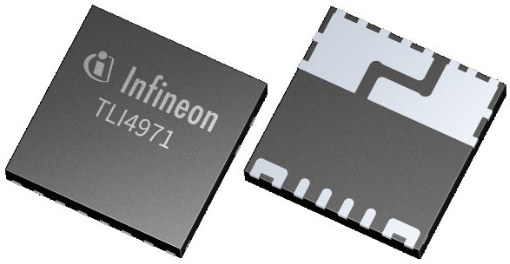
Current Sensor TLI4971

Stray field suppression and intrinsic cross talk cancelation



About this document

The intention of this document is to show the stray field and cross talk robustness of the TLI4971 core less current sensor.

This document explains the functionality of the intrinsic cross talk cancelation due to the differential measurement principle. The designed sensor operates in harsh environments and shows a high immunity against stray field influences as well as cross talk.

The special physical arrangement of the differential hall cells relative to the current flowing through the sensor package further improves the robustness of the device, which gives a high level of cross talk suppression.

This document will also show measurement results of the TLI4971 exposed to stray field and crosstalk influences.

Intended audience

- Current Sensor Module Developers.
- Users who are interested in using galvanic isolated current measurement principles without the drawback of hysteresis or saturation due to core based sensing principles.
- User dealing with current sensing in industry applications like robots, general-purpose inverter, photo voltaic, white goods or smart metering.

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1 Introduction

In order to sense the magnetic field caused by the current, the primary current rail on a PCB needs to be connected in series with the sensor device.

The sensor provides high sensitivity as well as a very low electrical resistance. The low insertion resistance of 225µΩ gives very low power loss in high current applications.

The lead frame of the sensor carries the current and thanks to the special shape of the integrated current rail, the magnetic flux density will be concentrated and measured at the two Hall plates.

Figure 1 shows the double L-shape of the current rail foot print and describes the current flow through the package.

Because of hall plate position relative to the current path, both hall cells perceives a magnetic field with opposite polarity. This arrangement of Hall cells to measure the current called differential measurement principle. This differential measurement principle provides a very high stray field suppression in the real time applications.

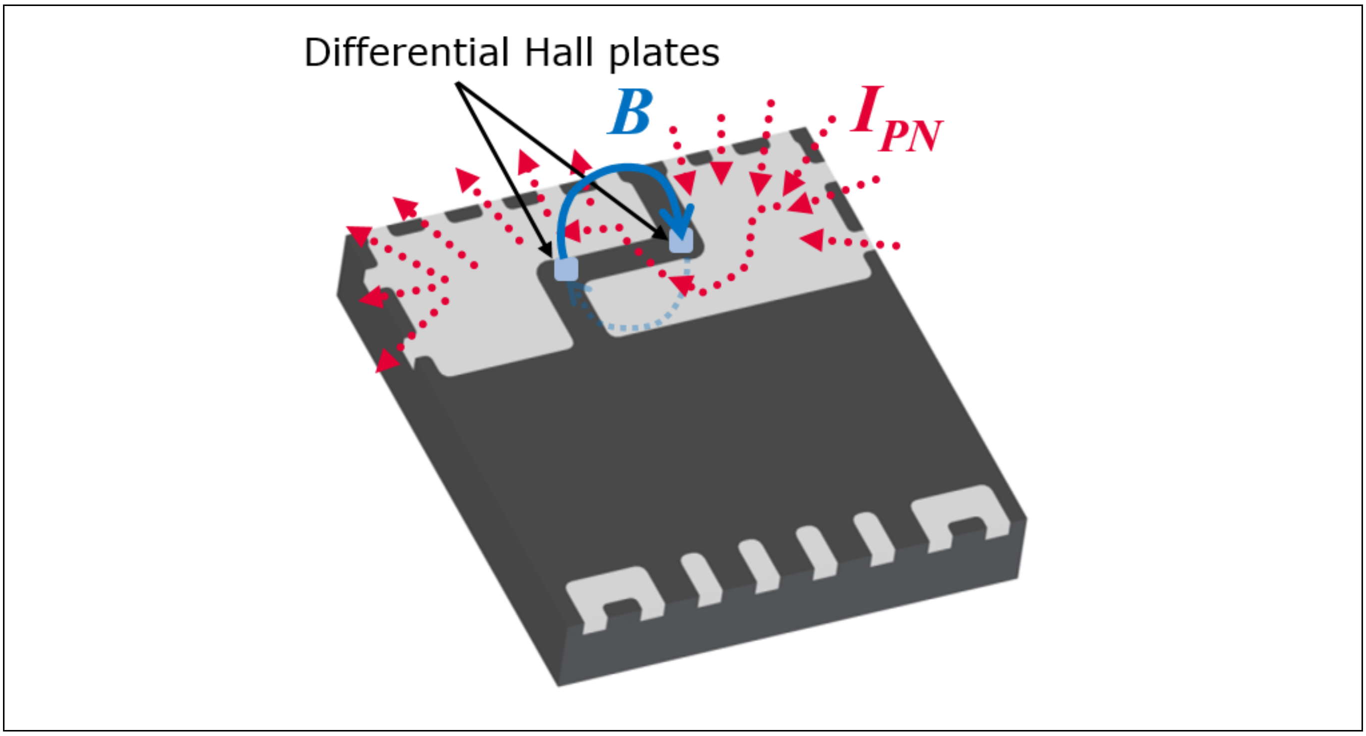

Figure 1 TLI4971 current flow and hall cells positions

2 About Differential Measurement Principle

Assuming the current flows from front to back side on PCB, then the left and right hall plates perceives the magnetic field with opposite polarity.

