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The influence of inertial loading on color gamut properties of a TFT LCD display

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Abstract

The article presents the results of an experiment where a 7 in. TFT LCD display was exposed to harmonic vibration with acceleration amplitudes up to 200 m/s^2 and frequency sweep in the range between 40 Hz and 1.5 kHz. The display was mounted on a shaker in three different positions: landscape, portrait, and face-up. Colorimetric measurements were taken during and after the loading. Euclidian distance in the CIE Lab color space was used as measure of color change due to the loading. The results show that color gamut tends to narrow when increasing the acceleration amplitude. In practical terms however the color change is barely perceptible. In most cases the color changes disappear within 5 h after the stop of the loading. Micro- and macroscopic examination of the LCD was performed to establish an indication of the cause of color change.

Keywords: LCD display; Harmonic vibrations; Acceleration amplitude; Color gamut change; Mechanical damage

1. Introduction (problem definition)

The use of LCD displays have been spreading very fast and we can find them in living rooms (TV), mobile phones, laptops, cars, airplanes, etc. Many LCD displays are subjected to a certain amount of shock and vibration during normal operation. In cars vibrations come from rough roads, in planes from accelerations during take-off and landing, etc. but the biggest influence of vibrations and shocks that can affect the performance of displays can be found in industrial environments. Displays that are designed for use in industrial environment are more mechanically resistant to shocks and certain amount of vibrations.

We all know what happens when we touch LCD display. We see rapid change of color around pressed area for short period of time. With touch we cause local load, but what happens if the entire display is under stress? The stress will probably cause a mechanical failure but what is the connection between stress and displays performance (specifically color gamut). Does it change?

A review of main industrial displays manufacturers had shown that industrial displays are capable to stand vibrations and shocks in average up to 10 G. Some of the displays, we reviewed have available data for constant vibrations but do not have available data for constant shocks so it's impossible to know what happens with the display if it is subjected to constant vibrations and constant shocks.

In this article, we examine the color performance of a 7 in. TFT LCD display subjected to harmonic acceleration with amplitudes in the range from 2 to 20 G and frequencies from 40 Hz up to 1500 Hz. In vibration industry, acceleration amplitude is usually represented by G, where 1 G is the amount of acceleration we experience as inhabitants of the Earth due to Earth's gravity. 1 G equals to 9.81 m/s^2. In this article, G units will be used for acceleration. Adding

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extra vibration (power) energy to the display we measured variations of color content of the emitted light during and after shaking.

Lots of research has been done in order to characterize displays in regards to working conditions like temperature, humidity, dust, influence of ambient illumination [1], viewing angle, etc. Results from these experiments were usually presented as color gamut changes or GOG (gain-offset-gamma) parameterization of the display. Except for a research conducted on the drop shock on LCD and housings [2] no research related to shock and vibration influence on LCD displays has been found in scientific literature. The aim of this paper is to examine the influence of the effect of inertial loading stress on the color performance of the display.

2. Experiment

2.1. Experimental set-up

A 7 in. TFT LCD display, widely used in many audio/video applications like cars, airplanes, machines, etc., was chosen as the test object of the experiment. According to the manufacturer's specification the display had the following properties: resolution $1440(H) \times 234(V)$ pixels, pitch dot $0.107\,\text{mm}\ (H) \times 0.372\,\text{mm}\ (V)$, brightness $400\,\text{cd/m}^2$ and contrast ratio 1:150. The display accepted composite video signal as input. The display was mounted in an aluminum housing to give it additional support during the vibration loading. The LDS V555 shaker [3] with the belonging control and acquisition system was used for stimulation of vibration (Fig. 1). The display was mounted on the shaker in three different positions: horizontal (face-up), normal (landscape), and standing (portrait) (see Fig. 2). The direction of the exciting force was always perpendicular to the mounting surface of the shaker.

