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4K: From the cinema to the home

The story behind the Sony® VPL-VW1000ES home theater projector.

Toward a more engaging home theater experience

Home theater projection has always promised greater viewer *engagement*, the prospect of a bigger, more exciting, more enveloping picture than just television. Greater engagement requires the screen to fill a larger field of view. This can only be achieved by sitting closer to the screen or increasing the overall screen size. But this has always run the risk of exposing image artifacts that pass without notice on smaller screens.

Compared to standard definition, 1080p high definition has enabled a quantum leap in home theater engagement. But high-end enthusiasts and custom installers understand that even 1080p HD has its limitations. At close viewing distances, individual pixels become discernable. Diagonal edges of on-screen objects that should appear smooth become jagged. Even the outlines around pixels can become strikingly evident.

Fortunately, a solution is on the horizon. A new development is poised to bring a higher level of viewer engagement and generate new opportunities for custom installation. It's nearly as far beyond 1080p HD as HD is beyond standard definition. And it's based on the same presentation standard that is transforming the movie theater. The solution is 4K, an innovative format that delivers more than four times the pixels of HDTV: 4096 horizontal x 2160 vertical.

This paper will review the rise of digital cinema, the impact of 4K on the cinema experience, the similarities between digital cinema and home theater design, and the prospects for 4K entertainment in the home based on Sony's revolutionary VPL-VW1000ES projector.

The digital cinema revolution

To appreciate the importance of 4K, it helps to understand the venue where 4K first emerged: the cinema. 4K is playing a prominent role in the digital cinema revolution and has helped usher in an impressive range of benefits.

Quality. The film print shown in theaters is typically a copy of a copy of a copy, three generations removed from the Original Camera Negative. Each generation sacrifices detail and contrast, leaving audiences with a pale imitation of the original. Digital presentation is typically far closer to the Original Camera Negative, enabling much higher picture quality.

Stability. Film projectors must "pull down" each frame, then pause while that frame is projected. This process is inherently mechanical and somewhat imprecise. Slight misalignments from one frame to the next cause the picture to hop around on the screen. In contrast, digital projection is free of these errors.

Clarity. Because film projectors are mechanically open, they permit dust, dirt and even hair to enter the light path. These cast shadows that can be painfully obvious. Because digital projectors are generally sealed, clarity is enhanced.

Simplicity. Film prints require complex chemical manufacturing as well as costly printing, packaging and shipping to cinemas. This consumes valuable resources and requires disposal of chemical by-products and the prints themselves after the theatrical run. The Digital Cinema Package (DCP) that replaces the film print is a simple computer file that can be distributed over a broadband network.

Reliability. Exposed to wear and tear, film prints can get scratched during the course of the theatrical run. After each showing, the movie looks slightly worse than it did on opening night. With digital cinema, the movie looks just as good at the end of the theatrical run as it did at the beginning.

Flexibility. Digital projectors can display not just films, but also a variety of alternate content including pre-show announcements and closed-circuit live HD entertainment such as concerts, sports and gaming.

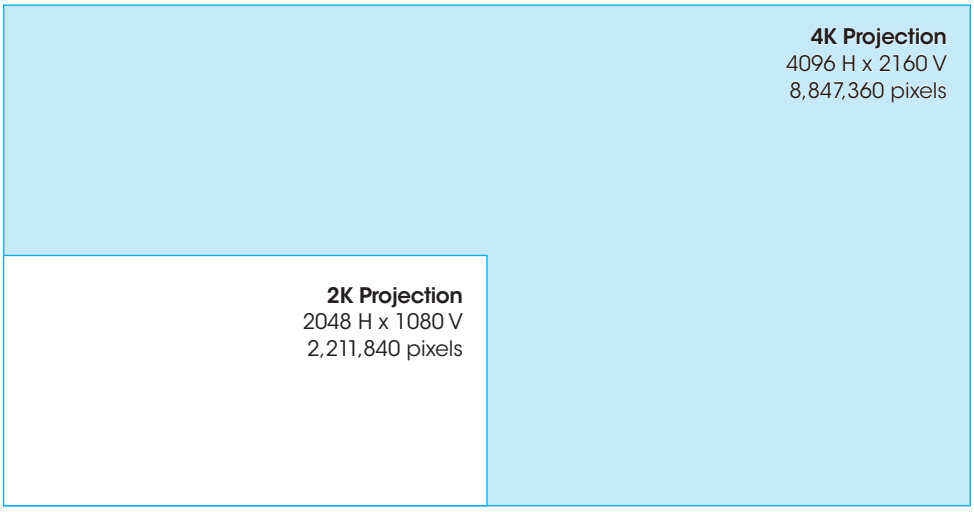
Versatility. Digital projection systems can support both 2D and 3D presentation. In fact, the rise of digital projection has contributed to the resurgence of 3D motion pictures.

