

White paper:

The ultimate guide to LED: High-impact visuals indoors and outdoors



Introduction

Eyes popped and jaws dropped when large scale, bright digital displays started finding their way into sports and entertainment venues as replay, score and information boards. Now, the next generation of LED-driven display technology is finding its way into everyday use for businesses — mainstreaming what used to be highly specialized technology with limited applications.

LED displays were, for many years, best viewed at considerable distances because of their technical design limitations. Now, direct view LED displays offer rich,

crisp viewing in a wide range of use cases, both indoors and outdoors.

The latest-generation LED displays create a superior viewing experience than conventional flat panel LCD displays — delivering premium color reproduction and sharp visuals even when the audience is in close proximity.

This white paper takes a deep dive into the technology behind LED displays, how they differ in types and applicable uses, and why they're now a viable option for mainstream display technologies.



LED basics: Miniaturized lights create larger-than-life displays

LED is short for light-emitting diode — miniscule chips of light that produce the red, green and blue lights that drive the visuals on full-color digital displays. What started as small, bulb-like devices have evolved through the years to much tinier light chips — the size of grains of sand — packaged together and set in electronic modules.

The next-generation of LED — called microLED — is built around light chips so small they're hard to see without the help of a microscope's lens.

The technology is now often described as direct view LED. Adding "direct view" provides some clarity for both sellers and end users.

The "direct" distinction refers to how viewers are looking directly at the LED light source and its constantly blending red, green and blue light chips. Most televisions and

commercial flat panel displays, meanwhile, use white LED chips to illuminate the LCD, or liquid crystal display, layer that provides the visuals. But viewers don't directly see those LEDs.

Direct view LED displays are generally manufactured as modular units that are then consolidated into display cabinets. Those cabinets are then stacked and tiled together to create displays that are not constrained by the rectangular norms of LCD displays. While 16 cabinets tiled across and stacked nine high could create a super-large version of a conventional widescreen display, LED opens the possibility to think beyond TV-like rectangles.

An LED screen can be as wide or as tall as it needs to be. It can scale in size to meet the dimensions of a room and even work its way around and over entryways. Versions can be gently curved against walls. LED can be suspended facing down from a ceiling (something not possible with LCD's core technology) and function as an active and interactive floor.

Specifications vary between products and types, but LED is generally much brighter than conventional LCD displays — fully capable of overcoming reflection and the glare of the sun or bright ambient lighting. Drapes don't need to be drawn, blinds don't need to be closed and lighting dimmers don't need to be used to view most direct view LED displays.

The biggest attraction to LED for indoor applications, however, is in the edge-to-edge design of LED display cabinets. Even premium LCD video walls require a frame that holds the units together. When displays are stacked and tiled to create LCD video walls, even the skinniest bezels (frames) create thin but noticeable grid lines. With high quality, properly installed direct view LED, video walls are truly seamless — with no lines interrupting the content and viewing experience.

Some direct view LED manufacturers, including Samsung, have developed bundled solutions for smaller projects, using fixed sizes and setups that equate to super-large TVs. Solutions providers and end users who are unfamiliar, and possibly uncomfortable, with the custom design required in direct view LED projects can instead buy bundles with all the technology components they need in turnkey sets.

Key components

Components can vary by manufacturer and job, but the key components of a direct view LED system are:

- **LED display cabinets**
And their interconnecting system
- **Media playout hardware**
Everything from a simple PC to more sophisticated image processing and display control devices
- **Media playout software**
Everything from manufacturer-supplied, simple control software to full digital signage content management systems and video wall management applications that handle multiple sources and streams at once
- **Mounting and other infrastructure**
Relatively simple variations on LCD video wall mounting systems to custom metalwork, data closets and remote power supplies

Technology tuned to tasks

There are two primary types of LED displays: outdoor and indoor.

Both types share many of the same core technology attributes — notably the idea of LED light chips in tiled arrays. But the engineering and use cases can be dramatically different.

Outdoor LED

Technology that needs to work reliably outdoors demands different engineering than similar-looking and -working devices intended for indoor use. The biggest factors are variable weather conditions, dust, pollution and sunlight.

Outdoor displays are engineered to work reliably for years in everything from snow, rain and wind to extreme temperatures. They generally have Ingress Protection (IP) ratings that specify the level of protection against elements and airborne particles.

