TLI4971 Current Sensor

EMC & ESD Recommendations in harsh EMC Environment

About this document

Scope and purpose

The TLI4971 is a highly accurate coreless magnetic current sensor. The high-bandwidth output signal is highly linear and without hysteresis. However, a built-in differential measurement principle of output signal helps to suppress the effective electro-magnetic disturbances typically occurring in the applications, such as inverter in-phase current measurements.

This document is addressing the EMC and ESD recommendations for different applications in different environments. More and more industrial applications are going to introduce active semiconductor current sensors on their applications like Inverter Drive, DC-DC Converter and charger applications.

As the application is 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

Current Measurement and detection Module design engineers

Table of contents

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 millimeters an external voltage-surge or current surge may harm some of these structures. Even a small harm may lead to a nonfunctional device. Additionally even small external disturbances may affect the function of a device temporarily.

1.1 EMC

EMC is the abbreviation for "Electro Magnetic Compatibility" and sum up a large family of electromagnetic 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 circuits 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 any external source 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 wires of the current sensor is near the powerful electric motor and catches distortion, e.g., in case a supply wire or a data wire of the sensor exceeds the length of few centimeters or more in parallel to a wire of a powerful electric motor. The fast transients from switching on and off several Ampere or hundreds of Volts induce energy in the parallel 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 customers worldwide added additional test as described in international EMC standards on IC level such as IEC 62132-4 or IEC 62215-3.

1.2 ESD

ESD is the abbreviation for "Electro Static Discharge" and basically refers to a situation of a rapid exchange of charged carriers between objects following a different electrostatic potential. Depending on the situation, either the sensor device itself represents a charge source or becomes part of a discharge path. In both scenarios, the sensor device is exposed to a critical stress situation. For that the sensor device is equipped with specific ESD protection network supporting protection against several standardized ESD discharge models until a certain value.

In the industry the HBM and the CDM are of interest for characterizing the ESD robustness on component (IC) level:

- 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 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.

For ESD protection on application level the placement of additional external components on PCB level (like TVS diodes, Caps, Resistors) might help to achieve desired ESD robustness values.

2 Protection circuit

We distinguish between internal and additional external protection.

2.1 Internal protection of TLI4971

As mentioned in the datasheet, TLI4971 has a basic protection against electrical stress.

The external protection devices are in addition to a TLI4971 internal ESD protection. There is an internal ESD protection for each of the sensor pins up to ±2kV (HBM value) and ±1.5kV (CDM value).

2.2 External protection of TLI4971

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

2.2.1 Standard protection as used in Current Measurement modules

Additionally to the application circuit mentioned in the datasheet, we strongly recommend to add a resistor in series to "AOUT", "OCD1", "OCD2" and "VREF" on the MCU side in order to limit the electrical power. In this case the Zener diode sees less energy as already the resistor and the capacitor absorbs the major part of the external energy induced from external. Here, the care must be taken to design the low pass filter in each path as the band width of the specific pin will get effected. The basic EMC protection topology for current sensor module is shown in Figure 1.

