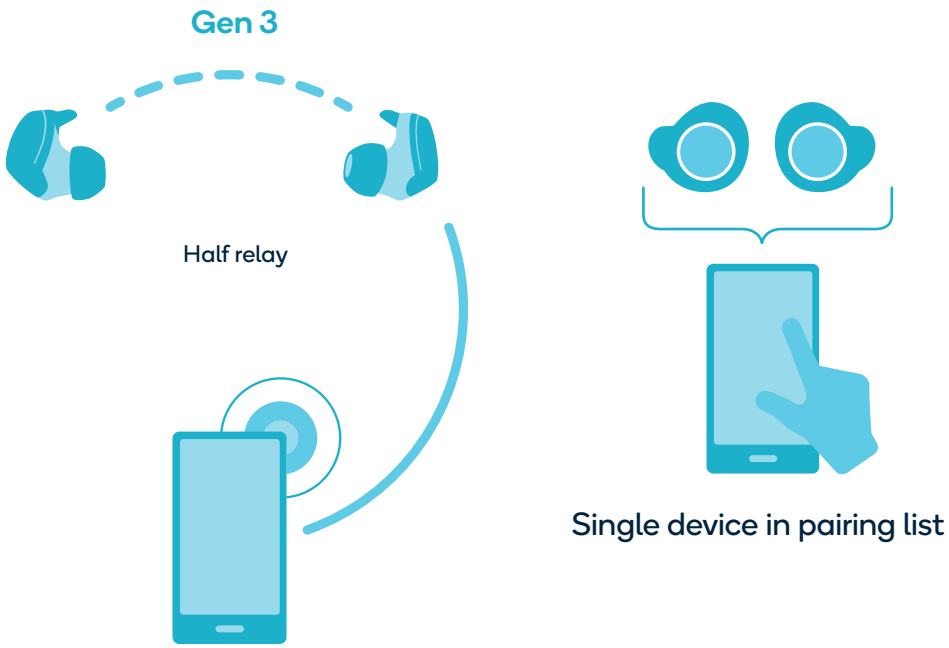


1st and 2nd Generation Qualcomm TrueWireless Stereo



The simplest solution to needing a single Bluetooth address is to designate and permanently fix primary and secondary earbuds and use relaying. In this case, the primary earbud is connected to the phone and relays the information to the secondary earbud. Only the primary earbud address is discoverable. Unfortunately, relaying uses double the Bluetooth bandwidth and requires the user to ensure that the primary earbud is being used at all times. The bandwidth required can be reduced by using a half relay solution in which only the audio data needed by the secondary earbud is relayed. Some audio codecs, such as the Qualcomm® aptX™ audio codec, can help to significantly reduce bandwidth; however, other codecs only have a limited reduction in bandwidth.

3rd Generation Qualcomm TrueWireless Stereo



Support for:

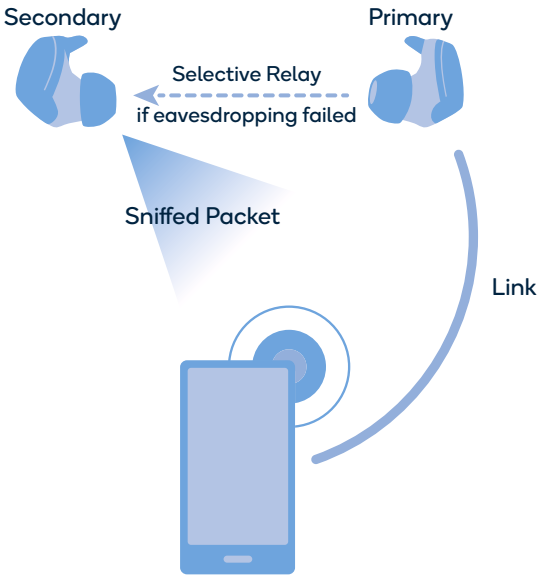
- Single Bluetooth Address Management
- Role transitioning between earbuds

A more complex approach that helps to remove the need for users to be aware of primary and secondary earbuds is to let the earbuds decide which is primary and secondary. However, in the case that a user wants to use one earbud as a mono device, whichever bud the user takes from the charging case first becomes the primary and there is no way for the earbuds to switch roles. This solution also still requires relaying between the earbuds and, therefore, requires more Bluetooth bandwidth than a conventional wireless headset. There may also be issues when the earbuds are used individually or when there is interference from other devices.

Qualcomm TrueWireless™ Mirroring

Qualcomm TrueWireless™ Mirroring builds on earlier relay techniques—it is designed to improve connection resilience, remove some of the limitations, and increase user convenience. This approach uses dynamic primary / secondary role swap with three additional techniques: eavesdropping, synchronization, and selective data relay designed to deliver a seamless user experience.

