

## Electroluminescent (EL) Display Technology FAQ

### **What is an Electroluminescent (EL) display?**

EL is an abbreviation for “electroluminescence”, which is the phenomenon of light emission due to a strong electric field. EL displays consist of a solid state thin film phosphor and insulator stack deposited on a glass substrate and driven by high voltage electronics which generate alternating +/- 200V pulses. For details, see the EL white paper on Planar’s proprietary EL technology:

[http://www.planar.com/advantages/whitepapers/docs/ELD\\_200307.pdf](http://www.planar.com/advantages/whitepapers/docs/ELD_200307.pdf)

### **What are the main advantages of Electroluminescent (EL) displays over other display types?**

Some of the main advantages are 1) wide operating temperature range (many models are -40C to 65C, with some at -40C to 85C and one at -50C to 85C) with no need for heaters or fans; 2) instant turn on at low temperatures with no change in performance (compared to LCD displays which are very slow and often pinkish at low temperature); 3) unlimited viewing angle with no color shift; 4) extremely long life with no maintenance costs (no backlight to replace); 5) very rugged package due to the solid state nature of the EL technology; 6) the crisp, high-contrast “look” of EL, which differentiates the OEM’s product from competitors’ product offerings.

### **Don’t lots of companies make Electroluminescent (EL) displays?**

No. Electroluminescent (EL) backlights are common, but much different from Planar EL displays. EL backlights do not display information; they simply provide a “light bulb” for illumination purposes. EL backlights utilize a thick film process where a slurry containing an EL phosphor is screened onto a substrate. The resulting thickness of the solidified slurry is about 100 microns. The Planar thin film EL process results in films approximately 2 microns thick and allows for relatively fine pixel resolutions (such as 0.36 mm dot pitch) while providing good reliability and phosphor stability. Planar’s EL displays are sometimes referred to as TFEL displays due to the use of thin films. For details on the differences between thick and thin film EL, see:

[http://www.planarembded.com/whitepapers/assets/TFEL-Comparison\\_12-07.pdf](http://www.planarembded.com/whitepapers/assets/TFEL-Comparison_12-07.pdf)

### **What colors are available?**

Nearly all EL display models are yellow only. Two models are available which generate red, green, and yellow colors by filtering the yellow phosphor. Red, green, blue, and white EL phosphors have been developed by Planar in the past but are not commercialized.

### **How about transparent displays?**

EL technology can be made transparent. Due to the transparency of the phosphor stack, replacing the standard aluminum row electrodes with ITO row electrodes results in a transparent display which has all the beneficial properties of standard EL. For more information see the white paper on transparent EL: <http://www.planarembded.com/whitepapers/assets/wp-Planar-Transparent-EL-Displays.pdf>

### **Are Electroluminescent (EL) displays “plug and play”?**

No, EL displays are display components intended to be embedded in systems. They cannot be connected directly to standard PCs. Some engineering effort is required to interface to EL displays, as is the case for most display technologies. In fact, the interfaces on most EL displays are identical to the interfaces found on many passive LCD displays (the so-called 4 bit LCD interface where data for four pixels are clocked in on every clock.)

### **What third party interface solutions are available?**

There are flat panel controller ICs, microprocessors with flat panel control capabilities, and SBCs which contain flat panel controllers. See the application note “EL Interface Solutions for Planar’s EL Displays” on the Planar website: <http://www.planarembded.com/whitepapers/>

### **How bright are Electroluminescent (EL) displays?**

Brightness ranges from 20 to 150 nits (nit = cd/m<sup>2</sup>) depending on the model and the frame rate at which the display is driven. Most models are in the 50 to 100 nit range. Though this seems low compared to the 250 nits of a common desktop AMLCD display, the high contrast of the EL technology results in good viewability (in fact, at a recent trade show a 1200 nit LC15 AMLCD was running next to a 150 nit EL320.240HB, and the EL display looked brighter to most people.)

