How to protect TLE4921-5U in harsh EMC environment

Guideline for satellite module design

Scope and purpose

TLE4921-5U is a well established cam, crank and transmission sensor in automotive 4 wheeler application.

This document is addressing the upcoming 2 wheeler market. More and more OEM are going to introduce active semiconductor sensors on their 2 wheeler. The protection of satellite modules is partially difficult as only few electronic circuits are on the vehicle.

As the application is in cost sensitive environment Infineon will give guidance how to implement the minimum needed protection circuit and how to design the pcb (printed circuit board) in the module.

Intended audience

Module designer of satellite sensor and responsible designer for cable harness on the 2 wheeler is recommended audience.

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1 Environment

Semiconductors are basically built of transistors, diodes, capacitors and resistors integrated on one piece of silicon. As very small structures are integrated on a few square millimetres an external voltage-surge or current surge may harm some of these structures. Even a small harm may lead to a non functional device.

1.1 EMC

EMC is the abbreviation for "Electro Magnetic Capability" and sum up a large family of electro magnetic distortion. We distinguish between:

- RE: Radiated emission is not a problem for the sensor as these emissions are generated by the device and might disturb other circuit around.
- CE: Conducted emission is similar as radiated emission and uses the connecting wires to distribute distortion to other parts of the electrical circuit.
- **RI: Radiated immunity** means radiation from anysource is affecting the sensor and causes harm to the sensor. The harm might be permanent or temporary. The following sources of RI are known in the field:
  - A supply wire or a data wire of the satellite sensor is near the alternator or powerful electric motor and catches distortion
  - In case a supply wire or a data wire of the satellite sensor exceeds the length of half a meter or more in parallel to a wire of a powerful electric motor or relay. The fast transients from switching on and off several Ampere or hundreds of Volts may induce energy in the parallel line of the satellite. Typically the satellite sensor has an impedance of 1k ohms. A coupled current of 50mA may generate 50V on the sensor line.
- **CI: Conducted immunity** is the highest risk for a semiconductor as electrical power is coupled directly on the sensor wires. The effects are very similar to RI. Different OEM worldwide added additional test as described in ISO 7637 or in LV124.

1.2 ESD

ESD is the abbreviation for "Electro Static Discharge" and basically refers to a harm that happens when two different voltage levels discharge. In worst case the different voltage levels are balanced through the sensor. In the automotive industry the HBM and the MM are of interest:

- HBM: Human Body Model is a certain circuit of capacitor and resistor to simulate the discharge using a human finger.
- CDM: Charged Device Model has less impedance and is equivalent to a discharge between pars of a robot or any kind of machine.

The mechanism is to apply several thousand volts between the discharge point and ground. According to HBM or CDM a specific coupling network is applied to the discharge point. Now the discharge point which can have the shape of a needle or of a finger is moved closer and closer to the device under test. At a certain time the distance is small enough and through a spark the energy will discharges to the grounded device.

The sensor has a protection circuit (Zener diode) to prevent from being permanently damaged.

ESD is typically not the problem in the running application.

2 Protection circuit

We distinguish between internal protection and additional external protection.

2.1 Internal protection of TLE4921-5U

As mentioned in the datasheet TLE4921-5U has a basic protection against electrical stress.

The protection devices are in addition to a ESD protection which is not shown in the datasheet. Pins 1 (“Vs”), 2 (“Q”) and 4 (“C”) have ESD protection device. Please find the rating of ESD-diodes in the datasheet in table “ESD Protection”.

2.1.1 Pin “Vs “

The supply pin has two diodes implemented. The first diode is called “protection device” and is used to block negative voltage. The Zener diode is the next mechanism and protects the internal supply-rail from too high positive voltage. Please find the rating of the protection diodes in the datasheet in table “AC/DC Characteristics”.

To ensure the Zener diode is not harmed by electrical over stress we recommend a resistor in series to “Vs” to limit the current through the protection device.

2.1.2 Pin “Q”

The output pin has only one diode implemented. The Zener diode is the mechanism to protect the internal supply-rail from too high positive voltage. According to the characteristic of a Zener diode a protection against negative voltages is implemented as well. Please find the rating of the protection diodes in the datasheet in table “AC/DC Characteristics”.