Digital cinema standards

In order for the digital cinema ecosystem to function properly, theaters and studios both needed assurance that any studio's movie would be able to play in any theater on any authorized projection system. The major Hollywood movie studios also sought assurance that digital presentations would meet their requirements for security as well as color, brightness, clarity and resolution.

To establish the required level of interoperability and define the required quality, the studios came together to create a unified standard. Thus was born the Digital Cinema Initiatives, LLC, which created the DCI Specification. This document includes detailed requirements for digital encryption, image compression, frame rate, color gamut, sound tracks and most importantly image resolution.

Digital cinema resolution is measured in units of "K," which stands for 1024 horizontal pixels. In the early years of the DCI Specification, the dominant resolution was 2048 pixels horizontal x 1080 vertical, known as 2K. But 2K represents only 7% more pixels than 1920 x 1080 HDTV. Fortunately, a more future-oriented, higher-resolution option was also written into the DCI Specification: 4K. At 4096 pixels horizontal x 2160 vertical, this is exactly four times as many pixels as 2K, and greater than four times the pixel count of HDTV.



In the DCI Specification, 4K projection offers
8.8 million pixels, exactly four times the count for 2K.

The relationship between Pixels and Picture Height

A more engaging movie experience depends on sitting closer to the screen. But how close is close? The answer varies by screen size. The same viewing distance that is "close" for a 70-foot screen is "far" for a 20-foot screen. To account for screens of different sizes, we need a special way to measure viewing distance. That's why engineers consider viewing distance as a multiple of Picture Height (PH).

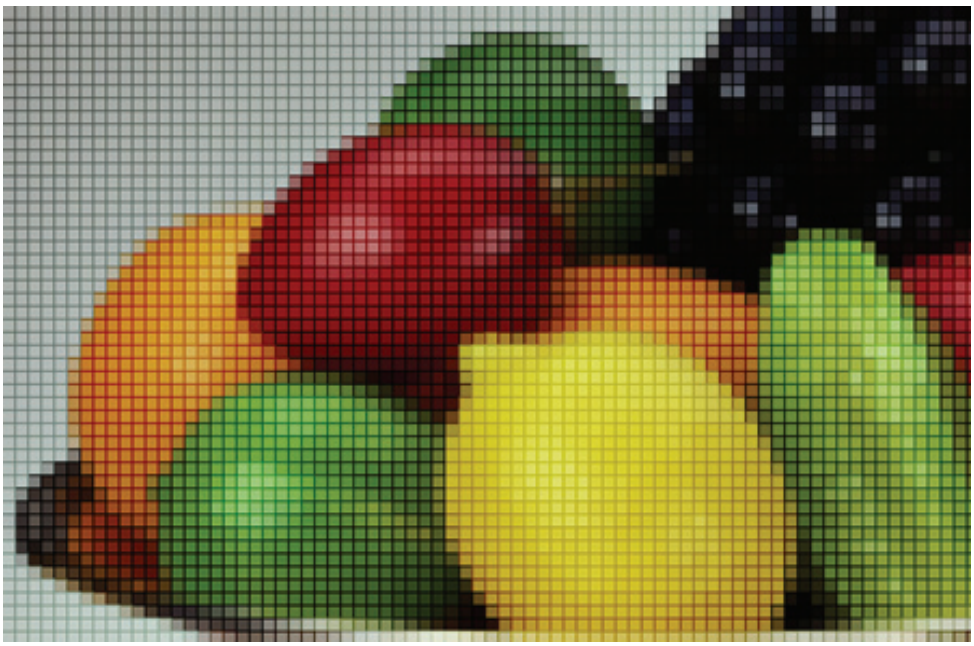
Based on widely-accepted measures for the threshold of visual acuity, 2K presentation will satisfy audience members with 20/20 vision who sit at distances of 3.16 Picture Heights or more. At these distances, the 2K picture will appear seamless. However, for viewers who sit *closer* than 3.16 Picture Heights, 4K can provide a superior, more engaging image.[1]

