

How to design backlights for LCD TV displays with scrolling LEDs

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You can improve contrast and reduce motion blur by sequentially flashing zones in an LCD display that is back lit with edge-mounted LEDs. You achieve this scrolling illumination with improved LED driver ICs. With the help of some timing diagrams this article will reveal how this works in principle and will give a description of the different modes of operation.

LEDs have become the dominant technology for backlighting LCD displays in TVs and desktop monitors. LEDs have consigned cold-cathode fluorescent (CCFL) tubes to the dustbin of history. Since they contain no mercury, LEDs are more environmentally friendly than CCFLs. Manufacturers must now optimize designs to extract maximum performance for minimum cost. This often comes down to what's right for a particular application.

Direct LED backlighting using a two-dimensional array of LEDs behind the LCD panel offers the ultimate performance for high-end TVs. Yet the performance possible with edge-lit panels now provides the mainstream market solution. Edge-lit panels account for over 90% of all LED backlit displays. These panels use LED light bars at the top or bottom or sides of the display. If you are using the high-brightness LEDs now available, edge-lit displays require far fewer LEDs than a direct backlight array. The cost benefit and ease of design are obvious.

Scrolling is all about timing

Edge-lit panels must deliver a sufficiently bright backlight evenly across the entire LCD panel. Edge-mounted cold-cathode tubes achieved this with a combination of diffusers and polarizers. Having a row of LEDs at the edge of a display opens up other possibilities. You can allow the light from individual LEDs to be directed to specific areas of the display, known as illumination zones. While dimming a cold cathode backlight could provide enhanced contrast when viewing dark scenes, this was generally restricted to the whole screen. This means only a frame-to-frame brightness variation is allowed and illumination would more likely spill over to neighboring video frames. LEDs can illuminate more localized areas of the screen, and have much faster response times. It is now possible to dim the backlight in darker parts of the scene while retaining full brightness elsewhere in the same frame.

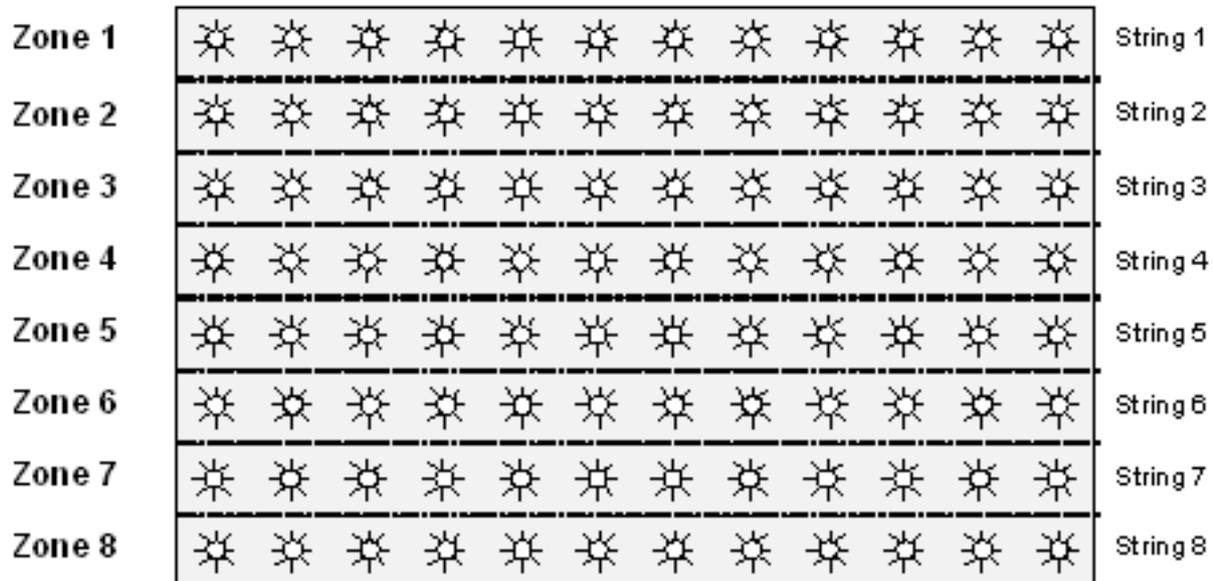
The secret is timing the illumination to deliver the light to the screen at precisely the right moment. You synchronize this with the displayed image to allow for varying LCD characteristics and any other losses in the optical components. This solution is referred to as a 'scrolling backlight system' but it includes a number of techniques to realize a superior picture. These solutions are available in

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sophisticated LED driver technology, including Atmel's MSL2164 series devices, which embody all these features (Figure 1).