In almost all cases, the density of light pixels used in outdoor displays is far lower than the density used in indoor configurations, simply because viewers tend to see the displays at far greater distances. That density is referred to as pixel pitch (more on that below).

Those outdoor displays intended to be seen from considerable distances — sometimes from hundreds of feet away — often use dual inline package (DIP) LED diodes. Shaped like miniature Christmas tree lightbulbs, they offer high durability and brightness at less cost than newer “packaged” LEDs.

The downside of DIP is the diodes are relatively large and, therefore, can't be packed together to a density of pixels that delivers a positive viewing experience at closer distances. In short, screens that look amazing at a distance start to degrade in image quality as viewers get closer. Their eyes start to discern the individual light pixels and the image visually pulls apart.

A version of the surface mounted diode (SMD) technology used for most mainstream indoor direct view LED displays is used for higher-resolution outdoor projects, such as high-profile advertising displays in major cities. (Think Times Square in New York and Leicester Square in London.) It is also being used for live game screens on the facades of sports venues, so fans who couldn't score tickets can still go to the venue and have a shared game experience.

Outdoor LED is also being capably applied for more utilitarian applications, like dynamic information and visitor directions

at the entry gates to attractions and large venues and as messaging beacons for everyone from shopping mall operators to automotive brands and their dealers.



Samsung leads the outdoor LED market

Samsung markets numerous outdoor-rated and ready LED display products sorted primarily by pixel pitch, brightness and application. Samsung displays are in action everywhere from sports stadiums to New York's Times Square.

Pixel pitches for outdoor LED displays typically range from 6mm to 20mm.

Pixel pitch explained

Both indoor and outdoor LED products have a base rating of their pixel pitch, which is directly related to the concept of pixel density. Each is measuring the amount of light pixels in a prescribed dimension, like pixels per inch, centimeter, foot or meter.

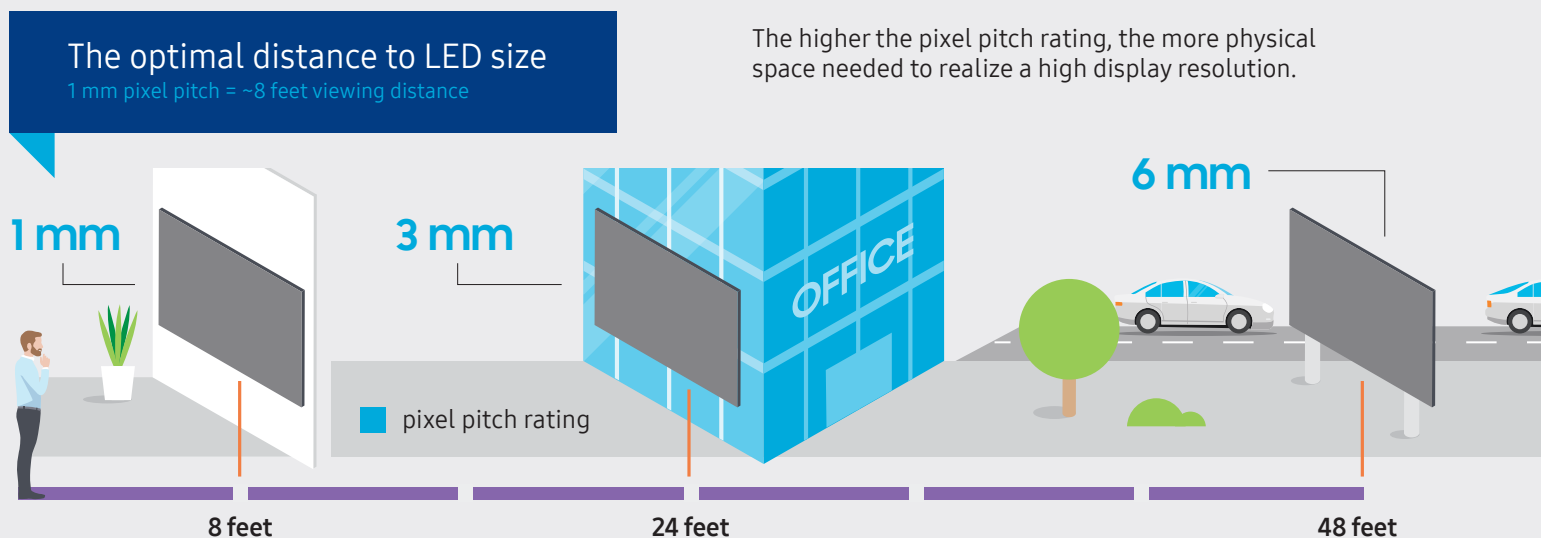
Pixel pitch is the measure of distance in millimeters between the center of each LED package. An outdoor display suited to an advertising billboard along a major highway may have a pixel pitch of 16mm, sometimes referred to as P16. An indoor display, by comparison, may have a pixel pitch of 1.6mm, meaning the light pixels are packed together at a far higher density.

