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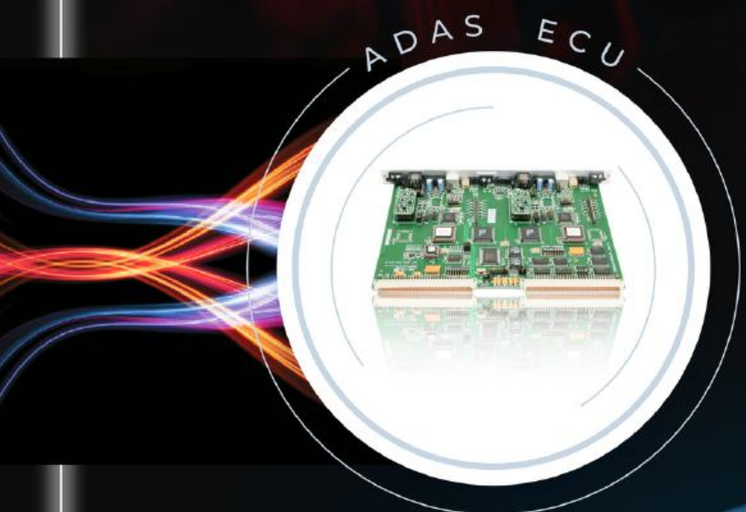
98% of CEOs Agree: SIGNAL INTEGRITY is Key for the Automotive Electronics - Here's Why?



Foreword

Signal integrity

You're cruising down the highway,
Your car effortlessly adjusts its speed to match the flow of traffic, keeping a safe distance from the car ahead without you lifting a finger.
As you approach a busy intersection, your vehicle automatically slows down, scanning for potential hazards.

The car even parks itself while you relax and check your messages.
So, how the automotive industry is evolving?
The world of **ADAS** is constantly evolving, with new technologies and features emerging at a rapid pace.
From making your daily commute easier to setting the stage for fully autonomous driving,
ADAS is transforming how we think about transportation.

From customizable ambient lighting to memory seats that adjust based on your preferences,
Imagine a vehicle that tailors every detail to suit you perfectly.
Ever wondered how ADAS features in your car work so smoothly?
It all comes down to how well signals are sent and received.
That's the **signal integrity** comes into play.

Let's get start with the insights!

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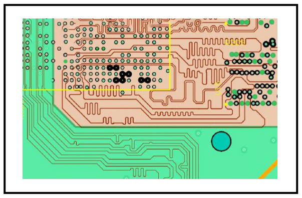
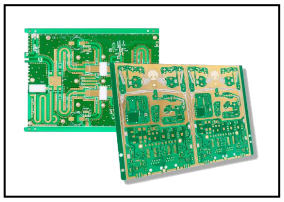
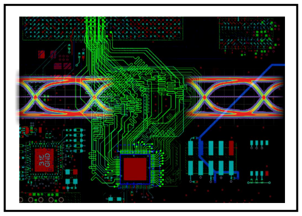
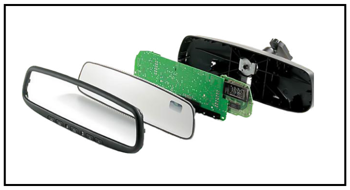
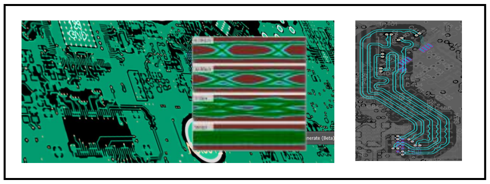
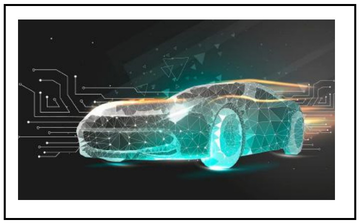












1.Electronics Transformation in Automotive Systems

In the early days, transportation was dominated by horse-drawn carriages.

While simple and effective, these carriages had their limitations, particularly in terms of speed, capacity, and reliability.

The need for more efficient and faster modes of transport led to the birth of the automobile.
In the late **19th century**, the invention of the internal combustion engine revolutionized transportation. Early automobiles, like the Ford Model T, were mechanical marvels but lacked any form of electronic control.

These vehicles were basic, prone to frequent mechanical issues and lack of reliability.
By the **mid-20th century,** basic electronics began to appear in automobiles
The electric starter replaced hand cranking, making cars easier to use. Simple electronics like battery ignition systems and radios enhanced the driving experience, with limited functionality and continued mechanical failures.

The **1970s and 1980s** brought electronic fuel injection and ECUs, improving fuel efficiency, reducing emissions, and enhancing engine performance. ECUs provided precise control over engine parameters, surpassing mechanical systems, in the struggle of balancing performance with environmental regulations and fuel efficiency.

To address the environmental concerns and enhance vehicle performance,

Advances in microprocessor technology led to ADAS in the **1990s and 2000s,** including anti-lock braking systems (ABS), electronic stability control (ESC), and adaptive cruise control (ACC).
These systems significantly improved safety and driving comfort.

But there is the challenge of increasing complexity and multiple system integration.

Digital technology brought infotainment systems, integrating navigation, entertainment, and communication functions. Touchscreens, voice recognition, and connectivity features like
Bluetooth and Wi-Fi became standard.

The **21st century** shifted towards sustainability with EVs. Companies like Tesla developed high-performance electric cars with advanced battery management systems and regenerative braking. These vehicles relied on sophisticated electronics to manage power distribution and efficiency.

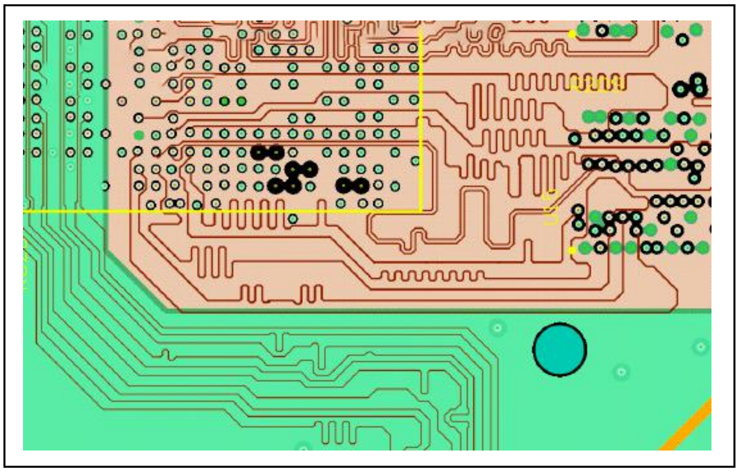
Today, the development of autonomous vehicles represents the pinnacle of automotive evolution. These vehicles use sensors, cameras, and algorithms to navigate with minimal human intervention. Full-scale ADAS includes lane-keeping assist, automatic emergency braking, and traffic sign recognition.

Present Day: Advanced ADAS and Autonomous Vehicles

Currently, advanced ADAS systems and the push towards fully autonomous vehicles showcase the latest in automotive technology.

High-speed, low-latency communication between electronic systems ensures safety and
efficiency, making signal integrity crucial for real-time operation.

2.High Speed Electronics



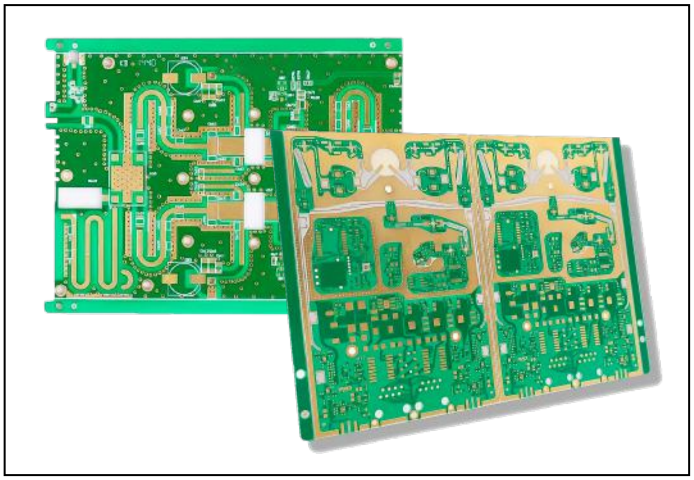
In recent years, electronic devices have become **more advanced, with new features, faster speeds, and smaller sizes.**

Older devices used simpler signals with lower frequencies, larger voltage swings, and were less affected by noise, making them easier to design.

