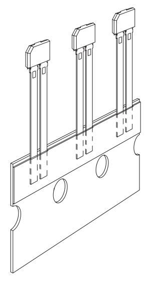
Differential Two-Wire Hall Effect Sensor IC

TLE4942
TLE4942C

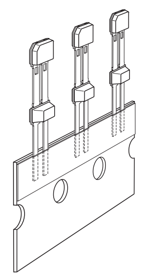
Data Sheet, please ask for latest version

Features

- Two-wire PWM current interface
- Detection of rotation direction
- Airgap diagnosis
- Assembly position diagnosis
- Dynamic self-calibration principle
- Single chip solution
- No external components needed
- High sensitivity
- South and north pole pre-induction possible
- High resistance to piezo effects
- Large operating air-gaps
- Wide operating temperature range
- TLE4942C: 1.8 nF overmolded capacitor



P-SSO-2-1



P-SSO-2-2

Type	Marking	Ordering Code	Package
TLE4942	4200E4	Q62705-K428	P-SSO-2-1
TLE4942C	42C0E4	Q62705-K437	P-SSO-2-2

The Hall Effect sensor IC TLE4942 is designed to provide information about rotational speed, direction of rotation, assembly position and limit airgap to modern vehicle dynamics control systems and ABS. The output has been designed as a two wire current interface based on a Pulse Width Modulation principle. The sensor operates without external components and combines a fast power-up time with a low cut-off frequency. Excellent accuracy and sensitivity is specified for harsh automotive requirements as a wide temperature range, high ESD robustness and high EMC resilience. State-of-the-art BiCMOS technology is used for monolithic integration of the active sensor areas and the signal conditioning.

Finally, the optimised piezo compensation and the integrated dynamic offset compensation enable easy manufacturing and elimination of magnet offsets.

The TLE4942C is additionally provided with an overmolded 1.8 nF capacitor for improved EMI performance.

Pin Configuration
(top view)

