ALL LED DISPLAYS ARE BASICALLY THE THE SAME... RIGHT?

Accurate Information is Key to Evaluating the Quality and Performance of any Manufacturer's LED Display

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All LED displays are basically the same, right? If the answer to that question were "Yes," this paper could be shortened to a fortune cookie insert and we could get on with the rest of our lives. But in the interest of those new, or relatively new, to direct-light LED display technology and not blessed with an electrical engineering or electronic design degree, let's spend a page or two on explaining the points of differentiation.

The scope of this paper does not deal with the larger, billboard sized large-pitch discrete LED displays you see on the side of your city's freeways, but rather will focus on tighter pixel pitch (<=10mm), surface mount device (SMD) direct-light LED displays – both designed for indoor and various outdoor environments. Neither will we be discussing LED mesh products or LED backlit LCD displays.

▸▸ For weekly information on LED technology and digital signage, follow Nanolumens on Twitter @nanolumens.

Direct-light LED displays, those which emit their own light and deliver content as the name indicates, directly, are comprised of many discrete components. Various commercial manufacturers around the world may or may not include these components in their quotations. You may see items such as framing, power supplies, controller cards, cabling, mounting/hanging points, display controllers or display interface units either included in the bottom line or broken out as separate line items in a quotation. One word of caution before we focus on the piece of the display with the most points of differentiation. If you are comparing pricing, make sure you are aware of all the components required to make the display operational in the environment for your solution and make sure you're comparing apples to apples when reviewing quotations. One bottom line price may include everything you need to be operational where as a second may be the price just for the LED panels.

		Competitive Quote
Project		
Product		
Number of Sides		
Pixel Pitch		
Display Height		
Display Width		
Display Weight		
Display Depth (profile)		
Display Controller/Processor Unit	(included in price)	
Custom Frame	(included in price)	
Power Supplies	(included in price)	
Cabling	(included in price)	
Mounting/Hanging hardware	(included in price)	
Spare Parts Kit	(included in price)	

LED Circuit Boards – Where the Rubber Meets the Road

"Boards", "building blocks", "panels", "modules", "cabinets" or simply "displays," along with numerous other designations in the culture-specific parlance of the individual manufacturer, are in effect the biggest differentiator when comparing one SMD LED solution to another. These "Boards" are made up of a number of electronic sub-components including layers of reinforced fiberglass (rigid or bendable). These layers house power circuitry and electrical grounding. Also electronic circuitry to deliver, drive and distribute both data for rendering the digital content and electricity to power the LE(D)iodes (Light Emitting Diode) will be housed in these layers. With respect to the "pixels" - the individual RGB LED packages – there are circuitry, diodes, resins, design elements, and peripheral surfacing materials/colors to consider as well.

The "Frame" for the "Canvas"

What we are considering here is the bulk of the material used in the construction of the LED circuit board, the reinforced fiberglass plies used as the physical structure for board itself. Manufacturing fiberglass quality aside, what we're really discussing are the number and design of layers/plies of fiberglass used in constructing the individual circuit panels. Ceteris paribus, standard in the industry is typically 4 plies with 1 used for housing power and data circuitry and 1 being used for grounding purposes, the remaining 2 being used strictly for structural purposes. There are manufacturers that use less than 4 plies in their build, others using as many as 6. For those using more than the standard 4 plies, the additional plies typically offer additional grounding and power capabilities – addressing data/electrical redundancy and additional grounding to combat RFI radiation and EMI. This is especially useful in command and control environments and other commercial and industrial environments with high prevalence of electromagnetic interference and RF radiation. Additional grounding and redundant power/data plies combat these digitally unfriendly environments reducing the incidence of current flow disruption and the occurrence of digital visual artifacts.

Data and Electrical Circuitry Design – the "Art" in the Frame

The designs of the actual circuitry to deliver data and power to the diodes are as different and recognizable in the LED display manufacturing industry as the brush strokes of Monet and Lautrec are in French Impressionism. This is where the real intellectual property of the individual manufacturers of these displays begins to differentiate the products. The end game of these designs is to maximize the conversion of electrical wattage to light vis-à-vis heat. More light, less heat wins the race.

Industry standards show that current typical circuitry design renders somewhere in the 60%-75% range as the percentage of wattage converted to light in the displays. This means the remaining 40%-25% of wattage is converted to heat. Depending on the environment where the display solution will be used that could be a problem. Imagine LED displays emitting a high level of heat in a high-end retail cosmetics store adjacent to say a lipstick PoP structure. There are a handful of tier 1 (read: high-quality) display manufacturers who's elegance of design with their circuitry, is rendering conversion percentages approaching 85% to-light efficiency.

