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EMC Optimized Transmission of Pixel Data for Display and Camera Sensor Applications in Vehicles

By Roland Neumann

Abstract

Vehicles continue to turn into multimedia devices on four wheels. Driving safety and comfort is not only enhanced by displays for information, navigation or menu-guided control systems but also by new and sophisticated camera-based driver assistance systems. Depending on their configuration, vehicles employ multiple digital transmission links transferring image data through copper cables at a data rate of 1 Gbit/s for the time being. Next generation display systems will require at least 3 Gbit/s to display high-resolution HDTV content or to replace pointer instruments or complete dashboards.

In minimum available space, vehicles utilize not only digital data links with inherent wide-band RF spectrum but also numerous conventional RF systems like VHF radios, GSM mobile radio, GPS navigation and Bluetooth which are highly sensitive to RF interference. The key challenge for new gigabit transmission solutions in vehicles is the reliable transfer of safety-relevant pixel data that does not affect other vehicle-based systems.

Munich-based company Inova Semiconductors is now dealing with this issue in the scope of a research project. In 2007, Inova launched their "APIX" (Automotive Pixel Link) series of innovative products designed to meet the specific requirements of automotive display and camera applications.

The technology facilitates the simultaneous transmission of video signals at 1 Gbit/s and bidirectional control data transmission at 8 Mbit/s between source and sink. It sets a new benchmark and provides a basis for powerful and highly economic system concepts for a wide range of automotive display and camera sensor applications.

Leading manufacturers of graphic products such as Fujitsu and Toshiba, have licensed the APIX technology, and Fujitsu launched their first graphics and display controller components that feature the APIX interface a few months ago. World market leader in FPGA technology, Xilinx, already offers APIX interface based solutions.

The APIX technology is supposed to establish itself as new worldwide standard for automobiles. APIX technology offers excellent EMC characteristics that meet even the highest demands of leading vehicle manufacturers and thus finds such a high degree of acceptance. The quality of this technology is not just coincidence but rather the result of selective measures and considerations at the early stage of product design.

Due to its high importance, the "AutoKom" research project is supported by the German Federal Ministry of Education and Research (Bundesministerium fuer Bildung und Forschung, BMBF). In the scope of this project, Inova Semiconductors, supported by Fraunhofer Gesellschaft IIS, explores and develops new processes and technologies to significantly increase transmission rates to the 3 Gbit/s range without affecting EMC behavior and transmission characteristics.

Another objective of the AutoKom project is to develop a solution design that can be ported to complex, next generation graphic components of other suppliers (FPGAs, graphic processors or display controllers) with process technologies of 65 nm, 45 nm and even below.

1. Gigabit/s Data Transmission in Vehicles " A Huge Challenge

1.1 Information Demand in Vehicles

Car drivers have always had a need for information while en route: speed, mileage, cooling water temperature or oil pressure in the beginning and an increasing amount of new information as technology advanced. The development of 7-segment LEDs made it possible, for the first time, to present drivers with real numerical values and simple text information which was further perfected in dot-matrix displays - the next generation of display technology. Extensive information was summarized in one single, concise text line, e.g. "Check on".

The first LED displays opened a new era of information transfer. At first, they were only available in monochrome technology. Starting in 1994, they were further developed to offer color and QVGA resolution (320 x 234 pixel). This technology made it possible to display not only text information and pictograms but also color graphics such as maps and moving images in vehicles. Automotive infotainment systems were born.

In this first generation of automotive display systems, image data was transferred analog, in the form of so-called FBAS signals, at a bandwidth of a few Megahertz only. By and by, displays were further developed to provide for higher bandwidths and more colors but they soon met the limits of technology. For the first time in 2000, image signals were transmitted fully digitally in HVGA format and at a resolution of 640 x 240. Current developments already employ WXGA 1.280 x 480 pixel displays for image data transfer at 850 Mbit/s - and the trend continues. Leading manufacturers envisage 1.600 x 600 resolution for dashboard, or 1.920 x 1.080 resolution for full HD multimedia applications requiring data stream transmission at 3 Gbit/s and higher.

