The Smart Home Installer's Guide to Structured Wiring for Audio & Video

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The future of connected smart homes lies in something as old school as structured wiring. Why? Because it takes the burden off the wireless network!

Download our guide to understand the nuts and bolts of what affects network speed and bandwidth, how to manage the demands of 4K and 8K video, and what to do about lossy compression.

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Why Structured Wiring Needs to be on Your Radar as a Builder or Installer

From appliances to lights to blinds to thermostats, smart home devices are finding their way into every nook and cranny in the modern household. In many ways, these devices are making our homes more efficient and user-friendly than ever before. But they're also clogging up bandwidth on home internet networks and slowing everything down.

Today's home typically has a full house of connected devices vying for network attention, including smart TVs, gaming consoles, laptops, tablets, smartphones, and smartwatches. Factor in the rapidly growing consumer adoption of smart home devices, which each suck up even more bandwidth, and the problem is only going to get worse.

If you're a homebuilder, smart home specialist, a broadband integrator or telecom installer, it's critically important you plan for the future needs of tomorrow's smart homes.

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The future is paved with structured wiring

The biggest piece of the future-proofing puzzle lies in structured wiring—bundles of cable that connect different rooms and areas within a home. A common structured wiring plan consists of coaxial cables, several fiber optic cables, and lots of Ethernet cables (Cat5e, Cat6, etc).

Structured wiring can be run to every room in a home, and terminated with a variety of specialized wall plates and ports for easy plug and play connection to the home network. This will allow homeowners in the future to connect more of their devices directly to high-bandwidth cabling, such as fiber. It will also alleviate the pressure on hardworking Wi-Fi networks, which can become overwhelmed with signal noise.

It goes without saying that structured wiring is easiest to plan and install during construction, when walls are open. Taking the time and care to integrate cabling in house plans can have a tangible impact on the home's appreciation and resale value. It can also save the future owners from taking on an expensive (and likely inevitable) retrofit to add structured wiring later on.

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Structured wiring and the wireless home

One of the biggest benefits of distributing structured wiring throughout the home is the burden it takes off the wireless network. Part of that is because more devices can be connected directly but can also strengthen Wi-Fi connections as well.

With more speedy and higher bandwidth cabling available, homeowners can take advantage of whole home mesh Wi-Fi systems. A mesh Wi-Fi system includes wireless satellite nodes that can be plugged directly into a structured wiring Ethernet port in the wall. Once plugged into the wired network, these nodes extend the range of the Wi-Fi router's full wireless signal, and help the network manage the onslaught of signals it receives.

Building a faster and more efficient future

It's ironic: The future of connected smart homes lies in something as old school as structured wiring. Those who fail to take these trends into account could soon be scrambling to pivot and catch-up to companies that establish themselves as leaders in smart home future proofing.

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Resolution Confusion, Part 1: The Road to High Definition

It might be early days for 8K television, but one thing is already clear: The bandwidth demands it's going to put on the smart homes of tomorrow will be extreme. And tomorrow is closer than most people think — some studies estimate 8K will become widely adopted as early as 2023.

If you're an installer, this means it's the perfect time to educate clients and consumers on the need for structured wiring installations, to futureproof their homes for the bandwidth crunch lurking just around the corner.

The bits and bites of digital video

We all know computers and televisions use pixels, and the more pixels a display has the higher the resolution. But there's more to bandwidth than resolution. We also need to account for bits, colors, frames, fields, and frequency. They all combine to create particular bandwidth requirements.

