Advanced Image Sticking Measurements

Measurement purpose

Static image content is typical for specific displays, for instance, in the public sector at airports and train stations (traveling information), on touch screens (app symbols), or even video gaming in consumer applications or smartphone applications. If the image is updated, a ghost image of the previously static content may remain temporally or permanently visible. This phenomenon is called image sticking, residual image, latent image, image retention, or burn-in [1]. This application note helps to understand important aspects of the sticking image measurements and describes the options and advantages within the TechnoTeam evaluation procedures using either an LMK5 or LMK6 and the LabSoft.

General measurement procedure

Usually, the measurement procedure to quantize image sticking consists of three steps, shown in Figure 1 [1-6]. The first step is a warm-up period to recover the display from possible initial image sticking and to ensure a steady-state condition. During that time, a pattern rolling procedure, which continuously displays different grey levels, is applied until the warm-up time has passed. A few reference measurements are carried out at the end of the pattern rolling.

The second step is the burn-in, which displays the burn-in pattern. The pattern depends on the method used and can be considered a worst-case scenario to induce image sticking. Depending on the application, environmental conditions, such as the temperature, might also have to be adjusted [2].

After the burn-in time has passed, the relaxation period starts. The display is switched to the relaxation image(s) during this step. After an agreed delay time, the LMK performs continuous photometric measurements. The final sticking image values are evaluated based on these relaxation images.

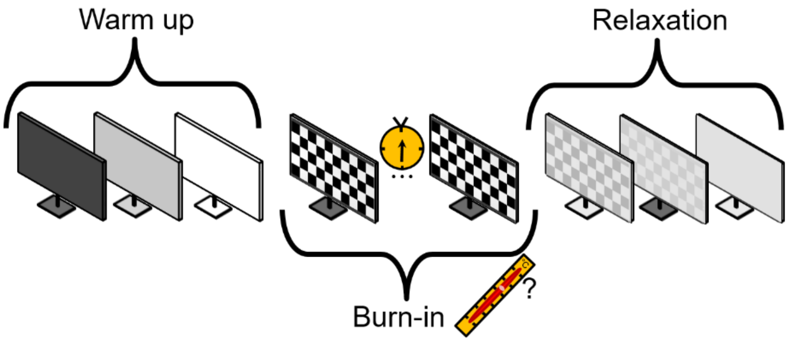


Figure 1: Typical schedule of an image sticking measurement

Sticking image measurement can be extremely time-consuming and may not be repeated with the same device under test (DUT). Therefore, all details should work the first time.

TechnoTeam has developed advanced hardware and software options to cover all details to ensure that you perform the correct measurement because sticking image measurements can be very time-consuming. Also, depending on the display technology, the measurements cannot be repeated with the same display [1]. Therefore, all details should be covered correctly right from the start.

Delay time and content-based trigger

From a measurement point of view, the most critical measurement concerning timing is the first measurement of the relaxation during a sticking image measurement series [7]. If the measurement starts "as soon as possible" (ASAP) or with a slight delay (<200 ms) [1,5,6], it has to be checked carefully as to what extent synchronization and temporal alignment are required.

In order to test the influence of a missing alignment on a sticking image evaluation, you can perform a sticking image measurement according to [5] but apply only a burn-in time of a few seconds. TechnoTeam performed this test on the same display on two different computers with different interfaces such as HDMI, VGA, and a USB to VGA adapter. For each setup, the evaluation was carried out 15 times. We evaluated only the first sticking image value. Table 1 summarizes the statistical results for each configuration [7].

The theoretical influence of a delayed measurement depends on the relaxation speed of the Image Sticking. According to [8], a sticking image relaxation may be approximated by the exponential equation:

$$SI(t) = SI_0 \cdot e^{\frac{-t}{\tau}}, \qquad (1)$$

where SI_0 is the initial level of image sticking ($\mathrm{t_{start}} = 0\ s$) and τ is a time constant, which describes the relaxation speed. In the case of $\tau = 8$ s, as reported in [8], the relative deviation between a sticking image value of $\mathrm{t_{start}} = 0.1$ s and $\mathrm{t_{start}} = 0.5$ s would be 5%. If the measurement starts after 1 second instead of 0.1 seconds, the error is 10%. In each case, reproducibility cannot be ensured [7].

An external trigger configuration, as shown in Figure 2, could be used to synchronize the pattern switching to the first image capture. However, reproducibility can also be influenced by additional hardware and complex setups.