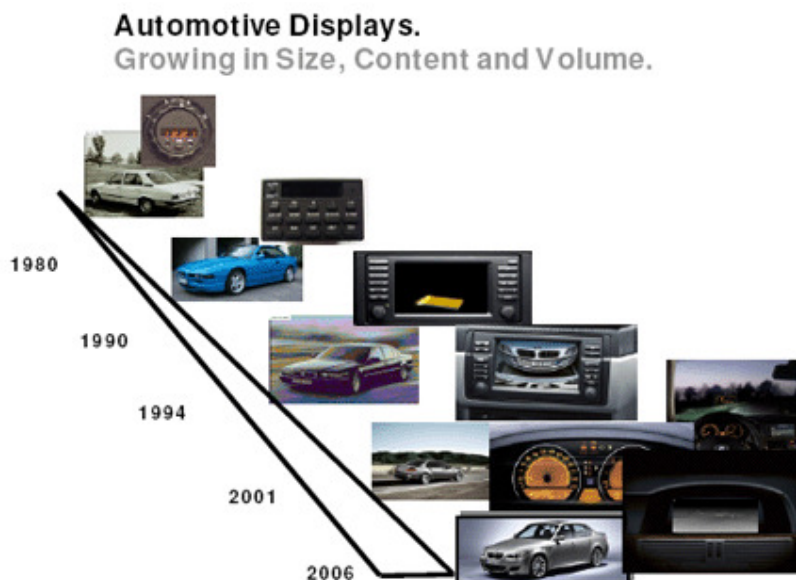


Figure 1: Development of display formats for vehicle applications (source: BMW)

1.2 High Data Rates and EMC "Big Problems for Vehicle Electronics

The change from analog to digital image data transfer entailed a completely new set of problems for electronics developers as regards EMC (electromagnetic compatibility). Other than analog electronic systems, digital logic "switches" between two defined states (0/1) resulting in switching edges that induce high-frequency, high-energy interference spectrums already at relatively low data rates. They are radiated by circuit paths and cables, acting as an antenna, and cause interference in other electronic devices.

The problem aggravates as higher-quality displays with higher data rates are used (see 1.1). At the same time, vehicles are equipped with increasingly sensitive RF receivers for mobile radio, radio and satellite navigation, all accommodated in confined space. EMC has thus become the central issue in vehicle electronics development over the past few years. Striving to solve this problem, manufacturers have invested a lot of money in sophisticated EMC test and measurement systems.

1.3 Goals of the "AutoKom" Research Project

The set of problems described before defines the goals of the "AutoKom" project that comprises three main issues.

In order to implement the data rates that are required for next generation displays, new circuit concepts and techniques have to be developed that provide for high data rates in a range of 3 Gbit/s. The physical conditions and limitations of components used in vehicles (cables, connectors, ICs) have to be considered. At the same time, EMC behavior shall be achieved that is uncritical as to radiated emission and immunity, regardless of data rates, the use of multiple link systems and image data transfer distance.

The project pursues a new and innovative approach that involves the simulation, evaluation and optimization of the expected EMC behavior of components at the early stage of chip development. In current practice, EMC measurement is carried out on finished components, followed by optimization through several design and production cycles. The new approach involves substantial cost and time advantages in product development.

AutoKom mainly focuses on improvements that can be realized through optimized chip design, even though this requires extensive considerations of the overall system and other peripheral components (boards, ICs, connectors, etc.).

A third and equally important aspect of the AutoKom project is cost economy. Cost projections of the automotive industry force semiconductor manufacturers to develop smaller structural dimensions for their products " 180/90 nm today, and 65 nm, 45 nm or below expected soon " to be able to compensate for cost pressure with ever increasing functional integration. Consequently, the concepts and techniques developed in the scope of AutoKom shall be laid out such that they can not only be used in discrete components but also in complex graphic and display processors of the latest technological generations.