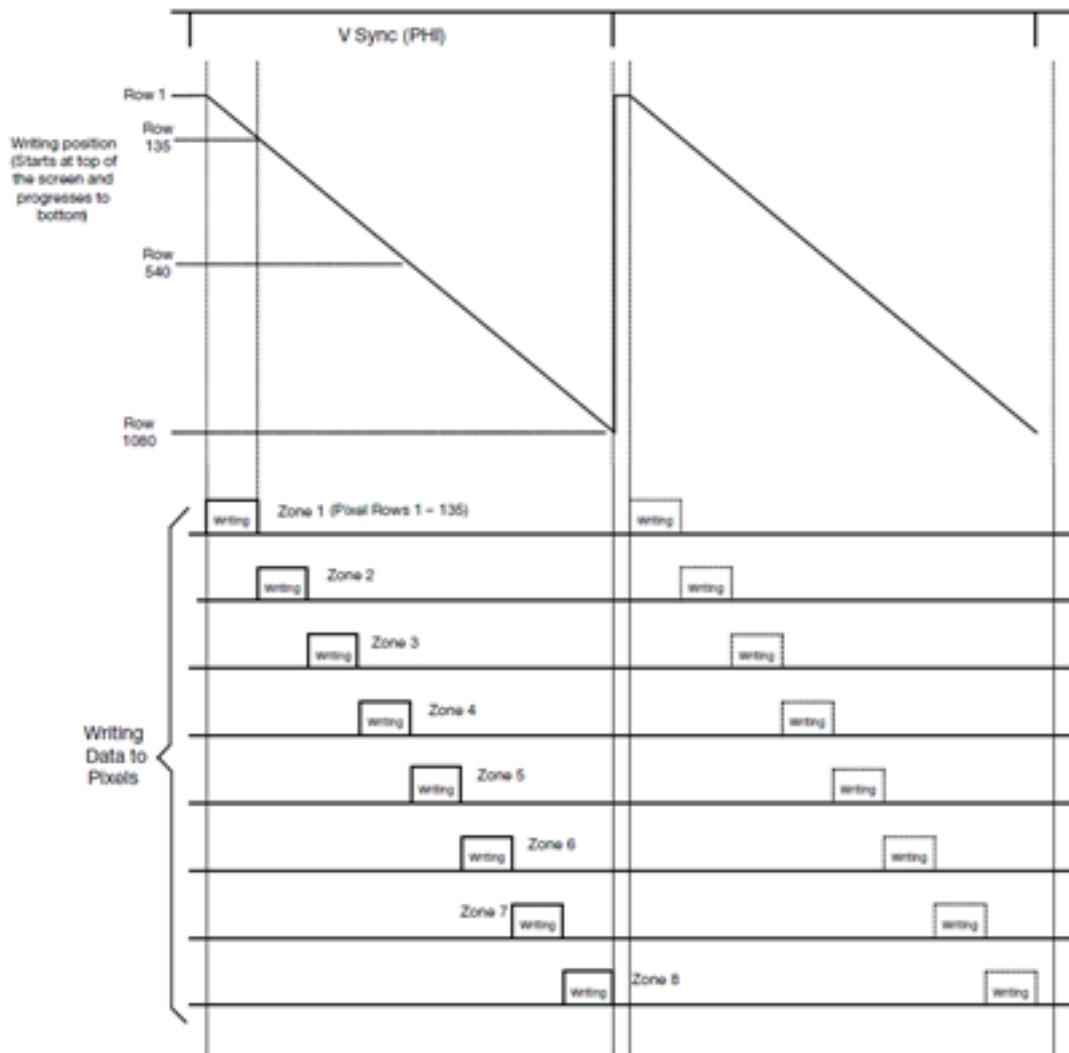