The calculated distance numbers can vary, but the optimal viewing distance is typically considered roughly 1 millimeter for every 8 feet of viewing distance.

So, a super-fine pixel pitch display rated at 1mm has an optimal viewing distance of 8 feet. That means the display looks crisp and vibrant at the viewing distance used in the living rooms of most consumers.

If the average viewer will be 24 or more feet away, then an LED display with a pixel pitch rating of 3mm will deliver the same visual experience as the 1mm display, but at a lower pixel density and cost.

However, a direct view LED rated at 6mm pixel pitch, when viewed at 24 feet, would look unsatisfactory to viewers because their eyes can see the individual light pixels. If they stepped back to 48 feet or further, their eyes would no longer see each pixel, and the visual experience would tighten up.



The pitch is important for two key reasons:

Cost: Pixel pitch or density is most actively sold and used at roughly 1mm to 3mm for indoor applications, though there are options with lower densities and a variety of manufacturers offering solutions that are 1mm in pitch or even finer. The simplest equation here is: More electronics equals more cost.

Displays with higher pixel density are more expensive, which is the main reason why direct view LED displays often share key product characteristics but come in a variety of pitches.

Smart projects “right-size” the display pixel pitch to match the expected viewing distance, as there is no tangible benefit to using costlier, finer pitch displays. Viewers won’t appreciate the difference unless they come closer than the defined, expected distance. Samsung LED displays range from 0.8-16.6mm pixel pitch.

Resolution: With conventional displays, resolutions such as Full HD and 4K are contained within single LCD or QLED units. Whether a 55, 65, 75 or 85-inch display, that single unit can likely deliver 4K or even 8K resolutions. With LED, each display cabinet has a defined number of LED lights, which directly equate to pixels.

If a display cabinet has roughly 400 horizontal pixels, a tiled LED video wall would need about 10 cabinets tiled horizontally to add up to the 4,000 or so pixels needed to deliver 4K visuals accurately. A 4K LED video wall might need to fill the entire wall of a room, whereas a 4K LCD would just mount on a small portion of that wall.

The higher the pixel pitch rating, the more physical space needed to realize a high display resolution.

Indoor LED

Numerous technology advances have enabled LED to expand its applicability inside venues of all kinds, and LED is starting to replace LCD technology for video walls. The technology is also expanding how digital displays can be applied across diverse vertical markets and use cases.

Display cabinets are smaller and quieter, the displays manage power better (leading to lower operational costs), and serviceability and management are much easier than in past generations. But the real game-changer has been the evolution of how light chips are made and packaged.

Advances in SMD technology have made the light packages increasingly smaller in dimension, which has, in turn, made it possible to pack light pixels closer together and resulted in LED displays that look amazing from just a few feet away.

The technology has also followed the advancement path of flat panel displays, using sophisticated image processing and handling technologies, like AI upscaling and high dynamic range (HDR), to make what can be super-large screens look as good as premium consumer TVs. LED's advanced grayscale technology delivers consistent reds, greens and blues without distortion.

High pixel density enables everyone from retailers, venue operators and media brands to do marketing, promotions and advertising with super-sized visuals that can dominate designed spaces. But that density also opens up the ability to put these big, bright and seamless displays to use in operational situations.

Fine pitch displays in control rooms, command centers and network operations facilities all benefit from wall-filling displays that have the brightness to be comfortably seen in rooms flooded with artificial or natural light. They're also sufficiently tight in pixel density to show text, schematics and high-resolution imaging without making any visual compromises.

