



Computer Audio Demystified 2.0

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What is Computer Audio?

From iTunes®, streaming music and podcasts to watching YouTube videos, TV shows or movies, today's computers are the hub that connects people to a vast universe of digital entertainment content. Computer audio playback can be as simple as playing those files or streams on a portable media player like an iPod®, iPad®, or a smart phone device such as the iPhone® or an Android phone. Or it can be as sophisticated as a component-based home entertainment system using a high-end Digital-Audio Converter (aka DAC).

In this brave new frontier of computer-based digital audio, the current reality is that a lossless 16-bit/44.1kHz digital music file can sound far better than the CD it was ripped from when each is played in real time, and a high-resolution 24-bit/88.2kHz digital music file can truly compete with vinyl's sonic beauty without our beloved vinyl's flaws. Notice there is a bunch of "cans" in the line above. Great audio is possible in this new computer audio world, but it is not automatic. Just as adjusting the stylus rake angle properly is critical to getting the best performance from a turntable, knowledge is required to optimize the hardware and software that will define the performance boundaries of your computer audio experience.

AudioQuest's Computer Audio Demystified is a guide created to dispel some of the myths about computer audio and establish some "best practices" in streaming, acquiring and managing digital music. Along the way will be easy instructions for getting the most performance and convenience out of the music stored on your hard drive, Network Attached Storage (NAS) drive, and computer. In addition, we'll also talk about the parallel UPnP™ / DLNA® and Apple AirPlay® infrastructures for sharing your digital music library once it's on your home network. Included will be links to setup guides for iTunes for both Apple's Mac OS® X and Microsoft®'s Windows® operating systems.

We're also going to offer some proven tips and techniques for enthusiasts looking to use computer audio as the basis for a "best it can be" pursuit. Computer audio is for every music lover at any and all budgetary and aspirational entry points.

Computer Audio Now



As Apple has demonstrated with iTunes, getting started with computer audio is and should be fast and simple regardless of whether you're using a Mac or a Windows-based PC. While the latest and greatest iterations of both the Mac® and Windows operating systems offer valuable new computer audio enhancements, all that's required to get started is a computer running the Mac OS 9 operating system or newer, or a Windows PC running XP or newer.

Getting your digital music library to your home entertainment system(s) at its simplest can be a single run of HDMI, Toslink optical, or even an analog mini-to-RCA stereo cable directly from a computer. Or, instead of going directly from your computer to your home entertainment system, you can also stream content from your computer to a set-top box connected to an AV receiver or surround processor. Apple TV® and Roku® are great examples - a tiny box, one HDMI cable and you're in business. But the first step is to determine how you expect to connect your computer to your audio system.

-  **Analog:** All modern computers are equipped with an internal sound card and an analog 3.5 mm headphone output. This terminal can be used to connect headphones, an amplifier, or to connect a pair of powered desktop speakers to the computer. This approach results in employing the computer's built-in Digital-Analog (D-A) conversion, which is typically not a high-performance solution. Aftermarket sound cards with traditional stereo analog outputs using RCAs can be purchased to improve performance.
-  **S/PDIF:** (Sony/Philips Digital InterFace.) S/PDIF refers to the coaxial and Toslink optical digital connections that have become ubiquitous in the consumer electronics world, featured on virtually every AV receiver and surround processor manufactured since the 1990s and scores of external DACs. Some computers come equipped with a Toslink or coax digital output. Mac computers come with a headphone output that doubles as a Toslink optical digital audio output when used with the appropriate cable. If not, a S/PDIF output card can be added to your computer. In addition, there are a number of devices available that will convert USB to S/PDIF allowing computers to be used as a source for traditional S/PDIF-equipped consumer electronics gear. S/PDIF is a unidirectional (single direction) digital connection capable of transmitting digital

signals comprising a number of digital audio formats, including the uncompressed 16-bit/44.1kHz PCM used to encode compact discs.

S/PDIF has no defined data rate and is therefore compatible with high-resolution digital music files up to 24-bit/192kHz. With S/PDIF the original word clock is extracted from the digital audio data packet via a PLL (Phase-Locked Loop receiver), which can be prone to digital timing errors such as jitter. However, there are a number of sophisticated and mature solutions that correct for jitter. Performance can be state-of-the-art. S/PDIF offers a connection that is reliable up to 20 meters in cable run length.

-  **HDMI/Mini Display Port:** As HDMI has become the standard digital audio/video interconnect among consumer electronics components, many computer manufacturers recognize this and consequently more computers are equipped with this connection. HDMI provides bidirectional communication between connected devices. If an HDMI device offers digital audio capability, it is required to support stereo PCM (uncompressed), the baseline format. Clocking issues and jitter often hinder HDMI's audio performance. Other formats are optional, with HDMI allowing up to 8 channels of uncompressed audio at bit depths up to 24-bits and sample rates as great as 192kHz. HDMI also supports legacy, lossy-compressed digital audio formats such as Dolby® Digital and DTS, and up to 8 channels of DSD audio (the digital encoding used on Super Audio CDs). HDMI 1.3 and 1.4 support lossless compressed audio in the form of Dolby TrueHD and DTS-HD Master Audio, each of which can support up to 7.1 channels of high-resolution audio.
-  **USB:** USB stands for Universal Serial Bus. All modern Mac and Windows computers feature one or more USB ports and include the necessary USB hardware and device driver support. True to its name, this is an honest to goodness universal open standard. As a result, the number of computer audio products on the consumer electronics market that use the USB interface is substantial and growing. USB.org has established a set of open standards that allows any manufacturer carte blanche access to USB technology. USB offers bidirectional communication and excellent audio performance potential as it has the ability to operate in either asynchronous or adaptive transfer modes. These distinctions will be explained in full later in this guide. USB cable runs are limited to 5 meters unless a repeater or active USB-to-Ethernet converter is used.



- **FireWire:** FireWire, also known as IEEE1394, was developed as a high-speed serial bus that can move large amounts of data in real time at speeds of up to 800Mbps. For the playback of digital music files FireWire offers excellent performance potential as it too can operate in either asynchronous transfer mode or adaptive transfer mode. Although any computer with a FireWire connection will have the requisite drivers that allow a computer to communicate and transfer data to and from an external FireWire hard drive, FireWire audio devices such as DACs require special drivers in order for a computer to communicate with the device, as there are no universal FireWire audio device drivers built into the Mac OS X or Windows operating systems. FireWire also offers bidirectional communication and a 5 meter maximum cable length.



