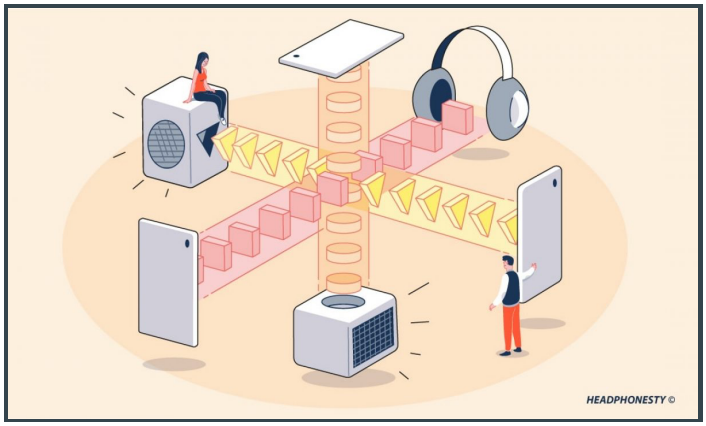
LEARN FUNDAMENTALS

Bluetooth Audio Codecs Explained

By Alan Gleeson Updated on June 2, 2022



Understanding Bluetooth audio codecs is one of the key milestones in the pursuit of excellent wireless audio quality.

Whether you are looking at wireless headphones for workouts, gaming, TV watching, or even to protect your ears from the noise, you

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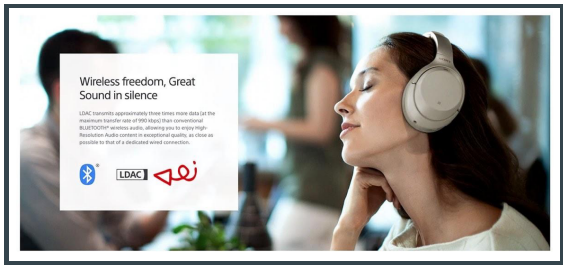
must not overlook this important feature: **Bluetooth audio codec**.



The Sony WH1000XM3 has support for the “LDAC” audio codec.

> There are annoying companies (I’m looking at you, Bose) who choose not to display the supported audio codec.

In this article, we will attempt to break down the mystery and jargons of Bluetooth audio codecs in a beginner-friendly way.

We will also discuss:

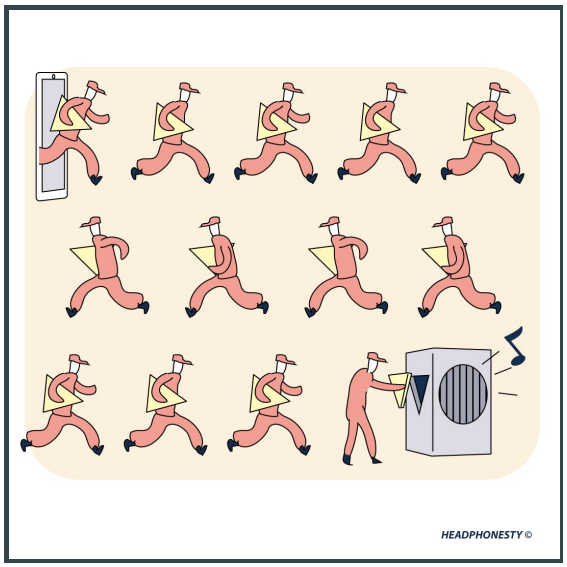
- How does wireless audio transmission work

- How does the Bluetooth audio codec affect audio quality and latency
- The different types of codecs and their characteristics
- And more!

Let’s dive right in.

Use these quick links to navigate around the article.

The Journey of Wireless Audio Transmission



Types of wireless connection

Even before discussing the journey of wireless audio, we have to first talk about the

type of wireless connection. Imagine you want to get from point A to point B, selecting the type of connection is similar to picking the type of transport (car, train, etc.) you want to complete your journey.

In general, there are three types of wireless connection for headphones:

- **Infrared** (IR)
- **Radio Frequency** (RF)
- **Bluetooth** (BT)

Since we are on the topic of Bluetooth audio codec, we will focus on the BT connection. But in general, the underlying mechanism is the same.

