

## Deep Dive into Curved Displays

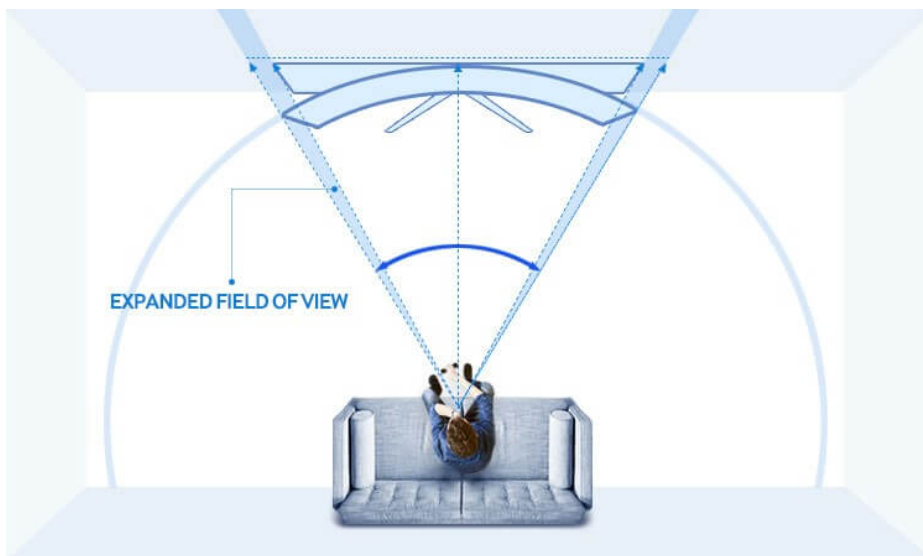
First introduced at CES 2013, curved displays were primarily used for TVs. Today's curved technology employs a range of backlighting technologies, comes in a variety of sizes, curvatures, and resolutions optimized for a wide range of applications—TV, monitor, smartphone, and wearables.

Let's take a closer look at curved displays: how does the technology work and why are these screens gaining popularity?

### Do curved displays enhance the viewing experience?

Vision is not what you see, but what you perceive. The main objectives of the curved design are to provide a wider field of view (FOV) and improve the perception of vision—a challenge that occurs due to the physiology of the human optical system.

The human visual field is described by the angle that is visible during sight fixation. Curved displays expand the field of view (FOV) by bending the edges of the screen towards the viewer and making the image enter the peripheral vision area. This makes the image look wider and improves depth perception. Because of this effect, curved displays are said to provide a more **immersive**, theater-like experience.

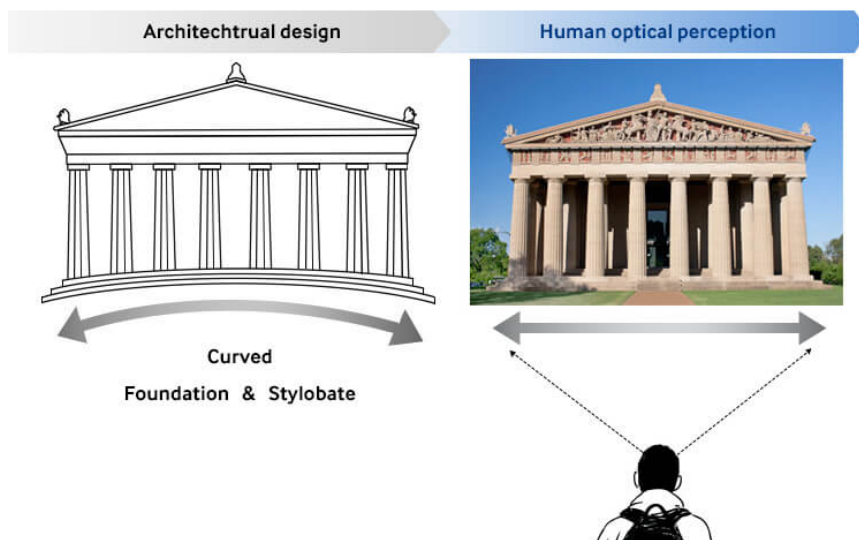


*Curved displays provide an expanded field of view*

Another aspect of human vision that is being 'corrected' via curved technology is the image distortion that occurs due to the spherical shape of the eye's retina. While flat images may appear slightly tilted—an effect referred to as a **trapezoidal distortion** in geometry—if the screen is curved, the image, in contrast, appears flat to the human eye.