2K, 4K and viewer engagement

In pursuit of a more engaging experience, one might be tempted to sit closer to a 2K presentation. But moving closer than 3.16 PH causes unwanted on-screen artifacts to become more obvious. The illusion of a continuous image begins to break down as individual pixels become evident. Subjects that present fine detail such as motion picture credits will appear especially rough. Image diagonals will appear jagged. And gaps between the pixels may also become visible. This is called "screen door effect" because viewing the movie becomes like looking through a screen door.

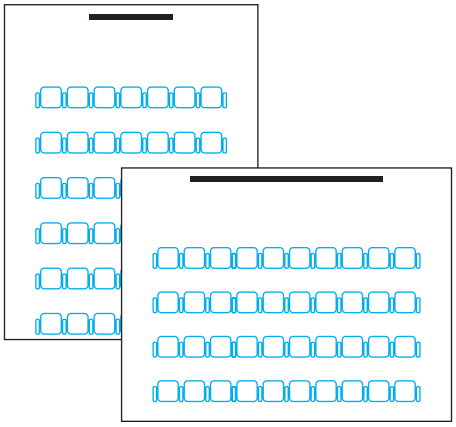
With 4K presentation, detail is smoother and better resolved. Jaggies are minimized, even during the credits. And screen door effect is dramatically reduced. This enables the audience to *sit closer* without the distractions of these unwanted picture artifacts. The on-screen presentation simply looks more real. It's a difference you can literally feel. As a result, 4K delivers a more compelling, more *engaging* movie experience.

Comparison of actual 2K and 4K images. There's no question which appears smoother and more lifelike

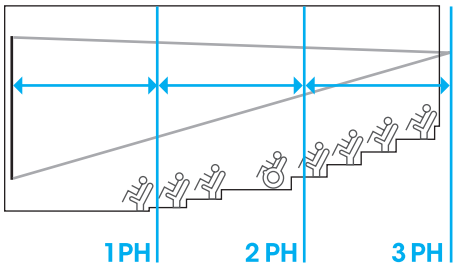


Insufficient resolution can leave individual pixels visible to the observer. This is especially evident as "jaggies:" rough diagonal edges for on-screen objects such as these fruit. In addition, gaps between pixels create "screen door effect."

4K and movie auditorium design



In the classic "sloped floor" auditorium (top), the screen is relatively small and placed on the short wall. Modern "stadium seating" (bottom) turns the design 90 degrees, with a relatively large screen placed on the long wall.



Architectural drawing of a stadium seating auditorium, showing the relative locations of the projector, audience and screen. Overlaid is the viewing distance in Picture Heights (PH).

Now that we know sitting closer than 3.16 PH reveals 2K artifacts, how close do people actually sit in movie auditoriums? The historical trend has been to sit ever closer.

1920s—1940s. In comparison to today's theatrical experience, the old movie palaces had perceptually smaller screens and longer seating distances. You can think of the classic theater as a long rectangle with the screen on the short side. Seating distances ranged from 8 PH in the back to 2.7 PH in the front. While today's audiences might find this presentation puny and unimpressive, it was well accepted in the era before home theater.

1980s—1990s. As movie theaters increasingly competed against home theater, auditorium design began to change. The consistent trend was toward ever more engaging presentation: audiences sitting closer and closer to the screen.

2000s. The trend toward more engaging presentation led to a dramatic break with the past: the old "sloped floor" auditorium gave way to "stadium seating." It's as if we had turned the classic theater 90 degrees, placing the screen on the long side of the rectangle. In this new era, the *back* of the room is about 3 PH, which is roughly as close as the *nearest* seats used to be. Today the closest seats are less than 1 PH from the screen. In this environment, the flaws in 2K projection become obvious.

