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WHITE PAPER

Validating the Use of Compression for Automotive Displays

A study verifying VDC-M's visually lossless compression properties demonstrates that MIPI DSI-2 offers a solution to the growing bandwidth challenges in next-generation vehicles

March 2021

An Evaluation of Visually Lossless Display Compression in Automotive Use Cases

Executive Summary

IN BRIEF

Use of image compression is essential to address the proliferation of high-performance displays in next generation vehicles. This paper details the trends impacting automotive display design and describes a new MIPI Display Working Group (DWG) study that verifies how the use of Video Electronics Standards Association Display Compression-M (VDC-M) within the MIPI Display Serial Interface 2 (DSI-2SM) protocol can provide visually lossless compression for automotive displays.

Automotive display requirements are evolving rapidly as trends in connectivity, automation, sharing and electrification demand that automotive designers incorporate a growing number of larger and higher-resolution displays inside vehicles. These advanced display systems must meet the stringent reliability, power, weight and electromagnetic compatibility (EMC) requirements demanded by the automotive industry—yet the increase in total bandwidth demand generated by vehicle-display data makes it difficult for designers to meet these requirements with display protocols that do not support compression.

To make such a capability available to automotive and other high-bandwidth applications, MIPI Alliance has integrated the VDC-M visually lossless image compression standard into version 1.2 of the MIPI DSI-2 display protocol. VDC-M achieves a maximum compression ratio of 6:1, reducing a 24-bit uncompressed source RGB pixel to 4-bits per pixel when compressed. This image compression can be leveraged by automotive designers to connect high-resolution displays with lower-bandwidth physical interfaces using lower-cost cables and connectors, or to connect the highest-possible resolution displays that require data rates that far exceed the underlying bandwidth of the physical interface. Because the automotive cable harness is one of the most expensive and heaviest components within a vehicle, the use of image data compression technologies also can help reduce the complexity of this component.

The use of a high data compression rate must be approached with caution as it may adversely affect image quality and transmission latency—factors that are unacceptable in safety-critical, in-vehicle display applications. This white paper presents a technical approach to assessing visually lossless compression quality for automotive displays and describes a recent MIPI automotive image compression study undertaken for the benefit of automotive display architects who wish to evaluate the visually lossless properties of VDC-M. The study concluded that a wide selection of automotive images compressed using VDC-M met the visually lossless objective as shown in the following figure.

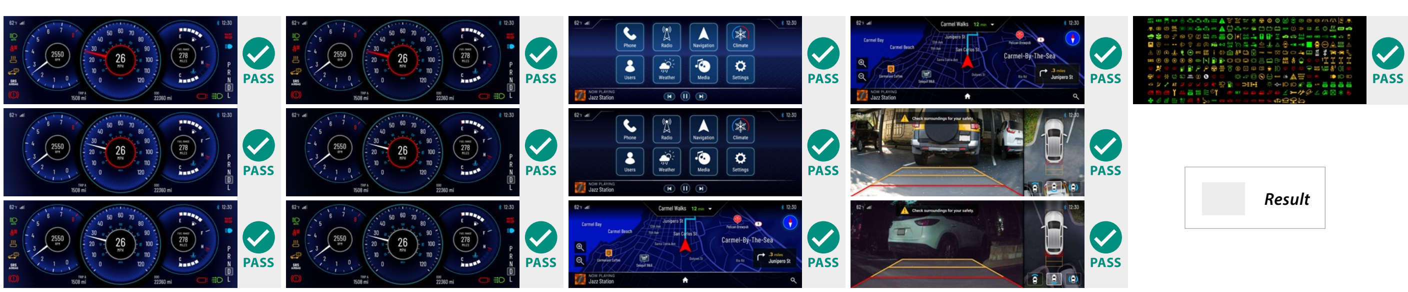

Figure 1 Summary of MIPI automotive image compression study results

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1. Introduction

1.1. Automotive Trends

Automotive display systems are undergoing an accelerated evolution driven by the disruptive industry trends of connectivity, automation, sharing and electrification (known as "CASE"). This combination of trends is driving an increased number of in-cabin automotive displays, along with increased pixel color depth and display resolution, as described in Table 1.

Trend	Description	Impact on Display Requirements
Connected	Enhanced automotive connectivity through the adoption of 5G, vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) standards are revolutionizing the industry: • Enabling enhanced "connected" use cases[1] such as intersection movement assist, hazardous location warning and high-definition sensor sharing • Allowing passengers to communicate, work, surf the internet and access high-bandwidth multimedia throughout their journeys • Enabling digital services to be offered that will update and enhance in-vehicle experiences throughout a vehicle's lifetime, such as regular digital asset customization updates to change the look and feel of the car interior with personalized content and downloadable backgrounds	• Increased need for visual bandwidth • More, larger, higher-resolution displays • New display form factors to curve and match the style of the interior cabinet
Automated	Full or partial self-driving cars will have a profound impact on the industry. Vehicles that offload the driving task allow the driver and automobile to interact differently, with the potential to use advanced display capabilities for gaming, entertainment and information not related to the task of driving.	• Increased use cases for display content • More, larger, higher-resolution displays
Shared	Autonomous vehicles will enable highly customized car-sharing solutions where driver/passenger preferences are automatically configured when the driver starts the car. Future vehicle display interfaces will be highly customizable with a much richer multimedia experience that includes animations, personalized content, wide color gamut images and audio.	• Customized user experience to travel with the driver and individual passengers • Displays must adapt to constantly changing requirements
Electrified	The transition to emissions-free transportation creates new constraints on in-cabin electrical consumption. The distance traveled on a single charge is directly proportional to the power efficiency of the electrical and electronic subsystems. The multiple displays required in modern cars can leverage the power-efficient techniques pioneered in mobile wireless phones.	• Dynamic display power reduction at the hardware protocol level • Display bandwidth optimized through compression to reduce power

Table 1 Description of automotive industry trends and their impact on displays

To meet these new display requirements, contemporary automotive systems engineers are challenged to create scalable display system architectures capable of supporting entry-level vehicles all the way to flagship product lines, while still meeting all functional safety, weight, power and electromagnetic interference (EMI) requirements.

[1] *5GAA White Paper—C-V2X Use Cases Methodology, Examples and Service Level Requirements (2019)*

1.2. Automotive Display Configurations and Requirements

The next-generation automobile cockpit is evolving as a result of the trends discussed in the previous section. Figure 2 illustrates how new displays are replacing traditional analog instrument clusters, mirrors and mechanical buttons for car controls and how additional displays are being added to support increasing demand for in-vehicle infotainment services and digital vehicle customization.

