Very Large-Screen Video Displays

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Abstract

Very large or very bright video displays have traditionally been difficult to accomplish well. Front and rear projection suffered from lack of brightness and contrast (fairing quite poorly under high ambient light conditions). Traditional CRT-based solutions, such as the SONY JumboTron, while excellent, were heavy and power hungry. LED video display technology has at last made large, bright video displays practical and accessible.

What is a Large-Format Video Display?

A large-format video display's purpose is to show full-colour moving images to a large crowd of spectators. The program material is usually some combination of image magnification (detail that the crowd cannot readily see), sports instant replay, or advertisements. The one thing these all have in common is that they are true video sources – generally cameras or tape.

These jumbo video displays are typically used in venues where a very large number of people must be able to see the display such as sports arenas and pop concerts. These displays are generally large (from 10 to 50 feet in width) and very bright – to overcome high ambient light such as television or theatrical lighting.

For screens of this size, there have been only two viable technologies: CRT and LED – other technologies such as video projection, videowall cubes, and lamp-based matrix signs have proven unsatisfactory. Traditionally, this could only be done with CRT technology. **LED technology** has now advanced to the point of rivalling and surpassing CRT technology for resolution and brightness. We look at each of these large-screen display technologies in more detail.

How Big Should It Be?

Unfortunately, the size of a large-screen video display is often dictated by some arbitrary physical constraint or "I want one the same as they have in LA" In fact, the display size and the number and location of the displays should be carefully calculated based on your arena's sight lines and distances to furthest viewers and VIP seating. When designing a centre-hung display, the nearest viewer is often overlooked – auxiliary displays are sometimes required.

Matrix Lamp Technology

While there are matrix lamp displays for graphics and general information, these are really just very sophisticated signs, and are not suitable for video. They do not have sufficient resolution to produce a good video image, they are high maintenance (bulbs must be replaced on a regular basis), and the incandescent bulbs have an objectionable persistence effect – they cannot be switched on and off instantly. These displays do have their place for announcements and advertising, and are most commonly used outside the venue to announce upcoming events.

Rear Projection & Video Cubes

The limitation of video projectors is brightness. To achieve a bright image with acceptable contrast (vital for video) in the high ambient light conditions of an indoor arena, requires a minimum display luminance of about 1500 Nits. If we assume a medium-sized display of 10' wide by 7' high and a rear screen with a gain of 1.3, we would require a video projector with over 20,000 lumens output. A screen with higher gain (such as 5 or 6) will reduce this requirement but in doing so will also reduce the horizontal viewing angle of the image to unacceptable limits. A typical large-venue video projector with 5,000 lumens of output will achieve only about 20% of the required brightness level. If you have television lighting (e.g.: NBA or NFL broadcasts), this brightness requirement is increased by almost 70% – if your facility is an outdoor venue, it will at least triple. In our opinion, the required brightness levels are simply not practical with current video projector technology. The result will be a washed out image, lacking in contrast and saturated colours.

Videowall cubes also have a brightness problem (average only about 400 to 600 Nits). Their additional disadvantage is that the image is chopped up into blocks, with a thin, but visible, dividing line. It is very hard to adjust each cube to exactly the same colour balance, and even harder to keep them this way. The end result is a patch-work effect. They also suffer from some inflexibility in screen size. Cubes must be configured in a square matrix (2x2, 3x3, 4x4, etc.). In our example of a 10' x 7' screen, assuming 40" cubes, we can use a 3x3 configuration to yield about 8' x 6' or a 4x4 configuration to give us 10.7' x 8' – we cannot get 10' x 7' exactly.

CRT Technology

The original giant screen technology, these screens have now been superseded by LED technology. The best known examples of CRT screens are the **Mitsubishi Diamond Vision**, **Panasonic Astra Vision**, and **SONY JumboTron**. These screens were for many the mainstay of large-format video display in high ambient light situations such as an arena or stadium.

Just as with a newspaper photograph, the video picture is divided up into a number of dots called pixels. Each pixel is made up of at least three tiny CRT's (cathode ray tubes) – one red, one green, and one blue. By varying the brightness of each of these, any colour can be created. Each of these CRT's is like a tiny television picture tube, except that it is producing only the intensity of one picture dot, and the entire picture is made up of hundreds of thousands of CRT's, rather than one. The end result is a large, bright video image.

LED Technology

In the late 1990's, LED technology (**L**ight **E**mitting **D**iode) advanced to the point of rivalling and surpassing CRT's for resolution and brightness. LED displays work on exactly the same principal, except that the tiny CRT's are replaced by LED's.