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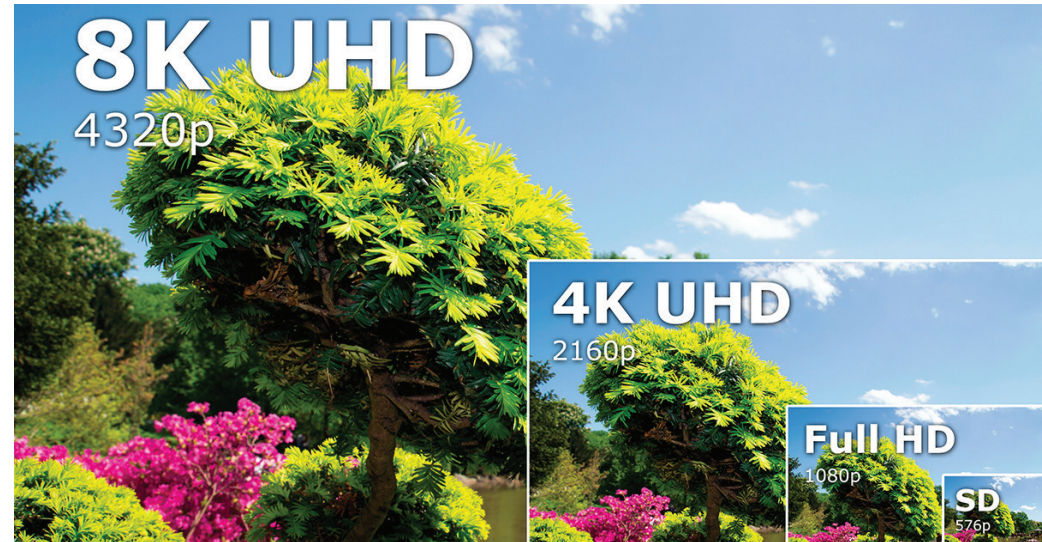
In simpler times, we had 1-bit video — each pixel was either black or white (or another 2 colors, such as green and black or yellow and black). Then came 4-bit video and the miracle of color displays. With 4-bit video, each pixel combines the primary colors of red, green, and blue. One bit was assigned to each color, while the fourth bit controlled intensity. All in all, 4-bit video could produce 16 colors.

What does that mean for bandwidth?

Take IBM's early CGA display from 1981 as an example. It had a resolution of 320 x 200 (64,000 pixels) and used 4-bit color (4 bits per pixel). Multiply 64,000 by 4 and you get 256,000 bits of data.

When VGA appeared in 1987, it increased resolution to 640 x 480, quadrupling the pixels (307,200) and data (1,228,800).

Fast forward to today, where we have high definition (1920 x 1080) and 24-bit color. That's 2,073,600 pixels and nearly 50,000,000 bits of data to wrangle.

History of Resolution

- *1-bit*
- *320 x 200 (4-bit)*
- *640 x 480 (4-bit)*
- *1920 x 1080 (24-bit)*

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Understanding fields and frames

Of course, the story doesn't end with resolution and color. Frames, fields, and frequency also impact bandwidth demands.

In North America, standard definition television began as an analog technology that used horizontally scanned lines of light in a cathode ray tube. The rate at which the scanned lines created an image on screen was tied to the frequency of the TV's AC power, which in North America is 60 Hz (or 60 times per second).

This means there are 60 images shown on screen each second. These are known as fields. Each field only shows every other horizontal line, so the two fields combine to create a complete frame. This is known as interlacing. Under this technology, video consists of 30 complete frames per second.

The impact of progressive scan technology

When HDTV first appeared on the scene with resolutions of 1080i it was still using interlacing. That's what the "i" stood for. But then came 1080p. What's the main difference? The "p" stands for progressive scan, which means each field shows every horizontal line (instead of every other one).

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This requires double the bandwidth from 1080i, as every field in a 1080p display has 2,073,600 pixels. If the display is using 24-bit color, then every field is consuming 49,766,400 bits of data. Each second, there are 60 fields in a 1080p display, so this equates to 2,985,984,000 bits of data (3 megabits) per second.

Today, this is entirely manageable. But 1080p has already given way to 4K ultra high definition, and the forecasts are already in place for when 4K will begin being replaced by 8K. With each advance in display technology, the demands on bandwidth exponentially increase, further underscoring the need to futureproof new and existing homes with structured wiring.

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Resolution Confusion, Part 2: Travelling the Data Highway

Untangling bandwidth, speed, and throughput

When it comes to explaining bandwidth and network speed, we're all familiar with the pipe analogy: The wider the pipe, the more data squeezes through at once, the higher the network speed.

Of course, it's not quite that simple. A better analogy is to think of bandwidth and network speed like a bridge. Early network connections were essentially a single-lane bridge, where cars would have to take turns travelling in each direction. Later networks introduced full duplex communication, which turned that single-lane bridge into a two-lane one.