Figure 2 Example automotive display configuration

Display Type		Number	Size (Inches)	Example Resolution	Description	Net Data Throughput (Gbps)
1	Driver Instrument Display	1	12.3	3840x1440	Improved visibility with customizable user experience	8.4
2	Center Information Display	1	12.3	3840x2160	Center navigation and general information display	12.6
3	Lower Control Display	1	12.4	3840x2160	Controls interior functions such as air conditioning and lighting	12.6
4	Co-Driver Display	1	12.3	3840x2160	Extends information across entire dashboard	12.6
5	Side Digital-Mirror Displays	2	7	1280x800	Improved viewing in direct sunlight, improved viewing range, optical correction and reduced blind spot	1.5
6	Heads-Up Display	1	3.1	850x480	Nearly 300 ppi with 60 Hz update rates	0.6
7	Rear Seat Entertainment	2+	12.5	3820x2160	Provides full 4K UHD displays	12.6
8	Rear Digital-Mirror Display	1	9.7	1280x320	Replacement for traditional rearview mirror	0.75

Table 2 Example of automotive display types

These advanced displays are increasing in number, resolution and color depth, as shown in Table 2. It is noted that the resultant net data throughput required to drive all of these displays presents a significant design issue, and there is little debate that image compression will be essential to future automotive display architectures.

2. Overview of Study

The MIPI DSI-2 specification incorporates the VDC-M compression standard, which can be used to significantly reduce display bandwidth while preserving visually lossless image quality. This white paper details the method and results of an automotive compression study completed by the MIPI DWG, using representative automotive display images commissioned by MIPI Alliance for visually lossless compression analysis of the VDC-M standard.

The international gold standard for visually lossless compression testing is defined in ISO/IEC 29170-2:2015[2] (referred to, from this point forward, as the "ISO standard"). This rigorous test protocol is specifically designed to test low-impairment compression codecs that have visually lossless quality by using human test observers to evaluate a series of reference images vs. compressed images. Members of the MIPI DWG implemented a focused test procedure, guided by the principles laid out in the ISO standard, using multiple expert observers.[3] The test procedure used two test protocols:

- "Non-Flicker Testing"—A forced-choice paradigm using non-flickering images, described in section 3.3.2.1
- "Flicker Testing"—A forced-choice paradigm using interleaved images, described in section 3.3.2.2

A tabulated test report was then prepared, providing the test results for each image tested using the two protocols.

The study concluded that all evaluated images were visually lossless using the statistical models defined in the ISO standard. The full study is contained in sections 3 and 4 of this paper.

It is important to note that the DWG study, which followed the focused test procedure described in this paper, is an example of automotive visually lossless analysis. Readers must evaluate their own images using the full ISO standard test procedure because visually lossless quality assessment is highly dependent on source image content and display configuration.

[2] *ISO/IEC 29170-2:2015 Information technology - Advanced image coding and evaluation — Part 2: Evaluation procedure for nearly lossless coding*

[3] *Three subjects were under the recommended 40 years of age, and four subjects were older.*

3. Study Phases

The study was completed in four phases, as shown in Figure 3. A summary of each phase follows, and a detailed description of each phase is provided in sections 3.1 to 3.4.

Figure 3 The four phases of the MIPI compression study

Phase 1—Generate Source Images: The MIPI DWG defined specific automotive test image requirements to enable the evaluation of the VDC-M compression standard. The test image requirements were provided to a graphic artist who generated 13 images covering telltale icons, driver instrument display, center information display, navigation map and rearview camera display. These images formed the foundation for Phase 2 of the study.

Phase 2—Generate Test Images: The images were compressed using the VDC-M codec at the maximum 6:1 compression ratio (i.e., compressing a 24-bits per pixel source image down to a 4-bits per pixel compressed image). The maximum compression ratio was chosen to test the upper bound of the codec's capabilities to ensure visually lossless quality margin; if 4bpp images passed, then any lower compression ratio would also be acceptable. It is also important to note that the flicker testing protocol (described later in this paper) provides nearly 2 dB of additional visually lossless margin.[4]

Phase 3— Run Limited Subjective Quality Trial: The MIPI DWG engaged experts to implement both flicker and non-flicker test protocols. The telltale icon, driver instrument display, center information display and navigation map images were tested using both flicker and non-flicker protocols, while the rearview camera images were tested using only the non-flicker test protocol because of their motion content.

Phase 4—Analyze Results and Generate Report: The study organizers analyzed the results from each test iteration, for all observers, and generated a table of final results for each image tested.

The results obtained from the study are contained in Section 4 of this paper.

[4] *Perspectives on the definition of visually lossless quality for mobile and large format displays (11 Oct 2018)*

3.1. Phase 1—Generate Source Images

In this phase of the study, the MIPI DWG defined the specific automotive test image requirements to enable the evaluation of the VDC-M compression standard. A summary of the requirements is provided in Table 3.

Image quality requirements	• **All images use a 2.2 gamma curve for luminance and an sRGB color gamut** • **Telltale warning icon size of 120 pixels x 120 pixels @3840x1440 resolution** • **All images are supplied in the following formats:** › Adobe Illustrator (.ai) › Scalable Vector Graphics (.svg) › Uncompressed 24-bit PNG (.png) › Uncompressed 30-bit PNG (.png) • **Alignment with the following standards:** › ISO 15008:2017 — Road vehicles — Ergonomic aspects of transport information and control systems — Specifications and test procedures for in-vehicle visual presentation › ISO 2575:2010 - Road vehicles — Symbols for controls, indicators and telltales › SAE J1362 - Graphical symbols for operator controls and displays on off-road self-propelled work machines
Graphic artist's reference display requirements	• **Monitor supported a maximum luminance of 1000 nits** • **Monitor resolution of 3840x2160** • **sRGB color gamut** • **Viewing distance 28 inches (71 cm)**

Table 3 Source image and reference display requirements

Thirteen source images for the telltale icons, driver instrument display, center information display, navigation map and rearview camera display were created. Samples of these images are shown in sections 3.1.1 to 3.1.5 of this paper. Similar images are used by car manufacturers when performing similar tests.

The raw test images, in the formats shown in Table 4, can be made available to researchers upon request to MIPI Alliance (**admin@mipi.org**).

Image Description	*Category*	*Format*	*Max Luminance (nits)*
Telltale Icons	Telltale warning symbols	***3840x1440***	***100***
Driver Instrument Display	Daytime and nighttime driver instrument cluster • With red and white speed needle • With and without telltale icons	***3840x1440***	***1000***
Center Infotainment Display	Daytime and nighttime infotainment controls (radio, air conditioning, etc.)	***3840x1440***	***100***
Navigation Map	Daytime and nighttime navigation (maps, bird's-eye view, point-of-view)	***3840x1440***	***100***
Rearview Camera	Daytime and nighttime rearview camera with graphics overlay	***3840x1440***	***100***