Focus group research conducted for Sony[2] confirms that real-world theater-goers can see the difference. We showed movies in 2K and 4K, without identifying which was which—and without saying anything about the technical differences between the pictures. Audience members were not told to expect a resolution difference in these "unaided" tests. Even under these demanding circumstances, respondents consistently gave 4K higher marks for every aspect of picture quality.

Growing momentum behind Sony Digital Cinema 4K

While 2K projection had a long head start, theater owners currently purchasing digital projectors in the US are overwhelmingly embracing Sony Digital Cinema™ 4K.

As of August 2011, over 9,000 screens worldwide had converted to Sony 4K projectors. This includes more than 7,000 screens in the United States alone. About half of these Sony systems are also 3D capable. In fact, in the US, Sony 4K accounts for nearly as many 3D-capable projectors installed as all other brands combined.

This large and rapidly growing installed base of 4K projectors has prompted the studios to release movies in 4K. As of August 2011, there have been nearly sixty major studio releases in the 4K format, including blockbuster titles and digitally restored movie classics.

In response to these trends, 4K has received the ultimate validation. Competitors who originally dismissed 4K as unnecessary now offer their own 4K projectors.

Sony and the expanding 4K universe

It's no surprise that the world leader in 4K digital cinema is Sony. We've been doing this for years.

2005. Sony introduces the world's first commercial 4K projectors: the SRX-R105 and R110. These use a professional 1.55-inch version of the Sony SXRD™ microdisplay chip.

2007. World's first 4K projectors dedicated for digital cinema: the SRX-R220 and R210.

2009. Sony extends 4K projection to 3D presentation using RealD™ filter technology.

2011. Sony's SRX-R320 projector and LMT-300 media block become the industry's first 4K digital cinema projection system to be declared compliant with the DCI Specification.

Fixtures in thousands of movie theaters, Sony's SRX-R320 Digital Cinema Projectors incorporate a professional version of Sony's SXRD microdisplay chip.

As a company with strong commitments to both movies and movie technology, Sony understands that 4K theatrical presentation does not exist in a vacuum. It's the product of a complete digital cinema workflow, which Sony supports end-to-end.

Sony 4K camera. The upcoming Sony F65 features a 20 million pixel 8K sensor to achieve resolution of 4K and beyond.

Sony 4K recorders. The SR-R4 and SR-R1000 capture 4K imagery on solid-state SRMemory™ cards.

Sony direct-view monitor. The SRM-L560 TRIMASTER™ monitor accommodates 4K and other presentation formats.

Sony 4K projectors include the Sony Digital Cinema™ 4K SRX-R320P as well as the SRX-T105, T110 and T420, which are optimized for visualization, simulation, auditoriums and postproduction.

Sony 4K media block. The LMT-300 server is another strategic part of the Sony Digital Cinema 4K offering.

Sony Pictures 4K postproduction services are offered through our Colorworks digital intermediate facility.

Sony Pictures 4K releases include movies transferred from 35mm film, movies originally produced in digital 4K and classic titles digitally restored in 4K.

Now that 4K is well established in motion picture production and in the movie theater, 4K is ready for the next step: high-end home theater.

Sony supports 4K from end to end. The F65 captures 4K on the movie set, while the Sony SRX-T110 displays 4K in the postproduction suite.

The transition to 4K home theater

Just as the history of movie theater design is a story of ever greater engagement, so is the history of home theater.

Standard definition television was designed under the assumption that viewers with 20/20 vision would want to sit at a sufficient distance for the picture to appear seamless. Early TV engineers calculated that distance to be 7.15 PH. For the typical viewing distance in American homes (nine feet), 7.15 PH translated to a television of 25 inches diagonal.

However, people who bought either big-screen rear projection TVs or front projectors and watched from nine feet had to endure visible gaps between scanning lines. Entertainment enthusiasts were not satisfied. This gave rise to line doublers, technology that filled in the gaps and gave home theater owners the more engaging pictures they craved.