### **Why is there so much brightness variance between display models?**

The brightness is linearly related to the frame rate at which the display is driven. Physically larger displays are limited to lower frame rates than are smaller displays due to the increased number of rows which must be scanned per frame. Thus larger displays tend to be less bright. In addition, there are variations in the display electronics and glass fill factor (the percent of glass area which emits light) which impact brightness.

### **Most desktop AMLCD displays have brightness around 300 nits. Why do Electroluminescent (EL) displays look good even though they are 150 nits or less?**

Contrast is important, and EL displays have great contrast—typically 1000 to 1. In addition, the emissive nature of the display means there is no color shift or viewing angle dependency. The result is a pleasingly crisp image which conveys information at a glance..

### **How important is the frequency of the VS input which the customer provides to the display?**

For nearly all models, the VS frequency determines the display frame rate (the frequency at which the pixels are energized) and thus the display brightness is linearly proportional to the VS frequency (e.g. brightness at 150 Hz is 2x the brightness at 75 Hz). The user should provide the maximum specified VS if maximum brightness is desired. Some models (such as the EL320.240 HB) have a built-in frame buffer such that the display runs at a fixed frame rate regardless of the user’s VS frequency.

### **Are Electroluminescent (EL) displays sunlight readable?**

In general, EL displays are not sufficiently bright to be considered sunlight readable. However, due to the good contrast of EL displays, they are easily “daylight” readable especially for the brighter models and especially when used in conjunction with optical enhancements such as AG or AR. (See FAQ regarding optical treatments.)

### **Can an Electroluminescent (EL) display be dimmed for night viewing?**

Yes, most models have an analog (0-5V) input which enables the user to dim the display down to black.

### **Does the display look perfect as it is dimmed to black?**

The display looks good, but not perfect. As the display is dimmed, some anomalies begin to show. Below 10 nits, one can perhaps see brightness variations such as bright edges, and possibly burned-in

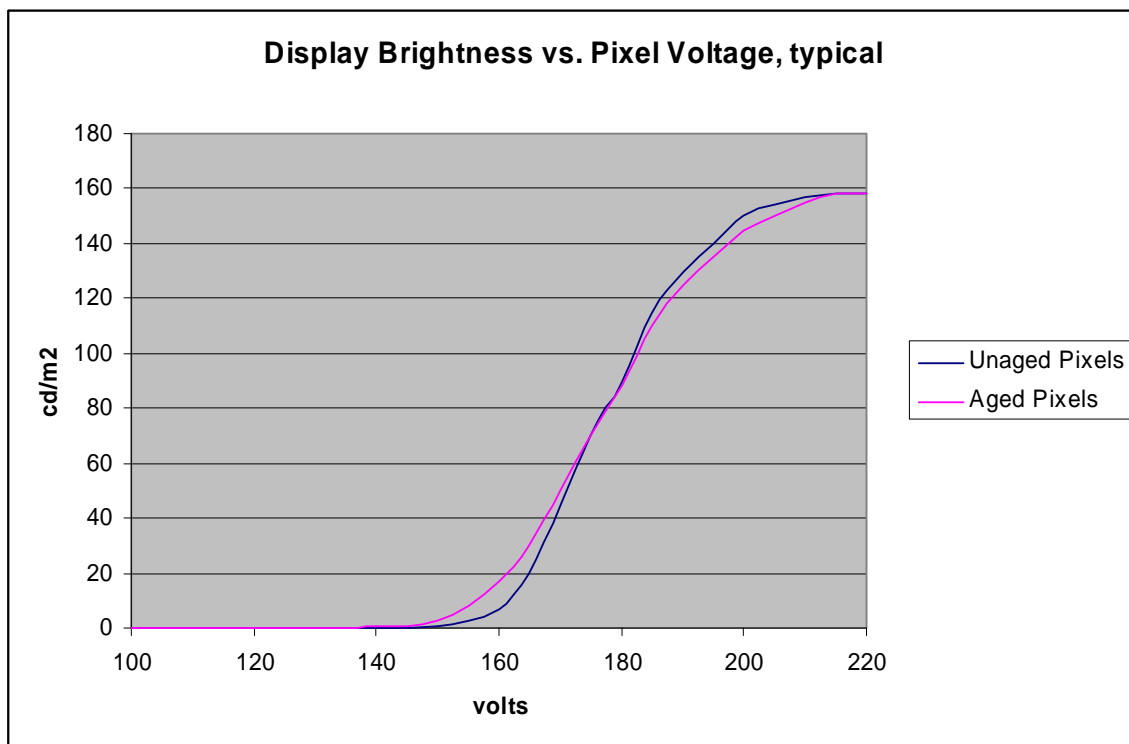
images of previously shown patterns. But these amount to cosmetic concerns as the information displayed is useable down to a nit or less. Lowering the frame rate to 70 Hz before using analog dimming will minimize the visual artifacts seen.

