CH504 & CH504C

Differential Wheel Speed Sensor IC with PWM Protocol

Features

- Two-wire current interface according PWM protocol
- Integrated capacitor: 1-nF (C version)
- Wide operating range: 4.5V to 20V
- Wide temperature range: -40°C to 150°C
- Other variants available in the sensor family:
  - CH505 & CH505C: AK protocol
  - CH503 & CH503C: Single pulse (standard protocol)
- Detection of speed, rotation direction, assembly position, and air gap warning
- 2-mm distance between two outer hall elements with the 3rd element in the middle
- On-chip EEPROM with factory-programming options to optimize performance
- Compliant with requirements in ISO 26262:2018, 8-14 for a component supplier to support safety requirements up to ASIL B

Package

Functional Block

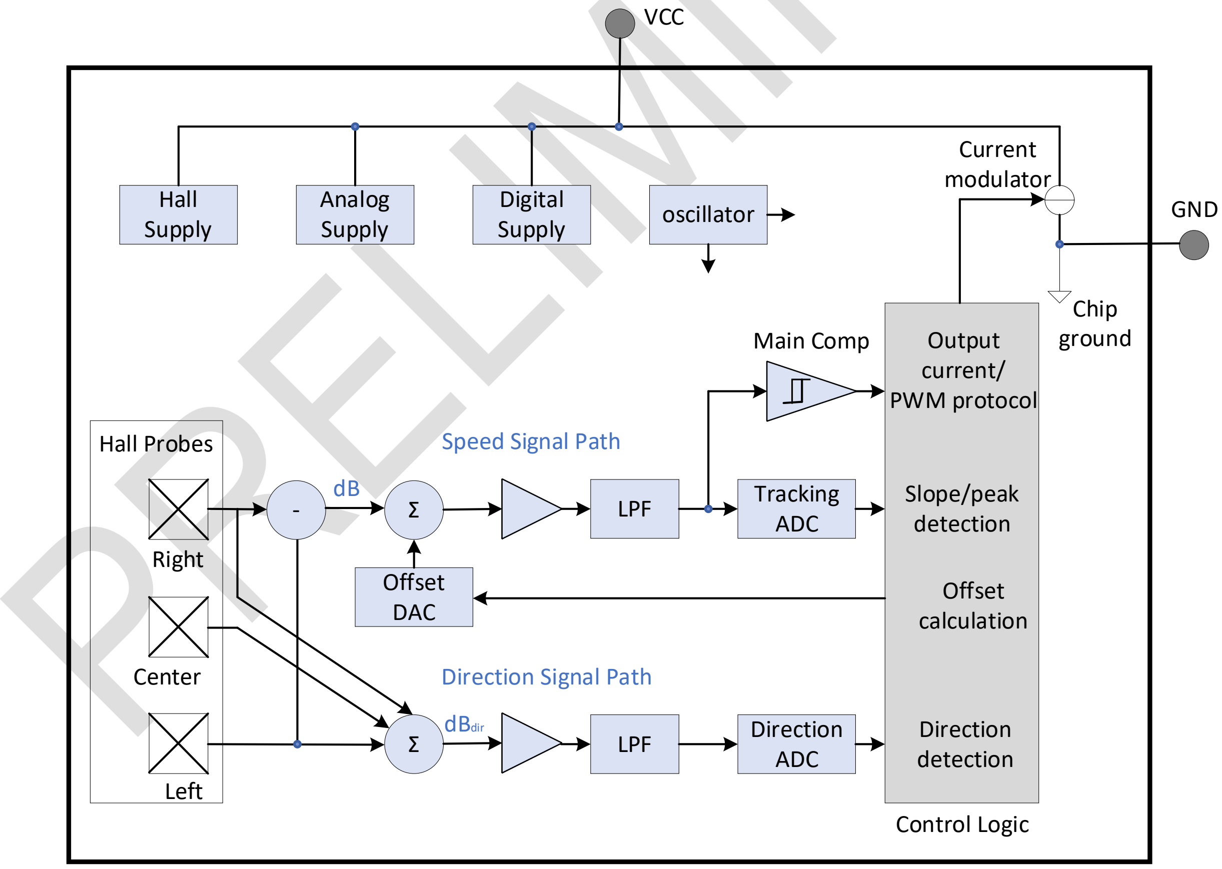

Figure 1 CH504(C) Block Diagram

Description

The CH504(C) hall-based wheel speed sensor has a two-wire current-interface with PWM protocol. It provides speed information, direction of wheel rotation and airgap warning for vehicle & motorcycle dynamics control systems and Anti-Lock Braking Systems (ABS).

The device is specified over a wide temperature range of -40 to 150ºC, and is designed to meet harsh automotive environment with optimized ESD and EMC performance. For best BCI performance, the CH504C is provided with a 1-nF integrated capacitor.

Revision History

Date	Revision	Change
April 2022	0.1	Preliminary

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1. Product Family Members

Part No.	Marking	Description
CH504	C504	Two-wire PWM protocol, CSO-2 package, packing blister carrier tape, QTY TBD, without integrated capacitor
CH504C	C504C	Two-wire PWM protocol, CSO-2 package, packing blister carrier tape, QTY TBD, with integrated capacitor

*See separate datasheets for CH504 and CH504. *目前处于前期样片阶段，为方便备样，丝印暂时是统一的，但会做标签区分。请以原厂沟通的信息为准。

2. Pin Definitions and Descriptions

Pin No.	Name	Type	Function
1	VDD	Supply	Supply voltage
2	GND	Ground	Connect to ground

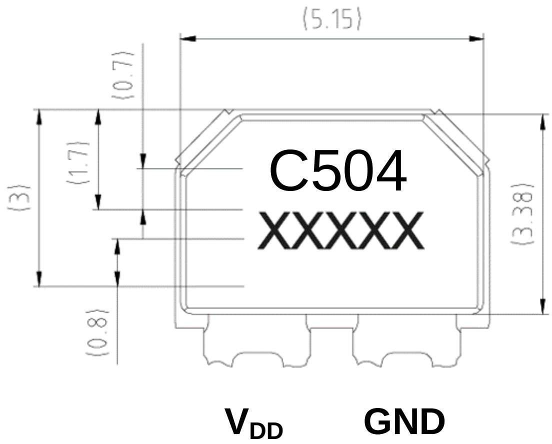


Figure 2 Pin Assignment and Top-Side-Marking of CSO-2 Package

3. Absolute Maximum Ratings

T_J= – 40℃ to 150℃, 4.5 V ≤ V_{DD} ≤ 20 V unless otherwise noted.

Parameter	Symbol	Test Conditions/Notes	Limit Values Min	Limit Values Max	Unit
Supply voltage	V_{DD}	T_J ≤ 80°C	-0.3		
		T_J ≤ 150°C		20	V
		t = 10 x 5 min		22	V
		t = 10 x 5 min, R_M ≥75Ω included in V_{DD}		24	V
		t = 400 ms, R_M ≥75Ω included in V_{DD}		27	V
Junction temperature[1]	T_J	5000 h	-40	150	°C
		2500 h	-40	160	°C
		500 h	-40	170	°C
		4 h, Vcc < 16.5V	-40	190	°C

[1] Lifetime data pending on final qualification test results.

Reverse polarity current	I_{rev}	External current limitation required, t < 4h		200	mA
		External current limitation required, t<1h		300	mA
		External current limitation required, t<10h, T=25°C		200	mA
Number of power on cycles			500,000		cycles
Storage Temperature	Ts		-40	150	°C
Package thermal Resistance	R_{thJA}			TBD[2]	K/W

[2] Pending on Cosemitech's CSO-2 package data

4. ESD Protections

ESD values below are to be updated after ESD report ready

Parameter	Test Result	Classification level	Notes
HBM	TBD	AEC-Q100-002, H3B	R = 1.5 kΩ, C =100 pF
CDM	TBD	AEC-Q100-011, C4	

Results below are tested by a leading transmission sensor Tier1 customer.