To ensure the Zener diode is not harmed by electrical over stress we suggest a resistor in series to “Q” to limit the current through the protection device.

2.1.3 Pin “C”

Pin “C” has no additional protection. For the function of TLE4921-5U it is mandatory to add a capacitor close to the pin. No further wiring across the pcb is recommended. Wire length should be less than 20mm.

2.2 External protection of TLE4921-5U

In satellite modules it is mandatory to place additional passive protection components in front of the sensor to limit the external energy of electrical distortion.

2.2.1 Standard protection as used in satellite modules

Additionally to the mentioned application circuit we strongly recommend to add a resistor in series to “Q” in order to limit the electrical power. In this case the Zener diode sees less energy as already the resistor and the capacitor absorbes the major part of the external energy inducted from external.

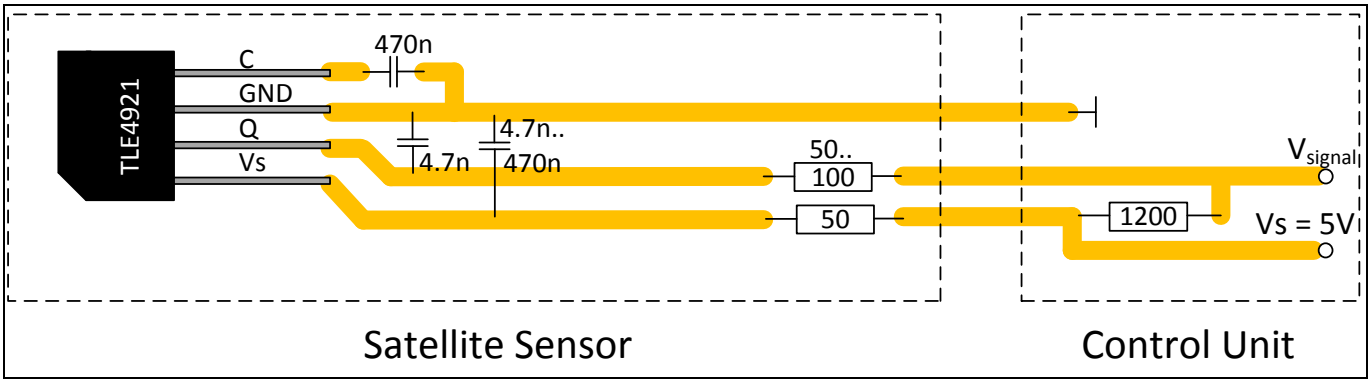

Figure 1 Basic EMC protection for satellite sensor module

2.2.2 Extended protection as used in satellite modules

For harsh environment we recommend additional external Zener diodes. The internal Zener diodes of TLE4921-5U have too less power capability to absorb all the energy coming through the wire to the satellite module.

