6.7 Application Notes: Differential Hall IC TLE 4923

Applications

- Detection of rotational speed of ferromagnetic gear wheels
- Detection of rotational position
- Detection of rotational speed of magnetic encoder wheels
- Generation of trigger signals

Main Features

- Evaluation of very small magnetic field differences
- Large airgap in dynamic mode
- Low cut-off frequency
- Fully temperature compensated
- Reverse polarity protection
- Guarded against RF interference
- Wide temperature range
- Current interface

General Description

The TLE 4923 has a combination of two Hall cells, a differential amplifier and evaluating circuitry, all on a single chip. Evaluating field difference instead of absolute field strength means that disruptive effects, like temperature drifts, manufacturing tolerances and magnetic environment are minimized. Further reduction in interference is obtained by the dynamic evaluation of the difference signal using a highpass filter with an external capacitor.

The IC is designed for use under aggressive conditions found in automotive applications. A small permanent biasing magnet is required for sensing ferromagnetic gear wheels of various shapes. Correct switching for even the smallest field differences between tooth and gap is guaranteed. The typical lower switching frequency is about 10 Hz for a 470 nF filter capacitor. The TLE 4923 is offered in an ultraflat package with three leads (P-SSO-3-6).

Design and Function of the Chip

When the Hall IC is exposed to a constant magnetic field of either polarity, the two Hall elements will produce the same output signal. The difference is zero, regardless of the absolute field strength. However, if there is a field gradient from one Hall element to the other, because one element faces a field concentrating tooth and the other one a gap of the toothed wheel, then a difference signal is generated. This signal is amplified on the chip. In reality the difference exhibits a small offset which is corrected by the integrated control mechanism. The dynamic differential principle allows a high sensitivity in combination with large airgaps between the sensor surface and the gear wheel.

The TLE 4923 incorporates a current interface that enables transmission of the output signal through the supply current. Protection against reverse polarity as well as against EMI are integrated and allow application in the hostile environments found in the automotive industry.

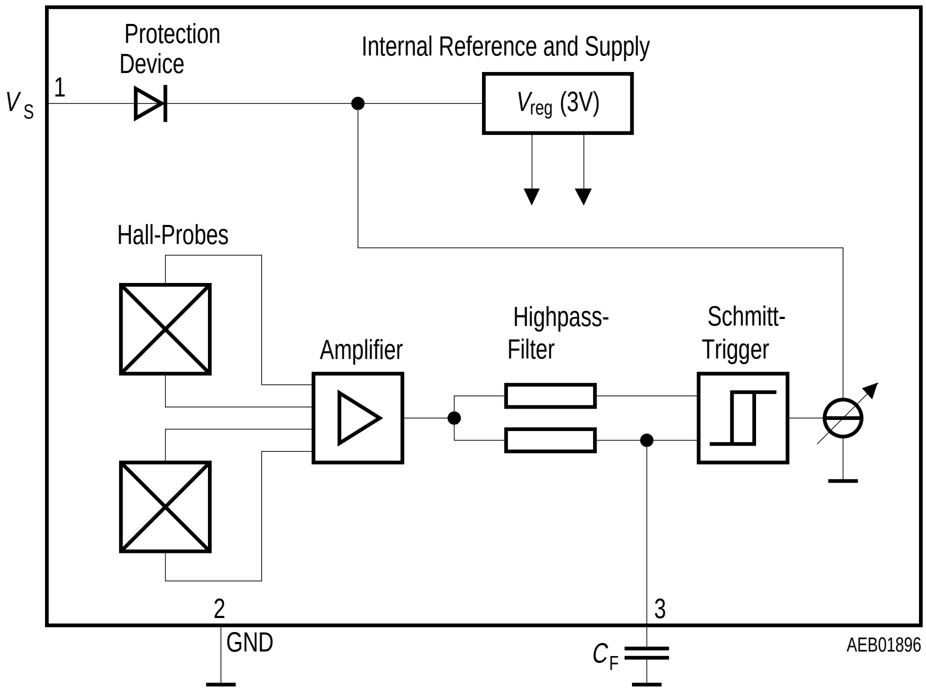

Figure 78
Block Diagram TLE 4923

Method of Operation

The generation and evaluation of the difference signal can be explained with reference to a typical application such as sensing a ferromagnetic gear wheel.