Qualcomm TrueWireless™ Mirroring Control/Retransmission



Combines:

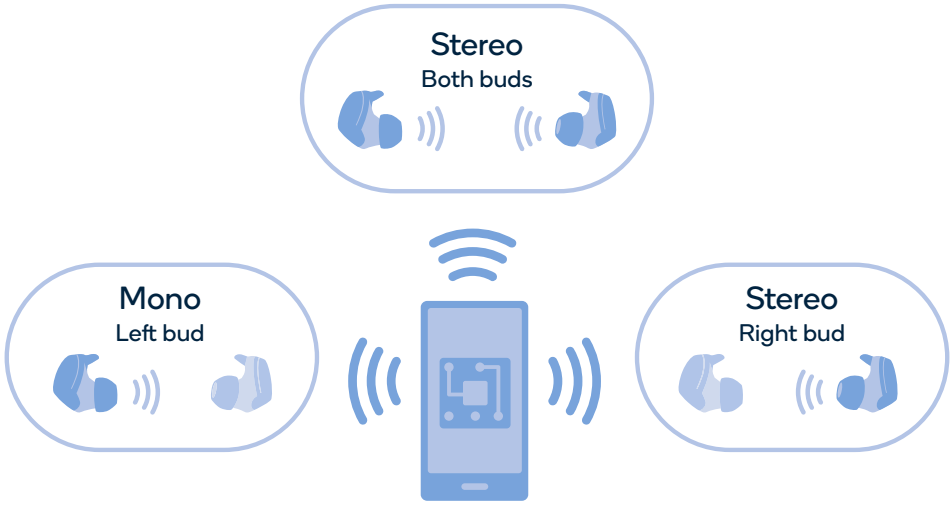
- Eavesdropping by secondary earbud
- Selective data relay to secondary if eavesdropping did not work
- Synchronization between left & right earbuds
- Dynamic role swap of earbuds for enhanced robustness

When the current primary earbud connects to the phone, the secondary earbud is aware of the connection and starts listening in, or eavesdropping, on the messages being sent. Synchronization between the earbuds allows the secondary earbud to follow Bluetooth link updates, including channel maps and encryption changes. This supports synchronization of the audio content, including voice prompts. By eavesdropping, the secondary earbud will receive most packets, however there is no guarantee against packet loss. To help the secondary bud receive all the packets, the primary bud can selectively relay any lost data. The selective relay technique combines two approaches. When link conditions are good, a 'sniffing' approach is utilized; however, when conditions are bad—for example, when a phone is placed in a pocket by the user and the connection between the phone and earbuds is less stable—a relay approach is used to resend any lost packets.

Another factor that helps improve the robustness and resilience of the Bluetooth connection—and helps to deliver glitch-free audio—is the use of the Qualcomm® aptX™ Adaptive audio codec, which has a variable bit-rate that is designed to dynamically scale based on the quality of the Bluetooth link. The aptX Adaptive audio codec also allows left and right audio channels to be separated before decoding. This means that each earbud only needs to decode the stereo channel that it is rendering which reduces DSP activity and helps to lower power consumption.

Qualcomm TrueWireless™ Mirroring is also designed to allow the user to choose any earbud combination and transition between them dynamically with virtually no interruption to the audio—and without any need for button presses or reconfiguration through a phone app. Importantly, this seamless, interruption-free experience is designed to be delivered regardless of whether the consumer is listening to an audio track or in the middle of a phone call. When both earbuds are worn the user hears stereo audio. If just the left or right earbud is worn the user hears mono through that earbud.

Choose any earbud combination and switch between them dynamically with no interruption to the audio



The power used by the primary and secondary earbuds is similar, so it does not matter if one earbud—perhaps the one nearest to the phone—is predominantly the primary earbud. The earbuds will seamlessly swap roles if the primary earbud is taken out of the ear, the primary earbud battery is critically low, or the primary earbud is put in the charging case. The earbuds may also swap roles if the Bluetooth link or MIC quality is significantly better for the secondary than the primary. The solution supports up to 9 hours of play time from a 45mAhr battery. If the battery in one of the earbuds becomes critically low, the user is notified via an audio message and if necessary, roles switch so that the earbud with most charge becomes primary and can continue to be used.

Conclusion

Truly wireless earbuds are taking on an ever-increasing presence in the headset category as consumers take advantage of the convenience, enhanced feature sets, and improved audio quality. Wireless earbuds have certain benefits when used for rapidly growing applications, including fitness, hearing enhancement, voice assistants, and Active Noise Cancellation. The market for truly wireless earbuds has grown beyond the premium segment and now covers entry/mid-tier segments as well.

To provide a device that is designed to deliver a seamless user experience, the issue is overcoming the three challenges in connecting any wireless earbud to any mobile phone using Bluetooth connectivity—and supporting continuous high-quality audio. Any solution for next generation truly wireless headsets should use a single Bluetooth address to avoid the need for a proprietary protocol between the headset and mobile phone, help to minimize Bluetooth bandwidth usage and interference from other devices in the ISM band, and support virtually all likely user behaviour.

Qualcomm TrueWireless™ Mirroring is designed to allow users to choose any earbud combination and switch between them dynamically without interruption in high quality audio. Bluetooth bandwidth usage is minimized by limiting the relay of information between earbuds, and the quality of audio is designed to be maintained even when there is interference from other devices. By using a combination of primary/secondary role swapping, eavesdropping, synchronization, and selective data relay, Qualcomm TrueWireless Mirroring is designed to deliver a quality user experience that is expected of next generation truly wireless headsets.

Qualcomm TrueWireless Mirroring technology is available on the latest generation of Qualcomm Bluetooth audio SoCs—the entry-level flash programmable Qualcomm QCC304x and premium tier Qualcomm QCC514x, which are designed to elevate the truly wireless consumer experience by supporting more robust and superior connectivity, prolonged use, integrated active noise cancellation (ANC), both voice and button activated voice assistant support, and premium wireless audio quality.

Qualcomm creates intelligent communications systems, supporting innovation that looks to deliver significant value to the audio industry and consumers worldwide. We invent foundational technologies that transform how the world connects, computes, and communicates.

Qualcomm

Follow us on:

For more information, visit us at:

www.qualcomm.com