Communications between devices in the automotive industry and EMC challenges

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Introduction to automotive communications

Communication methods in Automotive industry

Nowadays, vehicles incorporate a lot of electronic systems that are controlled by the car's ECU or BCM (Body control module). The same also applies to electronic systems in automotive Lamps that are most of the time controlled by either CAN or LIN bus [3]. Both busses technology are adopted in modern vehicles to reduce the wiring harness and control the vehicle using electronic systems. Typical instructions and information that are exchanged via these buses are: requests to turn on/off passing beams or driving beams, blinking the direction light (DI), sending instructions for lamp diagnostics and returning its status…

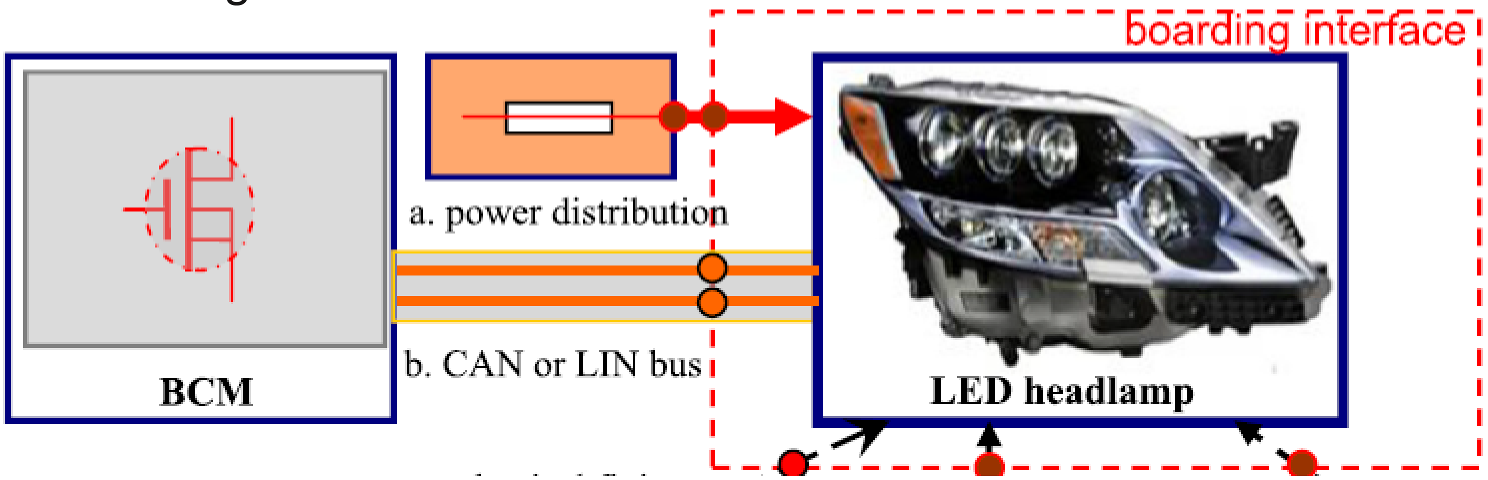


Fig. 1. Illustration of the boarding interface of the LED headlamp in a vehicle [3]

CAN bus (Controller area network)

CAN is an International Standardization Organization (ISO) multi-master serial bus connecting at least two or more electronic systems via two wires. This typically is the connection of the main car controller unit (ECU) with all the car‘s other critical sub-electronic systems or nodes, making it very robust and cheap by connecting all these systems using just two wires. These subsystems are breaks, electric steering system, air conditioning, headlamps, airbags, antilock braking... An example of nodes connected together is represented on figure below:

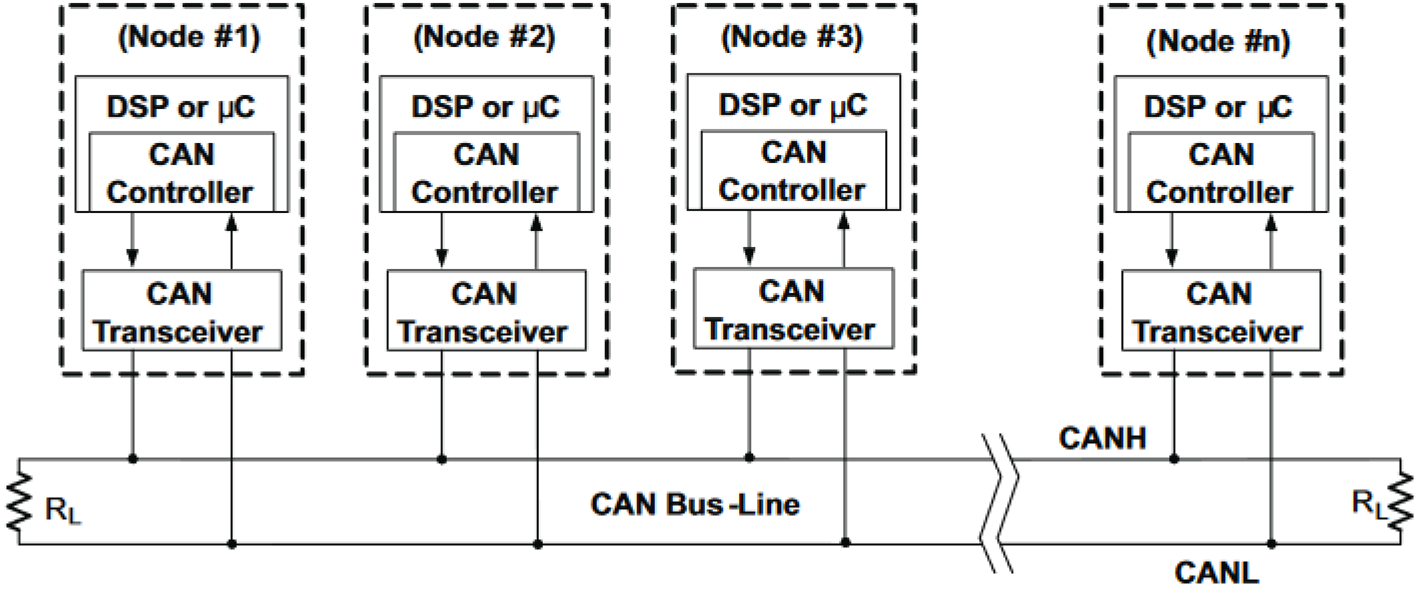


Figure 6. Details of a CAN Bus [2]

CAN bus Signaling, terminations and speed

Signaling is differential which is where CAN derives its robust noise immunity and fault tolerance. Balanced differential signaling reduces noise coupling and allows for high signaling rates over twisted-pair cable. Balanced means that the current flowing in each signal line is equal but opposite in direction, resulting in a field-canceling effect that is a key to low noise Emissions [2]. It runs from one end of the environment to the other, where it is terminated using a resistor or optional capacitor for split operation. According to ISO **11898-2,** the end resistors values are 120 Ohms. Picture below represents connection of typical termination, which is executed one one end and the other end of the bus:

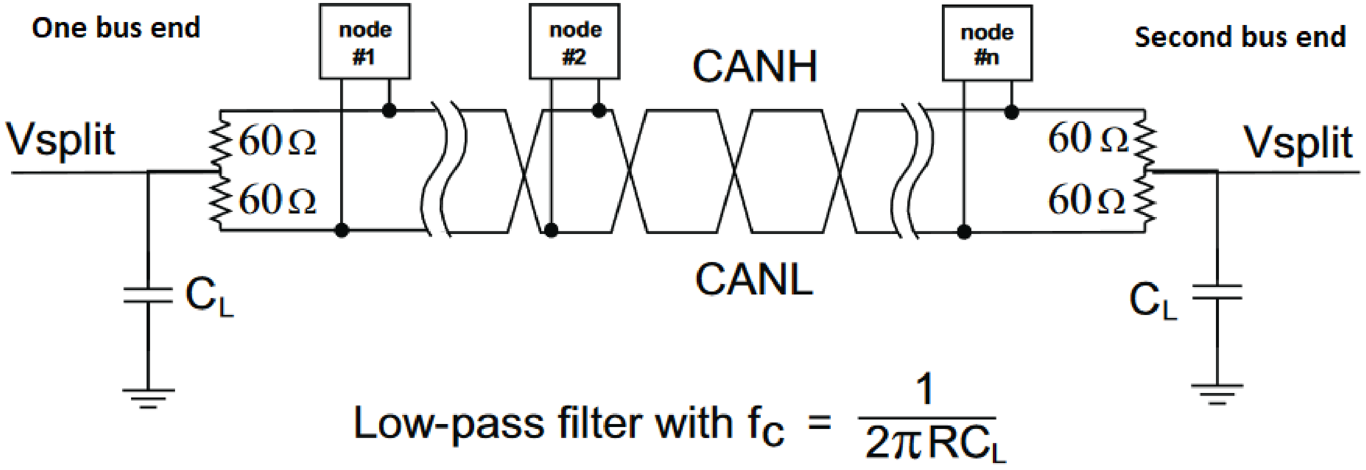
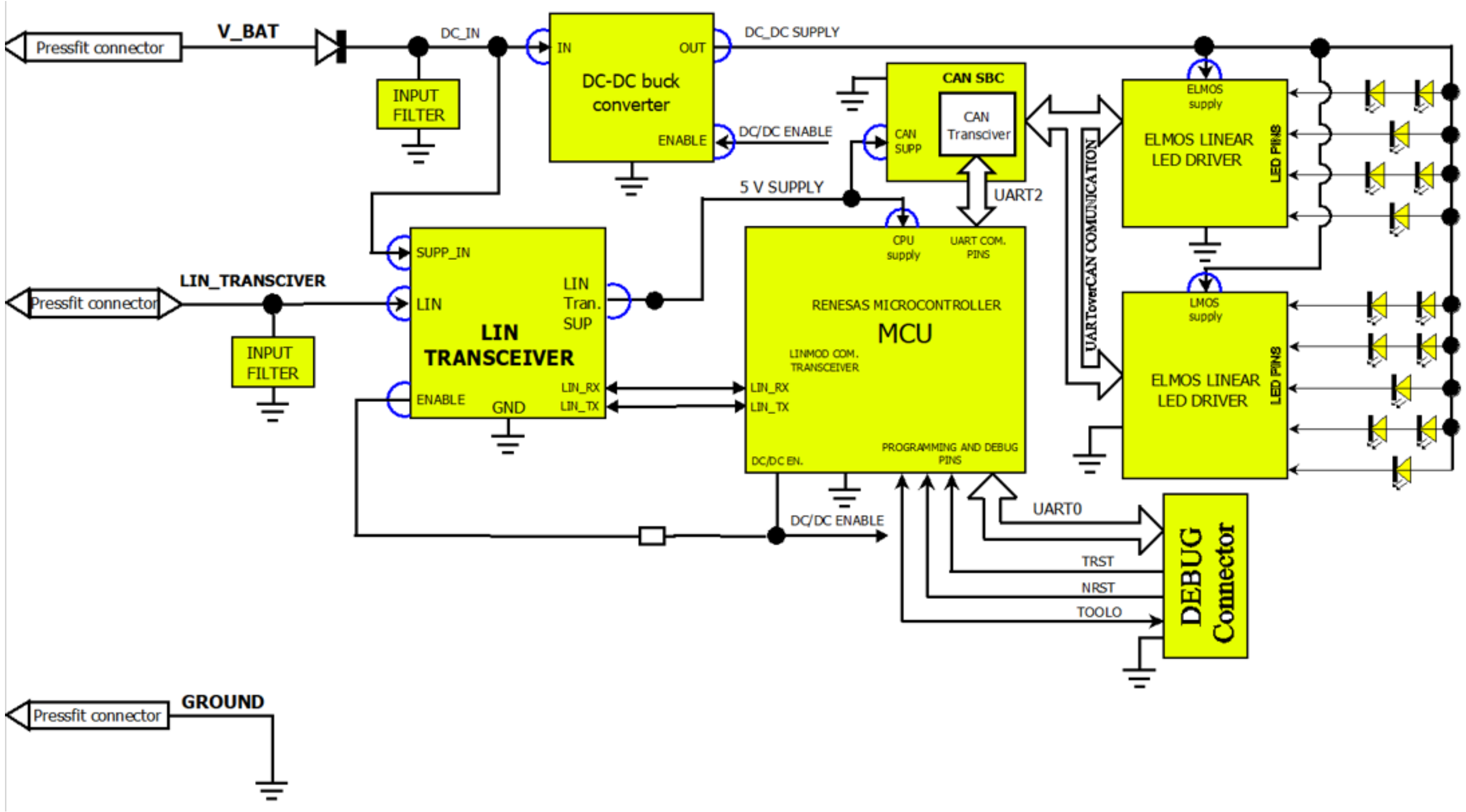