The early adopters for fine pitch LED displays were flagship retailers and specialty environments like casino sportsbooks. But as pitches have tightened, costs have lowered and industry awareness has grown, fine pitch LED began seeing much wider application.

Fine pitch LED can be found lining the concourses of sports arenas, airports and conference centers, but they're also the feature walls in skyscraper lobbies, the big screens in sports bars, and the marketing and promotions displays in flagship retailers.

LED has evolved from a specialty application to a mainstream option for a venue owner or operator who wants to make a visual statement that dominates the space or fits its dimension and dynamics.

Samsung has a broad range of indoor-focused LED products

IE and IF Series

The mainstream IE and IF Series come in a range of pixel pitches, from 1.2mm to 6mm. Some versions are also pre-sized and bundled with all the accessories and support needed to start quickly.



The Wall for Business (IW)

Stunning, premium microLED displays at 0.8mm, 1.2mm and 1.6mm pitches. See more below.



The IE, IF and IW series are all TAA-compliant, secure and ready for use in sensitive government and military installations.

The Wall: Breakthrough LED technology

Major global display manufacturers like Samsung are now heavily involved in both indoor and outdoor LED, and these widely known global brands are joined by a subset of large specialty LED display companies and hundreds of smaller LED manufacturers, many servicing their domestic markets (notably China).

All that activity breeds not only competition, but also innovation. Research and development (R&D) has pushed down the size and price of LED packages and triggered new manufacturing processes and types of LED.

Manufacturing processes like Chip-on-Board and new chip sizes like miniLED have emerged, but most observers see microLED as the future of direct view LED.

A handful of microLED products have come on the market, with Samsung's cutting-edge The Wall garnering the most recent attention and marketplace adoption.

With The Wall's microLED, the story is less about pixel pitch and more about the microscopic size of the light chips and how that leaves much more room for black backgrounds. The Wall, an LED display like none other, surrounds each tiny set of red, green and blue light pixels with much larger swaths of black, producing high levels of contrast normally seen on premium flat panel displays. This minimizes interference and glare from natural or ambient lighting.

Image and color quality rely heavily on producing deep and true blacks, and in more conventional SMD LED displays, the tight pixel densities pack in the light chips. That largely hides the black background of the display modules, reducing contrast.

Samsung's microLED also addresses a common operating concern in the AV industry. Conventional SMD-based LED displays are fragile and easily damaged, accidentally or



willfully. The little light packages are soldered to printed circuit board backplates and are easily knocked off by an errant hand or bag in a store. They're also exposed to accidental spills and electrostatic shock.

At times, video wall owners have had to resort to ropes or even security staff to keep the screens safe from damage.

The Wall, by comparison, has a coating over its microscopic LEDs that is impact, dust and spill resistant. In scenarios such as flagship retail store feature walls, operators using The Wall would not have to worry about damage and costly repairs.

MicroLED is still relatively new on the market, and it is positioned as a premium product. It's being used in luxury retail, corporate briefing centers and even executive offices by companies who want to make a big, seamless and jaw-dropping visual statement. Homeowners who want a bold living room centerpiece or a flawless home theater display, such as entrepreneur Phil Trubey, have had The Wall installed in their homes.

R&D work is happening globally to address some of the key barriers to reducing costs and triggering widespread adoption. The biggest challenge is refining manufacturing methods that speed up the accurate placement of millions of tiny LEDs on electronic substrates, while minimizing the number of dead or damaged pixels that can be inherent in mass manufacturing.

Industry observers expect this to be resolved relatively

quickly, and when that happens, microLED adoption will become widespread.

The new finish

Direct view LED changes how professionals think about designed spaces. Historically, architects and commercial interior designers have looked at big spaces in retail, public buildings and workplaces and made decisions about wall finishes that involved materials like paint, stone, metal, glass or other finishes. If digital was incorporated, displays were added to the wall or built into it — like a big LCD video wall array attached to a main wall in a lobby or concourse area.