> **RELATED:** RF vs IF vs BT Headphones

The Bluetooth

was originally called “short-link” radio technology.

The journey begins

You first have **a Bluetooth audio transmitter** which is the audio source. In this case, it can be your phone. Next, you need a **BT audio receiver**, which can be your headphone or speaker.

The transmitter’s job is not as simple as sending over the music file to the receiver. Depending on the quality of the recorded audio, it affects the audio’s file size. Higher quality recording equates to larger file size. The file size directly affects the bandwidth needed to transmit the audio over to the receiver.

Think of **bandwidth** as the width of the **traffic highway** and the **file size** as the **traffic flow**.

If the traffic flow exceeds what the highway allows, traffic jams occur and the journey becomes slow and unstable.

> **RELATED:** How to Reset Your Bluetooth Headphones

A Bluetooth connection has a maximum bandwidth that it can accommodate. Lossless file formats like **WAV** and **AIFF** are huge in file size. If we were to plainly send these raw files wirelessly, the bandwidth will be eaten up, exceeding what the Bluetooth connection can handle. The audio connection will start to stutter, affecting the overall audio connection quality.

This is where processes like **encoding** and **decoding** come in handy.

Encoding and Decoding

To reduce the size of the audio file, the BT transmitter encodes the original file with a special sauce (I believe scientists call them algorithms) into a compressed form. The compressed form itself is not a viable audio file. This is then sent over to the receiver.

The BT receiver will decode the compressed form into an audio file which then becomes playable.

Enter the codec

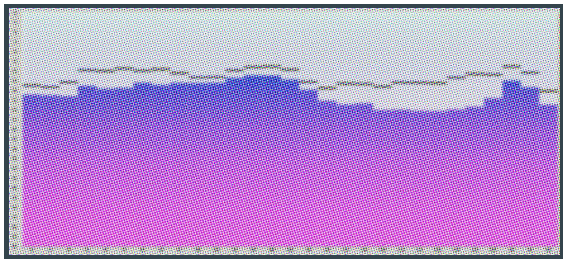
Codecs are not that mysterious
(From videomaker.com)

So what is the special sauce that we mentioned above?

It is actually, surprise, the **audio codec**.

A codec is a piece of software, or algorithm, that takes your data (music), compresses it to reduce file size and encodes it in a format for transmission. The same codec is also required to decode the encoded data so that we can listen to our music.

The BT receiver must support the same audio codec as the BT transmitter. For example, the LDAC codec will only be used if both the transmitter and receiver support LDAC.



Compression, a potential loss of resolution and quality

Once a file has been compressed, it is not possible to restore it to its original quality.

Reducing file size while maintaining the fidelity of

the audio data is no simple task. Through psychoacoustic research and analysis, the codec disregard masked information in the music, information that can be removed without a noticeable loss in quality.

> **RELATED:** How Do We Hear? The Human Hearing Mechanism Explained

Each Bluetooth audio codec has its own unique compression algorithm and also speed of transmitting the data. This affects the quality of wireless audio in terms of latency and fidelity.

The common codecs that you will come across are the following;

- **SBC**
- **AAC**
- **aptX**

- **aptX HD**
- **aptX LL**
- **LDAC**
- **LC3**
- **Samsung Scalable Codec**

Before we dive into codec and their characteristics, we need to recognize and understand some basic audio terminology.

Bluetooth headset for mobile phone (From Wikipedia)

Basic Audio Terminology

When reading articles and specifications about Bluetooth codecs, there are some terms that will come

up again and again. Let's discuss these first.

If you have some basic knowledge of digital audio, you may have come across these before.