2. EMC in Vehicles " A Complex Issue

2.1. The Problems in More Detail

2.1.1 Bandwidth Requirements for Image Data Transfer in Vehicles

Vehicle equipment for navigation, central information display (CID), head-up display or rear-seat entertainment is based on displays with ever increasing resolution and thus demands higher bandwidths for image data transfer. Also, the use of fast, high-resolution cameras for driver assistance systems requires image data transfer at high bandwidth and minimum latency. Data compression is not an option in most applications that necessitate high image quality and detailedness.

Mode	Refresh Rate	PxClk (VESA)	Color Resolution					
			36Bit	32Bit	24Bit	18Bit	12Bit	10Bit
	HZ	MHz	Bandwidth [MBit/s]					
1080i	60	74,25	2896	2599	2005	1559	1114	965
1080p	60	148,50	5792	5198	4010	3119	2228	1931
SXGA	60	108,00	4212	3780	2916	2268	1620	1404
UXGA	60	162,00	6318	5670	4374	3402	2430	2106
1600x600	60	76,43	2981	2675	2064	1605	1146	994
1600x600	100	132,00	5148	4620	3564	2772	1980	1716
1600x480	60	59,64	2326	2087	1610	1252	895	775
1280x480	60	43,00	1677	1505	1161	903	645	559
800x480	60	33,00	1287	1155	891	683	495	429

Figure 1: Bandwidth requirements according to image format and color depth

As high cost pressure applies for all of these vehicle systems, solutions based on optical transfer media can virtually be ruled out. This is also true for solutions based on less expensive copper cables where image data transfer in the 3 Gbit/s range, even at maximum resolution, has to be implemented through one single pair of wires.

Moreover, because of its physical properties, the maximum transmission frequency of copper cable is limited to approximately 1 GHz. Higher signaling frequencies are subject to strong attenuation and distortion due to the cable transfer characteristics that are of increasingly non-linear character at that frequency (see figure 2).

Transmission frequencies of more than one Gigahertz can only be achieved through specific compensation components and high circuit complexity, so this approach must be discarded for cost reasons.

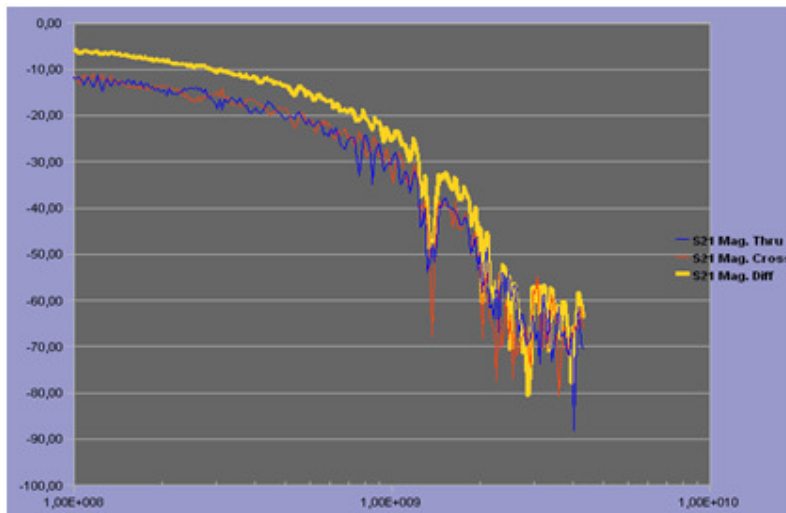


Figure 2: Attenuation characteristics of a CAT5 cable

2.1.2 Electromagnetic Compatibility (EMC) Requirements

Navigation systems (GPS), VHF radios, digital TV (DVB-T), mobile phones (GSM) and, last but not least, Bluetooth and wireless Internet are integrated in a complex structure of highly sensitive transmission and receiver devices in vehicles. They operate over a wide frequency spectrum of below 100 up to 1,500 MHz and higher and must not be disturbed or affected by digital image data transfer.