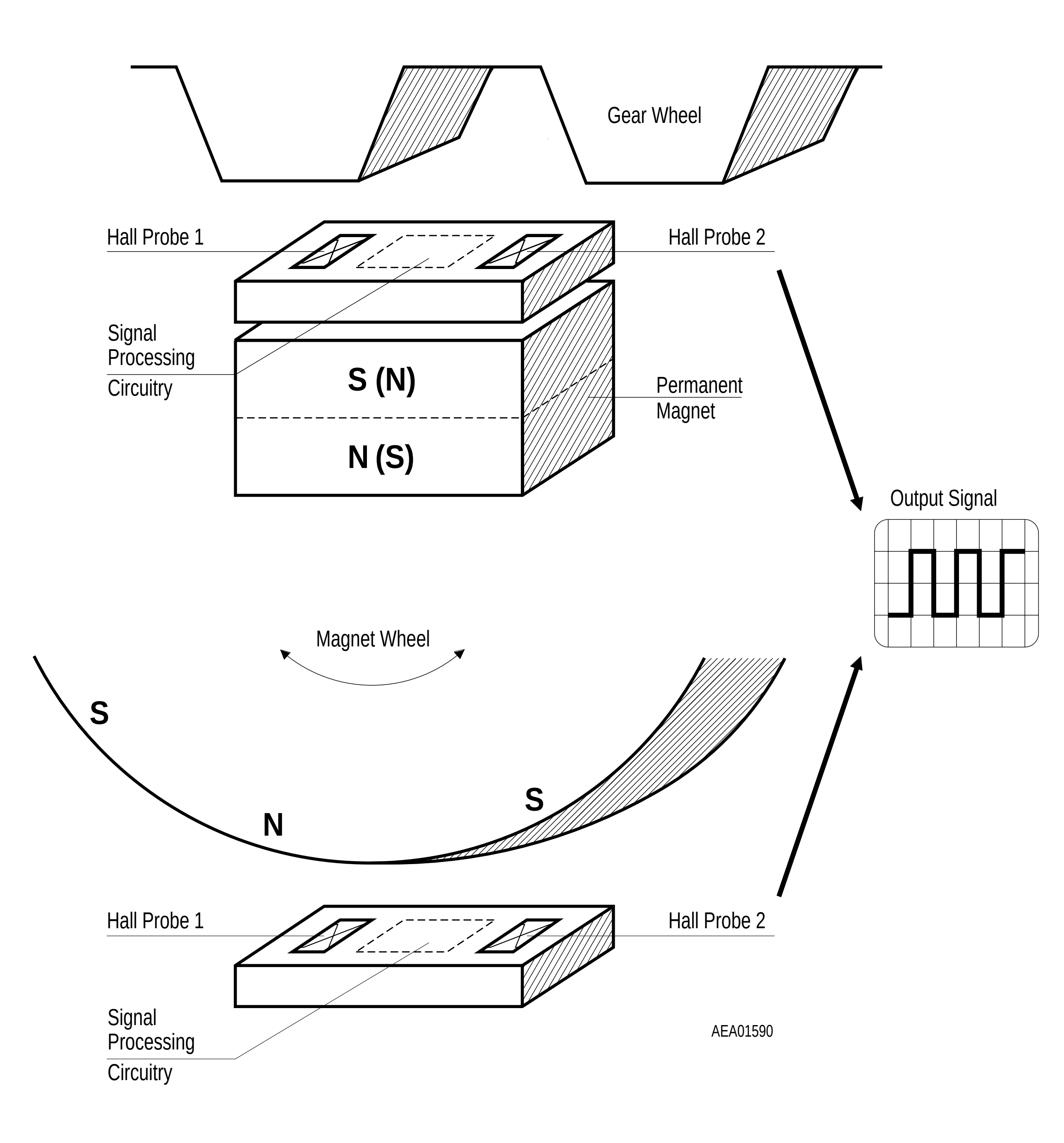

Figure 79
Application as a Gear Wheel Sensor and as an Encoder Wheel Sensor

A permanent magnet mounted with either pole on the rear side of the IC produces a constant magnetic bias field. The two Hall probes are spaced at 2.5 mm. If one cell faces momentarily a tooth while the other faces a gap of the toothed wheel, the gear tooth acts as a flux concentrator. It increases the flux density through the Hall probe and a differential signal is produced. As the toothed gear wheel turns, the differential signal changes its polarity at the same rate of change as from the tooth to the gap.