工作状态	放电位置	放电类型	放电网络	电压等级	功能状态要求	CH505	CH505C
断电	引脚	接触放电	C=150pF, R=330Ω	±4KV	Ⅰ	Pass	Pass
	导体外壳	接触放电	C=150pF, R=330Ω	±6KV	Ⅰ	Pass	Pass
	非导体外壳	空气放电	C=330pF, R=2kΩ	±8KV	Ⅰ	Pass	Pass
通电	传导位置	接触放电	C=150pF, R=330Ω	±8KV	Ⅰ	Pass	Pass
	传导与非传导位置	空气放电	C=330pF, R=2kΩ	±8KV	Ⅰ	Pass	Pass
			C=330pF, R=2kΩ	±20KV	Ⅲ	Pass	Pass

5. Operating Range

Parameter	Symbol	Note / Test Condition	Values			Unit
			Min	Typ	Max	
Supply voltage	V_{DD}	Directly on IC leads; voltage drop at R_M excluded	4.5	–	20	V
Supply voltage modulation	V_{AC}	V_{DD} =13V; 0 < f_{mod} <150kHz[1]			6	V_{pp}
Junction temperature	T_J	12500h[2]	-40		110	°C
		10000h[2]	-40		125	

[1] Sine wave
[2] Lifetime data pending on final qualification test results.

		5000h	-40		150	
		2500h	-40		160	
		500h	-40		170	
Pre-induction	B_o		-500		500	mT
Pre-induction offset between outer probes	$B_{stat\ l/r}$		-30		30	mT
Differential induction	dB		-120		120	mT
Pre-induction offset between mean of outer probes and center probe	$B_{stat\ m/o}$		-30		30	mT
Signal frequency	f		1		2500	Hz
			2500		5000[3]	Hz
Frequency changes	df/dt				±100	Hz/ms

[3] High frequency behavior verified by design/characterization only. Frequency >2.5kHz may have influence on jitter performance and magnetic thresholds. DR-R pulse length will be cut off above approximately 3.3 kHz. Therefore direction detection may not be possible anymore at high frequency.

6. Parameters Specification

6.1 Electrical Characteristics

All values specified at constant amplitude and offset of input signal

Parameter	Symbol	Test conditions/Notes	Limit values			Unit
			Min	Typ	Max	
Supply current	I_{Low}		5.9	7	8.4	mA
Supply current	I_{High}		11.8	14	16.8	mA
Supply current ratio	I_{High}/I_{Low}		1.9			
Current slew rate	SR_r, SR_f	Output rise/fall slew rate, R_M =75Ω, T<125°C	8		22	mA/µs
		Output rise/fall slew rate, R_M =75Ω, T<170°C	8		26	mA/µs
Line regulation	dI_X/dV_{DD}	[1]			90	µA/V
Initial calibration delay time	$t_{d,input}$	Additional to n_{start}	255	300	345	µs
Magnetic edges suppressed until output switching	$n_{DZ\text{-}start}$	After power on and stop pulse			1[2]	edges

[1] Higher values due to R_M-C combination
[2] The sensor requires up to n_{start} magnetic switching edges for valid speed information after power-up or after a stand still condition. During that phase the output is disabled.

Magnetic edges required for offset calibration	$n_{DZ\text{-}calibration}$	7^{th} edge correct[3]			6[2]	edges
In rare cases	$n_{DZ\text{-}calibration\text{-}rare}$				8	edges
Number of pulses in uncalibrated mode	$n_{DZ\text{-}Startup}$				5	pulses
In rare cases	$n_{DZ\text{-}Startup\text{-}rare}$				7	pulses
Number of pulses with invalid direction information	$n_{DR\text{-}Startup}$	$dB < dB_{EL}$ After $n_{DR\text{-}Startup}$ pulses +1 the direction information is correct			7	pulses
		$dB > dB_{EL}$ After $n_{DR\text{-}Startup}$ pulses +1 the direction information is correct			2[4]	
Number of pulses with invalid assembly bit information	$n_{EL\text{-}Startup}$	After $n_{EL\text{-}Startup}$ pulses +1 the assembly bit information is correct			7	pulses
Number of pulses where the airgap warning info is suppressed	$n_{LR\text{-}Startup}$	LR information is provided only in calibrated mode			5	pulses
Signal behavior after undervoltage or standstill > t_{Stop} Number of magnetic edges where the first pulse in given.	$n_{DZ\text{-}Start}$	Magnetic edge according to $dB_{Limit,\ early\ startup}$, $t_{d,input}$ has to be taken into account			2	edges
Shortest time delay between pulse 0 (stop pulse) and pulse 1		Reference rising edges, includes pre-low length	293	345	397	µs
Shortest time delay between wheel speed pulse 1 and 2 and all further pulses		Falling to rising edge - identical with pre-low bit length	38	45	52	µs
Phase shift change during PGA switching			0		80	°
Phase shift change during transition from uncalibrated to calibrated mode	$\Delta\Phi_{switch}$		-90		+90	°

[3] One magnetic edge is defined as a montonic signal change of more than 3.3 mT
[4] Direction signal is given already during uncalibrated mode. Assembly Bit information is only provided in calibrated mode.

Duty cycle	duty	[5]Measured @dB = 2mT sine wave	40	50	60	%
Jitter 1Hz < f < 2.5kHz	$S_{Jit-close}$ ([6]1σ value)	T_J < 150°C, V_{DD}= 12 V, dB ≥ 2mT			±2	%
		TJ < 170°C, V_{DD}= 12 V, dB ≥ 2mT			±3	%
Jitter 2.5kHz < f < 5kHz	$S_{Jit-close}$ ([6]1σ value)	T_J < 150°C, V_{DD}= 12 V, dB ≥ 2mT			±3	%
		T_J < 170°C, V_{DD}= 12 V, dB ≥ 2mT			±4.5	%
Jitter 1Hz < f < 2.5kHz	$S_{Jit-far}$ ([6]1σ value)	T_J < 150°C V_{DD} = 12 V, 2mT ≥ dB > dB_{Limit}			±4	%
		T_J < 170°C V_{DD} = 12 V, 2mT ≥ dB > dB_{Limit}			±6	%
Jitter 2.5kHz < f < 5kHz	$S_{Jit-far}$ ([6]1σ value)	T_J < 150°C V_{DD} = 12 V, 2mT ≥ dB > dB_{Limit}			±6	%
		T_J < 170°C V_{DD} = 12 V, 2mT ≥ dB > dB_{Limit}			±9	%
Jitter during startup and uncalibrated mode	$S_{Jit-close}$ ([6]1σ value)	– 40°C ≤ T_{amb} ≤ 150°C			±3	%
		150°C ≤ T_{amb} ≤ 170°C			±4	%
	$S_{Jit-far}$ ([6]1σ value)	– 40°C ≤ T_{amb} ≤ 150°C			±5	%
		150°C ≤ T_{amb} ≤ 170°C			±7	%
Jitter at board net ripple	[6]S_{Jit-AC}	V_{DD}=13V ± 6Vpp 0 < f < 50kHz, dB = 15 mT			±2	%
Jitter at board net ripple in uncalibrated mode	S_{Jit-AC} ([6]1σ value)	V_{DD}=13V±6Vpp 0 < f < 50kHz, dB = 15 mT			±3	%

[5] During fast offset alterations, due to the calibration algorithm, exceeding the specified duty cycle is permitted for short time periods.,
[6] Verified by design/characterization only.

6.2 Magnetic Characteristics

All values specified at constant amplitude and offset of input signal, over operating range, unless otherwise specified. Typical values correspond to V_{DD} = 12 V and T_A = 25°C.

Parameter	Symbol	Test conditions/Notes	Limit values			Unit
			Min	Typ	Max	
Limit threshold	[1]dB_{Limit}	1Hz < f < 2.5kHz	0.35	0.8	1.5	mT
		2.5kHz < f < 5kHz			1.6	

[1] Magnetic amplitude values, sine magnetic field, Limits refer to the 50% criteria. 50% of pulses are missing or wrong. Valid in calibrated mode only.