Consequently, the threshold limits for electromagnetic radiation in vehicles are substantially lower than those applying for the CE certification of consumer devices. Typical radiation thresholds for vehicle components are in the 10 to 15 dBV range for a frequency range of 100 kHz to 3 GHz. This corresponds to a maximum permissible radio interference voltage of only 3 V (0.000003 V).

Besides starters, modern vehicles also feature numerous servo motors for comfort systems like seat adjustment, window lift, steering wheel adjustment or door closers causing strong electromagnetic fields in operation as well as current and voltage peaks in the on-board supply system.

Besides starters, modern vehicles also feature numerous servo motors for comfort systems like seat adjustment, window lift, steering wheel adjustment or door closers causing strong electromagnetic fields in operation as well as current and voltage peaks in the on-board supply system.

In earlier times, nobody complained about a flickering lamp when the automobile was started. Today, nobody would accept the flickering of a display system in any situation " for example, when starting the engine or activating the window lift, and any kind of image interference due to environmental effects (radio or TV station, mobile radio base station, other vehicles) would be claimed as defective.

Even when operated in close vicinity to the display, a mobile phone that generates a field strength of up to 100 V/m during log-in must not cause any interference. Consequently, interference resistance against field strengths of several 100 V/m is required.

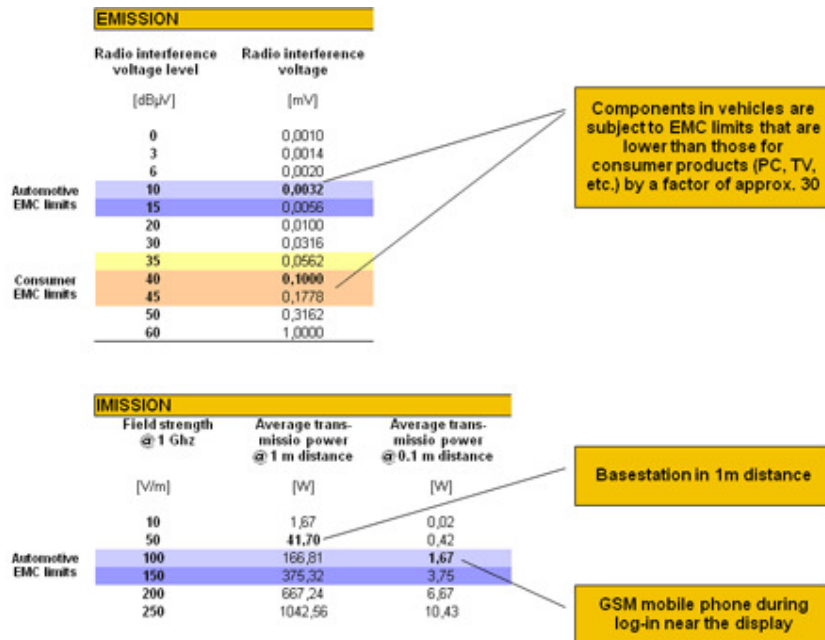


Figure 3: Radiation and immission levels (For higher resolution, [click here](#))

In addition, video systems in vehicles are often distributed systems with a separate supply of source and sink, resulting in high equalizing current in the vehicle's ground system which in turn causes significant ground offset of several 10 V at different ground points in the vehicle. This extreme case must not impact image data transfer quality either.

In case a mechanic touches the cables and connectors of the image link system during installation or service repair, an electrostatic discharge (ESD) of several thousand volt may occur in the worst case which directly affects the system and thus, in many cases, the semiconductor itself. Additional protective measures against ESD are required and have to be considered as they often interact with EMC measures.

Modern image data transfer systems for future vehicle generations are not only required to achieve significantly higher bandwidths of up to 3 Gbit/s and feature extremely low electromagnetic radiation. They also have to provide extremely high electromagnetic and electrostatic discharge (ESD) immunity.

2.1.3 EMC as Design Objective " New Ways of Chip Development

To make sure that image data transfer systems using data rates in the Gbit/s range fulfill all these requirements, new technologies for the development of semiconductor components that comprehensively support EMC optimized system design have to be applied. For the first time, EMC requirements have become a "hard" design objective and an inherent part of the specification.

