# How to Match the Color Brightness of Automotive TFT-LCD Panels

## Introduction

The need for gamma correction originated with the invention of CRT TV displays. The CRT uses an electron beam raster to illuminate the phosphor coating behind the display front panel. The applied grid control voltage proportionately controls the luminous intensity and it follows the power law: Luminous Intensity = Control Voltage to the power Gamma. This is inherently non-linear. The nominal gamma for the CRT is ~2.5. The human eye on the other hand has an inverse response and is relatively sensitive to changes in the darker portion of the grayscale. Therefore, to make the final image display the grayscale true-depth variation to the human eye, gamma correction must be implemented on the red, green and blue signals prior to transmission. This is done at the system where the video originates, such as a TV broadcast camera.

This white paper examines the practice of gamma correction, also known as gamma calibration, to ensure consistent brightness and color matching of TFT-LCD panels used in automobiles. We'll discuss how to calibrate an LCD panel's gamma response using a 14-channel programmable gamma buffer. And we'll look at three examples that illustrate high, nominal and low gamma settings.

Cameras are designed to output a voltage that is proportional to luminous intensity raised to power 1/2.5 or luminous intensity raised to power 0.4. Since a gamma slightly greater than 1 is preferred, the broadcast standard typically uses a gamma of 0.5, which leads to a system gamma of 1.25. Figure 1 shows that the camera's built-in gamma response is the inverse of the CRT response and, therefore, no additional system gamma correction is required. However, the TFT-LCD's signal must be adjusted to compensate for the camera's gamma adjustment, which was originally set for the CRT display.
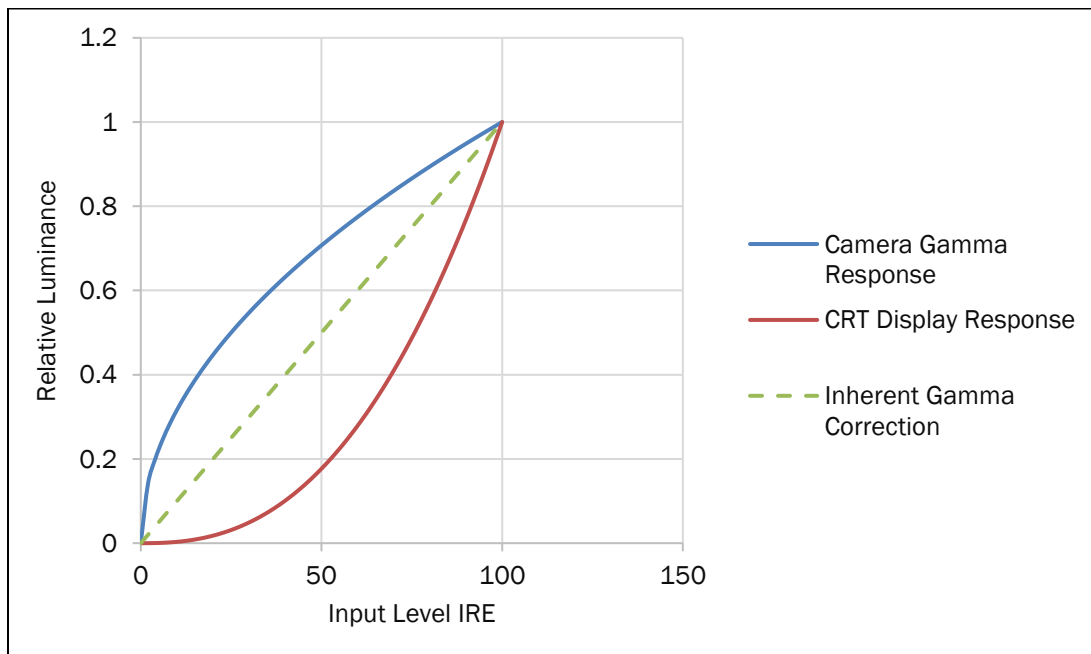


Figure 1. Gamma for legacy CRT systems

# Gamma Calibrating Automotive LCD panels

TFT-LCD panels are increasingly used in an automobile's instrument cluster, infotainment and navigation head unit, and advanced driver assistance system (ADAS) smart mirrors. They do not have an electron gun and phosphors to generate luminous intensity, but instead apply a voltage to a liquid crystal pixel, which controls the transmittance of "backlight" through the pixel. A cold cathode fluorescent lamp (CCFL) or light emitting diode (LED) array is used to provide the "backlight". The voltage applied to a liquid crystal pixel controls the amount of backlight allowed to pass to the front to recreate the transmitted image and this defines the transmission curve for the TFT-LCD.