As shown in the Figure 2, the hall probe A and B will measure the magnetic field produced by current flowing through the conductor as well as the external field. Since the external filed has the same polarity on both hall sensor cells, the superimposed field becomes canceled due to the differential measurement principle as described in the below formula.

For example, the left hall cell total field B_{left} is (B_A + B_S) and the right hall cell total field B_{right} is (B_B + B_S). Here, B_S is the external magnetic field, which is assumed as same on both side hall cells as the hall cells placed very near to each other so that they perceives same magnetic field in real time applications. B_A is the magnetic field caused by the current in the current trace measured by the left Hall cell. B_B is the magnetic field caused by the current in the current trace measured by the right Hall cell.

$$Differential\ output = Total\ B_{left}\ at\ \text{left Hall cell} - \text{Total}\ \text{B}_{\text{right}}\ \text{at right hall}$$
$$Differential\ output = (B_A\ + B_S) - (-B_B + B_S)$$
$$Differential\ output = (B_A + B_B)$$

The resultant measured field is the magnetic field (B_A + B_B) of the PCB current, which is flowing through the conductor as shown in the Figure 2. Thanks to the arrangement of the sensor cells, which cancel the cross talk from neighboring current rails in a multiple phase application system such as the three-phase output of a motor control circuit.

To maximize the cross talk suppression in an n-phase application, it is recommended to route the current rails in parallel. The typical attenuation of TLI4971 is -40dB for external homogenous magnetic stray-field.

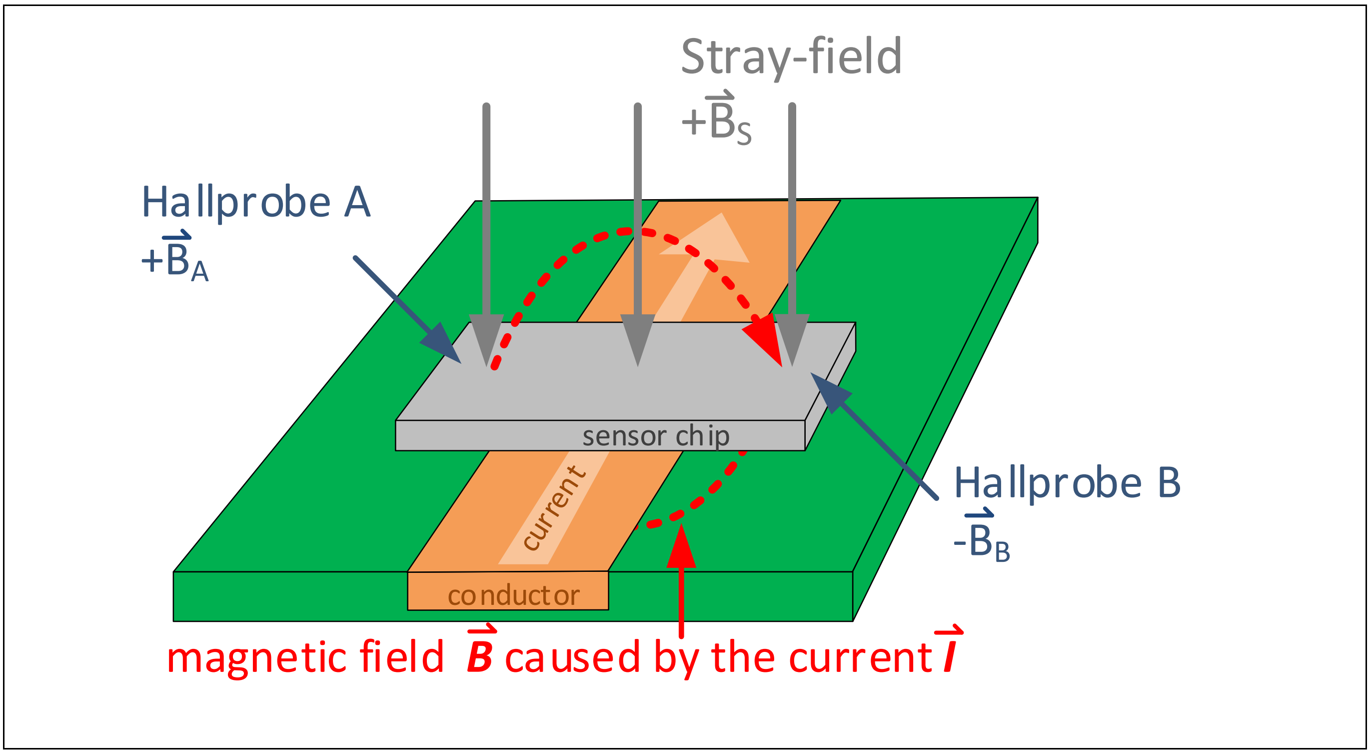

Figure 2 Differential measurement with background field cancelation

3 TLI4971 Static Stray Field Suppression

To verify the stray field suppression, the device exposed to a high static magnetic field of 200mT. Figure 3 shows the measurement setup.