Today, designers need to pay close attention to issues like controlling impedance, terminating lines, reducing crosstalk, and maintaining signal integrity right from the start.

Modern high-frequency PCBs use many small, integrated components.

Require **multilayer designs** to minimize signal interference and parasitic effects while improving grounding.



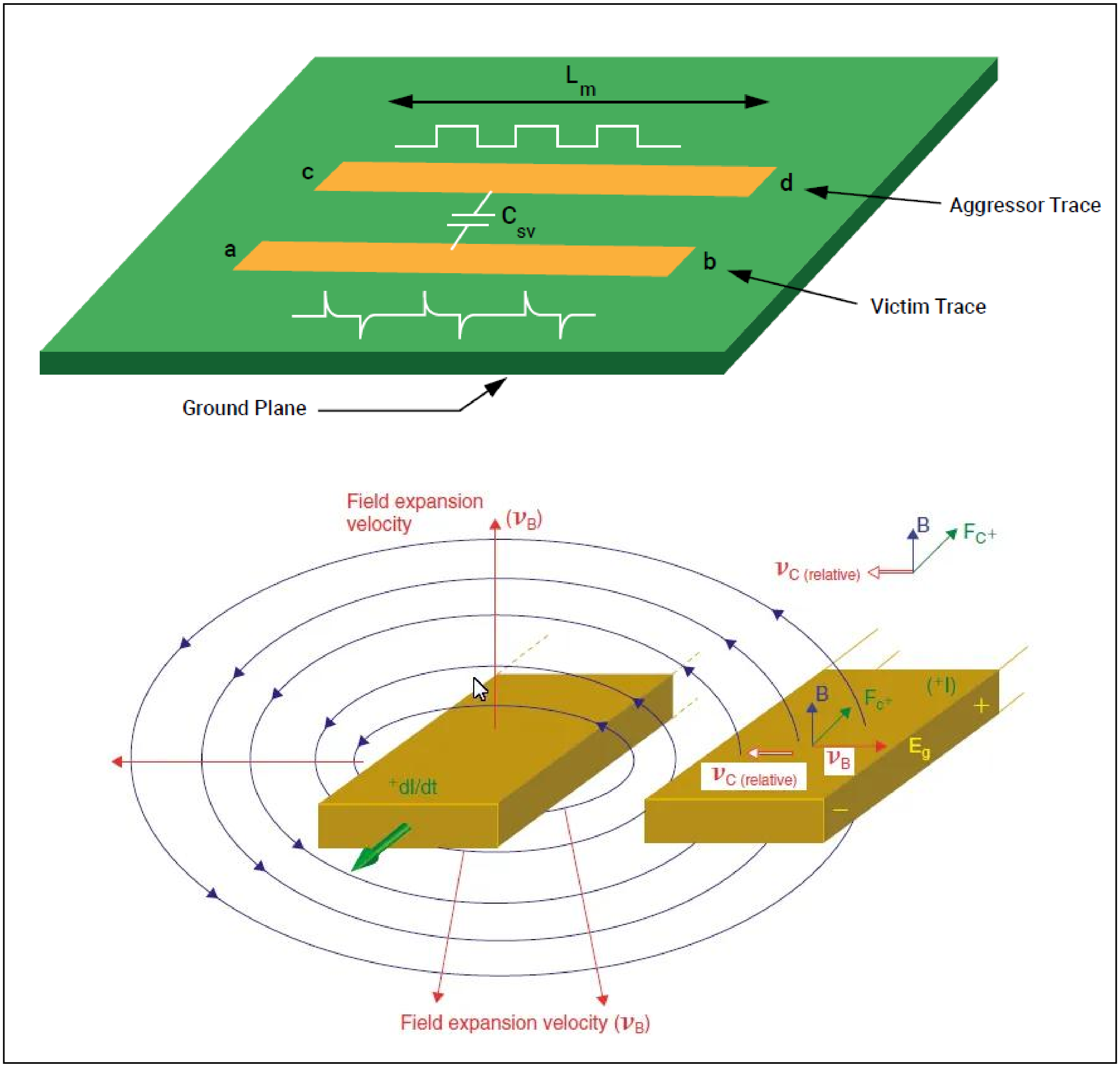
However, a PCB designed for **high-frequency signals** needs more precise and detailed design to ensure the signals remain clear and reliable.

That's why companies that use high-density and high-frequency components (like FPGAs, GPUs, SoCs, and RF modules) often design their own boards.
Generally, a PCB is considered **"High-Speed"** when signals switch at megahertz or gigahertz frequencies.

For these high-speed designs, additional rules are necessary:

Control Noise:
Manage noise from the power distribution network, especially if using switching power supplies.

Reduce Crosstalk:



Minimize interference between nearby traces. High frequencies can cause capacitive crosstalk where induced currents have a capacitive impedance.

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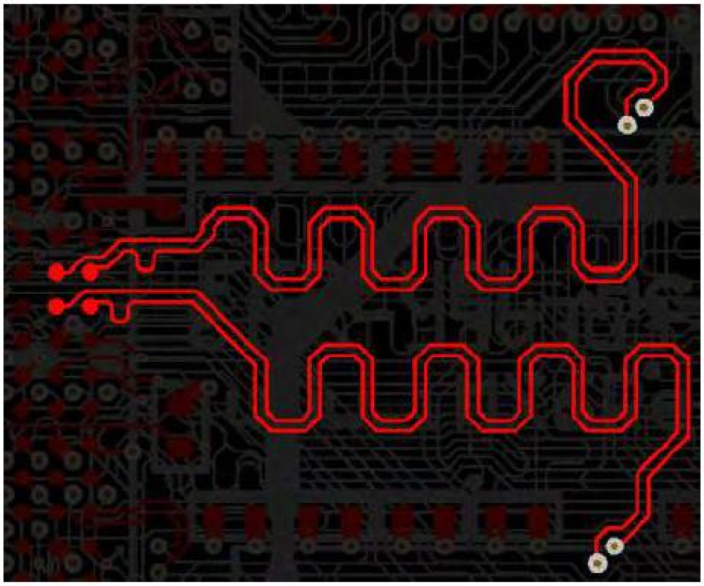
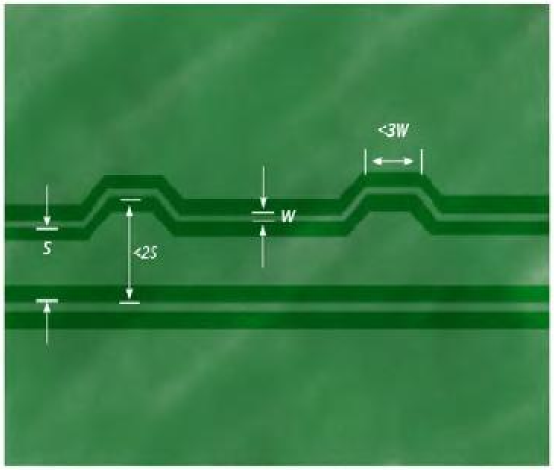
Manage Ground Bounce:
Address ground bounce issues, which affect signal integrity. Proper PCB stack up and separation of logic and analog areas can help.

Impedance Matching:

Ensure proper impedance matching to avoid signal reflection.