Figure 12. Split Termination [3]

UARTtoverCAN bus on a physical CAN BUS

In the case of developing automotive lamps by Forvia, there are cases where demand is to use multiple smart LED drivers, which have to be controlled by the Lamps ECU. As already mentioned, lamps ECU is controlled by the car's **main ECU** or **BCM** via LIN or CAN bus (depending on the application) and it has to properly control all LED drivers, which the whole electronic system contains. Example bellow represents this type of lamp control.



LIN Bus - local interconnect network

LIN bus is an inexpensive alternative to the CAN bus. It's very simple but necessarily limited to one master and 15 slave nodes. LIN is a serial unidirectional messaging system, where the slaves listen for message identifiers addressed to them [4].
Because of its lower bandwidth and node count limitations, LIN is normally used to control small electric motors and controls. LIN is limited to 19.2 kbps or 20 kbps data rate [4]. Typical sub-electronic systems where the main ECU uses LIN are: interior decoration smart lamps, exterior decoration lamps (logos), electric windows, electric mirrors, power seats…
Although not as powerful and fast as CAN, it is still extremely robust as one requires only one communication wire and common ground. An example of LIN communication is available below:

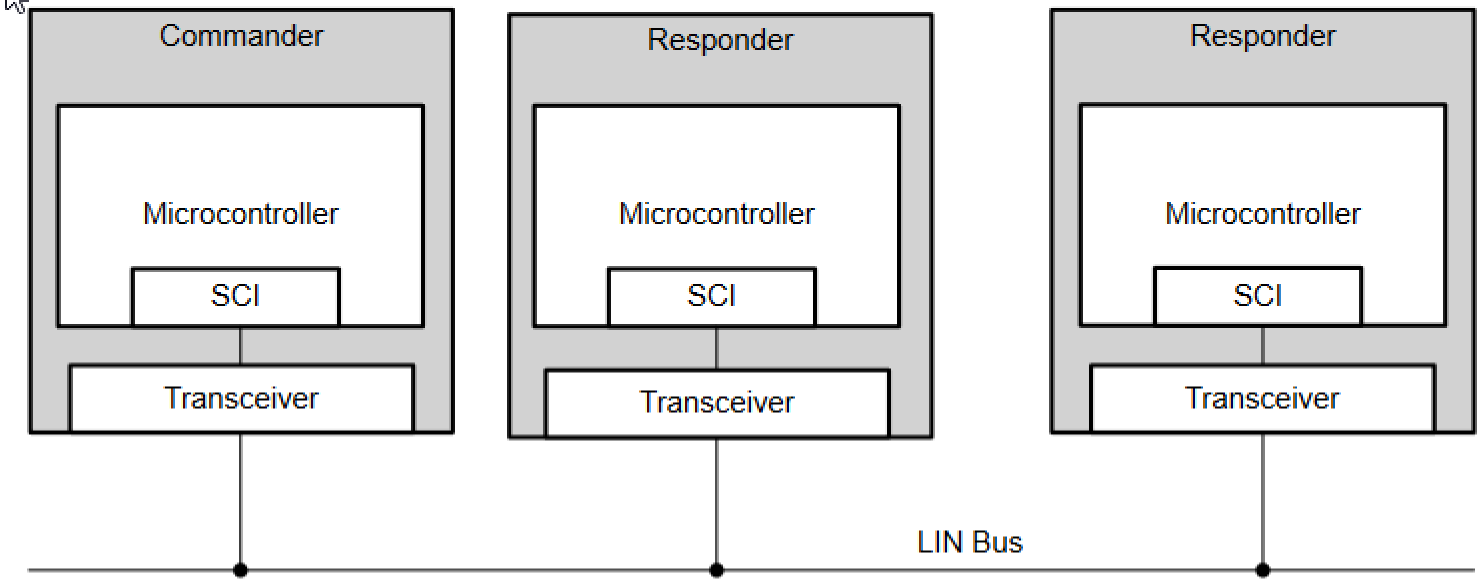


Figure 2-1. High-Level LIN Transceiver in Network

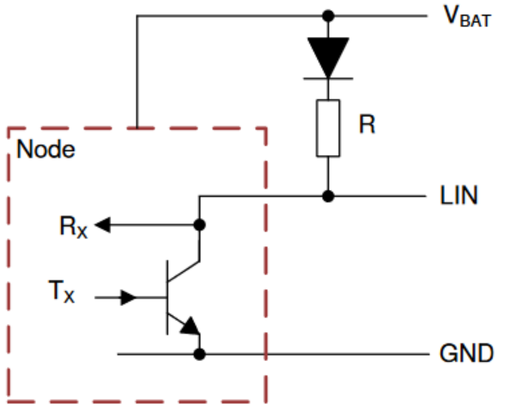


Figure 3-1. Simplified LIN Driver Schematic

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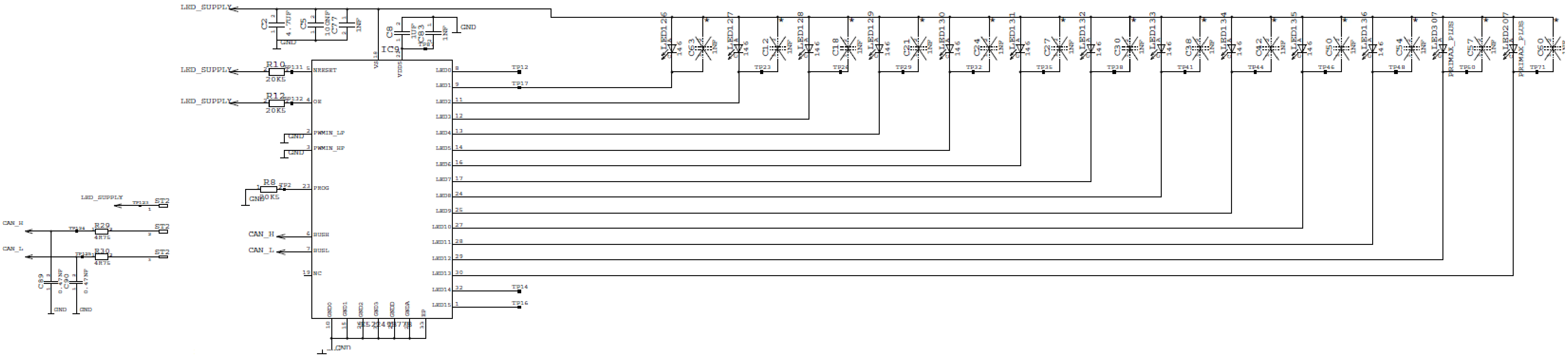
LIN and CAN bus connection for example connection and EMC troubleshooting

First example (problems with CCS)

The first example represents a case, where a problem appeared on UARToverCAN bus, which connects a smart CCS driver and ECU. When RI Emmisions were forced, using a log periodic antenna, LEDs on one smart CCS flickered. Solutions: An RC filter was placed in series with the group of smart CCS controllers, located in the middle of the bus. Additional conclusion: Smart CCS Controllers transceiver is weak compared to the UARToverCAN transmitter on the MCU‘s side. Most of the immunity is achieved with CCS which incorporates a powerful transceiver.