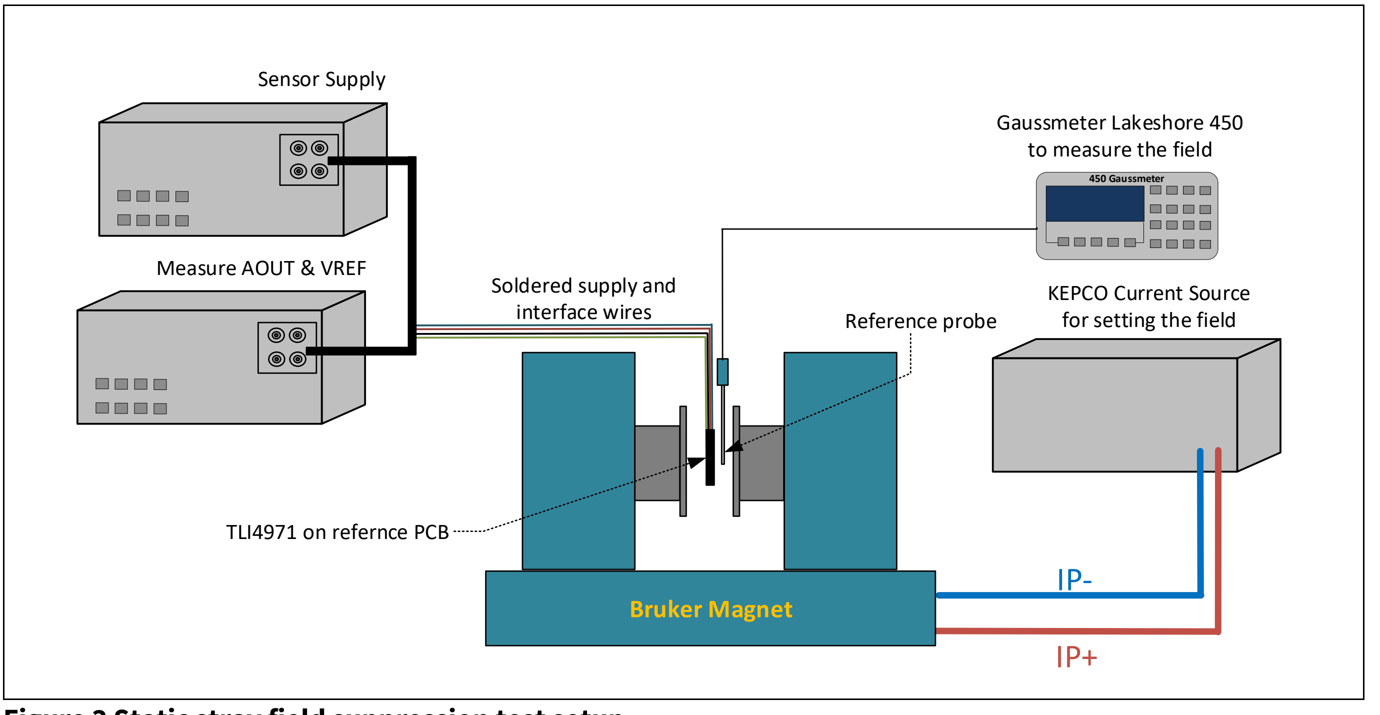

Figure 3 Static stray field suppression test setup

In the setup, the device exposed to a high magnetic field (200mT).

A reference probe, which is near to the current sensor, is measuring the applied magnetic field.

The device is set to a sensitivity of 48mV/A

While applying the magnetic field to the device the differential output voltage AOUT-VREF is measured.

The formulas below show the calculation of the stray field suppression.

$$measured_{field} = (A_{out} - V_{ref})\ offest\ compensated$$

$$Suppression\ [dB] = 20 * \log 10(\frac{applied_{field}}{(measured_{field})})$$

Figure 4 shows the stray field suppression of 10 tested TLI4971 parts.