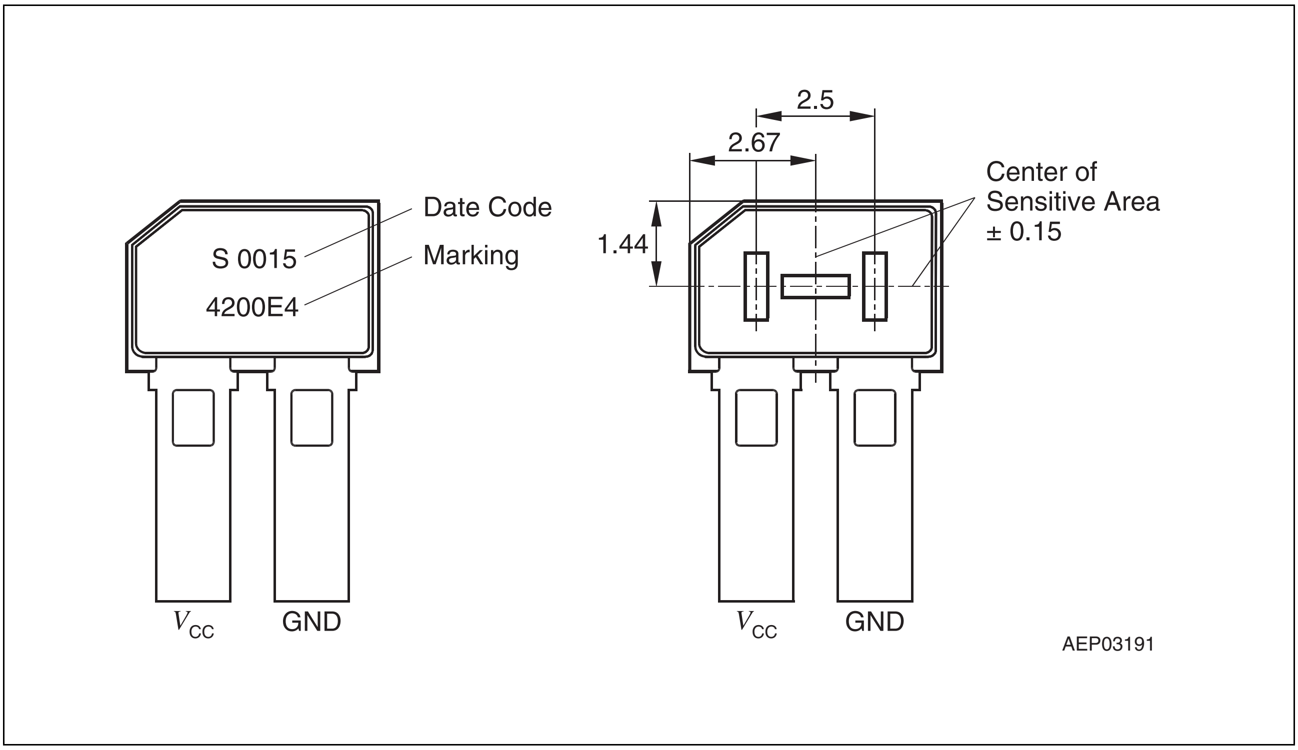


Figure 1

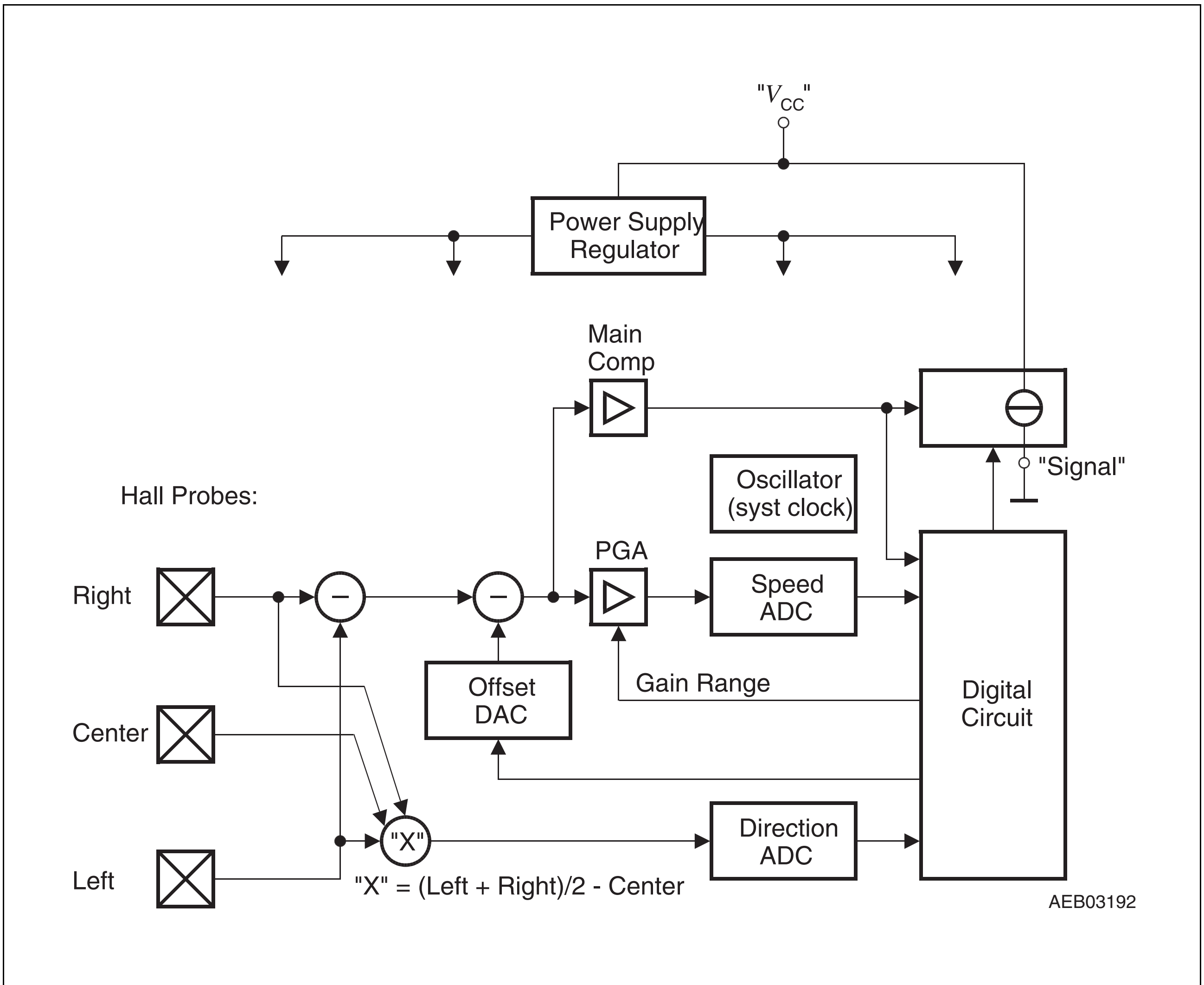


Figure 2 Block Diagram

Functional Description

The differential Hall Effect IC detects the motion of ferromagnetic or permanent magnet structures by measuring the differential flux density of the magnetic field. To detect the motion of ferromagnetic objects the magnetic field must be provided by a backbiasing permanent magnet. Either the South or North pole of the magnet can be attached to the rear, unmarked side of the IC package.