Table 4 Summary of source image formats

3.1.1 Telltale Icon Source Images

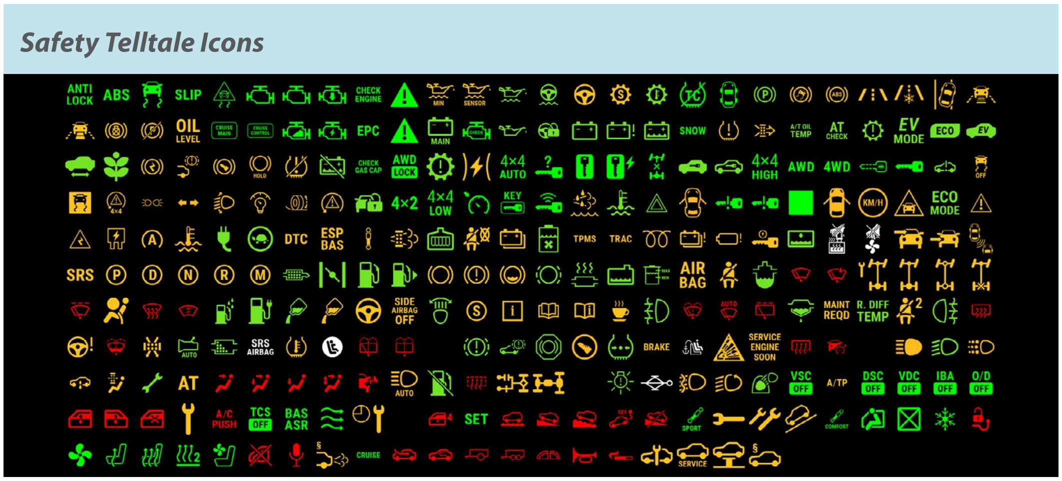


Figure 4 Telltale safety icon source images

3.1.2 Driver Instrument Display Source Images

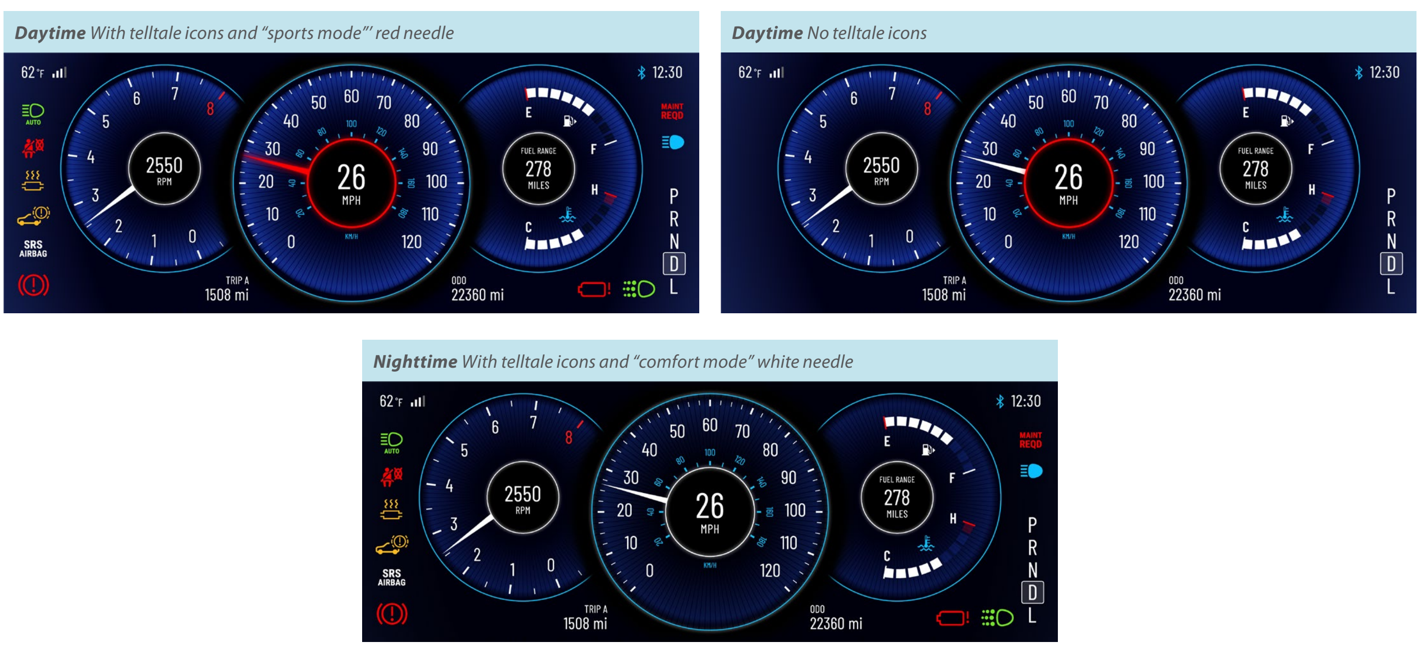


Figure 5 Driver instrument display source images

3.1.3 Center Infotainment Display Source Images

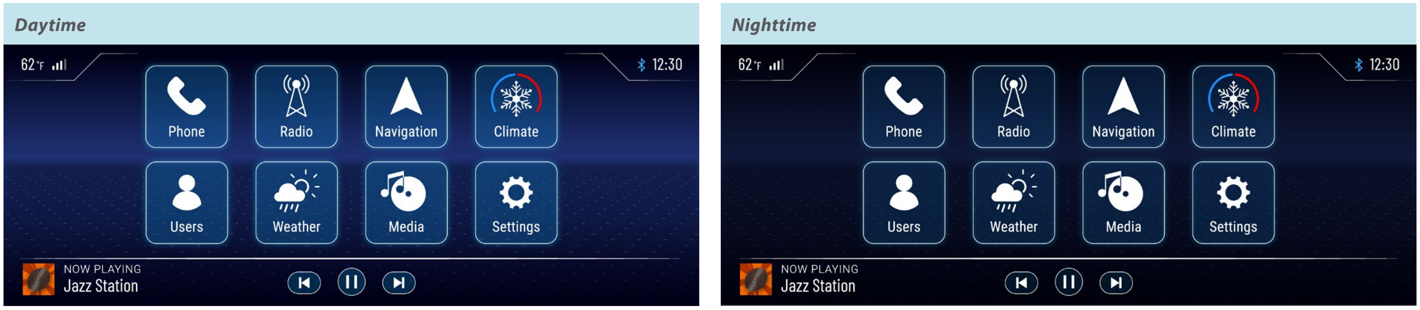


Figure 6 Center infotainment display source images

3.1.4 Navigation Map Source Images

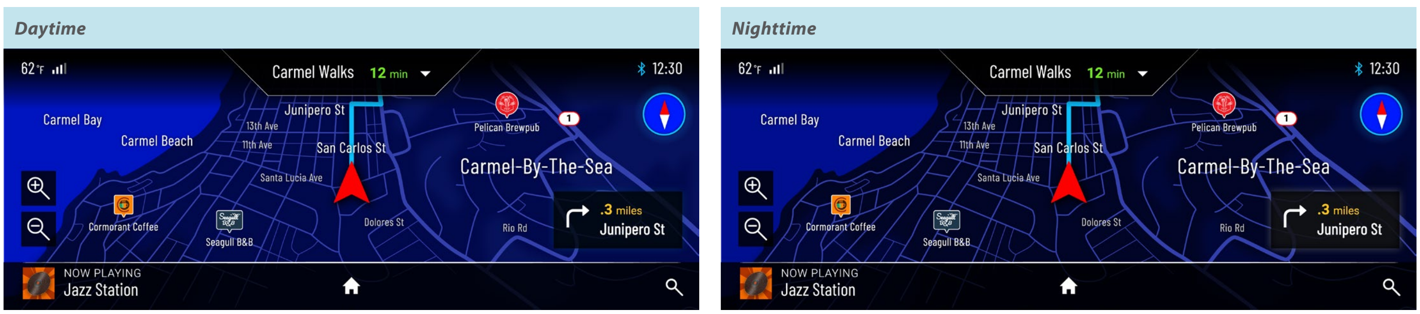


Figure 7 Navigation map source images

3.1.5 Rearview Camera Source Images

Figure 8 Rearview camera display source images

3.2 Phase 2—Generate Test Images

In this phase of the study, the workflow shown in Figure 9 was used to prepare the test images for Phase 3 of the study.

