Aftermarket Detection of Line Defects in Display Panels Using New TDDI with Testing Mode

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Abstract

In this paper, we propose a set of tests for detecting line defects in display panels by integrating Touch with Display Driver (TDDI) technology and Gate-driver-on-array (GOA) circuits. Currently, TDDI is widely adopted in displays with integrated touch functionality, serving both display driving and touch sensing purposes. The primary advantage of our approach is the utilization of the TDDI module's self-diagnostic capabilities, which allow for effective defect detection even after the displays have been installed in high-value products such as automobiles.

Author Keywords

Defect Detection, Gate-driver-on-array, Touch with Display Driver, Touch Sensor

1. Introduction

With the increasing popularity of touch panel technology, TDDI has been widely applied in various display devices, including mobile phones, tablets, laptops, and automotive displays. As display resolution continues to increase, the pixel count grows exponentially, significantly raising the probability of manufacturing defects among the vast number of pixels. To ensure product quality, panel manufacturers perform multiple defect inspections before shipment, including automated optical inspection, electrical testing, and visual inspection.

However, these inspections must be completed prior to shipment and require substantial investment in costly equipment, which increases both production costs and facility expenses. Post-shipment defect detection is currently limited to manual visual inspection, with accuracy constrained by human vision. To meet safety and regulatory requirements in the automotive industry, the sector seeks to enhance panel display monitoring functions through ICs, enabling the system to automatically report display abnormalities, thereby allowing for potential real-time correction.

The key feature of TDDI technology is its integration of the display driver IC and touch IC into a single chip【1】, which not only reduces component costs but also improves system stability and reliability. During manufacturing and testing, conducting various inspections of the touch panel is essential to ensure its quality and performance. Among these, open and short circuit detection for scan lines is especially critical, as such anomalies could impact the overall operation of the display system.

This paper proposes a set of tests for the line defects detection in display panels driven by TDDI with Gate-driver-on-array (GOA) technology by taking advantages of the analogue-front-end (AFE) feature in TDDI. By analyzing the test signals of read by the AFE channels in TDDI, the abnormalities can be promptly detected, even after the displays are installed in valuable aftermarket products.

2. Aimed Display Panels

A key application of the proposed method is testing automotive display panels, where reliable defect detection is essential for safety and performance. These medium-to-small displays often integrate GOA circuits with TDDI technology, enabling compact designs with enhanced functionality.

GOA circuits are typically made from a-Si, IGZO, or LTPS, each offering unique benefits. a-Si and IGZO TFTs commonly use bottom-gate structures for simplicity and scalability, while LTPS TFTs use top-gate structures for higher mobility and resolution, albeit with more complex processes. They are all considered in this study.

Automotive displays demand durability, temperature stability, and low power consumption. By combining TDDI and GOA, the proposed method ensures precise defect detection, meeting the high-quality standards required for automotive applications. This approach is adaptable to various panel technologies and can be extended to other industries needing robust inspection of advanced displays.

3. Proposed New TDDI

The display circuit architecture based on TDDI technology integrates display driving and touch sensing functions into the same system, achieving a more streamlined hardware structure while enhancing functionality. This integration technology enables the display panel to provide high-quality visuals while also supporting touch functionality, further reducing the number of components and system complexity, and enabling a thinner design.

The core of the system to be tested consists of several key components, as shown in Fig. 1, including the display area, row scanning driver modules (GOA_L and GOA_R), the receivers (RX), the switch block, and the clock drive output (CGOUT). The display area is the main section of the panel, responsible for outputting display content and detecting touch operations. The GOA_L and GOA_R modules are responsible for generating row scanning signals and controlling the switching of the panel's row electrodes, thereby driving the display of each pixel and ensuring the accurate synchronization of the display image. These signals are driven by TFTs to output the display content.