The maximum difference is produced by the tooth edge when the zero crossover comes directly in the center of the tooth or gap. When the difference exceeds the upper threshold ΔB_{RP}, the output current turns low ("OFF" state). This is the case when the tooth is sensed by the Hall probe 2 near pin 3 in **Figure 82.** As the difference falls below the lower threshold ΔB_{OP}, the ourput current turns high("ON" state). This is the case when the Hall probe 1 near pin 1 sense the tooth.

The integrated highpass filter regulates the difference signal to zero by means of a time constant that can be set with an external capacitor. In this way only those differences are evaluated that change at a minimum rate (depending on the capacitor value). The output signal is not defined in the steady state. The accuracy that is produced will permit a small switching hysteresis and therefore also a large airgap (up to 3.5 mm).

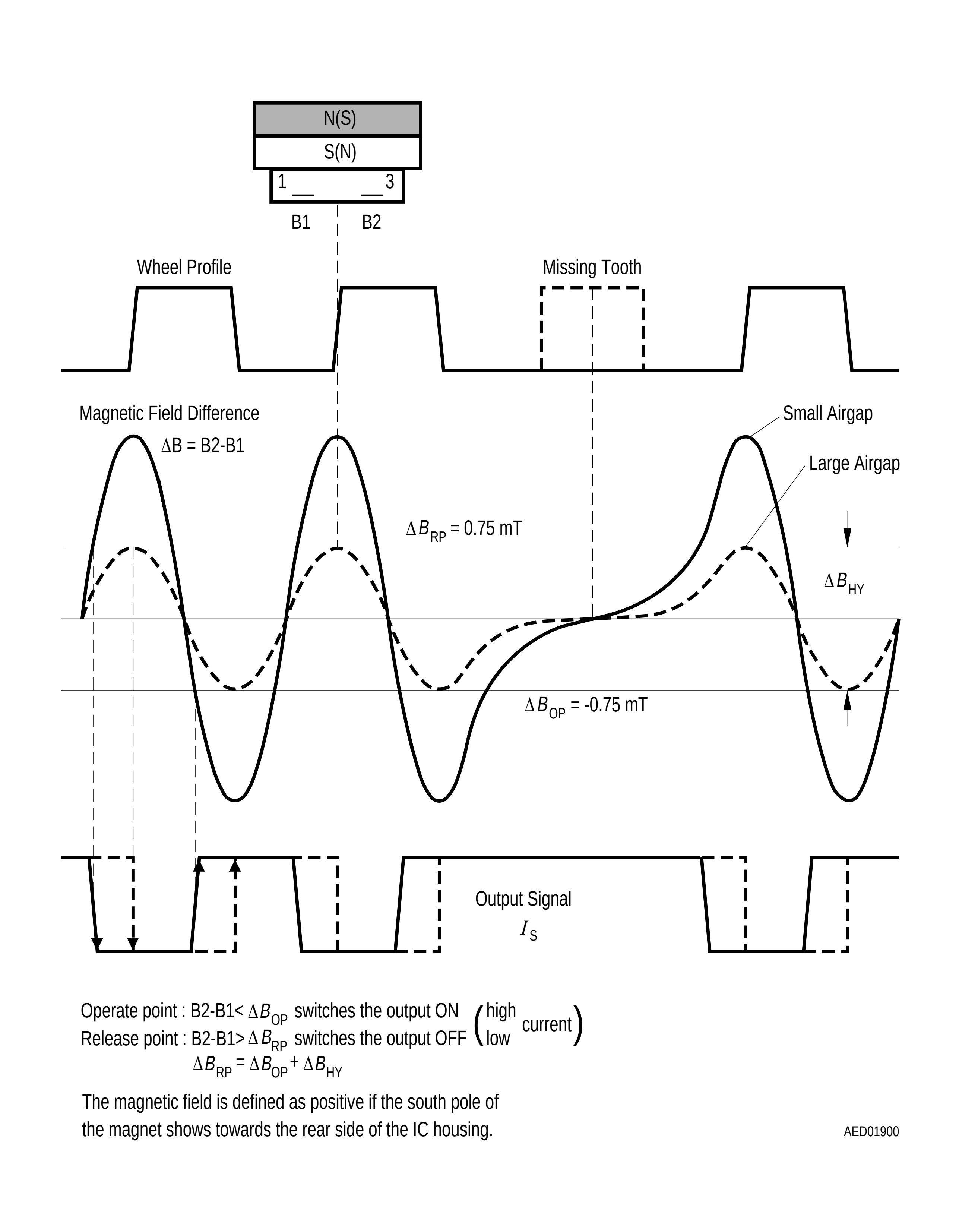

Figure 80
Sensor Signals Produced by a Toothed Gear Wheel, Example TLE 4923

Filter Capacitor

The filter capacitor C_F plays an important role in the correct function of the Hall IC. If an application requires operating temperatures higher than 100 °C, ceramic capacitor types (X7R) are recommended. The connections between the filter capacitor C_F, the C pin and the GND pin need to be as short as possible. Further recommendations are listed in one of the following subsections.

A leakage current at the capacitor pin will cause a shift of the switching thresholds and therefore spurious switching. The shift of the switching threshold is calculated as

$$\Delta B_m = \frac{I_L \times R_C(T)}{S_C(T)}$$

where I_L, S_C and R_C are the leakage current, the filter sensitivity to ΔB and the filter input resistance as specified in the datasheet respectively.