### What about latent image?

Latent image, where a commonly-displayed image is burned into the display, is an issue for all emissive technologies. EL displays are susceptible to latent image, but the effect is subtle and latent image has not been a major problem for EL applications. There are two types of latent image: "on" LI, where the aged pixels become less bright compared to the unaged pixels, and "off" LI, where aged pixel's brightness increases slightly when in the off state. Off LI is possibly seen when the displayed is operated in a dark room and formerly aged pixels can be seen to glow slightly. On LI—usually less of an issue—is possibly seen only when large blocks of pixels are turned on in an area of aged pixels such that the faint outline of the aged pixels can be seen.

### What causes latent image?

The LI mechanism is not fully understood, but in general ionic charges in the thin film stack (mostly sodium ions) migrate over time due to the applied voltage. Due to the charge migration, a DC bias accumulates on aged pixels and thus the aged pixels see a different net voltage than unaged pixels when driven by the electronics. This difference in voltage impacts the pixel brightness as shown in the following graph.



**Based on the above graph, couldn't latent image be eliminated by simply driving the off pixels at 140V and driving the on pixels at 220V?**

Yes, but the display power consumption would increase dramatically (by about 3x) and the higher component temperatures would need to be thermally managed. To balance power/thermal performance and contrast/latent image performance, Planar typically drives off pixels at 150V and on pixels at 200V, though the exact voltage varies from unit to unit and is controlled by a factory-set potentiometer on the display.

### Does Planar have specifications for latent image?

There are internal specifications for latent image, found in the display's Engineering Specification. Typically, on LI is specified at no more than a 7% brightness change after 1000 hours of aging (some models use 10%). Typically, the off LI spec is aged pixels must be less than 0.5 nits after 1000 hours of aging. Note that after the 1000 hours the rate of LI formation decreases, with most of the LI forming in the first few hundred hours of operation.