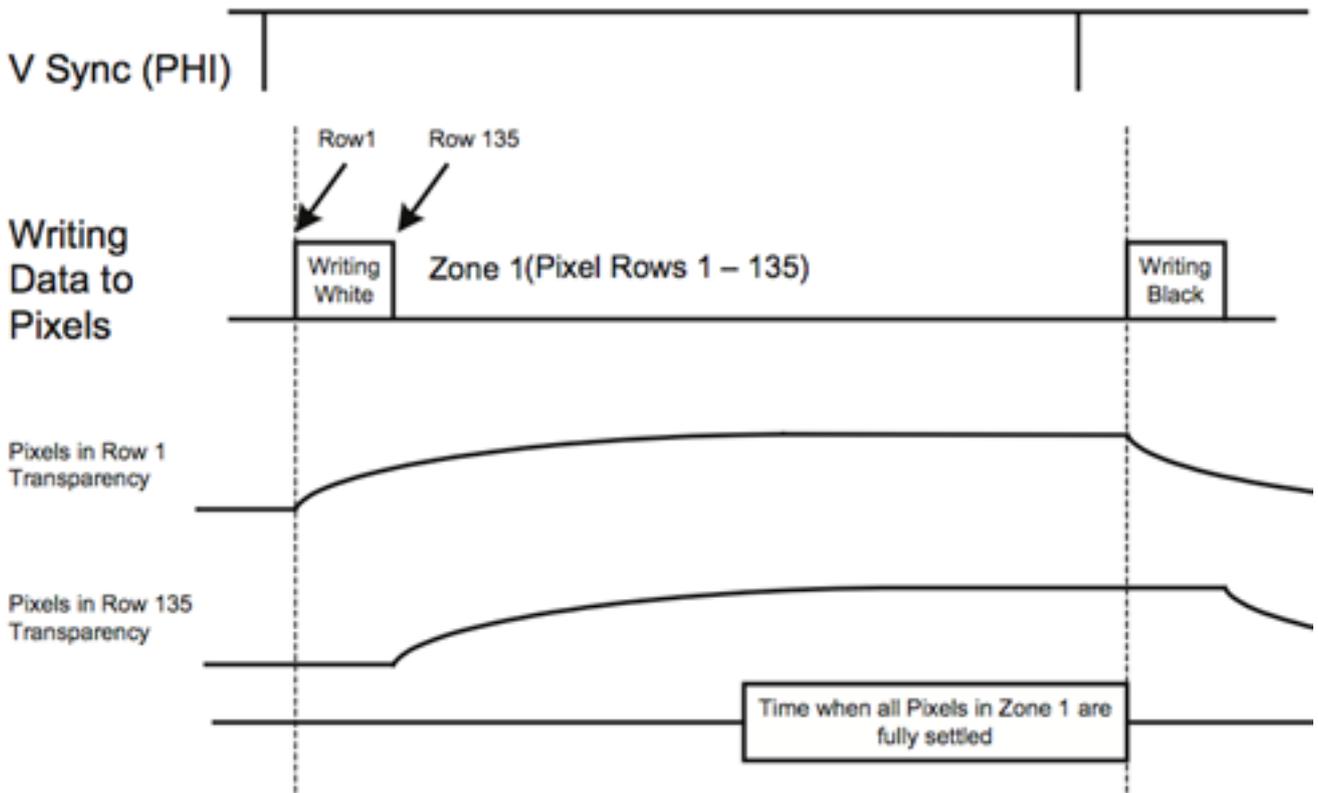
Illumination Zones
On LCD Screen



