System Tuning Considerations

Liquid Crystal Based Spatial Light Modulators

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Introduction

Achieving maximum contrast in a liquid crystal based spatial light modulators (SLM) involves tuning the system to match the characteristics of the SLM. Adjustments can be made to the drive electronics, polarizers and waveplates in the system that, together with the SLM, determines the actual system performance. Tuning the system parameters requires an intimate understanding of how SLMs work.

Modulation Performance

Ferroelectric Liquid Crystal (FLC) Spatial light modulators change the optic axis of a birefringent waveplate at a given pixel based on the amount of voltage that is applied to that pixel. The actual behavior of the liquid crystal at a given pixel is dependent upon the difference between the cover glass voltage and the voltage applied at a given pixel.

Un-driven State

When the voltage applied to a given pixel matches the voltage on the cover glass the liquid crystal at that pixel is said to be un-driven. In this condition, the liquid crystal returns to a relaxed state. In this relaxed state, the uniformity of the device is not as high as it is in either of the driven states. It is best to reserve this state for unusable states of a device. In display applications, this is a gray value that is not achievable by the device.

Driven States

When the voltage applied to a given pixel is greater than or less than the cover glass voltage, the pixel is said to be in a driven state. Over the entire voltage range, the device will exhibit from its zero to its maximum change in the optic axis. Note that the relationship between changes in voltage and optical response is NOT linear and is not symmetric. Therefore, if the cover glass voltage is set to 2.5 volts, a pixel voltage of 2.0 volts will produce a different change in optical response than a pixel voltage of 3.0 volts.

The response curve (voltage vs. optical axis rotation) will vary significantly from device to device. Devices that have the same modulation range and the same liquid crystal materials may have very different response characteristics due to differences in fabrication techniques.

Preferred Modulation Direction

Liquid crystal devices always have a preferred modulation direction. This is a result of the fact that liquid crystals are polar molecules and may be attached to the alignment layers in different ways. In general, the preferred modulation direction provides a smaller slope response when compared with the non-preferred direction that has a very high slope response. When the device

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is operated in the preferred direction it operates as an analog device and when it operates in the non-preferred direction it operates much like a binary device.

The preferred modulation direction cannot always be easily determined. It may be that for a given device, changing the pixel voltage from 0 to 5 volts drives the device in the preferred direction, whereas for another device, changing the pixel voltage from 5 volts to 0 volts drives the device in a preferred direction. Operating a device counter to its preferred operating direction will give a binary response.

System Tuning

The following three steps will help optimize a spatial light modulator system for maximum contrast. First, determine the preferred modulation direction of the device. Second, choose a suitable voltage for the un-driven state of the system that will have the lowest system impact. Third, linearize the system response by choosing a look-up table that produces optimal response.

Determine Optimum Modulation Direction

To determine the optimum modulation direction, you must determine whether changing a pixel voltage from 0 to 5 volts produces a slow changing response, or whether changing the pixel voltage from 5 volts to 0 produces the slower change in response. To determine this, load an image that linearly changes from 0 to 255 from left to right in an image into the system. Make sure that any look-up tables that change the image are linear. Adjust the waveplate so that the left side of the image is black. The displayed image should be a smoothly changing function of position from left to right.

If the resulting image shows a very sharp transition from left to right when the image is displayed, then the preferred modulation direction is in the opposite direction. To confirm this, change the system lookup table[1] so that binary 0 is mapped to 255 (5 V) and binary 255 is mapped to 0 (0 V). Adjust the waveplate so that the left side is black corresponding to the image put into the system. The transition across the image should be much smoother than in the case tried before.

Choose Suitable Un-driven State Voltage

If the device is being used in a system where its uniformity is important, choose a voltage value for its un-driven state that has a minimum system impact. It may be for example, in the black output state, uniformity is very important. It may also be important that the white state be very uniform as well. In a display application, the completely black state and the completely white state may be common conditions that require better performance. A system designer might choose a look-up table that does not allow the un-driven state to occur. In this case, the cover glass voltage could be chosen as 2.5 volts. The look-up table could be chosen to avoid this voltage altogether. This would allow the fully white and fully black state to be driven while the un-driven state is not seen.

[1] If the system look-up table cannot be easily changed, the image may be pre-distorted before loading into the system. For example, if the system has a linear look-up table, and an inverting, linear look-up table is desired, the image may be pre-inverted before displaying.

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Linearize the System Response

After the first two steps are complete, it may be desirable to choose a look-up table that produces the most linear system response. Non-linearities in the SLM response will produce a response that is very unpleasant or undesirable. Using the same linear response image and the previously chosen linear look-up table, capture an image from the system on a digitizing device. Using the digital output as a reference, choose look-up table values that will produce a linear system response. When these values are properly selected, the system will concentrate output values in the driven direction, with fewer in the non-driven direction.

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