LED displays consume far less power, and are considerably lighter than their CRT-based counterparts – this, coupled with the fact that they occupy less volume (they are less than half as deep), has made them very attractive for touring shows. As an example, we specified LED technology as part of the centre-hung scoreboard for the **London Arena** (a hockey venue in London, UK which opened in 1999). The roof structure in the arena would only allow 22,000 lbs. for the gondola, scoreboard components, and video displays – four CRT video displays alone would have weighed this much.

CRT technology has been limited to three principal vendors primarily due to the complexity of the manufacturing process. LED technology is much more accessible – resulting in many more players (one industry report cites as many as 50 manufacturers). This is unfortunate in a sense, since this accessibility can result in some poorly designed product and some short-term manufacturers who may sell only a few systems before vanishing. **The key is to select a manufacturer with a track record, and who is committed to the industry**. You do not want to wind up owning an unsupported "orphan." In particular, beware of a new LED video product from a company that has only previously done animated LED signs, and has no video experience.

Screen Resolution

No discussion of large-format video screens is complete without mentioning resolution. **The key to a quality image on a large-format video display is to buy the highest resolution you can afford**.

Resolution, simply stated, is the total number of vertical and horizontal pixels (dots that form the picture). The video signal that the screen will be reproducing has a native resolution of about 486/576 (NTSC/PAL) vertically and anywhere from about 240 to 720 horizontally (depending on the quality of the source). Thus, to reproduce these signals with no loss of image quality, you want an ideal minimum screen resolution of about 648 x 486 (NTSC) or 768 x 576 (PAL) – the horizontal figures for a fixed resolution display are determined by the aspect ratio of the video image.

Unfortunately, we do not live in an ideal world. Jumbo video screens at these resolutions may not be economically feasible, or they may exceed physical limitations (i.e.: the display may simply be too large). For example, if we assume our medium-size 10' by 7' screen again, we would need pixels spaced no more than 4.5mm (0.18 inches) apart to achieve full video resolution. This distance between pixels is called pixel pitch, and is usually measured in millimetres. Or, working the other way, a 648 x 486 screen at 12mm pixel pitch would be about 7.8m x 5.8m (26 x 19 feet).

Typical pixel pitches for indoor screens are 4mm, 6mm, 8mm, 10mm, 12mm, 15mm and 18mm. Typical pixel pitches for outdoor screens are 15mm, 18mm, 20mm, 25mm, 30mm, and 40mm – outdoor screens tend to be larger than indoor screens, as the viewing distance is often greater. The finer the pixel pitch the more expensive the display. Note that actual LED screen products come in fixed blocks of pixels (e.g.: 16x16 or 32x16), and you may have to adjust your overall screen size slightly to accommodate a whole number of blocks.

Let's look at an example: assume an indoor screen with a nominal size of 10'x7', and further assume that all sizes of LED's come in 16x16 blocks – remember, the resolution of the raw video image is 650 x 486:

Pixel Pitch	Blocks	Actual Resolution
4mm	47 x 33	752 x 528
6mm	32 x 22	512 x 352
8mm	24 x 17	384 x 272
10mm	19 x 13	304 x 208
12mm	16 x 11	256 x 176
15mm	13 x 9	208 x 144
18mm	11 x 7	176 x 112

Table 1. Blocks and Resolution for Nominal 10'x7' Screen

As you can see, as we increase the pixel pitch while keeping the screen size the same, the detail in the picture can be severely reduced. Another consideration is that the larger the pixel pitch, the more prone the image is to pixelisation – you can start to see the pixel structure, much like looking at a newspaper photograph with a magnifying glass. This is a function of the distance between the viewer and the screen, and **needs to form part of the design calculation**.

Let's look at a further example: suppose you have two video screens which each measure about 4m x 3m (13 by 10 feet). One has an 8mm pixel pitch and the other is 12mm. The first screen will have 500 pixels horizontally (4000/8) and 375 vertically (3000/8), or a resolution of 500 x 375. The second screen will have a resolution of 333 x 250. Although both of these fall far short of our ideal resolution (particularly for a PAL image), the first is clearly preferable – it will, of course, also be more expensive. Note that the actual screen resolution available will depend upon the size of a given manufacturer's LED module and how flexible they are in combining them.

For screens with pixel pitches of 15mm or greater, the number of LED's per pixel will also help reduce the perceived pixelisation of the image – although this is no substitute for increased resolution. While the minimum number of LED's per pixel is obviously three (one each of red, green, and, blue) there are configurations with four and five LED's per pixel. Increased LED density is especially important in an outdoor display to increase brightness. At 12mm pixel pitch and lower, it is currently impossible to have more than three LED's per pixel (due to physical limitations).