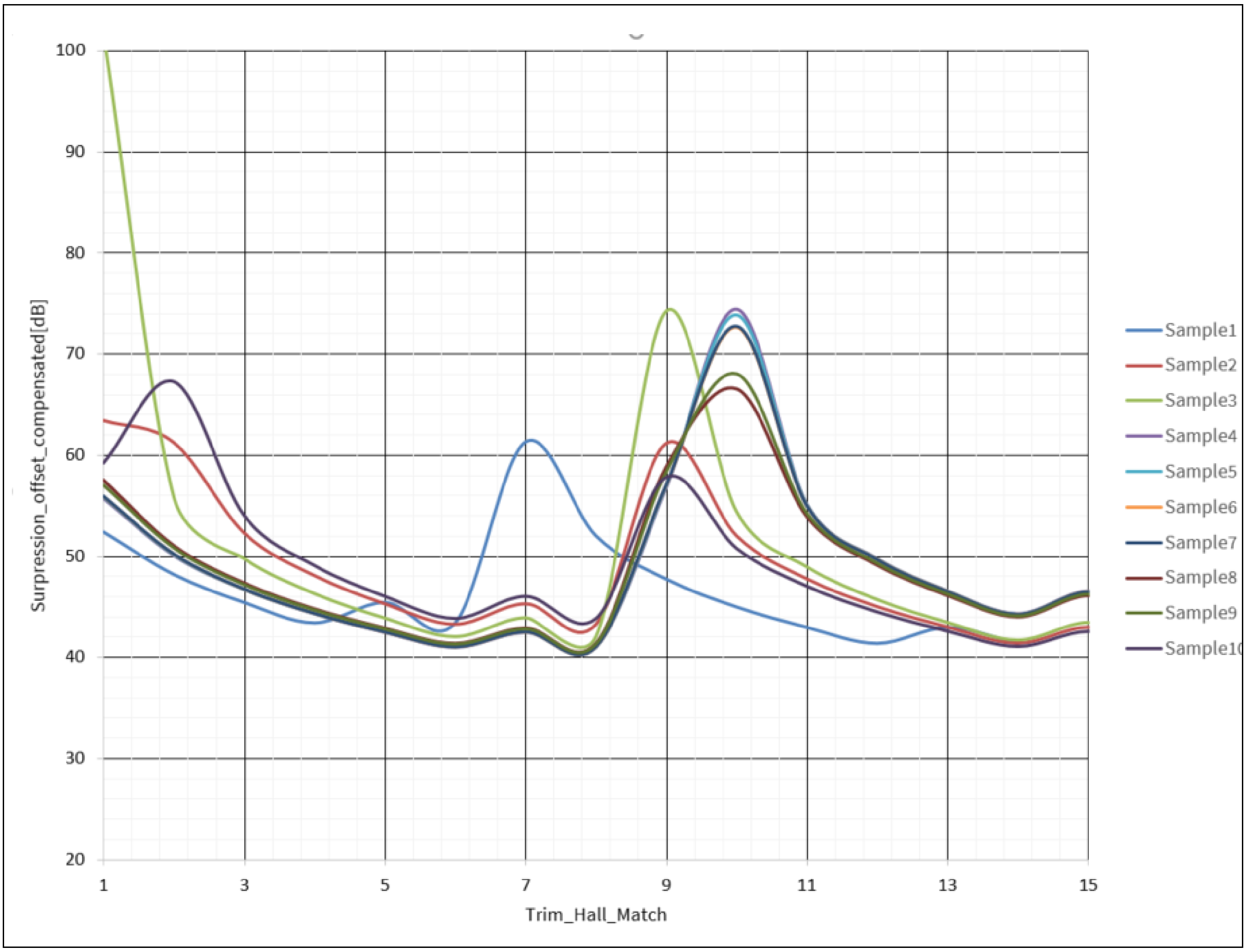

Figure 4 Stray field suppression at applied field of 200mT

4 TLI4971 Dynamic Stray Field Suppression

This section describes the dynamic stray field setup and measurement in a Helmholtz coil.

Here, for an example a 3-phase reference board with three sensors exposed to a dynamic homogenous field, which will be applied over a wide frequency range. The applied magnetic field changes in frequency and magnitude as shown in Figure 7.

Figure 5 and Figure 6, shows the measurement setup of the sensor PCB in the Helmholtz coil.

Figure 7 shows the measured offset voltage of the device while applying a dynamic homogenous magnetic field over the TLI4971 recommended operating frequency range.

This test gives an evidence that the differential output of each device has no effect or disturbance over the TLI4971 recommended operating frequency range of stray field.

The purple dotted line in the graph shows the magnitude vs frequency of the applied magnetic field.

The graph shows also the differential output voltage of the three current sensors placed in the Helmholtz setup.

The magnetic field shows a magnitude of 1.3mT up to 1 kHz and for frequencies between 10 and 100 kHz, the field amplitude is limited to 10µT.

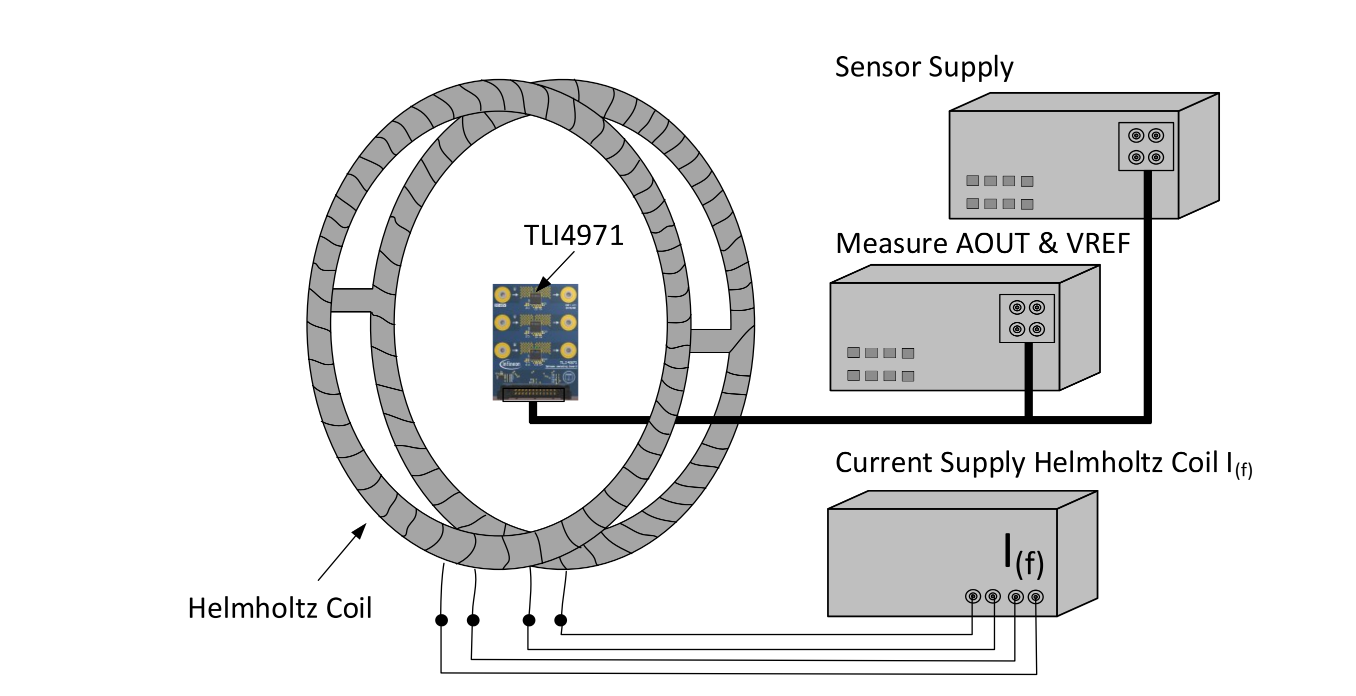

Figure 5 TLI4971 in Helmholtz setup (Stray field test over frequency)