Table 1: Measurement "As soon as possible" without temporal alignment [7]

Setup		First measured sticking image value		
Computer	**Interface**	**Median**	**Min**	**Max**
PC 1	**HDMI**	**5,8%**	**1,5%**	**41%**
PC 1	**VGA**	**2,7%**	**0,5%**	**9%**
PC 1	**USB**	**5%**	**3%**	**50,5%**
PC 2	**HDMI**	**3%**	**2%**	**6%**
PC 2	**VGA**	**35%**	**8%**	**61%**

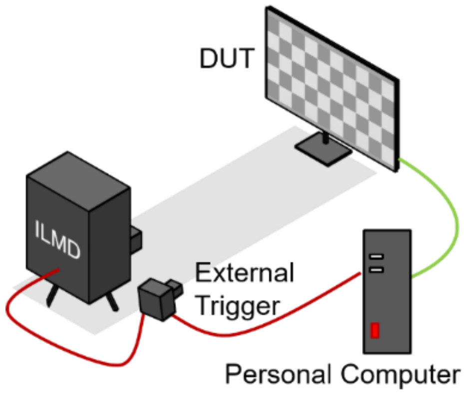


Figure 2: Possible solution: external triggering [7]

TechnoTeam image content-based trigger

The LMK6 content-based trigger mode allows precise detection of changing image content by observing a small user-defined ROI (region of interest) with a frequency of a few microseconds. Therefore, the luminance camera only reacts to the pattern switching and becomes independent of any software or hardware-induced delays during image generation. With the trigger mode, time-critical measurements are made right at the exact time. This also applies for the first image of a sticking image measurement series. The working principle and parameters are shown in Figure 3.

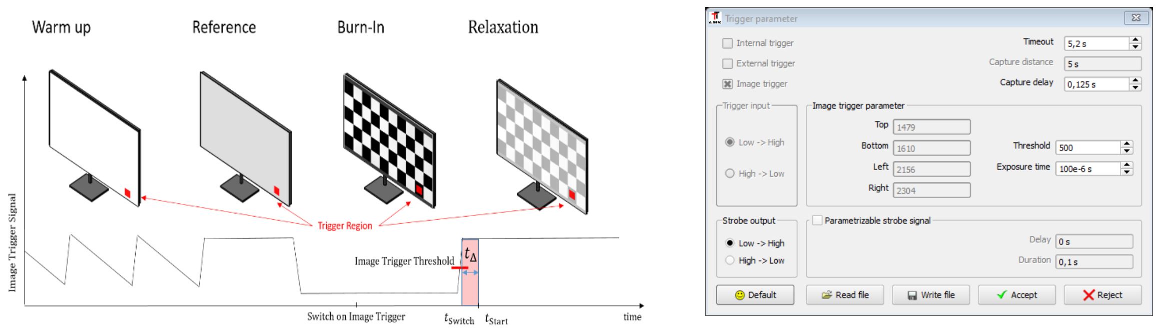


Figure 3: Working principle of the image content-based trigger during image sticking. Parameters to adjust the trigger

Within the user-defined ROI, the trigger observes the grey value of the camera with the settled exposure time in a high-speed mode. The image capture starts if the observed grey value is higher than the threshold value. That way you can detect the pattern switching in the ROI from a dark area to a bright area with high reproducibility if the trigger is enabled before pattern switching.

Simply drag and drop the "ROI" directly on the region of the burn-in image that will become brighter when the relaxation period starts. Perform the complete parametrization easily and intuitively by using the live mode of the LabSoft (Figure 4). Finally, adjust the "Capture delay" to define the time delay between the detection of the trigger signal and the start of the first sticking image relaxation measurement.

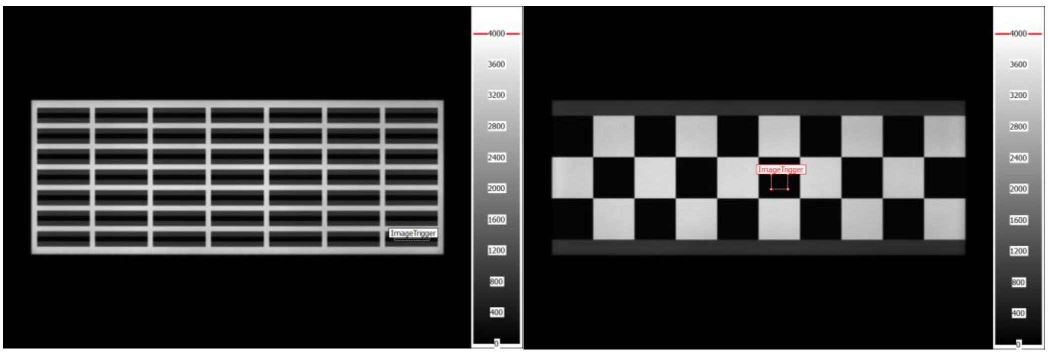


Figure 4: Examples of a burn-in pattern and a placement of the region of interest for the image content-based trigger

The LMK6 image content-based trigger is easy to use via drag and drop and the best option to ensure a perfect synchronized sticking image measurement between any display regardless of any hardware or software-caused delays

Spatial Uniformity Correction

Another critical aspect of each sticking image evaluation is the capability to differentiate between image sticking and spatial non-uniformity in the luminance distribution of the reference grey level [7,9,10]. The corrections are part of the evaluation methods. Generally, two approaches can be used:

The first general approach relies on luminance values measured before any burn-in period. This is the time reference method.

