White Paper

10 Arguments for I-Guard®

A front screen sensor technology for flat panel medical displays

What's inside?

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- Benefits of I-Guard
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Only I-Guard sees what you see. Since I-Guard continuously analyzes the image at the front of the LCD (Liquid Crystal Display) screen, it detects and corrects those instabilities that you will see when evaluating medical images. By “seeing what you see”, only I-Guard solves the issues associated with the use of flat panel displays for medical imaging.

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1 How do Liquid Crystal Displays work?

1.1 Comparing LCD-based electronic displays to film

Liquid Crystal-based flat panel displays are basically light-valves, acting just like film in front of a light-box, only in this case the film is an electronic medium: the Liquid Crystal Display (LCD).

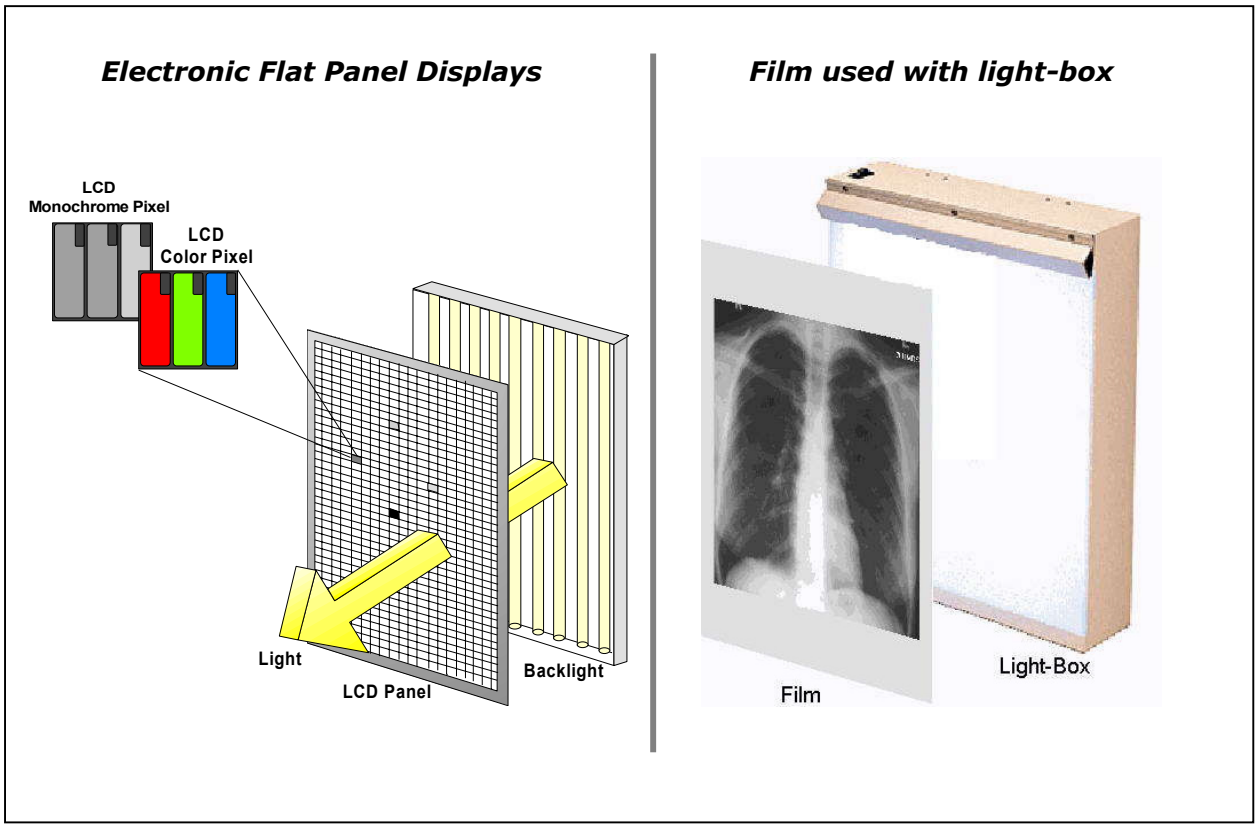

Fig. 1: The equivalence between electronic displays and film

In electronic displays, the light-box is called a backlight. To make the display thin, it is made of small, tubular fluorescent lamps with a diameter of around 5mm. As with a light-box, the lamps are always on at full power, independent of the actual image content displayed. The backlight thus has no image forming function; it is just there to emit light and send it through the electronic display valves. The image forming element, equivalent to the film, is the LCD panel. Composed of millions of switch-able light-valves, it is possible to construct an image by turning on or off (and variations in between) specific