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Preventing Automotive Lighting from Noise Emissions

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The emergence of software-defined vehicles is revolutionizing the automotive industry, bringing substantial advantages to automotive digital lighting systems. Enhanced integration facilitates seamless operation, while advanced diagnostics minimize downtime. Optimized power management enhances reliability and extends the lifespan of these systems. Additionally, superior EMC compliance mitigates electromagnetic interference/susceptibility, ensuring consistent and dependable performance.

Noise emissions can significantly impact the performance of digital lighting systems, potentially causing interference with other electronic components in the vehicle. To address this, rigorous testing, such as the 150 Ω testing, can be employed.

The 150 Ω testing is essential for evaluating the electromagnetic compatibility (EMC) at the device level. This test assesses emissions directly from the device's pins, including outputs, regulators, and the battery. Unlike system-level testing such as CISPR25 (voltage method), which is conducted solely on the battery line, the 150 Ω test offers a more detailed understanding of EMC performance at the device level.

While DPI tests involve injecting signals to assess susceptibility, the 150 Ω test focuses on emissions, ensuring that the device does not interfere with other electronic systems in the vehicle. This is particularly critical for automotive digital lighting drivers, which must function reliably without causing electromagnetic interference that could impact other essential vehicle systems.

In addition to ensuring EMC compliance, the 150 Ω testing also allows the optimization of the vehicle's design. By providing detailed insights into the emissions characteristics of digital lighting systems, manufacturers can make informed decisions about the placement and configuration of these systems within the vehicle. This can lead to reduced cable lengths, lower weight, and cost savings, further enhancing the efficiency and performance of the vehicle.

Overall, the emergence of software-defined vehicles, coupled with rigorous EMC testing such as the 150 Ω test, is driving significant advancements in automotive digital lighting systems. These developments are contributing to the creation of more reliable, efficient, and high-performing vehicles, meeting the evolving demands of modern automotive technology.

Test Methods

The conducted RF tests have to be performed for all ICs and are addressed to conducted emission and immunity, as described in the following table (Tab. 1).

Test Type	Coupling Method	Method Name	Reference
Conducted emission	Direct coupling via 150 Ω / 1 Ω network	150 Ω / 1 Ω method	IEC61967-4
Conducted immunity	Direct RF-power injection via DC block capacitor	Direct power injection (DPI)	IEC62132-4

Tab. 1 - Conducted RF test methods.

Section 4 of IEC 61967 specifies a method to measure the conducted electromagnetic emission (EME) of integrated circuits through direct radio frequency (RF) current measurement using a 1 Ω resistive probe and RF voltage measurement with a 150 Ω coupling network. This method enables the characterization of emission levels on individual pins, ensuring a high degree of repeatability and correlation of EME measurements due to the minimal influence of external parameters on the results. The 1 Ω section aims at measuring the RF current flowing from the input supply pin of the circuit to the reference ground, as shown in Fig. 1.

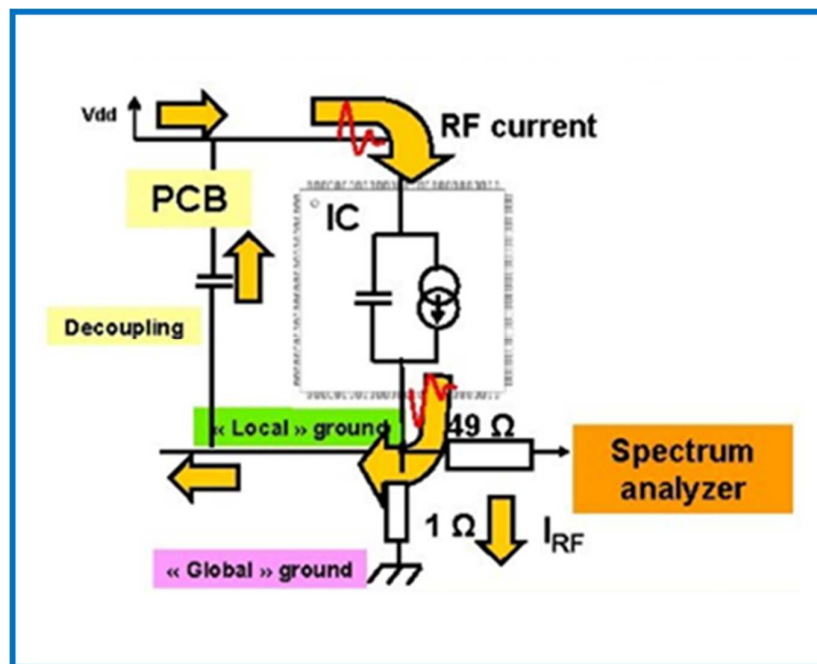


Fig. 1 - Testing circuit for the 1 Ω section.