Special attention has to be paid to the choice of the capacitor (high DC resistance) and its assembly. Leakage currents may occur on the PCB between the connections or in a defective capacitor and can be a source of sensor malfunction.

EMC: Injection of supply line transients (DIN 40839-1)

For the measurements with the TLE 4923 the test circuit as in **Figure 81** is used. The filter capacitor C_F = 470 nF is connected directly to pin 3, additionally a shunt capacitor C_S = 4.7 nF is connected in the supply line. A load resistance R_S = 180 Ω is used.

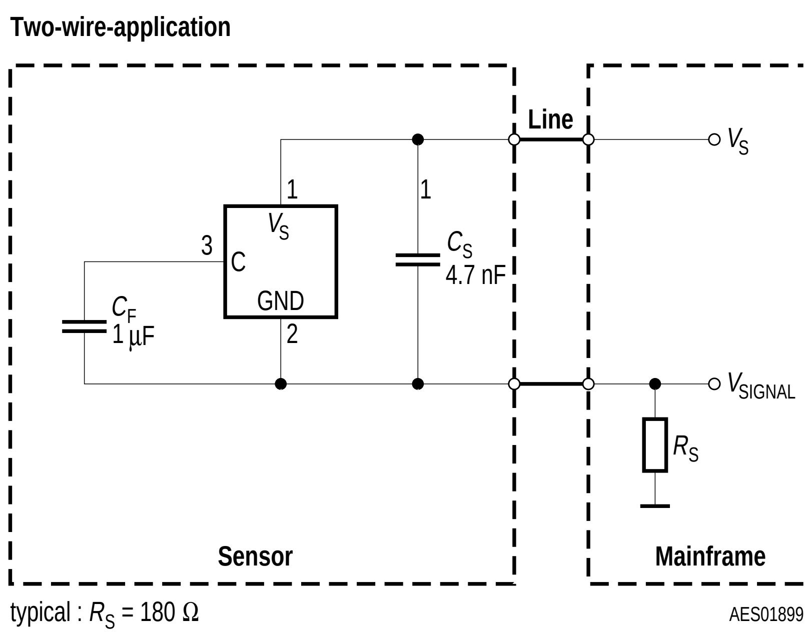

Figure 81
Test Circuitry for DIN 40839-1 Test

Table 16
Functional Status of TLE 4923 according to DIN 40839-1 Test Levels

Test Pulse	Functional Status according to Test Levels			
	I	**II**	**III**	**IV**
1	C	C	C	C
2	B	B	B	B
3a	C	C	C	C
3b	C	C	C	C
4	C	C	C	C
5	see **Table 17**			

The load dump pulse 5 is investigated in more detail. The results are shown as a function of the pulse amplitudes V_S, the pulse duration t_d and the signal resistance R_S:

Table 17
Functional Status of TLE 4923 according to DIN 40839-1 Pulse 5

V_S / V	t_d / ms	R_S / Ω	Class	COMMENT
45	400	180	C	
50	400	180	C	
55	400	180	C	
58	400	180	E	
60	200	180	C	
60	300	180	E	I_S increases $\rightarrow$ destruction
60	300	180	E	
65	100	180	E	
65	400	330	C	800 ms recovery time
82	400	330	E	
84	400	330	E	
110	200	330	E	I_S increases $\rightarrow$ destruction

Also for the TLE 4923 the signal resitor size must be adapted to the load dump requirements of the application or vice versa. Optionally a suppressor diode can be placed in the supply line, eliminating the need for a large signal resistor.