> **RELATED:** **Understanding Sample Rate, Bit Depth, and Bit Rate**

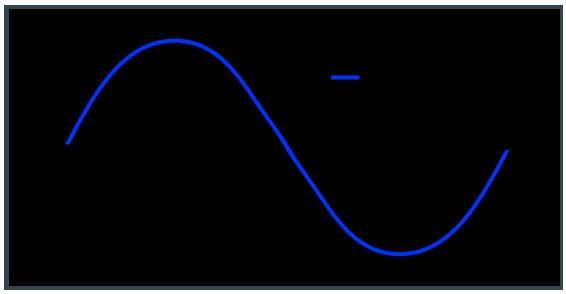
1. Sample Rate
2. Bit Depth
3. Bitrate
4. HD Audio

Sample Rate

An audio signal is stored using pulse code modulation (PCM). In order to capture, store, and reproduce a signal accurately, snapshots, or samples of the incoming signal are taken at a specific rate, a sampling rate,

measured in Hertz (Hz).

In order to reproduce the full spectrum of a musical signal, a sampling rate of 44,100Hz, or 44.1kHz, is the minimum that is used. That's 44,100 samples per second.



Sample Rates (From masteringthemix.com)

You will also see higher sample rates used for music, 48kHz, 96kHz, and even 192kHz. There are many arguments for using higher sample rates than 44.1kHz.

For most consumers, 44.1kHz is more than acceptable. It is the most commonly used rate for music. Using this sample rate allows accurate

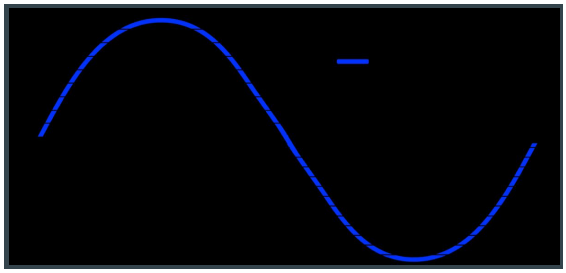
reproduction of frequencies up to 22050Hz, just above the limit of human hearing.

Lower rates can be used when critical listening is not required, such as with speech.

Bit Depth

For music, the bit depths you will come across are 16bit and 24bit. While the sample rate is concerned with capturing frequency accurately, bit depth is related to dynamic range.

Dynamic range is the distance between the quietest and loudest sounds in a piece of music, and the quality of the resolution within this range.



16bit versus 24Bit (From masteringthemix.com)

For many years 16bit was the standard, the depth used on CDs. While 16bit is still very common, 24bit is now becoming more widely used for Hi-Res (HD) audio. Consumers can now purchase music in lossless formats that support higher sample rates and bit depths.

Bitrate

Bitrate is the measure of the rate at which data is transferred from one point to another. It is measured in bits per second (bps), kilobits per second (kbps), or megabits per second (Mbps).

We also use bitrate to describe the fidelity of audio files. An MP3 file that was compressed at 320kbps, will have a much better

dynamic range and sound quality to one compressed at 128kbps.

With higher bitrate, audio files with higher bit depth and sample rate can be sent wirelessly, thus increasing the quality of the audio. However, this means an increase in bandwidth used for transmission.

> **Bitrate formula** = **Sample rate** x **Bit-depth** x **No. of Channels**

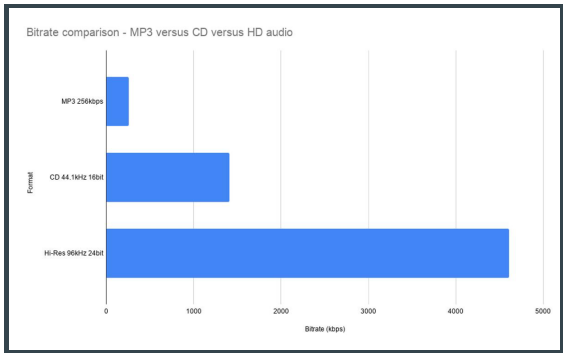


Chart comparing the bitrate of different formats: MP3, CD, and HD audio.

Codecs have the ability to alter the rate at which the data is being sent, directly affecting quality.

HD Audio

As internet speeds have increased and technology has developed, lossless formats have become more popular as a means to distribute and purchase music. Music streaming platforms like Qobuz and Tidal are already using lossless files.