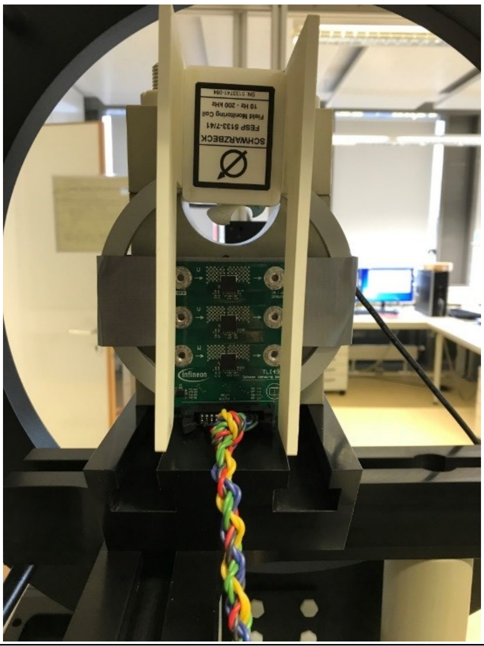

Figure 6 Stray field measurement in Helmholtz coil

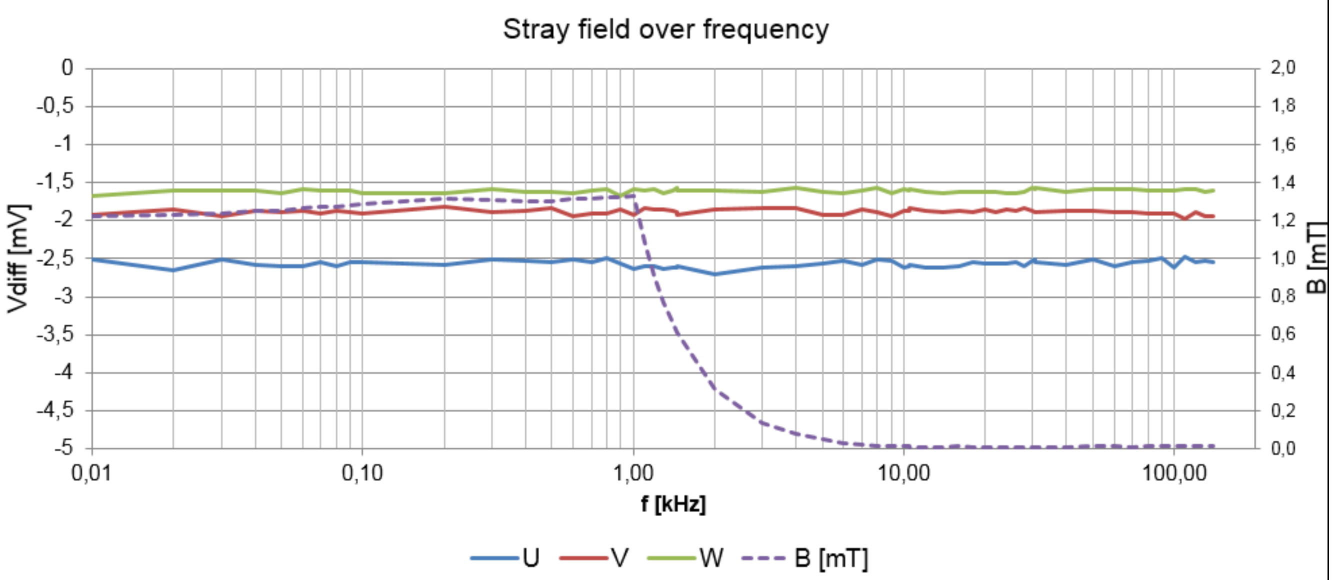

Figure 7 TLI4971 stray field immunity over frequency

5 Intrinsic Cross Field Cancelation

A typical wiring schema of multiple phase system will route the output phases in parallel.

To eliminate the cross talk with the neighboring current rail phases that are physically close to each other, the device Hall plates arranged in parallel to the current path.

Figure 8 shows an example of a wiring schema of three phase current measurement system where the sensors placed in parallel to the current rails on the left side and the magnetic field caused by the current in v-phase effecting the sensors on the u and w-phase on the right side.

Thanks to the parallel position of the sensors to the current rail, both Hall plates will detect the same magnitude of magnetic field and the cross talk cancelled out due to the differential measurement principle.

To benefit of the intrinsic cross-field cancelation it is recommended to install the devices in parallel on a PCB as illustrated in Figure 8. In addition, Figure 11 shows the recommended parallel setup.