- **Ethernet:** Audio over Ethernet (AoE) was developed for high-fidelity, low-latency audio and offers the potential for low jitter and high performance. There are several different and incompatible protocols for AoE, some of which, like UPnP (Universal Plug N' Play) and DLNA (Digital Living Network Alliance) will be discussed in greater detail further on. Using Category-5/6/7 cable, each protocol can generally transmit as many as 64 channels of audio at 48kHz. Some can stream signals with sample rates as high as 192kHz, as well bit depths as great as 32-bit, with a corresponding reduction in channel capacity. Ethernet offers a reliable connection with a maximum cable length of 1,000 feet. There are a multitude of excellent products from Sonos®, Meridian-Sooloos®, Linn®, Naim and Squeezebox (to name but a few brands) that move digital music files and audio data between a computer or NAS hard drive to a digital audio device or home entertainment system over Ethernet. However, while performance over Ethernet can be outstanding, to one degree or another the systems from some of these manufacturers require proprietary components from the same brand to be networked together, creating something of a 'closed system.' While this is not a performance limitation of any kind, it is something to be aware of when system planning.



- **Wi-Fi Streaming:** As the name implies no wires are required to move your digital music files among computers on your wireless network, or from your computer to your home entertainment system. The Sonos and Squeezebox devices are examples, as is Apple's AirPlay (more on that later). There are some limitations both in sonic performance and the digital music file sizes that can be accommodated. However, Wi-Fi can be extremely

convenient. Apple also sells simple, inexpensive Airport Express® boxes that plug into any AC outlet and can stream music from any iTunes library on the network (on a Mac or Windows PC) using Wi-Fi. Connect a simple mini-cable or Toslink optical digital audio connection to a powered speaker or amplification component you've got distributed audio.

Taking Control



Regardless of what type of computer audio connection works for you, mobile devices using Apple's iOS or Android's operating system make superb and sexy touch screen remote controls for distributed digital music libraries. For iTunes libraries, Apple offers its own free Remote app for iPod Touch®, iPad and iPhone on its App Store. Naim, Meridian-Sooloos, and Sonos are among the many companies that make remote control apps for their network music systems that work on Apple iOS mobile devices. Using tablet PCs like the iPad for control enhances the usability of a digital music library so dramatically that you'll likely find that you listen to more music more often in more areas of your home as a result. Linn's Kinsky control-point software can be run from your desktop PC, laptop, or iPad, and since it's open-source it has the potential to be used as a control-point solution in a variety of UPnP systems with components from other manufacturers.

Acquiring Music in the Computer Audio Age

While many of us will start our computer audio journey by ripping our own library of CDs, a discussion is in order for the best ways to acquire new music for a digital music library. iTunes and Amazon aren't the only game in town.

Buy and Rip CDs

Using CDs as fodder for building a digital music library sounds at least a little old fashioned, right? But if you're quality-driven and want mainstream rock and pop, very little is currently available for high-resolution (24-bit) download. As you'll read below, none of the current streaming or download purchase platforms can match the CD's uncompressed (1411kbps) 16-bit/44.1kHz resolution, which is vastly superior to even the highest bitrate AAC or MP3 streams or files (these max out at 320kbps; iTunes

Plus is 256kbps). In addition to higher sound quality, purchasing a CD is often cheaper than purchasing a lossless or uncompressed 16-bit/44.1kHz download, and with shipping services like Amazon Prime they'll arrive in a hurry. And it never hurts to have a physical backup. The CD still has a place in the computer audio age. Go figure...

Purchase Downloads

Purchasing music downloads - in which you buy a music file or files that are stored locally on your computer and that music is owned by you - is currently the predominant digital music distribution model. While the term "download" may elicit thoughts of being stuck with lossy compressed audio from iTunes or Amazon, a whole new and dynamic world of high-resolution music downloads is emerging. HDTracks® in the USA (hdtracks.com), HighResAudio in Germany (highresaudio.com), and other content providers are offering music files with native resolutions significantly greater than CD's 16-bit/44.1kHz. Keep in mind that while much of this music may not be mainstream rock and pop, a shift is beginning. Artists such as Madonna, M83, Nine Inch Nails, and the Bob Marley Estate recognize that change is in the air, and offer downloads at higher-than-CD resolution.

High-resolution downloads tend to be 24-bits, with sample rates between 48kHz and 192kHz. One note: While higher sample rates may sound seductive on paper, the most significant improvement comes from the increase in bit depth. 24-bits offers 256 times the data of 16-bit digital word lengths (CD-quality resolution). This is not to diminish the importance of sample rates, as both are important, and contribute to sonic improvements.

See AudioQuest.com for links to sites from around the world that offer high-resolution music for purchase:*

Free (and legal!) Concert Downloads

Many artists have taken the attitude that sharing is caring. In this spirit, artists will often allow fans to bring portable digital (and analog) recorders to their concerts. These can be "checked in" at the soundboard where they can then capture a direct feed. This is a first-come, first-serve opportunity. Some savvy fans show up with devices capable of 24-bit/192kHz captures, while others choose to record compressed MP3. Sites such as <http://Archive.org> allow users to upload these files as long as the artist in question complies. The motivation for many artists is they hope you like the recorded shows so much you won't be able to refuse buying a ticket (and a t-shirt) next time they perform in your home town.

**Subscription Streaming Services:
To Rent or to Own, That is the Question...**

Just as Napster® and iTunes upended the traditional retail music channel, streaming is in the midst of creating another revolution in how we consume and discover new music. While purchasing downloads is still popular, streaming subscription services such as Pandora®, MOG, and Spotify™ offer consumers access to a wide range of music for a modest amount of money. For as little as \$10 a month, users can have access to tens of millions of songs categorized by new releases, genre, featured artists, etc. ... Additionally, most of the streaming services offer their own unique advanced search features such as Pandora's artist/song matching capability.

While streaming is not (yet...) qualitatively equal to the Compact Disc (streaming data rates typically range from 128kbps to 320kbps compared to CD's 1411kbps), many streaming services have already surpassed the quality offered by download purchase services, such as iTunes and Amazon. In fact, while iTunes and Amazon offer music files up to 256kbps, services such as MOG and Spotify offer streaming at 320kbps. This means that a given song from MOG or Spotify has the potential to sound better than the exact same song purchased and downloaded from some of the aforementioned online stores.

While an obvious downside to this model is that you don't own the music, the major upside is that you have access to a broad variety of music from all over the world.

These subscription services offer you access to music from both your desktop/laptop computer and mobile devices, and Spotify is even available in some AV receivers. In addition, MOG and Spotify subscribers can download full albums or individual songs to their mobile device (also referred to as "offline"). The music remains on that device for as long as the subscription remains current and up to date - when the subscription becomes inactive the content is erased. This is an especially convenient feature for those who travel often. Being able to create a new playlist for your next trip is easy.