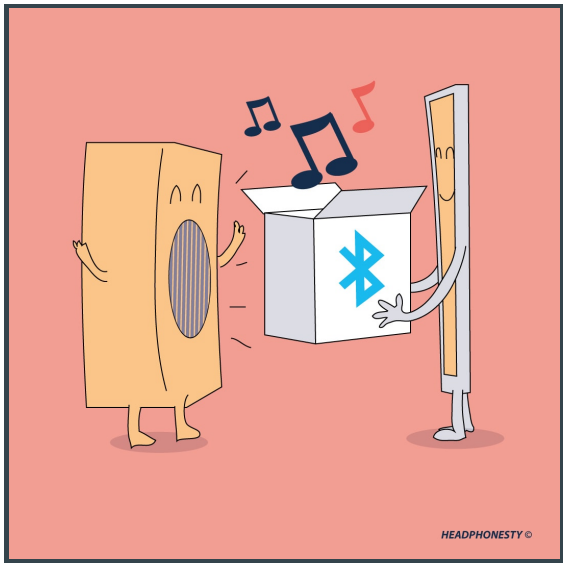
Digital HD formats such as **FLAC**, **ALAC**, **WAV**, and **AIFF**, are the choice of audiophiles and music collectors who are moving away from the physical medium.

If HD audio is something that is paramount for you, you will need to choose

equipment that implements codec(s) that can deliver the result you need.

Which codec you use will inevitably be linked to the equipment you have. But if you are entering the world of Bluetooth audio, or upgrading, knowing the qualities of the different codecs is important.

Other than Codecs, What Affects the Quality of Bluetooth Audio?



Other the codecs itself, there are other factors that can directly affect the quality of the Bluetooth Audio:

- **Distance between the transmitter and receiver:** The further the two devices are away from each other, the less stable the connection will be. This decreases the speed of transmission, thus resulting in stuttering audio. Keep the distance as close as possible.
- **The number of**

blockages between the transmitter and receiver: Bluetooth can travel through the walls. But take note that once the signal pass through walls, the signal strength is attenuated and the range decreases. It doesn't need to have line-of-sight between two devices but as least keep them within the same room. Having a lot of blockages may result in the issue where Bluetooth headphones are connected but has no sound.

- **Electrical interference by other devices:** As Bluetooth signals are electromagnetic waves, they can be affected by other interfering electromagnetic wave-emitting devices such

as radio, mobile phones, etc.

- **Bluetooth versions:** Even though Bluetooth has now been the standard for wireless connectivity, it is still far from perfect. That's why, Bluetooth's manufacturers are still continuously upgrading its features and fixing bugs. Having a lower Bluetooth version may result in different audio problems that may have already been solved in latter versions.

Types of Bluetooth Codecs

SBC

- Low demand for computing power
- Low power

consumption

Supports bit rates up to 345kbps (realistically 256kbps)

- Universal compatibility

SBC or “Low Complexity Subband Coding” is the first Bluetooth codec introduced to transfer audio. It is integrated into the Advanced Audio Distribution Profile (A2DP) – a set of default Bluetooth specifications for streaming audio over Bluetooth.

As such, **every Bluetooth device you have** will be compatible with this codec, and they will communicate with each other without any issues.

If there are any

codec mismatches, your device will default to using the SBC codec.

Unlike nearly all the other codecs discussed here, SBC is public domain, so equipment manufacturers can use it for free.

SBC has a bad reputation among the Bluetooth audio codecs for its high lossy compression algorithm and hence, overall lower audio quality. But in fact, SBC is a pretty flexible codec. It is able to support up to the 48 kHz sampling rate at 16-bit bit depth. It is also able to transmit data at rates as high as 345kbps.

However, manufacturers don’t always take full

advantage of SBC's features or bandwidth, for reasons of improved device performance. A more realistic bitrate will be 256kbps which is roughly equal to the quality of MP3 recording.

You will run into latency issues when using this codec for gaming and watching streams. This issue is not exclusive to this codec.

If you're not concerned about HD audio, and using lossless files, SBC will be totally fine. It's efficient at what it does, so it will go easy on your battery.

In noisy situations such as the gym or public transport or when you are only using lower-quality ear-buds, you won't notice the difference between this and the codecs discussed below.