Magnetic offsets of up to ± 20 mT and mechanical offsets are cancelled out through a self-calibration algorithm. Only a few transitions are necessary for the self-calibration procedure. After the initial self-calibration sequence switching occurs when the input signal crosses the arithmetic mean of its max. and min. values (e.g. zero-crossing for sinusoidal signals).

The ON and OFF state of the IC are indicated by ***High*** and ***Low*** current consumption. Each zero crossing of the magnetic input signal triggers an output pulse.

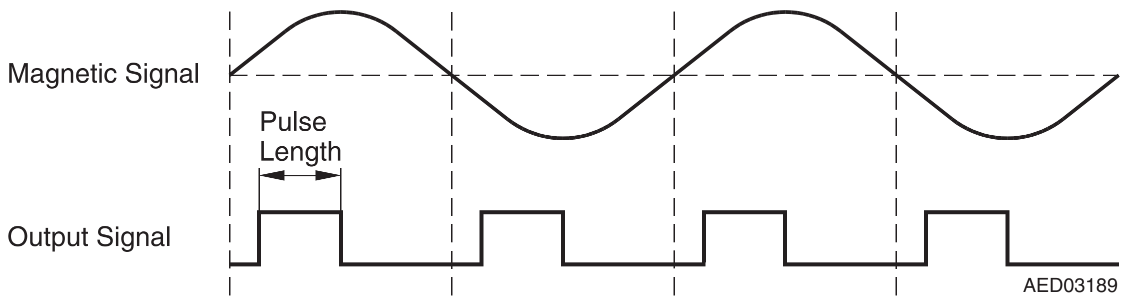


Figure 3 Zero-Crossing Principle and Corresponding Output Pulses

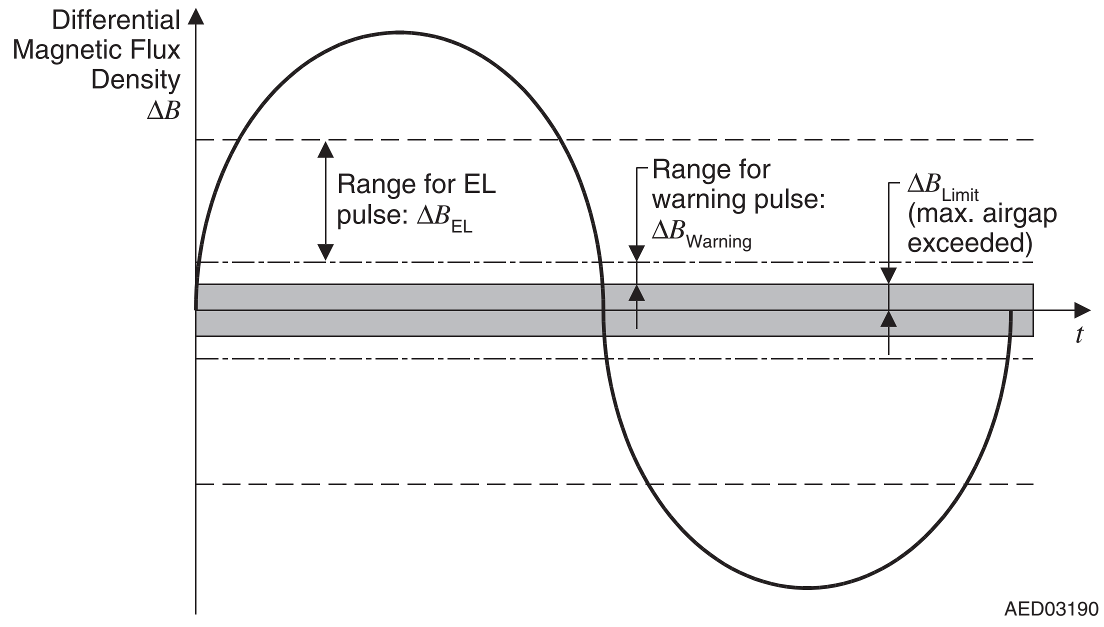


Figure 4 Definition of Differential Magnetic Flux Density Ranges

In addition to the speed signal, the following information is provided by varying the length of the output pulses in Figure 3 (PWM modulation):

Airgap Warning range = **Warning**

Warning information is issued in the output pulse length when the magnetic field is below a critical value. (E. g. the airgap between the Hall Effect IC and the target wheel exceeds a critical value). The device works with reduced functionality.

Assembly position range = **EL**

EL information is issued in the output pulse length when the magnetic field is below a predefined value (the airgap between the Hall Effect IC and the target wheel exceeds a predefined value). The device works with full functionality.