### What can be done to prevent latent image?

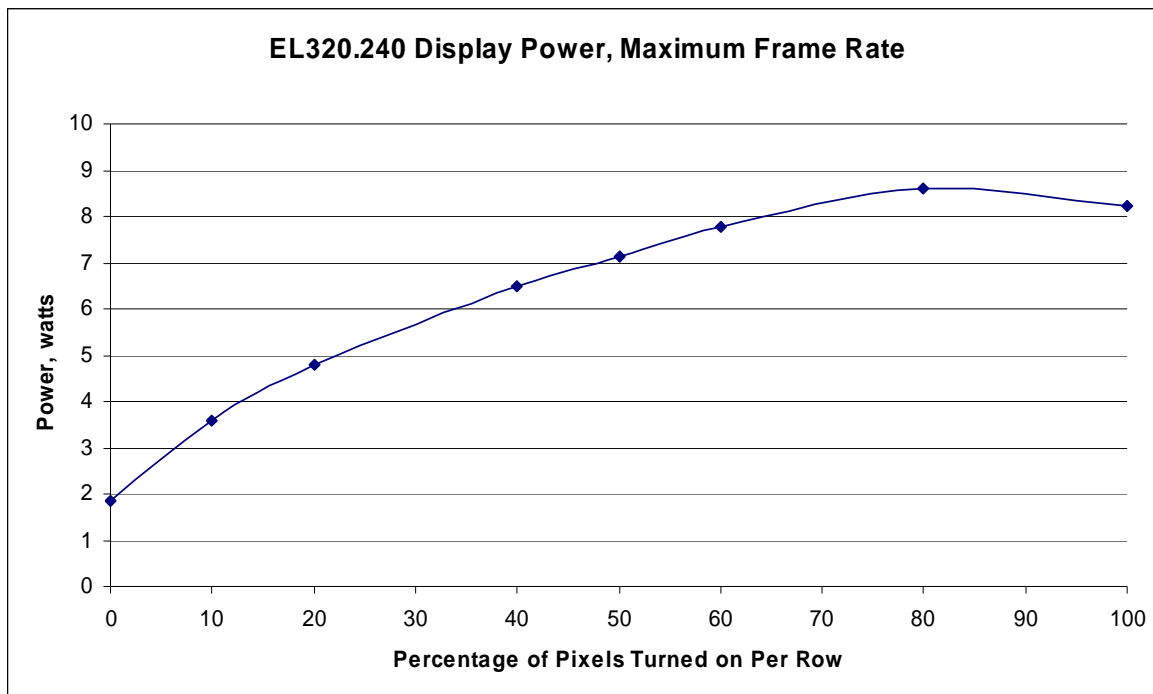
Screen savers work well but are not always feasible for the application. Image inversion, if done periodically such that all pixels are aged evenly, will eliminate latent image. Performing an extended burn-in as part of the OEM's manufacturing process with all pixels turned on will reduce any subsequent latent image. Avoiding the use of large blocks of on pixels will make "on" LI difficult to detect. To minimize "off" LI, a special calibration can be done at Planar's factory where the display is set to a lower voltage than normal (however this will reduce the display brightness and also make "on" latent image slightly more conspicuous, and is only applicable if volumes are relatively high).

### Is there any reason why a user would want to drive an Electroluminescent (EL) display at less than the maximum frequency?

The user may want to dim the display for night viewing as described in a previous FAQ. In addition, lowering the frame rate will save significant power because power consumption is directly related to frame rate.

### What is the power consumption of Electroluminescent (EL) displays?

Power consumption ranges from 1 to 15W and is highly dependent upon the display model, the frame rate, and the displayed pattern. For the EL320.240HB, typical power is 5.5W with 20% of the pixels on and at the maximum frame rate. The highest power consumption will occur when 50 to 80% of the pixels per row are lit, depending on the model type. Below is a graph showing the power and pattern relationship for an EL320.240HB display.



### **What voltages must be supplied to an Electroluminescent (EL) display?**

Most models require a 5V power input for the logic and a 12V power input for the analog circuitry. The 5V supply current is typically about 30 mA and thus nearly all of the input power is provided by the 12V supply. Some models can tolerate an 8 to 18V variance on the "12V" supply input. Consult the display's operations manual for details (see [http://www.planar.com/Support/Support\\_By\\_Product/Embedded/EL/index.html](http://www.planar.com/Support/Support_By_Product/Embedded/EL/index.html).)

### **Can Electroluminescent (EL) displays provide gray scale?**

Only two models have inherent limited gray scale—the red/green AA1 and FA3 displays. All other models are monochrome and the pixels are either on or off. However, third party flat panel controllers often have algorithms which manipulate the video data stream to provide some levels of gray scale. Typically, frame-based dithering is used to write pixels on only a portion of the frames such that dimmed pixels are not written as often as bright pixels. The user must be careful to select gray levels that look acceptable, as the frame dithering method often causes objectionable video artifacts (shimmering, flicker, etc.) due to the fast response time of the EL phosphor. For displays running at 120 Hz, one or two acceptable-looking gray levels are typical whereas for displays running at 240 Hz three or four good gray levels are achievable.

### **How long does the Electroluminescent (EL) phosphor last?**

The phosphor lasts essentially forever. There will typically be a 5% drop in brightness after the first 1000 hours of operation, and thereafter the rate of brightness decay will decrease. Planar has never run a test long enough to see a display decay to the traditionally-used end of life point of 50% of initial brightness. The typical EL specification is an estimated 15% drop in brightness after 100k hours (about 11 years).