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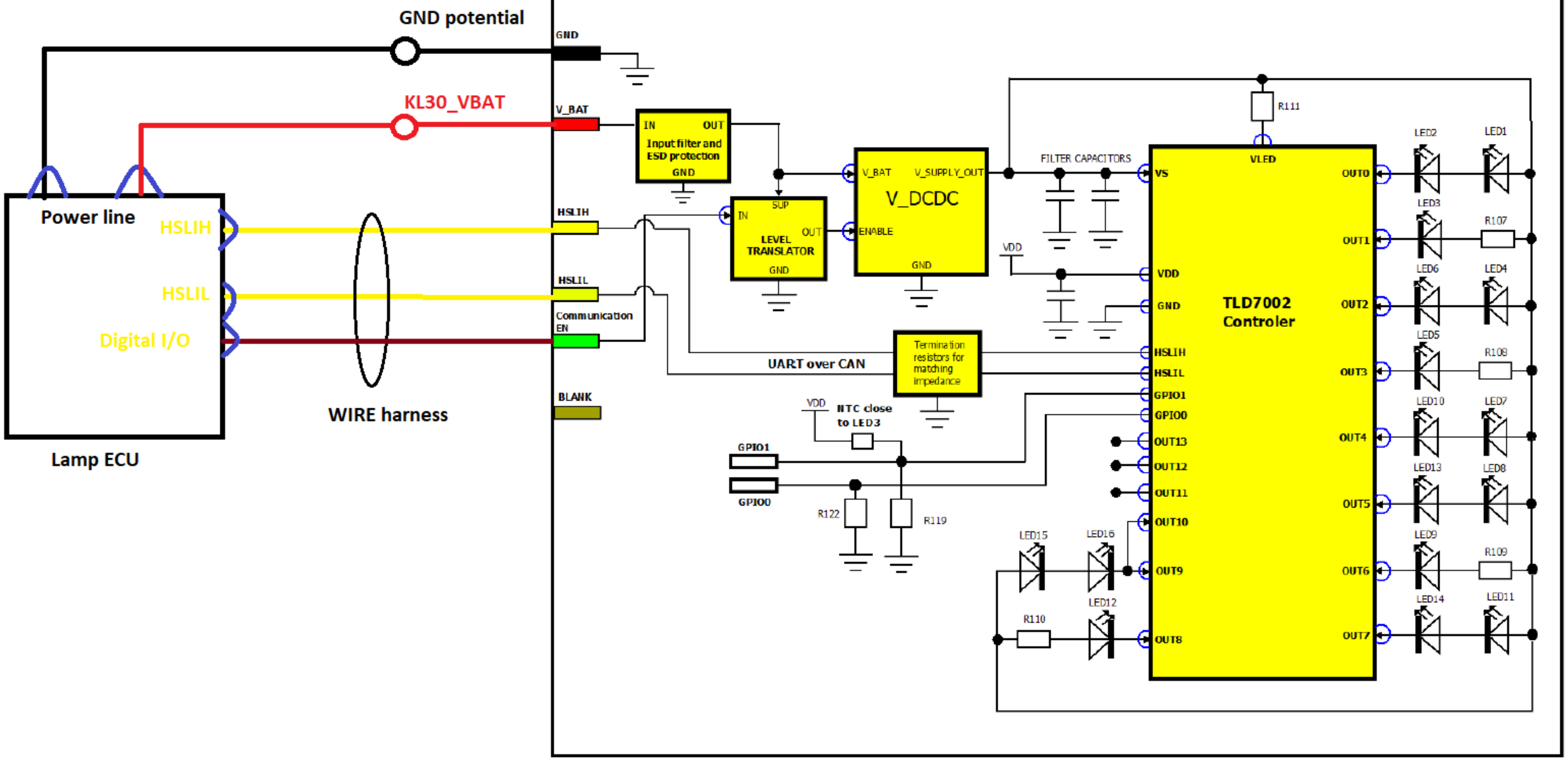
Second Example (Measuring emissions levels)

In the second example, CE and RE levels were observed from the electronic module and its wire harness, where UARToverCAN was used to communicate with light ECU and its smart CCS controller.



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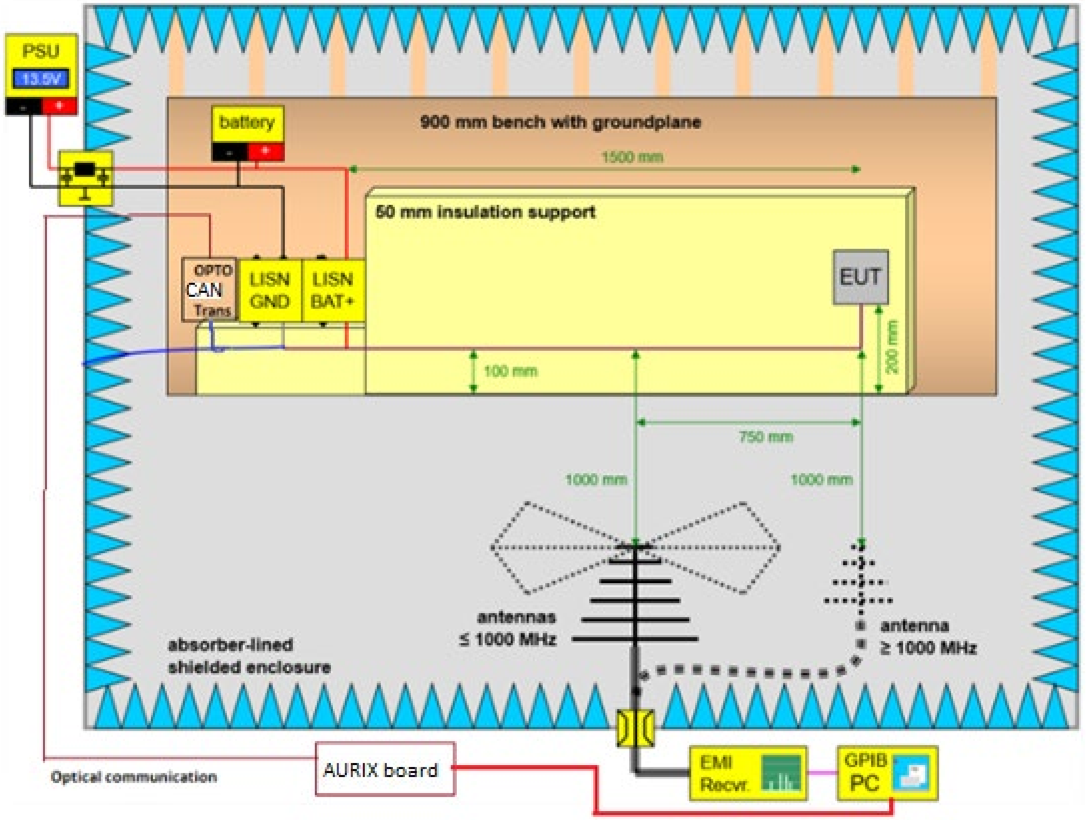
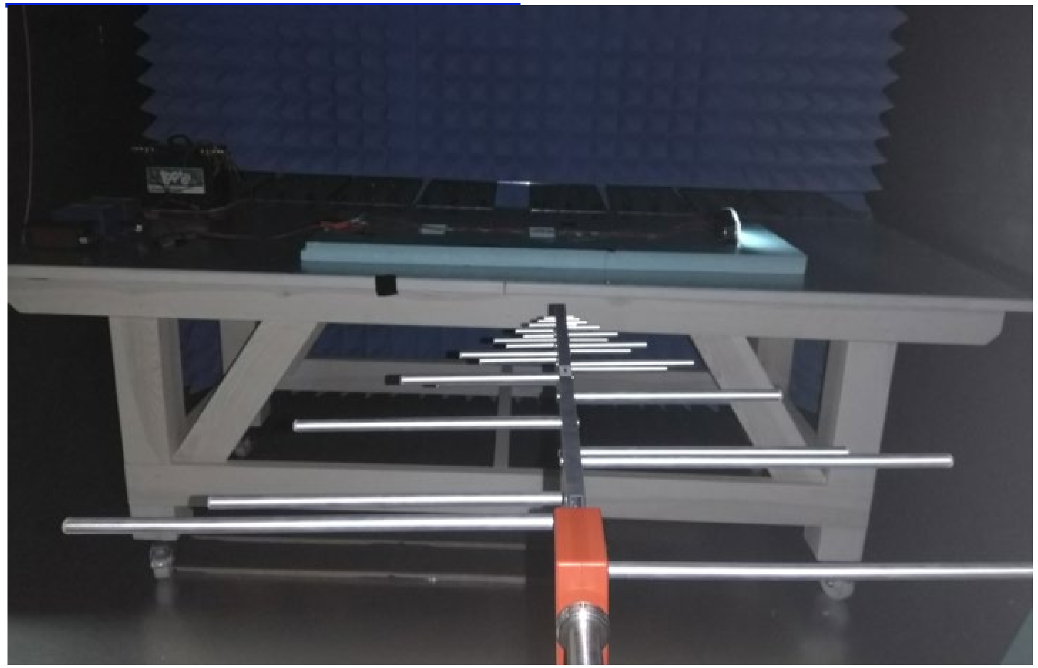
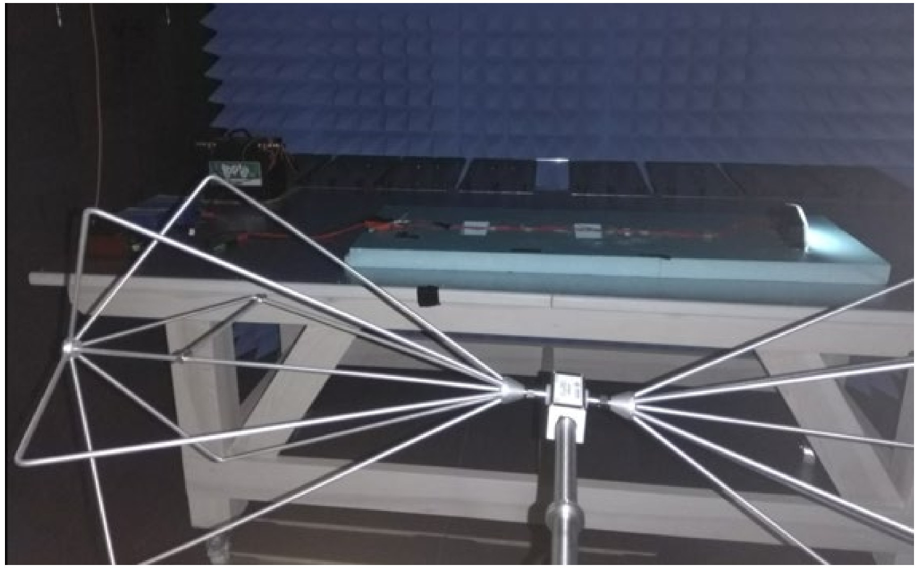
EMC chamber measurement setup for measurement of electronic modules

When measuring RE, procedures have to be followed, which are described in the automotive norms document (example TL81000, GMW3172). They include a required setup and the radiation levels, that the antenna must emit. A setup is shown in figure bellow.