Now, LED can be the wall, the ceiling, the support columns — whatever a designer dreams up. Designers are excited about the possibilities for a few reasons:

- The look and feel of a feature wall or ceiling can have motion and vibrant colors.
- The on-screen content can be scheduled by time and date, or creative pieces scheduled or launched on demand.
- Changes to walls made of granite or tile require costly, disruptive construction projects. With a direct view LED display wall, if the owners or bosses want to change the look, the only revisions needed are new or different creative files. The look of the wall can be entirely transformed with just a few keystrokes.



LED displays are being used as the feature walls in office tower lobbies, hotels and airport concourses. They're the experiential show in waiting and greeting areas, and the motion backdrop at everything from hotel reception desks to airport rental counters.

They're abstract sculptures running digital art, but they're also feature entertainment screens in sports bars and poolside at resorts. The giant sportsbooks in major casinos have converted many properties from older technologies like rear projection cubes to seamless LED that can curve with corners.

LED at work

In addition to LED being used as a design feature, it has a huge array of practical applications. Here's how direct view LED is being used in some highlighted vertical markets:

Corporate

Along with high-profile lobby feature walls that attract new office tenants and make existing ones want to stay, large LED display walls are being used for branding and other messaging in reception lobbies. Seamless display walls are replacing projection in executive briefing centers or boardrooms, and fine pixel pitch products like The Wall for Business have sufficient crisp, rich visual qualities to work as large format displays in control rooms and operations centers. Outdoor LED can welcome and inform employees or visitors with vibrant visuals.



Retail

Many flagship stores have shifted design thinking for in-store digital from multiple smaller flat panel displays, or LCD video walls, to large-format LED feature walls that drive both the brand and the shopping experience. Individual retailers and malls have also started installing LED displays on the outside of their stores — using LED as gateways that flank the entry, act as entry ceilings or even become a fully active store facade, replacing traditional signs and store exterior design elements. Interior design centers and real estate sales galleries are leveraging The Wall for Business to showcase high-end products with high-end visuals.



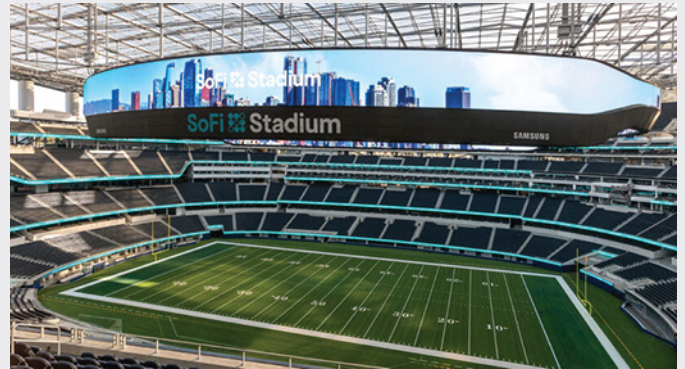
Automotive

Traditional big parking lot auto dealers are using outdoor LED on buildings and at roadsides to attract consumers, and then using large screens inside showrooms to create visual excitement and to drive the brand and buyer emotions. With increasingly urbanized populations, auto manufacturers have started creating micro and satellite showrooms in downtown shopping malls, busy retail streets and even in airports. With just one or a handful of cars on display in such showrooms, manufacturers then use wall-filling LED displays to share several product offerings, giving customers a multitude of options.



Sports & entertainment

Arenas and stadiums were among the earliest adopters of LED, and buyer demand has broadened through the years. Along with giant LED scoreboards and replay screens in the seating bowls that provide immersive experiences, sports and entertainment venues are using LED displays and ribbons in the fan concourse areas for advertising and sponsor support. The big screens enable a billboard-like presence at eye-level, but also enable arena owner-operators to easily change sponsor messaging between events. While an ice hockey team may have one set of sponsors, an NBA team that also plays there may have entirely different tenants. Big LED displays on the facades of buildings also enable owners to promote events and sell tickets, as well as show live games outside and run special events. The Wall in owner suites and club spaces elevate the experience and distinguish stadiums as technology leaders.



Food & beverage

The ability to change menus or update pricing drove the switch from static to digital signage in restaurants over the last few years. Now, fast-casual restaurants can display delicious menu items with true-to-life colors using LED menu boards and outdoor video displays that entice consumers. Outdoor electronic message centers showcase ongoing promotions and help customers choose what they want before they even enter the premises.