Airgap warning threshold	[1]$dB_{Warning}$	1Hz < f < 2.5kHz	0.9	1.4	2.6	mT
		2.5kHz < f < 5kHz			2.8	
Limit - Airgap warning threshold ratio	$dB_{Warning}$ /dB_{Limit}		1.3	2	2.7	
Assembly position threshold	[1]dB_{EL}	At room temp	5.2	7.2	9.6	mT

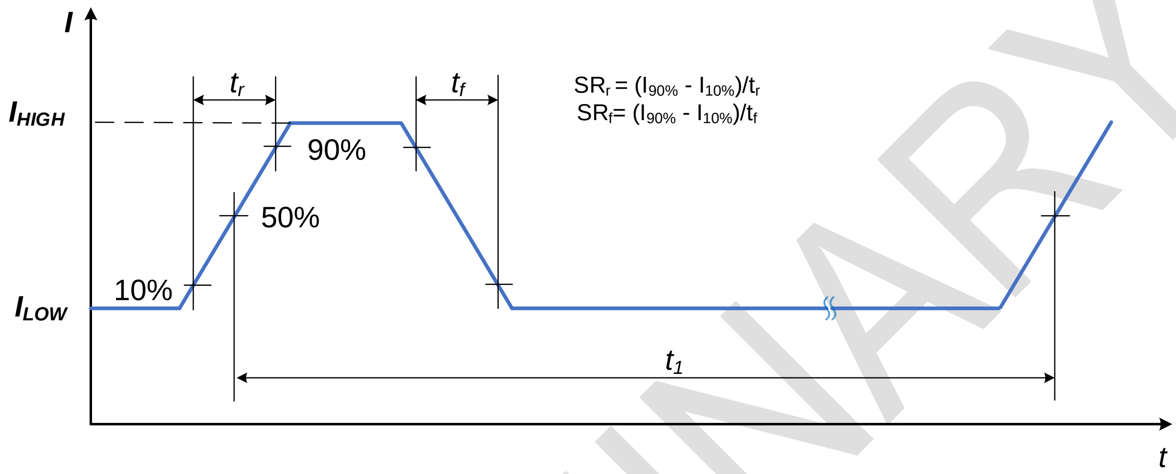


Figure 3 Definition of rise and fall time

6.3 Timing Characteristics

Parameter	Symbol	Limit Values			Unit
		Min	Typ	Max	
Pre-low length	$t_{pre\text{-}low}$	38	45	52	µs
Length of Warning pulse	$t_{Warning}$	38	45	52	µs
Length of DR-L pulse	$t_{DR\text{-}L}$	76	90	104	µs
Length of DR-R pulse	$t_{DR\text{-}R}$	153	180	207	µs
Length of DR-L & EL pulse	$t_{DR\text{-}L\&EL}$	306	360	414	µs
Length of DR-R & EL pulse	$t_{DR\text{-}R\&EL}$	616	720	828	µs
Output of EL pulse, maximum frequency	$f_{EL,\ max}$		117		Hz
Length of stand still pulse	t_{stop}	1.232	1.44	1.656	ms
Stand still period[1]	T_{stop}	590	737	848	ms

[1] If no magnetic switching edge is detected for a period longer than T_{stop}, the stand still pulse is issued.

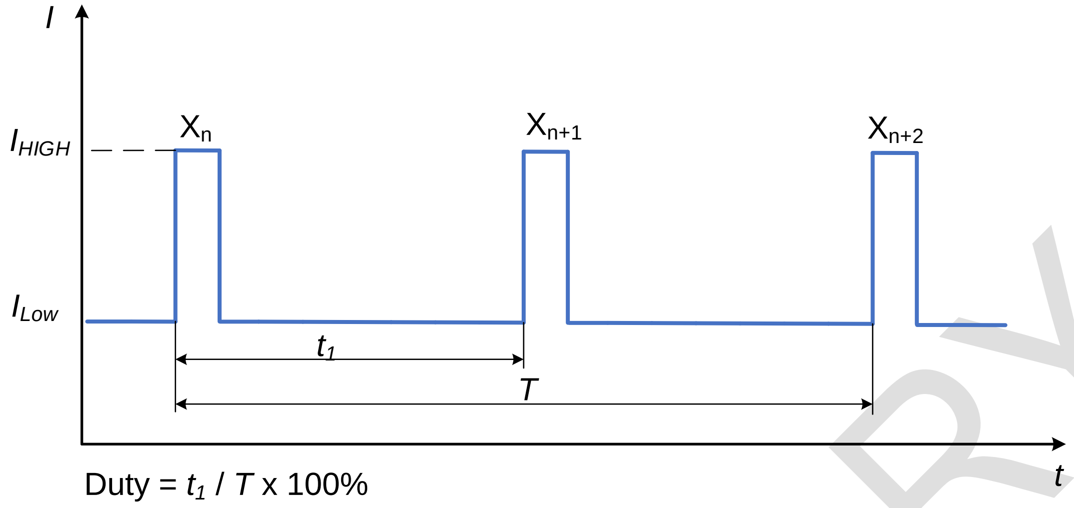


Figure 4 Definition of duty cycle

6.4 Degradation of Direction Signal

With the two outer hall elements distance being 2mm, the direction signal **dB_dir** (= center - (left + right) / 2) is optimized for a target wheel pitch of 4 mm. Increase the magnetic input signal to compensate signal loss for pitches other than 4 mm. With an ideal pitch of 4 mm, the absolute speed signal is 2 x higher than direction signal due to differential principle. Both speed and direction signals in **Figure 5** are normalized to magnetic speed signal for an ideal pitch of 4 mm.

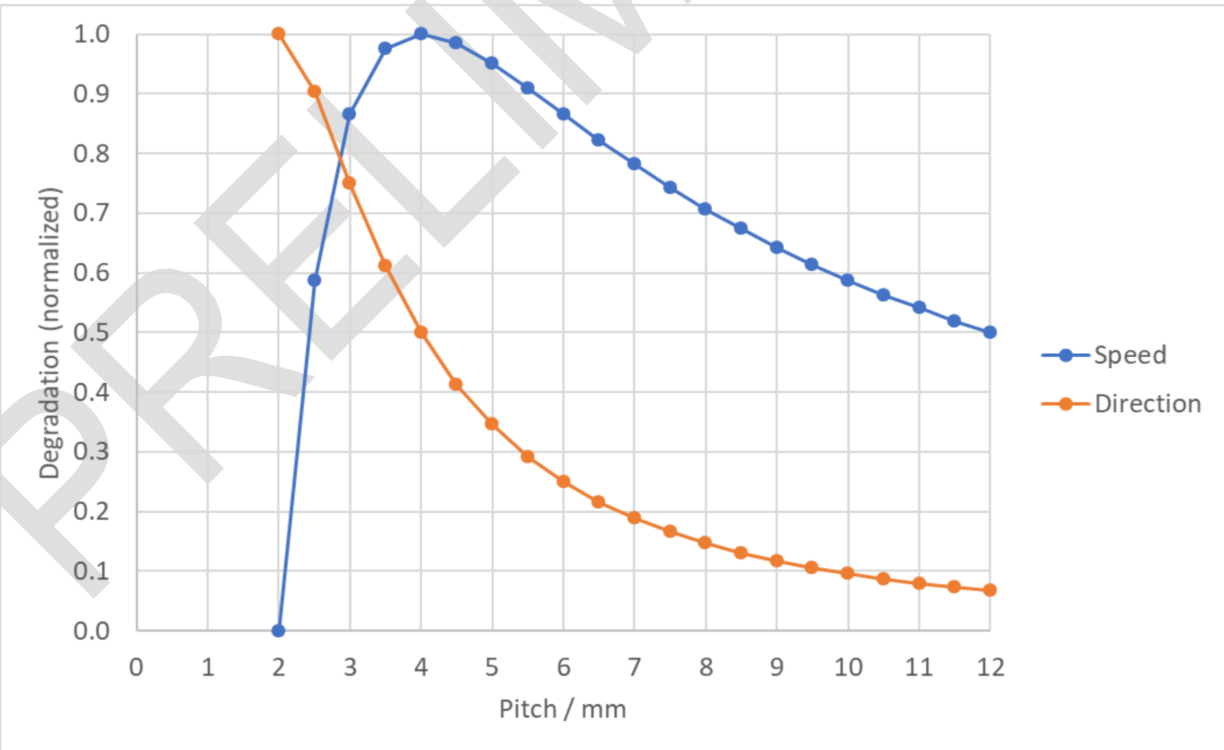


Figure 5 Degradation of speed and direction signal

7. Function Description

7.1 General

The CH504(C) detects the motion of active wheels (multiple encoder) and passive wheels (i.e., having ferromagnetic teeth) by measuring the differential flux density of the magnetic field. A back-biasing permanent magnet must be used when pairing with passive wheels. Either south or north pole of the magnet can be attached to the back side of the IC package.

Both speed and direction of rotation information are provided. This is accomplished with three equally-spaced Hall elements, integrated on the IC. The two outer Hall elements have a distance of 2 mm, generating a differential signal that derives the speed of the wheels. The 3rd Hall element is placed in the middle, and together with the outer ones for direction detection.