## Rooted in history, recreated by technology

The master builders of Greece were well familiar with this effect. One of the greatest ancient cultural monuments, the Parthenon built in 432 BC was designed considering this [difference in perception](#). While the Parthenon 'looks' flat to the human eye, it is built on a curved foundation and stylobate. The curve reaches 2 3/8 inches on the end facades and 4 5/16 inches on the long facades, for a [radius of 3 1/2 miles](#). Striving for perfection, the designers added these curves, compensating for the illusion by creating their own curves, thus negating this effect and allowing the temple to be seen as they intended.



*The Parthenon was designed to factor in human optical perception*

As the famous British historian and travel writer [John Julius Cooper](#) observed, "(Parthenon) enjoys the reputation of being the most perfect Doric temple ever built. Even in antiquity, its architectural refinements were legendary, especially the subtle correspondence between the curvature of the stylobate."

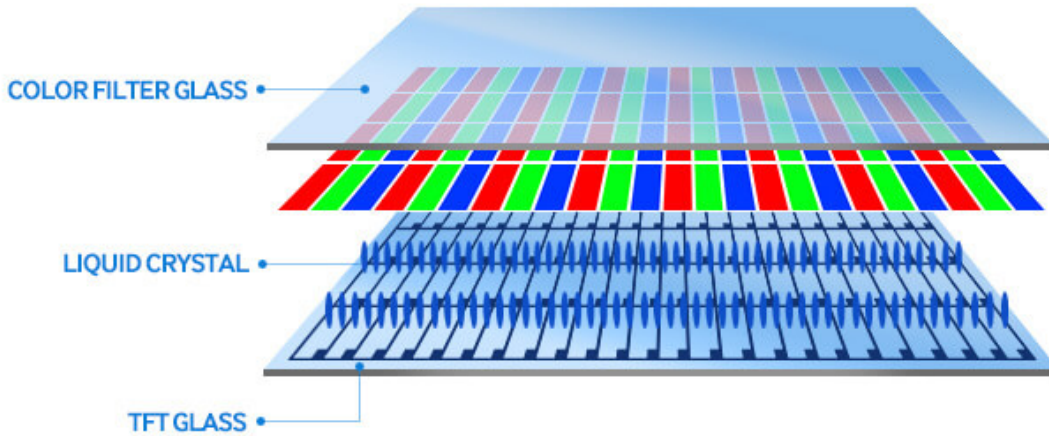
Until recently, technology hurdles prevented displays from adopting this feature. Let's examine the technology that brought curved displays to the market.

## How are curved displays built?

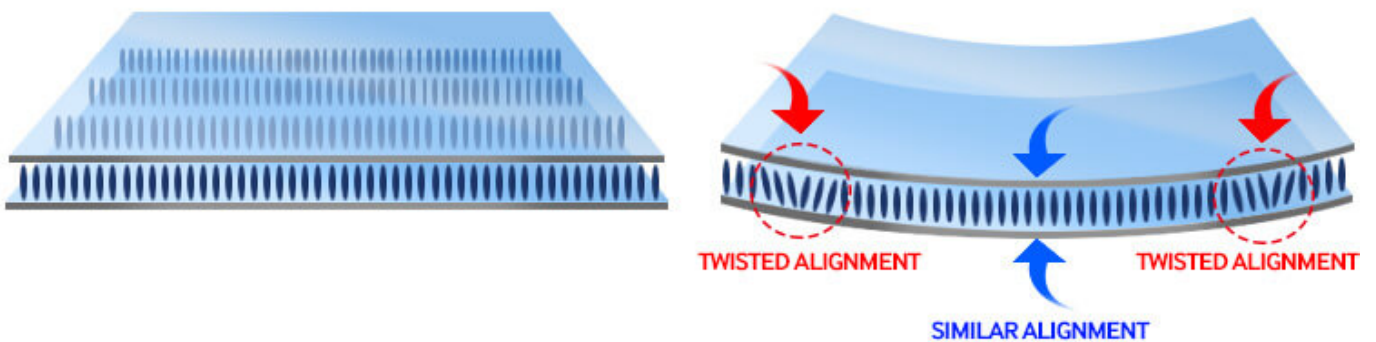
When manufacturers were first tasked with marrying the concept of the curved screen with the modern flat LCD technology they faced several challenges. Early curved panels were made by bending the flat panel after it was already manufactured. This resulted in performance issues, such as oval mura and color mixture observed at curved edges.