The continuing importance of social networking isn't lost with these services either. For those who use Facebook® MOG and Spotify offer a feature (which can be enabled or disabled) that can let you know what your friends are listening to now. There's no better reference than from a friend.

While streaming services may not be the last word in "high performance," the convenience is fantastic and this is an excellent way to find new music

with very little financial risk. Streaming opens many new doorways into a wider world of music.

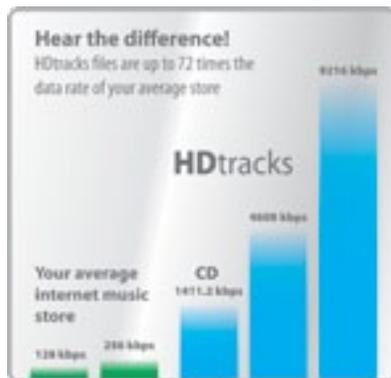
(Usually Free) Podcasts

“Podcasting” has been around for some time (the word “Podcast” is derived from neological combination of Broadcast and iPod). The premise behind podcasts is the streaming or downloading of syndicated programs can be made available and portable. Sometimes they’re free, sometimes paid subscriptions are required. Podcasting content includes a rich variety of musical performances, interviews, television shows, books and more. Any other spoken or sung word can be podcast.

A great example of the power of the podcast is Seattle, Washington’s KEXP.org, which offers daily podcasts from in-studio performances by fantastic artists. This is a brilliant way to hear musicians in an unrestricted, improvisational setting. Additionally, some “podcasters” offer higher quality downloads (up to 48kHz sample rates). A wonderful resource for finding and discovering new podcast outlets can be found at podcast.com, and the iTunes store offers a broad range of subscription podcasts.

Not All Digital Music Files Are Created Equal

The Best Audio Comes From the Best Source Material



Whether you’re ripping your own CD library or acquiring downloads from online music sites such as HDtracks, HighResAudio, or iTunes, choosing the best music file format and import settings will play an important role in determining the ultimate quality of the playback performance. To many, digital music files have become synonymous with low bitrate and often-inferior sounding MP3 or AAC (Advanced Audio Coding)

downloads. MP3 and AAC are “lossy” compression file formats that permanently throw away most of the data in the original music file—sometimes as much as 90% of the original data! Fortunately not all digital music files are created equal. It’s never really just 1’s and 0’s. iTunes is capable of supporting lossless compressed and uncompressed music files as large as 32-bit/384kHz. While 256kbps AAC files are popular at Apple’s iTunes store in the form of iTunes Plus, MP3s and AAC files come in a variety of data rates. Higher data rates such as 256kbps or even 320kbps are also offered from a number of sources, and the result is audibly better sound. In addition, AAC or MP3 files at higher bitrates sound far superior

to typical low bitrate lossy files. In more and more cases high-resolution digital music files with greater bit depths and higher sampling rates can be downloaded as either uncompressed files or files with lossless compression. Uncompressed or lossless-compressed high-resolution digital music files have the potential to sound dramatically better than CDs and compressed MP3 or AAC files. So, if you have a choice in your downloads, opt for the highest data rate/bit depth and the least compression you can get and your ears will thank you.

When ripping your own CDs to your library you'll have more control. In iTunes you can choose higher bit rate MP3 and AAC (192kbps, 256kbps iTunes Plus or 320kbps) for your music, or you can choose to rip and store your music using an uncompressed audio format such as AIFF or a lossless compression format such as Apple Lossless. As you'll learn, metadata like song titles, album art and other convenience features can be downloaded from the Internet and directly through iTunes, JRiver, and other music library management and playback suites. Metadata is a big-time enhancement to the convenience of using computer audio for music library management, but not all file formats support it. Here's a rundown of the prevalent lossless/uncompressed file formats and their respective strengths and weaknesses:

Apple Lossless Compression. This is an Apple file format option in iTunes that employs "lossless" compression, which reduces the stored data to as little as half of the original music file's size but restores bit-for-bit identical to the original music file on playback. The process is not unlike a zip file in which a large amount of data is "zipped" down to a smaller file size for storage and "unzipped" to its full size when opened. In spite of this being an Apple technology, iTunes running on Windows XP/Vista/7 is fully compatible with Apple Lossless with full rip and playback capabilities and Apple Lossless offers full metadata support on both platforms. Since the original music file is restored bit-for-bit Apple Lossless files offer much better sound than lossy MP3s and is compatible with high-resolution music files including 24-bit/192kHz. Interestingly, we've found that uncompressed music files such as WAV or AIFF can sound better than lossless compression formats like Apple Lossless or FLAC. Perhaps this is because uncompressed music files don't require the additional step of being "unzipped" and restored to their original PCM data package during real-time during playback. Listen and you'll hear the difference.

FLAC (Free Lossless Audio Codec). Like Apple Lossless Compression, FLAC employs "lossless" compression, which reduces the stored music file's size, but then restores the data package bit-for-bit identical to the original music file on playback. It supports high-resolution audio, including

24-bit/192kHz, and also supports metadata tagging and will retain metadata when the files are backed up. In spite of the fact that FLAC is an extremely common and accepted format, it is not supported by iTunes. This means you can't rip, store or play back FLAC music files using iTunes. A variety of programs are available for converting FLAC files to iTunes-compatible file formats such as Apple Lossless, AIFF, or WAV, including Max (sbooth.org/max), Fluke (macupdate.com/app/mac/28768/fluke), or DB Power Amp (dbpoweramp.com/dmc.htm).

Be aware that FLAC files are high-quality files and that converting them to MP3 or AAC will permanently delete much of the data from the original music files. To maintain the integrity of FLAC files it is important that they are converted to a lossless or uncompressed file format such as Apple Lossless, AIFF or WAV. This is not only recommended but essential!

WAV (Waveform Audio File Format). WAV is a music file format capable of storing Linear PCM audio (the digital encoding format used on Compact Discs) in completely uncompressed form. Ripping a CD and storing it as an uncompressed WAV results in "bit perfect" storage; the ripped music file is identical to the original CD data package. WAV files can also store high-resolution music files at greater bit depths and sampling rates than CD's 16-bit/44.1kHz resolution - including 24-bit/192kHz. Uncompressed WAV files can be ripped and played back in iTunes and are very high quality. However, they do take up more hard drive storage space than AAC, MP3, FLAC or Apple Lossless. WAV files have one notable limitation - they do not support attached metadata tagging. Things like album art, song titles and other convenience features that enhance music library management and playback will be lost in subsequent generations (backups).