The source images from Phase 1 were compressed using the VDC-M codec to the maximum 6:1 compression ratio (from a 24-bits per pixel source image down to a 4-bits per pixel (4bpp) compressed image). As previously discussed, the maximum compression ratio was chosen as the upper bound of the codec's capabilities to ensure visually lossless quality margin; if 4bpp images passed, then any lower compression ratio would also be acceptable. It is also important to reiterate that the flicker testing protocol provides nearly 2 dB of additional visually lossless margin.[5]

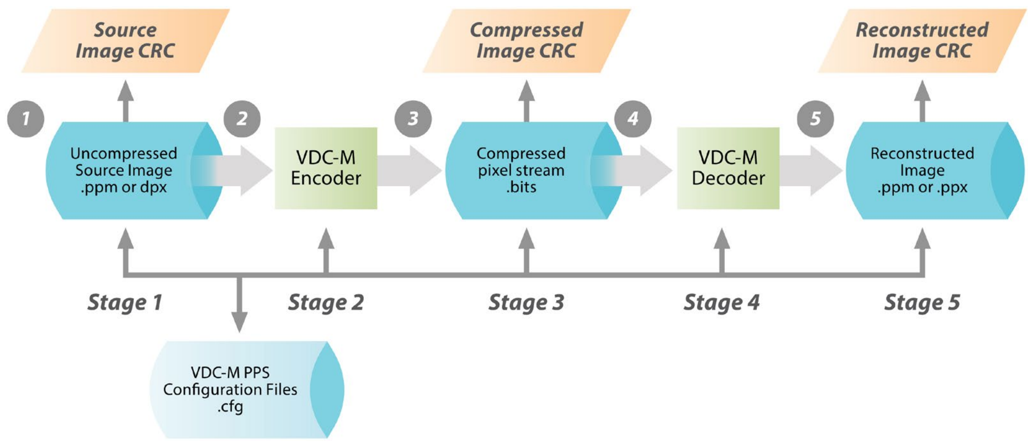


Figure 9 Test image generation workflow

Stage 1: Reference source images were prepared by rendering directly from .SVG vector files into a 3840x1440 24-bits/pixel .PPM file bitmap image.

- Four cropped reference images were prepared from each corner of the 3840x1440 .PPM reference with a resolution of 1920x720 @24bpp. Care was taken to ensure the cropped references were not modified, only cropped.

Stage 2: The VDC-M v1.2 VESA reference codec binary for Windows was configured to compress an input reference source image and output a 4-bpp compressed output using two horizontal slices per line.

Stage 3: All 3840x1440 @24bpp reference source images were compressed using the VDC-M v1.2 VESA reference codec binary for Windows.

Stage 4: The VDC-M v1.2 VESA reference codec binary for Windows was configured to decompress a 4-bpp image and produce a reconstructed 3840x1440 @24-bpp .PPM image.

Stage 5: The 3840x1440 reconstructed images were used to prepare 4x cropped reconstructed images from each corner to create a 1920x720 @24bpp image. Care was also taken to ensure the cropped reconstructed images were not modified, only cropped.

These final cropped images were used in the human subjective trials in the next phase of the study.

[5] *Perspectives on the definition of visually lossless quality for mobile and large format displays (11 Oct 2018)*

3.3 Phase 3—Run Limited Subjective Quality Trial

In this phase, the MIPI DWG engaged experts to implement the test protocols. The telltale icon, driver instrument display, center information display and navigation map images were tested using both flicker and non-flicker test protocols, while the rearview camera images were tested using only non-flicker protocols because of their motion content.

3.3.1 Guiding Principles for Evaluating Visually Lossless Compression

The ISO/IEC 29170-2:2015 technical standard provides a gold-standard process to evaluate visually lossless compression codecs, using human subjective trials to build statistical models indicating whether the codec is visually lossless. It standardizes the test protocols, media selection, observer selection criteria, viewing conditions, viewing time and test-report preparation required to evaluate visually lossless codecs.

Guided by the principles laid out in the ISO standard, MIPI DWG ran the two focused test protocols described below, which, if passed successfully, would provide high statistical confidence in the visually lossless quality of the selected codec.

3.3.2 Overview of Low Impairment Compression Testing

The uncompressed reference and reconstructed images from the previous phase were formatted according to the ISO standard-inspired subjective protocol described in this section. This advanced protocol is required because the reconstructed version is so close to the original that objective metrics such as peak signal-to-noise ratio (PSNR) cannot accurately determine whether the image is visually lossless. The PSNR difference equations are too simple and do not accurately model the human visual system (HVS). Human subjective trials are required to properly assess whether the majority of people cannot see any differences between the original and compressed reconstructed images.

The MIPI DWG automotive compression study was performed with a limited number of participants (seven experts) to stress test VDC-M 6:1 compression of the selected MIPI automotive images to determine whether a full ISO standard test procedure was required. The MIPI experts followed the focused test protocol, guided by the principles contained in the full ISO standard, with additional stringent changes to accelerate detection of lossless compression artifacts described in Table 5.

	ISO Standard Recommendation	*Actual Protocol Used in this Trial*	*Comment*
1	Cropped areas of interest	Full image viewing	Full image viewing allowed experts to contrast and compare all areas of the image for compression artifacts.
2	Strict 5-to-8-second viewing duration per image	Unlimited viewing duration	Unlimited viewing duration allowed experts to carefully review each area of interest for compression artifacts.
3	Fixed distance from display for a specific 100 pixels-per-degree (PPD) pixel density	Unlimited viewing distance	Unlimited viewing distance allowed experts to move within a few centimeters of the display for up-close inspection while looking for defects.
4	Multiple observer trials to create accurate statistical models	Limited observer trials prevent full statistical model	The purpose of the MIPI DWG study was to determine whether a full subjective trial was required. However, given the stringent viewing conditions and lack of compression artifacts, no further MIPI DWG trials are planned.

Table 5 Elements of the MIPI DWG test protocol that differed from the full ISO standard

There are many factors, as described in Table 6, that influence the accurate comparison between original and visually lossless compressed images.