### **What about MTBF?**

Most Planar EL displays have a specified MTBF of 50k hours, with some specifications as high as 100k hours, and all display models have been tested to verify compliance with the MTBF specification. It is highly likely that higher MTBF numbers could have been demonstrated for each model but typically MTBF tests are terminated after the specification is met.

### **What is the typical failure rate for Electroluminescent (EL) displays?**

Based on customer service return data, the failure rate for the first year is less than one percent. This is lower than the flat panel industry average.

### **What are the common failure modes?**

Some common failure modes are interconnect failure (resulting in dark rows or dark columns), row driver IC failure (dark rows or dark display), or MOSFET failure (dim or dark display).

### **Are there fuses on the Electroluminescent (EL) display?**

Not on most models. If concerned, OEMs can add fuses or current limits to their 5V and 12V inputs to the display.

### **How much performance variation is there from sample to sample for a given display model?**

Due to lot to lot variations in the thicknesses of the deposited thin films and other processing variations, there can be performance differences between display samples. Brightness variation is perhaps +/- 20%, with similar power variations (brighter = more power). In addition, the dimming performance (percentage of full brightness for a given voltage applied to the analog dimming input) will vary significantly. These variations have not caused major problems for customers in the field, but should be noted.

### **What testing does Planar perform on its Electroluminescent (EL) displays?**

During Planar's manufacturing process all EL displays are burned in, typically for 24 hrs depending on the model, in an environment which varies from -20C to 55C every six hours. After burn-in, the displays undergo a Final QC test where brightness, brightness uniformity, and power consumption are verified to meet the specification and where patterns are displayed and observed to ensure all columns and rows are properly connected. Prior to being assembled in a display the glass panels themselves are burned in for 8 to 24 hours at elevated temperatures (exact burn-in parameters vary with glass model). And, of course, during product development extensive testing is done to ensure that the display model meets all specifications such as mechanical shock, vibration, operating temperature, EMC, MTBF, etc.

### **Do Electroluminescent (EL) displays make acoustic noise?**

Yes, the EL thin film stack is slightly piezoelectric, which means some physical displacement occurs when a drive voltage is applied. Because the frequency of the row voltage pulses are typically in the 10 kHz range, an audible hum can sometimes be detected. The hum will vary greatly depending on model type, displayed pattern, VS frequency, and quality of the observer's hearing. Once the display is embedded in the final system the hum is not as detectable as when the display is run by itself and has not been known to be a problem.

### **How about the response time of Electroluminescent (EL) displays?**

The response time of the EL phosphor is fast (<2 msec), but it is somewhat limited by the fact that the phosphor relies on an AC waveform and only a unipolar waveform is applied on any given frame. For a given pixel, the full brightness occurs only after two frames (such that the pixel has seen both positive and negative voltage pulses.) So for the case of a cursor moving rapidly across a screen, sometimes artifacts can be seen if pixels do not remain lit for at least two frames. Assuming a 640x480 display running at a 120 Hz frame rate and a cursor moving across the display in a horizontal directly, to guarantee no artifacts the cursor must not move across the screen in less than 10 seconds. That said, scrolling waveforms look fine due to the thinness of the illuminated line, which is fortunate given the many applications which show waveforms. A moving square (for instance ten pixels wide) will be a different story: the leading and trailing edges of the square may be noticeably dimmer than the center of the square.

### **How hot does the front of the glass get?**

Most models see a temperature rise of 5 to 10C above ambient. However, some models are hotter, most notably the EL160.80.50 which has a 40C rise above ambient on the glass surface with a worst case power pattern displayed at the maximum frame rate.

### **If a display is rated for an ambient of 65C, then can the host system be run safely in a 65C environment?**

Probably not. The temperature-sensitive portion of the EL display is the electronics, so the ambient for the electronics cannot exceed 65C. Thus the interior of the host system adjacent to the display electronics must not exceed 65C, which implies that the outside of the system must be less than 65C due to the temperature rise in the box.