light-valves. The light-valves make up tiny elements of the image just like pieces of puzzle. They are called pixels (picture elements). Only, in this case, the pieces of the puzzle can be changed instantaneously. And this is the biggest advantage of the electronic medium: any image at any time at any place.

1.2 Comparing LCD-based electronic displays to CRT-based electronic displays

Prior to the advent of flat panel displays, the most common technology used for electronic displays was the Cathode Ray Tube (CRT). Although their working principle is identical to that of the well known CRT from the television set at home, medical grade CRTs use precision electron gun optics and high frequency deflection to reach ultra high resolution.

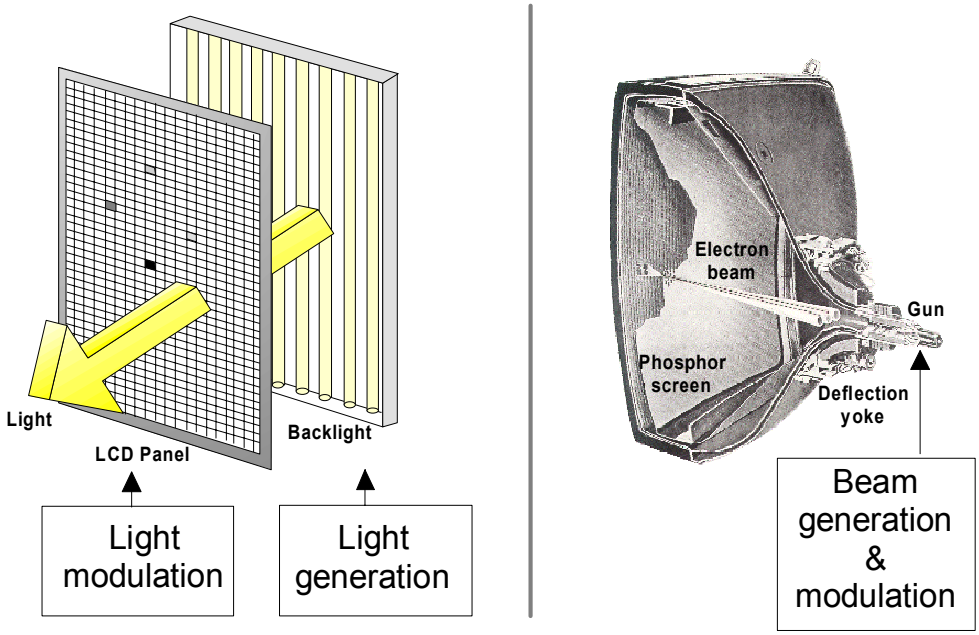

Fig. 2: Comparing CRT to LCD

LCD-based flat panel displays basically differ from CRTs in the way the light is generated and modulated. With LCDs, the light generation is physically separated from the light modulation. The light generation is done by a light source, called the backlight, and is continuously on at full intensity. This light source knows nothing about the image information. The light modulation is realized by shutting off the light flux from the source by means of the LCD panel. Only the LCD panel is driven by the video signal information, not the light source.

In CRTs, light generation and light modulation are one process controlled by one physical component.

Because of this difference, LCDs perform best when a lot of luminance is demanded from the display, but not as well when all the light generated by the backlight needs to be cut-off completely.