At the early stage of chip design, blocks that are potentially susceptible to interference have to be identified and optimized. This would be very complex to handle once the components are finished.

In addition, there is a high degree of interaction between EMC and ESD protection measures, however, they have mostly been developed as completely separate functions and with different techniques up to now. Ideally, their impact and interaction are identified and evaluated in the design phase already. To this end, requirements on ESD resistance, radiation and interference level have to be defined and implemented in a set-up with simulatable parameters like voltage or current.

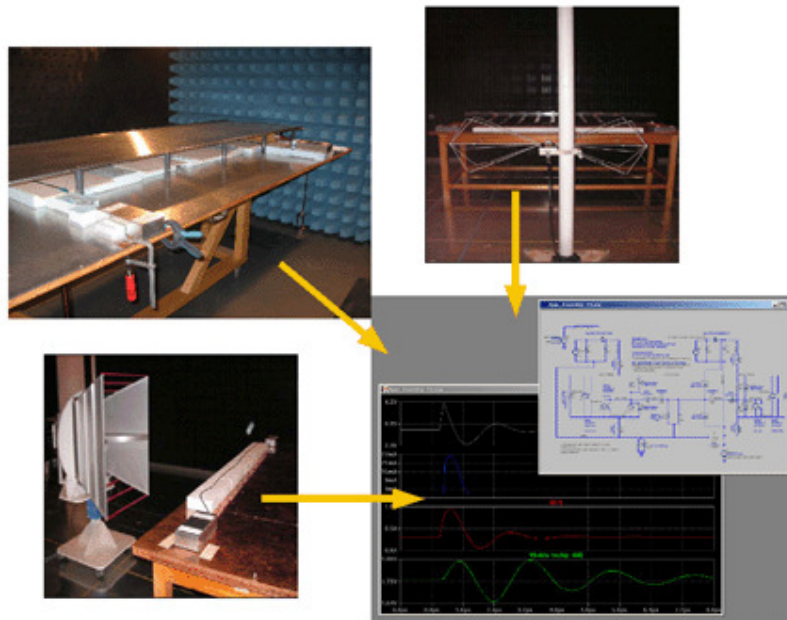


Figure 4: Measurement of EMC radiation and interference level, chip simulation (For higher resolution, [click here](#))

2.2 Concepts for Increasing Bandwidth and Optimizing EMC

2.2.1 Concepts for Increasing Transmission Bandwidth

One concept could involve an increase in the so-called symbol rate, i.e. increasing the amount of information per time unit and transferring n bits instead of only one bit per time unit.

A second option would be to leave the symbol rate at "1". This facilitates simple modulation techniques, but transmission frequency initially increases proportionate to bandwidth. However, real signal frequencies can be reduced by selecting suitable line codes. Whereas the so-called Manchester (or RZ coding) method requires a 3 GHz signal frequency at 3 Gbit/s, NRZ coding has a signal frequency of only 1.5 GHz.

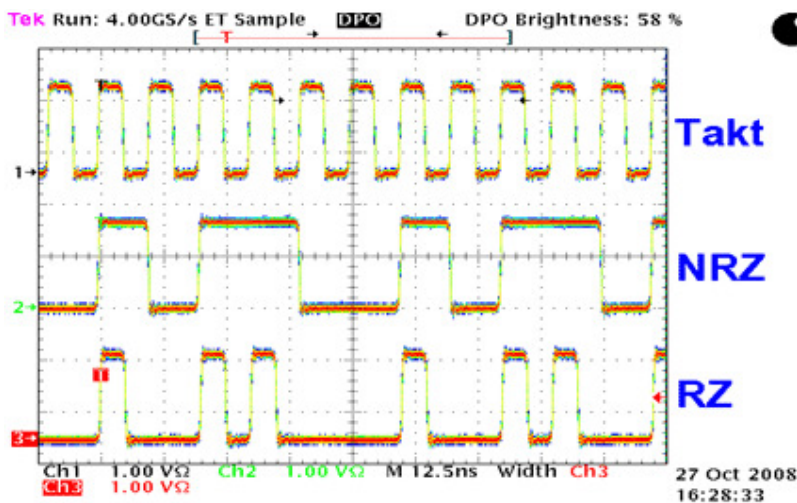


Figure 5: NRZ vs. RZ coding

In a further complementary approach, the fault protection and protocol overhead required for data transmission is minimized.