Surface-mount LED packages are now available to allow 8mm, 6mm, 4mm, and even 3mm pixel pitches – a 12mm pitch is about the limit for conventional LED packaging. This same package style could, in the future, provide higher LED densities at 10mm or 12mm pixel pitches. I have seen a 3mm LED screen running Windows at 640 x 480, and it was spectacular. The unit I saw was for a command centre status display, and was only about 1.8m x 1.2m (6 feet by 4 feet), but could easily be made larger – the principal barrier is cost.

The choice of pixel pitch and screen resolution is dictated by: any physical size constraints you may have; viewing distance and sight lines; and, of course, budget – these displays are costed by area (typically about $40K US per square meter).

Video Processing

There are two parts to a large-screen video display: the display device (rather obvious), and the video processing electronics (hidden behind the scene). Once you have two screens of the same technology, the same size, and the same resolution the first part of this equation is likely more or less equivalent – although, to be fair, there are differences in LED manufacturers, drive electronics, and LED mounting methods which must be evaluated. A standard video signal cannot be directly displayed on an LED matrix without first being processed. **It is the quality of this processing that is most often overlooked by prospective buyers of this technology**.

The first process that must occur is de-interlacing. A video image is made up of a number of horizontally scanned lines – the visible lines number about 486 for NTSC video and 576 for PAL. These don't all appear on a television screen at the same time. In the first 1/60 of a second (1/50 for PAL) the odd lines are shown, and in the second 1/60S the even lines are shown. This is called an interlaced display, and everyone's television works this way. This is not the best way to display an image, and most displays that don't need to pick up a broadcast signal use a non-interlaced system whereby everything is shown at once.

To convert from an interlaced to a non-interlaced signal is not as straightforward as you might think. The simplest way to do this is to take the first set of lines (field), double it up, and show it – ignoring the second field. There are some video processors that do just this – they throw away half of the original picture resolution. A better approach is to store the first field in memory, combine it with the second field when it comes along, and then display a complete frame. While this is a superior approach, there is, of course, also a problem with it. Each field represents a 1/60 or 1/50 of a second snapshot. If an object was moving rapidly it may be in a different position in the odd field than in the even field – if you have ever paused your VCR and seen a person's waving hand fluttering while everything else is frozen, you have seen this effect. To fix this requires some real-time digital processing whereby the two fields are interpolated before being combined – this is called motion compensation, and requires real-time digital signal processing. Thus, the analog video signal must first be digitised. Even the method and resolution of this digitisation process will impact the final result.

Assuming we have digitised and de-interlaced a PAL signal to a resolution of about 700 x 576, and we have a screen with a resolution of 333 x 250, we clearly need to reduce the incoming resolution of the video to match the display. This is the next job for the processing electronics. This can be done in a brute-force fashion by simply discarding pixels, or, again, digital processing can do this intelligently to retain as much picture detail as possible. This latter operation again involves real-time digital processing – this cannot be done cheaply.

There are considerable differences in how display manufacturers process the video signal for display, and obtaining this information from the manufacturers is not an easy process. **It is a very worthwhile endeavour, since the processing can make a dramatic difference to the quality of the displayed image**. In particular, beware of signal degradation and artefacts introduced by cascaded processors. Imagine an installation with a black box to convert PAL to NTSC, then another black box to convert this NTSC signal to 640 x 480 VGA, and a final processor to scale the 640 x 480 to the lesser resolution of the LED display – this is a real-world example.

Brightness, Contrast, and Other Issues

There are, of course, other comparison factors beyond resolution and type of processing. Unfortunately, we are dealing with an industry that has not yet established standards for itself. Consequently, some key specifications generally used for comparing display devices are problematic when it comes to LED video screens. Some of these other key considerations are brightness, contrast ratio, and angle of view.

For a radiating display device, brightness or luminance is generally measured in nits (cd/m^2) – the higher the number, the brighter the display. As a general rule, you will need 1,500 to 2,500 nits for an indoor display (lean towards the upper range if you have television lighting) and 5,000 or more for outdoor displays. The problem is that, while each manufacturer will present you with a brightness figure, there is no standard method of measuring this, making comparisons difficult. To be meaningful, each manufacturer should: set their LED drive current to a specified amount (preferably the same current setting they used to determine the LED life), then adjust the brightness and contrast for optimum video viewing using standard test patterns, then apply a known signal (such as 100 IRE white), and finally measure the brightness on-axis with a specific type of light meter.