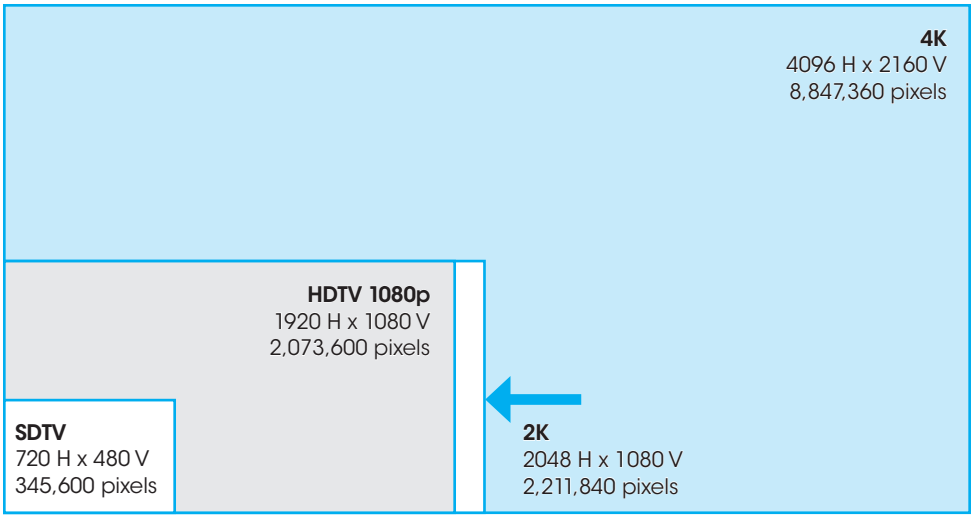
All this is why HDTV was an enthusiast's dream come true—a dream that Sony was first to realize with the Qualia™ 004, the world's first digital home theater projector with full 1920 x 1080 resolution. Thanks to HDTV, viewers with 20/20 vision can sit as close as 3.16 PH and still enjoy the illusion of a continuous picture.

While 1080p represents the current home entertainment standard, today's cutting edge home theaters require even more. Enthusiasts want to recreate the level of engagement they experience in modern movie theaters. That means sitting even closer than 3.16 PH. As we've seen, when you sit closer, the picture begins to fall apart. Unwanted artifacts once again become visible.

To overcome this, you need higher resolution than 1080p. With 4096 x 2160 resolution, 4K has more than four times the pixels of 1080p. It's nothing less than the future of home theater.

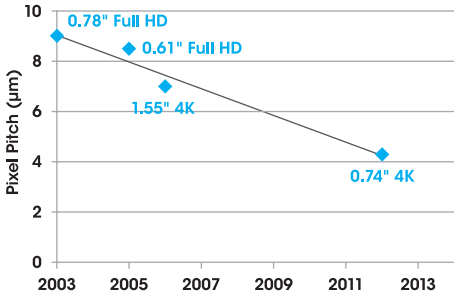
Not only is 4K irresistible to enthusiasts, it's equally compelling for installers. It represents a unique opportunity to spark renewed interest in high-end projectors, to revisit and refresh previous installations, and to attract a new generation of home theater customers.

However, all this requires a projector powerful enough, scalable enough, quiet enough, and versatile enough, as well as affordable enough to work in a home theater environment. The Sony VPL-VW1000ES is the world's first projector specifically designed to meet all of these requirements.



The 4K image has more than four times as many pixels as 1080p HD. It's a generation ahead.

Sony Home Theater™ 4K: Bringing the experience home.



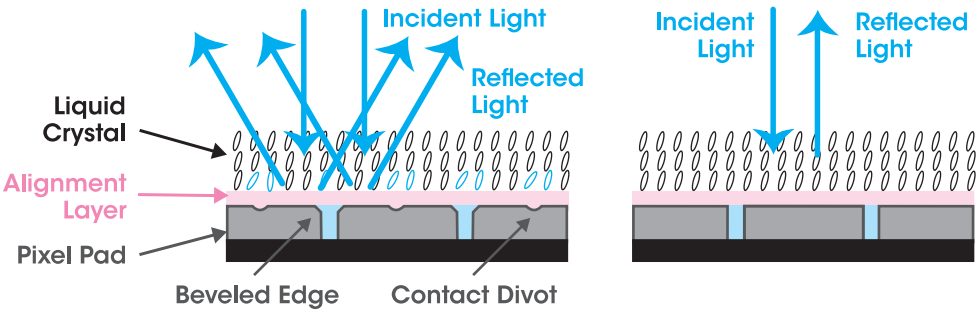
Fitting 8.8 million pixels on a 0.74-inch diagonal chip required a drastic reduction in the "pixel pitch," the center-to-center distance between pixels. Sony SXRD technology has long been a leader in minimizing pixel pitch, maximizing pixel density.