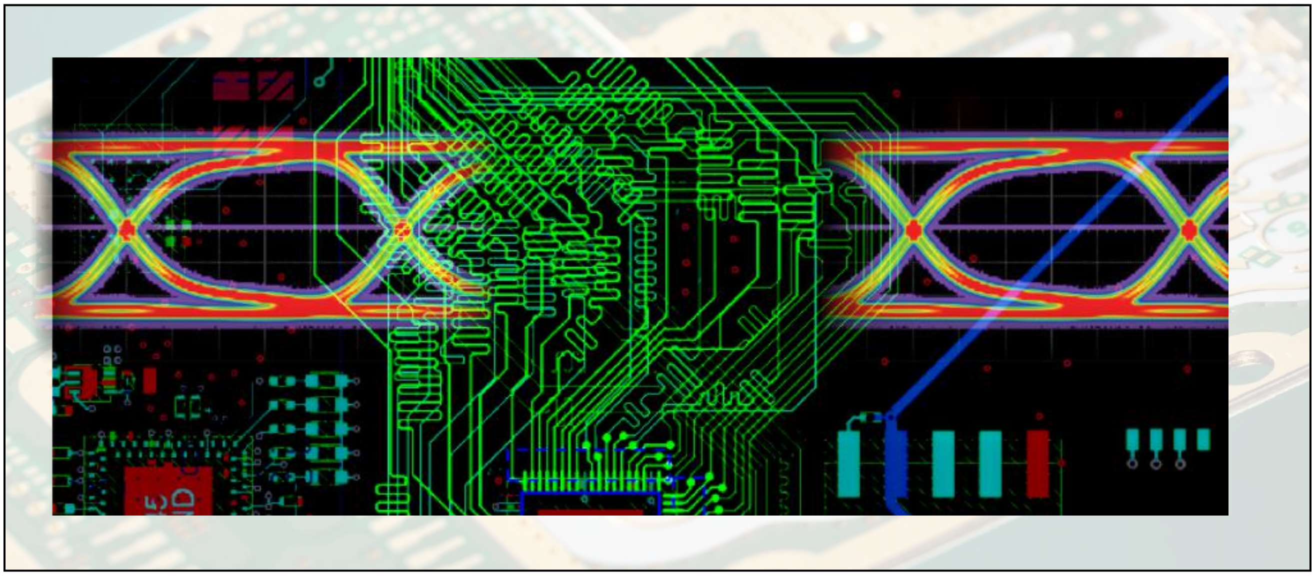


Eliminate Ringing:
Prevent transient ringing, which can happen if traces are too narrow.

Signal Termination:
Correctly terminate each signal line to prevent reflections and improve signal quality.

EMI Immunity:
Ensure the PCB is resistant to both conducted and radiated electromagnetic interference (EMI).

3. How Signal Integrity is influencing High Speed Electronics?



Signal integrity plays a critical role in high-speed electronics, influencing the overall performance and reliability of electronic systems.

Here's a breakdown of how signal integrity impacts high-speed electronics.

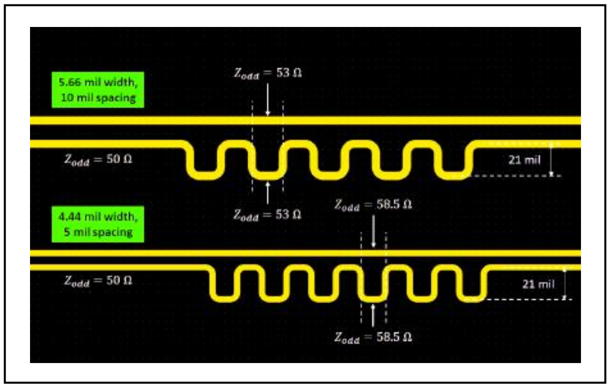
Signal Distortion: High-speed signals are more susceptible to distortion from impedance mismatches, reflections, and crosstalk. This distortion can cause errors in data transmission and reception.

Error Rates: Poor signal integrity leads to higher error rates, which can compromise data integrity and reduce system reliability.

Timing and Synchronization: Accurate timing is essential for high-speed systems. Signal degradation can cause timing mismatches, leading to synchronization issues and reduced performance.

Data Throughput: High-speed signals require precise transmission to achieve high data rates. Signal integrity problems can limit data throughput and overall system efficiency.

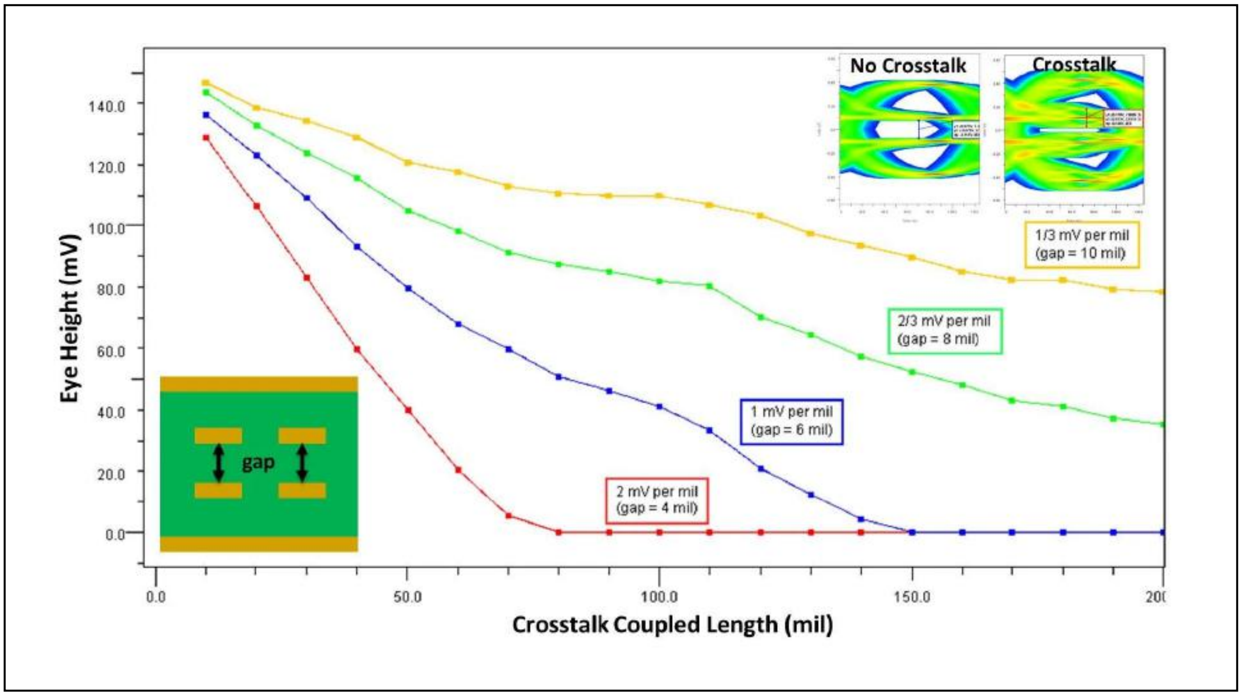
PCB Layout: High-speed designs require careful PCB layout to minimize signal degradation.



This includes managing trace lengths, routing, and ensuring proper impedance control.

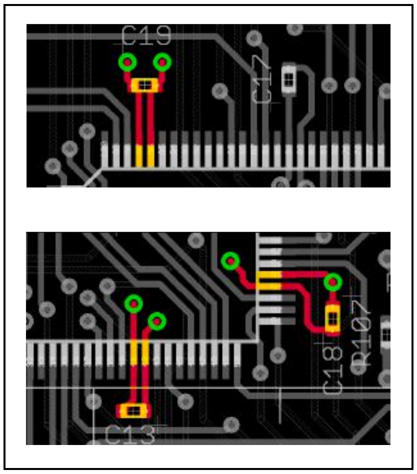
Advanced Techniques: Techniques such as differential signalling, controlled impedance traces, and precise grounding are necessary to maintain signal integrity in high-speed designs.

Crosstalk: High-speed signals can induce unwanted noise in nearby traces, causing crosstalk. This can interfere with other signals and degrade system performance.



Shielding and Grounding: Effective shielding and grounding are essential to protect high-speed signals from external EMI and to reduce noise generated by the signals themselves.

