DMD Field Reliability:
A Comparison of Competing Technologies Used In Data Projectors

by Michael R. Douglass and Rick W. McCall

Introduction

Texas Instruments (TI) launched a study in May of 2002 to investigate Digital Micromirror Device (DMD) field reliability and learn how Digital Light Processing™ technology compared to competing technologies. The goal was to obtain objective data on DMD, as well as other data projector light modulators in a simulated end use environment as a benchmark for comparisons in future marketing and reliability activities. A sample of projectors using DMD and LCD light modulators were placed in a "head to head" life test. The purpose of the test was to gain insight into optical performance over time. Parametric data measurements and picture quality evaluations were performed at periodic intervals to gauge useable lifetime, or time to unacceptable performance (based on picture quality), for each projector tested.

Munsell Color Science Laboratory (MCSL) at Rochester Institute of Technology carried out this study under the direction of Texas Instruments (see appendix 1). MCSL was responsible for data collection as well as projector use and maintenance. TI was responsible for evaluation and interpretation of the data.

The end goal was not only to validate the reliable performance of the DMD when compared to LCD, but to learn how a DMD light modulator performs over time when assembled within its final projector configuration. It was known from laboratory testing that DMD performance did not degrade for many thousands of hours, however, no end-use data was available to confirm what had been seen in the lab. It was also suspected that LCD could not make this claim. The Quality Assurance department within TI volunteered to perform a high level study, to see how data projectors perform over time, and to determine how competing technologies compared.

Though intended as a preliminary investigation, the validity of the following assumptions were evaluated by the study:

- Picture reliability of a DMD will ensure sustained quality over the life of the projector
- Optical performance and picture quality of an LCD will degrade over time
- Optical performance failures of an LCD is unrecoverable even after lamp replacement
- Optical degradation in an LCD translates into an unacceptable picture quality defect

Methodology

TI selected a representative sample of the commercially available data projectors. Five featured LCD and two featured DMD light modulators. The projector sample varied in features such as panel size, weight, resolution, and brightness. All units were placed in a darkened lab at MCSL and run in a continuous operation mode at an ambient room temperature of approximately 25°C.

Using the standard, ANSI/NAPM IT7.228-1997 (Audiovisual Systems – Electronic Projection - Fixed Resolution Projectors), MCSL collected the following parametric data at periodic intervals:

- Luminance
- Full Field, or Full On/Full Off (FOFO) Contrast
- ANSI Contrast
- Uniformity
- Full Field and ANSI Contrast for red, green, and blue colors
- Color Chromaticity for white, red, green, and blue

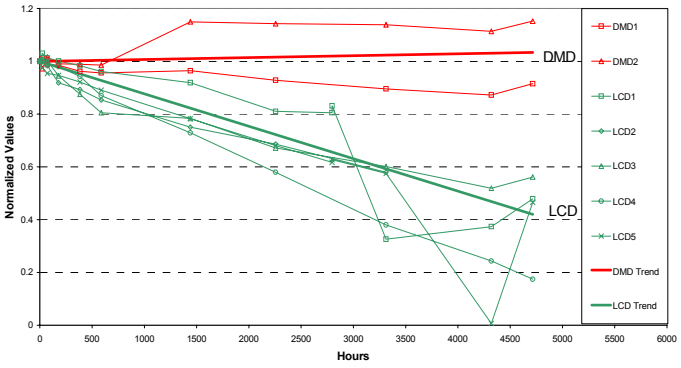
All units received their input signals from the same source material. Lamp replacement was determined by either an on-board system, or by 1/2 starting lumens (ANSI standard) where no on-board system existed.

Results/Observations

After approximately 4700 hours of operation, the following observations and trends were noted in the data:

Full Field and ANSI Contrast degraded over time for LCD, but remained steady for DMD, as expected (see Figure 1).

Figure 1: Change In ANSI Contrast Ratio Over Time



The optical degradation seen in LCD washed out the screen picture and raised the dark levels. Trends in color contrast supported the evidence gathered in Full Field and ANSI for white screen. Graphing just the Dark Levels for all projectors also supported the validity of the contrast data.

Data collected for both on-screen lumens and uniformity did not yield any solid conclusions, as far as the two light modulators tested were concerned. These two parameters seem to be driven more by the lamp than the modulator.

Significant changes in Color Chromaticity values supported the picture quality degradation seen on the screen for LCD (see figures 2, 3, 4, and 5). Color Chromaticity remained stable for DMD.

The term 'Picture Reliability' was selected to refer to picture quality over time. Within this study, Picture Reliability was defined as “The time to unacceptable picture quality attributed to the light modulator subassembly”. A graphical representation of Picture Reliability was included in this study (see figure 6).