Contrast ratio is a measure of the dynamic range of a displayed image – the difference in brightness level between the whitest white and the blackest black. This is a **very important specification** in judging how well an image will be produced in an environment with high ambient lighting (such as an indoor arena). When we compared figures from various manufacturers, we found they fluctuated wildly (a difference of over ten to one between the highest and lowest). Again, they were all using varying techniques. To complicate matters, a very different method must be used when measuring the contrast ratio of an indoor display versus an outdoor display. The numbers, of course, will be quite different, and can only be compared similarly (i.e.: indoor with indoor, outdoor with outdoor).

Angle of view is another important consideration – can every seat in the house see the display equally well. There are two factors at play here: the viewing angle of the display and maximum viewing angles for people trying to make sense of ***any*** display – this latter is a design issue for the arena, and needs to take into account size, number, and location of screens. The display's viewing angle is quoted by the manufacturer and, again, it is not always clear how this is measured. One typical method for other types of displays is to (while taking the brightness measurement) move off-axis to a point where the brightness drops to 50% and record this angle. Unfortunately, LED displays have a problem that is unique to this technology called "shouldering." There can be a colour shift caused by one LED blocking the view of another LED at extreme angles. Thus, for LED technology, the 50% brightness measurement is not a completely valid specification – **it should also take into account colour temperature shifts**. If a significant colour shift occurs before the brightness falls to 50%, then this lesser angle is truly the viewing angle. A similar effect (caused by built-in sun visors) can seriously degrade the vertical viewing angle of an outdoor display.

Life expectancy is another interesting issue. Quoted life figures for the LED's range from 20,000 to 100,000 hours. These figures are clearly only meaningful if they are determined at the **actual drive current that will be used under real display conditions** – and certainly at the drive levels used to produce the brightness measurement.

Check Those References!

When evaluating any large-format video display system, always ask for references (for ***both*** the manufacturer and the installer). Try to ensure that these previous customers are in a similar situation to your own (e.g.: if you are an indoor hockey arena, a comparison with an outdoor football venue may not be completely useful). Also try to get references for the same product (e.g.: if you are buying a 12mm LED board with the latest processor, a reference for a 30mm board with a processor that is two generations old will not help much).

Steps To Take Before You Buy

Before contacting any vendor, calculate the number, size, and locations of your screens. Determine the required brightness and viewing angles.

Budget for a high resolution display. For an indoor display we recommend a minimum of 15mm pixel pitch, and much prefer 12mm or less. For an outdoor display, the recommended minimum is 30mm.

Be proactive – itemise your exact requirements and minimum performance standards in a specification and provide a copy to each prospective vendor before they submit a quotation. Their proposals will then be based on a common set of requirements, and can be compared.

Once you have narrowed the field, arrange to see exactly the product you are considering. When we came to this part of our evaluation for our London project, we found that one manufacturer hadn't actually produced the 12mm display they were trying to sell us – although they didn't mention this until we asked to see one! I was not prepared to recommend that my client become a guinea pig for the first commercial model of a manufacturer's jumbo video screen. If you find yourself unavoidably in this situation, be sure to contract-in a free upgrade to whatever changes may be made within, say, six months or the next four screens sold. This is reasonable, as you are essentially testing a prototype. If the manufacturer gets it right, and there are no problems, then they have nothing to lose. If things don't go right, the manufacturer will learn from your problems to the benefit of subsequent customers – you should be compensated in some way for being placed in this situation.

Also pay attention to the physical construction of the screen. These screens are made up of a number of smaller modules mounted to a frame. If the modules are not properly aligned **in all three axes**, you can start to distinguish the block structure of the unit. One unit we evaluated for London was rejected partly for this problem.

An ideal situation is a "shoot out," with competing screens set up side by side being fed from the same sources. This, of course is not always possible to arrange (trade shows allow some comparisons to be made). At the least, you should see your short-listed three screens in situ. Insist on seeing your own material on the screens. Bring a high-quality video typical of the material that will be displayed in your installation. In particular, scenes with a lot of motion and camera pans will show up certain LED processor problems. You should also view standard video test signals to get an idea of white and black balance, uniformity, linearity, etc. Look in particular for objectionable noise artefacts in large expanses of a single colour.

Summary

Clearly, this is not an exhaustive description of the rigorous evaluation process that should be undertaken when evaluating products of this nature and price range, but it does give you an idea of some of the key items to look for. The best advice we can give you when faced with evaluating any relatively expensive high-tech system is to produce a detailed specification outlining system performance and quality of workmanship – **prior** to soliciting vendor proposals. Research the current state of the technology (for displays, it changes about every six months), evaluate actual displays in similar usage situations, and check references.

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