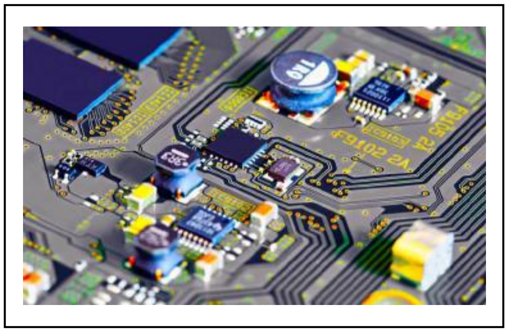
Decoupling: Stable power supply is crucial for high-speed electronics.



Decoupling capacitors and robust power management help maintain signal integrity by reducing noise and voltage fluctuations.

Power Distribution: Proper design of power and ground planes is essential to ensure consistent power delivery and minimize signal interference.

High-Speed Components:



Choosing components with appropriate electrical characteristics and placing them correctly on the PCB are vital for maintaining signal integrity.

Minimized Parasitics: Proper placement and routing help reduce parasitic inductances and capacitances that can affect signal quality.
Signal integrity is fundamental to high-speed electronics, affecting accuracy, performance, and design complexity.

Ensuring good signal integrity involves managing **distortion, crosstalk, power integrity, and electromagnetic interference,** and requires careful design, component selection, and rigorous testing.

As electronics continue to advance, maintaining signal integrity becomes increasingly important to meet the demands of high-speed, high-performance systems.

“Let’s delve into the deeper insights to understand the critical importance of signal integrity in automotive systems"

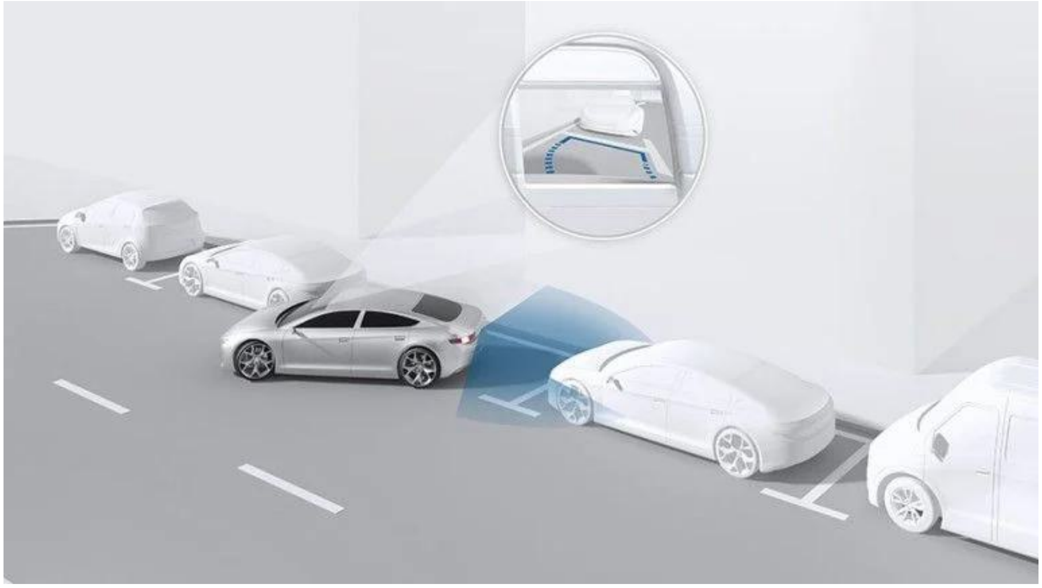
4. High-Speed Digital Electronics in ADAS-Camera Monitoring System (CMS)

Mirror ECU-Camera Monitoring System

A **camera monitoring system** in vehicles enhances safety, security, and situational awareness.

It assists with **parking, blind spot detection, and collision avoidance** by providing real-time video monitoring and displaying of the vehicle's surroundings in the center mirror.

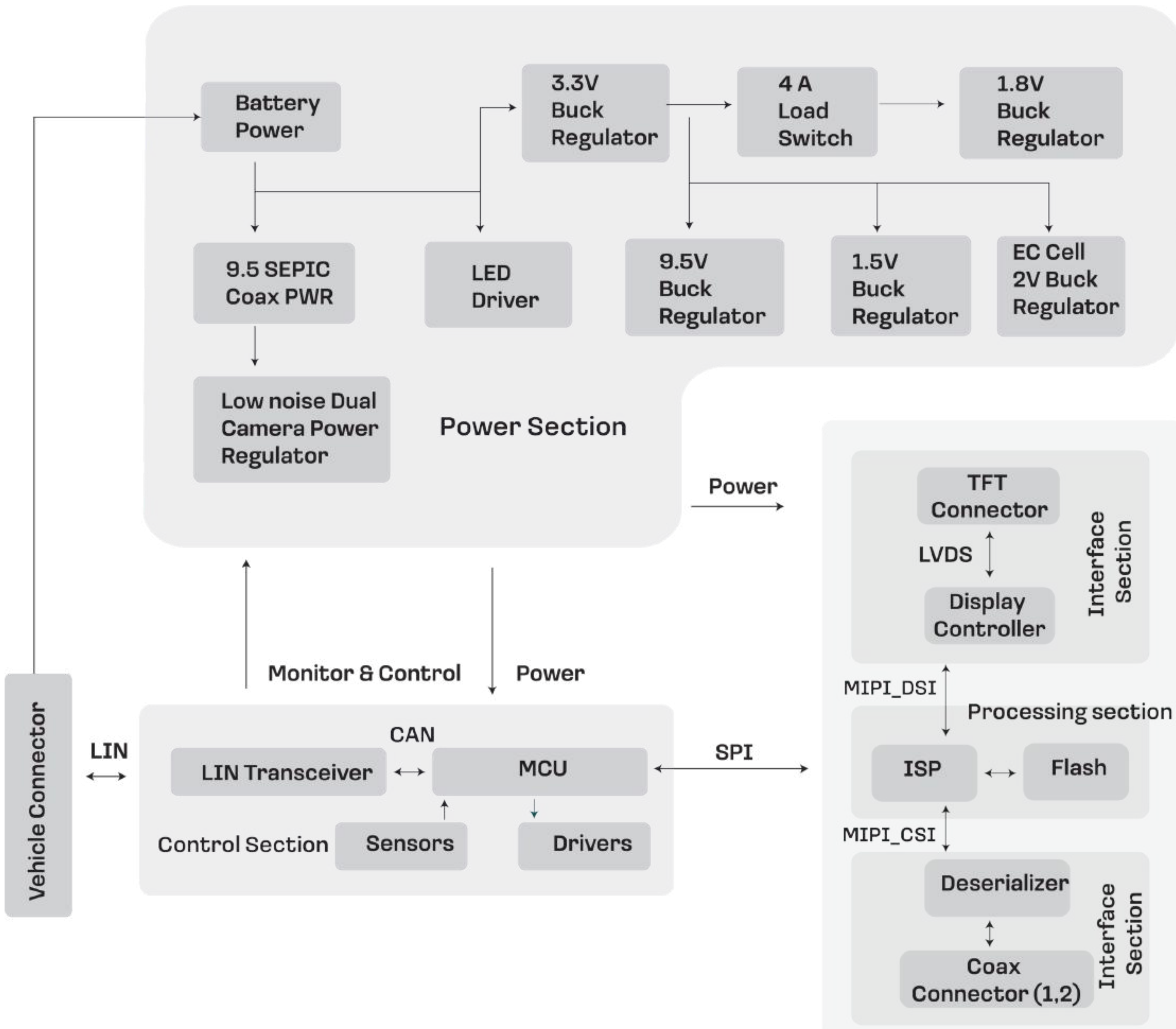
This technology captures footage of both sides of the vehicle, offering a comprehensive view to improve the overall driving experience.



a) Block Diagram

Power Section:
The power section of the Mirror PCB ensures that **all components receive stable and adequate power** (12V, 9.5V, 8.6V, 3.3V, 2.0V, 1.8V, 1.5V, & 0.9V) for optimal operation of control, processing and interface sections.