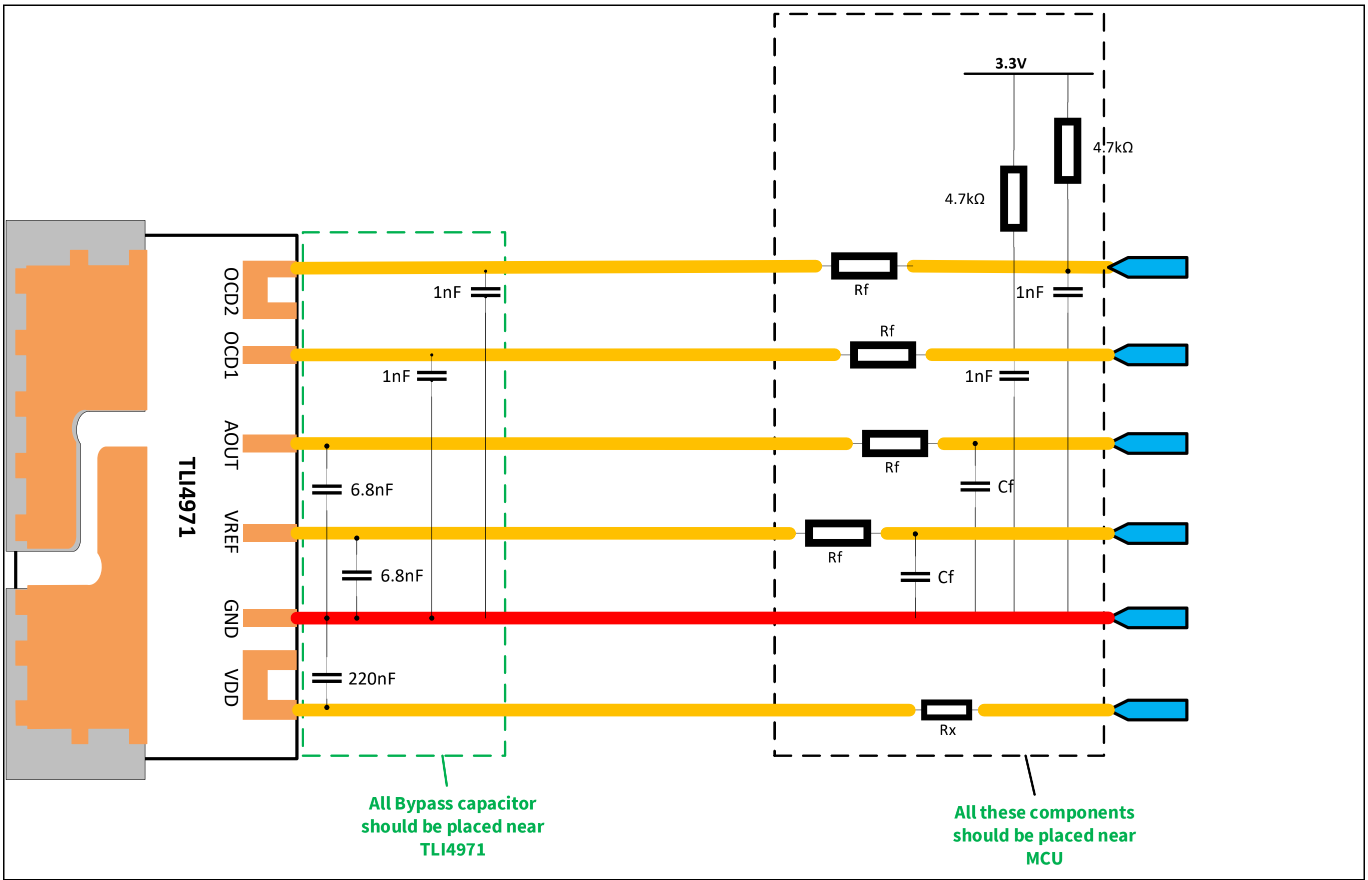

Figure 1 Basic EMC protection for Current Sensor Module

2.2.2 Extended protection as used in Current Sensor modules

For extremely harsh environment we recommend additional external Zener diodes as shown in the below Figure 2. The internal Zener diodes of TLI4971 have less power capability to absorb all of the energy coming through the wire to the current sensor module. In this document, the required zener diode ratings are not suggested as the ratings may vary for different applications.