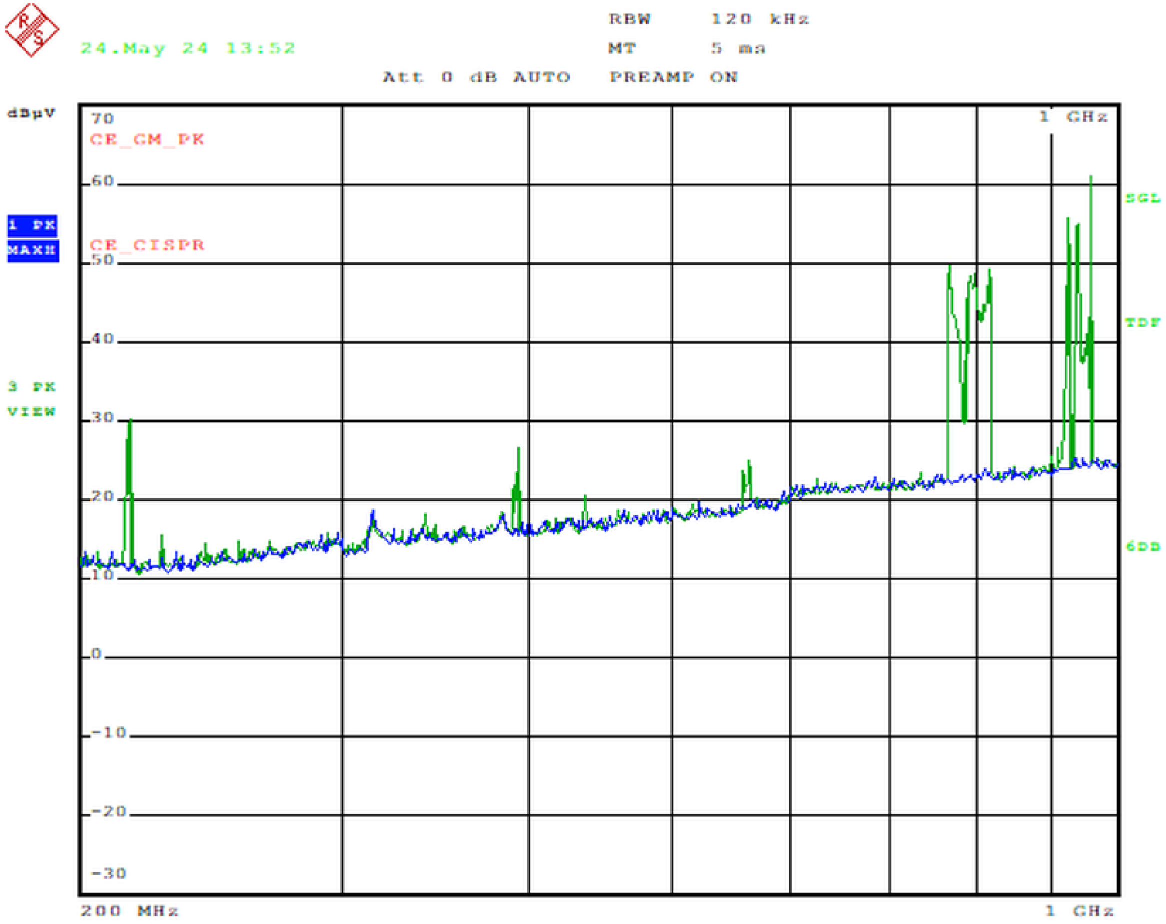


Antena, DUT and wire harness positions



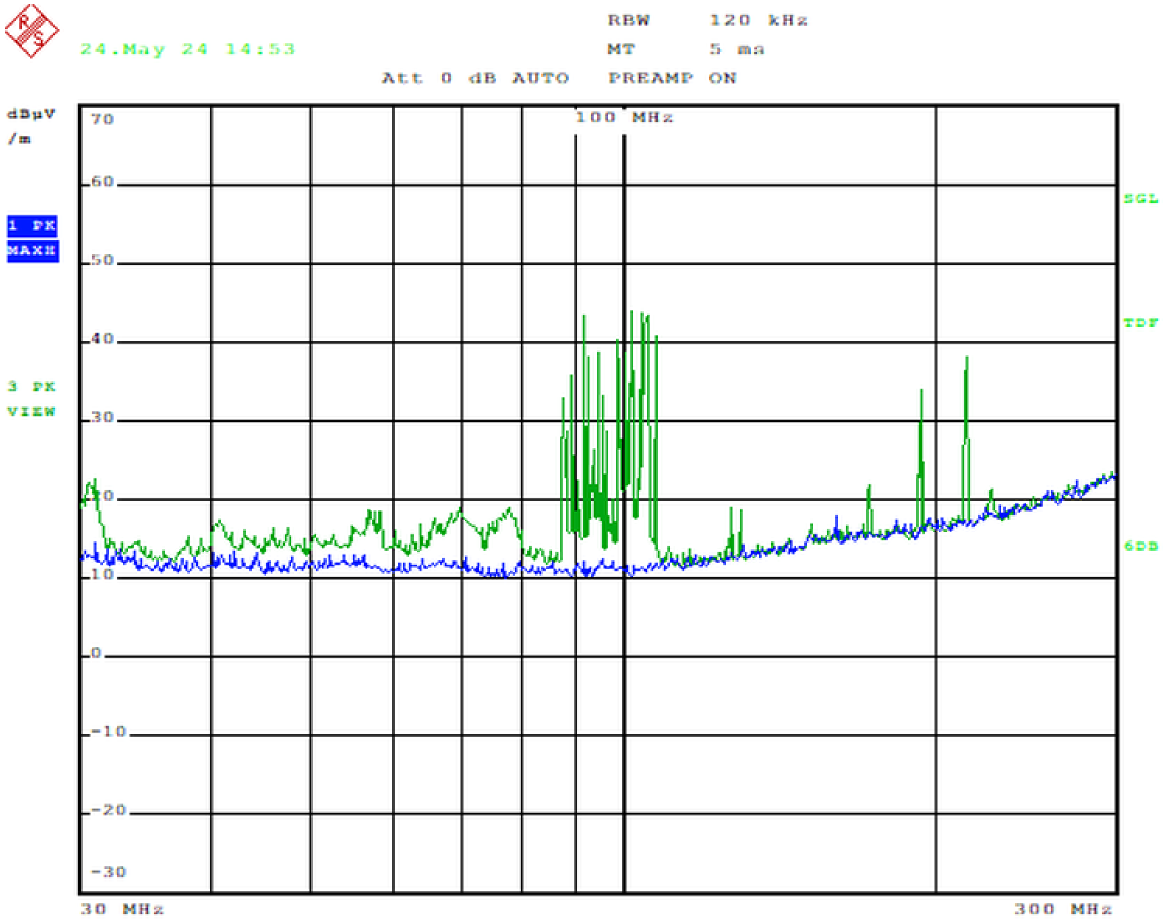


Circuit radiated emissions results with logper and bicon antena



Radiated emissions = Testing the antenna with an open EMC chamber, to confirm that it properly detects outised noises.

Radiated emissions = Testing circuit operation when LEDs are dimmed, using a square shape current with 70 % duty cycle at a frequency of 400 Hz. The slew rate of the duty cycle was disabled as well as phase shifting.



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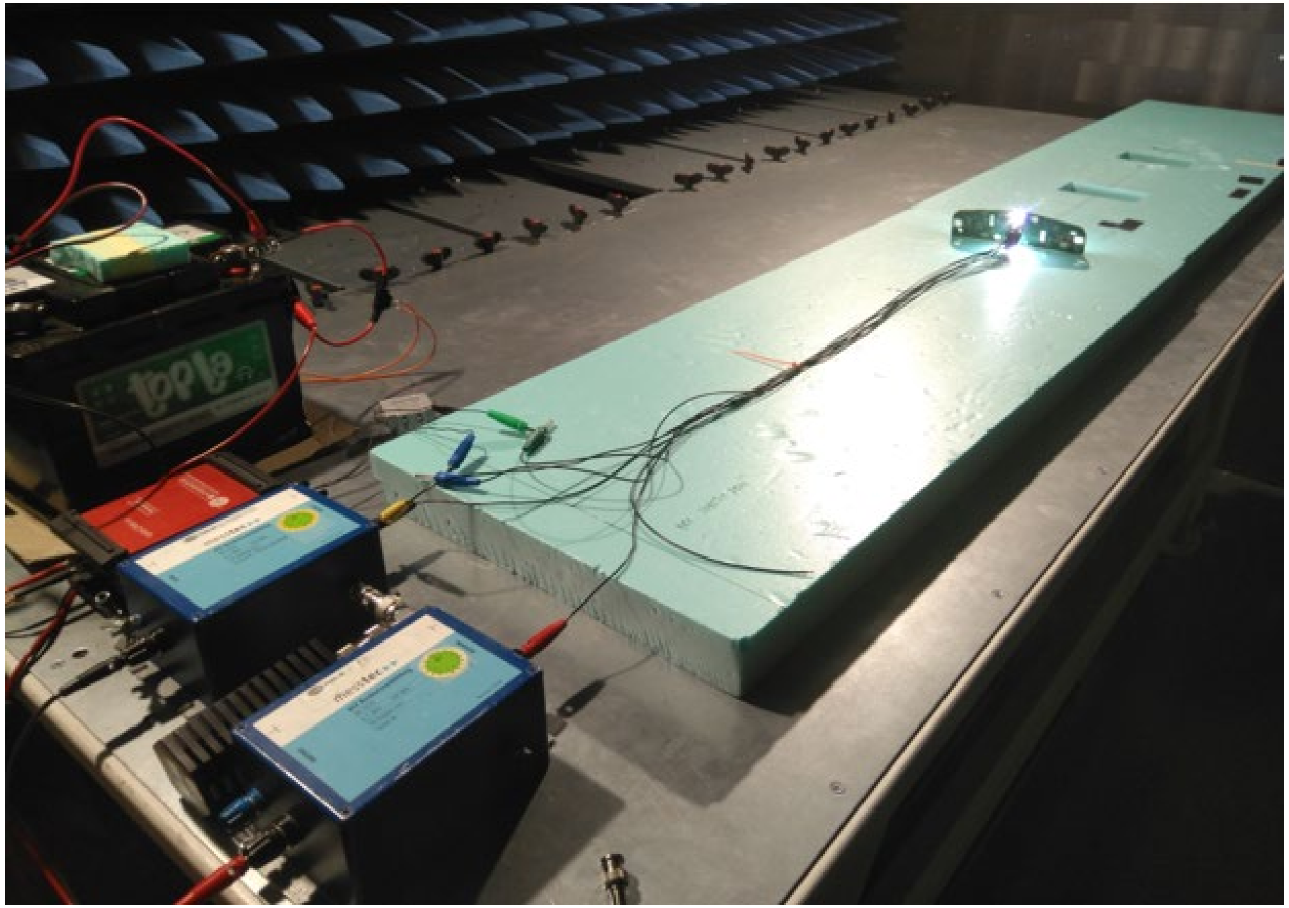
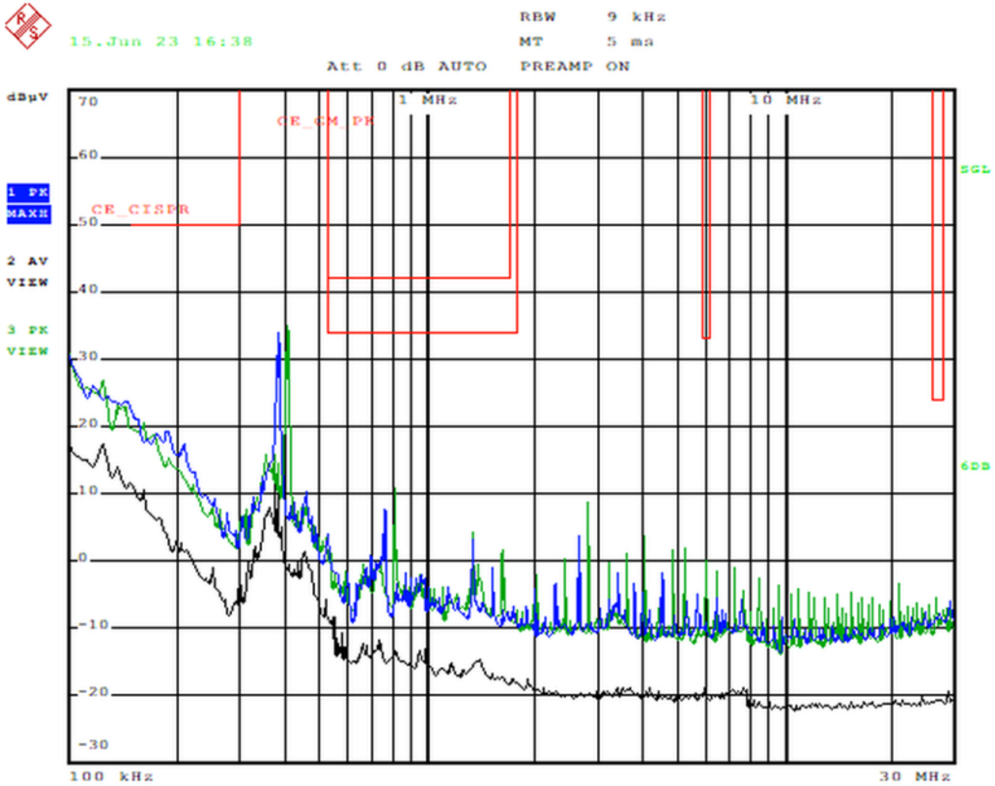
Conducted emission measurements and results

