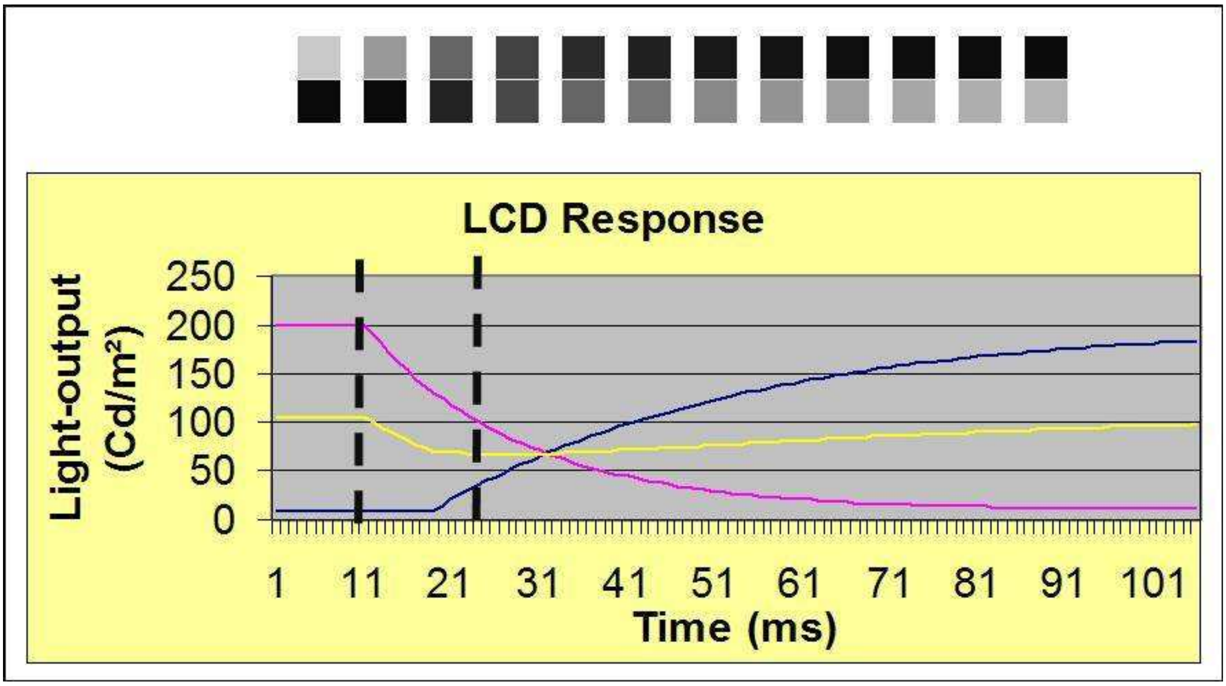
# LCD Flicker and Flicker Compensation - November 2007

## 1 Root cause of Liquid Crystal Display (LCD) flicker when displaying a sonar image.

A sonar image is created by displaying acoustic data in a graphic format. An LCD display represents this as a range of bright and dark pixels scrolling down line by line. To increase the usability of sonar images, the bright and dark pixels are set to their maximum values, comparable to a Pixel On/Pixel Off pattern. When this high-density, high-contrast image is presented on an LCD, the difference between the rise and fall curves on the LCD causes flicker. This optical response results from turning a pixel on (a rising edge) and turning a pixel off (a falling edge).

We can easily understand this phenomenon by following a bright pixel on a dark background during its transition to a dark pixel.




At time 0, the top pixel (pink line) is a bright pixel. The bottom pixel (blue line) is a dark pixel. The eyes of the operator will integrate the two pixels and see an average brightness (yellow line).

About 10 ms later, the screen is updated and the top pixel scrolls down resulting in a bright bottom pixel and a dark top pixel. The transition time and shape of the curve are not equal for rising (black to bright) and falling (bright to black) transitions. The top pixel falls to black quickly, while the bottom pixel rises to bright more slowly. At time 25 ms, the top pixel has already fallen to 100 or 50% luminosity, while the bottom pixel has risen only to 40 or 20% luminosity.

As the eyes of the operator continuously integrate the different pixels to an average brightness, the total resulting brightness that the operator sees will be about 100 at time 0 and at 10 ms, but it will drop to 70 at 25 ms, and then gradually rise back to 100 after that. This short intermediate drop to 70 is perceived as flicker when it occurs over a certain screen area filled with moving high-contrast data (such as sonar data).

## 2 Why are the rise and fall curves not equal?

The brightness of a Liquid Crystal Display pixel is determined by the rotation of crystals in the liquid underneath. When a voltage is applied, the crystals turn in a certain direction – this increases the transparency of the liquid, thus increasing the brightness. When the voltage is turned off, the crystals turn back to their original position.

Two opposing forces determine the speed of a pixel's transition from dark to bright and from bright to dark:

1) The force induced by the voltage, which rotates the crystals into the 'open' position,
2) The natural force that pulls the crystals back to their original position (determined by the roughened surface on which the crystals rest).

These forces are not equal, and in addition, the order of the transition is not the same. The force pulling the crystals back into their normal (black or dark) position is basically a first order exponential phenomenon. The force induced by the voltage to rotate the crystals into an open or bright position is a higher order exponential phenomenon. The liquid crystals react more slowly at first and then pick up speed. Barco calls this delayed reaction the 'response delay'.

An important side effect of these two forces is that, even if the rise and fall times are equal, the curves will still be different.