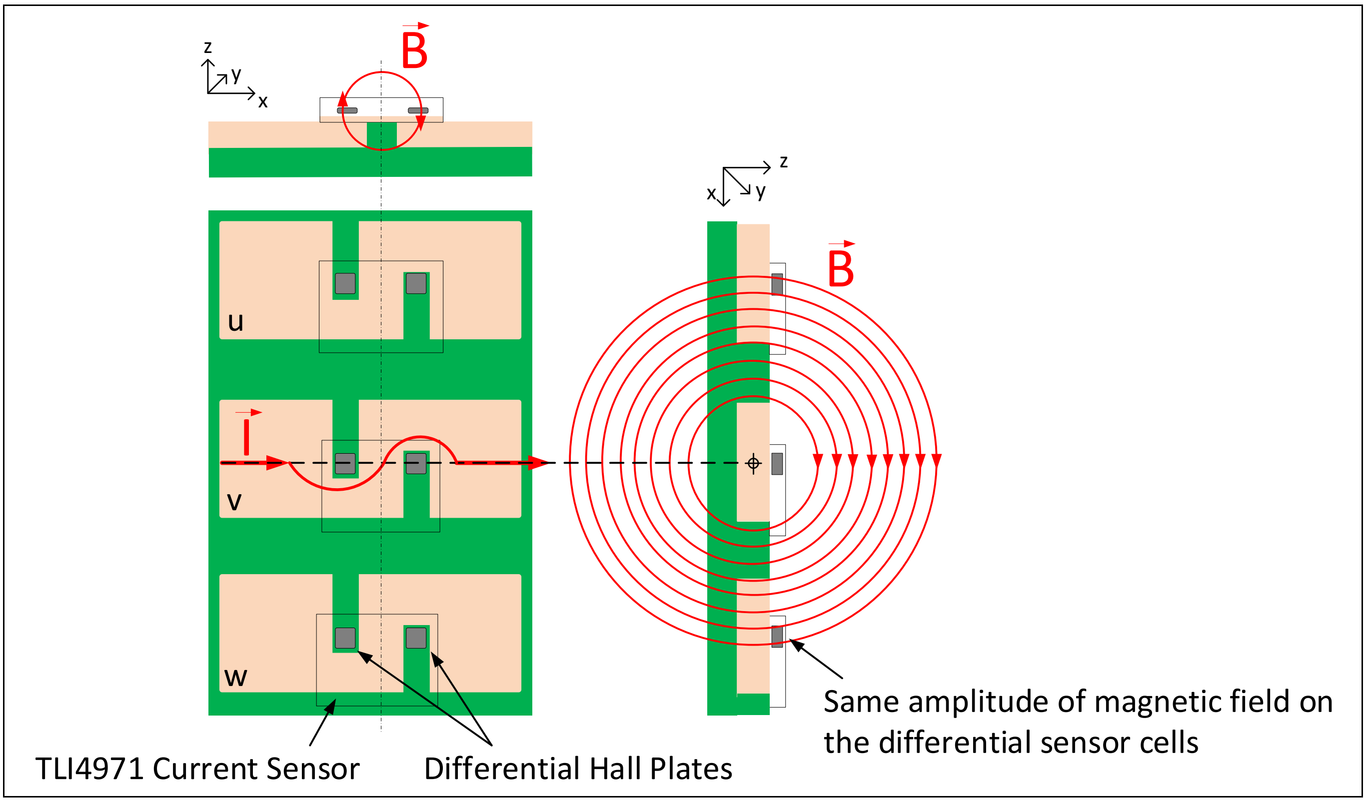

Figure 8 Three phase parallel wiring schema example for intrinsic cross talk cancelation

Figure 9 describes the magnetic field at the distance r_1 & r_2 from the current carrying conductor of straight & S-bend current rails. The following formula shows the differential field calculation at the distance r_1 & r_2.

$$B_{diff} = \mu_0 \frac{I_{err}}{I_{sense}} \left(\frac{1}{r_1} - \frac{1}{r_2} \right) \cos \alpha$$