Monitor & Control Section:
The control section is a critical part of the Mirror PCB, responsible for **managing and coordinating the functions** of various components and ensuring smooth operation by using sensors and drivers such as Power Monitoring and Control, Communication Interfaces, Timing and Synchronization.



Processing Section:

This section enhances the image quality by performing tasks such as

- Noise reduction
- Color correction
- Image scaling

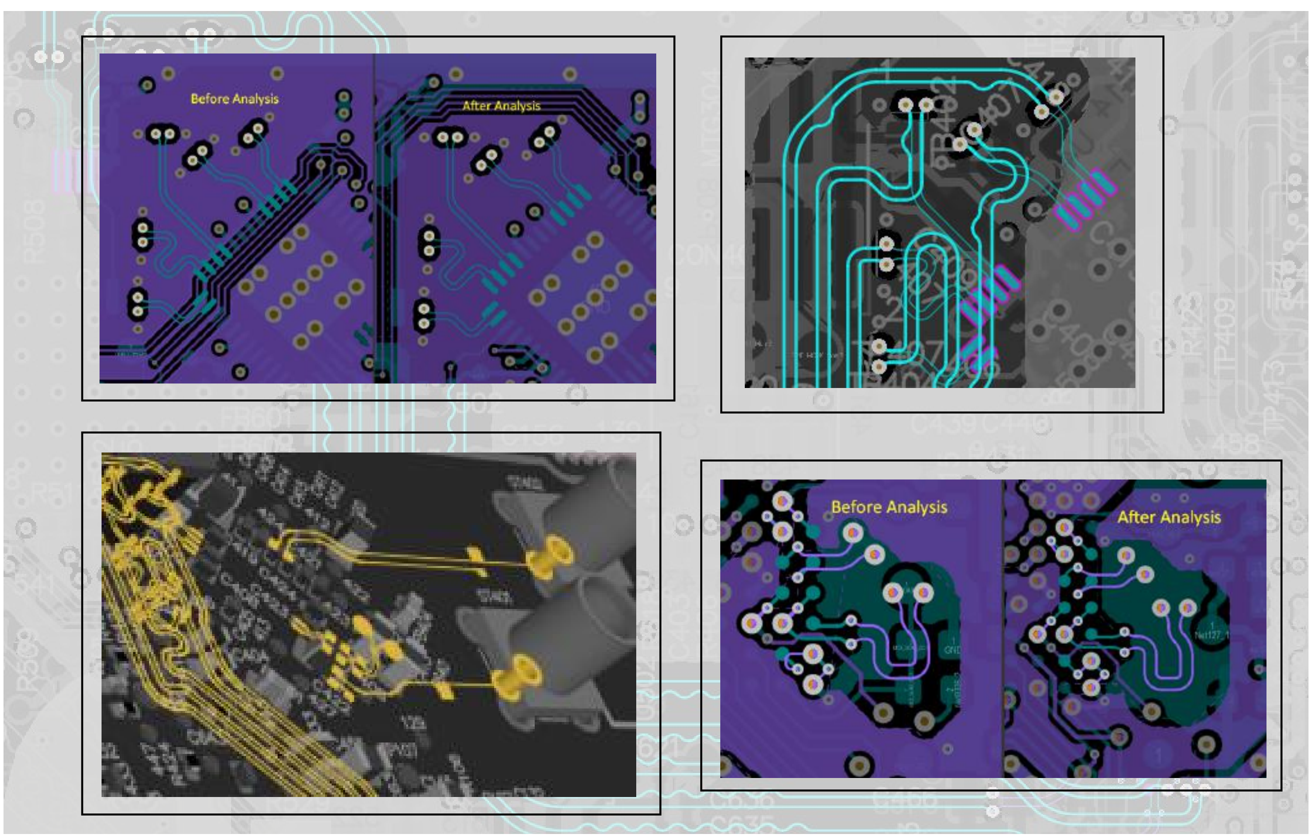
which ensures that the images are clear and detailed for display and further processing.

Interface Section:

The interface section handles communication between the imager IC to display.

The **LVDS Interface** ensures high-speed data transfer with minimal interference,

MIPI delivers high speed data transmission within the board, and Coaxial Connectors transmit high-speed image data from cameras to the Deserializer with minimal loss.

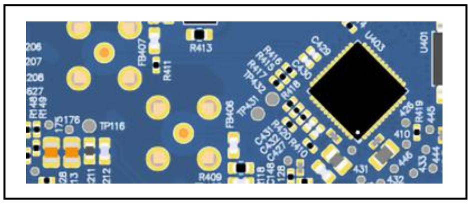


b)High-Speed Digital Electronics section

The following are the High-Speed Digital Electronics section of the Mirror ECU,

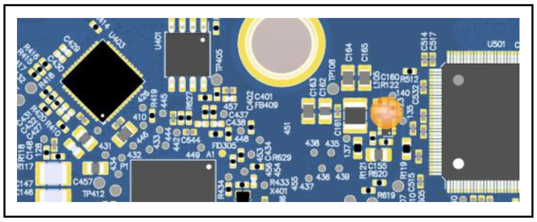
Coax connector to Deseralizer

In the mirror ECU system, the **coax connector** ensures that the high-frequency image signal from the camera is transmitted to the **Deseralizer** at **4.16 Gbps** with minimal loss and interference.
This is crucial for maintaining the data speed and quality of the image signal.
It transmits power and send/receive data at 4.16 Gbps, providing a robust and secure connection.



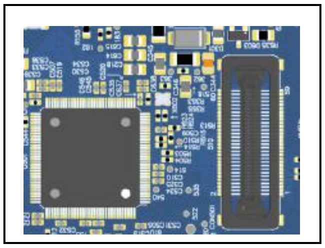
Deseralizer to Display Controller

The parallel data from the **Deseralizer** is send using the **MIPI interface (MIPI-CSI)** to the Image Signal Processor (ISP) at a speed of **1.6 Gbps.**
Then the processed data is transmitted from Image signal processor to **Display controller** through the **MIPI Interface (MIPI-DSI)** at **655 Mbps.**



