Pixel Pitch: What is it?
Why Does It Matter?

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Introduction:

High resolution, high definition, pixel density, pixel pitch etc., etc., - at the end of the day, what do all these terms mean as they relate to your potential digital display? In the following pages, these and other terms will be demystified and placed in the proper context for investigating LED display technology for your particular application or project.

Frequently AV professionals ask essentially irrelevant questions when trying to ascertain whether a large-format LED display of a particular dimension will deliver the content clarity and sharpness they require for an application. This is largely as a result of the comfort in using incumbent LCD technology terminology inherited from earlier generations of resolution parlance. Questions such as: “Are your displays Hi-Def? Are your displays 4K?, Can I run HD content on your display?” Let’s take a look at what these terms really mean.

Resolution: High Definition vs. High Resolution

In summary, High Definition and High Resolution are terms that attempt to describe the clarity and sharpness of digital content being delivered via some form of viewing technology.

High definition and high resolution are often used interchangeably and sometimes share a similar connotation depending on the audience, but they are actually quite different. Both are measures of resolution, which is defined as the fineness of detail that can be distinguished in an image.

High Definition is a situational definition of High Resolution. In order for a digital image or video content to be considered “HD” it must meet 3 specific criteria: 1) The display must be a widescreen format incorporating a 16:9 aspect ratio, 2) have a resolution of at least 1280 pixels x 720 pixels, and 3) a frame rate between 24 and 30 frames per second. In order for something to be “true HD”, it must have a resolution of 1920 x 1080, commonly known as 1080p (p stands for progressive scan). These constraints were created as units of standardization for the AV industry, but the constraints are not necessarily optimal for every situation.

High resolution on the other hand is a more nebulous term and can refer to any display with a resolution that is sharp and finely detailed. As long as an image looks clear and detailed to the human eye, it can be considered to have a high resolution, even though it may or may not be HD.

Let's look at an example of why one of these terms doesn't really apply to large-format LED display technology. Your question might be "Are your LED displays true Hi-Def?" Well, if by high definition you mean 1080p, maybe not. In order for say a 4mm pixel pitch large-format LED display to be "High-Def" it would require it to be a minimum of 25 feet in width (at 305mm per foot there are roughly 76 pixels in a linear foot of this display). If the pixel pitch increases to 6mm, it would have to be a minimum of 37 feet in width! If your question changes to "Are your LED displays 4K?" in effect you're asking if they are (4 x HD) and…well, you do the math. You're describing a *huge* LED display area.

The question you really want the answer to is "Can I show high resolution content on a large-format LED display?" The answer is…yes…on some of them…depending on the total number of pixels (stated as the "pixel matrix".) High resolution content can be scaled to display properly and affectively on large-format LED displays of a high quality manufacture, where the LED lamps can properly emit content in a manyX:1 ratio.

Pixel Pitch – The Heart of the Matter

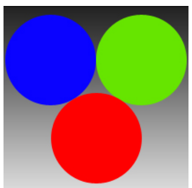
Now let's introduce the term in question - Pixel Pitch.

Pixel pitch and it's analogs, dot pitch, line pitch, P(x), strip pitch etc….what does this mean in terms of practical application as it is used in digital display technology and digital signage?

First, let's define what a pixel is before we discuss its "pitch." In digital imaging, a pixel, or pel (picture element) is a physical point in a raster image, or the smallest addressable display element in a display device; so therefore, it is the smallest controllable element of a picture represented on the display.

The address of a pixel corresponds to its physical coordinates. LCD and LED pixels are manufactured in a two-dimensional grid, and are often represented using dots or squares, but CRT pixels correspond to their timing mechanisms and sweep rates.

Each pixel is a sample of an original image; more samples typically provide more accurate representations of the original. The intensity of each pixel is variable. In color image systems, a color is typically represented by three or four component intensities such as red, green, and blue, or cyan, magenta, yellow, and black.



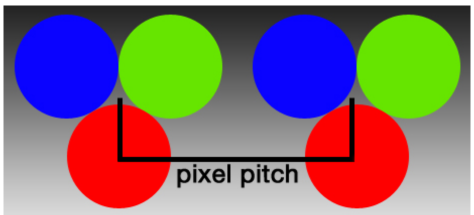
On a discrete LED or SMD-LED (surface mount device – LED) display, a pixel is in actuality an LED lamp composed of three “sub-pixels,” each of which is an individual LED comprising the three RGB components.

Now let’s discuss the “pitch” of “pixel pitch.” In its true definition, “pixel pitch” is the term used to describe the distance between pixels on televisions, monitors and other display screens. When discussing flat panel or curved display panels, where the display is either a light-reflecting or light emitting technology, pixel pitch is measured on the surface of the screen or display. With projection technology, it is measured at the projection source rather than the destination screen.