Quality Factor	Characteristic	Impact on Visually Lossless Quality Subjective Analysis	MIPI Automotive Study
Image Content	Static or motion	Static images allow more stringent quality comparisons because subjects can concentrate their focus on a small area of the display. Moving image assessment is more difficult and less stringent because subjects must shift their gaze.	All images were static but the rear image was intended to simulate a single frame from a motion video sequence.
	Hard-edged graphics or soft, natural images	Hard-edged graphics allow more stringent quality comparisons because artifacts are sharper. Soft, natural images are easier to compress, and errors are harder to detect.	The instrument cluster, controls and navigation map are all hard-edged computer graphics symbols. The rearview camera is a combination of natural camera images with hard-edged graphics overlay.
	Resolution	Using a source image with resolution that matches the resolution of the display is required for the most stringent quality analysis. Lower-resolution images on high-resolution displays may hide compression artifacts.	The source images are all 3840x1440 to simulate known automotive displays.
	Contrast	High-contrast images make artifact detection easier.	Images were generated on a 300-nit graphics display.
Display Characteristic	• Resolution and refresh of the display • Size of the display • Brightness of the display • Contrast • Display calibration	The display used for visual quality testing should match the compression use case as closely as possible.	Display used to generate MIPI automotive test images: Dell P2715Q, 27” 4K. 350 cd/mˆ2. sRGB 99%, Adobe RGD 79%, NTSC 72%. AH-IPS, W-LED, 3840x2160. Static contast 1000:1
Observer	Distance of the display to the observer	The distance from the observer to the display is calculated using the ISO/IEC 29170-2:2015 formula: $D = \frac{W}{H_{RES} \times \tan(\frac{1}{PPD})}$ Where: **D** is the distance to display in cm **W** is the screen width in cm **Hres** is the number of pixels across the display horizontally as viewed by the observer **PPD** is pixel per degree	Distance ‘D’ was set to 100 cm (approximately 3 feet) to simulate a driver’s distance to the instrument cluster. Width is 60 cm. Horizontal resolution is 3840. The observer will see approximately 112 PPD.
Other	• Room lighting conditions • Observer color and vision acuity • Length of observation • Experts or non-experts	• Instructions to the subject • Age • Use of training session	These parameters are specified in the ISO standard.

Table 6 Factors affecting subjective visual quality trials

3.3.2.1 Test Using Forced-Choice Paradigm with Non-Flickering Images

"Forced-choice paradigm with non-flickering images test protocol," or "non-flicker test" for short, is a test protocol designed to test static visual images. Figure 10 illustrates what an observer would see on a test monitor when following this test protocol.

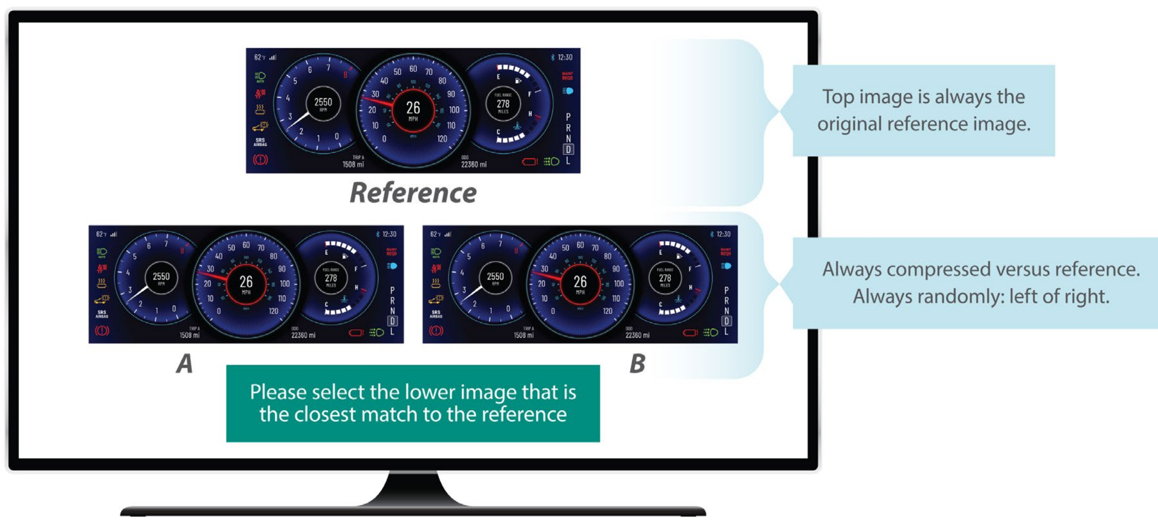


Figure 10 Forced-choice paradigm with non-flickering images (non-flicker testing)

In this protocol, three images are presented to the observer. Note that these images may be cropped from the original size to meet the visual criteria required by the standard.

1. Top Image—Reference original image with no compression
2. Left Image A—Randomly selected compressed or original image
3. Right Image B—Randomly selected compressed or original image
4. Bottom Text—"Please select the lower image that is the closest match to the reference."

   NOTE: The left and right images, A and B, are never the same (i.e., never both compressed images or both original images). They must always be different to ensure accurate comparison with the original reference image at the top.

Multiple test observers are exposed to this testing protocol using multiple randomized test images selected from a curated pool of images. The results are recorded and correlated as per the ISO standard. The final report (see Section 4.1) contains the test results for each image, from many iterations of the test protocol, leading to a high confidence in the final assessment. The reader is encouraged to review the full ISO standard for further details of the test procedure.

3.3.2.2 Test Using Forced-Choice Paradigm with Interleaved Images

"Forced-choice paradigm with interleaved images test protocol," or "flicker test" for short, is a test protocol designed to test static visual images. Figure 11 illustrates what an observer would see on a test monitor when using this test protocol.

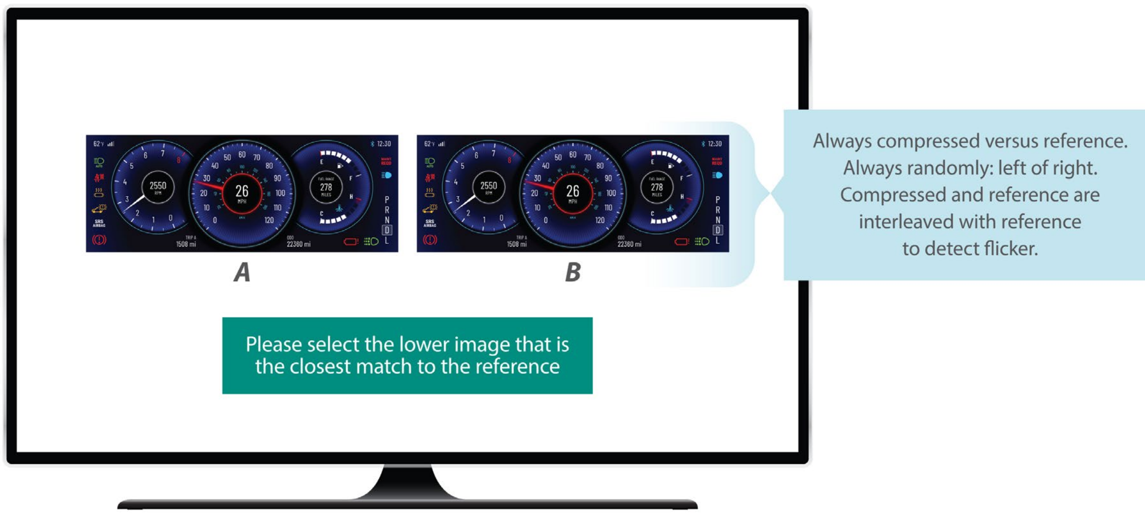


Figure 11 Forced-choice paradigm with interleaved images (flicker testing)

In this protocol, only two images are presented to the observer. Note that these images may be cropped from the original size to meet the visual criteria required by the standard.