The gamma of the TFT-LCD differs from the CRT; however, it does have a slight gamma response. You'll recall that legacy broadcast systems have gamma correction built into the transmission to compensate for CRT gamma response, and this combines with the inverse response as perceived by the human eye. Therefore, gamma correction must be done to the signal before applying it to the TFT-LCD pixels. It is necessary that TFT-LCD gamma correction follow that of a CRT display. The incoming video signals are digital and the gamma correction code is applied to the digital-to-analog converter (DAC), which generates the voltage that is then applied to the pixels. These gamma correction codes help panel display manufacturers determine applicable codes that enable the required visual performance. Often the system can store multiple gamma correction settings for varying ambient light conditions. Figure 2 shows the normalized gamma correction for use with TFT-LCD panels to achieve a system gamma of 1.
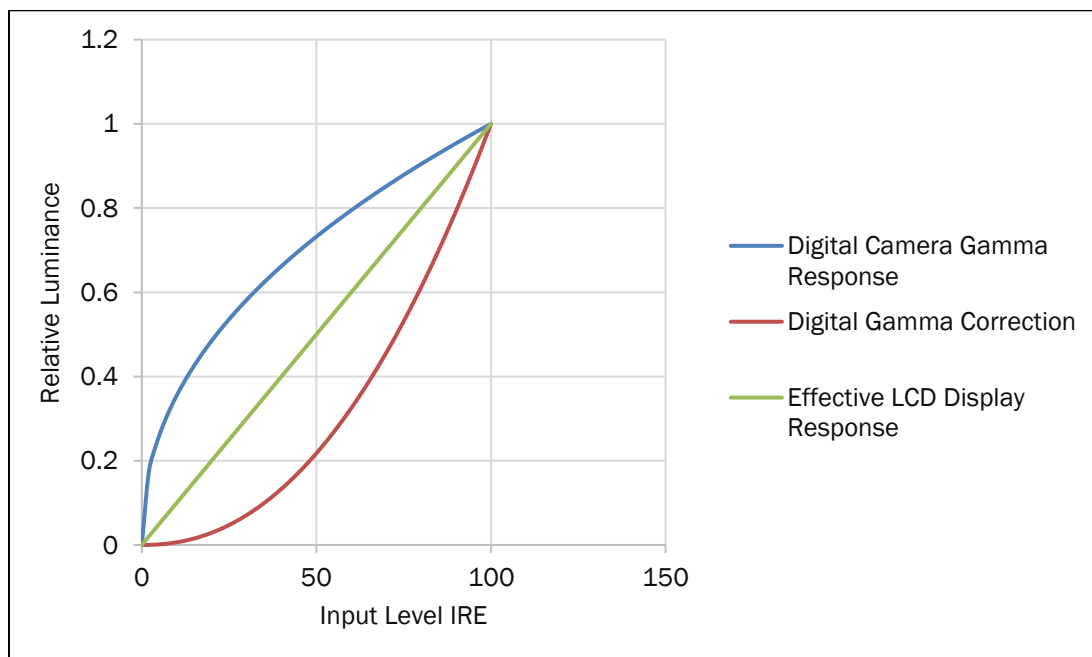


Figure 2. Gamma for LCD systems

Digital video data, typically low-voltage differential signaling (LVDS), must be converted using a DAC to generate an analog voltage for the pixel. Gamma is corrected (intentionally made non-linear) by the use of piecewise non-linear DACs in the panel's source/column drivers. The source driver DACs determine how many different voltage steps can be applied to the pixels (e.g., an 8-bit DAC yields $2^8$ or 256 steps of possible grayscale). Figure 3 shows that the perception of changes in grayscale intensity caused by each voltage step is relative to the panel's gamma response (voltage-transmission or V-T curve) and the response of the eye.