2.2 Concepts for EMC-Compatible Data Transfer

When using differential signaling techniques over a twisted and impedance-controlled pair of wires, the electromagnetic fields of forward and return current are compensated. The transmitted information (1, 0) is coded according to the potential difference (pos/neg).

In case of ideal twisting, interferences equally add up to the potential of both wires and therefore do not affect the potential difference of the video signal.

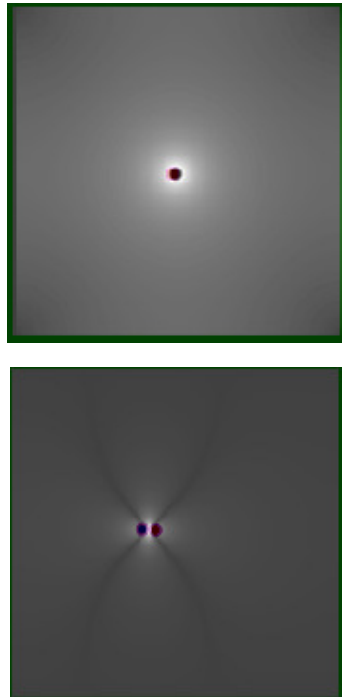


Figure 6: E-Field simulation. The picture shows the electrical field with one conductor (top) and with a pair of wires (odd mode, below)

Differential signaling techniques are thus inherently resistant to interference and offer ideal EMC characteristics.

EMC problems that occur even in case of differential data transfer are mainly due to common mode interference, i.e. interference levels that spread identically over both wires so that their electromagnetic fields are no longer compensated. This common mode noise is typically coupled into the data line through ripple and noise on the supply paths. Dynamic switching in the semiconductor component itself may also cause interference on internal supply paths and thus lead to further common mode noise.

Due to cost considerations (chip size) and higher power dissipation, it is not possible to implement the overall chip design, with all its complex and logic-intensive protocols and line code algorithms, in low-interference "current mode logic" (CML). These functions always require digital logic (CMOS) and a clear separation of the analog switching stages due to their high dynamic currents and the related interference potential.

2.2.3 Concepts for EMC Analysis in the Chip Design Process

While simulators used in chip development work with models of current and voltage sources, resistors, capacitors and inductors, EMC test set-ups comprise antennas and the complex "printed circuit board" system with numerous components. The semiconductor simulator calculates current and voltage profiles; EMC parameters are defined as interference or radiation levels.

In order to simulate EMC behavior in the design process, parameters have to be defined which correlate with real measurements in the EMC measurement chamber.

It is difficult to mechanically transform EMC radiation and immunity levels in a simulation set-up. However, the simulation values of existing components can be correlated with associated EMC values in order to set up a new simulation environment for the development of new components.

A further and even more important aspect of EMC simulation during chip design is that EMC-critical circuit elements can be detected and optimized at an early stage, and failure mechanisms are analyzed faster and more easily compared to real components. Interaction with protective structures for ESD, often developed separately, can also be incorporated.

2.3 Measures

2.3.1 Techniques for Increasing Transmission Bandwidth

For the frequency range to be realized, a higher symbol rate turns out to be too complex or susceptible to

interference. A combination of a specific line code and transmission technique has proven highly efficient as regards chip size (cost) and complexity (portability). This technique can be implemented with cost-efficient baseline CMOS processes.

At the same time, specific protective protocol measures are implemented for all data channels. Sensitive control data that is transmitted at low bandwidth is efficiently protected with a CRC24 protocol whereas image data requiring most of the available bandwidth is assigned "intelligent" and very economic error protection.