Where the Diodes Live – Package Design

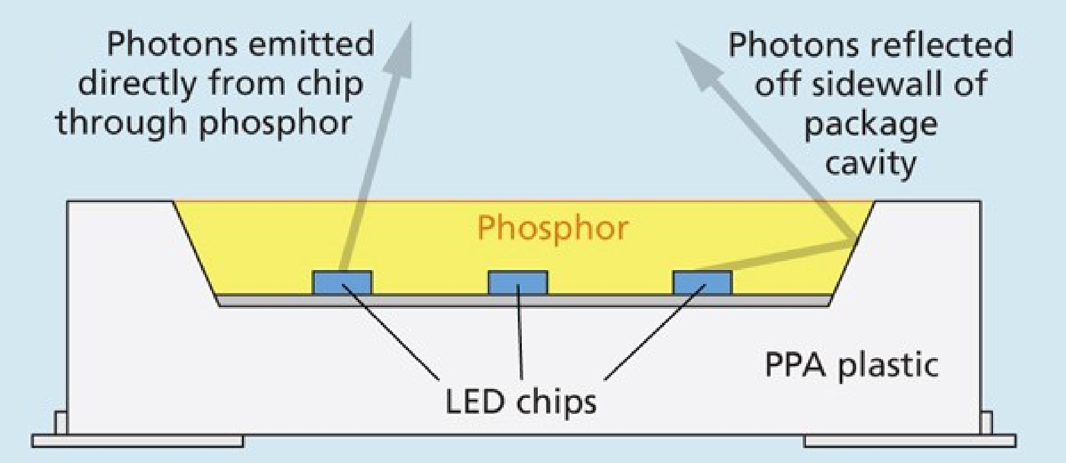


FIG. 1. A simplified cross-section of a plastic LED package.

On a direct-light LED circuit board, is a grid of attached pixels – or the smallest addressable components on the display from the perspection of content delivery. These "pixels" typically are what is referred to in the industry as a "package" and as you might expect, given the name, these actually are comprised of a number of individual elements – all of which can be differentiators in the performance and efficiency of the display.

The carrier, shell or chassis of the package is manufactured from Polyphthalamide (a.k.a. PPA, High Performance Polyamide). They are manufactured from either virgin plastic materials or from recycled materials. The performance degradation that occurs with the use of recycled PPA housing, is that it is typically less homogenous in composition and therefore more porous and absorbent – and more apt to collect moisture from the relative humidity of the environment. Water is an LED's worst enemy and will effectively destroy the LED. Additionally, recycled PPA degrades at a faster rate than virgin PPA.

The **conductor** and **wire bonding** in the package is the apparatus which, as you might suspect, transfers electric current from the circuit board to the diodes. Conductors are located on the underneath or back side of the package carrier and consist of an anode and cathode division (positively and negatively charged). These pieces are manufactured from one of three different metals – gold, zinc, or silver. There are variances in both conductivity and environmental performance with these three metals. Gold is the preferred metal for both situations, having both the best conductivity and being the most environmentally resistant – but as expected it is also the most expensive. Environmentally, silver is the most susceptible to corrosion. If you are in an indoor environment naturally this isn't usually a concern with controlled, low-humidity. Higher quality LED packages come with redundant wire bonding connections to the diodes to safeguard against failure should one of the connections go bad for whatever reason.

The lining within the diode's package cavity on the front of the package is referred to as the **reflector.** This comes in variations of two colors – either black or white. As you might suspect, white or whiter colors of reflectors better reflect, and more efficiently channel, the light from the diode outward away from the package. Black or darker reflectors tend to absorb more of the light from the diodes. The actual shape of the reflector cavity has much to do with the quality of the image and brightness. This will be discussed further on when we discuss **fill ratios.**

While we're discussing the coloration of the reflector, it is also a good time to talk about the **face** of the package itself. These also come in various gradients of white and black and serve a similar function as the reflector. As a general rule of thumb, both of these elements either serve to enhance brightness (whiter elements) or to enhance contrast (blacker elements). Black face LED packages typically are better when the preferred result is for greater image detail. White and lighter face LED packages are preferred when brightness is a key requirement for the content delivery – such as combatting hostile ambient light conditions. Package faces also come in different finishes, matte finishes, glossy and variations in between.

We've talked about all of the components of major differentiation within the LED package sans one. **The lens.** The lens of the package is comprised of an optically translucent sealer material – most commonly silicon – which fills the cavity housing the diodes. The lens composition, as you might guess, affects to a greater or lesser extent, the optical performance of the package. Counterintuitively, a certain amount of opacity within the lens material actually enhances overall image quality for the average human viewer with 20/20 vision.