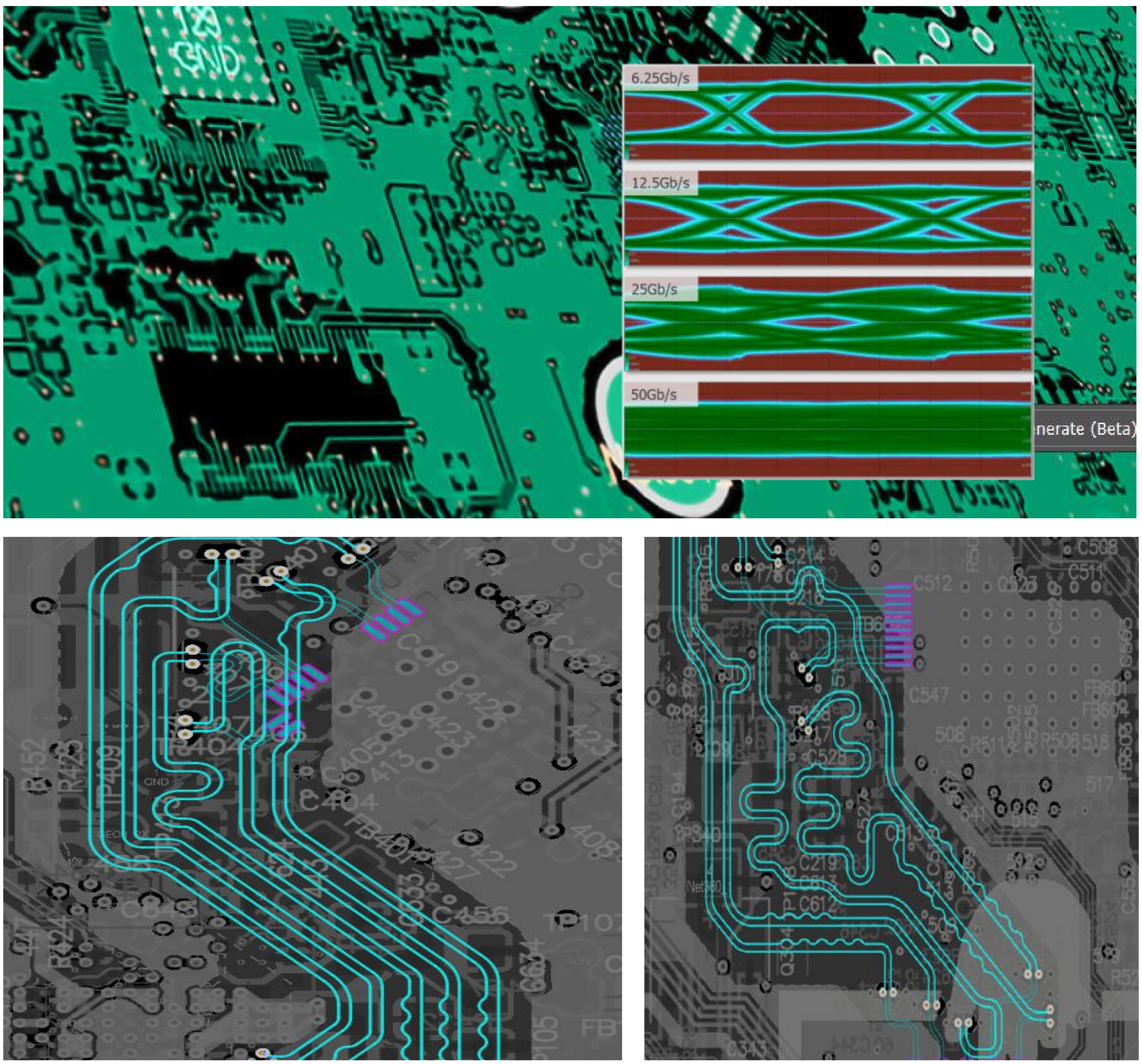
Display Controller to TFT Connector

After deserialization, the parallel data is transmitted using the LVDS protocol to the TFT Display through **TFT Connector** at **655 Mbps.**
The LVDS interface ensures high-speed and reliable data transmission, crucial for real-time image processing in automotive applications.



5. Signal Integrity Analysis in CMS Project-MIPI Interface

Let's conduct a **signal integrity analysis** for the high-speed section of the MIPI interface,Performing signal integrity analysis for MIPI interfaces is essential to ensure high-speed, accurate, and reliable data transfer, **minimize errors and interference**, and comply with industry standards.



This helps in achieving optimal performance and extending the longevity of the system. Detailed signal characteristics and their specific values serve as reference standards for assessing component behavior based on the project requirements,

Signal Characteristics	Signal Parameters	Signal Integrity Analysis
High-Speed Differential Signalling	1.6 Gbps speed	Ensures differential pairs maintain signal quality and balance, minimizing errors.
Propagation Delay	150ps per inch	Proper signal integrity measures prevent timing issues that could lead to data misalignment
Skew	15ps	Ensuring proper impedance helps maintain signal quality throughout the interface
Impedance Matching	100 ohms	Ensuring proper impedance helps maintain signal quality throughout the interface
Crosstalk	NEXT :<3% of Signal Amplitude FEXT: <2% of Signal Amplitude	Effective routing, shielding, and differential signalling techniques help mitigate these issues
EMI	CISPR 22 Class B standard followed	
Signal Attenuation	1 dB	Maintain signal quality, prevent data errors, and ensure reliable system operation
Overshoot	15% of signal peak-peak voltage Overshoot High Mode:60mv Overshoot Low Mode: 45 mv	Controls overshoot (excessive voltage spike) and undershoot (excessive voltage dip) to prevent signal distortion and ensure reliable data transfer.
Undershoot	Undershoot High Mode:15mv Undershoot Low Mode:15mv	

Initially, analysed the **length matching report** for the MIPI signal.

In MIPI Interface, which involves 4 data differential pairs and 1 clock differential pair, skew (timing differences between signals) can disrupt data synchronization.

Length matching helps to **minimize skew** by making sure all signals are of equal length.

MIPI_CSI					
PCB Net Name	Node Count	Signal Length (mil)	Total Pin/Package Length (mil)	Routed Length (mil)	Difference Within 10 mils
MIPI_3.CSI_CLK0_N (-)	2	1612.01	0.0	1612.86	0.01
MIPI_3.CSI_CLK0_P (+)	2	1612.02	0.0	1612.70	0.00
MIPI_3.CSI_D0_N (-)	2	1610.09	0.0	1611.48	1.93
MIPI_3.CSI_D0_P (+)	2	1610.73	0.0	1611.96	1.29
MIPI_3.CSI_D1_N (-)	2	1610.14	0	1611.12	1.89
MIPI_3.CSI_D1_P (+)	2	1610.09	0.0	1611.02	1.93
MIPI_3.CSI_D2_N (-)	2	1610.09	0.0	1610.86	1.93
MIPI_3.CSI_D2_P (+)	2	1610.91	0.0	1611.78	1.11
MIPI_3.CSI_D3_N (-)	2	1610.62	0.0	1611.57	1.40
MIPI_3.CSI_D3_P (+)	2	1610.19	0.0	1611.04	1.83
	Min	1610.09			
	Average	1610.63			
	Max	1612.02			

GEO_MIPI_OUT					
GEO_MIPI_OUT.STX1_C_N (-)	2	2702.21	0.0	2702.36	0.34
GEO_MIPI_OUT.STX1_C_P (+)	2	2702.55	0.0	2703.53	0.00
GEO_MIPI_OUT.STX1_D0_N (-)	2	2700.75	0.0	2701.10	1.80
GEO_MIPI_OUT.STX1_D0_P (+)	2	2700.85	0.0	2701.11	1.70
GEO_MIPI_OUT.STX1_D1_N (-)	2	2700.21	0	2701.79	2.34
GEO_MIPI_OUT.STX1_D1_P (+)	2	2700.71	0.0	2700.98	1.84
GEO_MIPI_OUT.STX1_D2_N (-)	2	2700.28	0.0	2701.49	2.27
GEO_MIPI_OUT.STX1_D2_P (+)	2	2700.37	0.0	2701.39	2.18
GEO_MIPI_OUT.STX1_D3_N (-)	2	2700.21	0.0	2700.85	2.34
GEO_MIPI_OUT.STX1_D3_P (+)	2	2700.70	0.0	2701.47	1.86
	Min	2700.21			
	Average	2700.82			
	Max	2702.55			

Hence, **CLK and Data** are routed with **same trace length (closely)** approximately 0.0 mil within differential pair and 5.0 mil (here 2.0mil) within high-speed signal group (MIPI).

Then, the setup proceeded with defining the PCB layer stackup and assign the **Components** (Deseralizer, Image Signal Processor, Display controller) **IBIS Model** to the simulation tool.