As all protocol measures require bandwidth that is, in most cases, proportionate to the amount of data to be protected, the effort for data protection is optimized. Errors in image data or individual pixels are virtually invisible up to a certain error rate, as this data is repeated 60 times per second. Maximum protection, however, is provided for control data in which one individual bit error could have serious impacts.

An overhead of clearly less than 20% is thus achieved for all data to be transmitted, whereas other techniques that are currently employed account for an overhead of 25% and higher.

2.3.2 Techniques for EM Compliant Data Transfer

Line drivers, input stages and the "RF front-end" required for control and analysis functions are implemented consistently in current mode logic (CLM). This circuit technology is based on differential amplifiers in which transistors operate as amplifiers in the linear range, contrary to CMOS logic where transistors operate in the saturated range and practically act as "switches".

A key factor for EM compliant data transfer and EMC optimized chip design is a supply current that is as constant as possible, like in CML technology. High dynamic currents, caused by each switching in CMOS logic, are the main cause of common mode interference.

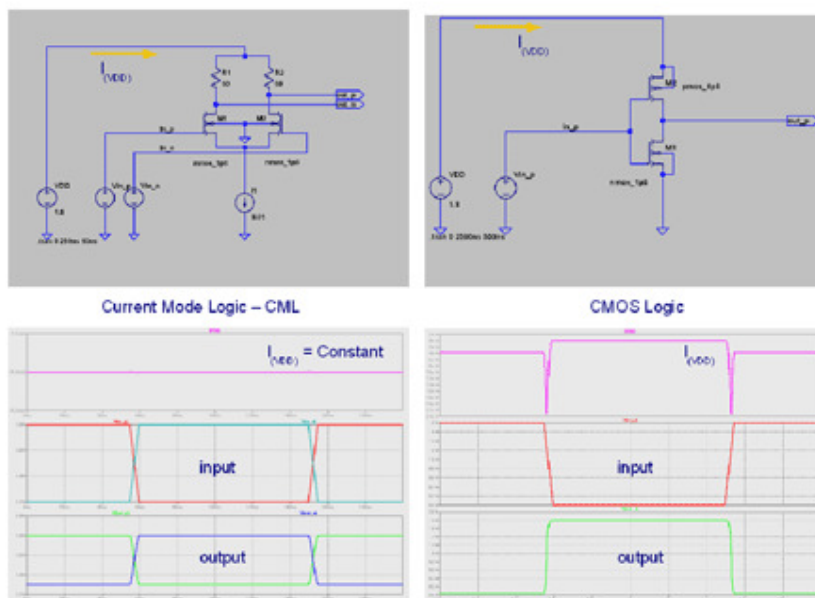


Figure 8: CML vs CMOS logic (For higher resolution, [click here](#))

Another key aspect for the consistent use of CML technology is that the forward and return currents in the chip compensate their inherent electromagnetic fields. This facilitates low-noise designs of input and output stages as well as the overall control system. Data line control becomes very precise and almost free of common mode voltage.

2.3.3 Techniques for EMC Analysis in the Chip Design Process

Simulation of the expected EMC behavior rests upon conducted EMC test methods such as "direct power injection" or the "150 ohm method".