### **What limits the low operating temperature specification?**

Generally the limiting factor is the display electronics. Meeting the -40C operating specification is generally easy: components (notably the capacitors) must be selected for low temperature operation. However some EL models are specified to only -20C or even -5C. These models in general were designed with low cost in mind and thus the low temperature components were not selected. Or possibly the display was designed for a certain customer who did not require -40C operation. Operating temperatures of -50C are possible; Planar does extensive verification and analysis to verify -

50C operation because most components are not available with -50C specifications and zebra type-interconnects can lose compression below -40C.

### **What limits the high operating temperature of Electroluminescent (EL) displays?**

As with low temperature, the limiting factor is the electronics. Planar's design must ensure that the device temperature specifications for the electronic components are not exceeded under the worst case conditions of maximum frame rate, maximum power pattern, maximum load due to glass panel variation, and maximum ambient temperature. High brightness capability is always desired, but higher brightness translates to higher component temperatures so there are trade-offs to be made during the design process.

### **Do customers typically put a cover or optical treatment over the Electroluminescent (EL) display?**

It varies. Some customers put nothing over the display. For applications in high ambient brightness, some customers place a clear cover such as a polycarbonate over the display. This eliminates much of the specular (mirror-like) reflections from the front surface of the glass and has the added benefit of allowing a good seal against dust and liquids. Also, there is the cosmetic benefit of a seamless tie-in mechanically to the customer's enclosure. On the downside, the polycarbonate cover will detract from the sharpness and brightness of the optical image. Instead of a polycarbonate cover, for a bit more expense AR (anti-reflective) or AG (anti-glare) films can be applied to the front of the EL glass.

### **Can Planar provide optical treatments for Electroluminescent (EL) displays?**

Yes, some products are available with an anti-glare (AG) surface treatment. Planar also has optical bonding capability and can provide customized optical solutions.

### **What are the available sizes of Planar's Electroluminescent (EL) displays?**

The largest EL display is a 10.4 inch diagonal 640x480 display. The smallest EL display is a 3.1 inch diagonal 160x120 display. The maximum size is limited to 10.4 inches due to the size of our glass processing equipment. There is no definite minimum size limit—Planar has made displays as small as 1 inch by 1 inch and could go smaller.

### **Planar's current offering of Electroluminescent (EL) displays are all matrix displays. Are segmented EL displays possible?**

Yes, segmented displays (such as the ubiquitous seven segment numerical digit) or displays utilizing fixed icons are possible. In addition, a single display glass could contain a portion that is arranged in a matrix along with icons or segmented areas. Any of these configurations would be custom products as of this date and thus would require significant volumes and/or NRE.

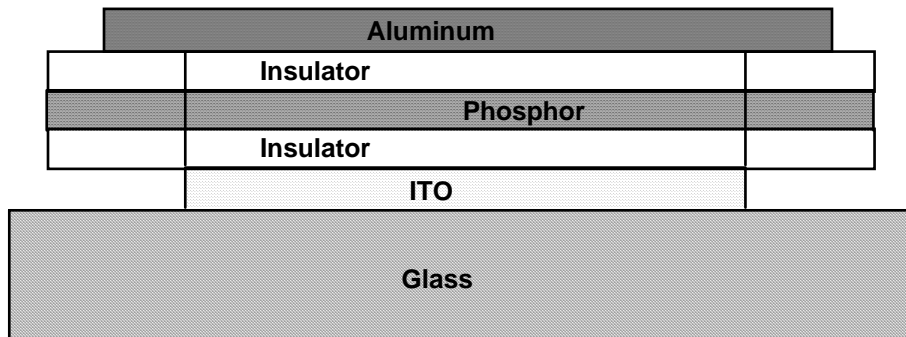
### **Instead of a complete Electroluminescent (EL) display module, will Planar sell just the EL glass?**

Yes, Planar has sold just the EL glass in the past, mostly to military customers. The OEM would then design the specialized drive electronics to provide the required high voltages to the glass and design the mechanical housing, as well as design the specialized equipment required to assemble the glass and electronics. This involves considerable engineering effort and makes sense only for large volume applications where the OEM has available engineering resources and time.