The measurement resistor consists of a 1 Ω RF resistor and is coupled with a matching resistor of 49 Ω to provide an impedance in the range of 40 Ω to 60 Ω . The conducted emissions are produced by the RF current induced by the IC activity. This current induces voltage fluctuations along the power distribution network and also generates radiated emissions.

The 150 Ω section aims at measuring the RF voltage induced at one or several output pins of the IC. The I/O switching is a major contributor to conducted emissions, which induce voltage fluctuations along both the power supply and I/O lines. A cabling network can often be represented by an antenna with an impedance of 150 Ω . To obtain accurate measurement results over the full frequency range, a termination network of 150 $\Omega \pm 20 \Omega$ should be used. Typical measurement equipment provides an input impedance of 50 Ω , so the matching network must match the signal line impedance to the equipment impedance. The circuitry is shown in Fig. 2.

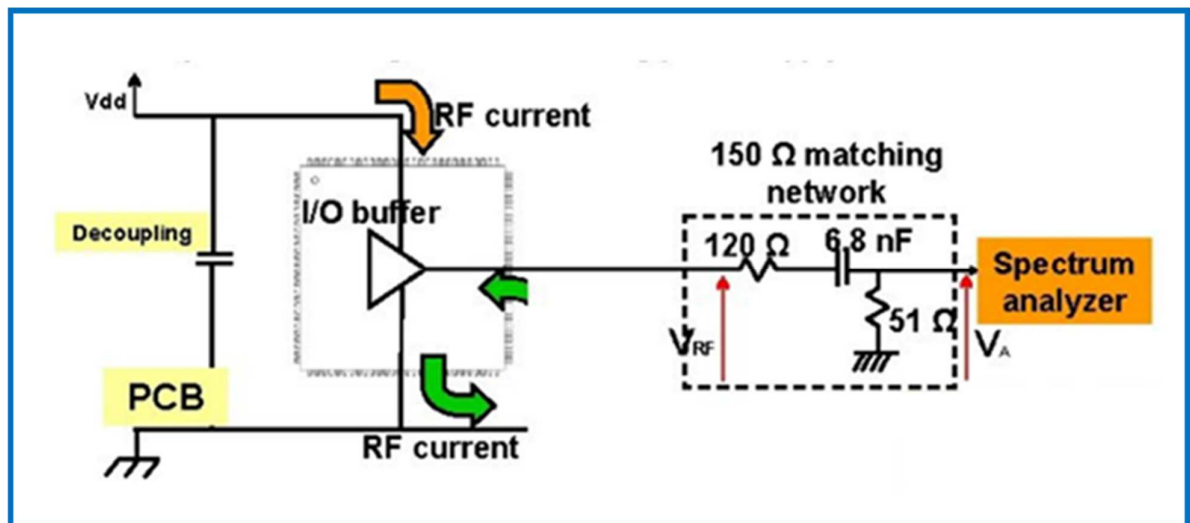


Fig. 2 - Testing circuit for the 150 Ω section.

The 150 Ω / 1 Ω method, similar to the Direct Power Injection (DPI) measurement, requires a clear distinction between LOCAL and GLOBAL pins, as defined by the BISS Bosch / Infineon / Siemens specification:

- Global Pin: A global pin carries a signal or power that enters or leaves the application board without any active component in between.
- Local Pin: A local pin carries a signal or power that does not leave the application board. It remains on the application PCB as a signal between two components.

Experimental data

The conducted emissions of the LED and OLED automotive driver L99LDLH32 have been experimentally evaluated with the 150 Ω .

In a typical testing setup, the IC and all necessary components should be mounted on the top side of the test board, with as much wiring as possible routed in the top layer. The IC should be placed in the center of the PCB, with the required matching networks

positioned around it. The wiring between the IC pins and the matching network should have a line impedance of 150Ω . The PCB used for the conducted emission measurements of L99LDLH32 is shown in Fig. 3.