Target thickness: 1.6mm+/-10%

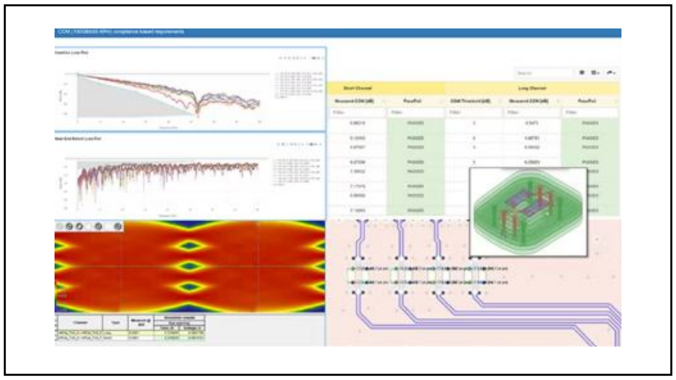
P/N:6 Layer1+4+1

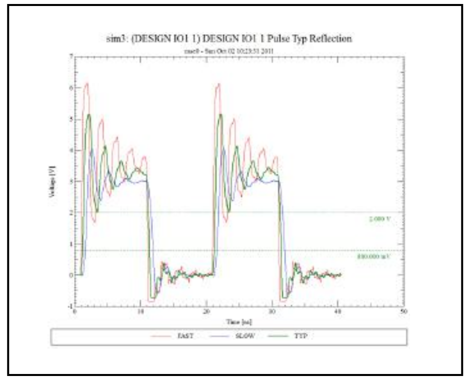
LAYER CONSTRUCTION				Tolerance			Material(NP-175F)
Thickness		mm	mil		mm	mil	
	SM	0.020	0.800	+/-	0.010	0.400	
	L1	0.036	1.400	+/-	0.010	0.400	Base copper(12um)+plating(min18um)
PP		0.076	3.000	+/-	####	0.800	PP: 1080*1
	L2	0.036	1.400	+/-	0.010	0.400	Base copper(12um)+plating(min18um)
PP		0.175	6.900	+/-	####	1.500	PP: 1506*1
	L3	0.036	1.400	+/-	0.010	0.400	
core		0.843	33.200	+/-	####	3.500	Core : 0.91mm(36mil) 1/1oz
	L4	0.036	1.400	+/-	0.010	0.400	
PP		0.175	6.900	+/-	####	1.500	PP: 1506*1
	L5	0.036	1.400	+/-	0.010	0.400	Base copper(12um)+plating(min18um)
PP		0.076	3.000	+/-	####	0.800	PP: 1080*1
	L6	0.036	1.400	+/-	0.010	0.400	Base copper(12um)+plating(min18um)
	SM	0.020	0.800	+/-	0.010	0.400	
Material: FR4 TG170	Total :	1.600	63.000				Note: IPC 6012A class2
	Tolerance :	+ 0.160	6.300				Through hole: min18um
		- 0.160	6.300				Buried hole: min18um
							Laser hole: min10um
Target thickness: 1.6mm+/-10%							

Signal Quality and Eye Diagram Analysis

Our detailed signal integrity analysis of the high-speed section MIPI interface reveals the signal characteristics below,

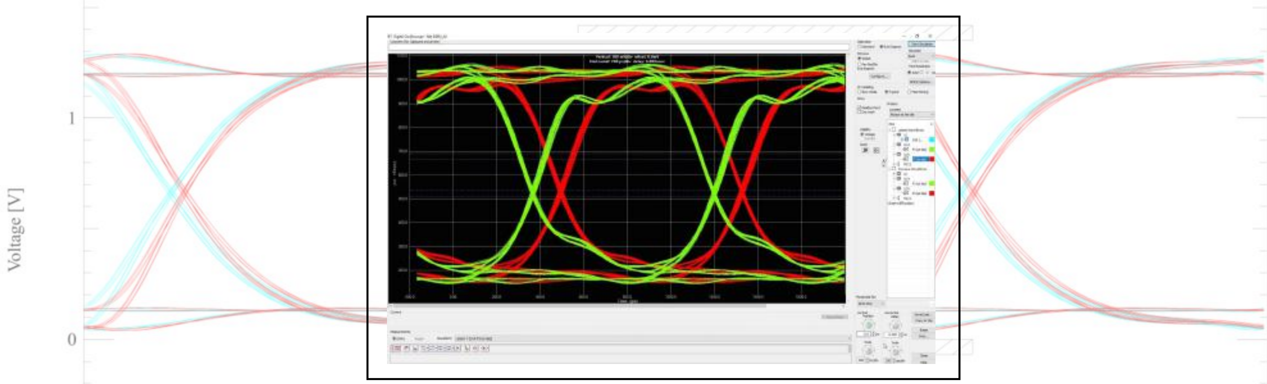
Simulation Tool: Hyperlynx





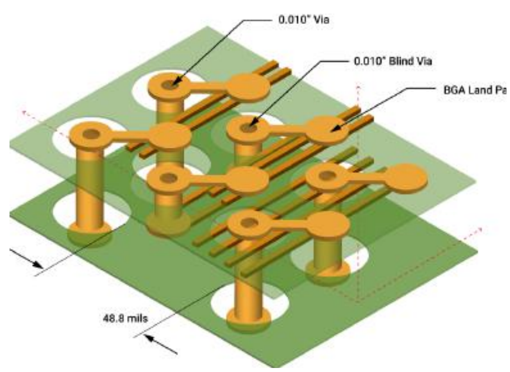
Eye diagram Analysis:

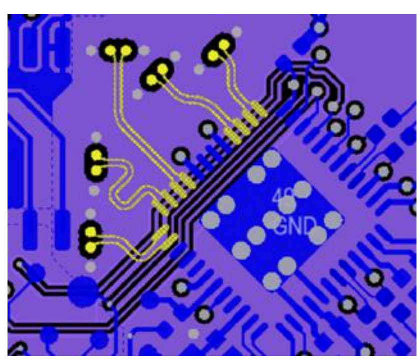
Analysed the circuit with IBIS Model for Component Behavior in High and Low Power mode.



Impedance Mismatch

Layer traces and pads doesn't have the solid GND reference plane of the high speed MIPI-CSI.



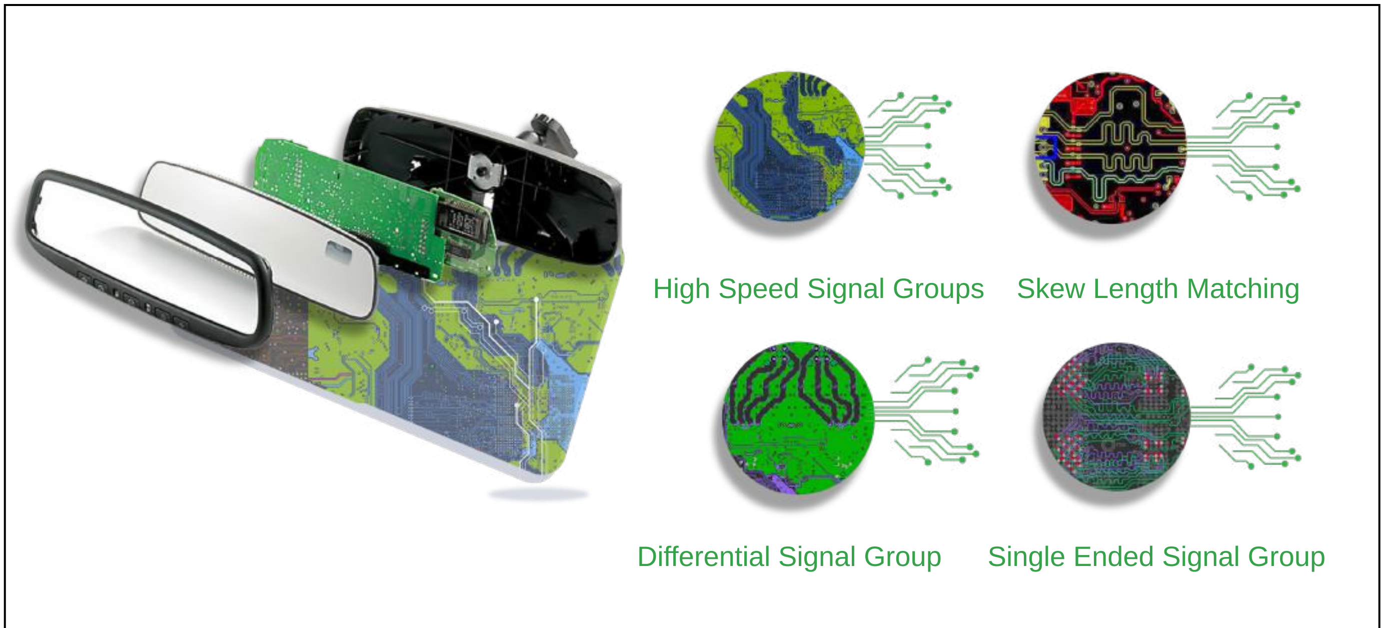


Signal Characteristics	Measured Signal Parameters	Signal Integrity Analysis
High-Speed Differential Signalling	1.6 Gbps speed	Pass
Propagation Delay	152ps per inch	Pass
Skew	17ps	Pass
Impedance Matching	97.32 ohms	**Fail (Traces and pads doesn't have the solid GND reference plane at some places)**
Crosstalk	NEXT :2.8% of Signal Amplitude FEXT: 1.9% of Signal Amplitude	Pass
EMI	CISPR 22 Class B standard followed	
Signal Attenuation	1 dB	Pass
Overshoot	Overshoot High Mode:0mv Overshoot Low Mode: 0 mv	Pass
Undershoot	Undershoot High Mode:0mv Undershoot Low Mode:0mv	