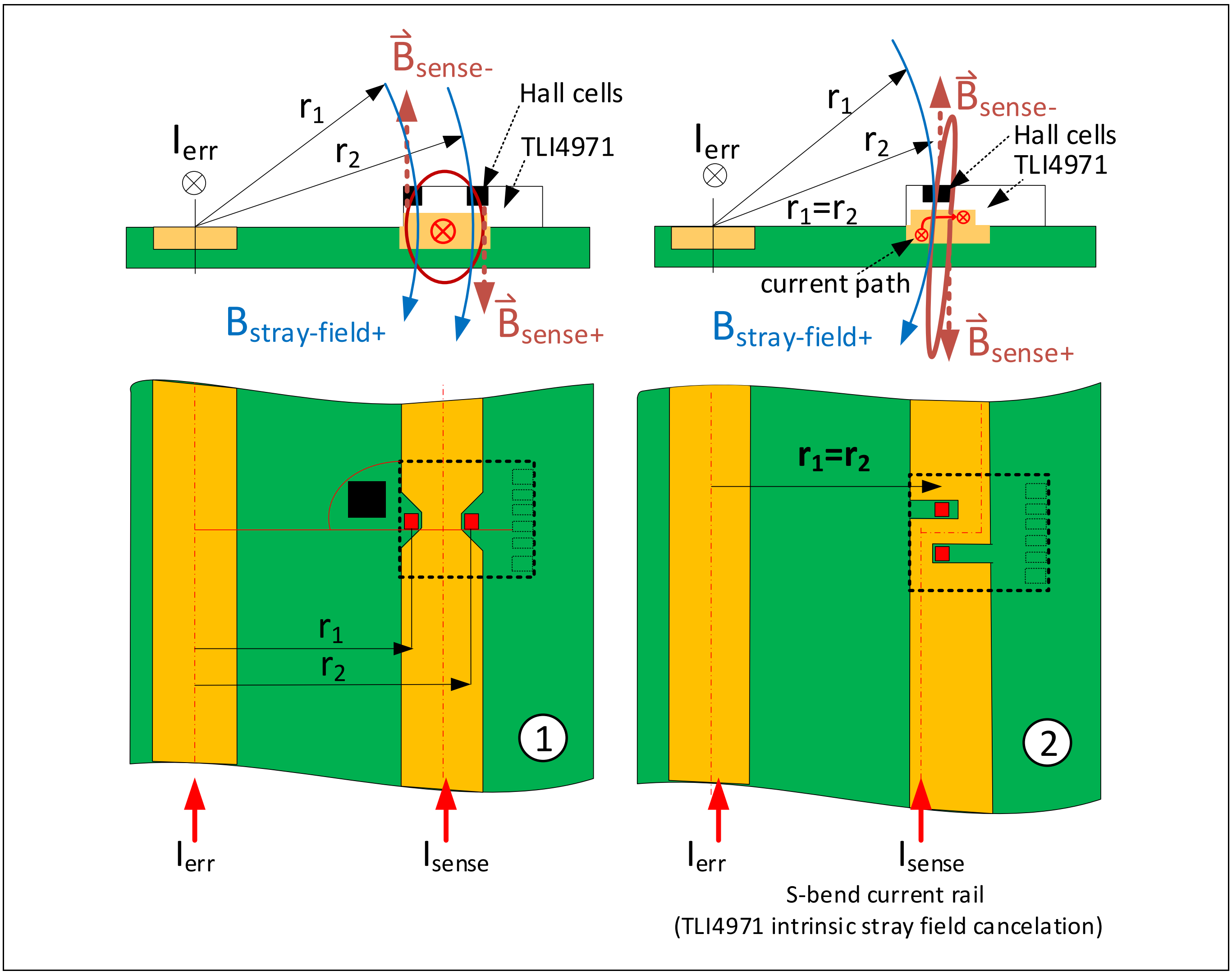

Figure 9 Cross talk field at two different points

The TLI4971 Hall cells placement results in the maximum cross talk suppression because of the differential measurement principle.

The sensors shall be in parallel in a multi-phase application to maximize the cross talk suppression.

Setup2 in Figure 9 shows the advantage of TLI4971 Hall sensor alignment compared to setup1 since both Hall cells of the differential Sensor has the same distance to the neighbor current trace.

The below Figure 10 shows the damping of field in a differential measurement system compared to the mono cell approach.

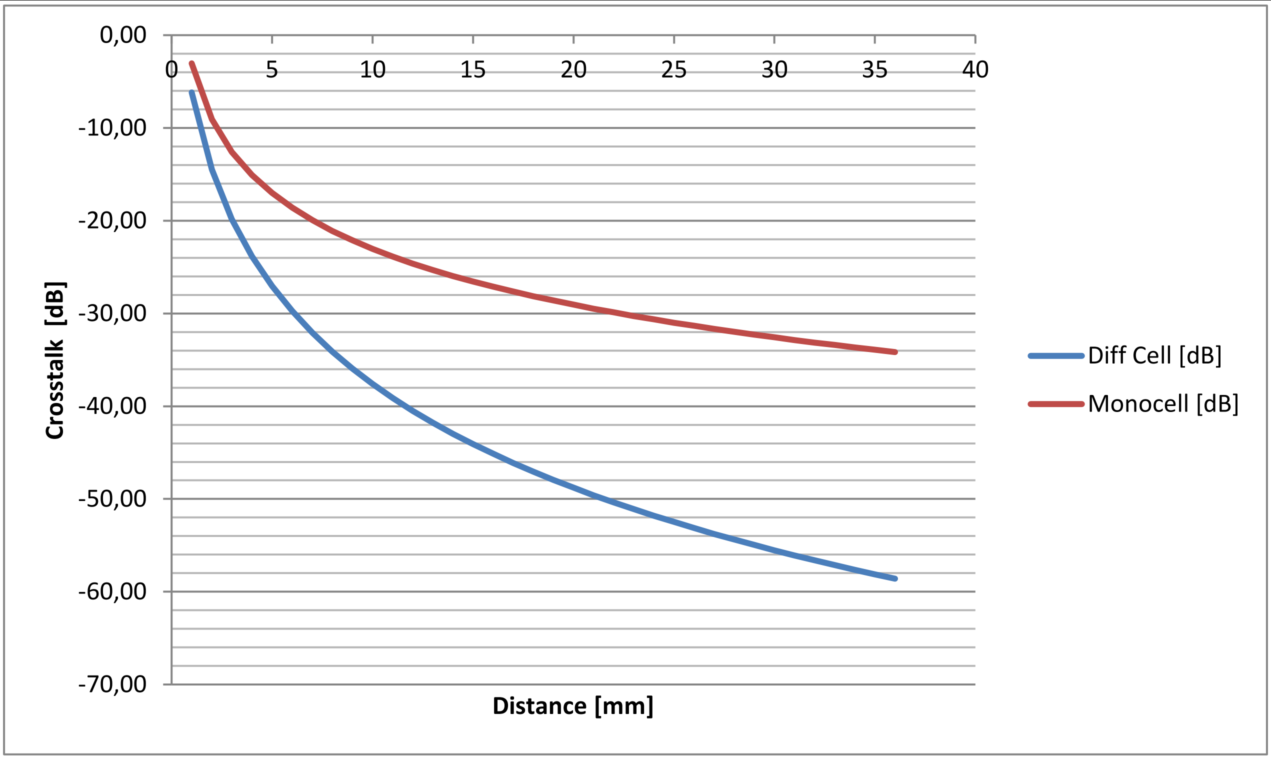

Figure 10 Cross talk suppression over the distance for differential and mono-cell measurement principle

5.1 TLI4971 Cross Talk Measurements

Figure 11 shows the three-phase reference board. In order to verify the cross talk suppression of the TLI4971 current sensor, vary the current through the U-phase from 0A to 100A in steps of 10A while measuring the output of the neighboring sensors on V, W-Phases. The sensors measurement range is set to ±120A.