If you have already ripped your music as WAV files you can convert them to AIFF using iTunes. This is easy to do. Simply highlight all the WAV files you wish to convert and then use the "Advanced" drop down menu from the iTunes nav bar and select "Convert to AIFF." Be certain that you have enough available hard drive space as this will temporarily double the amount of storage occupied by the music files you've chosen to convert. Once iTunes has completed the WAV to AIFF conversion you can delete the WAV files. Note that for high-resolution files we recommend using Max or some other aftermarket file converter. iTunes will not convert high-resolution music files at higher sample rates without downconverting the file and noticeably decreasing audio quality. Converting outside of iTunes will lose the attached metadata for the files, but that inconvenience is outweighed by the loss of sound quality that would result in decreasing the sample rate using iTunes' integral WAV-AIFF conversion.

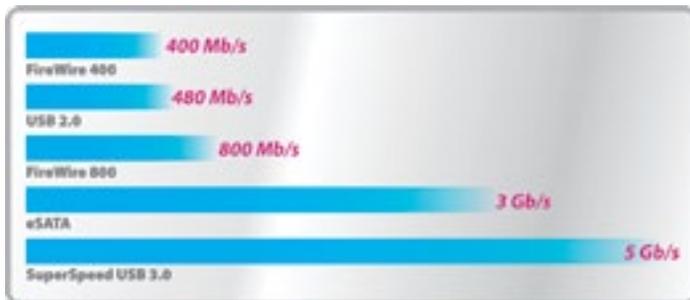
AIFF (Audio Interchange File Format). AIFF is similar to WAV. This music file format is capable of storing uncompressed Linear PCM audio. Ripping a CD and storing it as uncompressed AIFF results in “bit perfect” storage with the ripped music file identical to the original data on the CD. Like WAV files, AIFF files can also store high-resolution music files at high bit depths and sampling rates including 24-bit/192kHz. AIFF files can be created and played back in iTunes on Mac OS X and Windows XP/Vista/7 and are very high quality. But they, too, require more hard drive storage space. AIFF files support permanent metadata tagging, like album art, song titles and other convenience features that enhance music library management and playback. Backups of AIFF music files will retain all of the metadata making AIFF the best all around choice for performance and convenience.

Storing your digital music files in lossless or uncompressed form doesn't mean you have to reduce the amount of music stored on your iPod, iPhone or mobile device. iTunes allows users to convert higher data rate music files to 128kbps AAC on the fly as the music is sync'd to the mobile device in question. There is no need to maintain separate high- and low-bitrate libraries.

Storing, Distributing And Backing Up Your Music

Storage

The sonic benefits of higher data rates and lossless/uncompressed music files are tangible and substantial. Fortunately, hard drive storage is less expensive than ever for those who wish to indulge in higher-quality storage-intensive digital music files. A 1-terabyte external hard drive provides enough space to store approximately 2,000 CDs as uncompressed AIFF files, and there are now many options from name brand hard drive manufacturers starting under \$100. This is a very good thing as personal computer form factors have changed substantially over the years. While those using traditional desktop towers will find adding more internal hard drives to their computers simple and cost effective, users with Mac or Windows laptops, iMacs or Mac Mini computers will likely opt for external storage. External hard drives eliminate the single point of failure so that even if your computer crashes or fails all the money and time spent ripping your music collection into your computer are not at risk.



With external hard drives the cost increases with the speed of the drive, the quality of the drive, and the speed of the connectivity options. USB 2.0 (480Mbps), 3.0 (5Gbps) and FireWire 400 drives are the least expensive, with FireWire 800 and eSATA-compatible drives costing a bit more. Speed is your friend when it comes to these connections as the data transfer for ripping and backups is not only faster but better sonically as well. While eSATA is very fast (3Gbps), its use is more prevalent on Windows-based computers than on the Mac platform. However, for a nominal charge, peripheral devices such as PCI cards are available for either Apple or Windows based computers. FireWire 800 is common among Mac computers, allows transfer speeds of up to 800Mbps, and typically FireWire 800 drives aren't much more expensive than USB drives. Some newer computers and hard drives are equipped with connections for the emerging Thunderbolt interface, which increases transfer speeds dramatically to 10Gbps. The faster the connection is between the external hard drive used for storing digital music files and the computer, the better the sonic performance of the computer audio system will be. For the time being, however, Thunderbolt-equipped external hard drives are much pricier than their FireWire counterparts.

When choosing connectivity options for external hard drives there are some potential performance pitfalls to avoid. One of the more common mistakes is to use the USB bus to retrieve music data from an external hard drive while simultaneously sending music data to an external USB DAC, or to a USB-S/PDIF converter. This causes an issue known as Synchronous Conflict. While this won't prevent music from playing, it significantly reduces the performance potential of the computer audio playback system. When possible avoid synchronous conflict when using a USB audio decoding device by simply connecting an external hard drive via FireWire, eSATA, or Ethernet in the case of a NAS drive.



Generally, if you have a choice between a hard drive that supports FireWire 800 and its 800Mbps transfer speeds and a drive that supports USB 2.0 at 480Mbps or FireWire 400 at 400Mbps, and the FireWire 800 is a few extra bucks, buy the FireWire 800 knowing that's money well spent.

Network Audio

Networking offers the freedom to move media all over the home and, if you have or you are a really sharp I.T. person, all over the world, through your own private Virtual Private Network (VPN). As you'll read, DLNA/UPnP will continue to mature and we should see performance and user-capable setup continue to improve. On the other side, as Apple continues to successfully sell its closed ecosystem to a large part of the consumer world more and more electronics companies will seek Apple's approval to enter the AirPlay network.

It is also important to note that this isn't always an "either or" conundrum. Because of UPnP's open nature, Apple users can use both UPnP and AirPlay. Mixing systems shouldn't be an obstacle that keeps you from choosing the products you want inside of your own networked media world.

While Wi-Fi is undoubtedly more convenient, remember that wired networks are both more reliable and offer greater bandwidth. This is especially important when moving high-resolution audio and or video, and when multiple files are being requested and sent simultaneously to multiple locations on a network.