With CRTs this is just the opposite. The practical consequence is that the lowest luminance level of LCDs is still higher (about 1 Cd/m^2) than CRTs that go down to 0 Cd/m^2. At the maximal level of the luminance range, grayscale LCDs easily reach 600 Cd/m^2 whereas CRTs only perform well up to 300 to 400 Cd/m^2. Table 1 gives a short overview of typical values. The contrast ratios calculated are applicable for dark room environments. Contrast may be reduced both in case of CRTs and LCDs due to reflected ambient light. This increases the Luminance of Black and thus degrades contrast.

Type of Display	Luminance of White (typical, Cd/m2)	Luminance of Black (typical, Cd/m2)	Contrast Ratio (white/black)
Color CRT	120	0	Infinite
Grayscale CRT	400	0	Infinite
Color LCD	220	0.5	440
Grayscale LCD	600	1	600

Table 1: Comparing luminance range and contrast ratio of LCDs and CRTs

1.3 Digital is NOT perfect!

A flat panel display is the closest you can get to a full digital display, but LCDs still incorporate some key operating principles from analog technology. Several issues exist that make LCDs less than perfect (or even un-useable) for medical applications without appropriate compensation and correction.

What follows are descriptions of these imperfections and Barco's unique solutions for addressing each of them.

2 BARCO'S I-GUARD® TECHNOLOGY

The cornerstone of the detection and correction of all LCD-related instabilities is I-Guard®, a unique technology patented by Barco.

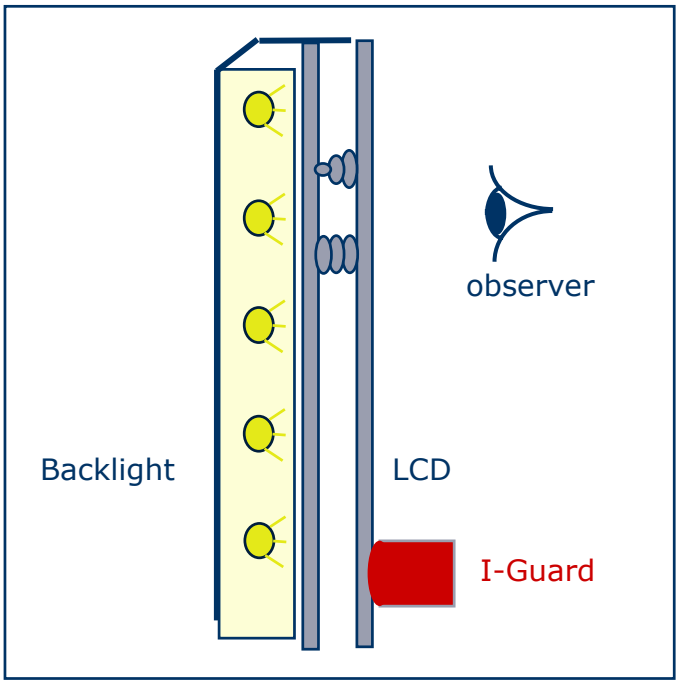

Fig. 3: The location of I-Guard with respect to the optical LCD stack and the observer

I-Guard is basically a tiny embedded optical sensor positioned at the front of the LCD screen. Positioned in a corner of the screen and only requiring a few square millimetres, I-Guard is continuously "guarding" the screen's output without disturbing the actual image display. The intelligent I-Guard sensor communicates it's readings to the controlling electronics, which translates the readings in corrective actions to the Liquid Crystal Display in real-time.

As will be explained, the position of I-Guard on the front of the screen, thus seeing and measuring from the same position as the observer, is key to the advantages offered by this unique technology.

3 10 ADVANTAGES OFFERED BY BARCO'S I-GUARD TECHNOLOGY

3.1 I-Guard detects and corrects backlight instabilities

The backlight, a kind of light-box with fine fluorescent lamps positioned behind the liquid crystal panel, is an important source of instabilities. The efficiency of these lamps is extremely temperature dependant. The luminance can fluctuate drastically in a short time frame (minutes to hours) due to temperature changes at start-up.
Over a longer time period - it's entire lifetime - the luminance slowly degrades because the phosphors used in the lamps wear out.
I-Guard, from its position in front of the screen, detects all of these changes and continuously corrects both the short term and long term instabilities (2 times per second).