### **What is the nature of the Electroluminescent (EL) glass?**

The heart of the EL display is a thin film stack consisting of a phosphor layer sandwiched between two insulating layers. The thin film stack is approximately one micron thick and each of the three thin film layers of the stack is grown in a carefully controlled proprietary ALD (atomic layer deposition) process to give uniform brightness across the display area. This thin film stack is sandwiched between two orthogonal arrays of conductors, and the entire structure resides on a glass substrate and is passivated by a back cover glass. The phosphor is zinc sulfide doped with manganese. The front (column)

conductors are ITO (Indium Tin Oxide), a transparent conductor, to allow the emitted light to reach the viewer. The back (row) electrodes are aluminum. Below is a diagram depicting the EL glass structure (the back cover glass is not shown.)

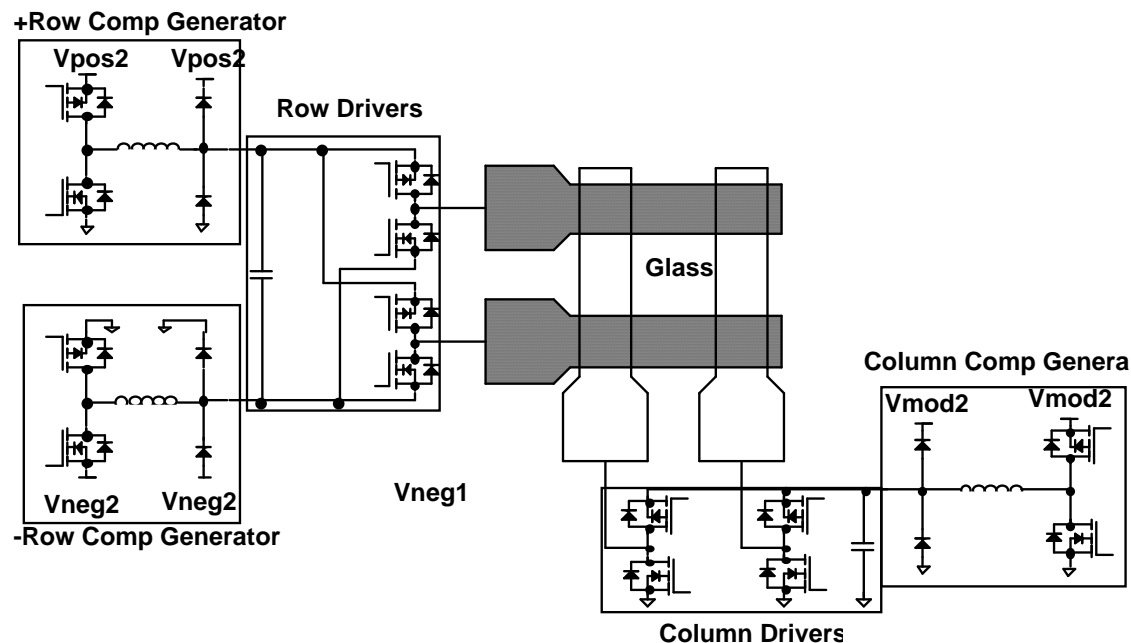


**What is ICE or ICEBright?**

ICE is an acronym for Integral Contrast Enhancement. ICE or the trademarked “ICEBright” refers to a process developed at Planar which greatly increases contrast by making the normally silver aluminum conductors appear black. The ICE effect is achieved by growing oxide layers on the aluminum row conductors. The layer thicknesses are such that reflected light interferes and is cancelled, much like what happens with an AR filter. All but a few of the older EL display models have ICE.

**What is the nature of the Electroluminescent (EL) drive electronics residing on the display?**

The Planar drive electronics include a power supply to provide the required three DC power rails: 50V, -150V and 200V. (Some models use as many as six DC rails, with three “extra” rails to increase drive efficiency.) An arrangement of MOSFETs and, in some cases, inductors are included to shape the DC rails into the waveforms required by the glass panel. High voltage column driver and row driver ICs are used to gate the shaped waveform to the row and column electrodes on the glass. A controller IC, typically an FPGA, is used to control the MOSFETs, column drivers, and row drivers based on the timing of the video signals provided by the host. Below is a simplified diagram showing a portion of the typical drive electronics (not shown is the power supply, controller and level translation circuitry).