Direction of rotation right = **DR-R**

DR-R information is issued in the output pulse length when the target wheel in front of the Hall Effect IC moves from the pin GND to the pin V_{CC}.

Direction of rotation left = **DR-L**

DR-L information is issued in the output pulse length when the target wheel in front of the Hall Effect IC moves from the pin V_{CC} to the pin GND.

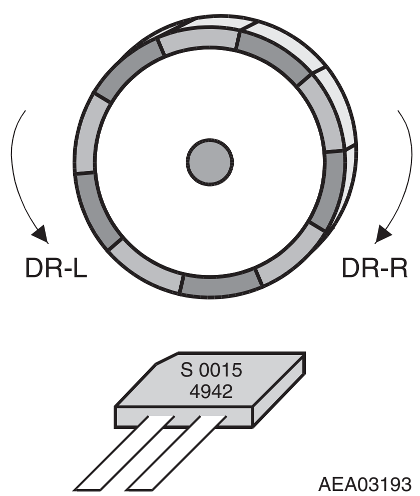


Figure 5 Definition of Rotation Direction

Circuit Description

The circuit is supplied internally by a voltage regulator. An on-chip oscillator serves as a clock generator for the DSP and the output encoder.

Speed signal circuitry

TLE4942 speed signal path comprises of a pair of Hall Effect probes, separated from each other by 2.5 mm, a differential amplifier including noise limiting low-pass filter, and a comparator triggering a switched current output stage. An offset cancellation feedback loop is provided through a signal-tracking A/D converter, a digital signal processor (DSP), and an offset cancellation D/A converter.

During the power-up phase (uncalibrated mode) the output is disabled.

The differential input signal is digitized in the speed A/D converter and fed into the DSP part of the circuit. The minimum and maximum values of the input signal are extracted and their corresponding arithmetic mean value is calculated. The offset of this mean value is determined and fed into the offset cancellation DAC.

After successful correction of the offset, the output switching is enabled.

In running mode (calibrated mode) the offset correction algorithm of the DSP is switched into a low-jitter mode, thereby avoiding oscillation of the offset DAC LSB. Switching occurs at zero-crossover. It is only affected by the small residual offset of the comparator and by the propagation delay time of the signal path, which is mainly determined by the noise limiting filter. Signals which are below a predefined threshold ΔB_{Limit} are not detected. This prevents unwanted switching.

The comparator also detects whether the signal amplitude exceeds $\Delta B_{\text{Warning}}$ or ΔB_{EL}. This information is fed into the DSP and the output encoder. The pulse length of the ***High*** output current is generated according to the rotational speed, the direction of rotation and the magnetic field strength.

Direction signal circuitry

The differential signal between a third Hall probe and the mean of the differential Hall probe pair is obtained from the direction input amplifier. This signal is digitized by the direction ADC and fed into the DSP circuitry. There, the phase of the signal referring to the speed signal is analyzed and the direction information is forwarded to the output encoder.

Absolute Maximum Ratings

T_j = -40 to 150 °C, 4.5 V ≤ V_{CC} ≤ 16.5 V

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		
Supply voltage	V_{CC}	– 0.3	–	V	T_j < 80 °C
		–	16.5		T_j = 170 °C
		–	20		T_j = 150 °C
		–	22		$t = 10 \times 5$ min
		–	24		t = 10×5 min, $R_M \geq 75\ \Omega$
		–	27		t = 400 ms, $R_M \geq 75\ \Omega$
Reverse polarity current	I_{rev}	–	200	mA	External current limitation required, t < 4 h
Junction temperature	T_j	–	150	°C	5000 h, V_{CC} < 16.5 V
		–	160		2500 h, V_{CC} < 16.5 V
		–	170		500 h, V_{CC} < 16.5 V
		–	190		4 h, V_{CC} < 16.5 V
Active lifetime	$t_{B,active}$	10000	–	h	
Storage temperature	T_S	– 40	150	°C	
Thermal resistance P-SSO-2-1	R_{thJA}	–	190	K/W	[1]

1) Can be improved significantly by further processing like overmolding

Note: Stresses in excess of those listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD Protection

Human Body Model (HBM) tests according to:
Standard EIA/JESD22-A114-B HBM (covers MIL STD 883D)

Parameter	Symbol	Limit Values		Unit	Notes
		min.	max.		
ESD-Protection	V_{ESD}	–	± 2	kV	R = 1.5 kΩ, C = 100 pF

Operating Range

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		
Supply voltage	V_{CC}	4.5	20	V	Directly on IC leads includes not the R_M voltage drop
Supply voltage ripple	V_{AC}	–	6	Vpp	V_{CC} = 13 V $0 < f < 50$ kHz
Junction temperature	T_j	– 40	150	°C	
		–	170		500h $V_{CC} \leq 16.5$ V, increased jitter permissible
Pre-induction	B_0	– 500	+ 500	mT	
Pre-induction offset between outer probes	$\Delta B_{stat., l/r}$	– 20	+ 20	mT	
Pre-induction offset between mean of outer probes and center probe	$\Delta B_{stat., m/o}$	– 20	+ 20	mT	
Differential Induction	ΔB	– 120	+ 120	mT	

Note: Within the operating range the functions given in the circuit description are fulfilled.