Increasing the bandwidth of a network really just means adding more lanes to the bridge, so more cars can travel across at once in both directions. The amount of cars (data) that arrive at their destination per second is known as throughput. How

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fast those cars are driving is important, to be sure, but consider this: A 6-lane bridge with cars driving at high speed will deliver a higher throughput than a 2-lane bridge with cars driving at blazing speed.

Eliminating network bottlenecks

Continuing with our bridge analogy, let's imagine that both ends feature a tollbooth. What happens to throughput? It drops—dramatically—as cars slow down to pass through each checkpoint.

In a network, tollbooths are things like routers, modems, Wi-Fi extenders, and even low-latency cable. It doesn't matter how much bandwidth your ISP is delivering into your home if there are bottlenecks spread throughout your network.

As we move rapidly toward the widespread adoption of 4K Ultra HD as a streaming standard (and soon thereafter, 8K), it's becoming more and more important to plan for future bandwidth demands in the home. That means ruthlessly eliminating any and all bottlenecks from the network. The most effective way? Structured wiring installations, with fiber optic cabling run throughout the home so more and more devices can skip the tollbooths entirely and be directly connected to the network.

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The future of video compression

When we talk about the future of 4K and 8K streaming, it's also important to include data compression. In the early days of video, we had simple forms of compression, such as run length encoding (RLE). This was a type that was considered "lossless" as none of the original data was lost in the process.

RLE simply records multiples of consecutive values to save data space. This worked fine for monochrome and 16 color video, but as video quality has increased, we've needed more complex compression technology.

Today, streaming video requires lots and lots of bandwidth. Compression may reduce the amount of data that needs to be transmitted, but this can lead to a loss in original video quality.

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Resolution Confusion, Part 3: Dealing with Lossy Compression

4K and 8K streaming problems

As we mentioned in the last installment, streaming video requires lots and lots of bandwidth. Compression helps reduce the amount of data that needs to be transmitted, but this can lead to a loss in original video and audio quality.

That wasn't a problem 10 or 15 years ago, when lower resolutions were the norm. But now, in the high-definition (720p and 1080p) and ultra high-definition (4K and 8K) era, "lossy" compression is the only way to squeeze all that data into the pipe for real-time video streaming.

What does that mean for the end user? It's simple: There's actually a very distinct difference between watching a movie on 4K Blu-ray and streaming that same movie in 4K through a service like Netflix or Amazon Prime. While the picture may be sharp and crisp on a 4K streaming service, it won't have the same level of richness and depth in color and contrast as a 4K Blu-ray.

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The streamed content also won't sound as cinematic. Audio on a service like Netflix is usually compressed Dolby Digital Plus in 5.1, whereas 4K Blu-rays pack uncompressed Dolby TrueHD or DTS HD Master Audio in 7.1, delivering powerful cinema-quality audio unmatched by anything on a streaming service.

The same goes for streaming music through some services, such as Spotify. On Spotify, all audio is compressed, and depending on your level of subscription you have the option of streaming at 96kbps, 160kbps, or 320kbps.

This is why most audiophiles subscribe to TIDAL instead, and opt for the service's HiFi package. Unlike Spotify, TIDAL HiFi streams completely uncompressed CD-quality audio.

Current limitations: Adaptive bitrates and lossy video compression

One of the ways streaming services like Netflix manage the demands of delivering high volumes of data to end users is something called adaptive bitrate streaming technology.

In a nutshell, this approach to streaming involves compressing and encoding content at multiple bitrates and allowing the player client to switch between the different bitrates

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depending on the end user's bandwidth. The advantage here is less buffering and faster start times, two things that are critical to maintain the single biggest advantage of video streaming: Convenience.

The downside, of course, is a loss in quality from the original source. Up until now, "lossy" video compression has served us all well, but it's on the verge of becoming unacceptable for video streaming. As 4K streaming becomes the new norm, and 8K streaming emerges for early adopters, customers will be unwilling to accept a loss in quality.

The evolution of compression codecs

Today, there's a competition underway to crown the next industry standard compression codec. This will mostly impact device manufacturers, but telecom technicians and installers should take note as well.

The battle is between Google's VP9 and the Alliance for Open Media's AV1. Both codecs aim to solve the same problem: Compressing and encoding ever-larger

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media files (4K and 8K video) into smaller bitrates.