**PERCIEVED LUMINANCE  (%)**

| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |

**GAMMA**

1.0

| | 0 | 1.6 | 5.6 | 11.4 | 19.4 | 28.7 | 40.2 | 52.7 | 67.4 | 83.0 | 100 |

1.8

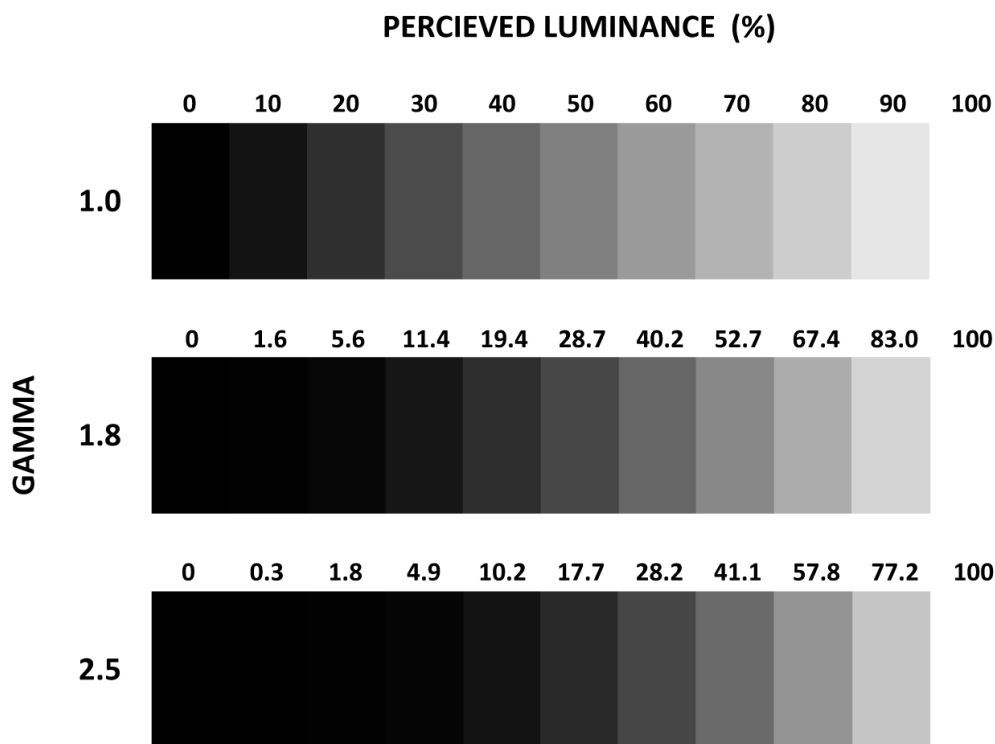| | 0 | 0.3 | 1.8 | 4.9 | 10.2 | 17.7 | 28.2 | 41.1 | 57.8 | 77.2 | 100 |

2.5

Figure 3. Changes in relative intensity compared to gamma response

The non-linear nature of gamma correction results in compressed image data that resides at the low luminance level, with little or no compression at the high luminance level. The low-level compression makes the image data in the "dark" to "not so dark" region stand out and be more discerning to the human eye. This improves the image depth. And as an added bonus, the compression and non-linearity results in a lower number of bits used for luminance coding (e.g., 8-bits for non-linear vs. 12-bits or 14-bits if it were linear). The compression also helps reduce video signal noise, if any exists.