AC/DC Characteristics
All values specified at constant amplitude and offset of input signal

Parameter	Symbol	Limit Values			Unit	Remarks
		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	–	–		
Output rise/fall slew rate TLE4942	t_r, t_f	12 7.5	–	26 24	mA/ µs	$R_M \leq 150\ \Omega$ $R_M \leq 750\ \Omega$ See **Figure 6**
Output rise/fall slew rate TLE4942C	t_r, t_f	8 8	– –	22 26	mA/ µs	$R_M = 75\ \Omega$ $T < 125$ °C $T < 170$ °C See **Figure 6**
Current ripple dI_X/dV_{CC}	I_X	–	–	90	µA/V	
Limit threshold	ΔB_{Limit}	0.35	0.8	1.5	mT	Amplitude values
Airgap warning threshold	$\Delta B_{Warning}$	0.9	1.4	2.6	mT	Amplitude values
Limit - Airgap warning threshold ratio	$\Delta B_{Warning}/\Delta B_{Limit}$	1.3	1.75	2.7		Amplitude values
Assembly position threshold	ΔB_{EL}	5.2	7.2	9.6	mT	at room temp
Initial calibration delay time	$t_{d,input}$	–	–	300	µs	Additional to n_{start}
Magnetic edges required for initial calibration[1)]	n_{start}	–	–	6[2)]	magn. edges	
Number of emitted pulses with invalid supplementary information[3)]	$n_{DR\text{-}Start}$	–	–	3[2)]	magn. edges	
Frequency	f	1	–	2500	Hz	
Frequency changes	df/dt	–	–	± 100	Hz/ms	
Duty cycle	duty	40	50	60	%	[4)]Measured @ΔB = 2 mT sine wave Def. **Figure 7**

AC/DC Characteristics (cont'd)
All values specified at constant amplitude and offset of input signal

Parameter	Symbol	Limit Values			Unit	Remarks
		min.	typ.	max.		
Jitter, T_j < 150 °C T_j < 170 °C	$S_{Jit\text{-}close}$	– –	– –	± 2 ± 3	%	1 σ value V_{CC} = 12 V $\Delta B \geq$ 2 mT
Jitter, T_j < 150 °C T_j < 170 °C	$S_{Jit\text{-}far}$	– –	– –	± 4 ± 6	%	1 σ value V_{CC} = 12 V (2 mT ≥) $\Delta B > \Delta B_{Limit}$
Jitter at board net ripple	$S_{Jit\text{-}AC}$	–	–	± 2	%	V_{CC} = 13 V ±6 Vpp 0 < f < 50 kHz ΔB = 15 mT

1) 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.
2) See Appendix B
3) The first 3 pulses containing direction information can have the wrong rotation information. (The first pulse after starting with the speed signal can have any length < t_{Stop}. At ΔB_{Limit} output pulses might have any length < t_{Stop}).
4) During fast offset alterations, due to the calibration algorithm, exceeding the specified duty cycle is permitted for short time periods.