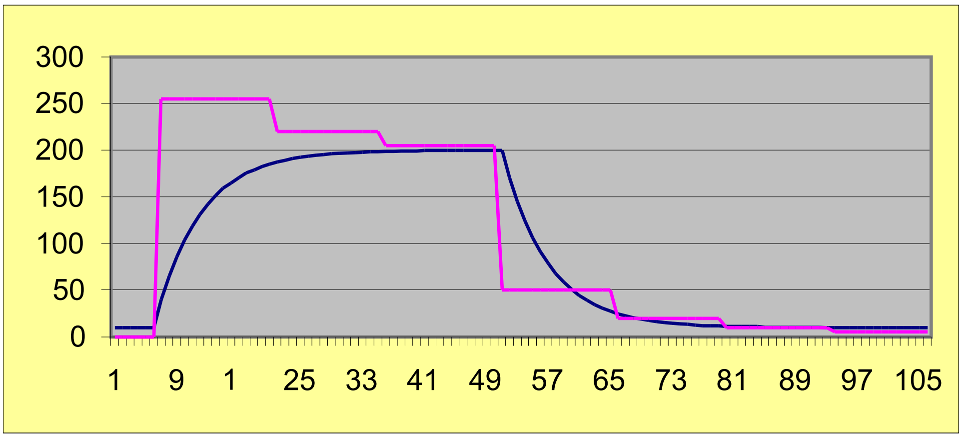
### *2.1* Additional parameters

In addition to the parameters described above, the rising and falling curves also change according to temperature and viewing angle (due to gamma shift). Furthermore, each individual LCD has its own characteristics and curves.

## 3 How Barco has solved the LCD flicker problem

The essence of Barco's solution is to implement a real-time algorithm that makes the rising and falling curves match a predefined profile. This is done on a pixel-by-pixel basis, in real time, and taking into account the temperature of the LCD liquid and the individual LCD's characteristics.

The display's electronics calculate the expected transition on a frame-by-frame basis. The slower transitions are accelerated by overdrive, and the faster transitions are slowed down by underdrive. The slopes of the rising and falling edges can be changed for each frame. In the illustration below, the pink line represents the drive, and the blue line represents the resulting response.




### *3.1* How does Barco calculate the correct responses?

Barco creates a characterization for each LCD panel by measuring the rising and falling response curves in 16 steps, from black to bright and bright to black (i.e. 16x16 data points). This is done for all temperatures in steps of 5°C and for the different vertical frequencies. This process takes about 20 hours in a burn-in chamber.

A software application is used to calculate a good target response for the overdrive/underdrive for each transition at a particular temperature.

Barco has developed algorithms to calculate 2 values for each pixel:

1) A prediction of the crystal orientation for the next frame
2) The overdrive/underdrive needed to generate the target response.

The technology described here has been developed and patented by Barco (see attachment, U.S. Patent 6359663). No licenses have been granted to any company or organization.

## 4 Why all LCDs exhibit flicker

Due to the physics of liquid crystals, today's LCD panels have inherently dissimilar response curves for the rising and falling transitions. Although LCD panels have become faster, the response curves are still different. So, even as LCD response times decrease – and rising and falling times become more equal – flicker still occurs. The visible flicker is becoming briefer due to the faster response times, but the flicker has a larger amplitude.

### *4.1* Different LCD technologies

There are 3 mainstream technologies among the various LCD technologies today: TN (Twisted Neumatic), VA (Vertical Aligned), and IPS (In Plain Switching).

When looking at an LCD at an angle, a gamma shift occurs. This makes a grey pixel look brighter when viewed at an angle than when viewed perpendicularly. As a consequence, each viewing angle requires a different LFC correction. However, because it is not possible to know at what angle an operator is viewing from (let alone multi-viewer viewing angles), compensating for all possible viewing angles is simply not practical.

So, each LCD technology has some gamma shift. For TN and VA technologies, the gamma shift is substantial and immediate: visible flicker occurs at a 15° viewing angle.

However, IPS technology has a marginal gamma shift: flicker occurs at a viewing angle of 45°. Therefore, Barco recommends an IPS panel as the solution for Sonar Imagery.

Note: Medical screens are always IPS panels, as it is critically important to be able to view grey scales accurately over the full viewing area.

# 5 Other possible solutions and their drawbacks

Barco realizes that there are other solutions to the flicker problem for stand-alone displays. Nevertheless, the Barco solution is superior because it does not induce unwanted side effects.

## *5.1* Blinking backlights and LCD running at 120 Hz.

A very fast LCD is used in this implementation, in which the response time is faster than the panel refresh rate. The backlight acts like a stroboscope, lighting the LCD only when the pixels have reached their final value. In this way, the transition artifacts occur when the pixel is not lit, and so they are not visible.

When using this technique at 60 Hz, the operator will not see sonar flicker, although eye fatigue will set in immediately. Using this technique at 120 Hz solves this problem, but the temperature range is limited: today, no LCD at 0°C ambient is fast enough to reach the final value for all grey-scale transitions in less than 8 ms (120Hz).

## *5.2* Flicker-free LCDs

Some LCD vendors have recognized that a commercial application can benefit from equal rising and falling times. Wire frame CAD drawings (e.g. Mechanical Engineering) have the same issues as sonar. Therefore, certain commercial LCDs use a reduced LFC algorithm.

However, it must be stated that the performance of these LCDs depends on temperature (10°C tolerance) and viewing angle (15°) – and so these LCDs are fine for an office environment but they are not suitable for a naval application.

## 6 Conclusion

It is fair to state that displaying sonar imagery on today's state-of-the-art LCD technology – without using Barco's patented LFC technology – will entail a processing, visual, or power compromise.

Visibly yours