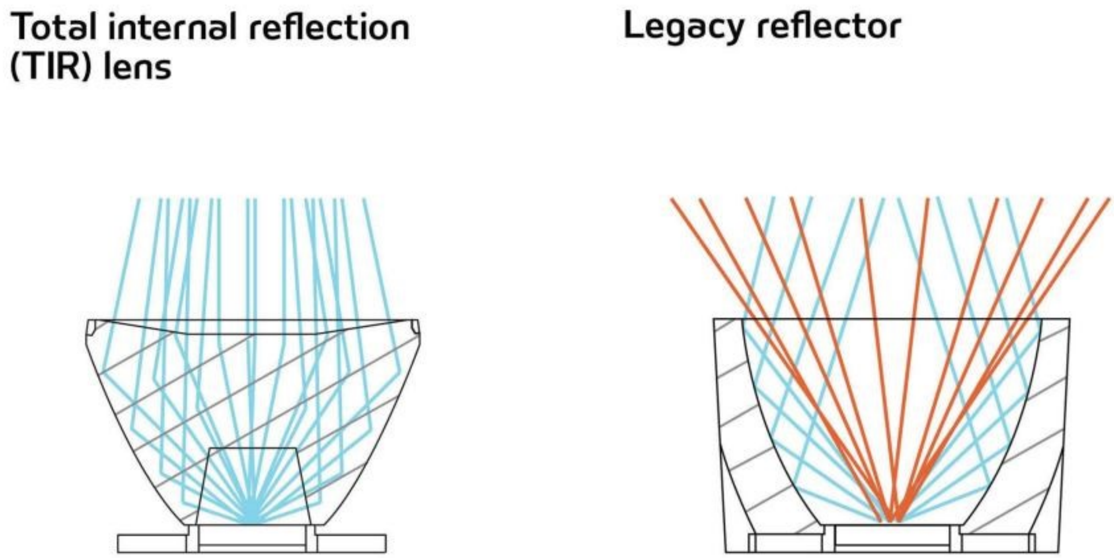
Active vs. Inactive face regions – Fill Ratio

As we briefly mentioned above, reflector cavities for LED packages come in several shapes, comprising greater or lesser percentages of active (light emitting/reflecting) surface area of the package. The three most common shapes for these cavities are: circular, rounded squares (similar to the shape of a radiant-cut diamond) and square. Since most of the industry uses an LED package referred to as a 35/28 SMD (which has a rectangular dimension of 3.5mm by 2.8mm) you can imagine which reflector cavity shapes allow for the highest active light regions within the package – square being the least and circular the most.

The fill ratio or comparison of the amount of active package surface to the inactive is calculated (good estimation) by taking the area of the front surface (length x height) of the package size over the area of the pixel pitch (pixel pitch being the distance between adjacent package centers). So for example, if we have a 4.7mm pixel pitch product constructed using standard 3030 SMD packages (3.0mm height by 3.0mm length) the formula would read thusly:

$$\frac{3mm^2}{4.7mm^2} = \frac{9}{22.09} = 0.4074 \text{ or roughly } 41\%$$

The higher the fill ratio, the more lighted surface area. There is another component affecting this ratio as well. There are typically two kinds of reflectors – those referred to as Legacy reflectors which allow light to escape the lens using the natural path of reflection, and Total Internal Reflection (TIR) reflectors which, via a faceted design, concentrating and narrowing the beam of light escaping the lens. Typically Legacy reflectors are used in commercial LED display environments and thus adhere more closely to the parameters of the fill ratio calculation.



LED Diode Quality

LEDs are diodes – meaning they are semiconductors. They are designed and manufactured in such a way that rather than power the processor of a laptop or iPad, they emit light. The material used in the semiconducting element of an LED determines its color. The two main types of LEDs presently used for lighting and display systems are aluminum gallium indium phosphide (AlGaInP, sometimes rearranged as AlInGaP) alloys for red, orange and yellow LEDs; and indium gallium nitride (InGaN) alloys for green, blue and white LEDs. Slight changes in the composition of these alloys changes the color of the emitted light.

The actual chips/dice/wafers of the (LED) manufacturing process is basically the same the world over. What makes one manufacturer's diode better than another is basically the consistency of the manufacturing process, the predictable, repeatable processes rendering consistent yields. This is accomplished by rigid manufacturing standards, "Six Sigma" processes, purity of chemical elements, etc. Diode manufacturers in the industry gain a reputation for delivering a consistent and reliable quality. If you've been in this industry for a minute or two, you know the names that always come up when discussing quality. One starts with an "N" and one starts with a "C". That being said, there are other contract manufacturing companies whose process is being guided and refined by the display manufacturers, which are turning out diodes of a comparable quality.