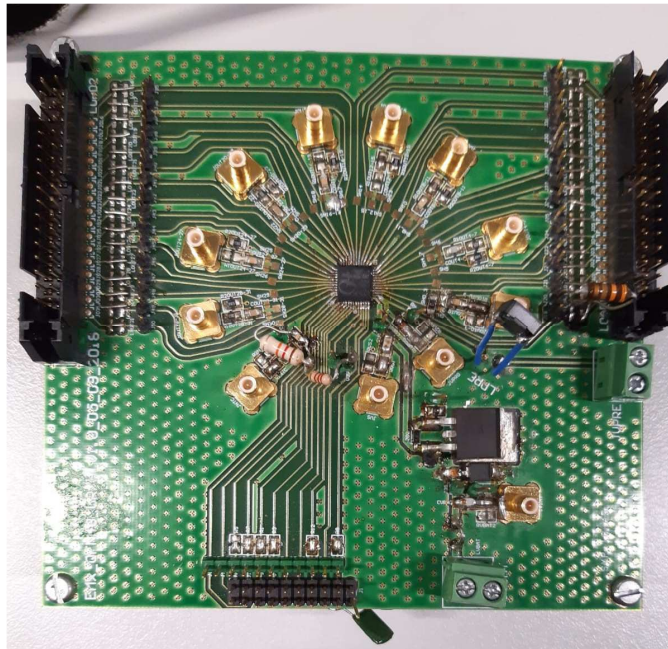


Fig. 3 - PCB for L99LDLH32 conducted emission measurements.

At the injection points, disturbances are coupled using passive components with a maximum value tolerance of 1%. The RF noise has been measured from the following coupling points:

- JV_{BAT} (car battery voltage)
- JV_S (input supply voltage of the driver)
- JV_{PRE_REG} (pin for connection to an external pre-regulator)
- JN_{TC} (voltage across the Negative Temperature Coefficient sensor)
- $JOUT_0$ (output pin of the driver)

at the following conditions:

- $V_{BAT} = V_{PRE_REG} = 12 \text{ V}$
- $T_{AMB} = \text{Room Temperature}$
- Load option: LED string board (5 LED string per channels)
- SW settings:
 - Device in Fail Safe configuration
 - Channels 0-31 set to 15 mA
 - PWM frequency 700 Hz
 - Dithering conditions: 000, 100, and 111.

The L99LDLH32 driver incorporates a clock dithering function internally to advance EMI mitigation. Specifically, it applies a triangular waveform to the embedded 20 MHz oscillator, as shown in Fig. 4.

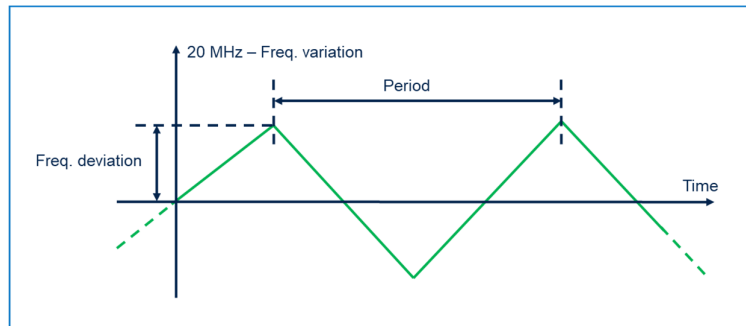


Fig. 4 - Oscillator dithering curve.

The triangular waveform induces a dithering effect on the oscillator frequency, spreading the noise across a wider range of frequencies. This action diminishes the peak amplitude of noise at any individual frequency by dispersing the energy from the fundamental frequency and its harmonics over a broader spectrum. The dithering technique assists in filtering noise and significantly reduces the device's overall electromagnetic interference (EMI) footprint.

Users can select from eight distinct configurations using three dedicated bits, allowing for specific adjustments in frequency modulation and deviation, as well as enhanced rejection values.

Emission results

Each coupling point drives the RF signal generated at one specific pin directly into the measurement instrument (EMI test receiver) input port. According to the BISS specification, all global and supply pins must be measured, while local pin measurements are optional, as shown in Tab. 2.

Pin	Function	Type	Coupling Point
V _{BAT}	Supply	Global	Mandatory
V _S	Supply	Local	Mandatory
V _{PRE_REG}	Supply	Local	Mandatory
NTC	Regional input	Local	Optional
OUT _N	Regional output	Local	Optional

Tab. 2 - Coupling point classification.

The conducted emissions of the L99LDLH32 were evaluated at various coupling points under different dithering conditions. The results are illustrated in the following figures. For the V_{BAT} coupling point, which is a global node, the conducted emissions measurements are presented in Fig. 5 under different dithering conditions.

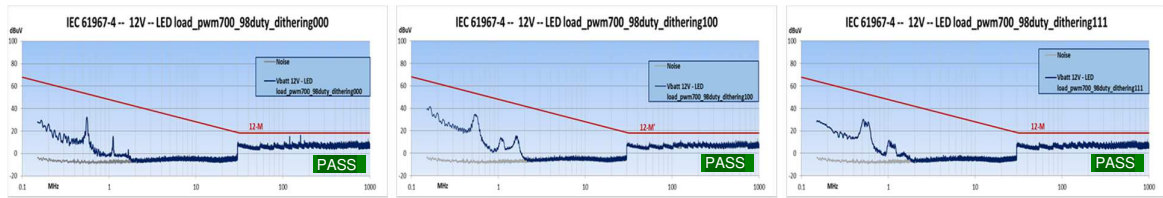


Fig. 5 - Conducted emissions measurements at V_{BAT} coupling point.