Recommendations for Enhanced Performance:

Signal Characteristics	Recommendations
Optimize Impedance Matching	Recommendation includes fine-tuning the PCB layout designs to ensure perfect impedance matching across all components and connections.
Enhance Grounding Practices	Implement additional grounding improvements, such as using multiple interconnected ground planes and increasing the density of grounding vias. This will further reduce ground bounce and improve overall signal stability.
Regular Integrity Monitoring	Establish a protocol for regular signal integrity testing, including periodic eye diagram analysis and impedance measurements, to ensure ongoing performance and early detection of potential issues.

Challenges in Signal Integrity for ADAS- Camera Monitoring System (CMS)



Obtaining IBIS Models for Components:

Acquiring detailed IBIS (I/O Buffer Information Specification) models to understand the electrical behavior of each component.

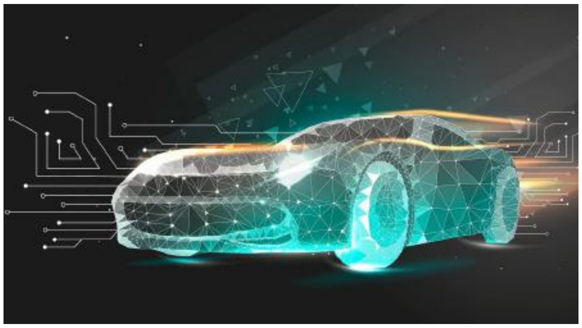
Simulation Setup at the Tool:

Configuring simulation software to model and analyse the component's performance under various conditions.

Layout Rework Based on Commands:

Adjusting the PCB layout as instructed to correct design issues or optimize performance.

6. Top Automotive CEOs Perspectives



We've researched and identified some of the top CEOs in the Automotive industry who are renowned for their leadership and vision in advancing Automotive technology.

These CEOs emphasize the importance of signal integrity and sustainability.

Here’s why they unanimously agree on its significance,

Do you know, Elon Musk (Tesla, Inc.)

Elon is Techno king of Tesla, CEO.

Elon Musk’s deep interest in cars, is fueled by his vision to transform transportation and tackle climate change.

His approach to automotive design emphasizes cutting-edge technology, especially high-speed electronics, to enhance vehicle performance and safety.
Musk’s method involves managing every aspect of car production, from battery creation to software development, ensuring top quality and efficiency.

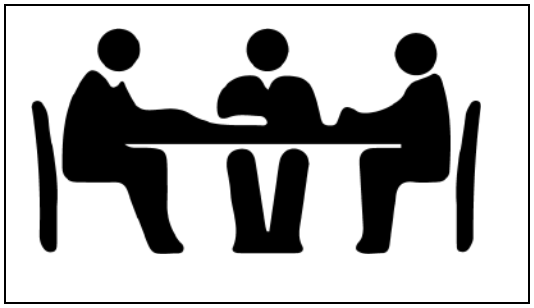
By integrating advanced electronics into features like **Tesla’s Autopilot and Full Self-Driving,** he pushes the boundaries of vehicle technology.

To overcome design challenges, Musk relies on rapid prototyping and continuous testing, refining his innovations with each iteration.
This relentless pursuit of progress has positioned Tesla as a leader in the automotive world.

In a recent interview, Elon Musk shared his insights on the automotive sector, particularly focusing on Signal Integrity (SI).

“Signal integrity is paramount in Automobiles as it ensures seamless communication between critical systems, optimizing performance and safety for our drivers”

Below are the researched viewpoints of some of the CEOs.,



Mary Barra - CEO of General Motors

“In the era of electric mobility, maintaining impeccable signal integrity is non-negotiable. It's the backbone of efficient operations and innovative advancements in our automobile lineup”

Jim Farley - President and CEO of Ford Motor Company

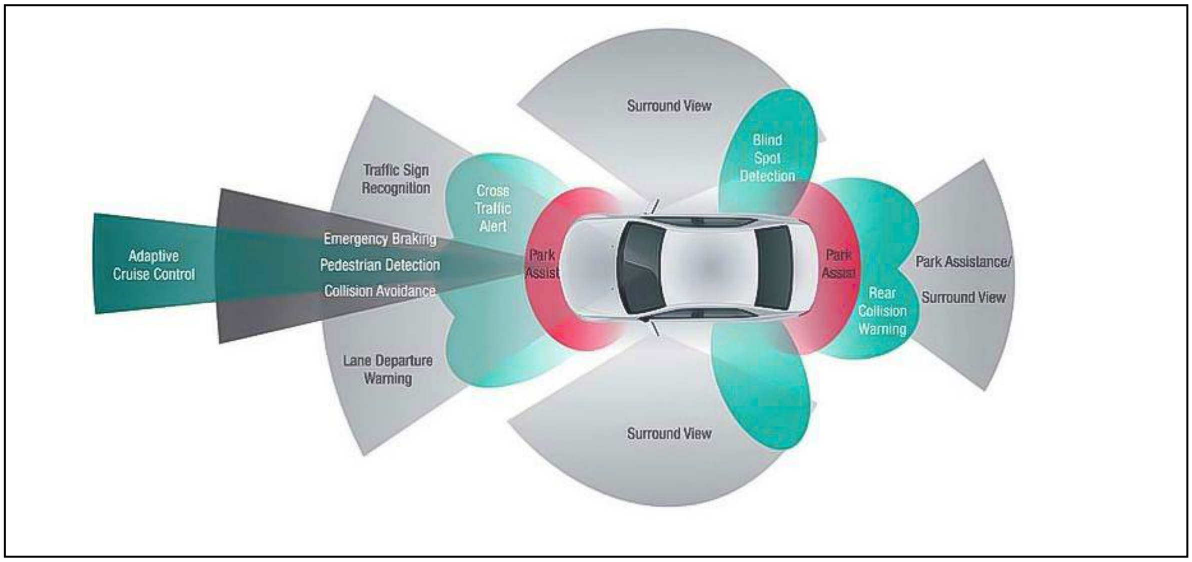
“Signal integrity stands at the core of our automotive strategy at Ford. It guarantees precise control over key functions, driving the reliability and sophistication of our electric vehicles”.

R.J. Scaringe - Founder and CEO of Rivian Automotive

“At Rivian, we prioritize signal integrity in our vehicles to deliver a seamless and responsive driving experience, setting new standards for performance and innovation in the EV landscape”

Stay connected with us to receive regular updates and thought leadership from automotive sector CEOs.

Final Summary



Imagine navigating through dense fog, relying on advanced driver-assistance systems (ADAS). The clarity and responsiveness of these systems hinge on one critical factor—signal integrity. Ensuring clear and reliable signals from cameras and sensors can mean the difference between a safe journey and a potential disaster.

This underscores the vital importance of signal integrity in the automotive industry. CEOs know that maintaining top-notch signal quality is essential for vehicle safety and performance.

Reflect on how signal integrity influences every facet of modern automotive technology. Apply these insights to enhance your projects. Ready to drive your innovations forward?

Contact us today at **https://calendly.com/gighz/30min**
to achieve exceptional signal integrity and ensure your automotive solutions meet the highest standards of reliability and performance.

Don't let signal issues derail your success—let's ensure your designs are safe and effective. Get in touch now to transform your automotive designs and secure a future where signal integrity drives excellence.