In this design, the RX signal channels serve several purposes. When a touch operation occurs, the RX receives signals from the touch panel and converts them into touch events. When no touch operation is active, the RX transmits the VCOM signal, which is critical for stabilizing the common voltage of the display panel, helping prevent flickering and ensuring stable display performance. The switch block dynamically switches between touch signals and VCOM signals as needed, effectively preventing interference between the display and touch functionalities and ensuring the efficient operation of the system. The CGOUT module provides clock signals to coordinate the synchronization between the display

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and touch functions, ensuring temporal consistency throughout the system.

This design not only improves the synergy between display and touch functions but also effectively reduces the number of components and the thickness of the panel, lowering system costs while maintaining high stability and reliability. Furthermore, the data buses driven by analogue buffers in display mode can be switched to AFE for testing in the test mode. This design supports high-resolution displays (1920 source signals and 960 RX channels) and enables effective coordination and interference suppression between touch and display functions.

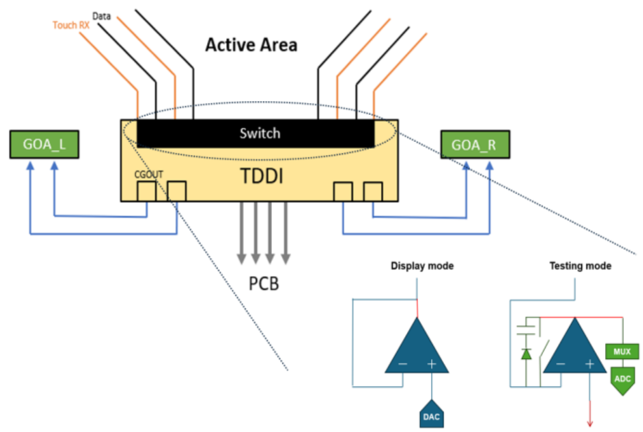

Figure 1. TDDI technology integrates display driving and touch sensing functions into a single system.

4. Proposed Testing Methods

Table 1 lists the sizes of TFTs in GOA circuits described in [3-5] we used for simulation. The respective SPICE models and device parameters are properly set to fit the typical TFT characteristics. The output waveforms are fed to the pixel array made with relative TFT technologies.

Table 1. Sizes of TFTs in GOA circuits used in our simulation

	a-Si TFT [3]	LTPS TFT [4]	IGZO TFT [5]
M1 W/L	2000um/5.5um	10um/4um	20um/9um
M2 W/L	8000um/5.5um	4um/4um	10um/9um
M3 W/L	800um/5.5um	4um/4um	400um/9um
M4 W/L	800um/5.5um	4um/4um	10um/9um
M5 W/L	1200um/5.5um	5um/4um	10um/9um
M6 W/L	1200um/5.5um	200um/4um	
M7 W/L	800um/5.5um	50um/4um	
M8 W/L	800um/5.5um	200um/4um	
M9 W/L	1200um/5.5um	50um/4um	
C1	220pF	10pF	0.5pF
C2	220pF	10pF	

The RC signal delays of scan and data lines were simulated using series circuits designed to reflect actual RC delays and operating voltages. For instance, in the simulation for the LTPS panel, the input signal's high voltage was set to 10V and the low voltage to -7V. The output signal exhibited significant RC delays, resulting in a rise time of 1.83 μs and a fall time of 2.61 μs. For the a-Si and IGZO panel simulations, the input signal's high voltage was set to 17V and the low voltage to -10V with rise time of 2.49 μs and a fall time of 1.8 μs. In the data line simulation, the LTPS panel demonstrated a rise time of 3.59 μs and a fall time of 3.32 μs, while the a-Si and IGZO panels exhibited a rise time of 2.62 μs and a fall time of 1.8 μs. These results highlight the impact of material properties and design parameters on RC delay performance across different panel technologies.

The proposed testing method involves analyzing the driving and reading waveforms of the pixel array at its four corners, with RC ladder structures serving as buses in between. Based on typical bus width and interlayer thickness, the crossover capacitance between scan and data buses was estimated to be approximately 8.594 fF. When the scan voltage transitions from low to high or high to low, feedthrough current signals are induced on the data line, which is virtually grounded by the AFE (Analog Front-End). These transient current signals can be monitored and captured by the AFE, which acts as an integrator to convert the current into voltage. Simulation results show that the integrated transient current charge is approximately 80 fC. With an integration capacitance of 800 fF, the corresponding output voltage is about 0.1V, which is easily detectable in amplitude. This approach enables the good identification of line defects by analyzing the output voltage waveform.