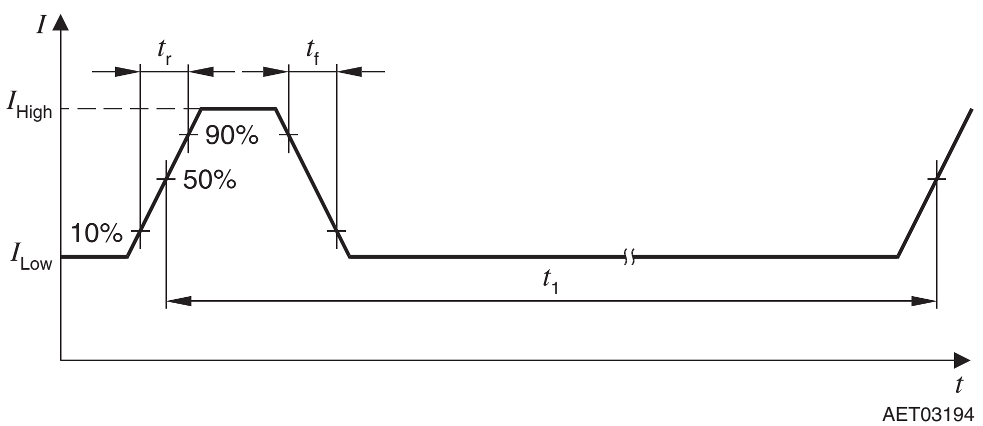


Figure 6 Definition of Rise and Fall Time

Timing Characteristics

Parameter	Symbol	Limit Values			Unit	Remarks
		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	See **Figure 9**
Stand still period[1)]	T_{stop}	590	737	848	ms	See **Figure 9**

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

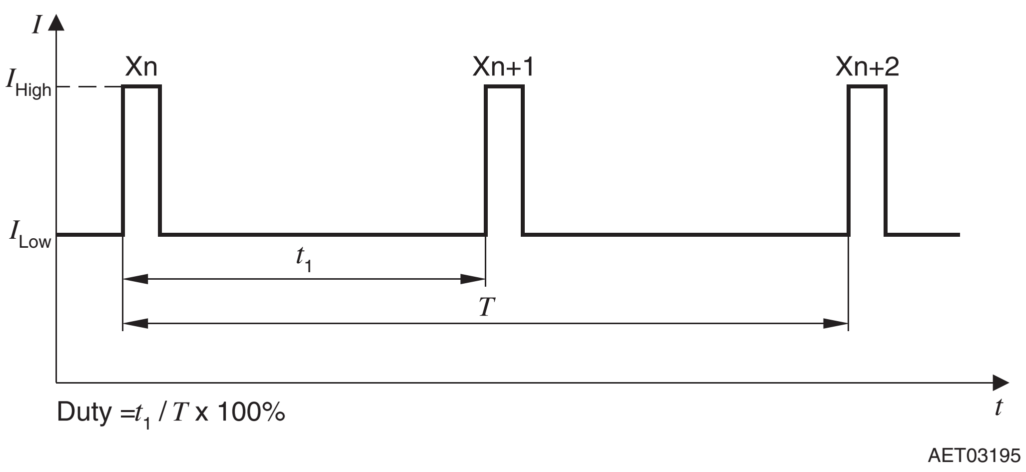


Figure 7 Definition of Duty Cycle

PWM Current Interface

Between each magnetic transition and the rising edge of the corresponding output pulse the output current is ***Low*** for $t_{pre\text{-}low}$ in order to allow reliable internal conveyance. Following the signal pulse (current is ***High***) is output.

If the magnetic differential field exceeds ΔB_{EL}, the output pulse lengths are 90 µs or 180 µs respectively, depending on the direction of rotation.

When the magnitude of the magnetic differential field is below ΔB_{EL}, the output pulse lengths are 360 µs and 720 µs respectively, depending on left or right rotation. Due to decreasing cycle times at higher frequencies, these longer pulses are only output up to frequencies of approximately 117 Hz. For higher frequencies and differential magnetic fields below ΔB_{EL}, the output pulse lengths are 90 µs or 180 µs respectively.

If the magnitude of the magnetic differential field is below $\Delta B_{Warning}$, the output pulse length is 45 µs. The warning output is dominant, this means that close to the limit airgap the direction and the assembly position information are disabled.

For magnitudes of the magnetic differential field below ΔB_{Limit}, signal is lost.

In case no magnetic differential signal is detected for a time longer than the stand still period T_{stop}, the stop pulse is output. Typically with the first output stop pulse, the circuitry reverts to the uncalibrated mode.