AAC

- Better lossy compression algorithm than SBC
- Support 44.1kHz/24-bit audio files
- Supports bit rates up to 320kbps
- Android support (8+)
- Better implementation on iOS devices
- Power-hungry

Advanced Audio Coding (**AAC)** is a complex codec when compared with SBC, it uses more computing power and causes higher power consumption.

When it applies lossy compression, it can produce better results than SBC.

It is the successor to MP3 and

provides improved audio quality results when using similar compression settings (kbps). This improvement comes at a cost, more power consumption.

AAC is not in the public domain, so manufacturers have to pay the patent holders to implement it in their technology. There is a one-time payment fee of $15,000 ($1000 if the company has less than 15 employees) and $0.98 for the first 500,000 devices.

Although it is the default codec on iOS devices, it is not owned by Apple. How each manufacturer implements it makes a big difference. Its implementation and audio quality are generally much better on iOS than Android devices.

Some of its specs may look similar or less than SBC, but it is a more advanced codec, and you hear the benefit of that.

aptX

The Sennheiser 4.4 BT lists “aptX” as its supported Bluetooth audio codec.

- Better lossy compression algorithm than SBC

- Support 48kHz/16-bit audio files
- Supports bit rates up to 384kbps
- Supported in Android 4.4+
- No iOS support

The **aptX** family of codecs is owned by Qualcomm. aptX was introduced as an alternative to SBC, and address complaints about SBC's implementation and sound quality.

It uses a different type of data compression to SBC and AAC – Adaptive Differential Pulse Code Modulation (ADPCM). Rather than using psychoacoustic analysis and masking to dump what's deemed to be unnecessary, it codes the file in a different way to reduce the data bandwidth.

Also not public domain,

Qualcomm charges manufacturers to implement it. They also provides a record of all devices that implement its codecs. Manufacturers who wants to use aptX codec have to pay a one-time payment fee of $6000 and ~$1 per device.

aptX HD

- Improved aptX encoding profile
- Support 48kHz/24-bit audio files
- Supports bit rates up to 576kbps
- Supported in Android 8+
- No iOS support

aptX HD is not a standalone audio codec but instead, it is an improved aptX encoding profile. It supports higher bit depths and bit rates. The result of this is heard as

better sound reproduction and less noise (more dynamic range).

With these improvements, it offers HD audio that can approach the quality of the original file (if it's HD)

Despite these improvements, it is not as widely adopted by manufacturers as the standard aptX.

aptX LL

- Low latency (~ 32ms)
- Supports bit rates up to 352kbps
- Support 44.1kHz/16-bit

audio files

- No smartphones support

Just like the aptX HD, the **aptX LL** is not a standalone codec. The LL stands for **low latency**.

This codec solves the latency issue, or at least vastly improves it compared to the other codecs.

Latency, is the delay introduced due to the processing of the audio. It's the delay between the data being encoded, transmitted, and received, and will cause an obvious delay in gameplay, and dialogue sync in films and TV.

Other than the **aptX LL** codec, latency is a common issue with other codecs. For just pure music listening, the latency is not much of an issue. But for gaming or

watching films, the latency becomes significantly obvious because you can visually see the non-sync problem.

If you want to use your wireless headphones for gaming or watching films, it should be a requirement that they support this aptX-LL codec.

However, make sure your audio source supports the same audio codec. Otherwise, they will default back to the common codec that they share (most probably SBC). Currently, there are no mobile phones

that support aptX LL. There is better support on Windows desktop.

LDAC

- Support 96kHz/24-bit audio files
- Supports bit rates up to 990kbps
- Android support (8+)
- Limited headphone options

The LDAC codec is developed by Sony. It offers the potential to offer near-lossless audio quality.

Both your transmitting and receiving device need to be able to firstly support the codec, but then they also need to be able to deal with the large data bandwidth being sent and received.

Signal strength always plays an important part when you

are using the LDAC codec. As this codec uses more data, any interference with the signal will reduce the bandwidth, consequently resulting in a drop of the signal quality. The benefits of LDAC's HD capabilities will then be lost.