To those who follow home theater technology, it's no surprise that the VPL-VW1000ES 4K projector comes from Sony. In addition to the Qualia 004 projector and our vast experience in professional and cinema projectors, Sony has been ahead of the curve in bringing home such projection technologies as Xenon lamps, anamorphic lenses, high frame rates and 3D.

At the heart of the VPL-VW1000ES is the latest generation of Sony's proven Silicon X-tal Reflective Display (SXRD®) technology. In 2003, the Qualia 004 achieved unprecedented pixel density: more than two million pixels in microdisplay chips just 0.78 inches diagonal. The SXRD chips of the VPL-VW1000ES accommodate more than four times as many pixels in even less space—just 0.74 inches diagonal.

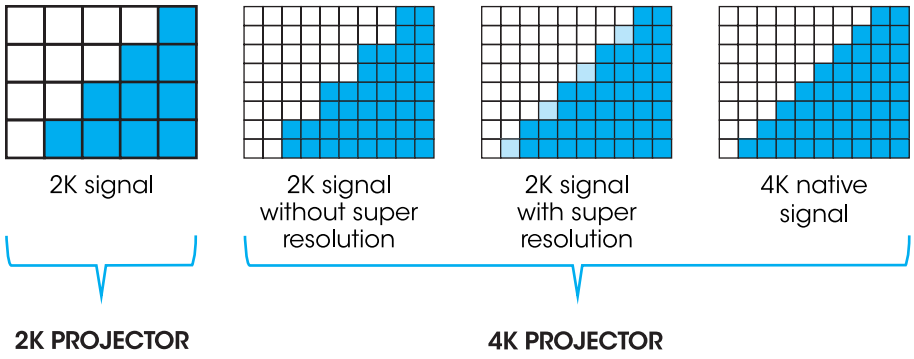
Inside consumer projection chips, the pixels can take the form of microscopic, reflective aluminum "pads," which can include a center "contact divot" and beveled edges. In the past, these elements have had the side effect of scattering some of the incoming light, causing stray reflections that degrade black levels and limit contrast ratio.

SXRD chips are manufactured in Sony's Kokubu and Kumamoto Tech Centers. The SXRD chips of the VPL-VW1000ES incorporate a series of Sony manufacturing process refinements, including improved aluminum etching and upgraded filler for the inter-pixel gaps. These enable flatter, more efficient aluminum pads without contact divots or bevels. The result is a dramatic improvement in black levels. When combined with Sony's Iris 3 technology, which incorporates a fast-acting motor-drive, this raises dynamic contrast ratio an incredible 1,000,000:1.



Previous consumer projection chips have allowed stray light reflections (left). A series of manufacturing process refinements in Sony's latest SXRD panels minimize stray reflections for a substantial improvement in black levels (right).

The VPL-VW1000ES projector can upscale 2K and HD signals with an adaptive super resolution algorithm that approaches the quality of a native 4K signal. Compared to native 2K display, the upscaled picture is considerably smoother.



While the VPL-VW1000ES can accept native 4K content over the HDMI® 1.4a input, most content will still originate as HD. For this reason, Sony developed an HD-to-4K "super resolution" upscaler. The VPL-VW1000ES uses this edge-adaptive, motion-adaptive digital algorithm to achieve smooth, lifelike results that leave conventional HD far behind.

For the utmost in versatility, the VPL-VW1000ES supports high-brightness Full HD 3D presentation plus anamorphic 2D and 3D display. The super resolution upscaler also addresses both 2D and 3D content.