## The Programmable Gamma Buffer

To change the LCD panel's gamma response to a desired V-T transfer function, the panel's source (column) driver DACs may use various reference voltages applied at multiple tap points. These voltages force each DAC to have a certain desired non-linear operation. The reference voltages are often supplied by gamma buffer ICs, which are generally buffer amplifiers that drive the analog voltages to the DAC taps. The gamma buffer ICs can be static or programmable. A device that can be used for automotive LCD panels is the Intersil ISL76534, which is an I²C based 14-channel programmable gamma buffer plus a VCOM channel, both with a 10-bit resolution. This device drives accurate and steady DC reference voltages to an automotive TFT-LCD source driver. Figure 4 shows a simplified system block diagram of a TFT-LCD panel.
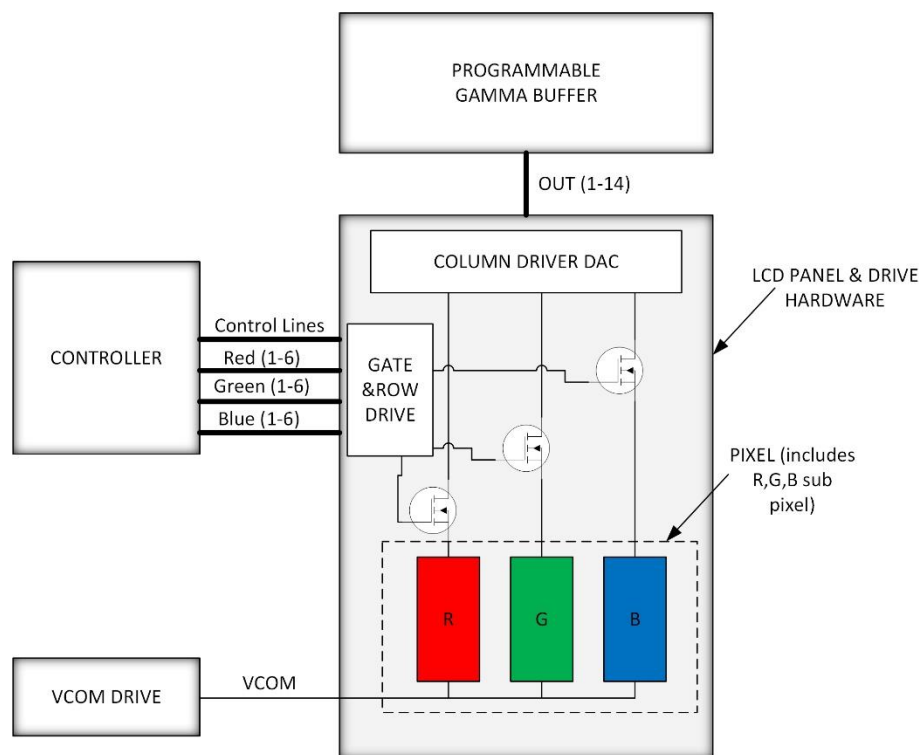
**Figure 4. Simplified TFT-LCD panel**

With the capability to control the DAC taps, automotive LCD panel makers can fine-tune the voltages to further adjust or calibrate the panel's non-linear gamma response, also called gamma calibration. It allows an automotive LCD panel maker to ensure that all of their LCD panels of a certain model exhibit the same gamma response from panel-to-panel. This means that any potential visual performance variations, caused by things such as variances in LCD fabrication and manufacturing, are minimized and thus the automotive LCD panel maker has a more consistent and visually appealing product. Consumers can be assured that the vehicle they purchase will include displays that visually perform like the ones they saw during their test drive at the dealership.

Panel makers ultimately decide how they want to calibrate the gamma response (e.g., $\gamma = 2.2$, $\gamma = 2.0$, $\gamma = 1.8$, or a combination of gammas based on the intended brightness), so that their display has a certain look. It's noteworthy that gamma characteristics tend to shift with wide viewing angles and different ambient lighting conditions. When shopping for a car at the dealership, it would be a good idea to compare the display under bright light and low light conditions to determine whether the image presented is visually appealing to you.

## Comparing Images at Different Gamma

Figure 5 compares the same image, but with different overall gamma. The differences are easily discernable. The middle image, Figure 5B, is the nominal (original) gamma (e.g., $\gamma = 2.2$), while the top image, Figure 5A, is more than nominal and the bottom image, Figure 5C, is less than nominal. The bottom image loses contrast as the darks disappear, and becomes more washed out. The top image gets more contrast, but overall has more darkened area.

Figure 5A. Example of high gamma for a given picture



Figure 5B. Example of nominal gamma for a given picture



Figure 5C. Example of low gamma for a given picture

## Gamma and Auto Infotainment Display Settings

Automotive LCD panels have black-to-white endpoint levels that are fixed by the capability of the source driver. However, digital adjustments can be made to the signal during video data processing. Brightness can also vary by simply adjusting the LCD panel's backlight intensity, which adds another dimension to system performance. Often the display controls can be adjusted for brightness and contrast, and for day and night settings.

The programmable gamma buffer simplifies the task of evaluating and setting the display transfer function by moving it into the manufacturing cycle of the auto display maker. These gamma settings are programmed into the EEPROM and they are transferred to the DAC on power up. Some have multiple banks to hold more than one display profile for various ambient light conditions, and a custom setting that could be user programmable with the facility to save and store it. The manufacturer set gamma profile is generally adequate for most automotive applications. This programming is done during the initial setup, after which the profile is never changed, unless fine-tuning is required to improve the display's visual performance.

## Conclusion

Automotive LCD panel manufacturers strive to make their display panels visually desirable to automakers and consumers. Doing so requires a stable gamma buffer reference that ensures the video color images displayed on their LCD panels are matched with the exact same contrast, brightness and color across all displays. This can be accomplished by using a high accuracy programmable gamma buffer like the Intersil ISL76534.

## Next Steps

- Learn more about the ISL76534

- Download the datasheet