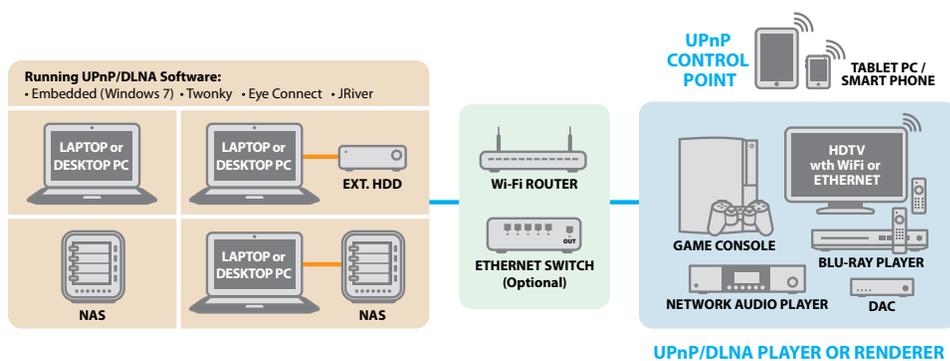
NAS hard drives use Wi-Fi or Ethernet and allow multiple computers/ devices on the network to access the stored music files. Using hardwired Ethernet tends to offer the most reliable and robust performance with NAS drives. Gigabit Ethernet offers transfer speeds as high as 1Gbps and it allows cable runs up to 1,000 feet without using repeaters or boosters.

Virtually every major networking equipment manufacturer produces NAS drives, including Netgear®, QNAP®, Synology®, Belkin®, Seagate®,

Buffalo®, LG® to name just a few. NAS drives can be the location where you store your music, movies, photos and documents. They typically connect to your home network and allow compatible devices to find them and share their content, including networked or Smart TV's, computers, media players and more. Importantly, integrating NAS with iTunes is also relatively straightforward. Most modern NAS drives actually have iTunes 'server' capabilities, which means they appear as a shared library in iTunes. It's important to discuss these options with your retailer, as a little time spent in carefully choosing your hardware and network configuration will maximize your interaction with all of your digital media content.



DLNA (Digital Living Network Alliance) is a trade organization that's developed interoperability guidelines for distributing digital media from computers and media server devices to a variety of consumer electronic components with embedded Universal Plug and Play (UPnP) capabilities over Ethernet/Wi-Fi networks. For example, a growing number of flat screen TVs on the market and Sony's PlayStation® 3 are DLNA "digital media player" client devices that can access content from DLNA digital "media servers" like computers, NAS drives, etc. Both the server and client devices must be DLNA compatible for content to be shared. DLNA is Windows-centric and reports indicate that DLNA can be a fragmented interoperability experience depending on the hardware platform(s) employed. In addition, third-party software suites like Twonky™ or EyeConnect™ are required for Mac computers to be part of the DLNA ecosystem.



Perhaps the most elegant method of implementing DLNA is to utilize a Network Attached Storage (NAS) drive or array which has its own DLNA server abilities. There's another hidden advantage in this approach. As you'll discover later, if you are tuning the performance of a computer as an audio source, we've found that using the same computer to store and serve media during real-time playback compromises performance. Freeing up the computer from resource-intensive duties like being a DLNA server

improves performance. So, shifting the DLNA server duties to a NAS allows the computer to dedicate its resources to optimizing playback performance.

The promise of UPnP/DLNA systems is the potential for end users to choose components from a multitude of manufacturers and network these devices seamlessly to share digital media. But keep in mind that networks can be complex so choosing a retailer or integrator with networking experience is just as important as selecting the components themselves. Once a network is set up and established it tends to be robust and reliable. Getting there may require some hidden knowledge. This is where experience adds real value.

Network Audio with iTunes

The question with more “open” Ethernet systems is how they interact with iTunes – ensuring that the iTunes library and the storage format you choose is compatible with all your network devices is crucially important. Close integration with iTunes is improving with many systems. Most are able to share, to at least some degree, a library that is created and managed using iTunes. However, such an approach often requires additional software to manage that interaction.

Some solutions do exist to go beyond this, for example Linn’s Kinsky control point software plays very well with iTunes. All of the iTunes music management, ripping, metadata procedures are observed. The added benefit is that you can then share those resources independently in many separate locations on the network, and even control the remote Linn components from a computer or from an iPad or tablet on the network.

AirPlay

Apple has its own media sharing protocol called “AirPlay” that, despite its name, works over both wired and Wi-Fi Ethernet networks. It enables media sharing from Apple computers and iOS devices like the iPad/iPod/iPhone to Apple TVs, AirPlay-enabled speakers and audio components like AV receivers, as well as other electronics components and devices. For a device to receive media via AirPlay it must have the Apple-approved AirPlay hardware inside programmed with all of the necessary protocols for sending and receiving, plus all of the commands that are required. Hundreds of millions of Apple computers and iOS devices are AirPlay equipped with millions more landing in consumers’ hands every day. Many electronics manufacturers are producing components that can communicate using AirPlay – B&W, Marantz®, Denon®, Pioneer®, Yamaha® to name but a few.

Where AirPlay differs from UPnP is that this is not an open-source standard. Infamous for tight control over its hardware systems, Apple has a strict approval program in place. To some this may be construed as an obstacle, but Apple's policies ensure that consumers have predictable and reliable experiences with AirPlay.

Once configured, AirPlay devices simply appear as “remote speakers”  in the iTunes window on your computer, and you can choose what music you want to send to where. The limitation with iTunes-based streaming is that you can only send one stream of music to either one remote speaker location, or to all locations. In other words, two people in different locations on the network can't listen to two different songs from the same iTunes library at the same time using AirPlay.

Network Audio, Hold the iTunes

Closed systems have a single notable advantage and disadvantage, depending on one's perspective: they work at their absolute best with little or no integration with iTunes. For those who don't want Apple iOS integration for portability, and prefer to avoid computers altogether, systems from Philips®, Naim & Meridian Sooloos offer a robust “turnkey” solutions that take the IT work out of computer and network audio. These systems offer solutions that rip and manage your library for you, including backups and auto-generating low-res copies of music files for syncing to mobile devices. You may not have as much freedom to choose file formats, and make other choices, but you may also be happier not being confronted with all that.

Backups: The Ultimate Insurance Policy

Always be mindful that hard drives can and do fail! Your music collection and the time invested in ripping are incredibly valuable assets that have to be protected with regular back-ups, and for most systems we recommend using an additional external hard drive(s). This means connecting another hard drive to the hard drive on which you've stored your music and backing up your library either by a hardwired interface or over a network. With larger music files and libraries we recommend performing at least your first major backup by a hardwired interface. Back-ups can be as simple as a file drag and drop exercise, but this method will become tedious if applied to your entire library. There are a variety of third party backup software suites for Windows and Mac that will perform a first complete backup and then incremental backups after that to external hard drives, only capturing new files and updating changed files. Apple offers its own Time Machine® backup utility integrated in the Mac OS X operating system. Carbon Copy

Cloner (bombich.com) and ChronoSync (econtechologies.com) are affordable and effective solutions that offer expansive features for automating and synchronizing backups between computers or external hard drives. Not only are the backups incremental, the files are backed up in a simple file folder structure. Time Machine backups embed all the files into one monolithic compressed file format.