The slow response time of the liquid crystal material can cause motion blur when an on-screen movement is faster than the time it takes for the pixel to settle to a new value. You can improve the image by blinking off the backlight while the pixel is changing. The term black frame insertion refers to when you would blank an entire frame with cold-cathode tubes. It is still called black frame insertion despite the fact that with LEDs you can just blank out the brief time the pixels are changing, not the entire frame duration. This technique works particularly well in conjunction with illumination zones because you don't blank the whole screen at the same time.

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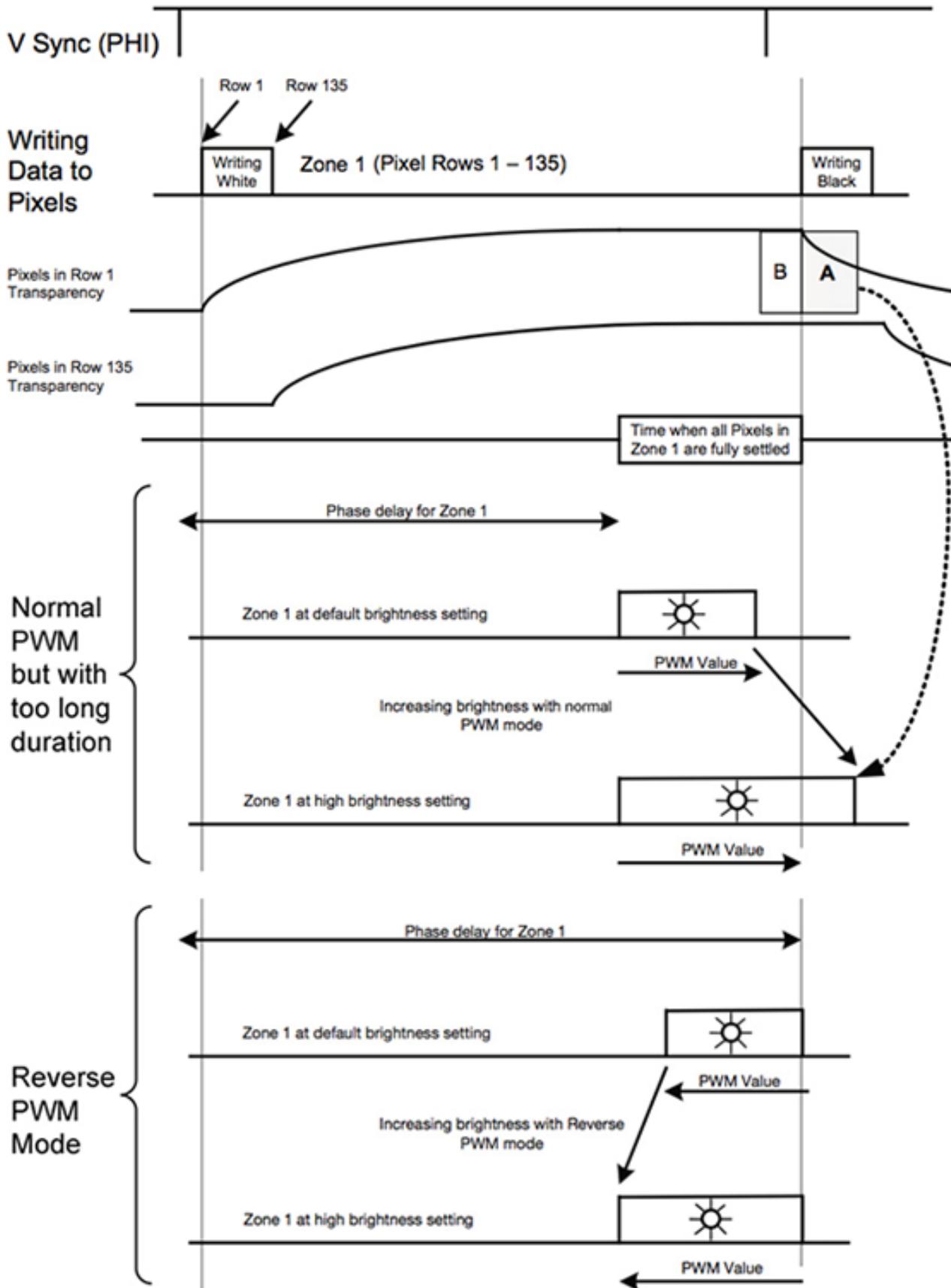
If you take an HDTV with 1080 rows of pixels that are edge-lit with just eight LEDs, you get eight horizontal illumination zones (Figure 2). Each zone contains 135 rows of pixels. As the LCD image is built up by writing one whole row of pixels at a time, there is a phase delay after the vertical sync pulse (VSYNC), before all the pixels in Zone 1 (rows 1-135) are fully settled (Figure 3). The optimum time for viewing this zone is once the pixels are settled. Ideally you only want to illuminate this zone during that period. For subsequent zones (zones 2 - 8) the optimum viewing and illumination period will be similarly offset by the phase delay from the start of that zone's pixel writing period. Since these zones are staggered throughout the frame, it results in the backlight illumination scrolling down the display (Figure 4).

Another limitation of LCDs is their limited contrast range. An LCD pixel is not a perfect shutter. In its dark state there is some light leakage, especially when you view the panel at an angle. You can enhance contrast by dimming the backlight for dark scenes, but when combined with scrolling LED backlights you can also control the brightness during the illumination period. The accuracy of addressing each frame and zone independently allows a much faster response for dark-to-bright scene transitions than is possible with non-scrolling backlights.