But all of that is academic in that you, during the course of vetting an appropriate display technology for your particular application, are unlikely to hear the term “pixel pitch” used to describe image quality on LCD, LED back-lit LCD, Front or Rear Projection, or any of the niche “tile” technologies. These technologies are more likely to be described in terms of their “resolution” or “definition” (e.g. high-definition, high-def, high-res, 2x, 4x, etc.)

The term “pixel pitch” is typically reserved for LED display panel technology.

In relationship to outdoor/indoor discrete and SMD-LED display technology we are talking about the horizontal and vertical distance between the centers of discrete LED lamps composed each of a red, blue and green diode.



So what does all this mean for my potential LED display application? At the end of the day, when inquiring about the pixel pitch of a particular LED display grid, you’re in effect asking – “How clear is the imagery that I’m trying to show going to be?”

That question is going to be answered by several additional ones: A) at what minimum distance, and further back, would your audience likely view the completed display installation? B) What is the nature of the content and your suspected length of audience interaction with that content? - Which leads to a subjective discussion of, “what is your tolerance for pixilation of that content?”

Let’s step away from the minutiae for a minute and look holistically at what you are really trying to accomplish. When reviewing a display application for technical fit, one should ask the larger question, “What am I trying to do?”

With an overlay of the aforementioned questions, let's look at a couple of scenarios where LED display technology could be deployed.

Scenario 1: You want a display to show a rotation of digital images and large-format text advertising to quickly inform customers entering your retail environment of current sales and lines being promoted. Here, let's assume that the display is going to be mounted above the entryway to a retail store and glanced at for perhaps 10-15 seconds by customers entering the store. The customer interaction with the display is going to be informational in nature and of a short duration. The minimum viewing distance in any real sense is going to be 15 feet and back.

Scenario 2: You want a display to be mounted above and behind a bar area within a resort destination showing high-definition simulcasts of major sporting events and performances of Grammy-winning musical artists – in effect simulating to the nearest extent possible, the experience of being live, in-person at the shown venue. The minimum viewing distance is potentially 10 feet, but using the 80/20 rule, a vast majority of the viewers will be 18-20 feet back and beyond. The duration of audience interaction with the content is likely to be anywhere in a range of 15 minutes to upwards of 3 hours.

In these two scenarios, there is a difference in the intended content, length of interaction with the content, resolution tolerance of the content, minimum viewing distance to the content and potentially over-all surface area of the content – all speaking directly to the appropriate pixel pitch of the LED display to be used.

Let's address the individual concerns dictating appropriate pixel pitch for an LED display application one at a time.

Minimum Viewing Distance

Depending on the pixel pitch of the display, a greater or lesser minimum viewing distance is possible before an image "pixilates." That is to say, there is a minimum distance beyond which a human eye with natural or corrected vision of 20/20 can no longer discern individual pixels on a particular display.

A general layman's rule of thumb says that distance is roughly 3x in the distance in feet as the pixel pitch is in millimeters. For example if a display was manufactured using a 5mm pixel pitch, you would begin to recognize individual pixels on the display at about 15 feet and closer (3ft.x5 = 15ft.).

The smallest viewing distance and LED display specification

Viewing Distance (m)	3 ~ 5	5 ~ 8	8 ~ 10	10 ~ 12	12 ~ 16	16 ~ 20	20 ~ 25	> 25
Viewing Distance (ft)	10 ~ 16	16 ~ 26	26 ~ 33	33 ~ 39	39 ~ 52	39 ~ 66	66 ~ 82	> 82
Pixel Pitches used depending on pixilation tolerance	P3 P4 P4.75	P4.75 P5 P6 P7.62	P7.62 P8 P10	P10 P12	P12 P14 P16	P16 P20	P20 P25	P25 P31.25

With LED display technology, however, this minimum viewing distance can be conditional based on the overall surface area covered by the display. This is true for a number of reasons. One, if a display is 20’ in width by 16’ high it will have exponentially more pixels to replicate the intended image than say a display of 10’ by 8’ providing more information for your eye to process, thereby increasing human-eye perception of resolution.

Additionally, because LED is a light-emitting technology versus a light-reflecting technology, the gaps between pixels tend to “soften” and are therefore, perceived as less distinct when resolved by the human eye. This optical artifice is accomplished in much the same way that oncoming automobile headlights at night radiate light into the surrounding dark space immediately surrounding their edges.

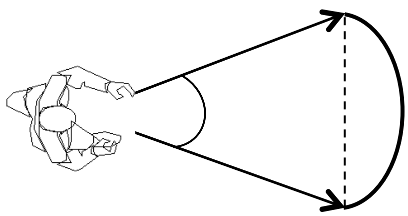
Optimum and Minimum Viewing Distances and Human Eyes:

The last major consideration we’ll look at is Optimum Viewing Distance. Simply put, optimum viewing distance is the distance from your display, where the individual pixels in a display resolve to form one clear image to the average viewer. The larger the pixel pitch and lower the pixel density, the further your optimum viewing distance will be from the display. Conversely, the smaller the pixel pitch and higher the pixel density, the closer your optimum viewing distance will be. Resolution only comes into consideration as it relates to pixel pitch and pixel density.