A more sophisticated and robust backup scheme is RAID, which stands for Redundant Array of Independent Disks. RAID provides increased storage functions and reliability through redundancy. This is achieved by combining multiple disk drive components into a logical unit, where data is distributed across several drives. When one drive fails you simply replace the failed drive with no downtime or loss of data. RAID is very effective but might be beyond the average person's capabilities to implement properly. A company called Drobo (drobo.com) offers turnkey BeyondRAID products that automate backup and provide multiple hard drive arrays with full data redundancy. These options are more complicated and pricier, but again, if a hard drive fails no data is destroyed and you don't lose any music listening time; simply swap out the failed drive and keep moving. Think of this as an insurance policy.

Many of the previously mentioned NAS solutions are available with multiple hard drive bays, and are designed to be run in a number of modes. They can simply be amalgamated together to work like one big drive, or they can be configured to work as a RAID system, which offers more robust data redundancy.

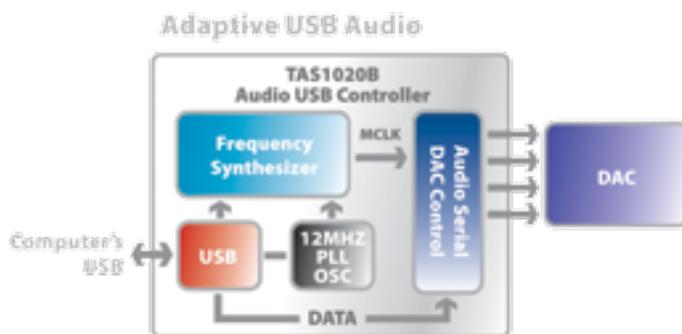
Playing Digital Music

The USB and FireWire Difference

USB and FireWire offer a variety of options for playing back your digital music files and streams that don't require a proprietary or closed system of media servers and playback devices from any single manufacturer. Most straightforward, there are powered speakers that accept a USB or mini-USB input from your computer, offering small standalone speakers that require no additional electronics to make richly detailed sound right on your desktop. Moving beyond that, USB and FireWire-based DACs and preamp/processors open the door for connecting your computer to component-based home entertainment systems on the desktop and elsewhere in the house and don't require a proprietary, or closed system of connected components/media servers to function. The DAC receives its digital data streams over USB or FireWire and converts them to an analog stereo output. Inexpensive DAC solutions abound, but for enthusiasts

wishing to push the computer audio performance envelope, the sky is the limit. Computer audio transferred via USB or FireWire doesn't just have the potential to be as good as a Compact Disc; both can offer substantially superior performance.

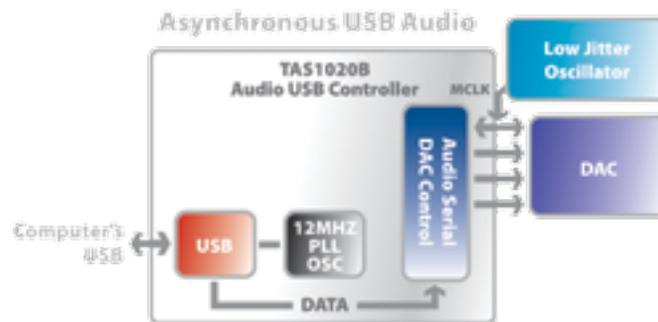
Since the advent of the Compact Disc in the 1980s time-domain errors have plagued CD playback. Jitter is the most prominent of these. Digital audio encodes amplitude, in time. Jitter refers to errors in the timing of the 1's and 0's that make up the digital audio bitstream. If the timing is off anywhere in the signal path it results in a distortion of the original recording. "Clocks" in the components that convert digital signals to analog determine the proper timing sequence for the 1's and 0's based on the sample rate. Clocking errors are a common source of jitter. The ubiquitous S/PDIF interface was originally developed for testing and analysis, not high-performance audio playback. S/PDIF digital audio transmission can create high amounts of jitter in a digital playback system with the transport operating on a fixed-frequency clock and the DAC receiver using a variable frequency clock and having to re-clock as each and every packet of audio data is received. Large buffers and superior Phase-Locked Loop Receivers overcame jitter with CD playback to some degree. USB and FireWire have the ability to transmit high-quality audio signals without introducing jitter into the playback system, making USB & FireWire DACs a superb choice for high-performance computer audio systems.



The two popular modes of transmitting USB and FireWire audio from a computer to an external DAC are Adaptive mode and Asynchronous mode. Let's talk about Adaptive mode first. As the name implies, adaptive mode uses an adaptive clock, better known as a variable frequency clock.

Because of the nature of variable frequency clocks this mode is susceptible to jitter. Adaptive mode is similar to S/PDIF in that as the audio data comes over the USB or FireWire bus the system references the 12MHz audio clock on the computer's USB bus. In other words, the computer controls the audio data transfer. Because computers are always multi-tasking this

results in inconsistent timing for the audio data transmission, which in turn causes timing errors in the derived master audio clock in the DAC as its variable frequency clock attempts to re-clock the audio stream upon receiving each and every packet of data. Think of this as a game of catch in which you're catching one ball after another as they're being thrown to you, but each ball is being thrown at a different speed. When the timing is consistent and you know when to expect the ball everything goes smoothly. When the ball arrives before or after you're expecting it you have to adapt quickly before the next ball comes and you are more likely to drop the ball sometimes. Another issue is that the 12MHz clock rate of the USB bus and the sample rate of almost all music (16-bit/44.1kHz) are not divisible by one another. This creates an additional layer of complexity for the DAC to overcome. There are adaptive mode DAC solutions available that substantially reduce the level of jitter created and offer untarnished audio performance. But the essential take away is that the adaptive transmission method itself creates jitter (just as S/PDIF interfaces do) and that must be dealt with elsewhere in the playback system for high performance sound. There's no such thing as a free lunch.