### Oval mura

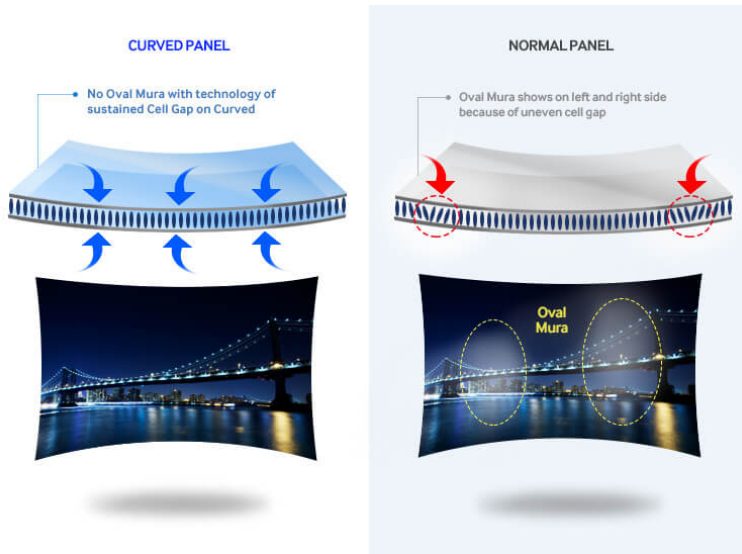
**Mura** is a clouding defect described by the lack of luminance uniformity. When a flat panel is bent to achieve the curved display shape, the non-uniform force distribution leads to uneven stress. This results in a cell gap becoming narrower on the panel's edges compared to the center, causing the liquid crystal alignment to change. This uneven cell gap causes an **oval mura** phenomenon.



*LCD panel structure*



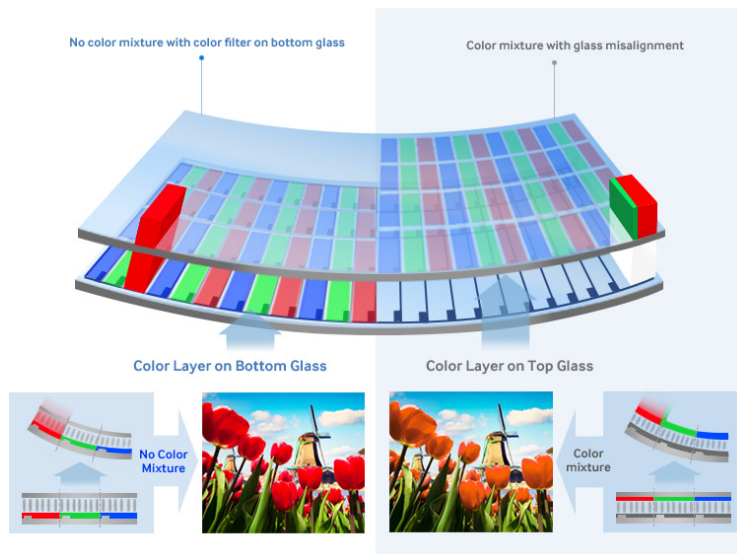
*Shift in liquid crystals alignment when flat LCD panel is bent*



*Oval mura occurs on a panel's sides when they are bent*

### Color mixture effect

Another anomaly that occurs when the panel is bent is a shift in the color filter glass layer. This misalignment causes the color mixture effect, resulting in color impurity and distorted image.