For the open-circuit line defects, figures 2(a) to 2(c) illustrate the pixel array circuits and their corresponding GOA driving waveforms, as well as the waveforms of the transient current to be integrated from left and right data buses, respectively. The black dashed lines in the figure show the pixel array circuit and its driving waveforms for the panel in test mode, with no line defects. These waveforms highlight the disruption caused by open-circuit faults, which can be effectively identified through the AFE current integrator's readout signals.

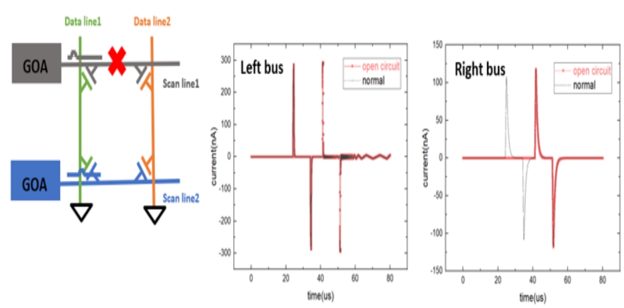

Figure 2(a). Method for detecting scan line open-circuit faults

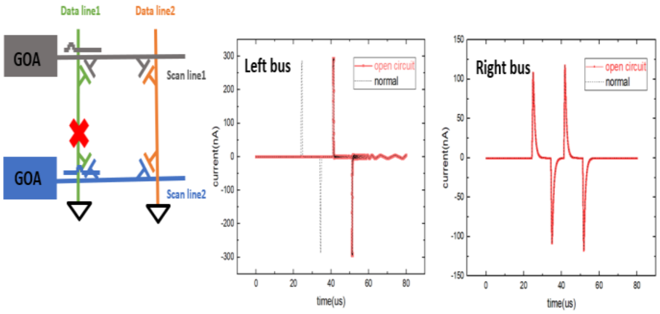

Figure 2(b). Method for detecting data line open-circuit faults

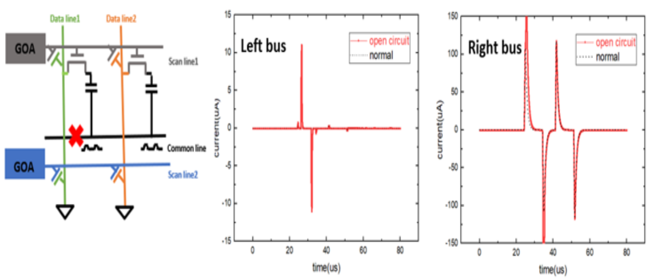

Figure 2(c). Method for detecting common line open-circuit faults

Similarly, Figures 3(a) to 3(e) present the pixel array circuits and their corresponding driving and reading waveforms for short-circuit line defects. Short-circuit faults induce distinctive patterns in the output waveforms, allowing for reliable defect detection through the same readout methodology.

To further validate the proposed approach, we conducted additional simulations across various pixel array configurations and defect scenarios, including mixed fault conditions involving both open-circuit and short-circuit defects. The results consistently demonstrated that the AFE-integrated readout method effectively distinguishes between defect types and locations within the array. This robustness underscores the method's potential for automated, high-precision defect detection in advanced display panels.