Probably due to licensing issues, wireless headphones that support LDAC codec are only Sony headphones.

LC3

LC3, or LE (low energy) Audio, also known as Low Complexity Communications Codec, is the new default Bluetooth codec, introduced at the CES 2020 trade show.

As it has just been introduced, the full spec is not available yet. It claims to be the "next generation of Bluetooth audio", building

on innovations from the last 20 years.

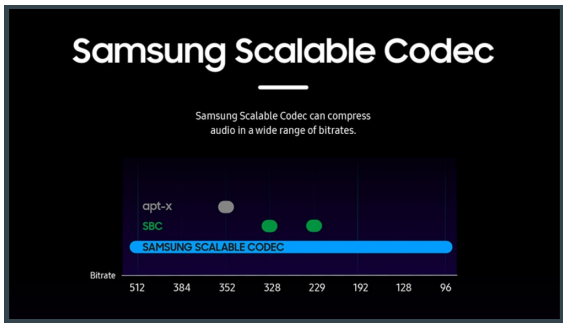
The information that has been shared claims that vast improvements have been made in the areas of;

- Audio Quality
- Latency
- Power consumption
- Audio Sharing (new feature)

If all this is true, it will be a game-changer for the user. With the Bluetooth headphone market continuing to expand, these new features might end the need for wired headphones.

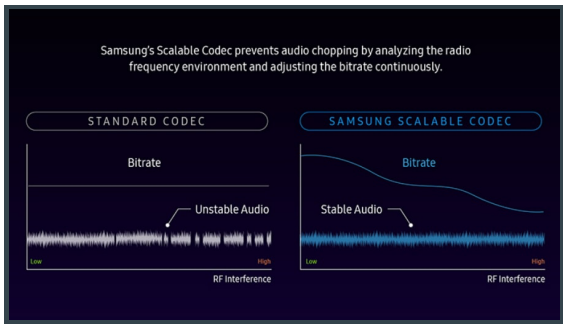
All the codecs discussed here are still relevant as it will take some time to implement and roll-out new tech that supports the LC3 codec.

Samsung Scalable Codec



Samsung Scalable Codec

This codec is a proprietary codec developed by Samsung for its Galaxy Buds – a True Wireless earbud. As expected, only Samsung devices support this codec.



Samsung Scalable Codec

The unique thing abt the Samsung Scalable Codec is its ability to support a wide range of bitrate. It can adaptively switch bitrate, depending on the stability of the Bluetooth connection, to

maintain stable connection and reduce choppy audio.

As the strength of the Bluetooth connection weakens, the audio codec will intelligently increase the compression ratio while lowering the bitrate. This might lower the overall audio quality but at least the connection does not get cut off.

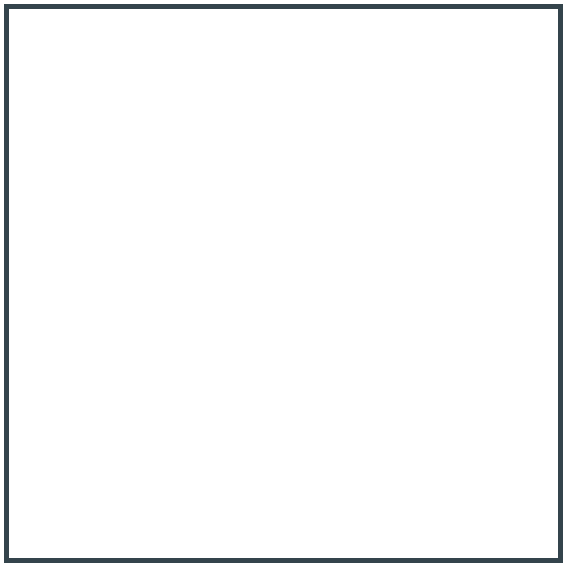
Comparison of the Codecs

Here's a table to let you easily compare the different characteristics of the codecs mentioned in this article.