One of the most familiar examples of how our eyes resolve a large-format LED display is the common digital billboards you probably see on your daily commute. From the distance you view the billboard; it looks like one solid image. The images are crisp and the words easy to read. However, if you were to climb up to that billboard and examine it close-up, you would see that it is actually made up of hundreds of pixels spaced so far apart that it is impossible to see the image at all (an average 14’x48’ billboard contains on average just over 150,000 pixels – actually *far less than* a 16:9 aspect 112” diagonal 6mm pixel pitch display). So, why do these dots merge together to form a single cohesive image from far away? The answer lies not within the specifications of the display, but in the science of your eyes.

As distance increases, your eyes can no longer tell the difference between two pixels, their respective colors blend together and they simply merge to form one image. The amount of pixels our eyes are able to “resolve” or distinguish between decreases as we move further from what we're seeing. Take a look at the example below. As the image gets farther away, the individual pixels merge together to form a single crisp image.

Resolving distance is most accurately defined in terms of an angle. Imagine that the human eye is at the vertex of this angle, which means that the field of view is expressed as the arc created by the triangle as you can see in the diagram below.



The average human eye can only resolve 1/60th of a degree of this arc. So, if the distance from the display increases, then the arms of the angle get longer, and the termination points of the arms get further apart, therefore, 1/60th of a degree contains more data. In other words, as we move further from a display we are decreasing the amount of individual pixels that our eyes are able to resolve resulting in the merging of all the pixels into a crisp, clear, cohesive image on the display. So, how does this relate to resolution, pixel pitch, and pixel density?

The best resolution, pixel pitch and pixel density for your display is subjective based on the size of your display and where the display will be viewed from most often. You should make sure that the optimum viewing distance of the display you are considering is the same or less than the actual viewing distance from your display installation.

See for Yourself:

The concept of how your eyes merge individual points into one cohesive image is similar to the way a newspaper or magazine is printed. If you pick up a newspaper and look at it from close proximity or under a magnifying glass, you will see that each picture is made up of small little dots. The distance you read the paper from allows your eyes to merge these dots together for the picture. When you examine a magazine, the image may look even better. This is because magazines often have a higher concentration of "dots per inch" or dpi (similar to pixel density.)

Intended Content and Pixilation Tolerance:

Knowledge of this piece of the application will address a number of questions including: intended length of content audience interaction, intended effect of the content on the viewer and tolerance for pixilation of the content. Let's go back to our two scenarios described above. The content in scenario 1 is intended to be informative, consumed in passing, quickly processed and potentially persuasive affecting purchasing habits of the viewer. The information conveyed is more important than the clarity or resolution of the image. It can still be eye-catching, flashy, have an aesthetic "WOW!" impact, but the tolerance for pixilation is likely to be greater here than in…

…Scenario 2. Here, the intention of the content is to attract, entertain, capture and hold the intended audience in a particular venue for an extended length of time, where perhaps, they will consume food and beverages, engage in amusements or other revenue producing activity and potentially encourage their social acquaintances to join them to do the same. Likely the tolerance for this audience is going to significantly less than in scenario 1.

Oh Yeah…and One More Thing – COST.

We would be remiss if we didn't show the relationship between pixel pitch and cost. Simple cost economics will dictate that you will pay more for a higher volume of anything. In this case we're talking about individual LEDs and LED lamps. When you drop a pixel pitch from say 6mm to 5mm, you will consume *exponentially more* pixels (read: LEDs) using the same width and height dimensions for a display. In many applications, this becomes the most important consideration, often causing the project owners to adjust expectations and engage in "value engineering," or in effect compromising expectations of what can be done.

Why all of this Matters:

Since we have shown that best resolution, pixel pitch, and pixel density is subjective based on where your display will be viewed from, how do you decide which display is right for you? The "better" the resolution, the higher the cost of a display due to the increase in number of LEDs, so you want to make sure you purchase the right display without purchasing too much display and overspending.

For this reason, it is important to see the display technology for yourself and perform a visual evaluation of the intended technology and simulate the conditions under which the intended application is to perform. Remember, not all LED display boards are created equal and just because a 4mm pixel pitch looks perfect from one manufacturer doesn't necessarily mean they all will. In other words if you evaluate Brand A, don't assume Brands B, C and D all look exactly like A.

There are other specifications outside the scope of this paper that you will want to consider as well, for instance, brightness, color contrast, off-axis viewing angle, power consumption, total cost of ownership and even content creation best practices, which your digital display professional will be able to help you with.

About NanoLumens:

NanoLumens (www.NanoLumens.com) turns display dreams into reality. With a unique and patented ability to create displays that are flat, curved or round, NanoLumens LED displays can bring any space to life. With installations with Fortune 500 customers on four continents, the Norcross, GA based company can meet customer needs wherever they might be. NanoLumens displays are space efficient, extraordinarily environmentally friendly, and offer a low cost of ownership. All NanoLumens displays are designed and assembled in America.