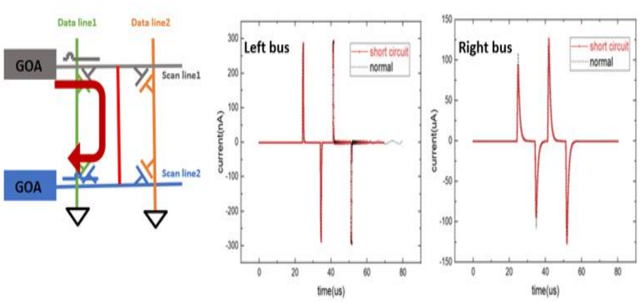

Figure 3(a). Method for detecting scan line short-circuit faults

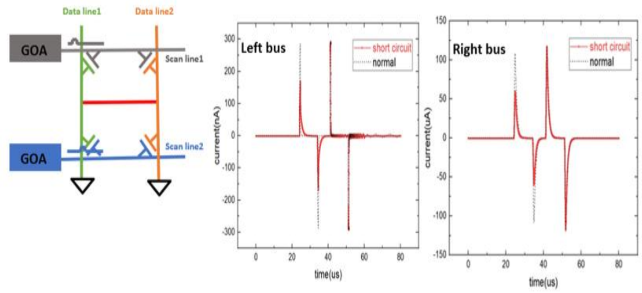

Figure 3(b). Method for detecting data line short-circuit faults

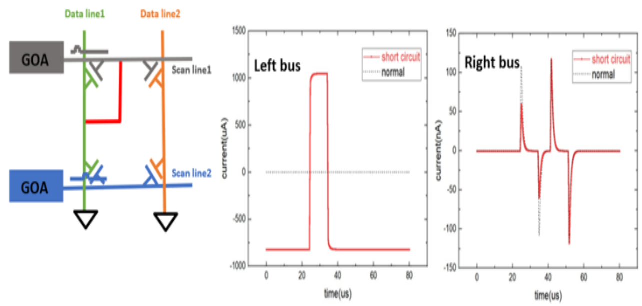

Figure 3(c). Method for detecting scan line and data line short-circuit faults

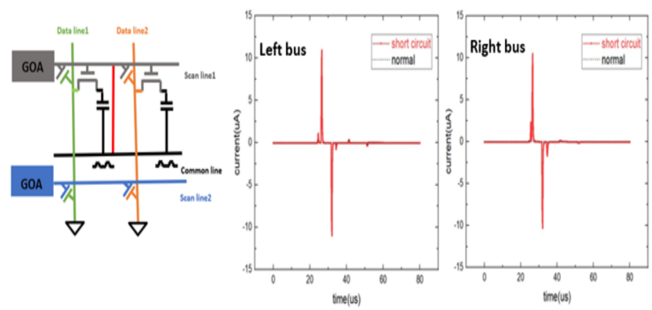

Figure 3(d). Method for detecting scan line and common line short-circuit faults

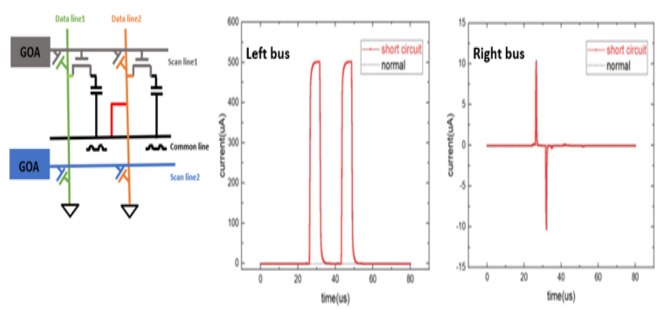

Figure 3(e). Method for detecting data line and common line short-circuit faults

5. Conclusion

An advanced line defect detection method for display panels driven by TDDI technology and GOA circuits has been proposed. This method takes full advantage of the TDDI module's self-diagnostic capabilities, improving the precision and efficiency of detecting display anomalies. By integrating this approach, manufacturers can detect defects more accurately, reducing manual inspection and improving production quality.

Additionally, the feasibility of using the AFE within touch sensors for electrical testing was explored, demonstrating the potential for implementing effective panel defect detection through TDDI technology. This system can detect faults by monitoring transient currents, making it particularly useful for automotive displays, where self-testing during startup enhances reliability.

This method not only streamlines defect detection but also reduces system complexity and costs, making it a scalable solution for automotive displays and other industries requiring high-performance panel diagnostics.

6. References

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