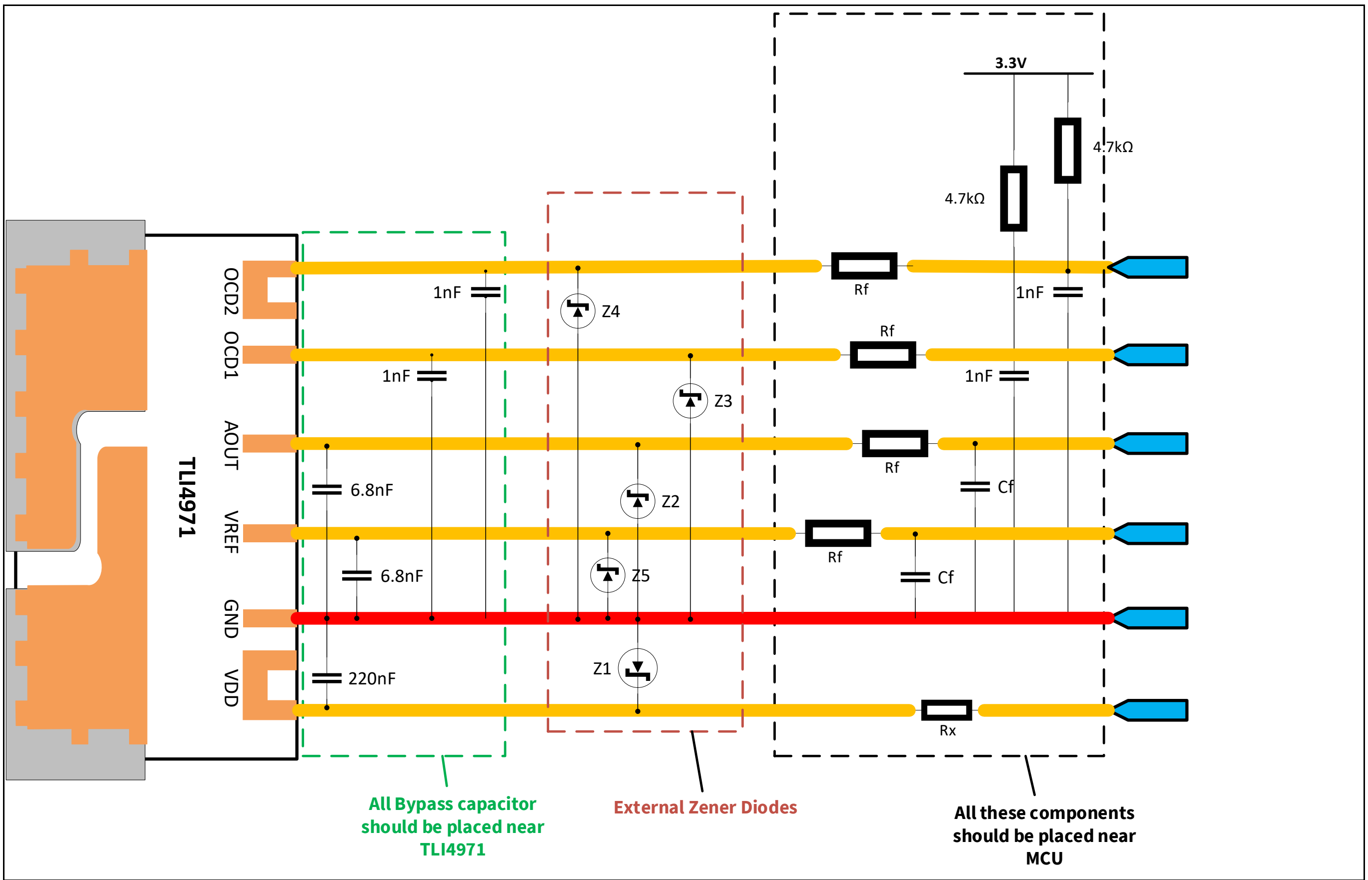

Figure 2 **Basic EMC protection for Current Sensor Module with Zener Diodes**

2.2.3 Extended protection as used in Current Sensor modules for extreme harsh conditions

We recommend a stronger Zener diodes externally near to the sensor for extreme conditions like no regulated voltage supply and additional bad wiring of the cable along the path. Further the Zener voltage shall be adjusted to guarantee absolute maximum ratings of sensor pins. An update of this document is planned to specify energy which can be absorbed by TLI4971.

Also, based on the user specific conditions, the recommendations for ESD protection topology will be suggested.

Selection of the Zener diode must be selected carefully as the Zener voltage will increase with current through Zener diode. The specified value in datasheet is typical at tested current through Zener diode. This shall be considered when selecting a suitable Zener diode for each of the sensors pins.

3 Module design of a Current Sensor

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

- Copper traces shall be as short as possible.
- A ground plane is preferred as an external distortion which is typically high frequency. The ground plane will act as a capacitor and shorten the RF signal before it touches the sensor:
    - The capacitor shall be physically between the connector and the sensor and as near as possible to the sensor. Thus the RF disturbances and fast transients will go along the leads and will be "shortened" at the capacitor.
    - SMD capacitors are preferred as wired capacitors have additional lead length and thus additional parasitic inductance diminishing the function of the capacitor.
- The value of the series resistor shall be adjusted to the external distortion.
    - When the resistor value is too high all energy will be absorbed in the resistor and the resistor might be destroyed.
    - In the case the distortion well understood in the application a smaller resistor (value and power dissipation capability) can be used as TLI4971 can absorb some energy as well.
    - Care must be taken to select the series resistor otherwise if the value of the resistor is too small a lot of energy can pass by and could harm the MCU permanently.
- The connection from GND pin to GND connector should be a straight line on the PCB (if a ground plane cannot be implemented) as all distortion will most probably pass through this line.
- Every Zener diode and capacitor shall allow the RF disturbances and fast transients 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."