Conducted emissions were measured simmilar way, except that wire harness from LISN‘s and Opto CAN were shorted. A figure of how they were done is available bellow:



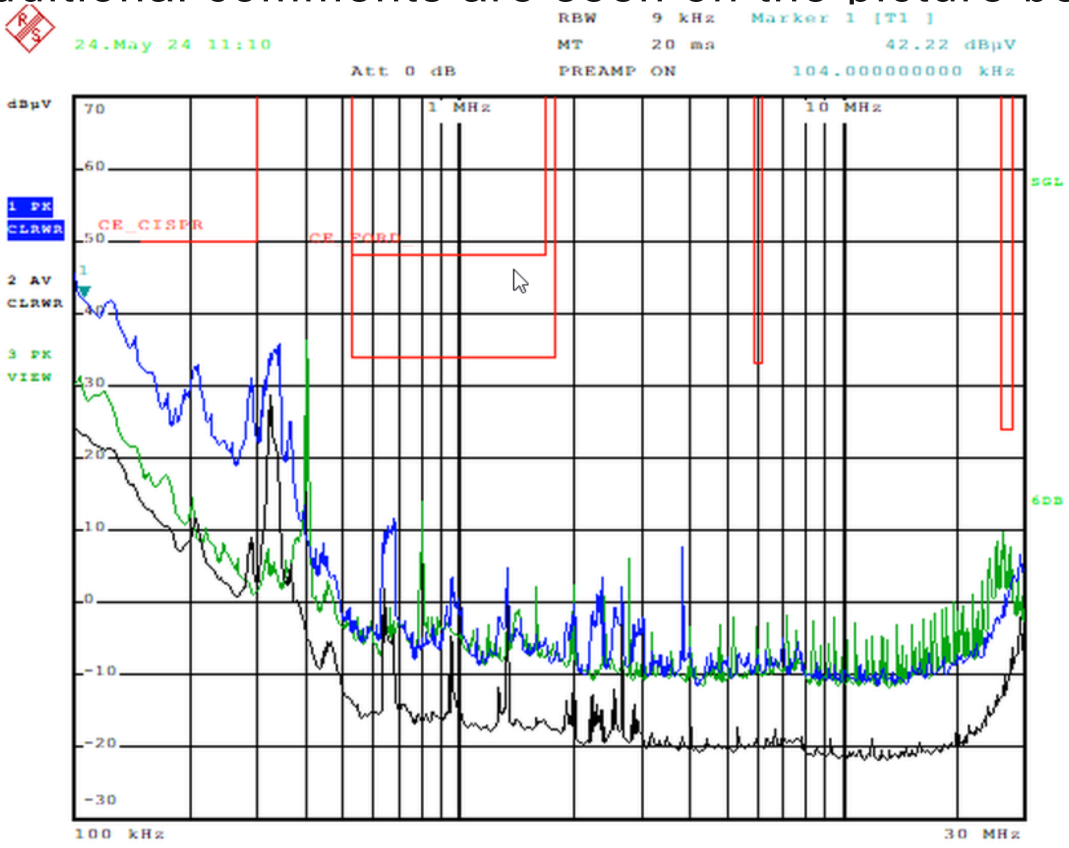


green line = Conductive emissions measurement results on BT1YL Logo when all LED strings consume 76 mA electrical current. Therefore, higher power appears on module itself.

Blue line = Conductive emissions measurement results on BT1YL Logo when all LED strings consume 36 mA electrical current. Power consumtion reduces however, conductive emission results do stay inside the legal limits and higher harmonics do reach even lower levels.

Circuit conducted emissions with EMI saftey levels disabled

The diagram below shows conducted emissions at full brightness and applied dimming at 70 %. Additional comments are seen on the picture bellow.



Conducted emissions = Board operating with full performance, DC/DC has steady switching frequency

Conducted emissions = Board operating with 70 % performance, Led current Duty cycle active with phase shifting

D5 sys, wMelco, g orig vs y UART mod FS CLMM and FS MXB

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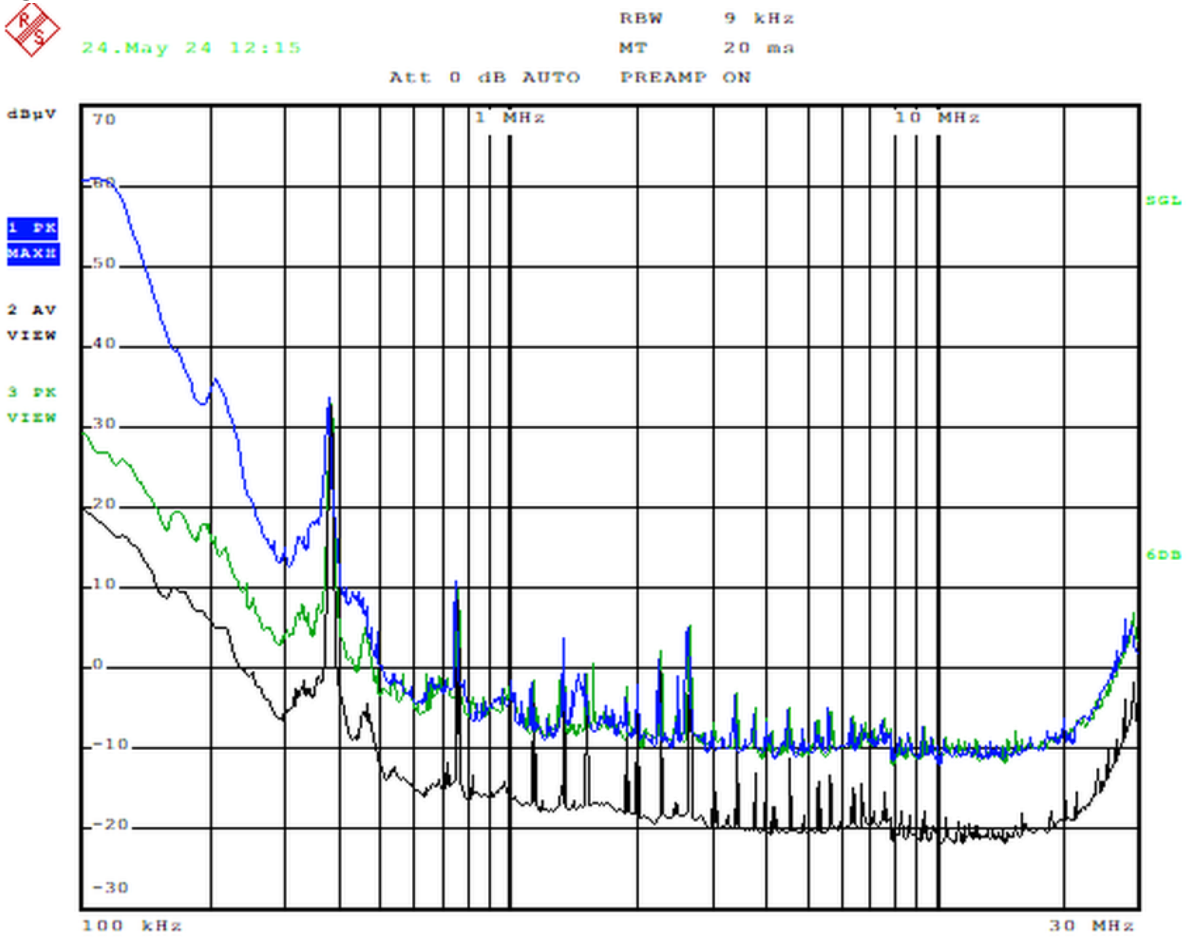
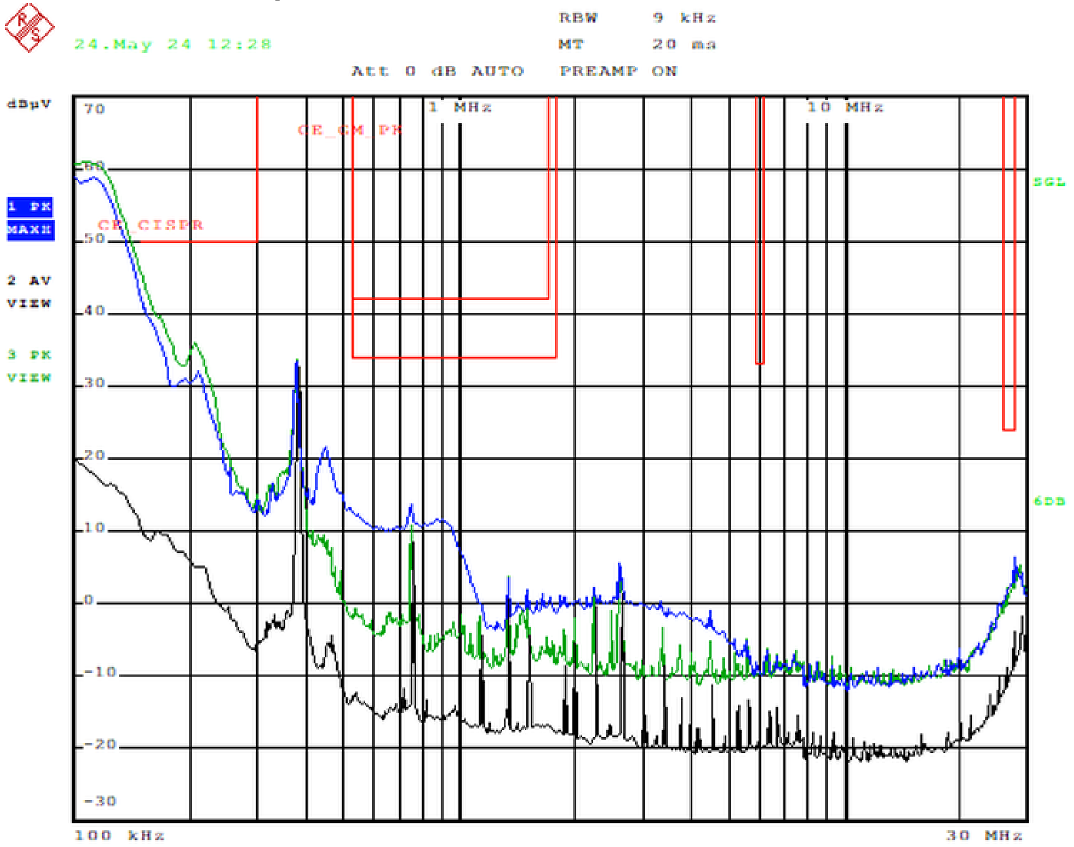