1. Left Images—Dynamically interleaved reference and compressed test images in the same position changing at a rate around 5 Hz. The video time is locked to the monitor to prevent any screen distortions and to guarantee synchronization with the right image.
2. Right Images—Dynamically interleaved reference and reference test images in the same position changing at a rate around 5 Hz. The video time is locked to the monitor to prevent any screen distortions and to guarantee synchronization with the left image.

   NOTE: Randomly, the left image may be interleaved between the reference and reference image, while the right image is interleaved between the reference and compressed image. The left and right image interleaving must always be different (i.e., they cannot be both left and right interleaved with reference and compressed, or both with reference and reference).

Multiple observers are exposed to this test protocol using multiple randomized test images selected from a curated pool of images. The results are recorded and correlated as per the ISO standard. The final report (see Section 4.2) contains the test results for each image, from many iterations of the test protocol, leading to a high confidence in the final assessment. The reader is encouraged to review the full ISO standard for further details of the test procedure.

3.3.3 Specific Areas of Focus Applied During the Test Protocols

Expert observers familiar with the full ISO standard test protocol evaluated all the MIPI automotive test images and paid extra attention to the key focus areas shown in Figure 12 and Figure 13. These example key areas have low-contrast background shading or high-resolution detailed text and graphics designed to challenge the VDC-M codec at high 4-bpp visually lossless compression rates.

Note: The references contained in Annex A contain additional details on the advanced application of the ISO standard test protocol for a variety of images.

3.3.3.1 Background Shading and Low-Contrast Areas

Areas of low contrast may contain subtle shading details that should be preserved by visually lossless compression. The instrument cluster and navigation images shown in Figure 12 and Figure 13 have these background shading areas highlighted by green bounding boxes. Experts carefully evaluated these areas using both the flicker and non-flicker test protocols up to 100 pixels-per-degree to simulate a driver's viewing experience. It should be noted that the final automotive application is more forgiving than the test protocol used in this study to test these types of areas because the vehicle is in motion and the driver's attention is focused on driving.

3.3.3.2 Detailed Text and Graphics in High-Contrast Areas

Areas of high-contrast text and graphics contain sharp details that must be preserved by visually lossless compression. VDC-M compression is optimized to preserve this type of information. The instrument cluster and navigation images shown in Figure 12 and Figure 13 highlight these example areas with green bounding boxes for extra attention during the flicker and non-flicker visual quality evaluation.

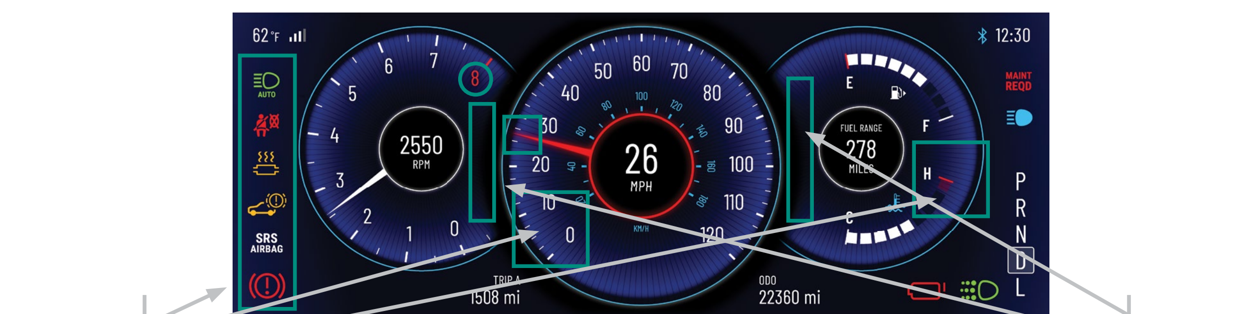


Figure 12 Key test protocol focus area—instrument cluster

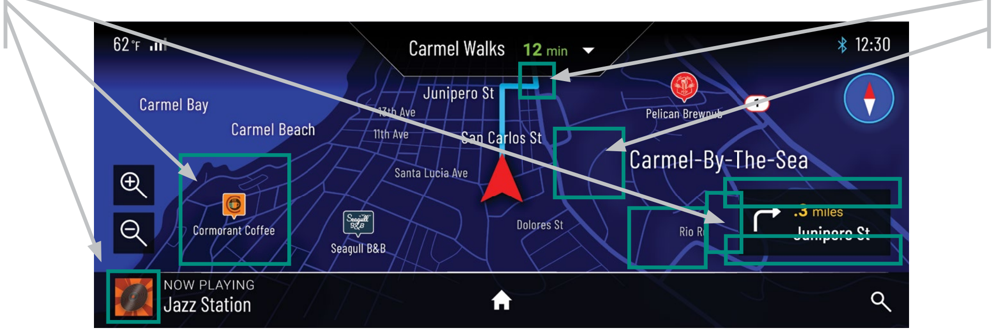


Figure 13 Key test protocol focus areas—navigation

3.4 Phase 4—Analyze Results and Generate Report

The test protocols from Phase 3 were run over many iterations using multiple expert observers and the test results recorded. As noted earlier, the MIPI DWG trials relaxed the viewing distance and time constraints to maximize the detection of compression artifacts. Each expert observer used a customized test configuration, but all distances and display resolutions were calibrated to ensure a minimum 100 pixel per degree visual experience in line with the study requirements as shown in Figure 14. There was no restriction placed on the minimum observer distance, and all images were evaluated up to 10 cm from the display.

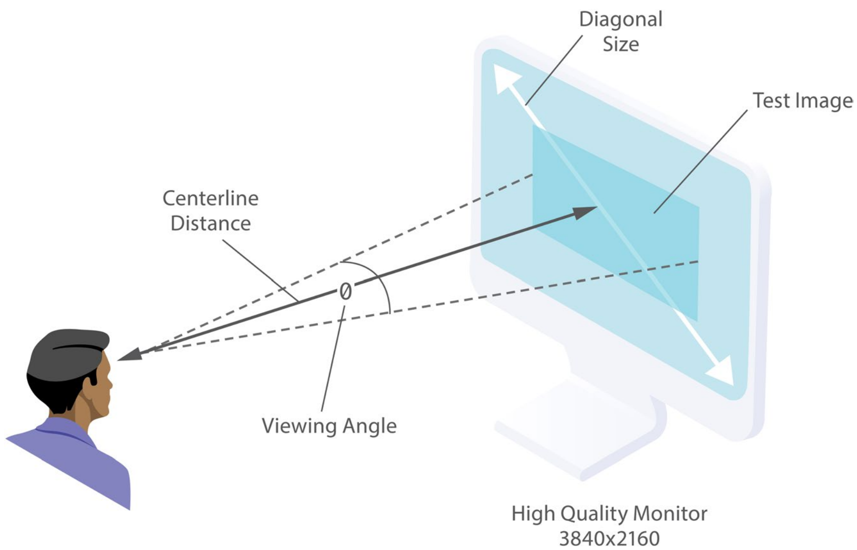


Figure 14 Observer orientation to the test image

In a full ISO standard subjective study, results would be collected from each observer, and the final statistical graph of the type shown in Figure 15 would be generated following the specified ISO standard test result format:

1. The Y-axis shows the average percentage of trials in which the reference image was selected. Special "catch" trial images would be used with obvious visual artifacts to ensure that observers were paying attention, and any observer who didn't properly categorize these images would be excluded from the study. This prevents a result at 0% where observers are not paying attention to the study. The total observations are displayed on the Y-axis using the I-bar, triangle and square symbols as explained in the diagram.