Figure 2: Comparison of Red Colorimetry Over Time

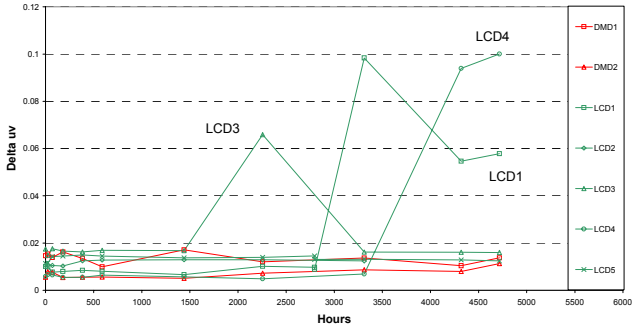


Figure 3: Comparison of Green Colorimetry Over Time

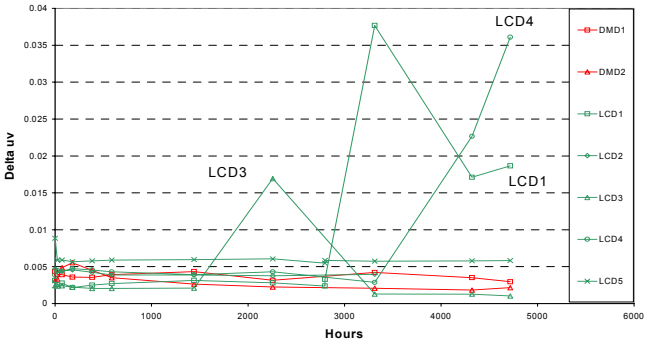


Figure 4: Comparison of Blue Colorimetry Over Time

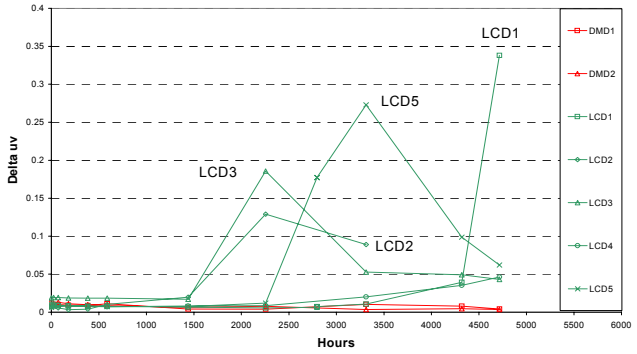


Figure 5: Comparison of White Colorimetry Over Time

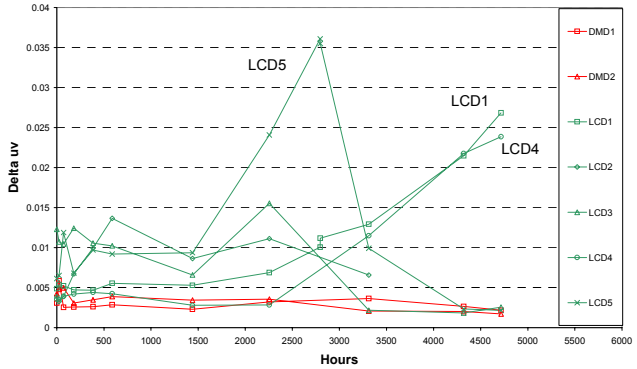
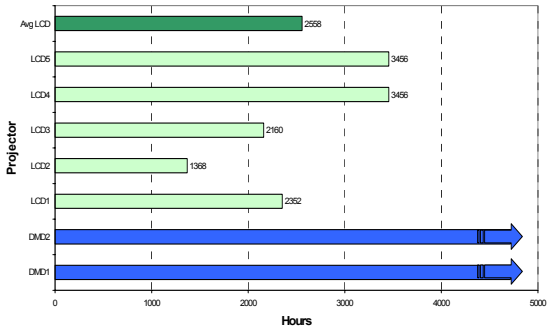


Figure 6: Picture Reliability
(Time to unacceptable image quality attributed to the light modulator)



As can be seen, the first blemish attributable to optical degradation occurred at 1368 hours for LCD (see figure 7 for sample baseline, and figure 8 for sample picture defect at 4700 hours).

Most LCD projectors exhibited a subtle yellowing of the screen picture, and later developed a blue blemish (see figure 9 for sample of "yellowing").

Picture quality remained consistent for DMD (see figure 10 for sample baseline, and figure 11 for sample picture at approximately 4700 hours of use).

Conclusions

Data shows definite signs of supporting our base assumptions. There is a marked difference in optical performance and picture reliability over time between projectors utilizing light modulators based on LCD and those based on DMD.