Federal government

The crisp, precise visuals of LED aren't just a nice-to-have in command and control centers. In these mission-critical operation centers, The Wall's accurate colors and high-contrast ratio allow operators to make informed decisions. Because of its superior visuals, 24/7 operational capabilities, fast refresh rates and TAA compliance, command rooms are upgrading from projection cubes and LCD video walls to the microLED Wall. Outside control rooms, LED signage is being used at military bases and hospitals for wayfinding.



Healthcare

In what can often be a high-stress environment, LED signage inside and outside a hospital helps ease the anxiety of patients and visitors. Outdoor electronic message centers direct patients to the right entrance and parking area on a hospital campus, while LED signage indoors helps individuals find the right floor for their appointment or to visit a loved one. Hospitals are also trading in static donor walls for video walls, creating an engaging visual impact for visitors while honoring donors and soliciting new donations.



Education

A continuous pain point for academic campuses is communication, especially as K-12 and higher education move toward hybrid models. LED signage creates a connected campus, informing and inspiring students, faculty and visitors — whether that's the outdoor marquee reminding everyone of upcoming parent-teacher conferences or the football field's video scoreboard announcing the school's win. In the front office and hallways, LED signage can help visitors get where they need to go, then switch to a slideshow of student art or a congratulatory message for a debate team win. In emergencies, signage across the campus syncs to display instantaneous messaging to evacuate the building, stay in place or move to a certain part of the campus.



Spectaculars & outdoor signage

The "wow" factor of digital out-of-home (DOOH) displays is amplified by leading outdoor LED technology. Cityscapes, from the Las Vegas strip to Times Square, are creating dramatic, memorable visuals that encapsulate a brand with the help of innovative LED technology. Brands can trust that their logo and colors will look exactly the way they intended due to the high brightness, deep contrast and full spectrum of vivid colors available with LED.



Hospitality

Like elsewhere, first impressions matter in the hospitality industry, which is why hotels, resorts, casinos and cruise lines are using The Wall and other LED signage in their lobbies to create a moment guests won't forget. Striking, life-like videos show the experiences guests are after — like lounging on a white sand beach or winning big on the casino floor — exciting guests and setting the mood for their stay. In high-end suites, The Wall enhances the luxury of the space.



The timing is right

LED display costs have dropped substantially in recent years as the quality and resolution of these displays have increased dramatically. That owes to rising marketplace demand and manufacturing capacity, as well as a better understanding of direct view LED among the professional AV community and their customers.

The cost differences between an LCD video wall and one done at the same dimension using direct view LED have been narrowing. Fine pitch and premium microLED display walls cost more than LCD, but this higher cost is balanced out by the following factors:

- ✓ **Long operating lives**
LED video walls can last eight to 10 years. They are tested to withstand vibration and environmental rigors for 24/7 seamless picture quality.
- ✓ **Design and use flexibility**
There are few location and technical restrictions. Wherever someone wants LED, they can have it.
- ✓ **Bright outlook**
LED delivers clear, glare-free viewing thanks to its brightness. Reflections or glare from natural or ambient light is not a limiting factor.
- ✓ **Lower maintenance**
LCD video walls are prone to drifting color and brightness properties, requiring regular, costly calibration and other maintenance. An eight-screen LCD video wall may, after a matter of months, show a single scene in eight versions of blue. Good LED systems and image processing ensure uniformity across a seamless viewing display, demanding minimal upkeep.
- ✓ **Cut costs**
Enhanced picture quality of LED signage reduces overall energy consumption, which lowers operating costs.

LED has mainstreamed

Just as flat panel TVs were a novelty 15-20 years ago and are now in almost every home, LED is transforming from a specialty display product to a mainstream visual application and design consideration.

Unlike flat panel TVs, which are essentially just larger, lighter and thinner versions of the originals, LED is mainstreaming as a technology but still evolving in its types and uses.

Already, LED displays are cladding buildings and embedded in everything from film and foil to commercial window glass. The near-term future will see the full-motion visuals of LED everywhere, and in ways still being dreamed up by forward-thinking enterprises — like yours.

Samsung offers the most comprehensive portfolio of indoor and outdoor LED displays on the market today. With an expansive range of sizes and shapes — for business or luxury consumers — Samsung's solutions have nearly endless applications.



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