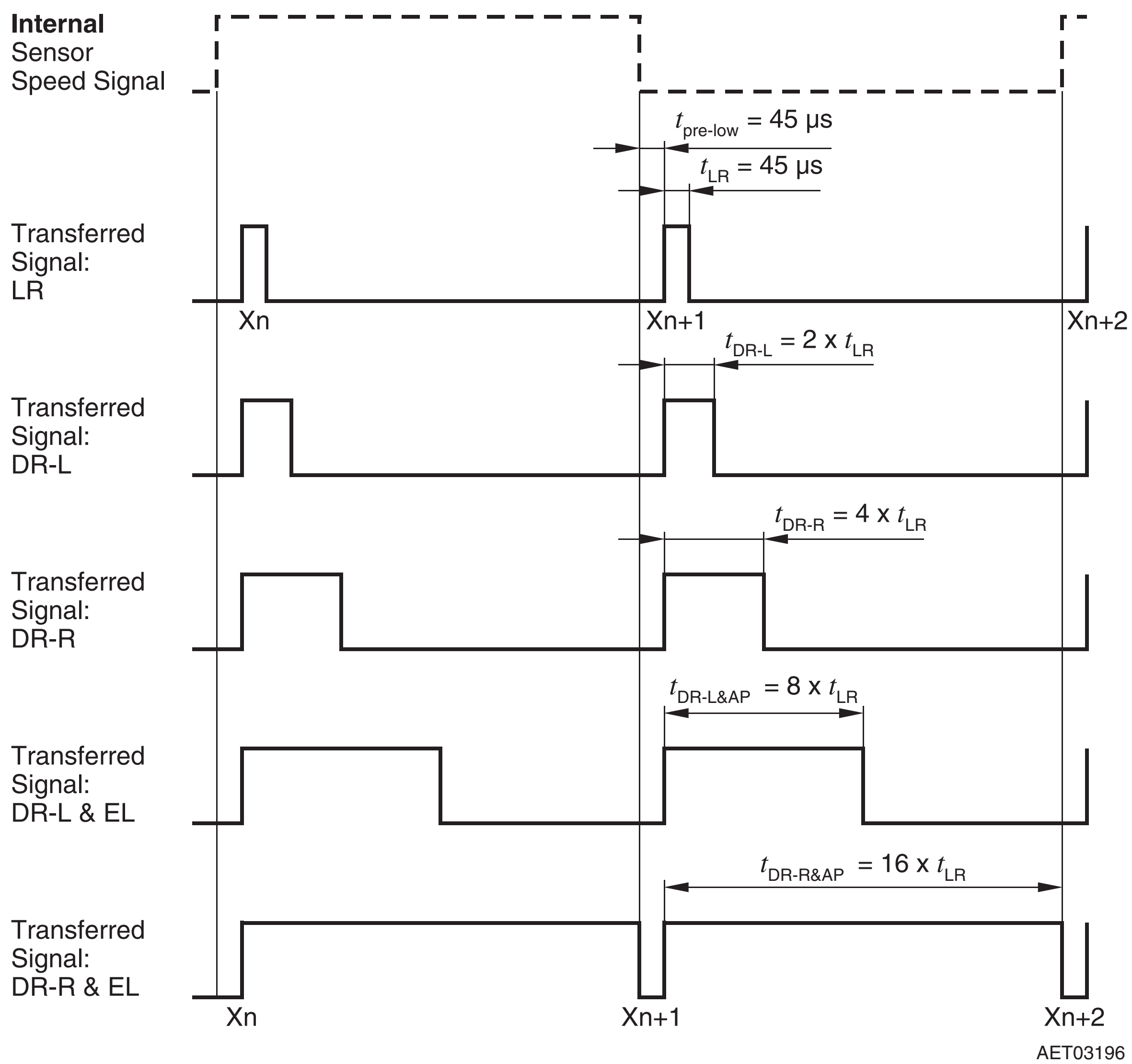


Figure 8 Definition of PWM Current Interface

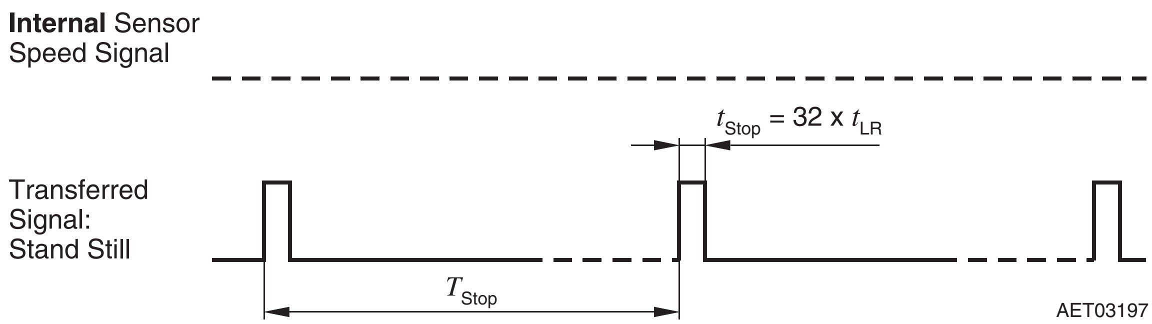


Figure 9 Definition of Stand Still Output Pulse

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, see ***Figure 10****.*

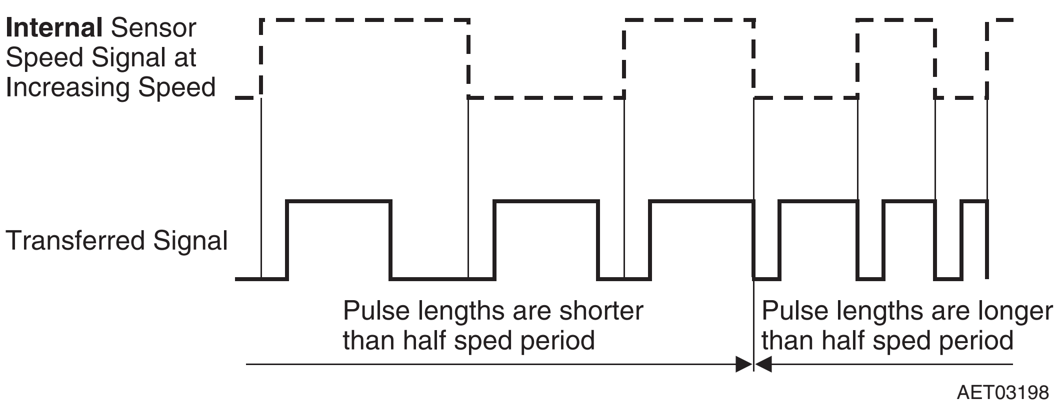


Figure 10 Deviation of Duty Cycle at Fast Changing Frequencies

Electro Magnetic Compatibility (values depend on R_M!)

Parameter	Symbol	Level/Typ	Status
Ref. ISO 7637-1; test circuit 1; ΔB = 2 mT (amplitude of sinus signal); V_{CC} = 13.5 V, f_B = 100 Hz; T = 25 °C; $R_M \geq 75\ \Omega$			
Testpulse 1	V_{EMC}	IV / – 100 V	C[1)]
Testpulse 2		IV / 100 V	C[1)]
Testpulse 3a		IV / – 150 V	A
Testpulse 3b		IV / 100 V	A
Testpulse 4		IV / – 7 V	B[2)]
Testpulse 5		IV / 86.5[3)] V	C

1) According to 7637-1 the supply switched "OFF" for t = 200 ms. For battery "ON" is valid status "A".