*Color mixture effect on bent panels*

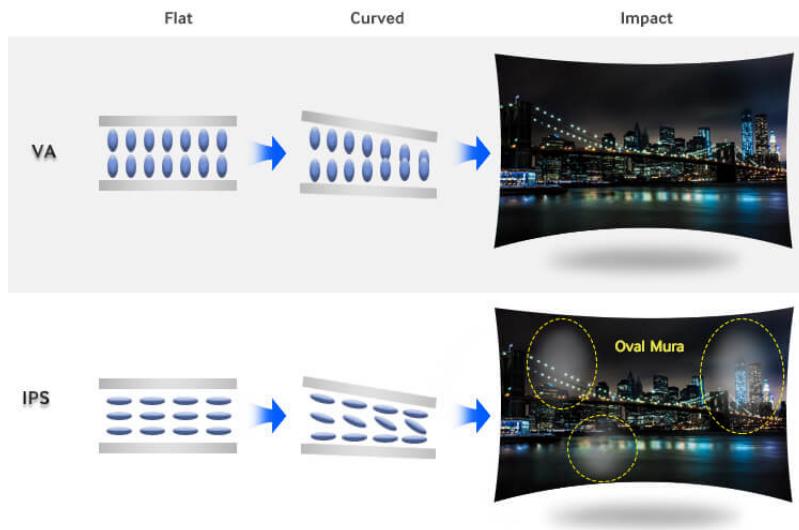
### Samsung Display curved panels

To overcome these technical challenges and create a high-performance curved display, Samsung Display employs a combination of advanced solutions.

## Liquid crystal alignment

All SDC panels use Vertical Alignment (VA) TFT LCDs. VA technology works best for curved displays as it helps to reduce any white glow that may affect the angular view, especially with dark content on display. VA also yields deeper blacks and higher contrast ratios, resulting in impressive color depth and further contributing to the immersive viewing experience.

### Why VA outperforms IPS in curved panels



#### VA vs IPS technology in curved LCDs

In contrast to VA, IPS has a horizontal alignment of liquid crystals, which doesn't provide enough support to keep the crystals aligned inside the curved display. This can result in failure to control the amount of light and thus lead to the degraded color expression and weak contrast ratio.

- IPS panels are more prone to developing oval mura
- IPS panels have a higher propensity for light leakage

This happens because when an IPS panel is curved, the horizontally aligned liquid crystals are more susceptible to distortion and variation in optical axis. If you want to learn more about VA technology, how it functions, and what benefits it provides, learn more about LCD modes and [difference between VA and IPS technologies here](#).

## Flexible glass

The introduction of the flexible glass made it possible to apply LCDs to curved surfaces, eliminating the need to bend panels. Samsung Display's curved screens use advanced curved glass that allows maintaining uniform cell gap while eliminating the occurrence of oval mura on the display.

## Curved color filter

SDC employs innovative curved color filter facilitating full alignment between liquid crystal molecules and [polarizing filters](#). By placing the color filter at the bottom of the glass, SDC ensures curved panels are free of color mixture issues.

## What is driving the widespread adoption of curved technology?

Display panel markets are seeing an explosion in curved screens demand, particularly in TV and monitor segments. Let's look at the consumer benefits the curved technology offers for these applications.

## Curved TVs



### *Benefits of curved TVs*

Curved TVs are gaining high adoption rates because of the following advantages:

- **Exceptionally immersive:** the curve in display expands the field of view due to the screen shape that extends our peripheral vision and provides more depth to the picture, contributing to generating an increasingly immersive viewing experience.
- **Enhanced eye comfort:** some users found the curved design easier on the eye in terms of viewing comfort and believe it to be healthier, particularly for the younger family members.
- **Improved design aesthetics:** many users enjoy the unique, more organic look of the curved television and prefer this option for interior design solutions.
- **Increased visibility:** curved TVs also allow avoiding most of the surrounding reflections from bright objects or sunlight in the room because of their shape.

## Curved monitors



### *Benefits of curved monitors*

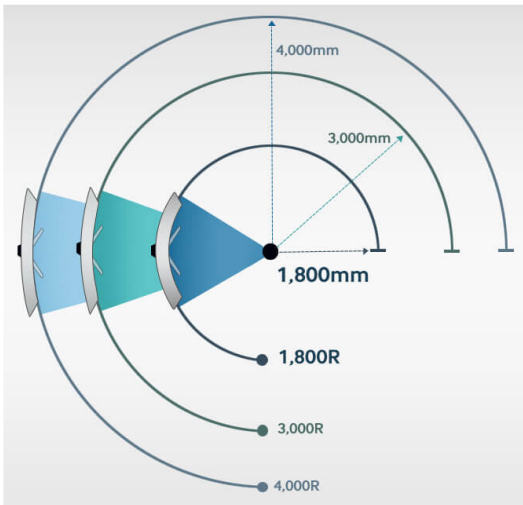
The benefits of curved design outlined above are also relevant to the monitor market. Driven by the gaming industry, demand for curved monitors skyrocketed over the last year. This year's monitor trends included new aspect ratios (21:9), increased resolutions, and flexible design.