3.2 I-Guard detects and corrects instabilities of the Liquid Crystal pixel cells

The liquid crystal display pixel is the element responsible for the actual image generation on the screen. Acting as an electronic light valve, it defines how much light from the backlight is allowed to pass through and reach the observer's eye. Obviously, the liquid crystal cells (laid out as pixels) are very important to the (in)stability and consistency of the image. LC pixels can be switched from on to off in a continuous, analogue fashion. The degree of "closure" of the light valve is defined by analog voltages and a complicated physical process of re-orienting LCD molecules. As all physical processes, these exhibit dependencies from ambient factors such as temperature. For example, the transmittance of the liquid crystal cells changes as temperature fluctuates, causing the luminance of the image to change.

I-Guard, located in front of the screen, detects all instabilities caused by the backlight AND the liquid crystal display, because it sees the overall effect of both elements. I-Guard is the only closed-loop feedback system incorporating all causes of instability. It will correct for any instabilities, as only feedback systems can do. Fig. 4 compares I-Guard versus Backlight Sensors in terms of their ability to detect LCD display instabilities. As can be seen, backlight sensors are only capable of detecting what they see: the backlight. The I-Guard sensor sees what you see: the result of the complete image formation process of the Liquid Crystal Display, including the graphic board, the Look-Up Table, the driving electronics, the backlight and (last but not least) the Liquid Crystal cells.

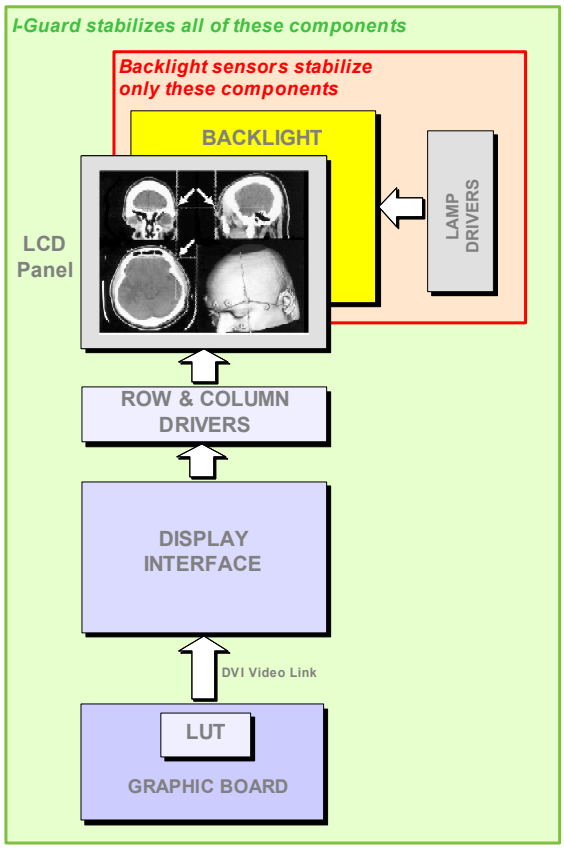

Fig. 4: Backlight versus I-Guard instability detection capabilities

3.3 I-Guard detects and corrects instabilities or inconsistencies of the driving electronics

The liquid crystal panel cells are organised in rows and columns, each driven by electronic drivers. By applying a voltage to each of the rows and columns, each pixel receives the needed driving voltage. The drivers are basically acting as A to D (analog to digital) converters: they supply an analog voltage to the row or columns in response to a digital input.

This conversion process requires a multitude of reference voltages and is another source of instability and a potential cause of inconsistency. However, instabilities of the drivers results in more or less transparency of the Liquid Crystal cells, which will be noticed by I-Guard and is thus corrected and stabilized.