Asynchronous mode USB & FireWire transmission is quite different. With true asynchronous transmission the DAC is remarkably immune to jitter because a buffer in the DAC controls the flow of the data. The DAC controls the audio transfer from the computer, ignoring the computer's USB bus clock and instead slaving the computer to the buffer in the DAC. The DAC requests the packets of audio data from the computer and stores this data in the buffer. The DAC's buffer and the digital converter chip itself are then sync'd with a single fixed-frequency clock. This method assures a virtually jitter-free transmission. To get back to the game of catch analogy, think of it as asking for a ball to be thrown, catching the ball, setting it down and asking for another, and so on, in perfect timing and rhythm, so you are always good and ready before asking for the next ball to be thrown. Because an asynchronous DAC controls the audio data flow instead of the computer, jitter is not introduced into the playback system during this

process. Because jitter is not introduced into the playback system to begin with it doesn't need to be corrected.

Currently the majority of USB and FireWire DACs operate in Adaptive mode. Asynchronous transfer mode DACs are fewer because there are currently no turnkey OEM solutions available. Adaptive mode DACs are undoubtedly capable of great sound, and we aren't discouraging their use, but asynchronous DACs offer the best potential for state-of-the-art digital playback.

Playing Digital Music:

iTunes and Alternative Music Player Software Suites

Playing digital music files on a computer requires a software-based audio playback program running on that computer. iTunes is so simple that hundreds of millions of people use it every day on both Mac and Windows computers. It excels at both library management and music playback, and allows users to sync music files to a wide variety of smart phones and portable media players. To use iTunes with an external USB or FireWire DAC requires manipulation of the audio input and output settings in the computer. Essentially you have to route the sound to your external DAC instead of the computer's internal electronics and speakers (again, links will be provided to our Windows and Mac OS X setup guides for more detailed information).

With the release of Mac's 10.6.4 Snow Leopard operating system iTunes began supporting music files with up to 32-bit/384kHz. However, if your music library is comprised of music files with different sample rates (for instance, if most of your music is 16-bit/44.1kHz material ripped from your own CDs but some of your music files are 24-bit/96kHz) you need to be aware that it's best to play your music files at their native sample rate and avoid sample rate conversions performed by the computer. As an example, while on a surface level it might seem like a good idea to configure your Mac's Audio MIDI Setup to output 96kHz and "upsample" your 44.1kHz material to that higher sample rate, you are not in fact increasing the resolution of the music file during playback. 44.1kHz does not divide evenly into 96kHz. Sample rate converters have to make some very sophisticated guesses to perform these conversions and the sample-converted data is a mere estimation that doesn't necessarily bear any relationship to the original data package. The best sonic performance will be achieved by sending your digital music files to an external DAC at their native sample rate.

Playing music files at their native sample rate using only iTunes requires

manually adjusting the outbound sample rate in your Mac's Audio MIDI Setup so that it matches the sample rate of the music file, and restarting iTunes each time the sample rate is changed for that change to take full effect. For example, if you want to play a 96kHz song the Audio MIDI Setup output must also be set to 96kHz. If the Audio MIDI Setup is set to 44.1kHz and you select a 96kHz song it will still play, it just won't play at the native rate of the file. Instead, the file will go through a sample rate conversion and play at the lower 44.1kHz sample rate, negating the sonic benefits of the higher sample rate. This is true in the opposite direction as well. If the Audio MIDI Setup is set to 96kHz and you play a song encoded at 44.1kHz the music file will be "upsampled" from 44.1kHz to 96kHz with the undesirable results described above.

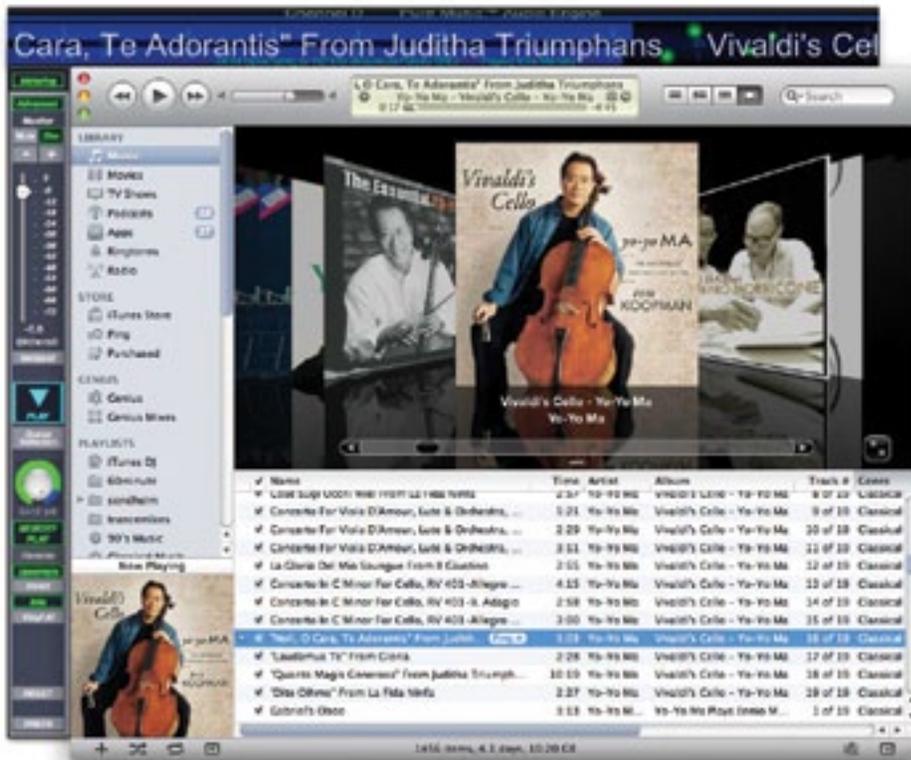
While Mac operating systems support sample rates beyond 96kHz, Windows operating systems do not. Windows 7 only supports music files up to 24-bit/96kHz. For those interested in playing files larger than 96kHz a third party driver must be installed. Thesycon offers a free driver here: thesycon.de/eng/usbio.shtml

Be aware that using iTunes on Windows also requires users to manually adjust the computer's audio output settings to ensure native sample rate playback. On Windows-based PCs QuickTime is used to configure the computer's audio output settings when playing digital music files using iTunes.

There are, however, a growing number of third party music player software suites that will automatically detect each music file's native sample rate when it's played and adjust your computer's audio output settings accordingly so that all of your music files are transmitted to external audio devices at their native sample rate. Additionally, these third party music players are format neutral. They will play almost any digital music file format including FLAC, Ogg Vorbis, Musepack, WavPack, Monkey's Audio, Speex, Apple Lossless, AAC, MP3, WAV and AIFF. Many of the third party music players for Mac computers operate as a nearly invisible skin over iTunes, meaning the user still manages his/her library and plays music using the iTunes interface, which is often as seamless as using iTunes and allows iTunes to do what it does best in managing your library, importing and playing music and syncing to mobile devices. Other music player developers chose to develop their own GUIs. Aside from convenience, it's also important to note that almost all of these third party music players sound noticeably better than iTunes itself!