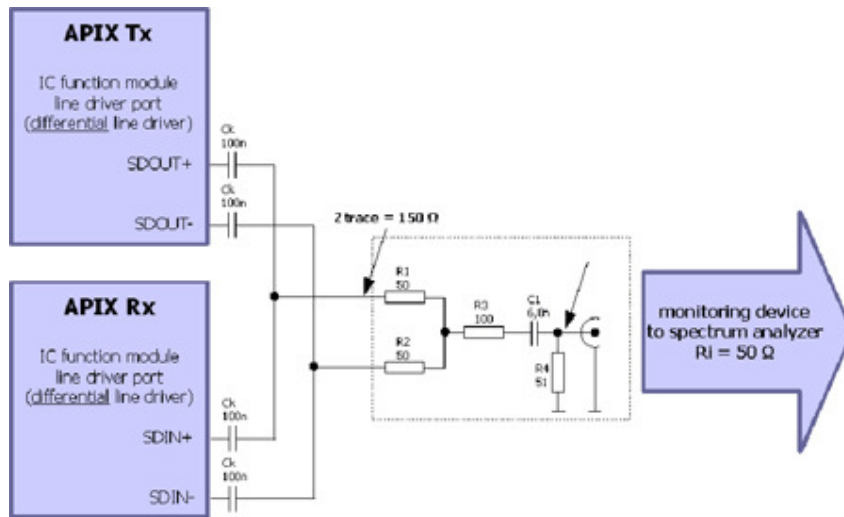


Figure 9: Example of a simulatable EMC set-up

The correlation of EMC values obtained through the measurement of radiation characteristics (e.g. "CISPR25b" standard) with the results from conducted emission and immunity level measurements (e.g. 150 ohm method) supplies reference values that can be used to simulate the conducted test set-up for chip design.

When comparing strip line measurement with conducted common mode interference measurement, it gets clear how well it works to compare radiated emission characteristics measurements with conducted interference level measurement.

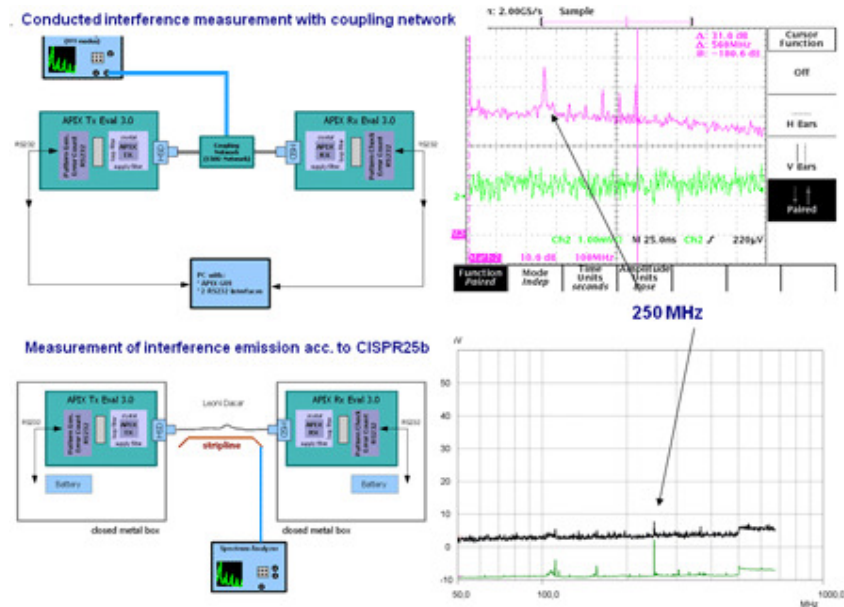


Figure 10: Strip line measurement vs. common-mode interference measurement (For higher resolution, [click here](#))

All circuit elements that control data lines or through which data is received are simulated in different conducted test set-ups. In addition, interference levels are increased during simulation until the first circuit elements start to fail. The mechanisms of action are analyzed in order to optimize the circuit elements that were affected.

In a second step, ESD measures are simulated concurrently to analyze the quality of their impact on EMC behavior.

2.3 Implementation in Practice

Inova Semiconductors is already going to implement the findings and results from this research project in the second APIX generation. Late 2009 already, first samples of "APIX 2.0" should be available. The components will offer a significantly higher transmission bandwidth in a range of 3 Gbit/s and full downward compatibility with existing APIX 1.0 products, such as discrete APIX components of Inova Semiconductors or more

complex graphic products of APIX license partners.

In addition, APIX 2.0 will offer further features designed to meet the specific requirements of latest vehicle display technologies and sophisticated system concepts. Driver assistance systems with multiple camera sensors will also benefit from the valuable functions offered by APIX 2.0.

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