3.4 I-Guard detects and corrects any inconsistencies generated by the graphic board and Look-Up Table (LUT)

Modern display systems use digital signal links between the graphic board and the display. The process is completely digital and is not a cause of instability or variation. However, our experience is that incorrect Look-Up Table (LUT) entries, or LUT settings that are changing without notice, are the most common source of inconsistency in modern medical imaging systems.
On modern workstations running several applications, it is not uncommon that the process of which application takes control of the LUT is not transparent or badly controlled. I-Guard, in combination with MediCal® Pro, will regularly step through the entire grayscale range and detect discontinuities or incorrect (non DICOM compliant) settings in the LUT. The system can automatically adjust the LUT entries to the values required to yield a previously programmed response (for example, conform to a DICOM curve).

3.5 I-Guard is specifically designed for precision optical measurements on Liquid Crystal Displays

Liquid crystal displays emit light in a completely different way than CRT displays do. While CRTs emit the same spectrum uniformly over a 180 degree angle, the emission spectrum of LCDs is very dependant on the angle to the screen. It can even change as a function of gray level (the same phenomenon is responsible for what is known as the viewing angle of LCDs). Nevertheless, we see that CRT sensors, or CRT-derived sensor designs, are still frequently used for the measurement of LCD displays, leading to incorrect readings and interpretations.
I-Guard's patent pending optical design has a small optical acceptance angle (the overall angle is smaller than 10°), guaranteeing that the non uniform emission pattern of LCDs does not distort the readings.
Every I-Guard is calibrated to each individual liquid crystal panel using a high precision primary reference in the factory. Calibration factors defining the correlation between the luminance measured in the center of the display and the luminance measured by I-Guard in the corner of the display, are stored in the device. These correlation factors are constant over the lifetime of the product. The display's spatial noise pattern is defined by deficiencies in the manufacturing of the LCD panel and is fixed, but depends on the gray level. Therefore, a table of calibration factors (different ones for different gray-levels) is actually stored in the device - leading to the I-Guard's excellent precision: 4% absolute luminance precision and <3% non linearity error.

3.6 I-Guard is DICOM compliant

DICOM requires that actual measurements are taken using optical sensors at the front of the screen, assuring that the true emitted luminance is measured. I-Guard fulfills this requirement - it was designed with DICOM in mind. Only I-Guard is capable of complying with the high precision required for calibration to the demanding DICOM standard.
Backlight sensors only "see" the back scattering of the backlight and have no clue about what is happening in the front of the screen. Therefore, a calibration precise enough to comply to DICOM is impossible with backlight sensor systems alone. To be DICOM compliant, systems equipped with backlight sensors require the use of an external optical measurement device for the calibration procedure. This device must be purchased separately. By nature, it must be positioned manually on the screen, thus requiring human intervention and expensive labor hours to complete every calibration procedure.

Some vendors try to accommodate for this shortcoming of the backlight sensor with a characterization of the panel response. This approach tries to estimate what the panel transparency will be for certain drive signals. Such a feed-forward system is like driving a car while looking in the rear view mirror.
The characterization approach will never be capable of estimating and characterizing the interactions of all variables in the complex physical process of the image generation on LCDs. That is why screens equipped with backlight sensors require a manual procedure of placing an external sensor on the screen surface to do DICOM calibration.

Some have concern that I-Guard is positioned in the corner of the screen instead of the center. Although diagnostic information is displayed throughout the screen, it is common to specify and measure luminance at the center of the LCD display. This is no problem for I-Guard since it is calibrated to the center of the display at the factory.
Research has shown that the relationship between the luminance at the center and the corner of the screen is dependant on video driving level and, to a lesser extent, temperature.

At the Barco factory, I-Guard is calibrated to a reference optical device taking measurements at the center of the screen. This is done for various video levels at defined temperature. As a result, a calibration table is obtained tracking the I-Guard measurements at any moment with the readings at the center of the screen.
Other effects defining the relationship between center and corner luminance are the LCD screen's inherent spatial non-uniformity. This non-uniformity can be as high as 30% but is fixed in nature. It is defined by the LCD manufacturing process (lithography stepper deficiencies, rubbing process imperfections, active matrix non-uniformities).
Using it's proprietary I-Guard calibration scheme, Barco obtains much higher precision than can ever be obtained from backlight sensors. After all, we calibrate to screen center measurements which is much closer to the physical reality of measuring at the screen center than backlight sensors, which do not measure at the screen surface at all and thus have to take a wild guess at how the LCD screen is behaving.

