A Real-Time Visualization EMT Technique for 2D Eye Diagram Measurements with 99% Height Accuracy

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Abstract
This paper proposes a Visualization EMT (Eye Margin Test) feature that enables the display of Eye Margin Test results on a screen. A method for implementing this visualization is suggested: where the EMT results are transmitted to the TCON for rendering. In addition, Eye Height Level calibration is performed to ensure the accuracy of the Eye Margin Test results. The IC with the implemented functionality is fabricated using a 45nm process.

Author Keywords
Intra-panel Interface; Eye Diagram; CDR; RDAC Voltage Calibration; Eye Margin Tester; Visualization; Display Driver IC

1. Introduction
As the data transmission speed through the intra-panel interface increases, the information provided by the eye diagram measured through module testing is becoming increasingly significant. However, in the current testing environment, it is only possible to measure the eye diagram at the input of package. Figure 1(a) shows the location of the input of package. With the current approach, it is impossible to directly observe the eye diagram within the RX. Furthermore, since the location of the input of package does not correspond to the actual RX input pad, the test results do not accurately represent the waveforms at the RX input. This discrepancy makes it difficult to identify the impact of COG or COF on the module test.

There is a method to measure the internal RX eye diagram which is Eye Open Monitor (EOM). However, EOM requires complex circuitry to implement its functionality, which makes it unsuitable for DDI, which chip size is a critical factor [1]–[3]. Another approach to test and visualize the internal RX eye diagram is the visual bit error rate test (VBERT), which allows observation of bit error rates for specific patterns [4]. However, it does not enable precise measurement of the eye diagram's width and height.

While conventional Eye Measurement Technology (EMT) can provide eye diagram information, but it requires post-processing of the data, making real-time visual observation impossible. To address these limitations, this paper proposes a novel Visualization EMT technology, which extends the capabilities of conventional EMT by enabling real-time visualization of the EMT results. With this technology, it becomes possible to observe the internal RX eye diagram in real time directly through the operating display panel, without the need for additional testing equipment. Figure 1(b) shows the measurement location of the eye diagram when using the Visualization EMT.

This proposed approach not only allows optimization of TCON performance but also enhances RX performance, thereby improving power efficiency. Moreover, it simultaneously outputs the eye mask alongside the eye diagram, enabling margin analysis against the eye mask.

For the Visualization EMT results to replace existing test results, accuracy is critical. However, conventional EMT performs calibration only for width, resulting in insufficient accuracy for eye height measurements. To address this issue, we apply range calibration to the resistor analog-to-digital converter used for eye height measurement, thereby improving the accuracy of EMT results.

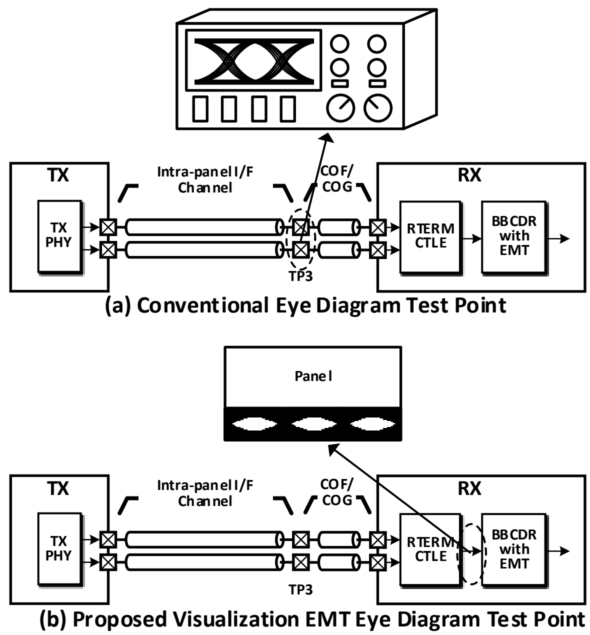

Figure 1. Test environment of intra panel interface

2. The Visualization EMT
One method to implement the Visualization EMT is to enable the DDI to independently output EMT results. This approach seems simpler and more efficient, as the DDI processes the data autonomously without requiring additional data communication. However, implementing this functionality requires sufficient memory to store all EMT results and eye mask information, as well as additional logic circuits within the DDI. Given the constraints on chip size in DDI, this method is less efficient for practical implementation.