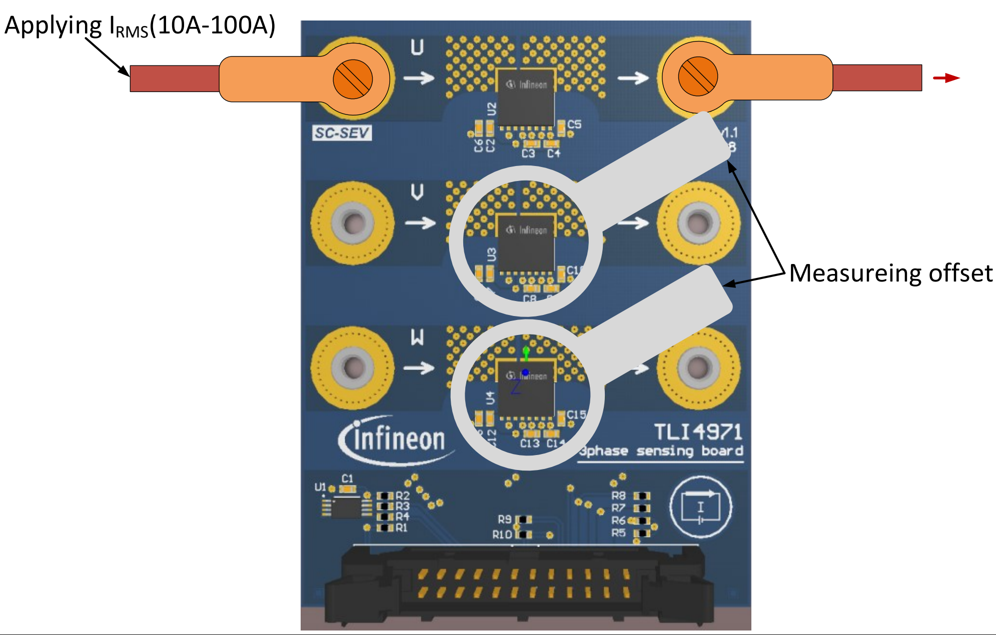

Figure 11 Cross talk measurement setup

After canceling the offset from the measured output, calculate the influence of the U-phase current on the V and W phases.

Figure 12 shows the measured voltages of U, V and W phases over applied current through the U-Phase.

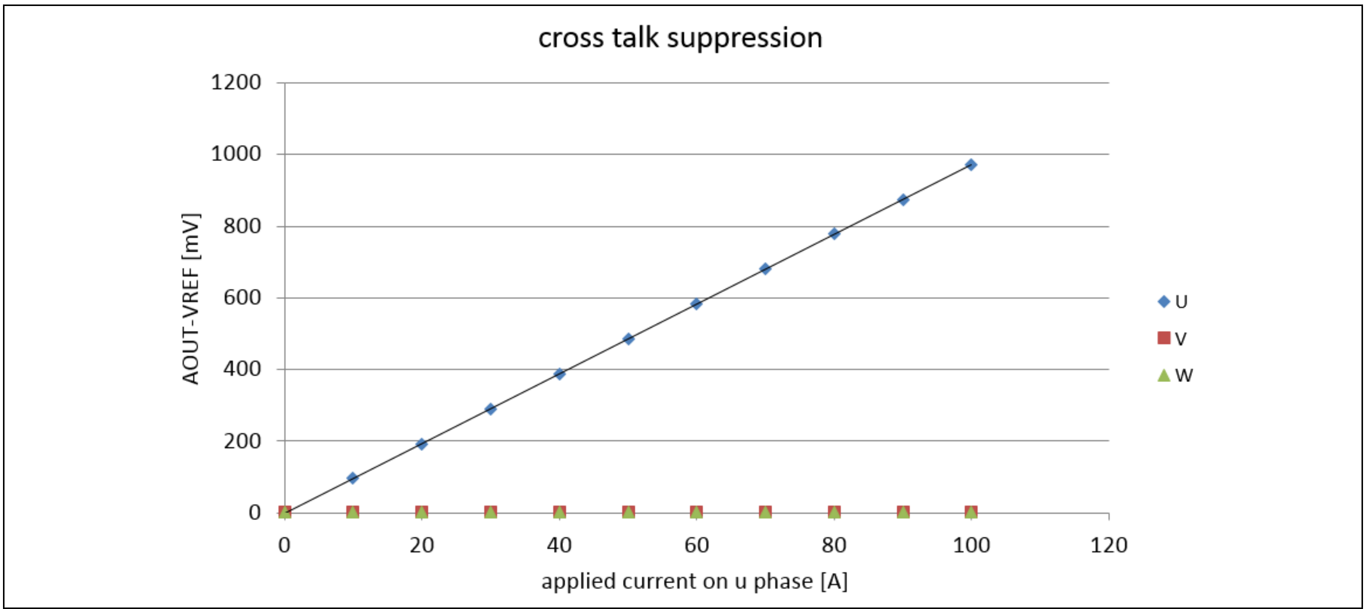

Figure 12 U, V & W-phase output voltage over Current

The results shows that the cross talk is negligible on TLI4971 for currents up to the sensors full scale range.

Table 1 shows the cross talk field damping on the V and W phases while applying the current on the U-phase.

Table 1 Cross talk damping

I(U) [A]	Vdiff [mV]						Crosstalk [dB]	
	U	Ucorr	V	Vcorr	W	Wcorr	UV	UW
0	0,8	0	0,8	0	1,5	0	-	-
10	96	95,2	0,8	0	1,5	0	-inf	-inf
20	192,8	192	0,8	0	1,5	0	-inf	-inf
30	290,8	290	0,8	0	1,5	0	-inf	-inf
40	388,7	387,9	0,8	0	1,5	0	-inf	-inf
50	485,5	484,7	0,7	-0,1	1,6	0,1	-73,71	-87,42
60	583,5	582,7	0,8	0	1,5	0	-inf	-inf
70	679,8	679	0,8	0	1,3	-0,2	-inf	-inf
80	778,7	777,9	0,8	0	1,3	-0,2	-inf	-inf
90	873,5	872,7	1,5	0,7	1,9	0,4	-61,92	-80,73
100	970	969,2	1,3	0,5	1,9	0,4	-65,75	-85,48

A Revision history

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V1.0	13.12.2019	Initial Version

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