"What Kind of Red, Green and Blue?" - Wavelength Selection Restriction

What you might hear when talking with a manufacturer is a term called **"binning."** To clarify – binning is a process a diode manufacturing company uses to classify individual parts of a run or batch of silicon wafers into different nanometer wave lengths of a particular color. An example of this process is illustrated further on.

When a wafer is manufactured to be parceled into individual diodes, there are minor fluctuations in two distinct areas: **color wavelength** and **forward voltage.**

Color wavelength: Light waves, like waves in water, can be described by the distance between two successive peaks of the wave - a length known as the wavelength. Different wavelengths of light appear to our eyes as different colors. In a wafer yield, you're not going to see variations like red, green and blue but rather, for descriptive purposes, variations more closely described as crimson, cardinal or ruby.

Forward voltage is the voltage drop across the diode if the voltage at the anode is more positive than the voltage at the cathode (if you connect + to the anode). This is the value to calculate the power dissipation of the diode and the voltage after the diode.

For instance: a manufacturer produces a batch of "red" diodes and the target wavelength of the manufacture is 625 nanometers of what they consider to be "true red" the acceptable (commercially useful) wavelengths to be kept for sale are between 600 and 650 nanometers – everything outside of that wavelength range is recycled or discarded. The same manufacturer also has determined that these diodes for perfection are to have a target forward voltage of 2.19 volts, with an acceptable variation of between 1.8 and 2.5 volts that are commercially saleable. Again, everything outside of this voltage range is discarded.

The result is a population of saleable diodes with a great deal of variation in both the color and performance. At one end of the spectrum you have a diode with a 1.8 volt forward voltage and a color wavelength of 600 nanometers and at the other one with a 2.5 voltage and a wavelength of 650. So, manufacturers divide their yields into **"bins"** or containers of like diodes – the term in the LED display industry commonly referred to for numerous descriptive purposes as **"binning"**. The consistency of both the performance and color of the diodes qualitatively separates high-end manufacturers of displays from mid-tier and commodity-quality display manufacturers. Naturally, the narrower the "binning" (read: variation in the color wavelength and forward voltage of the diode) the better consistency of color output, and thus, cost to manufacture.

The green shaded area in the diagram below indicates what, perhaps, a high-end or "tier 1" display manufacturer may set as their selection criteria for the diodes used in their displays. In our example, bin B18 would represent a wavelength of ±3.5 nanometers of target wL and a forward voltage of ±0.6 volts of target fV. Whereas a display manufacturer of lesser quality may accept diodes from ANY of the bins in order to save costs and keep their pricing down or in other words wL ±25nm of target and ±0.31 of target fV. Though color consistency and voltage discrepancies can to some extent be dealt with through calibration of the display – it would be virtually impossible to calibrate a diode from bin B1 and one from B35 to achieve wavelength and voltage parity.

		Wave Length						
VOLTAGE		600nm	608nm	617nm	625nm	633nm	642nm	650nm
	1.8v	B1	B2	B3	B4	B5	B6	B7
	1.95v	B8	B9	B10	B11	B12	B13	B14
	2.19v	B15	B16	B17	B18	B19	B20	B21
	2.35v	B22	B23	B24	B25	B26	B27	B28
	2.5v	B29	B30	B31	B32	B33	B34	B35

So if you've made it this far though the discussion, you can see that the answer is – No, all LED displays are NOT basically the same. There are a number of key points of differentiation from the actual fiberglass plies that make up the structure of the circuit board, circuitry design and variations in the manufacturing consistency of the actual components that make up the business end of the displays, the LED diodes and the packages that drive them. This paper just begins to graze the surface of optical and electrical engineering concepts used in design and manufacture of LED displays and there are reams of data available on the internet – but armed with the information above you should be better able to evaluate the quality and performance of (X) manufacturer's LED display.

ABOUT NANOLUMENS

NanoLumens, headquartered in Atlanta, Georgia, creates display visualization solutions that deliver truly immersive customer experiences and great return on investment. We provide unique solutions to problems that haven't been thought of yet. Our fully custom display solutions provide engaging customer experiences and the ability to realize solid returns on investment. Our brilliant displays, designed and assembled in the USA, are so thin, lightweight and curvable, they fit almost anywhere. With quality backed by an industry leading, Six Year Warranty, NanoLumens is your collaboration partner for visualization solutions that live up to your imagination for more information, visit www.nanolumens.com.