Image quality defects, caused by degradation of the LCD light modulator were as spectacular as anticipated and occurred quite early in operation. Assuming as much as 100 hours of operation per month, we would expect to see the earliest occurrence of an unacceptable picture for LCD at just over one year. The average time to an unacceptable picture for LCD would be at about two years.

Continued downward trends in optical performance for LCD are showing in all parametric data. Even after routine lamp replacements, degradation in LCD performance persists. Replacement of the lamp did not bring about improvements in any of the parametric data.

Changes in visual "on screen" performance for LCD was not gradual. Its occurrence was sudden and unacceptable under normal viewing conditions. Even the subtle yellowing of the image was judged unacceptable at the point it became apparent to the naked eye.

Figure 7: LCD Photo at Baseline

Figure 8: LCD Photo at 4700 Hours

Figure 9: Sample of Yellowing on L

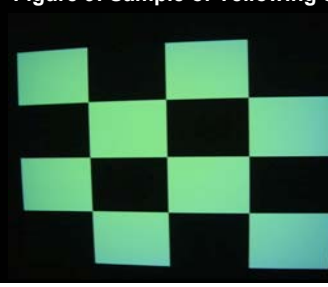


Figure 10: DMD Photo at Baselin

Figure 11: DMD Photo at 4700 Hours

The data revealed that DMD performance either remained steady over time, or fluctuated with lamp replacements. This was especially true of uniformity. DMD performance in this parameter was affected directly by lamp variation.

Data collected for both on-screen lumens and uniformity did not yield any solid conclusions, as far as the two light modulators tested were concerned. These two parameters seem driven more by the lamp than the modulator.

In Closing

The study appears to provide conclusive evidence of a substantial difference in the medium/long term picture quality performance of the two projection technologies. It highlighted a fundamental flaw in LCD light modulator technology. This flaw causes deterioration in picture quality well before the expected end of life of the projector itself. DMD light modulator technology, on the other hand, showed no such characteristics: its picture quality was both visibly and measurably unchanged throughout the tests.

This comparative data is significant to any end user planning to purchase a projector. A projector based on a DMD light modulator will continue to deliver excellent picture quality throughout the life of the unit. The same cannot be said for projectors based on an LCD light modulator. The LCD modulator can be expected to fail at about the same time as the lamp fails: however, while the lamp is user replaceable, the modulator is not. Failure of the modulator would require the projector to be returned to the manufacturer: the repair would be non-trivial. A projector based on DLP™ technology requires only user replacement of the lamp at periodic intervals for its out of box picture quality to be restored.

Only DMD technology is immune to degradation, so picture reliability ensures consistent performance over the entire projector life.

Appendix 1:

Comments on the Picture Reliability Study

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RIT completed all measurements using the guidelines of ANSI/NAPM IT7.228-1997. This specification includes procedures for the measurement of ANSI lumens, overall uniformity for white and chromatic output. In addition, ANSI contrast (checkerboard) and full on/full off (FOFO) contrast were measured.

The actual measurement procedure was completed under the control of in-house Matlab(TM) software which both displayed the appropriate images and recorded the data from the colorimeter. The measurement device was a Minolta CL-200, which reports Yxy luminance and chromaticity data for the 1931 2 degree standard observer. (The CL-200 was recently calibrated by factory technicians. Its stated accuracy is 2% in luminance and 0.002 in x,y chromaticity units. These are both well within the guidelines specified in the ANSI document.) The software displays the appropriate image and then places a white circle in the location of the next measurement. The operator aligns the device aperture port with the circle and signals the computer that the device is positioned for a measurement. The software then removes the circle and replaces it with the correct color, pauses for one second, then records a measurement. The one second delay is to ensure the Minolta has time to sample. (It is configured to sample every 0.5 seconds.)

Given that this was a life test, the test plan designed by TI personnel included measurement points at days 0,1,2,4, weeks 1,2,4, and months 2,3,4,5. At each point, we measured uniformity of luminance and chromaticity of full white, red, green, and blue. We also measured ANSI and FOFO contrast for white, red, green, and blue. Digital photographs were taken of all measurement screens at all data points as well as a few representative pictorial images. Ambient temperature was recorded at all points. During the test periods between measurement points, all projectors were subjected to the same set of cycling images to avoid burning in any particular image.

The Munsell Color Science Laboratory has a long-standing reputation in the color science community as a color measurement facility among the best in the world. Every aspect of the testing and measurements were carried out with the utmost care to ensure the validity of the results, and indeed their value to TI. We take every research and measurement project extremely seriously, and this was no exception.

RIT has no affiliation with TI other than the agreement to complete these measurements. TI was careful to never suggest possible failure modes expected, and any conclusions made were not biased by TI personnel or anyone outside our laboratory.