To overcome these limitations, this paper proposes an alternative approach where EMT results are transmitted to the TCON, and the TCON performs image processing. This implementation requires a backward channel. Instead of connecting each chip in a point-to-point, a shared backward channel is utilized. As shown in Figure 2, all DDIs are connected to the TCON via a single shared channel called shared backward channel (SBC) [5]. Through this channel, the EMT results are transmitted to the TCON in a time division method for each chip.

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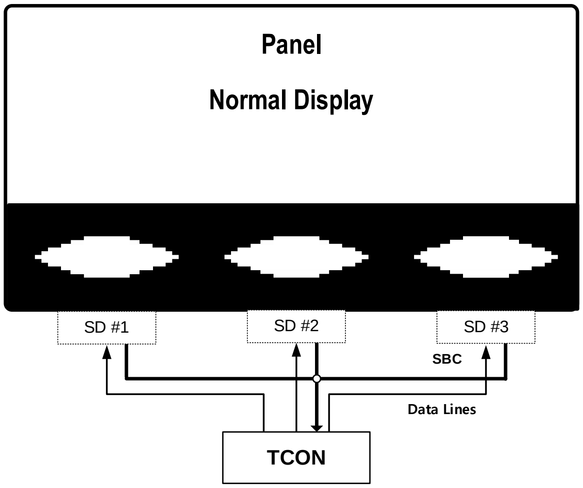

Figure 2. Configuration of the Visualization EMT

When the Visualization EMT operation begins, width calibration is performed first. Subsequently, HCODE for measuring eye width and VCODE for measuring eye height are swept automatically at specific time intervals. And EMT results from each chip are then transmitted to the TCON sequentially in a time-division method. Once the EMT results from all points are collected at the TCON, the TCON replaces specific locations in the image data with eye diagram and eye mask image data derived from the EMT results. These modified image data are then sent back to the DDI, which automatically displays the eye diagram and eye mask for each chip on the display panel, as illustrated in Figure 2. The sequence of the Visualization EMT is depicted in Figure 3. This method not only simplifies the hardware requirements within the DDI but also enables real-time visualization of EMT results directly on the display panel at 1-second intervals

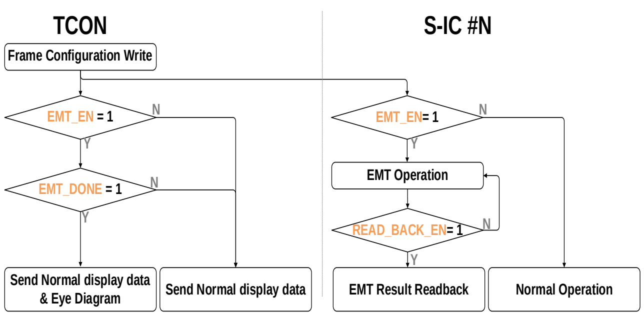

Figure 3. Sequence Diagram of the Visualization EMT

3. Improvement of Eye Margin Test Performance

In conventional EMT, calibration for eye height isn't performed, resulting in reduced accuracy. This inaccuracy becomes significant due to mainly process variation. As shown in Figure 4(a), the original RDAC circuit demonstrates that variations in resistance cause both VHIGH and VLOW to change simultaneously. Consequently, the RDAC range deviates from the desired value, altering the difference between DAC steps. If this step difference increases beyond the desired value, the EMT underestimates the actual eye height. Conversely, if the step difference decreases below the desired value, the EMT overestimates the actual eye height.

To address these issues, RDAC range calibration is introduced. The proposed circuit is illustrated in Figure 4(b). During calibration, the VHIGH and VLOW values of the RDAC are measured through pads, and the current DAC which is added for calibration is adjusted to ensure their difference matches the desired value. Figure 5 shows the monte carlo simulation results of RDAC range before and after calibration. By incorporating this functionality, the accuracy of eye height level measurements is improved by 9% from 90% to 99%.