You adjust brightness during the fully-settled pixel period by varying the duty cycle of time the backlight is switched on during that period. This is called pulse-width modulation (PWM). There is a default brightness level, with an associated PWM illumination period value, that is less than the full period when the pixels are stable. This allows for higher or lower brightness levels by setting larger or smaller PWM values. Conventional PWM dimming turns the backlight on at the start of the stable pixel period and off after the PWM illumination period. There is a danger that a large PWM value may result in the backlight remaining on into the next pixel-writing period for that particular illumination zone (Figure 5). To overcome this problem the Reverse PWM method aligns the end of the PWM period to the end of the fully-settled pixel period as seen at the bottom of Figure 3. It is better to always use area B and to start the illumination as early as necessary to achieve the desired brightness.

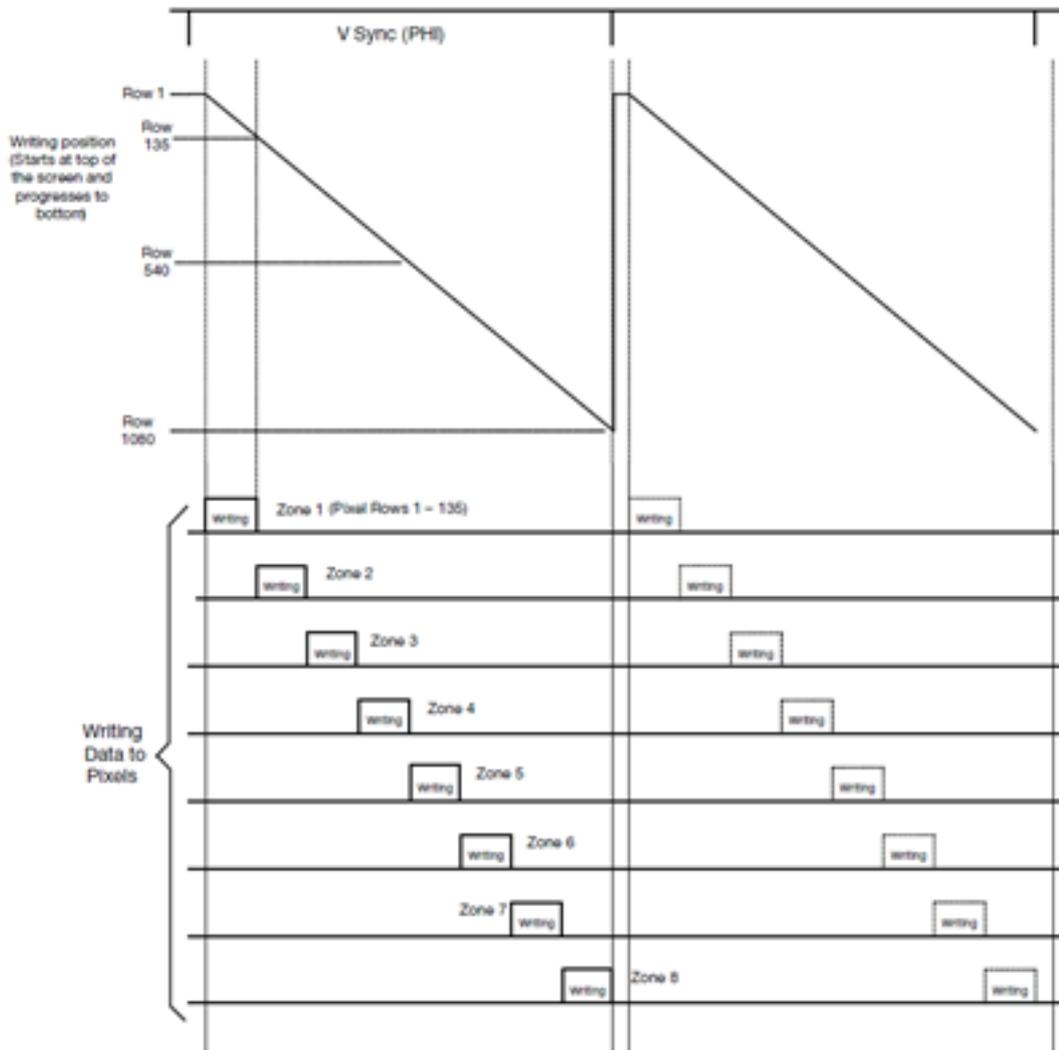
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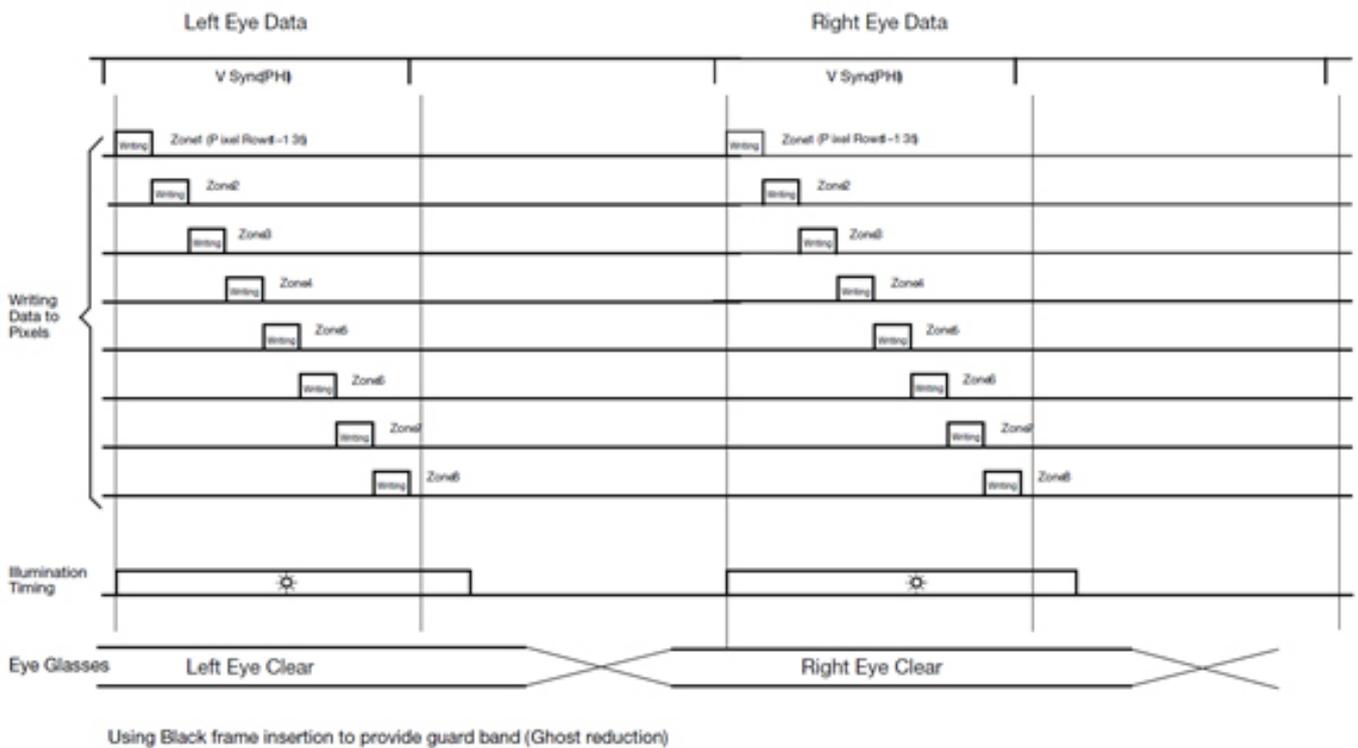
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It is important to reference the timing of all illumination zones to the same VSYNC that is associated with the start of that frame's pixel-writing process. Referencing some zones to a subsequent VSYNC can result in brightness banding due to variations in frame duration that can result from video manipulation.

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3-D TV, with left and right eye image, reduces the time available for backlight to be on. There is a possibility of needing a large PWM on-time that might spill over to the next frame. In this case, it may be better to illuminate before the pixels are settled in the current frame itself. For 3-D applications with active shutter glasses the timing requirements are more stringent. The LCD eyeglasses have slow response while changing from opaque to clear and vice-versa. There should be no time overlap (crosstalk) and this is guaranteed by inserting a black frame during this transition (Figure 6).

Conclusion

LED backlighting for LCD TVs using edge-lit display panels has rapidly become the technology of choice, providing both a high-performance and cost-effective solution for the majority of the TV and desktop monitor market. The faster switching speed of LEDs coupled with advances in driver IC design makes it possible to address some of the previous limitations of liquid crystal displays, such as motion blur and poor contrast.

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