Conducted emissions = DUT full load operation with phase shifting applied and slew rate ramp active

Conducted emissions = Duty cycle on LEDs applied with 70 % value. Phase shifting here is disabled, which means that all LEDs simultaneously turn ON and OFF.

Circuit conducted emissions with EMI saftey levels disabled follow up

The diagram below shows conducted emissions at applied dimming at 70 %. Additional comments are seen on the picture bellow.



Conducted emissions = Duty cycle applied on LEDs with 70 % value with phase shifting disabled. Slew rate during LED dimming with PWM is enabled.

Conducted emissions = Duty cycle applied on LEDs with 70 % value with phase shifting disabled. Slew rate during LED dimming with PWM is disabled.

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BCI (bulk injection current)

Forcing bulk injection current on wire harnesses is one typical test, that needs to be done on the lamp component level. Figure bellow represents one example of it and results:

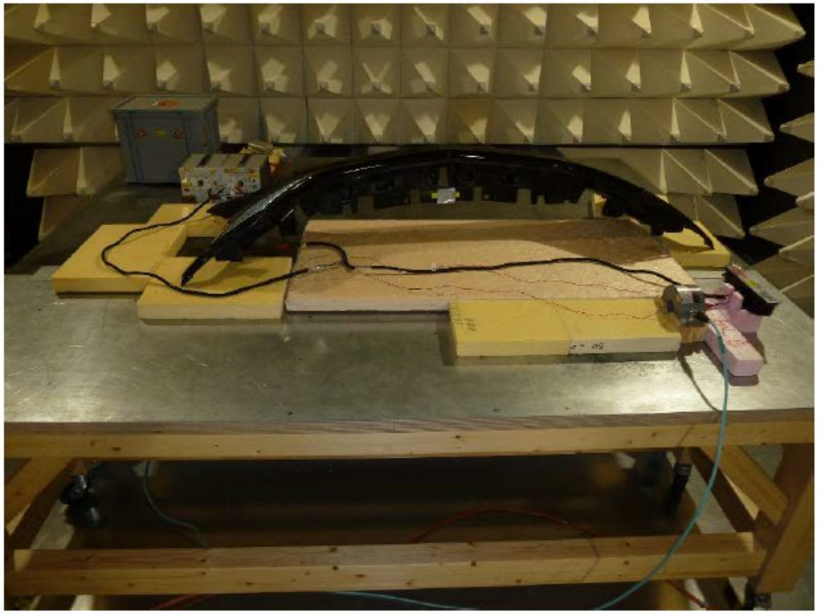

Figure 1: test setup

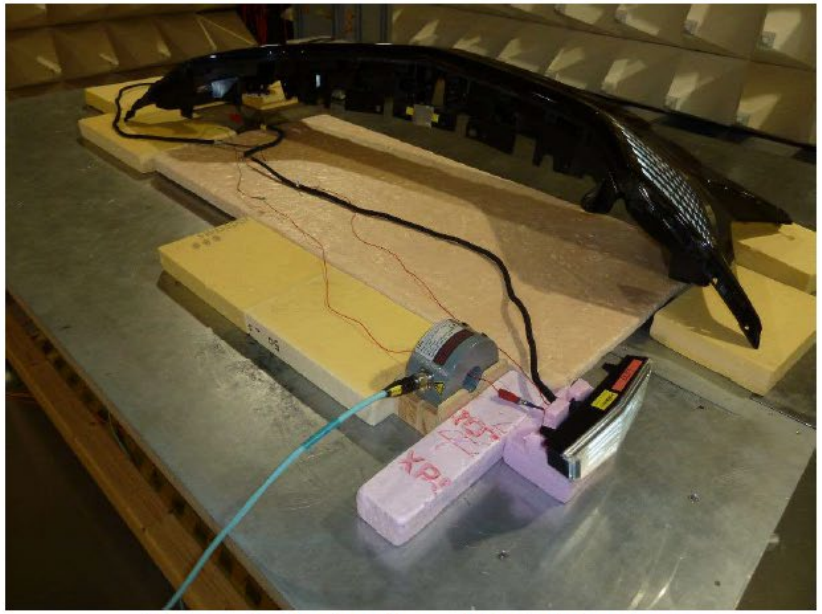

Figure 2: test setup, DUT side view

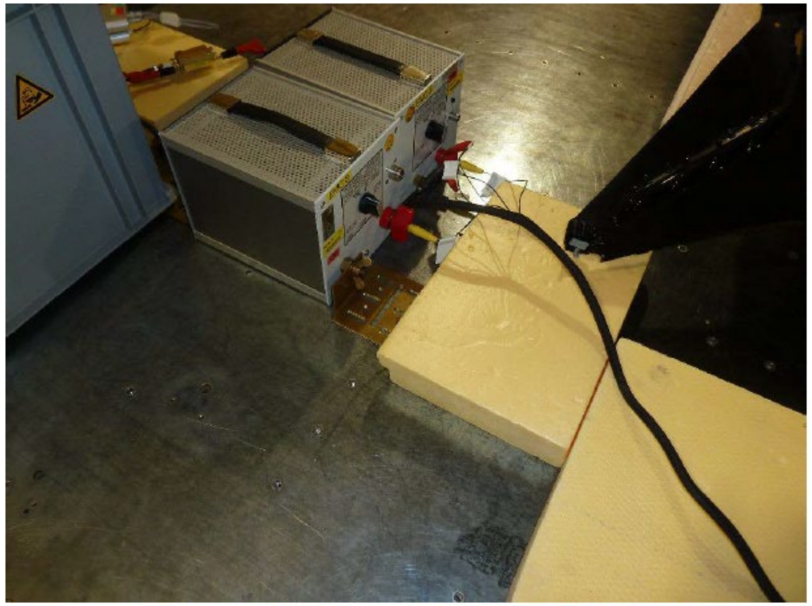

Figure 5: Connection LISN to harness

Figure 7: monitoring screen