Codec	Max Bitrate	Bit Depth	Max Frequency	Introduced
SBC	320 kbps	16 bit	48.0 kHz	2003
AAC	264 kbps	16 bit	44.1 kHz	2015

aptX	352 kbps	16 bit	48.0 kHz	2009
aptX HD	576 kbps	24 bit	48.0 kHz	2016
aptX LL	352 kbps	16 bit	44.1 kHz	2016
LDAC	990 kbps	24 bit	96.0 kHz	2015
LC3	N/A	N/A	N/A	2020

Conclusion



Based on my technical knowledge and additional research carried out for this article it has to be said that there is conflicting online

information on this topic.

Some of this is the result of the amount of information, or lack of, that manufacturers give out regarding how they implement the codecs they use.

The other is the ability to test what the manufacturers and codecs claim to do. With the multitude of configurations between transmitters and receivers available, it's hard to reach a consensus.

Some codecs offer advantages over others, this relates to;

- Bandwidth – directly impacts the audio quality
- Sample rate/bit depth support – lossy, lossless, HD audio
- Listening habits – headphone type,

latency, environment

- Headphone type/style versus audiophile requirements
- Audio source – the audio quality of your source, and the device you use (PC, Mac, Gaming consoles like Xbox One, Nintendo Switch, etc)

So codecs matter. They are something you should inform yourself about in order to get the performance, and listening experience you are after.

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APTX HD APTX LL

BLUETOOTH LC3

LDAC SBC WIRELESS

22 COMMENTS

Robert Jones

July 7, 2020 at 3:33 pm

Great informative article, thanks

Reply

David Crandon

September 5, 2020 at 8:17 pm

To make sure I understand…all the earbuds I've used in the past are Bluetooth enabled and support AptX. And my phone, usually the latest Google Pixel, supports all the codecs. The next earbuds I buy may support LDAC, and the Pixel I buy will also. But…it doesn't matter what music streaming service I use, correct? For example, going forward I'll probably be using Amazon Music HD, but that has no bearing on compatibility with the codec I use (AptX or LDAC), correct? Thank you.

Reply

Chief Editor

September 7, 2020 at 8:09

am

You are correct. The music streaming service will not affect what Bluetooth Codec you stream from your device to your headphones.
Reply

Jim
September 16, 2020 at 8:33 pm

When i use Cisco Webex or MS Teams from my Windows work laptop with bluetooth connected to Samsung Buds+ the quality of audio is really, really poor.

But when i play a YouTube video on my Windows work laptop with bluetooth connected to Samsung Buds+ the quality of audio is perfectly fine.

Also, when i use Cisco Webex from my Windows work laptop but get the WebEx to call my iPhone or Huawei mobile, which are bluetooth connected to Samsung Buds+ the quality of audio is again perfectly fine.

Can you join up the dots??
Reply

Deyr
September 17, 2020
at 1:47 pm

Really a great informatory article. Thank you.
Reply

Deyr
September 17, 2020
at 1:53 pm

Really a great article. I was looking for this collective informations. Could you pl. add more information about the Bluetooth headset handshake. Who determines which audio Codec to use?
Thank you.
Reply

Mrvoje
June 30, 2021
at 11:00 am

Its a problem exclusive to using Bluetooth devices within work environment.

BT is natively and inly has two chanells. So

the device has two pick, stereo sound or mono sound and microphone transmition. When you start the call on teams one chanell is lost due to this, leaving you with half bandwith single chanell sound for its duration. Once your call is done your win/mac should by default swap over to stereo, and sound quality will improve again.
Reply

Pranav Kumar Tallam
September 29, 2020 at 10:53 pm

Amazing article . Learnt a lot thanks for sharing this.
Reply

Amith
October 16, 2020 at 1:38 pm

Well written and informative. Thank you.

I’m a beginner and do not have much know how. I have a query and hope to get some information with your experience. I’m looking to connect upto 4 wireless headphones simultaneously (such as Sony XM4, Bose 700, Sannheiser Rs 175 or Sannheiser Rs 195) to my Sony A8G T.V for movies/Netflix etc without any lag in audio. Is this possible?