For demonstration purposes the flow of the energy is illustrated in Figure 3 when there is an external field interacted with the current sensor module traces. Here, the recommended Zener diodes, series resistors are planned to propose in the next version of this document.

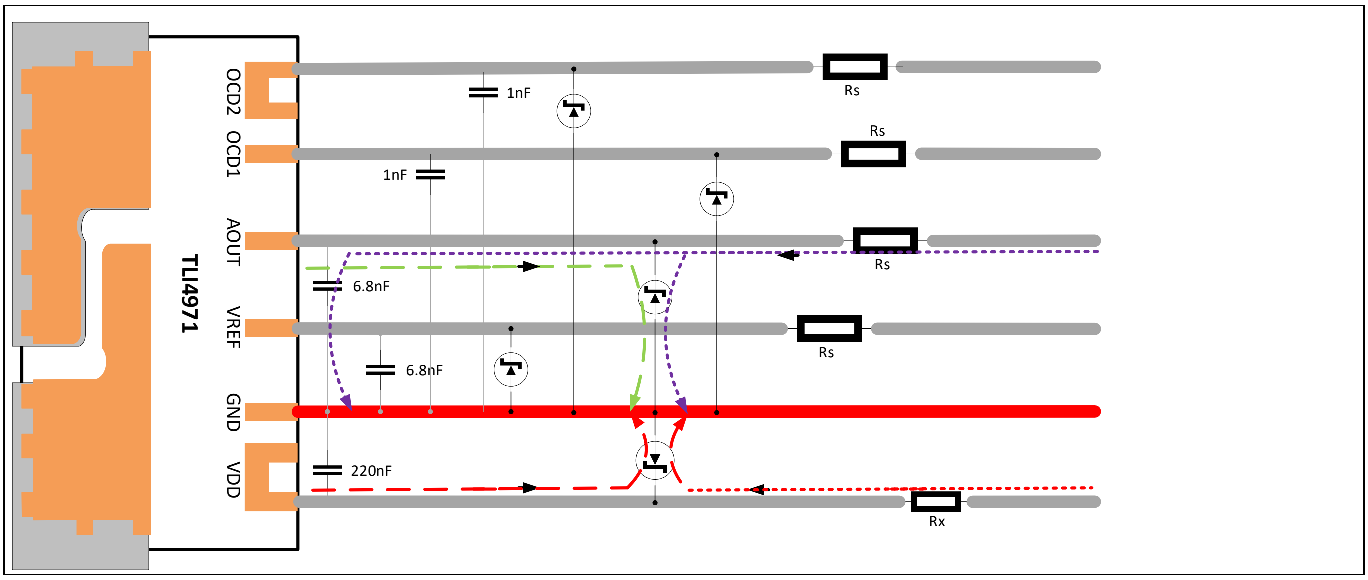

Figure 3 Flow of energy on Current Sensor Module PCB traces

The below example layout shows the TLI4971 current sensor and its passive components placement in the PCB. Here, one can observe that the capacitors and resistors are placed as close as possible.