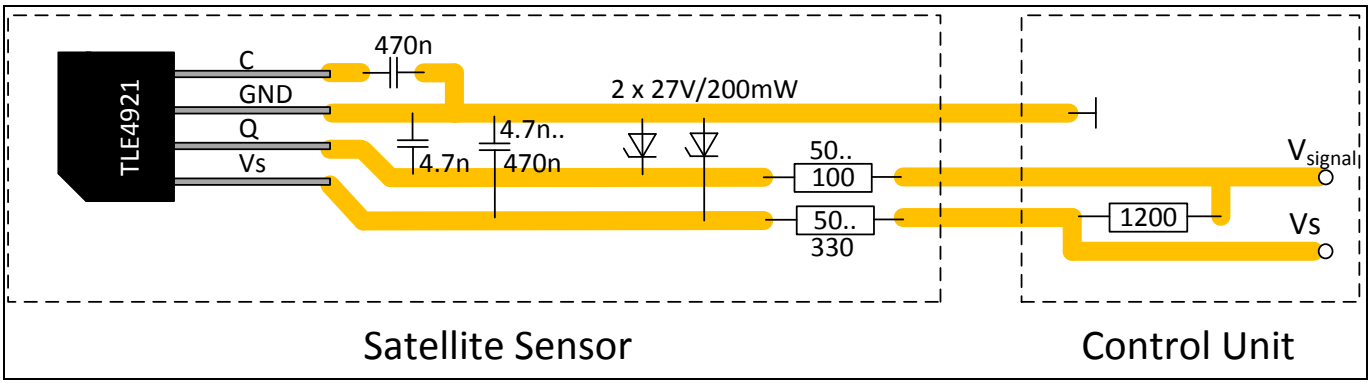

Figure 2 Basic EMC protection for satellite sensor module

2.2.3 Extended protection as used in satellite modules for extreme harsh conditions

We recommend a stronger Zener diodes with 500mW or more instead of 200mW for extreme conditions like no regulated voltage supply and additional bad wiring of the cable along the alternator. Further the Zener voltage shall be adjusted to smaller voltage like 24V to guarantee absolute maximum ratings of TLE4921-5U will not be exceeded. An update of this document is planed to specify energy which can be absorbed by TLE4921-5U.

Characteristics of Zener diode: Zener voltage will increase with current through Zener diode. The specified value is typical at 1mA current through Zener diode.

3 Module design of a satellite sensor

Some recommendations for the layout of a pcb to take the maximum effect of the used components on the pcb:

- Wires as short as possible.
- A ground plane is preferred as an external distortion is typical high frequency. The ground plane will act as a capacitor and shorten the RF before sensor is reached:
    - The capacitor shall be in between the connector and the sensor. So the RF will go along the leads and will be “shortened” at the capacitor.
    - SMD capacitors are preferred as wired capacitors have additional lead length.
- The value of the resistor shall be adjusted to the external distortion.
    - When the value is too high all energy will be absorbed in the resistor and the resistor might blow.
    - In the case the distortion well understood in the application a smaller resistor (value and power dissipation) can be used as TLE4921-5U can absorb some energy as well.
    - When the value of the resistor is too small a lot of energy can pass by and will harm the sensor permanently.
- The connection from GND pin to GND connector should be a straight line on the pcb as all distortion will most propably pass through this line.
- Every Zener diode or capacitor shall allow the RF to pass by using a shorter distance as going all the way to the sensor. Keep in mind: “RF is always searching the shortest path to GND. The sensor shall NOT be this shortest path.”

Following these rules the layout (yellow lines) as in figure 2 will give the best result.

For demonstration purpose the flow of the energy is illustrated in figure 3:

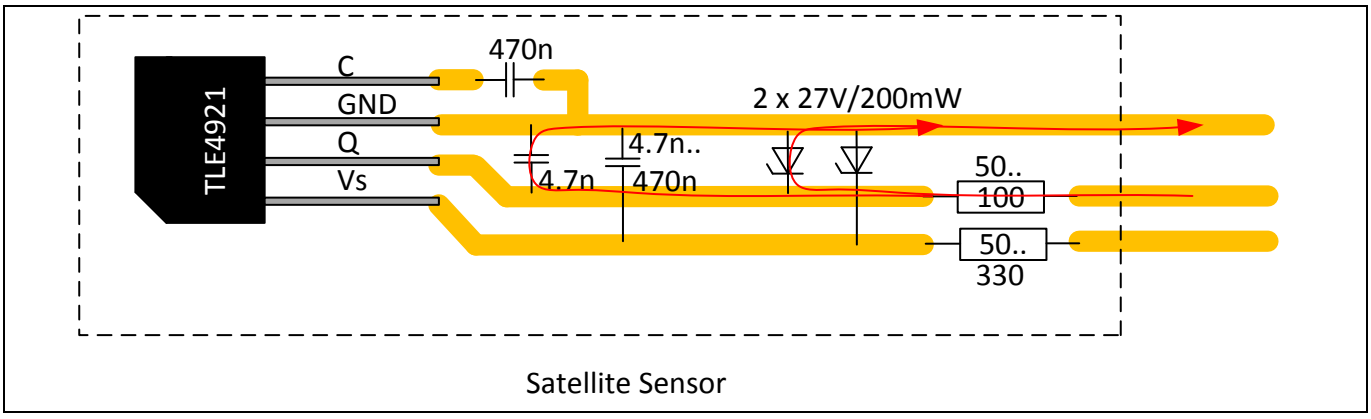

Figure 3 Flow of energy on satellite pcb

Revision history

Document version	Date of release	Description of changes
V 1.0	2019-02-28	Initial version

2019-02-26

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