The projector includes a host of additional capabilities:

High brightness: 2,000 lumens is twice the output of previous Sony models; suitable for both movie viewing in controlled lighting and television viewing in ambient light

Screen sizes up to 200 inches diagonal in 2D mode, up to 150 inches diagonal in 3D mode (depending on screen surface), made possible by the 2,000 lumens output

2.1x power zoom lens with picture position memories can toggle automatically between 16:9 television and 2.35:1 "scope" cinema presentation

Powered lens shift accommodates flexible installation away from screen center: 80% vertical shift, 30% horizontal shift

Wide range of throw distances often enables installation at the back of the room: 1.27 – 2.73 (for aspect ratio 1.78:1); 1.57 – 2.73 (for aspect ratio 2.35:1)

Quiet operation, suitable for home installation without a sound-isolated enclosure or projection booth

Improved cooling with front intake/rear exhaust

Compatible with major home automation integrators: AMX™ Device Discovery Beacon, Control 4™ SDDP, Crestron and others

Flexible control interfaces: RS-232C, IR input, two triggers, full IP control via RJ-45 Ethernet port with feedback

New installation considerations

Accomplished custom installers know how to deliver the best performance from Full HD home theater projectors. While these projectors achieve peak performance at viewing distances of 3.16 Picture Heights or more, the superiority of 4K becomes clear at distances of less than 3.16 PH. For this reason, getting the best performance from the VPL-VW1000ES requires a fresh approach to installation.

Ambient light. The VPL-VW1000ES is a powerful performer when it comes to brightness. With up to 2,000 lumens output, it generates a high-impact picture even for casual viewing in ambient light. 3D performance is also outstanding. Even so, eliciting the best performance still means reducing ambient light to a minimum.

Viewing distance. General guidelines for HD home theater projection typically suggest viewing distances of 3.0 to 3.5 PH. But 4K is an entirely new home theater experience. Sony recommends viewing distances of 1.5 to 3.5 PH. For home theater enthusiasts who currently sit further back, the VPL-VW1000ES offers the opportunity to sit closer for a new level of viewer engagement. And for those who currently sit closer than 3.0 PH, the Sony projector delivers a new level of clarity, one you can almost feel.

Screen size. Compared to previous Sony projectors, the VPL-VW1000ES produces substantially increased output: 2,000 lumens. In controlled lighting environments, this supports screen sizes of up to 150 inches diagonal (3D mode) and up to 200 inches diagonal (2D mode).

The future 4K home entertainment ecosystem

When Sony launched 4K projection, many in the motion picture community had never even heard of 4K. Now there's a complete ecosystem to support 4K digital cinema. We believe that the same development path will hold true for 4K in the home. The VPL-VW1000ES is just the beginning.

4K over HDMI™ cable. 4K is already supported by the HDMI 1.4a specification, as integrated into the VPL-VW1000ES.

4K AV Receivers. Just as AV receivers have been enhanced by HD, HDMI and 3D, future models will support 4K as well.

4K Blu-ray Disc™ Players. The Blu-ray Disc format has evolved to support 3D left-eye and right-eye content. The industry may see the same type of development for 4K.

4K Blu-ray Disc™ movie releases. The Hollywood studios already have dozens of 4K masters. As the 4K digital cinema rollout continues, we will see dramatic growth in the 4K movie library, which could ultimately support future 4K home video titles.

4K user-generated content. 4K is the equivalent of 8.8 Megapixels, a mark already surpassed by many digital still cameras. Enabling 4K output over HDMI 1.4a will bring more of that resolution to the screen. In addition, prototype consumer camcorders have been shown with the potential to capture and play back family memories in 4K.

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Conclusion

Dedicated enthusiasts are more than ready for the benefits of 4K. They're hungry for this experience. Their home theaters already feature well controlled lighting and a highly engaging viewing environment with seating frequently closer than 3 Picture Heights. All of which is why, for enthusiasts, 4K is the "holy grail"—the most engaging home theater experience possible.

sony.com/4KHomeTheater

1. For more on the advantages of 4K in the cinema, we invite you to download the Sony Digital Cinema™ 4K White Paper. http://pro.sony.com/bbsccms/static/files/mkt/digitalcinema/Why_4K_WP_Final.pdf
2. Study conducted by Parker Marketing Research at a Sony Pictures Entertainment screening room on March 3-4, 2009.

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