2. The X-axis contains the result for each individual image trial. The position of the observer results within the Y-axis determines whether that image is visually lossless, lossy or at the threshold.

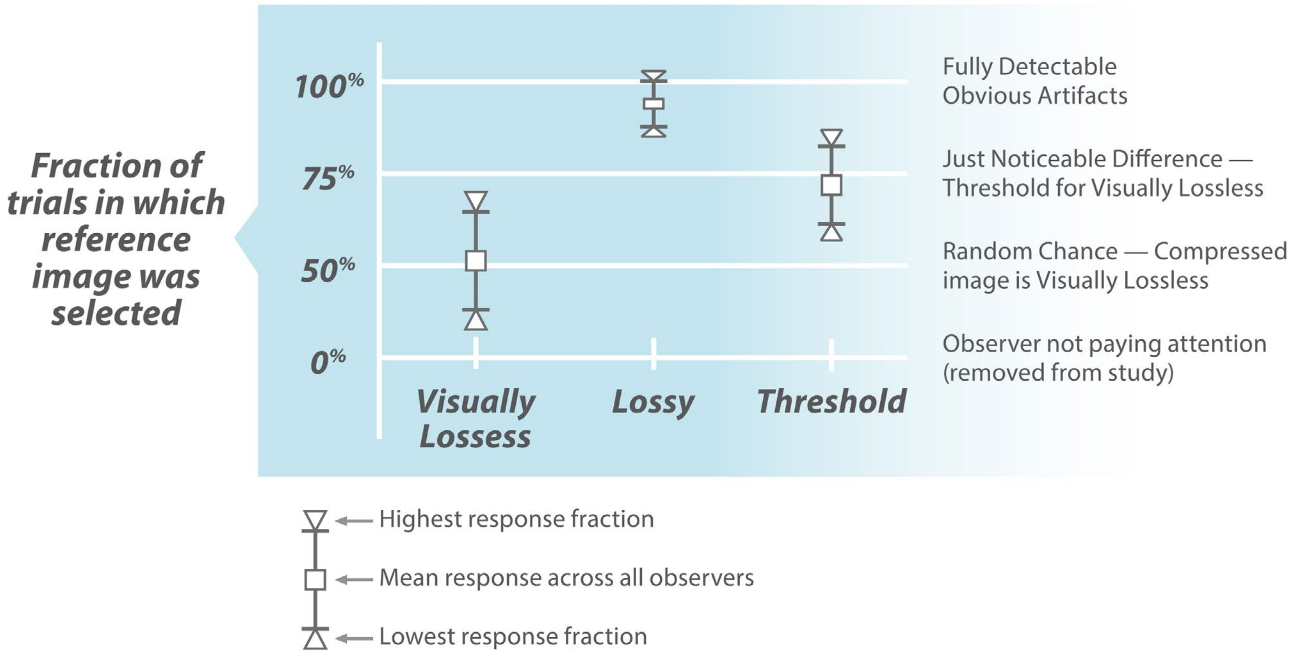


Figure 15 Example statistical reporting graph (ISO/IEC 29170-2 standard)

4. Test Results

MIPI DWG expert viewers evaluated all images using flicker and non-flicker comparison techniques, except for the rearview camera display images. The rearview camera display images were evaluated using only the non-flicker comparison technique because of the random noise in the images.

The results were obtained from seven expert viewers—a "pass" indicates that the pass criteria was met for every iteration of the test protocol by all seven viewers.

The overall test result using this test protocol was a "pass," indicating that all the images compressed using the VDC-M codec were visually lossless.

4.1 Non-flicker Side-by-Side Study Results

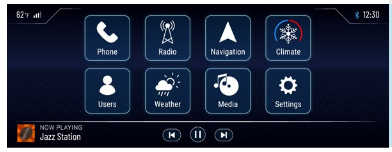
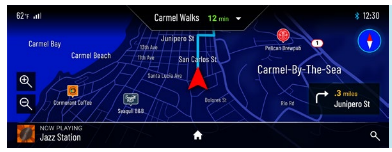
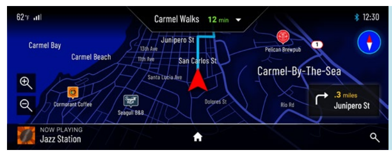
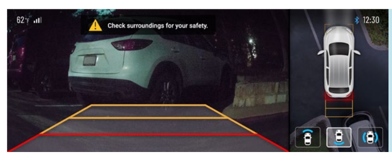
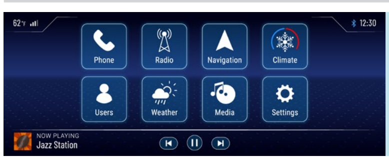
	Non-Flicker Test Pass or Fail			Non-Flicker Test Pass or Fail	
	*Daytime instrument cluster with telltale icons*	PASS		*Nighttime entertainment controls*	PASS
	*Daytime instrument cluster with no telltale Icons*	PASS		*Daytime navigation map*	PASS
	*Daytime instrument cluster with white center ring*	PASS		*Nighttime navigation map*	PASS
	*Nighttime instrument cluster with telltale icons*	PASS		*Daytime rearview camera*	PASS
	*Nighttime instrument cluster with no telltale icons*	PASS		*Nighttime rearview camera*	PASS
	*Nighttime instrument cluster with white center ring*	PASS		*Telltale icons*	PASS
	*Daytime entertainment controls*	PASS			