The device is designed with a dynamic self-calibration algorithm to cancel magnetic offset up to ± 20mT. Only a few magnetic edges after start-up (uncalibrated mode) are necessary for self-calibration. After the offset calibration sequence, switching occurs when the input signal crosses the arithmetic mean of its maximum and minimum values, see **Figure 6.**

A valid sensor output can only exist in two states, OFF or ON, which is indicated by **LOW** and **HIGH** current consumption respectively.

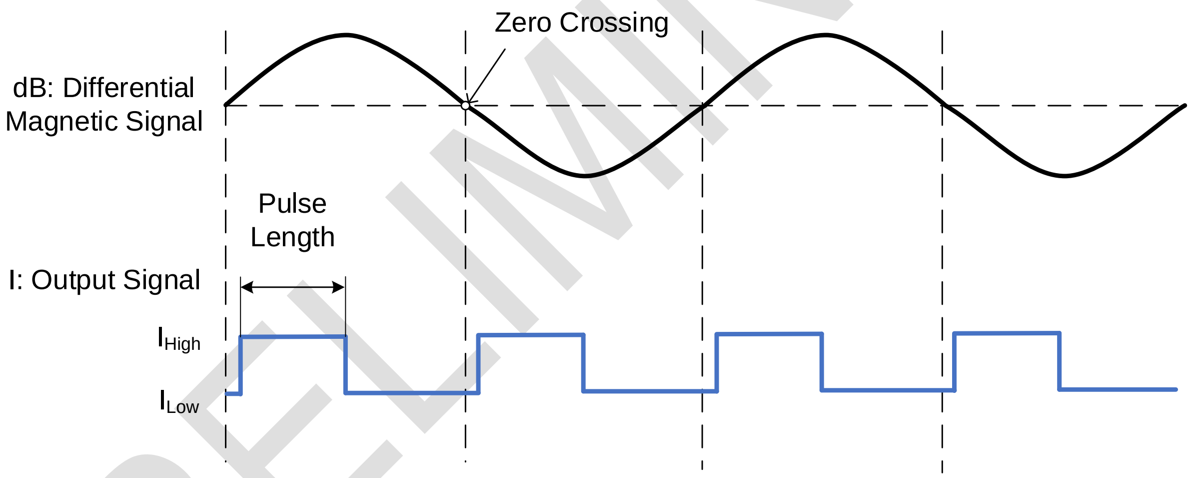


Figure 6 Zero-crossing principle and corresponding output signal

7.2 Block Diagram

CH504(C) main blocks are as follows.

- Three Hall elements (left, center, right)
- Speed signal (**dB**) path: Pre-amplifier, Low-pass filter (LPF), Main Comparator, Tracking ADC, Offset DAC
- Direction signal (**dB_{dir}**) path: Pre-amplifier, Low-pass filter (LPF), Direction ADC
- Digital Core (Control logic)
- Current modulator
- Supplies for Hall, analog & digital

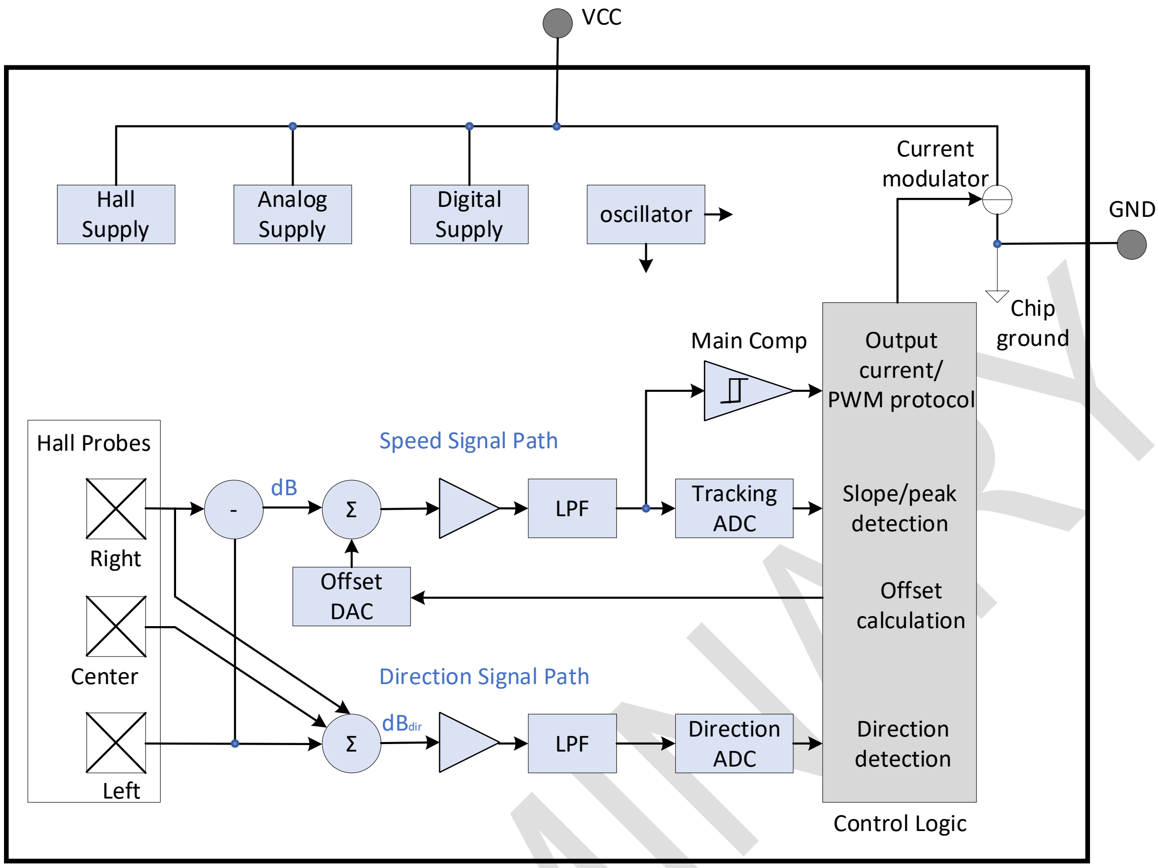


Figure 7 Block Diagram

The direction signal (**dB**) is calculated as Equation (1), amplified, filtered and then digitized by the tracking ADC.

$$\mathbf{dB = Right - Left} \quad (1)$$

Peak detection and offset calculation are done in the digital core. The calculated offset ((dB_{max} + dB_{min})/2) is fed back into the speed signal path with a 14-bit DAC to correct any offsets. The main comparator compares the speed signal with zero value. In uncalibrated mode, output of speed pulse is triggered in the digital core by exceeding a certain threshold (2 x dB_{limit}). The speed pulse of the output protocol is issued by zero crossing.

The direction signal **dB_{dir}** is calculated as Equation (2), amplified, filtered and digitized. The direction information is determined by the digital core which then issues the PWM protocol.

$$\mathbf{dB_{dir} = Center - (Left + Right)/2} \quad (2)$$

7.3 PWM Current Interface

For reliable internal conveyance, the output current is **LOW** for **$t_{pre\text{-}low}$** between each magnetic transition and the rising edge of the corresponding output, followed by the signal pulse, see **Figure 10**. In addition to the speed pulse, the following information is provided by varying the length of the output pulses (i.e., PWM modulation).

*Airgap Warning range = **Warning***: issued when the magnetic field is below a critical value, or when the airgap between the IC and the target wheel exceeds a critical value. The IC works with reduced functionality. The definition of differential magnetic flux density ranges can be found in **Figure 9.**

*Assembly position range = **EL***: issued when the magnetic field does not reach a pre-defined value. The device works with full functionality. As the CH504(C) uses a PWM output, the **EL** information has a specific pulse length as specified in **6.3**. The **EL** bit can be used to confirm the correct mounting of the sensor. This test can be done in production line applying a low-frequency speed signal.

*Direction of rotation right = **DR-R***: issued the target wheel in front of the sensor IC moves from the pin **GND** to the pin $\mathbf{V_{DD}}$, as shown in 错误!未找到引用源。**Figure 8.**

*Direction of rotation left = **DR-L***: issued the target wheel in front of the sensor IC moves from the pin $\mathbf{V_{DD}}$ to the pin **GND**. At sufficient magnetic field the direction information will be corrected already during uncalibrated mode after 2 pulses.