For end users, however, this is only one half of the resolution equation. Because both codecs still leverage adaptive bitrate streaming technology, video quality will ultimately hinge on the end user's available bandwidth. That's no different than the limitations of today, but imagine the videophiles of tomorrow who want to be early adopters of 8K video streaming. Do you think they'll accept having their 8K stream being downgraded to 4K video quality—or worse—just because their internet network can't support 8K streaming?

Preparing for the streaming demands of tomorrow

No matter what compression technology is available, and regardless of Wi-Fi quality or even the emergence of 5G, the demands of ultra-high definition streaming will require a robust internet network in the home.

Fiber to the premises delivers the highest bandwidth possible, but to truly futureproof homes for the streaming demands of tomorrow you need to go a step further. Structured wiring solutions in the home will remove the bitrate bottleneck of Wi-Fi and ensure the highest bandwidth possible is available for media streaming devices.

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HDMI 1.4 versus 2.0: How a Few Cables Can Hold Back an Entire A/V System

As we recently explored in our Resolution Confusion series, streaming ultra high definition video like 4K and 8K requires extraordinary bandwidth. So much bandwidth, in fact, that one of the best ways to future-proof a home for these bandwidth needs is to invest in structured wiring solutions, with dedicated Ethernet terminations run to a variety of locations within the home.

But what happens after you, the specialist or installer, completes a structured wiring job and walks out the door? The client begins connecting their devices to the new network, including gaming consoles and Blu-ray players. And they're likely using the same HDMI cables they've been using and re-using for years and years: HDMI 1.4 as opposed to HDMI 2.0.

The problem? The old 1.4 standard is incapable of delivering the best possible video and audio that today's clients demand. And they can take a lot of the shine off a brand new structured wiring project.

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HDMI 1.4 versus HDMI 2.0

HDMI 2.0 is nothing new. It first appeared in 2013 but only recently reached its true potential. For years consumers have operated off the conventional wisdom that 2.0 is no better than 1.4 — but that's changing with the widespread adoption of 4K video, streaming, and high-resolution audio.

In a nutshell, HDMI 2.0 is designed to handle more bandwidth than HDMI 1.4. Both can deliver 4K video, but HDMI 2.0 can transfer up to 18Gbps whereas HDMI 1.4 can only transfer up to 10.2Gbps.

That extra bandwidth allows HDMI 2.0 to deliver a few extras that might have seemed unnecessary just a few years ago. But for current content consumers — especially A/V enthusiasts — those extra goodies are seen as essential.

Higher frame rates at 4K

With HDMI 1.4 you're limited to a frame rate of 24fps when watching 4K video. This is still the standard for most movies and TV shows, but some in the entertainment world are trying to push the industry into filming in higher frame rates.

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Why? With higher frame rates, 4K video looks sharper and more vivid, especially fast-moving scenes. This is why it's especially useful for gaming. Slower, more traditional frame rates can make scenes appear blurry and choppy.

Because of its higher bandwidth and ability to transfer more data per second, HDMI 2.0 can support 4K video at up to 60 frames per second — optimal for watching live sports or playing video games.

Deeper color palettes at 4K

As well as supporting higher frame rates, HDMI 2.0 also supports an exponentially richer color palette at 4K. Whereas HDMI 1.4 can only deliver 8-bit color, HDMI 2.0 supports 10- and 12-bit color palettes.

For A/V enthusiasts and average consumers alike, this difference is profound. With 8-bit video, you get 16.7 million possible color combinations. With 12-bit video, you get a staggering 68.7 billion color combinations.

That might seem like overkill, given that the human eye can only detect around 10 million colors, but that doesn't account for the subtle shades within colors that our eye can

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detect but that 8-bit video can't replicate.

Richer and more immersive audio

Last but not least, HDMI 2.0 supports incredibly immersive and cinema-caliber audio, an essential piece of any home theater.

At a basic level, HDMI 1.4 supports up to 8 channels of audio. This was great for the surround sound of yesteryear, where you'd have some unidirectional speakers in the front, rear, and sides.

Today, HDMI 2.0 supports immersive surround sound technology like Dolby Atmos, which handles up to 32 virtual sound channels, all delivered through a handful of omni-directional speakers placed in your living room or home theater.

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