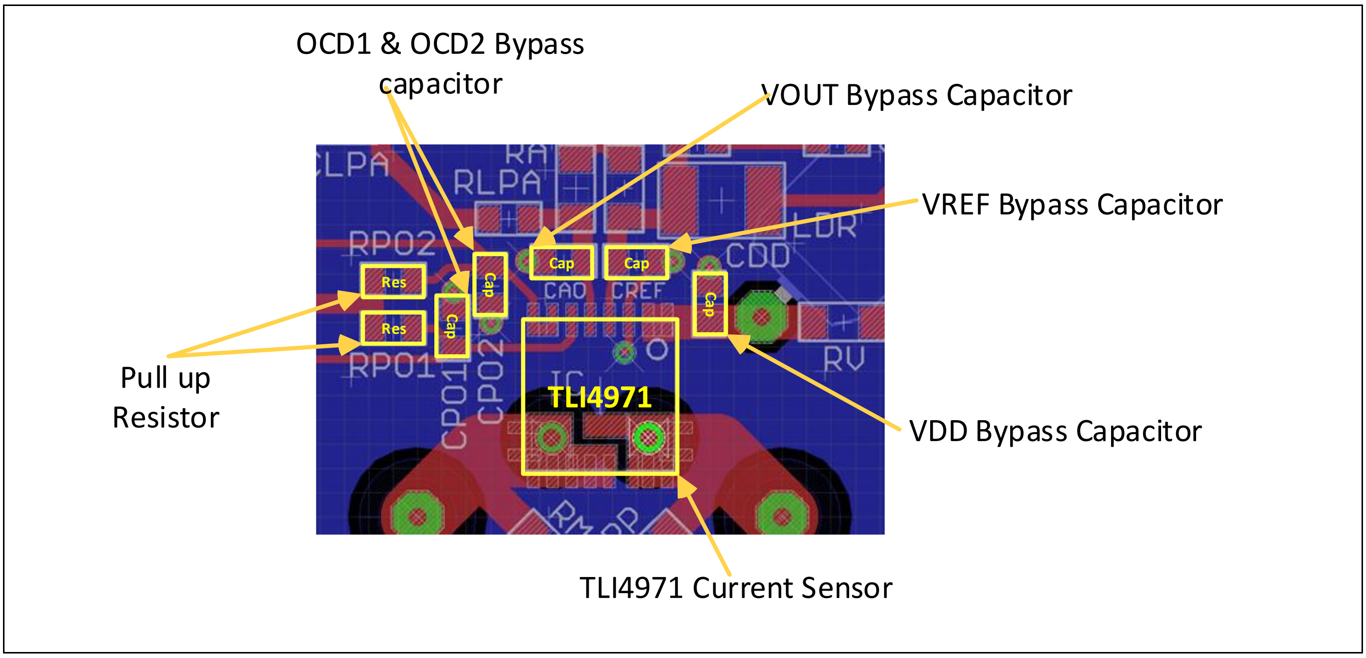

Figure 4 Example layout of TLI4971 and its passive component placement

An additional measure to reduce crosstalk between parallel traces routed on the same layer is to separate them using a trace connected at both ends to ground, called guard trace, as illustrated by Figure 5. It is essential that the guard trace is connected at all ends to ground, otherwise it will behave like an antenna.

A guard trace will also have beneficial effects on the electromagnetic interference of the trace with the surrounding environment, so guarding very aggressive and very sensitive signals is still recommended.

The layer stack up, signal tracing and guarding concept for external fields are shown in the following Figure 5 for four layer PCB applications.

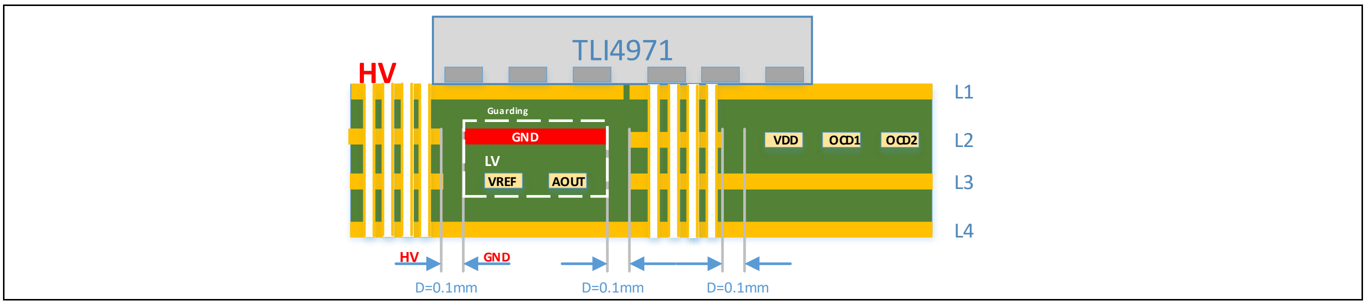

Figure 5 Guarding Concept in terms of layer stack up

4 Glossary

Notation	Description
EMC	Electro Magnetic Compatibility
ESD	Electro Static Discharge
PCB	Printed Circuit Board
GND	Ground
MCU	Micro-Controller unit
RF	Radio Frequency
OCD	Over Current Detection
HV	High Voltage
LV	Low Voltage
HBM	Human Body Model
CDM	Charged Device Model
TVS	Transient Voltage Suppressor
Cap	Capacitor
AOUT	Analog Output
VREF	Reference Voltage

Revision history

Document version	Date of release	Description of changes
V 1.0	2019-04-09	Initial version

Trademarks
All referenced product or service names and trademarks are the property of their respective owners.

Edition 2019-03-05

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AppNote TLI4971 EMC