For the V_S coupling point, which is a local node but also a supply pin, the measurements results are shown in Fig. 6.

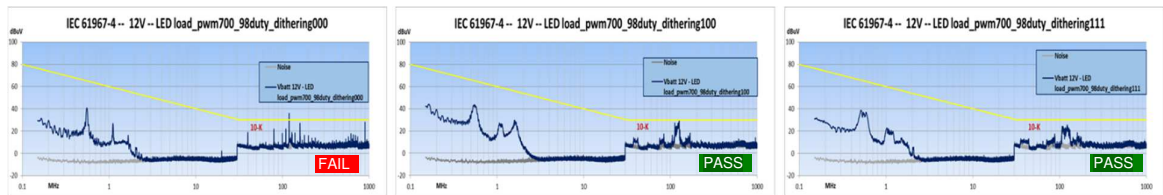


Fig. 6 - Conducted emissions measurements at V_S coupling point.

For the V_{PRE_REG} coupling point, another local node and supply pin, the measurements results are displayed in Fig. 7.

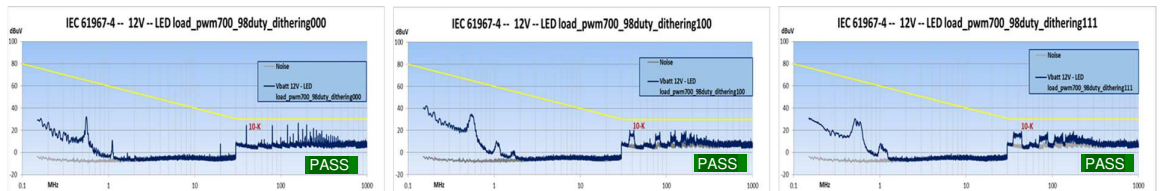


Fig. 7 - Conducted emissions measurements at V_{PRE_REG} coupling point.

For the J_{NTC} coupling point, a local node, the results are depicted in Fig. 8.

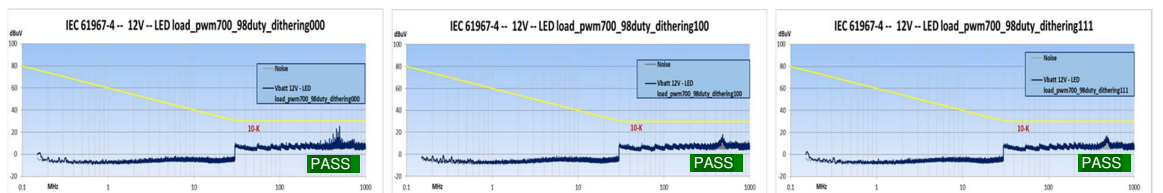


Fig. 8 - Conducted emissions measurements at J_{NTC} coupling point.

Finally, for the OUT₀ coupling point, also a local node, the measurements are shown in Fig. 9.

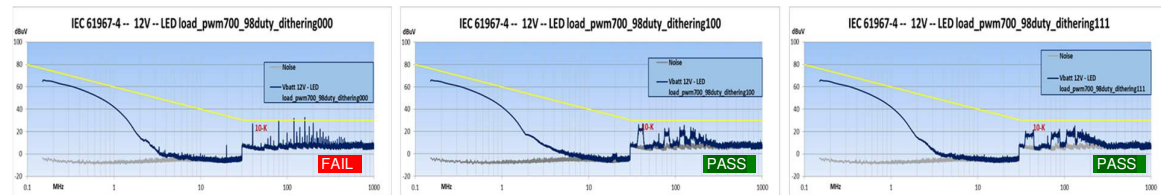


Fig. 9 - Conducted emissions measurements at OUT₀ coupling point.

The experimental data clearly indicate that the dithering setting 000, which means no dithering is applied on the main oscillator, is less effective in managing conducted emissions compared to the other two settings, 100 and 111. Therefore, for applications where minimizing conducted emissions is critical, settings 100 and 111 are preferable choices.

Conclusions

The L99LDLH32 LED and OLED automotive driver effectively manages conducted emissions, as shown by the 150 Ω method evaluation. The setup ensured accurate measurements with proper component placement and wiring.

Measurements from various coupling points under specific conditions indicate that dithering settings 100 and 111 are more effective than setting 000, which is the configuration without dithering. Users can choose from eight configurations to optimize the embedded oscillator dithering by adjusting frequency modulation and noise rejection.

In summary, the L99LDLH32 provides effective EMI mitigation, especially with settings 100 and 111, making it suitable for applications requiring stringent EMI control.

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