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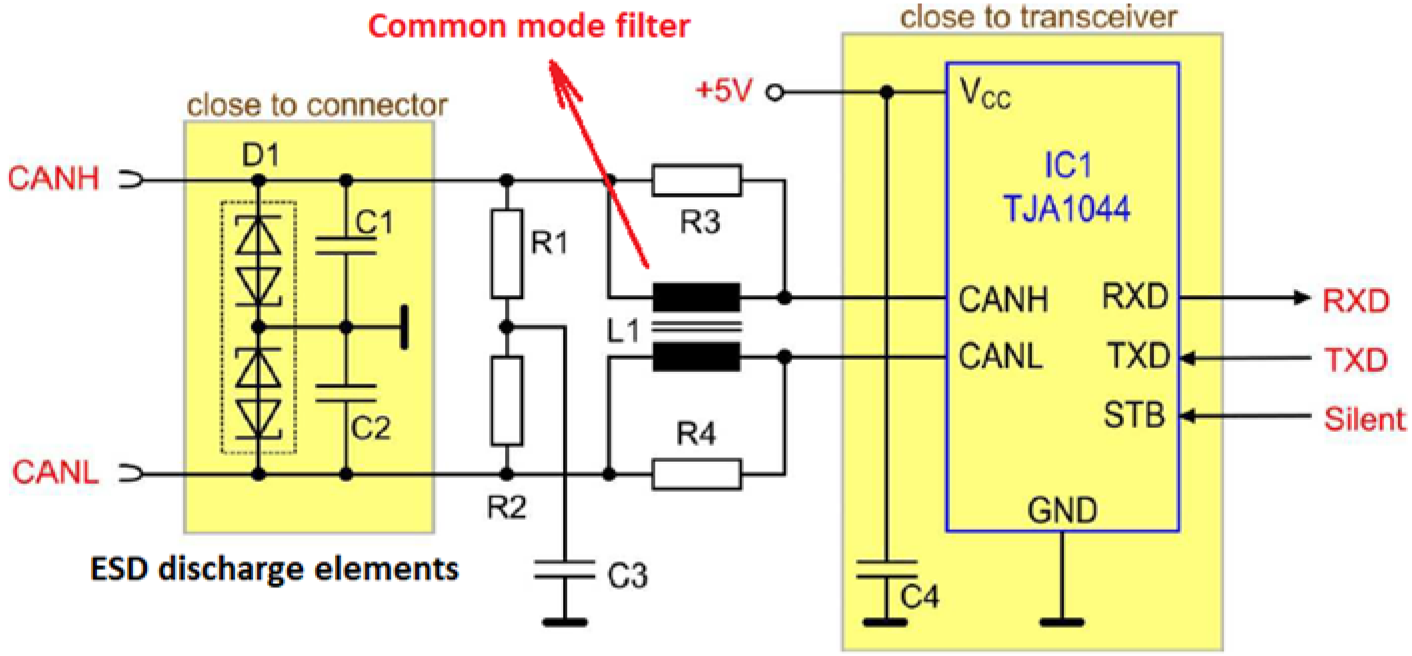
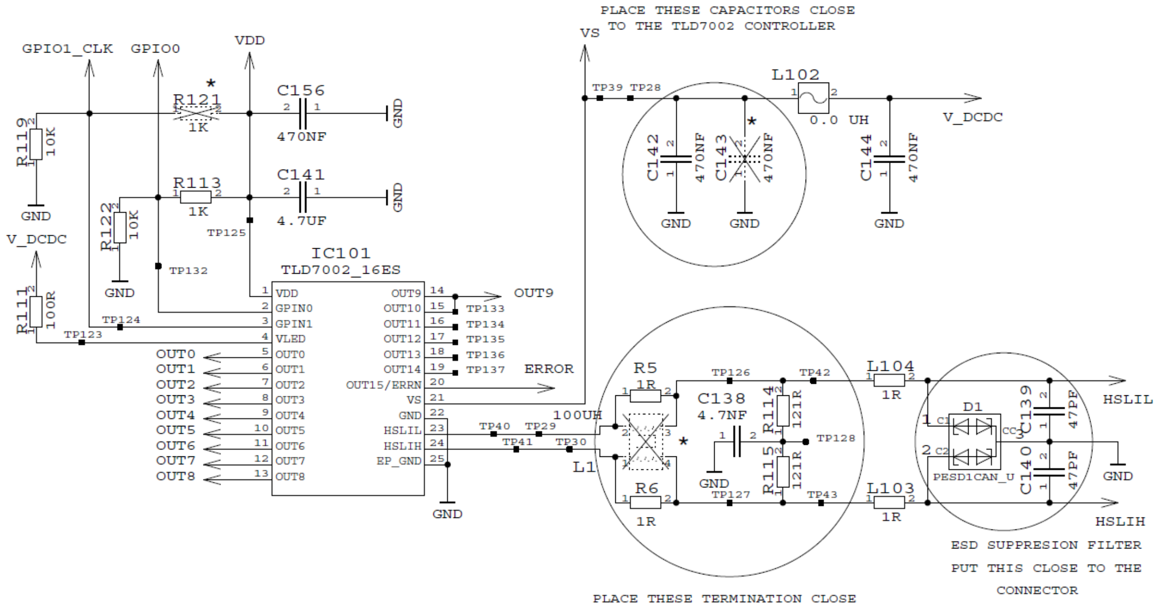
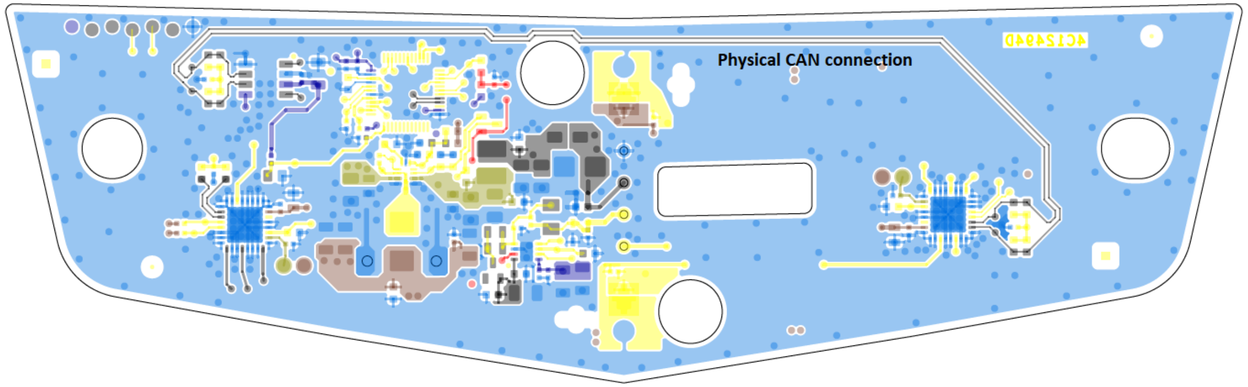
Suggestions for solving problems with RI and BCI on physical CAN bus

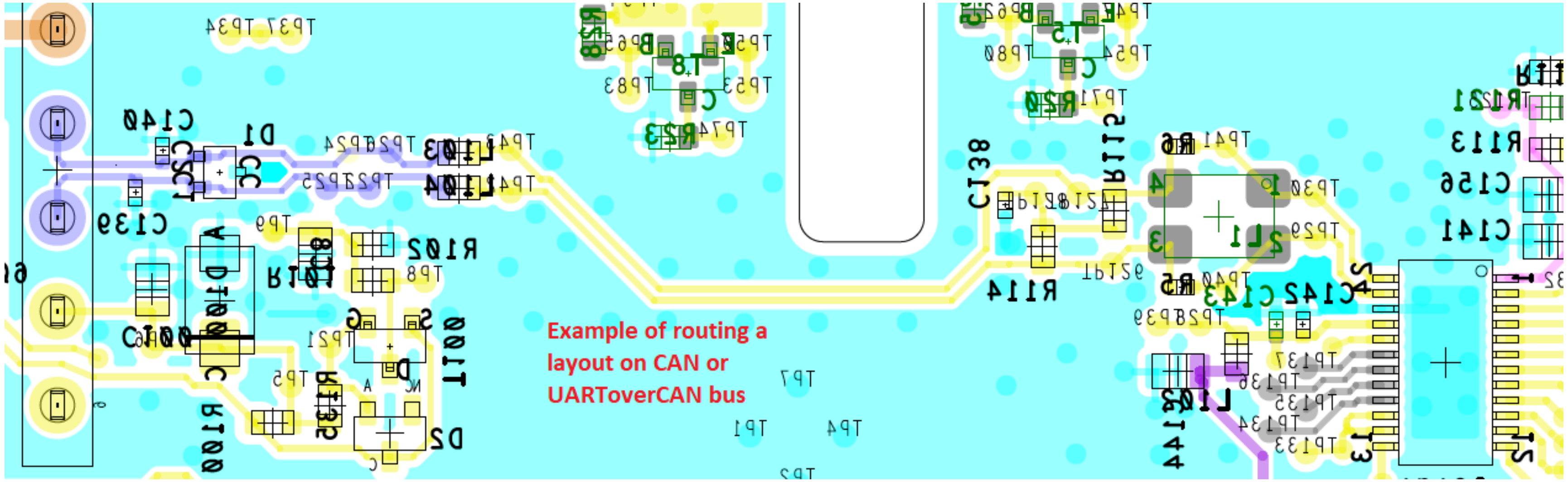
Troubles with EMC emissions are unpredictable in almost all cases. Therefore, here are some suggestions of how to cope if the troubles arise during the. The basic required connection at each end is of course termination with 120 Ohm resistors. If a fail appears, some additional filtering elements can be added. See the figure below:



Two examples of how to route and connect physical CAN on layout level:







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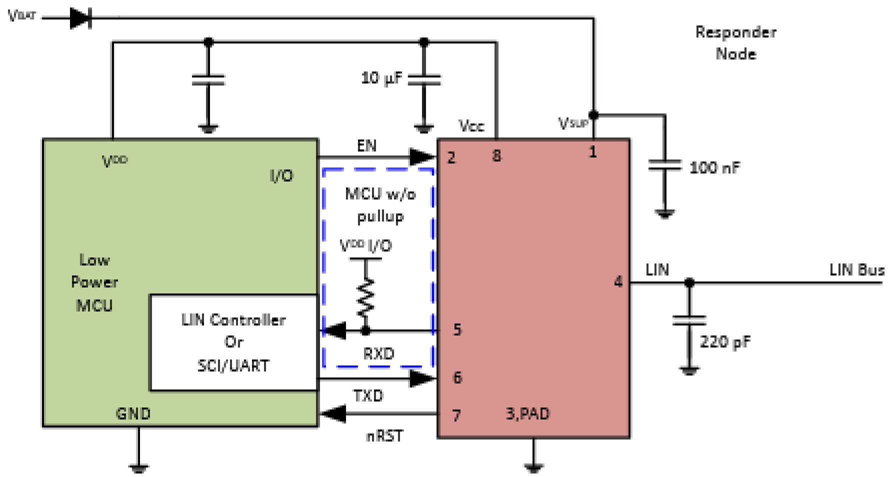
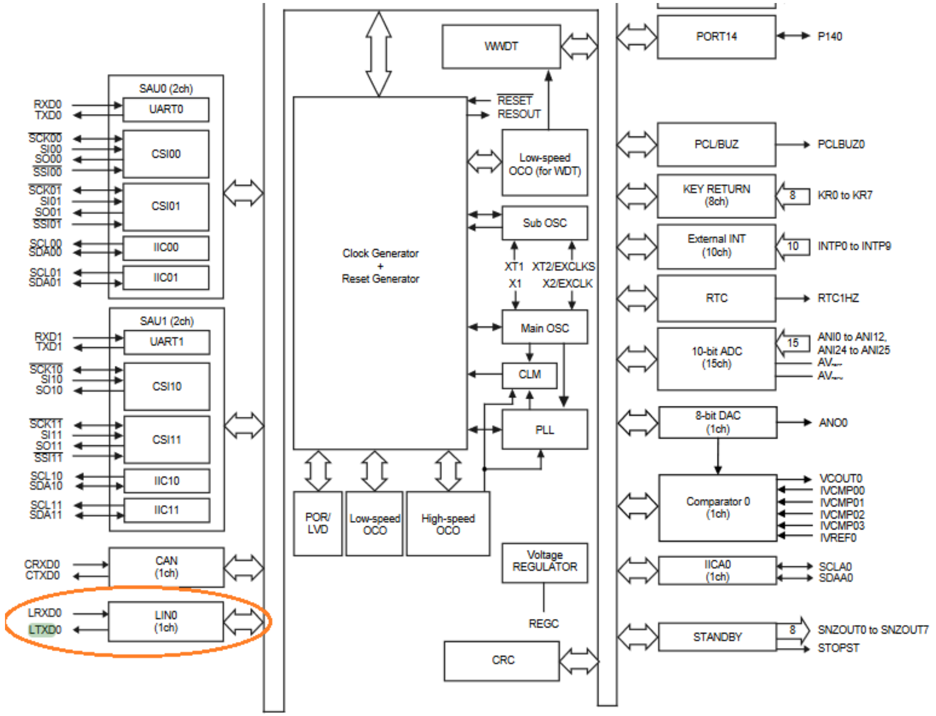
Suggestions for solving problems with RI and BCI on LIN bus

As well as for CAN, there are also some troubleshooting suggestions for solving problems, if they do appear on LIN BUS. Most basic connections with node ECU represents picture bellow on the right. Caution: When connecting the LIN transceiver, make sure that ECU accepts LIN signal on it's UART pads. Picture on the right shows an peripheral example, that accepts LIN messages.