The second method relies on local reference regions, which are not affected during the burn-in because the relaxation grey equals the burn-in grey

The 2-level approach according to Bauer [5] and the 3-level approach according to Lauer [3] are both recommended by TechnoTeam and each covers one correction type. While the 3-Level approach relies on local references of neighboring fields, the 2-level approach uses a reference image to ensure uniformity corrections. Both correction approaches have advantages and disadvantages, as shown in Table 2.

Table 2: Advantages and disadvantages of different sticking image uniformity correction methods

	Advantages	**Disadvantages**
Time reference **(available for 2-Level and 3-Level approach) [3,5]**	• *Very precise uniformity correction*	• *Requires temporal stability of the display because it references to the past* • *Requires a warm-up period*
Local reference **(available for 3-level approach) [3]**	• *Not affected by temporal stability caused by environmental issues or driver electronics because each image references to itself* • *The warm-up period can be skipped (warm-up during burn-in)*	• *Less precise uniformity correction*

How to test a uniformity correction:

The simplest way to check if the uniformity correction of an image sticking measurement methods works well enough is to perform a sticking image measurement without performing a burn-in. If the sticking image calculated is in the order of accepted tolerance values even though temporal alignment was considered, then you cannot use that sticking image evaluation method or measurement system in that configuration.

If a short-term time reference cannot bring the sticking image near zero, you should carefully check the properties of your display and measurement system before starting a real sticking image measurement (e.g., integration time, effects of modulation, etc.). An incorrect integration time or other attributes can cause problems [11].

Additional uniformity correction developed by TechnoTeam

TechnoTeam has developed a sticking image model, which bases on modeling the sticking image phenomenon of LCDs according to [12-14] and OLED displays according to [15] and derived an additional uniformity correction [9]. This additional uniformity correction relies on a time reference and is in agreement to [1].

This additional correction is especially interesting for the 3-Level approach. It allows you to toggle between a less precise local reference correction, which is not affected by global temporal variations (e.g., environmental conditions, screen saver modes, etc.), and a high precision temporal non-uniformity correction, which can, however be affected by temporal variations. Although it requires a warm-up period, this mechanism can be used to validate your results on an even higher level.

The difference between uniformity corrections is significant. In the LabSoft, simply check/uncheck a previously taught uniformity and observe how the results change (see Figure 5-7 for an example).

Easily toggle between both uniformity correction methods with the results of the 3-level approach and TechnoTeam's additional non-uniformity correction technique that relies on a sticking image model for LCDs and OLEDs. This allows you to cover both approaches: the more precise but unstable time reference and the less precise but more stable local reference

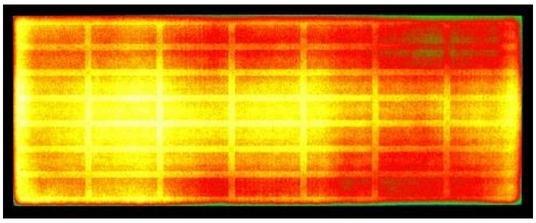


Figure 5: First relaxation image of the 3-Level approach (Correction based on local references) [9]

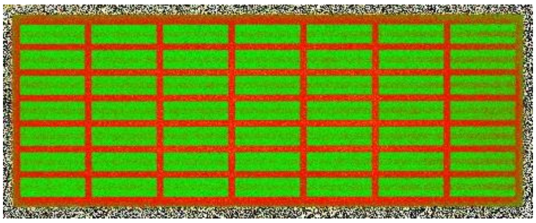


Figure 6: First relaxation image of the 3-Level approach with additional uniformity correction

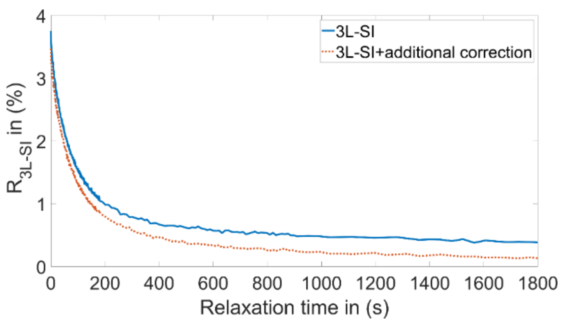
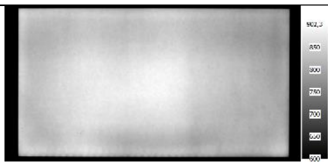
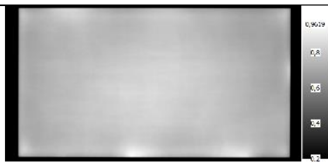
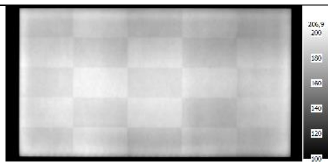
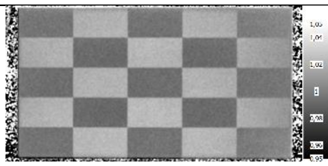