The first decision in choosing an alternative player suite is whether you want something that works in conjunction with iTunes or replaces it.

Replacing iTunes most often means giving up a lot of convenience in library management and playback. Leaving the Apple ecosystem entirely often means leaving behind fast and easy syncing with mobile devices and other Apple-based music distribution features as well, like Airplay, and using the Remote app on an iPad as a control device. While a program like Decibel (sbooth.org/Decibel) offers outstanding pure sound quality, the convenience of iTunes is what got a lot of us hooked on computer audio to begin with. Not being able to use the iTunes GUI will be viewed by many as a major weakness when considering some music player suites.



Among the available alternative music players for Mac users who wish to retain the iTunes user interface are Pure Music (channld.com/puremusic/), Amarra (sonicstudio.com/amarra), Bit Perfect (available through the Mac App Store) and Audirvana (<http://audirvana.com/>). At the time of this writing, these players ranged from just \$10 for Bit Perfect to \$189 for Amarra Computer Music Player. All sound better than stock iTunes and offer “bit perfect” playback, which means the digital files are not altered in any way during playback. Decibel (sbooth.org/decibel) is inexpensive (\$33 at the time of this writing) and also offers bit perfect playback and outstanding sound quality. While it can play back music and playlists

from your iTunes library it doesn't employ the iTunes interface for library management or playback. You have to manually select the music files you want to play and "load" them into the Decibel player. While this is more cumbersome the sound quality is so good that the extra steps will be more than justified for many audiophiles.

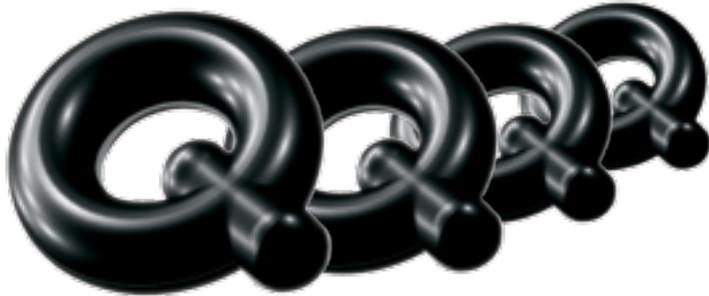


In the Windows world JRiver Media Center (www.jriver.com) offers a standalone solution that's a complete alternative to iTunes for \$50. In other words, JRiver users don't use iTunes at all for ripping, storing and playing back their digital music files. JRiver is compatible with Windows 2000, XP, Vista, Windows 7 and Home Server, and will sync music, movies and other media to iPods, iPhones, Android-based phones and other mobile devices. It supports a wide variety of digital music file formats including FLAC, WAV and AIFF, including high-resolution files up to 24-bit/192kHz. It will retrieve and attach metadata from the Internet and better still, it sounds better than iTunes on the Windows 7 platform. A hidden (or often forgotten) benefit of JRiver is that it also works as a DLNA server, meaning that it can very easily become a very complete and robust network media hub. JRivers has announced that a Mac version is forthcoming, with an audio-only version expected to be available by the end of 2012,

Everything Matters

As with any audio system, everything matters when pursuing the best pure performance. Whether you are using an external USB or FireWire DAC or an AV receiver, the quality of the DAC is critical. In addition to the preamplifier, power amplifiers and speakers, the cabling and accessories matter every bit as much in a computer-audio driven system as in an all-analog audio system. The analog interconnects that connect your

outboard DAC to your stereo matter, as do the AC power cables that connect the computer audio components to your home's AC power. But there are new considerations worth discussing as well.



The computer hardware itself matters. In addition to its typical list of chores, your computer is also undressing your audio from one of the many file container formats referenced above to play back your music files in real time. More CPU processing power and more RAM make your music playback sound better. Additionally, newer 64-bit operating systems like Windows 7 and Mac OS X tend to offer better sound quality than older 32-bit operating systems. Whether the hard drive you store your music on is internal or external, the quality of the hard drive and how it's connected to your computer impacts your computer audio sound. Higher transfer speeds sound better, so faster spinning hard drives sound better. A 7200RPM drive offers better audio performance than a 5400RPM drive. Solid-state drives with no spinning discs sound better still, but before purchasing a solid-state drive check the specifications for speed and get the fastest transfer speed you can afford. But since solid-state drives are still inordinately expensive most of us are likely to stick with traditional hard drives for the near future. In addition, as we outlined previously, be sure to use hard drives with the fastest data transfer speeds and configure your computer components to avoid synchronous conflict while transferring your music data.

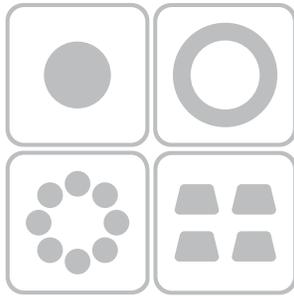
As you can see, until large solid-state hard drives are the norm, it's a myth that computer audio gets rid of the spinning disc entirely. Hard drives are spinning discs too, albeit discs that spin really, really fast! Mechanically isolating both the music server/computer that's playing music files and any external hard drive or NAS drive that is storing digital music files improves computer audio sound quality dramatically. Computers, external hard drives, routers and a host of peripherals you might have connected to your audio computer will have electronically noisy, "dirty" switching power supplies. Isolating these computer components from your other hi-fi components with high quality power conditioning is very important.

And of course, the new cables matter. When using a USB, Ethernet or FireWire DAC, the cables that connect the computer to the DAC have a profound impact on the sound you hear, just as the sonic characteristics of the DAC itself do. But what's perhaps more surprising and less intuitive is that the peripheral cables that connect to the computer to external storage and connect components over networks also make a staggering qualitative difference in sound quality. Any and all cables in a network computer audio system can and do add distortion to the signal. Therefore, the entire computer audio experience can be improved by using cables that are lower in distortion throughout your entire computer and network audio system.

Getting Started With Computer Audio

Now that you're armed with some crucial knowledge, you're ready to get started. Follow the links below to our Mac and Windows computer audio setup guides. And most importantly, have some fun and discover some new music or rediscover the music you already have. The computer audio future is now.

See our detailed iTunes setup guides for Mac OS X and Windows 7/XP:
<http://www.audioquest.com/pdfs/CA-Setup-Guide.pdf>



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