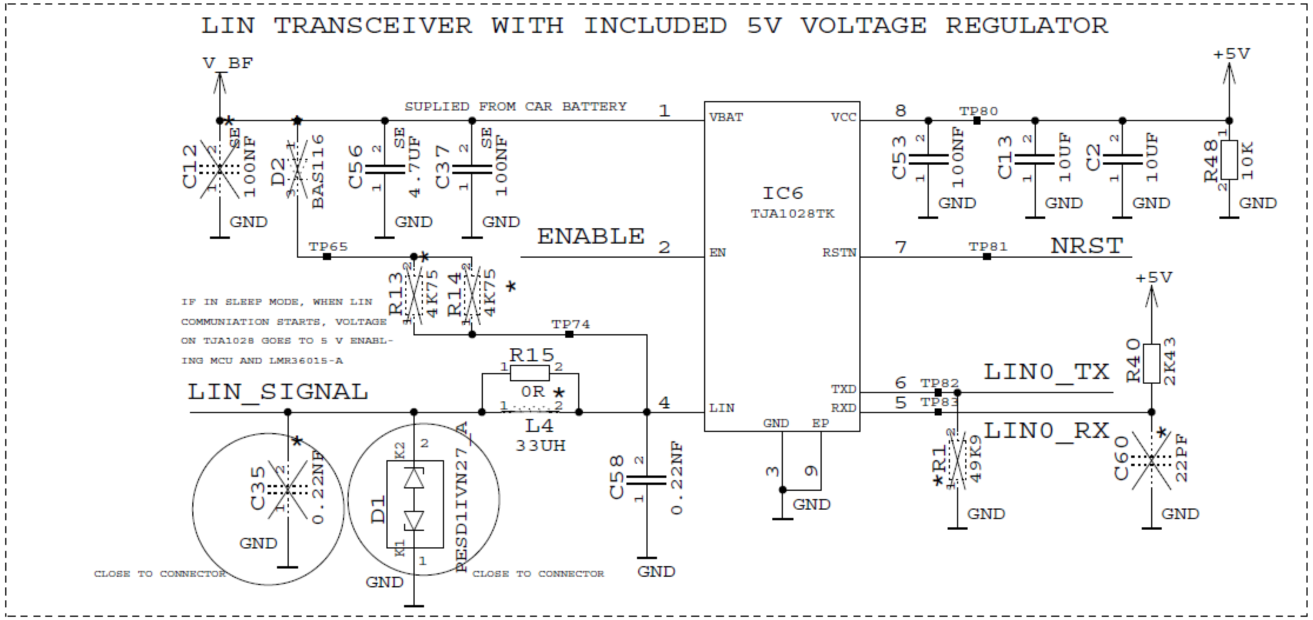


Fundamental LIN connection to node's ECU. There is a LIN transceiver, which translates signal levels to physical UART bus , which connects ECU



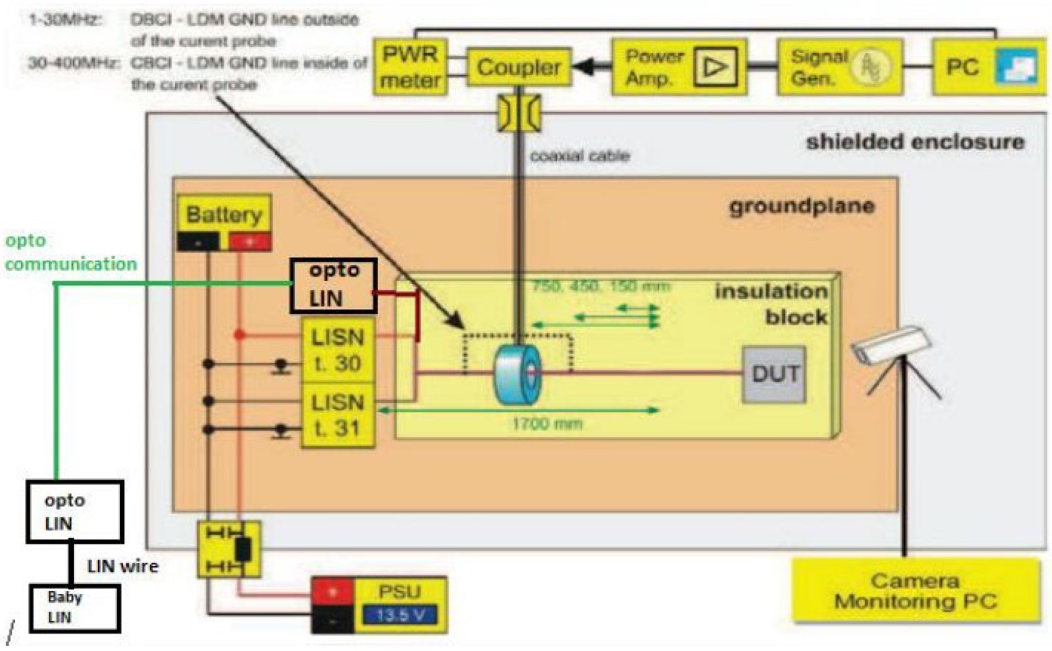
Suggestions of how to connect LIN on Schematics and route in on layout

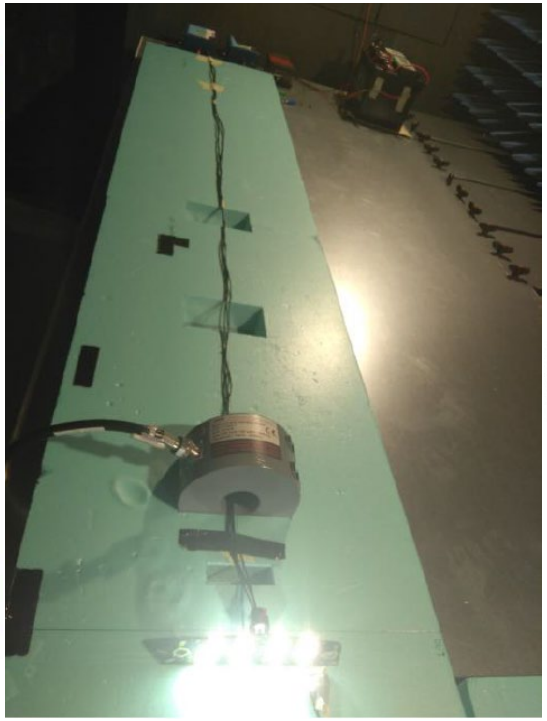
Wiring LIN properly is also essential to achieve good EMC results as well as using a proper transceiver circuit with a strong transmitter. However, there are also some additional electric elements, that can help solve immunity problems, if they appear on the LIN. Here is an example circuit diagram. Routing should also be shielded with the ground potential.

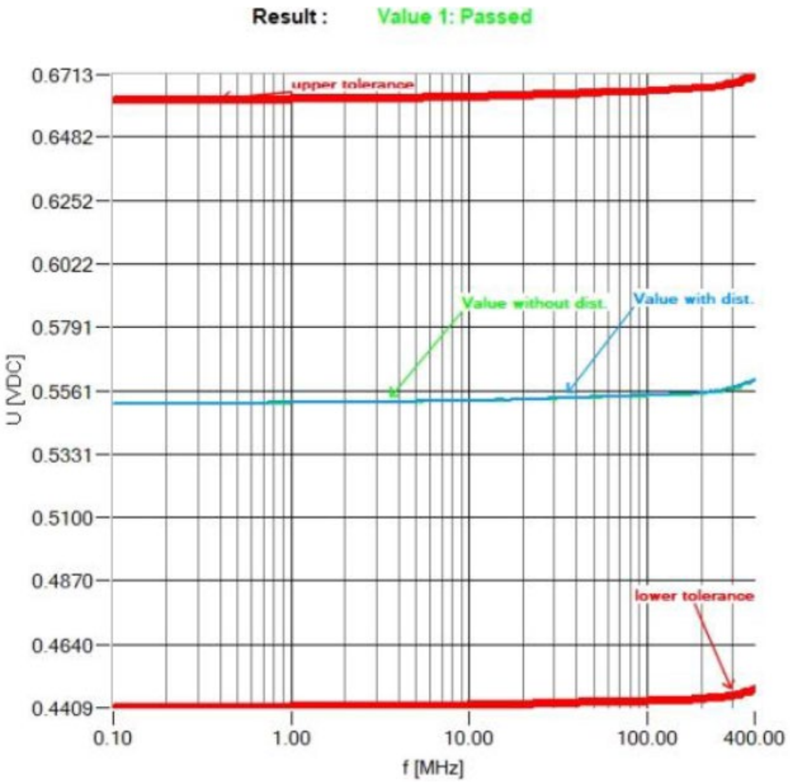


Example of measuring immunity to BCI when LIN signal is applied

Figure bellow represents setup and positions of each element isnside EMC chamber.







List of used sources

1. Wikipedia contributors. "CAN bus." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia, 15 May. 2024. Web. 27 May. 2024.

2. S. Corrigan (Texas Instuments), „Introduction to the Controller Area Network (CAN)", in *Application Report SLOA101B,* pages. 1 – 17, Revised 2016

3. X. Long, J. He, J. Zhou, L. Fang, X. Zhou, F. Ren in T. Xu, "A review on light-emitting diode based automotive headlamps," Renewable and Sustainable Energy Reviews, vol. 41, str. 29–41, 2015.

4. Grant Maloy Smith, What Is CAN Bus (Controller Area Network) and How It Compares to Other Vehicle Bus Networks, February 13, 2024, [Online], Accessed on: https://dewesoft.com/blog/what-is-can-bus [last time accessed on 27/05/2024]

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