Advantages of the curved design are amplified in case of curved monitors because of the nature of their use. While television sets are often enjoyed in a group setting, a monitor is personal by its design and function. Both in the office and gaming settings, the user is located close and directly in front of the monitor, with the screen at the eye level. This constitutes the optimal position for viewing experience and allows enjoying a full scope of curved screen benefits.

Additional advantages of the curved monitors:

- **For knowledge workers:** with ultra-wide curved monitors entering the market, we can now achieve surround effect and display multiple information sources with a single display. This means bezel-free experience and no need for a multiple display setup.
- **For gamers:** curved monitors utilized for gaming allow for more realistic and comfortable experiences due to their wide field of view. Traditionally, wide field views were crammed in flat screens. Curved screens give the player more context and provide more realistic game experiences, where visual information is properly distributed across a wider screen.

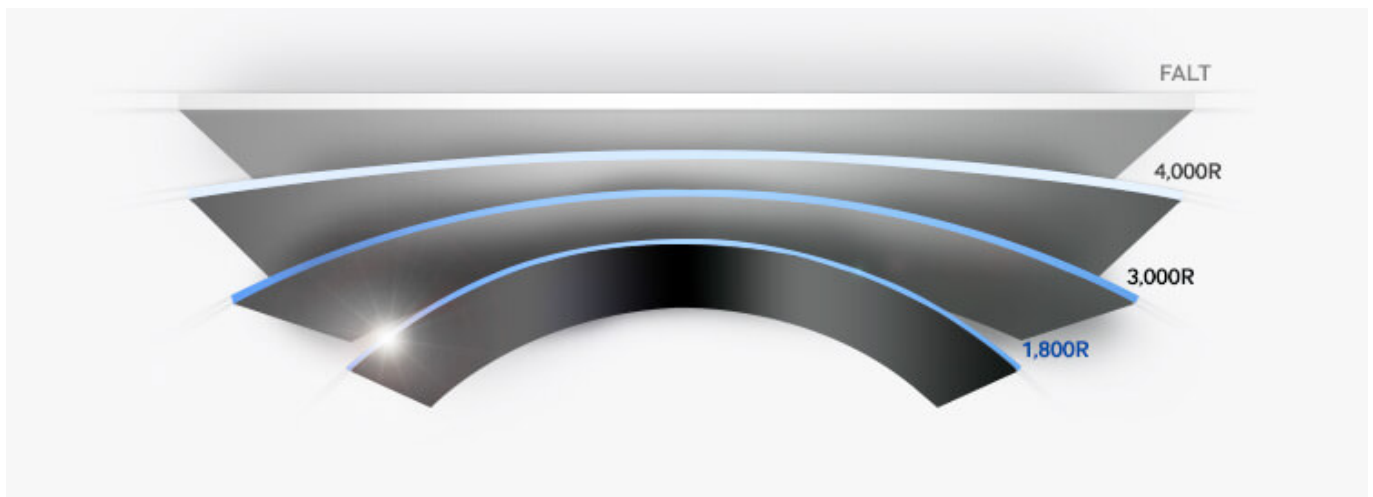
## What is the curvature of a display?



### *Display curvature radius*

A **display's curvature** is measured by the radius the curve would deliver if it formed a complete circle. When measuring curved monitors, the value 'R' is used to indicate the curvature radius. For instance, a 4,000R curvature monitor would form a circle with a 4,000 mm radius, which is 4 meters or 13.12 feet. The smaller the 'R' value is, the higher the monitor's curve.

Samsung Display provides many options of monitor panels with 4,000 R / 3,000 R / 1,800 R and TVs panel with 3,000 R and 4,000 R curvatures.



### *Panel curvature radius options*

## What is next?





With the growing adoption rates, innovative applications and customized design requirements—the curved technology is here to stay. Beyond curved TVs and monitors, this technology is widely utilized in smartphones and smart watches. The benefits of curved displays are amplified with an increase in the screen sizes, which most manufacturers are actively pursuing.

Learn more about Samsung Display's unique LCD manufacturing process [here](#).

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