### **How are the contacts on the glass panel connected to the contacts on the electronic circuit board?**

There are various methods. Most common is a compression connection using elastomeric connectors, or zebra stripes, which are compliant gasket-like strips with embedded conductors. Other display models have column driver ICs packaged in TCP (Tape Carrier Package) where one end of the TCP is bonded to the glass contacts and the other end of the TCP is soldered to the board. On models using TCP for the columns, heat seal is bonded between the glass row contacts and the board row contacts. Finally, a few older models use lead frames which are soldered to the glass and to the board.

### **Is Electroluminescent (EL) a new display technology?**

No, EL displays were first commercialized in the 1980s. EL continues to be a reliable technology for high performance applications.

### **How large can Electroluminescent (EL) displays be?**

Though Planar has made 19 inch diagonal EL displays in the past, at present the largest size is limited to 10.4 diagonal due to manufacturing equipment limitations. Larger glass sizes would require prohibitive equipment expenses.

### **How small can Electroluminescent (EL) displays be?**

There is no real limit, but as the active area (light emitting area) of the glass is decreased, the perimeter area would begin to dominate the glass size. A shelf of approximately eight mm must exist around the perimeter to provide for a seal area (area where the back cover glass is glued to the front glass keep water vapor out of the thin film stack) and to provide for an area for the contacts which connect to the electronics.

### **How small can the pixels be?**

The smallest pixel pitch on an existing model is 0.16 mm (pitch of the sub-pixels on the FA3). There is no lower limit to the pixel pitch, but lower pitches can impact yields and thus increase costs. Also, there must be sufficient room to fan-out the contacts for connection to the electronics.

### **How many Electroluminescent (EL) models are available?**

Planar has 17 EL product families available, each typically with several family members. There are 62 different models listed in the Planar catalog. In addition there are a handful of models not listed in the catalog because they are custom displays for which the customer paid NRE and thus are not generally available for sale to other customers.

### **Can Electroluminescent (EL) displays be made on curved surfaces?**

Some R&D work has been done to heat and deform the glass into curved shapes after the EL display glass has been manufactured. The work has been promising and demos have been created, but nothing has been commercialized.

### **Can Electroluminescent (EL) displays be fabricated on plastic substrates instead of glass substrates?**

Plastic substrates cannot be used due to the high temperatures involved with the thin film deposition processes.

### **What do the model names mean?**

Though there is some variation in the model name configuration, consider the most common model configuration such as "EL160.80.50 ET CC." The "160" means that there are 160 columns and the "80" is for 80 rows. The "50" is the pixel pitch (both vertically and horizontally because on nearly all EL displays the pixels are square) in hundredths of millimeters (thus 0.5 mm from the center of one pixel to the center of the adjacent pixel.) The "ET" means that the model has a wider operating temperature

range (Extended Temperature) than other models of the 160.80.50 family. The "CC" means the circuit board is conformally coated to ward off the effects of moisture or metallic debris. Note however that often there are portions of a model name which have no meaning, such as the "AM1" in EL640.480AM1.

**What is the best selling Electroluminescent (EL) display model?**

The best selling model is the EL320.240.36HB. Other popular models are the EL160.80.50, EL640.480AG ET, and the EL320.240.36.

**What are the full specifications for Planar's Electroluminescent (EL) displays?**

The specifications vary somewhat from model to model. See the link to Planar's website below for a list of the operations manuals which contain the display specifications.

[http://www.planar.com/Support/Support\\_By\\_Product/Embedded/EL/index.html](http://www.planar.com/Support/Support_By_Product/Embedded/EL/index.html)

**What are Planar's future plans for Electroluminescent (EL)?**

Planar is investigating the use of EL technology for segmented displays. Planar is also looking for applications for transparent EL displays and for EL displays with a mirrored surface which look like a mirror until the display is energized. All of this activity falls under the TASEL program (Transparent and Segmented EL.) In addition to TASEL, Planar's most recent EL product addition is the EL320.240 FA3, a red/green/yellow display.