EMC: Injection of Capacitive Line Transients (DIN 40839-3)

The test setup is as described in **Chapter 6.5**. The Hall IC is actuated with a magnetic coil (ΔB = 5 mT @ f = 200 Hz) and the supply line has a length of 2 m. Again the test circuitry in **Figure 82** is used. Missing pulses are the malfunction criteria. For all pulses and severity levels class A is achieved, i.e. no disturbance is measured. First spurious switching effects are observed for voltages larger than ± 1000 V, well above the levels of ± 60 V stated in the DIN standard.

EMC: Radiated Interference (DIN 40839-4)

This test is carried out in a TEM cell. The setup is described in **Chapter 6.4** (Electromagnetic Compatibility in Automotive Applications). Again the test circuit in **Figure 82** is used. The Results of the TEM measurement are shown in **Figure 82**. The TLE 4923 IC performs practically over the whole frequency range without disturbance for differential fields down to 5 mT.

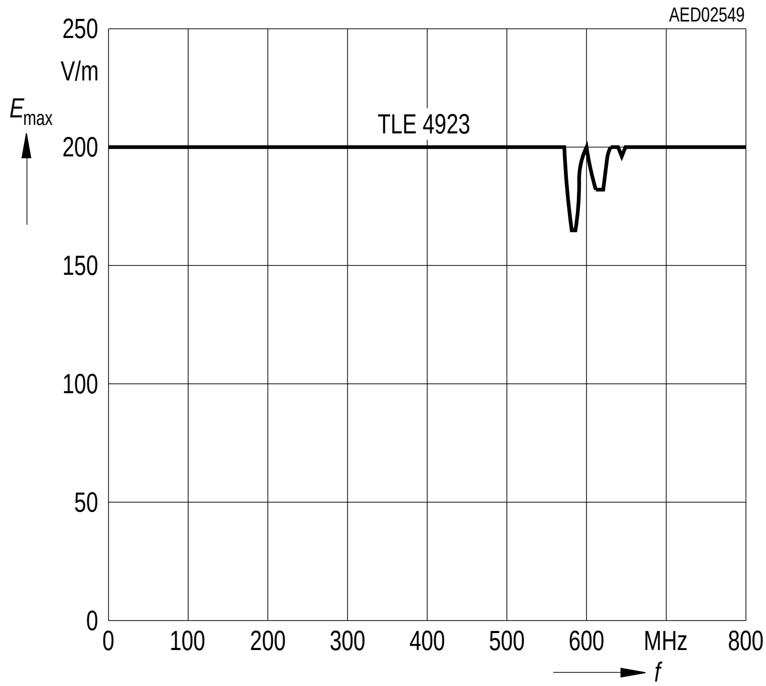

Figure 82
Results of the Radiated Interference Test with the TLE 4923

Optimization of TLE 4923 and Passive Circuitry for Improved EMI Performance

The following recommendation is the results of EMI measurements carried out on the device during in-house testing. It is referred to the application and test circuit in **Figure 81**.

Component values:

C_F = 470 nF – 1 µF	High pass filter capacitor
C_S = 4.7 nF	Additional HF shunt
R_S = 100 – 200 Ω	Signal resistor

Optimization points in detail:

1. Ground
   The reference point is the GND pin of the device. In order to avoid conductive interferences, all connections to this pin should be realized in a star configuration. If this requirement is not fulfilled, the EM immunity will be reduced.
2. Connection of the filter capacitor
   The connections between the filter capacitor C_F, the C and GND pins have to be as short as possible (ideally C_F should be placed close to the device housing), taking into account the above mentioned star configuration of C_F to GND. If this is not possible, a second smaller capacitor (e.g. 82 nF) between C_F and TLE 4923 is recommended in order to shorten the connection between C_F and the corresponding pins. This measure should be applied only if little space is available close to the Hall IC.
3. Additional HF shunts
   Ideally arranged RF shunts C_S can further improve the EMI immunity. A larger C_S will improve the RF performance.

Signal Behavior for Different Dimensions of Toothed Gear Wheels

Since the Hall probe spacing of 2.5 mm of TLE 4923 is identical to the one of TLE 4921-3U, the investigations carried out with the TLE 4921-3U (see section Application Notes) also apply to TLE 4923.