Figure 7: Resulting sticking image values for both cases in a time measurement series. The difference is around 0.5% percent absolute image sticking [9]

Relaxation and burn-in grey levels

The grey and/or color levels covered in the measurement are extremely important and should be clear in advance to all measurements. It has been shown that not only the burn-in but also the reference image can make a significant difference [6,7,16]. Table 3 shows the result of sticking image measurements according to [1], where only the relaxation was changed. While the extreme cases white and black have no image sticking, a clear image sticking can be seen for grey.

Table 3: Results obtained with the IDMS 10.4 approach (false color scale of quotient images always [0.95 1.05] and different relaxation grey levels: Sticking image values R [7]

	IDMS 10.4 White	IDMS 10.4 Black	IDMS 10.4 Grey
First Relaxation			
Quotient			
R	*1.002*	*1.002*	*1.026*

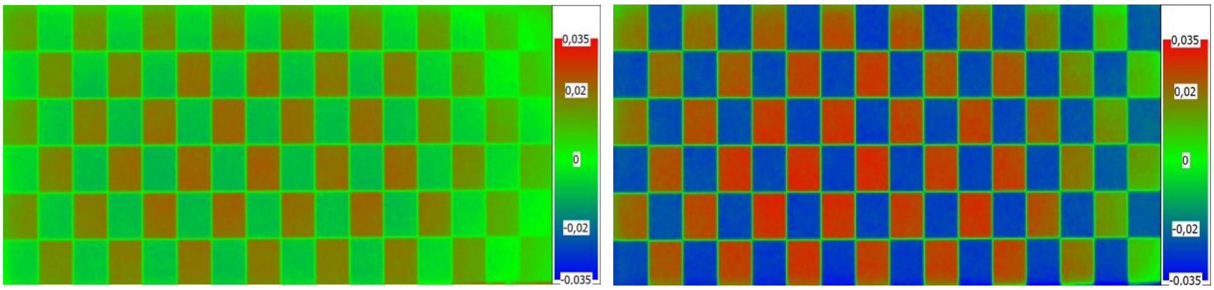


Figure 8: Comparison of different burn-in and relaxation grey levels: Left: sticking image from burn-in with 0%/100% grey level and relaxation to 50% Right: sticking image from burn-in with 50%/100% grey level and relaxation to 42% [7]

Figure 8 shows the results of a more advanced test presented in [7]. Grey scale wedges were used as burn-in and reference images to find the worst-case combinations for the image sticking. The results of the grey scale wedge test are shown in Figure 9.

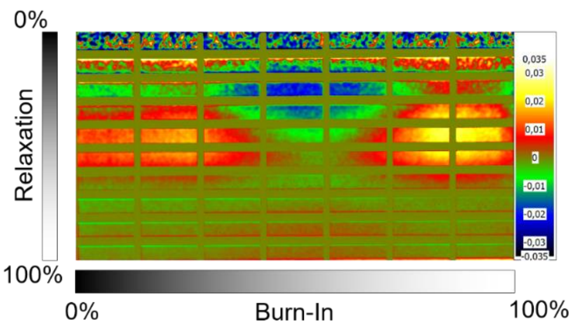


Figure 9: Grey level (Relaxation and burn-in) dependency of a display [7]

Customize your own image sticking application

In each case, the grey level dependence and an increasing number of measurement methods for image sticking lead to flexibility regarding the evaluation. Within the GUI of TechnoTeam's LabSoft, you can:

- freely parameterize the grey levels of the existing methods
- create complete time-controlled measurement series, including saving
- tailor the image content-based trigger for single images and measurement series
- optionally control the DUT via a pattern generator or to load user-defined test images
- define evaluation regions evaluate and to evaluate time-controlled series in real-time
- perform image processing, e.g. a time reference-based uniformity correction via image processing
- automatize all evaluations (requires enabled ActiveX functions) described above via simple-script-based languages such as Python, Matlab, VBA or LabView utilizing more than 350 ActiveX functions (including complete camera setup functions for geometrical alignment and compatibility of the implemented sticking image functions)

With enabled ActiveX-Interface, you are of course free to implement your own sticking image evaluation application. This includes complete control over image capture, image content-based trigger options, and if required template image generation.

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