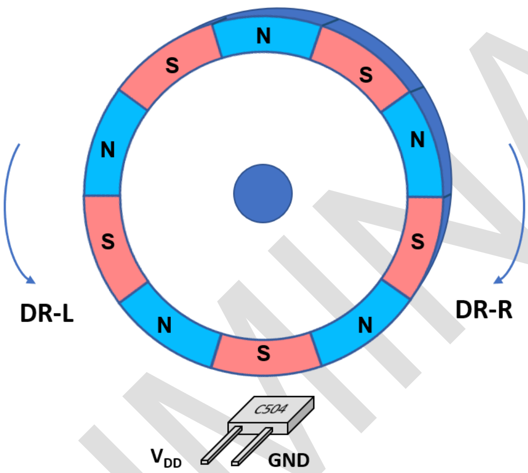


Figure 8 Definition of rotation direction

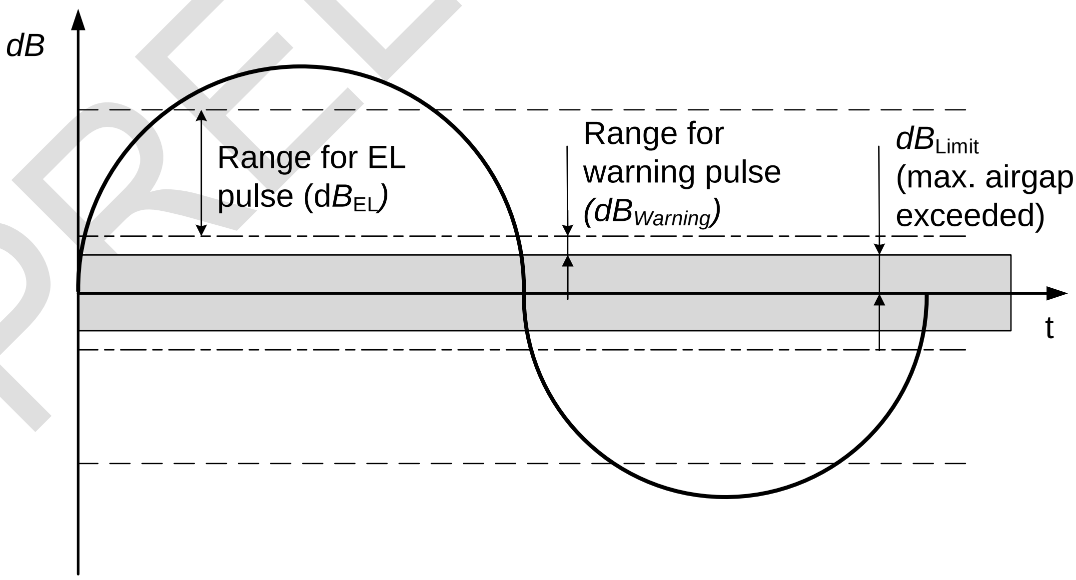


Figure 9 Definition of differential magnetic flux density ranges

The magnetic differential field is defined as **dB** in **Figure 6**.

- When **dB** < **dB_{Limit}**, signal is lost.
- When **dB** < **$dB_{Warning}$**, the output pulse length is 45µs. The warning output is dominant. This means, both the direction and the assembly position information (EL) are disabled as a result of being close to the limit airgap.

Depending on left or right rotation, when:

- **dB** > **dB_{EL}**, the output pulse lengths are 90µs (DR-L pulse) or 180µs (DR-R pulse).
- **dB** < **dB_{EL}**, the output pulse lengths are 360µs (DR-L pulse) and 720µs (DR-R pulse).

Due to decreasing cycle times at higher frequencies, these longer pulses are only output up to frequencies of approximately 117Hz. For higher frequencies and **dB** < **dB_{EL}**, the output pulse lengths are 90µs or 180µs respectively.

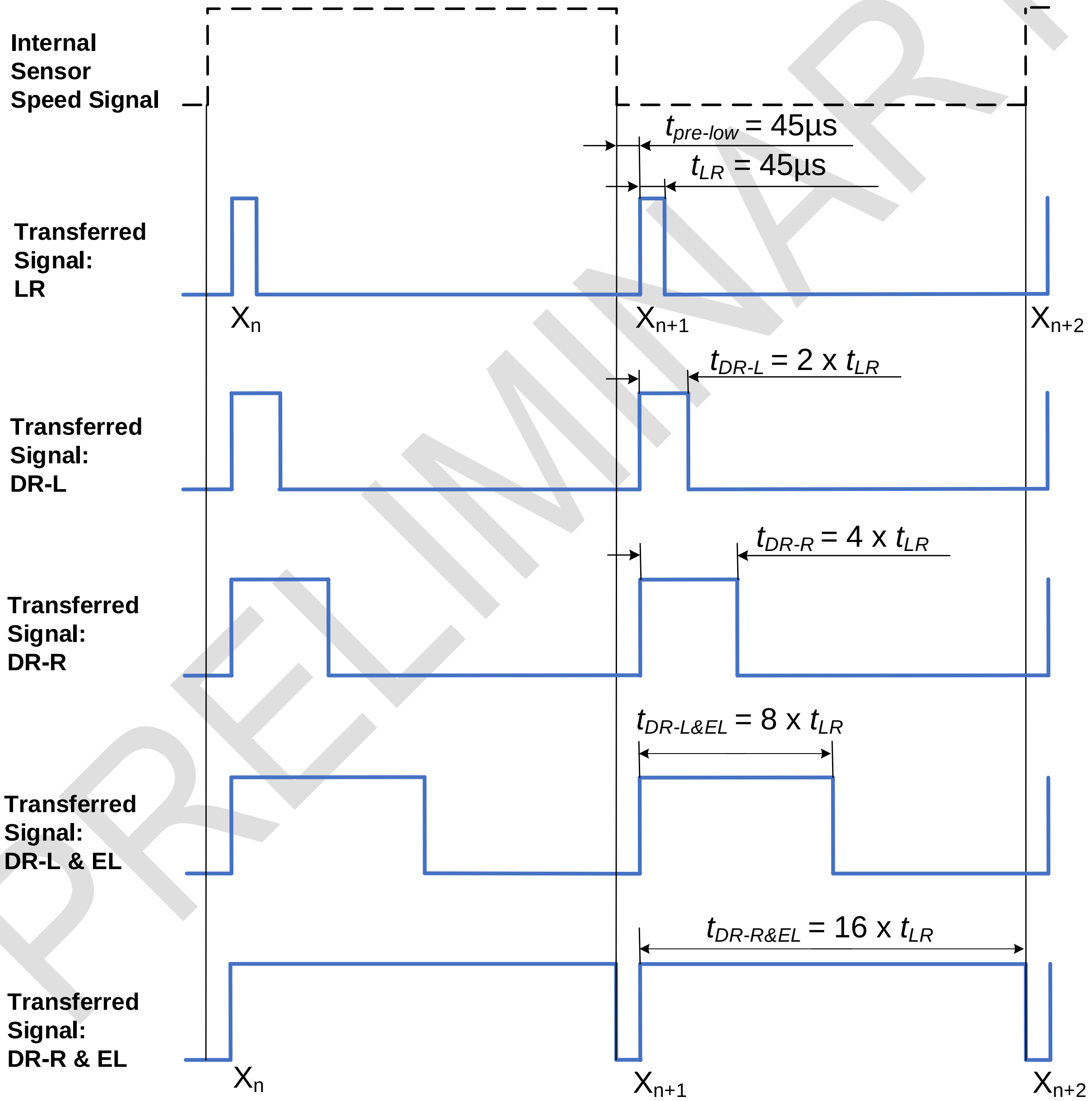


Figure 10 Definition of PWM current interface

7.4 Operation Modes

7.4.1 Uncalibrated Mode and Calibrated Mode

To detect the signal transient, a threshold DNC (digital noise constant) needs to be exceeded. This DNC is determined by the signal amplitude and initial offset value. The smallest DNC (in 错误!未找到引用源。), defines the parameter "**$dB_{startup}$**", which is 2***dB_{limit}**.

When the signal slope is identified as a rising-edge (or falling-edge), a trigger pulse will be issued to the current modulator. A 2nd trigger pulse is issued as soon as a falling-edge (or rising-edge respectively) is detected (and vice versa).

A phase shift between the magnetic input signal and output signal occurs, when the DNC changes ($d_1 \rightarrow d_2$) with the magnetic field amplitude. In the calibrated mode the output will switch at zero-crossing of the input signal. The phase shift between input and output signal is no longer determined by the ratio between DNC and signal amplitude. Therefore, a sudden change in the phase shift may occur during the transition from uncalibrated to calibrated mode. The summed-up change in phase shift from the first output edge issued to the output edges in calibrated mode will not exceed ± 90°. After calibration, consecutive output edges should have a nominal delay of about 180°.