3.7 I-Guard is the only intervention-free sensor allowing completely transparent DICOM calibration, Quality Assurance and diagnosis

Compared to other sensor technologies which measure luminance from the front of the screen, I-Guard is embedded in the display. Positioned safely behind glass facing the screen, I-Guard is always ready to take readings from the screen without requiring any manual interventions such as connecting or positioning the sensor. Clearly, this is an intervention free sensor.

I-Guard only requires a few square millimetres at the corner of the screen to do it's job unnoticed in the background, without disturbing your work. Whether it is overnight when the screen is not used, or during a busy day while the display is in use, I-Guard can take readings from the small test-patch displayed in the I-Guard area while the actual medical image is on the screen. This mode of operation is called transparent: although it is there, you don't see it and your work is not interrupted by it.

3.8 I-Guard and PIN protect your investment

I-Guard protects your initial investment by driving down the cost of ownership substantially. Just think of never having to go down to the room where the display is located to conduct quality assurance procedures! I-Guard is your remote eye on the display: it's readings are available over the web and can serve any purpose, from remote DICOM calibration to remote service interventions.

Together with I-Guard, Barco's quality assurance software tools, Medical PRO (the client installed on the workstation) and MediCal Administrator (the server centralizing the data in a database), allow you to track and manage the consistency of your entire display fleet from a central place.

The alternative without I-Guard?
Go down to the room where the screen is located, interrupt the ongoing medical procedures, connect the sensor and place it on the screen surface (requires a large area and hence makes it impossible to use the screen for medical readings during the calibration procedure), initiate the calibration software and wait for completion of the calibration procedure. No central traceability. Lots of time spent in the process. Loss of productivity of the radiologists during the calibration process.

I-Guard is an initial investment that is earned back quickly when considering the direct and indirect costs associated with the execution of QA procedures.

3.9 I-Guard is the ultimate self-diagnosis system

When a failure affects the visual performance of the complete display, I-Guard will notice this, no matter where in the image chain this failure was caused. Whether the graphic board goes down, or the interface board fails, or the Look-Up Table is not set right, there is a way to detect it with I-Guard. For example, a video cable having one bit missing or unconnected will be detected by I-Guard and MediCal PRO. Making use of I-Guard, a set of smart test combinations can be set up in MediCal PRO to diagnose a variety of functional aspects of the screen and to conclude if a service visit is needed or not.
On the contrary, backlight sensors will only see or detect catastrophic defects of the backlight. Defects of the LCD panel, the graphic board, the video link or any other element defining the image content will pass completely unnoticed by backlight sensors!

3.10 I-Guard is here to stay

For your capital investment, you want to think long term. It is important that future Quality Assurance concepts continue along the same line as what you currently buy. This avoids having to swap tools, systems or processes every time you switch to a new display technology.
With that respect, I-Guard is ready for the future. Here is why:
The future vision of medical image display points towards an increased use of color, not only in the user interface but also as a means to indicate valuable clinical information (such as the output of Computer Aided Diagnosis).
I-Guard is the only technology that is capable of detecting and correcting the individual colors generated by color displays. For obvious reasons, backlight sensors can not detect colors: the process of color generation happens in the LCD panel itself and not in the backlight. This is why backlight sensors, when combined with color displays, will require external sensors for DICOM compliant color calibration.

I-Guard can also be combined with future screen technology. Whether it is Organic-LED or any other emissive screen technology that will be used 10 years from now, it can be equipped with I-Guard for the purpose of stabilizing the optical output.
This means that whatever screen you buy in the future, I-Guard will be an integral part of it. As a consequence, your valuable investments in QA systems, procedures and software tools are safe and will be useful with future screen technology.