From my research online, i found
(1) Sannheiser Rs175/195 comes with the transmitter. However, can i connect 4 of these or combine different brand wireless headphones together to the Sony A8G T.V without any lag?

(2) I found Avantree Orbit or Avantree Oasis plus bluetooth transmitter that could connect 2 wireless headphones at a time. So can i connect two Avantree Orbit to the Sony A8G TV inorder to have the 4 wireless headphones working simultaneously without any audio lag?

Would this work and if not, is there any other/better

option I must consider?

I look forward to your response. Thank you.
Reply

Christopher Gunia

October 24, 2020 at 8:40 pm

Good article. This biggest issue I see is that the for an Android phone, the transmitter and receiver choose the codec automatically based on the highest possible data rate. However, that might be overkill in some situations and might cause occasional dropout where a lower rated codec might be more appropriate. On Huawei phones there is a new HD codec HWA, but it's tricky to disable on the phone without going into developer settings, and will reset itself when reconnecting.
Reply

Josef

November 2, 2020 at 9:45 am

Good article, but incomplete without the comparison table also showing the latency of the individual codecs.
In particular – comparing the aptXLL with the Sony LDAC.
Reply

David
April 6, 2021 at 1:59 am

Very informative article, thank you! However, there is something I haven´t found out yet. How do I know what codecs a desktop system with a USB Bluetooth adapter supports? I have researched and there is practically no information about this. Is it hardware or software dependent?
Reply

daveclark966
July 12, 2021 at 7:12 am

To get your AAC file changed with your wanted bitrate, a professional AAC bitrate converter – Avdshare Audio Converter

comes to help.
Reply

Anik Pramanik
May 3, 2022 at 6:23 pm

I really wanted to know more about samsung scalable codec. But you did not provide the bitrate, sampling rate and other technical info. Please update this if I wish for. Thanks.
Reply

IVAR
July 12, 2022 at 3:12 pm

Loved the detailed mentions of all kinds of codecs.
Reply

JM
October 27, 2022 at 8:38 pm

Nothing about how to use those CODECs on anything but a phone. I own an

LDAC supported headphone set (Sony WH-1000XM3), but I can't find a way to play LDAC to it. Not with my Samsung A71 5G UW phone (recent Android), and zero USB bluetooth adapters mention supporting LDAC.

And I can't find any details about what is needed to support the feature anywhere. I assume the transmitting chip needs to support it. But even a search for bluetooth LDAC chipsets turns up nothing.
Reply

David
November 6, 2022 at 3:17 am

Great job of breaking down that mess of a mystery i had been confused about since i first heard the word codec. Until now I thought it was some crazy magic. Thx well worth the read !!!
Reply

Chief Editor
November 10, 2022 at 4:54

pm

Thanks David! Glad you found it useful.
Reply

Rinku
November 22, 2022 at 2:37 am

Great article....

Thanks for this detailed explanation...
Reply

Miguel Silva
December 26, 2022 at 10:06 am

What puzzles me is the fact that in 2022 all Bluetooth headsets still have low audio bandwidth on microphone audio channel.
At least all Bluetooth I've tested have near CD quality audio when just listening to music but when you use a conferencing software the sound from microphone is like an old phone call limited to 8khz or similar... after more than 2 years of COVID and everybody started to use

computers for meeting that also send video in both ways at high bitrates, why are we still limiting audio quality on bluetooth headsets..
PS: maybe there are already some Bluetooth headsets that don't have this limitation (so many Bluetooth versions with increasing data bandwidth) but I don't know nor have listened to any that can do 44.1Khz 16bit both ways, maybe it's not standard and windows/Mac/Linux/Android don't support it?
Reply

Joe
January 7, 2023 at 4:44 pm

Creative. They made a codec called faststream that does just this and is SBC based I think. No one adopted it, and only their stuff used it. They dropped it themselves recently.

They likely have a patent on it.
Reply

Dixyy

April 27, 2023 at 1:04 am

Problem is that android inn audio configuration policy xml file, ofthen restrict to 16 bits so no mather you have better sound card is just going to bt up to 48K/16bits. I saw only few brands that configure correct android files. Huawei for example but not all his products

Reply

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