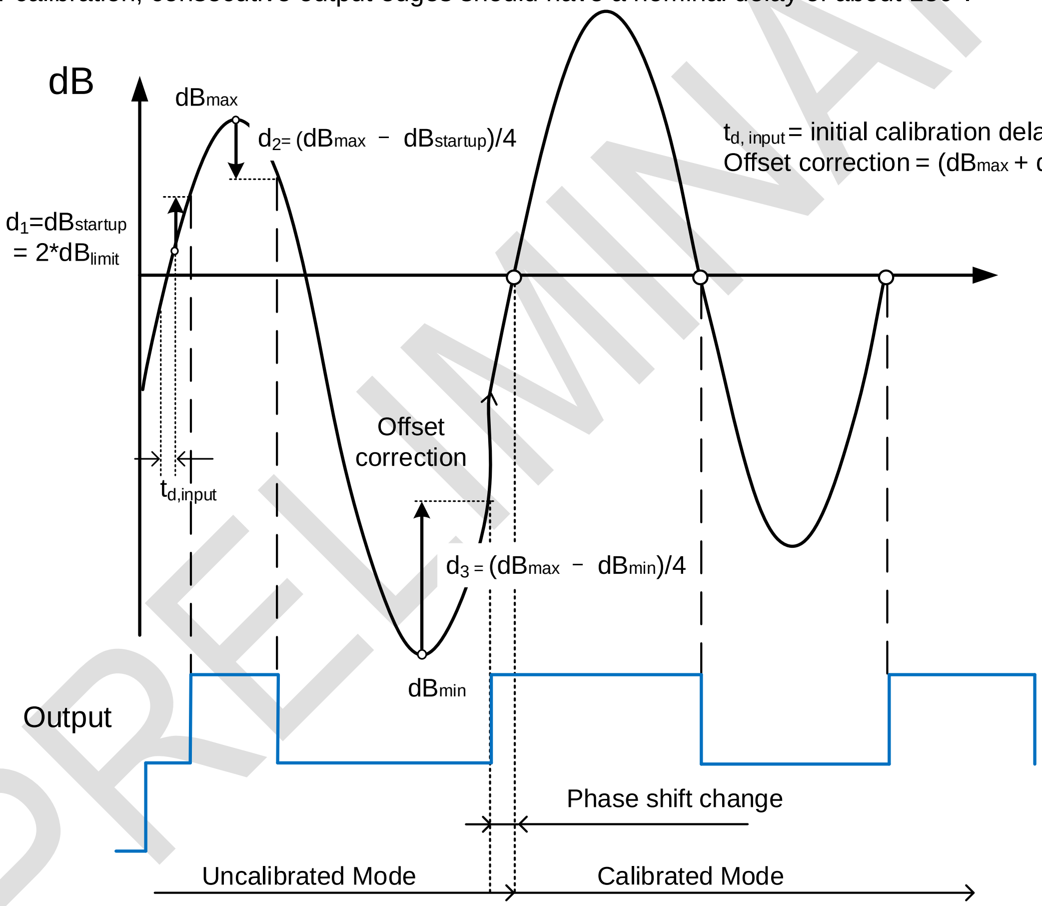


Figure 11 Example of transition from uncalibrated to calibrated mode

7.4.2 Operation at Standstill

If no magnetic differential signal is recognized for longer than standstill period **T_{stop}**, the IC sends the stop pulse. Typically, with the first output stop pulse, the circuitry reverts to the uncalibrated mode.

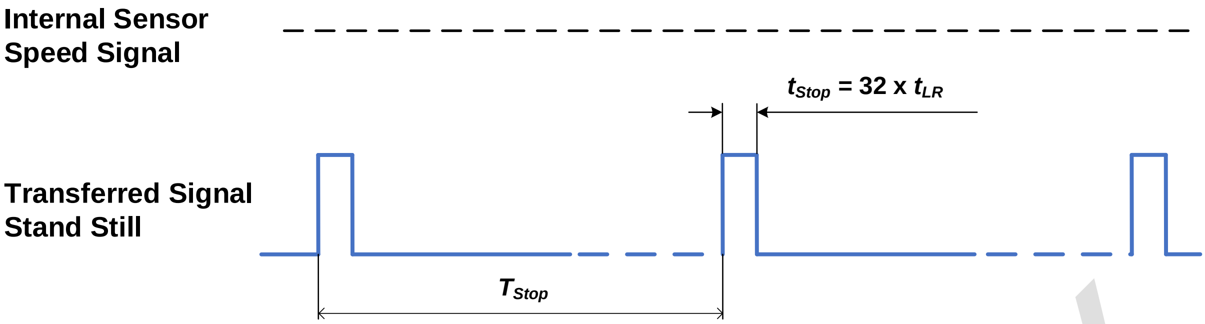


Figure 12 Definition of stand still output pulse

7.4.3 Duty Cycle at Fast Changing Frequencies

If the duty cycle deviates from 50%, it is possible that the present pulse length is output entirely once and cut once, within the same period.

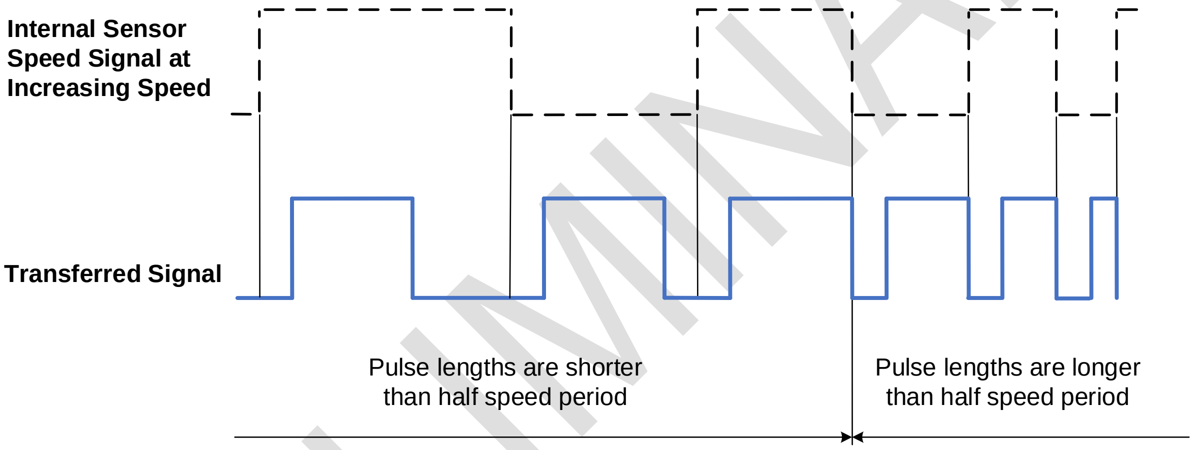


Figure 13 Definition of field direction and sensor switching

7.4.4 Change of Direction of Rotation

A fast rotation direction reversal (in t < 0.7s) can lead to a local extremum (maximum or minimum) of the magnetic input signal. This local extremum could be detected and incorrectly used for offset calibration. At worst case, a duty cycle up to max 15% to 85% could occur for a few pulses. **dB**$_{\mathbf{warning}}$ and **dB**$_{\mathbf{EL}}$ information can be incorrect during this short period. Typically, after 2-3 zero crossings, a re-calibration takes place, and the offset will be then correct and hence the duty cycle, **dB**$_{\mathbf{warning}}$ and **dB**$_{\mathbf{EL}}$ also. With that, the sampling points for direction detection are also at unusual signal phase angles. At small magnetic input signals (**dB** < 1.7 x **dB**$_{\mathbf{warning}}$) this can lead to incorrect direction information.

If the local extremum occurs close to the zero-crossing, it could theoretically cause distances down to 45 µs of two consecutive output pulses at the point of direction reversal as well as a **dB**$_{\mathbf{warning}}$ pulse.