The harmonic acceleration was measured with two accelerometers B&K type 4371. The first was placed on the mounting plate and was used to characterize the excitation (primary accelerometer) $A_p(j\omega)$. The second was placed on the top of the housing (secondary accelerometer) and was used to characterize the mechanical response $A_s(j\omega)$ of the LCD – housing assembly to the excitation (Figs. 1 and 2). The transfer function of the LCD – housing assembly $H(j\omega) = A_s(j\omega)/A_p(j\omega)$ was determined using the two accelerometer signals (see Fig. 5).

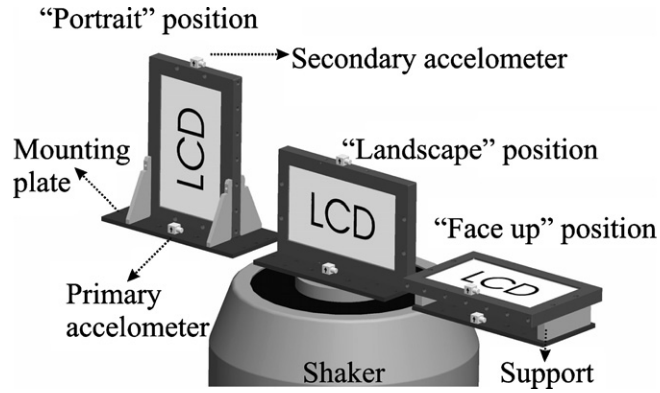

Fig. 2. Measuring deviation of colors after the shaking in three different positions.

The VGA signal from the PC was converted to composite video employing the *Grand ultimate XP pro* converter. The Eye-One-Display-2 colorimeter was used for the colorimetric measurements. A custom Java application was developed in order to enable automated measurements: set-up of the selected color patterns, acquisition of the colorimeter response. The selected test color patterns (12 grayscale and three pure colors – red, green, and blue) are shown in Fig. 3. The three pure colors were used to measure the corners of the gamut in the CIE *xy* color space while the grayscale patterns were used to measure the luminosity response of the display. Each color pattern was displayed separately on a rectangular area encompassing about 80% of the LCD screen surface (measurement area). The rest (a pure white stripe of about 20% of the screen area) was used for operators interface to the measurement control software. The colorimeter was placed in the centre of the measurement area. This placement was determined as the most suitable considering the size of the LCD and the colorimeter. The color patters were changed in the

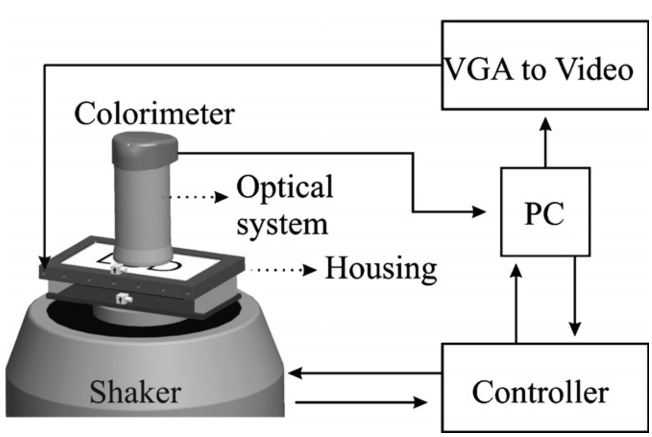

Fig. 1. Experimental set-up for testing during the shaking.

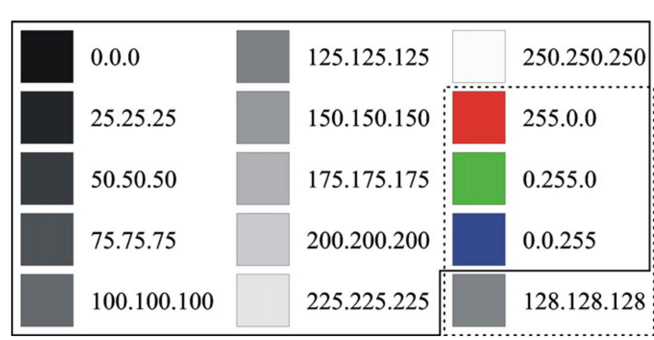

Fig. 3. RGB values of tested colors: solid line – characterization of color gamut change after vibration, dashed line – characterization of color gamut change during vibration.