Figure 16 Non-flicker side-by-side study results

4.2 Flicker Interleaved Study Results

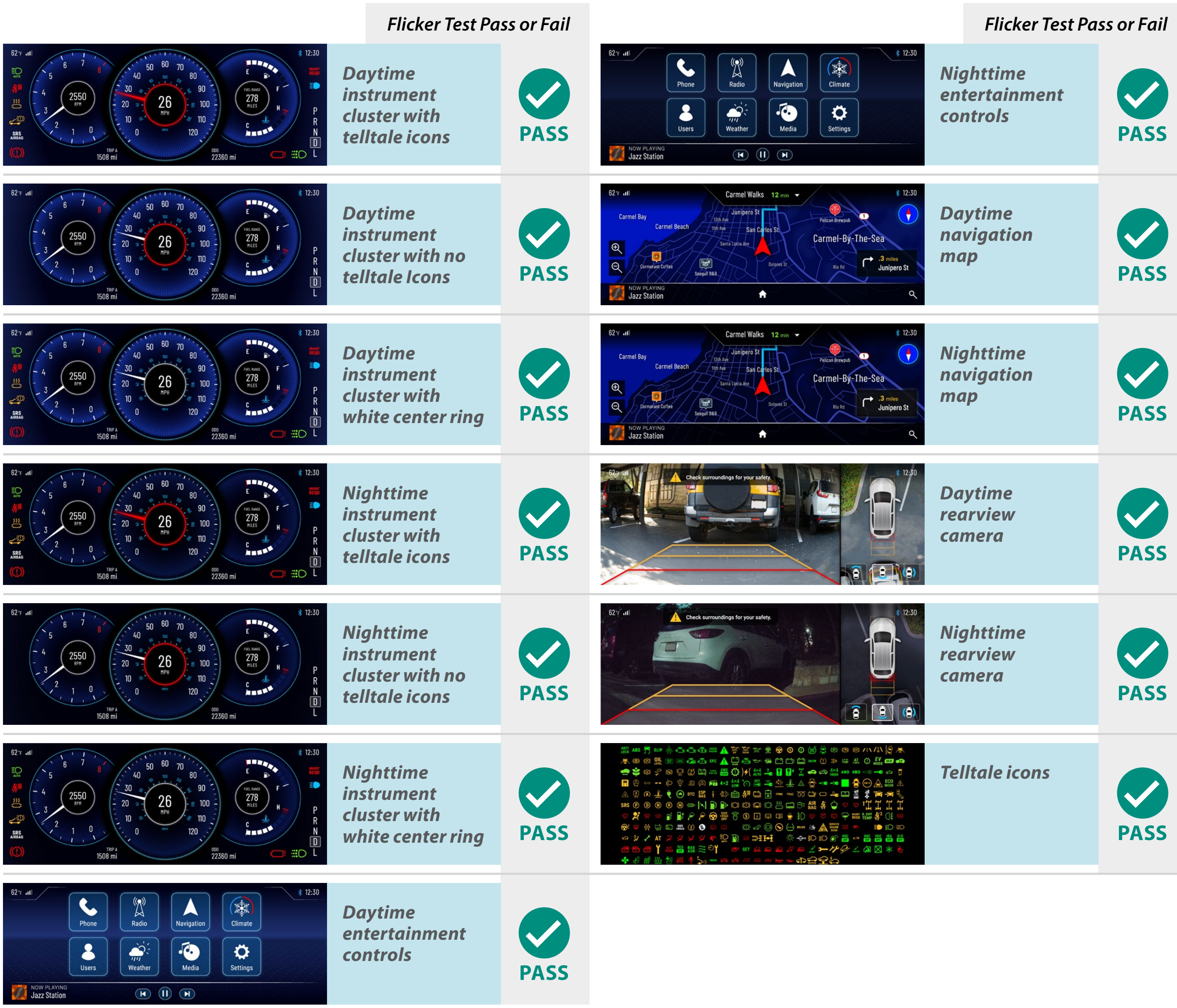


Figure 17 Flicker interleaved study results

5. Conclusion

The automotive industry will continue to evolve to meet the demands for connectivity, automation, sharing and electrification, and system designers will be required to incorporate additional, larger and higher-resolution in-vehicle displays.

MIPI Alliance has integrated the VDC-M visually lossless compression standard into the MIPI DSI-2 display protocol, which can help automotive designers to meet this demand for greater total vehicle display bandwidth. VDC-M achieves a maximum compression ratio of 6:1, reducing a 24-bit uncompressed source RGB pixel to 4 bits per pixel when compressed with minimum impact on latency.

The image compression study documented in this paper was undertaken to evaluate the visually lossless properties of VDC-M for automotive use cases. The study achieved this goal by:

- Creating a set of customized automotive-specific test images to accurately represent the in-cabin display content for next-generation vehicles
- Using these images to evaluate the VDC-M visually lossless compression algorithm using a focused test protocol guided by the principles laid out in the ISO/IEC 29170-2 standard

The test results concluded that all the customized automotive images compressed using the VDC-M compression standard met the objective of being visually lossless, demonstrating that MIPI DSI-2 offers a solution to the growing bandwidth challenges in next-generation vehicles.

This paper may be used by automotive system architects as an example to develop their own VDC-M codec quality evaluations using their own specific test material.

Annex A. Recommended Sources of Further Information

Perspectives on the definition of visually lossless quality for mobile and large format displays. Robert S. Allison, Kjell Brunnström, Damon M. Chandler, Hannah R. Colett, Philip J. Corriveau, Scott Daly, James Goel, Juliana Y. Long, Laurie M. Wilcox, Yusizwan M. Yaacob, Shun-nan Yang, Yi Zhang. **https://doi.org/10.1117/1.JEI.27.5.053035**

75-2: Invited paper: Large scale subjective evaluation of display stream compression. InSID Symposium Digest of Technical Papers 2017 May (Vol. 48, No. 1, pp. 1101-1104). Allison RS, Wilcox LM, Wang W, Hoffman DM, Hou Y, Goel J, Deas L, Stolitzka D.

85-1: Visually Lossless Compression of High Dynamic Range Images: A Large-Scale Evaluation. In SID Symposium Digest of Technical Papers 2018 May (Vol. 49, No. 1, pp. 1151-1154). Sudhama A, Cutone MD, Hou Y, Goel J, Stolitzka D, Jacobson N, Allison RS, Wilcox LM. 85-1.

3-4: Stereoscopic Image Quality Assessment. InSID Symposium Digest of Technical Papers 2019 Jun (Vol. 50, No. 1, pp. 13-16). Au D, Mohona SS, Cutone MD, Hou Y, Goel J, Jacobson N, Allison RS, Wilcox LM.

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About mipi alliance

Founded in 2003, MIPI Alliance is a collaborative global organization serving industries that develop mobile devices and other types of mobile-influenced connected devices. It initially focused on specification development for camera, display and modem connectivity but since then has introduced more than 50 specifications for a range of other essential needs, including those for connecting application processors to modems, audio, storage, sensors, antennas, antenna tuners, power amplifiers, filters, switches, batteries and other elements. These standardized specifications have helped to facilitate interoperability among component suppliers, simplify device designs (hence, reducing cost) and optimize performance and power, while allowing manufacturers to focus on product differentiation and reduce their time to market.

Today all major chip and component vendors use MIPI Alliance specifications, with every smartphone on the market using at least one MIPI specification. MIPI specifications can also be found in an ever-broadening array of devices, going well beyond mobile handsets into wearables, medical devices, drones, industrial equipment and vehicles. The organization itself has more than 330 member companies that reflect the breadth of the mobile and mobile-influenced ecosystem, including device manufacturers, semiconductor companies, silicon IP provider companies, test equipment companies, camera and display module providers, sensor providers, automotive original equipment manufacturers (OEMs) and Tier 1 suppliers, as well as organizations that are developing Internet of Things (IoT) solutions.

Organizations interested in joining MIPI Alliance can visit the "Join MIPI" section on the **MIPI website** to learn more.

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