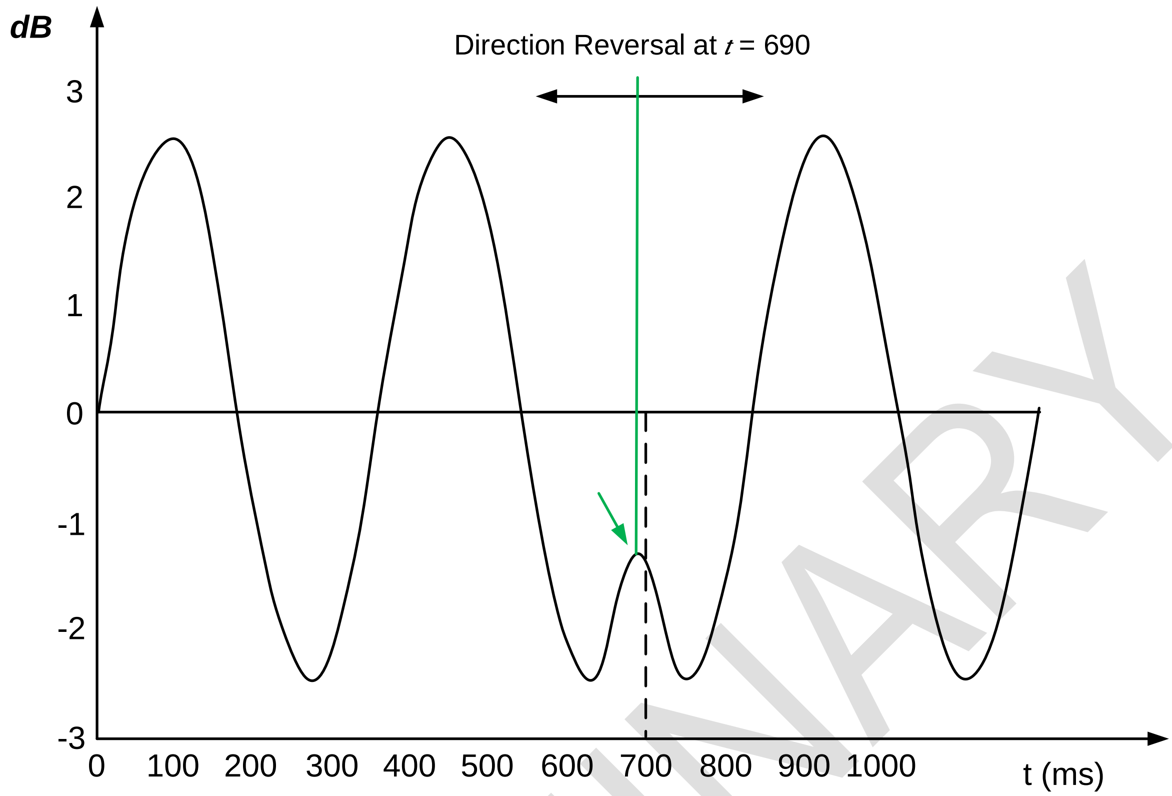


Figure 14 Example of fast direction reversal

7.5 Test Circuit

Following test circuit is used for evaluating electrical parameters on this datasheet.

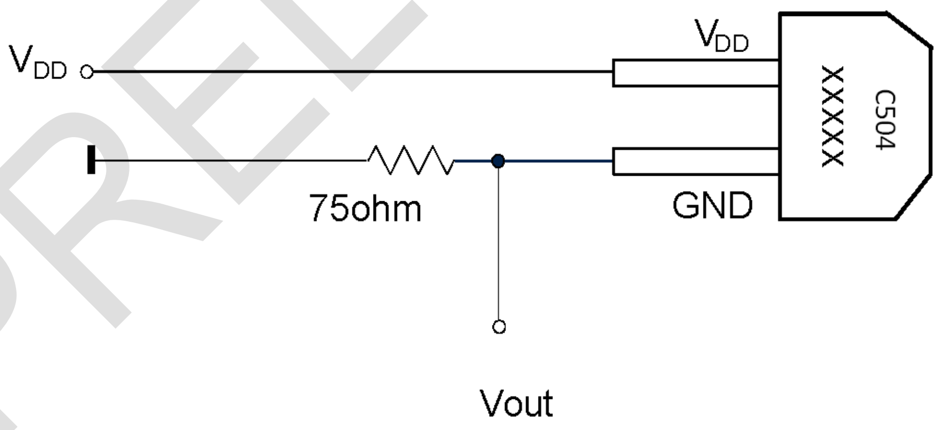


Figure 15 Test Circuit for CH504

7.6 Application Circuit

Circuit below shows the recommended application circuit with reverse bias and overvoltage protection.

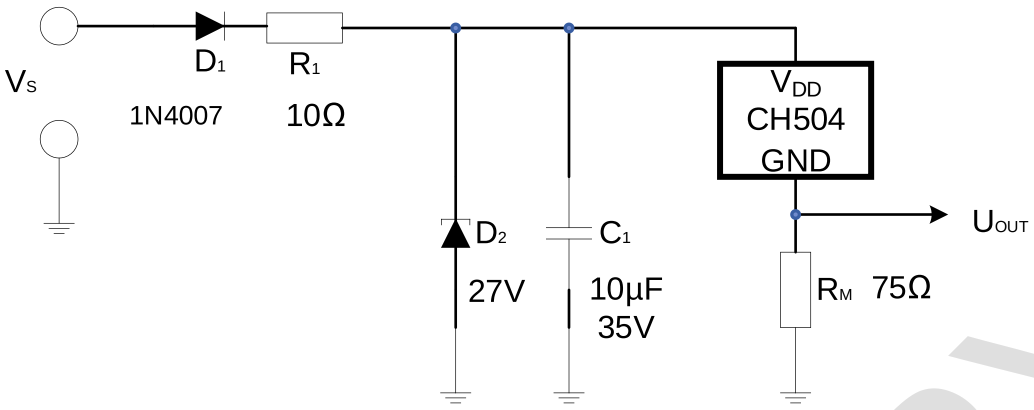


Figure 16 Application Circuit

An implementation of 10 Ω in V_{DD} path reduces minimum power supply direct on leads of the sensor, but decreases max current at D_2 and makes PCB more robust. This PCB represents a compromise of minimum power supply and current flow on D_2. With higher values than 10Ω a higher minimum supply voltage and higher robustness is reached.

8. Electro Magnetic Compatibility (EMC)

Suggested EMC test circuit, see **Figure 17**. External components can vary depending on the device version (with or without capacitor inside). Results are dependent on R_M!