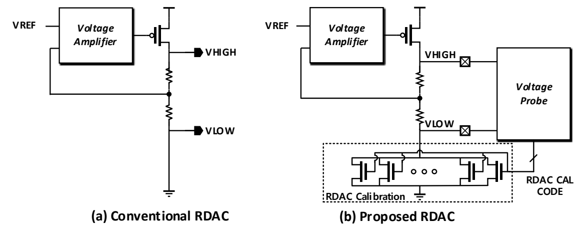

Figure 4. Schematic of (a) conventional RDAC and (b) Proposed RDAC

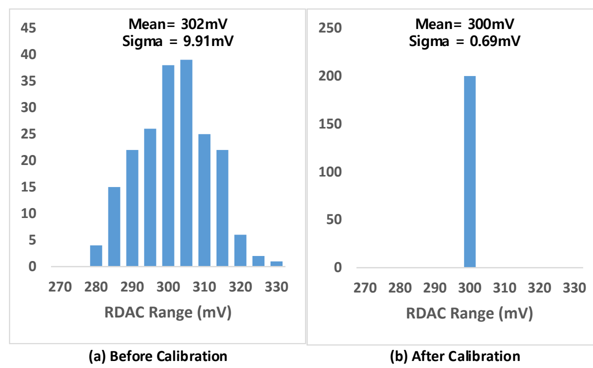

Figure 5. Monte Carlo simulation results of RDAC range (a) before and (b) after calibration

4. Experiment

The test chip was fabricated using the 45nm HVCMOS process, with an operating voltage of 1.8V for the LV transistors and 8V for the HV transistors. The test was performed at a 6Gbps operating speed. To verify the operation of the Visualization EMT, the EMT results were displayed and compared on the screen, as shown in Figure 6. And the eye width and height measured results for each EQ are shown in Figure 7.

Figure 6. Panel Demo of the Visualization EMT

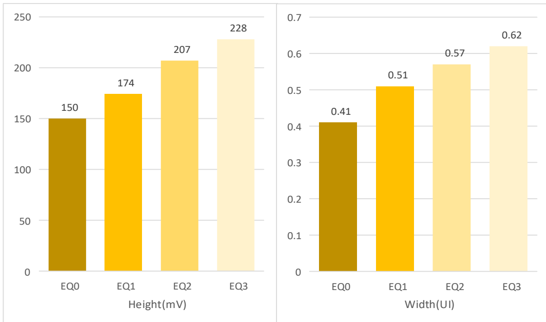

Figure 7. Results of the Visualization EMT for EQ code

To verify the accuracy of the EMT performance, the results of the EMT are compared with the jitter tolerance test results obtained using J-BERT equipment. As shown in Figure 8, the deviations in eye width are within 5% at both points 1 and 2.

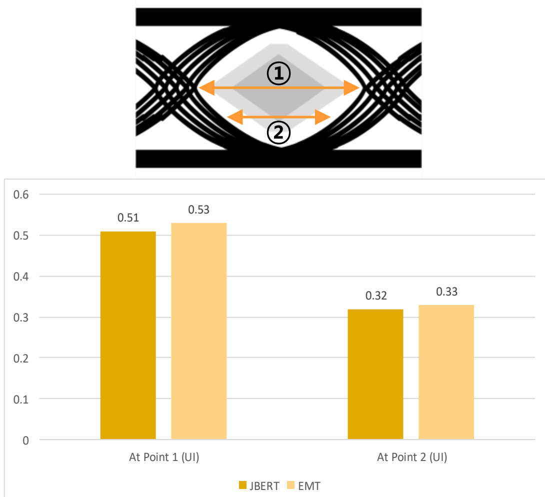

Figure 8. Comparison of JBERT and EMT Measurement Results

5. Conclusion

In this paper, a method for a novel EMT feature, which displays the results of the Eye Margin Test on the display in real time, is proposed. Additionally, by applying EMT RDAC calibration, this study enhances the accuracy of the Eye Diagram height derived from EMT, achieving a margin of error within 1%.

6. References

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