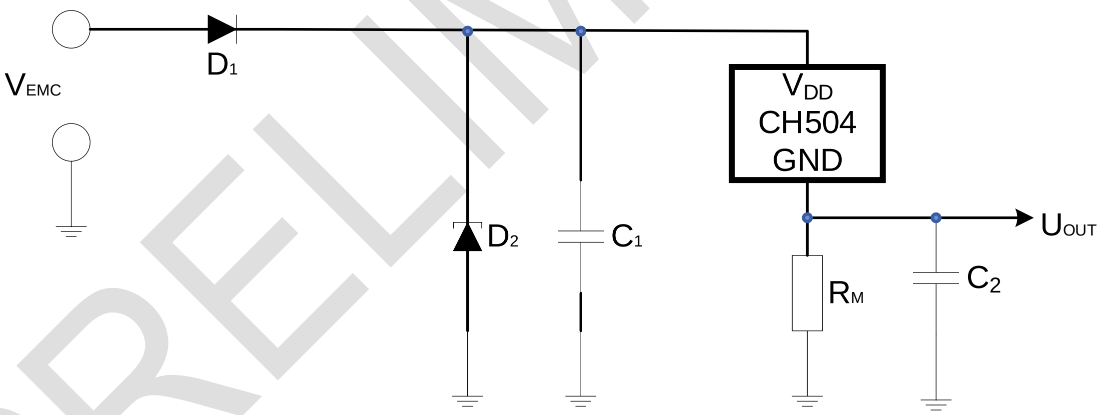
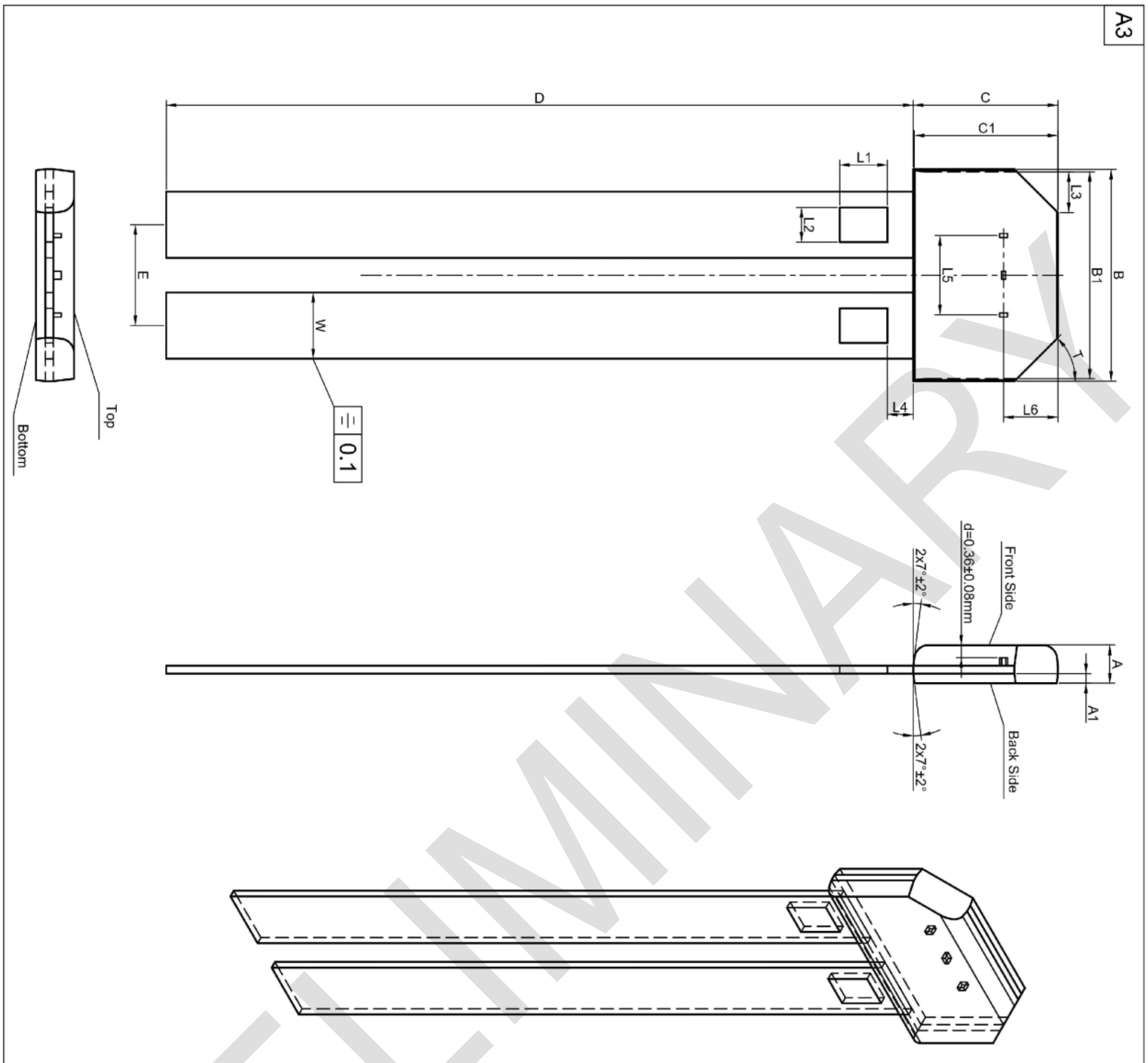


Figure 17 Recommended EMC Test Circuit

9. Package Information

For CH504 and CH504C, the L6 in POD dimension is different.
See details in **Figure 18** and **Figure 19.**

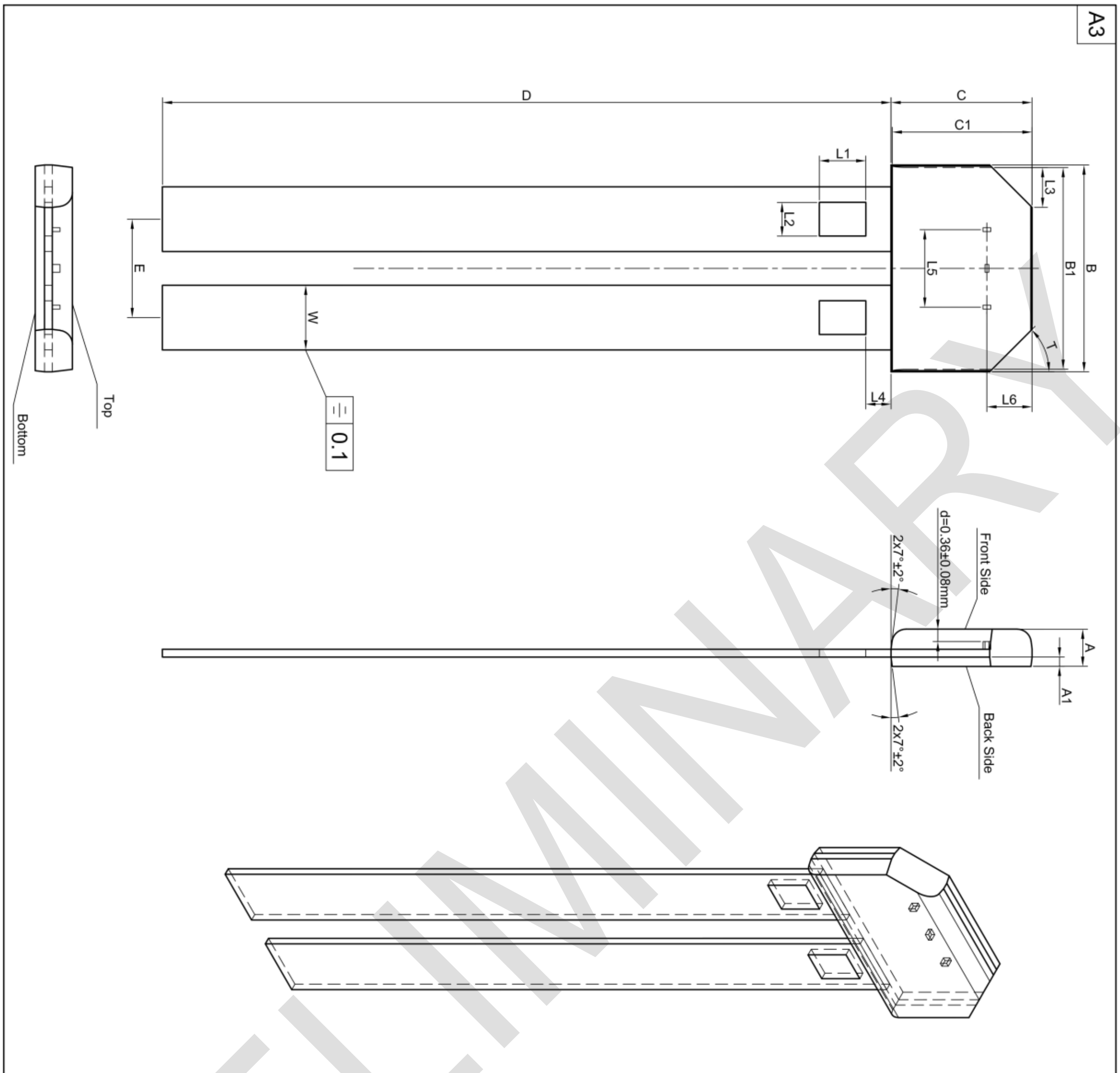
Part Number	Package	Package Dimensions
CH504	CSO-2	Figure 18
CH504C	CSO-2	Figure 19



SYMBOL	MIN	NOM	MAX
A	0.910	0.960	1.010
A1	0.190	0.240	0.290
B	5.290	5.340	5.390
B1	5.070	5.150	5.230
C	3.520	3.640	3.760
C1	3.300	3.380	3.460
D	18.600	18.800	19.000
E	2.490	2.540	2.590
F	0.192	0.200	0.208
L1	1.150	1.200	1.250
L2	0.820	0.870	0.920
L3	0.900	1.000	1.100
L4	0.550	0.650	0.750
L5		2.000	
L6	1.267	1.367	1.467
W	1.620	1.670	1.720
T		45°	

产品图	
比例	10:1

Figure 18 CH504 POD



SYMBOL	MIN	NOM	MAX
A	0.910	0.960	1.010
A1	0.190	0.240	0.290
B	5.290	5.340	5.390
B1	5.070	5.150	5.230
C	3.520	3.640	3.760
C1	3.300	3.380	3.460
D	18.600	18.800	19.000
E	2.490	2.540	2.590
F	0.192	0.200	0.208
L1	1.150	1.200	1.250
L2	0.820	0.870	0.920
L3	0.900	1.000	1.100
L4	0.550	0.650	0.750
L5		2.000	
L6	1.067	1.1670	1.2670
W	1.620	1.670	1.720
T		45°	

产品图	
比例	10:1

Figure 19 CH504C POD