2) According to 7637-1 for test pulse 4 the test voltage shall be 12 V ± 0.2 V
3) Applying in the board net a suppressor diode with sufficient energy absorption capability.

Note: Values are valid for all TLE4941/42 types!

Parameter	Symbol	Level/Typ	Status
Ref. ISO 7637-3; test circuit 1; ΔB = 2 mT (amplitude of sinus signal); V_{CC} = 13.5 V, f_B = 100 Hz; T = 25 °C; $R_M \geq 75\ \Omega$			
Testpulse 1	V_{EMC}	IV / – 30 V	A
Testpulse 2		IV / 30 V	A
Testpulse 3a		IV / – 60 V	A
Testpulse 3b		IV / 40 V	A

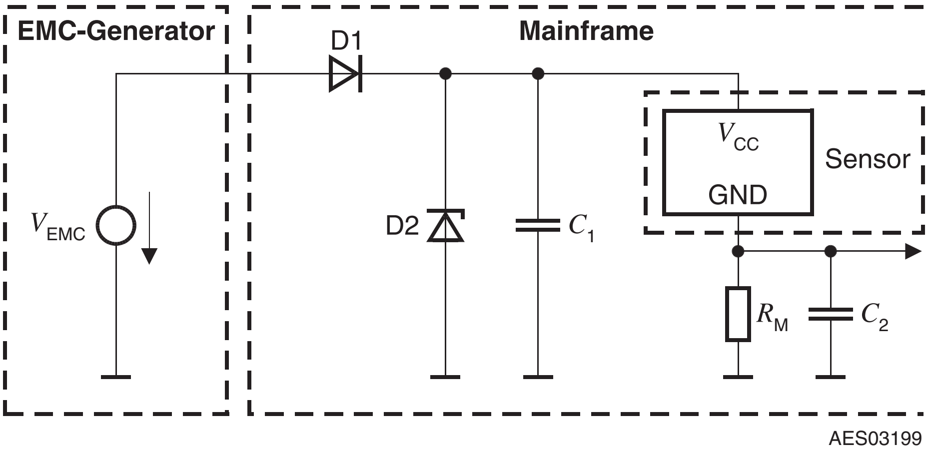
Note: Values are valid for all TLE4941/42 types!

Parameter	Symbol	Level/Typ	Status
Ref. ISO 11452-3; test circuit 1; measured in TEM-cell ΔB = 2 mT; V_{CC} = 13.5 V, f_B = 100 Hz; T = 25 °C			
EMC field strength	$E_{TEM\text{-}Cell}$	IV / 200 V/m	AM = 80%, f = 1 kHz

Note: Only valid for non C- types!

Parameter	Symbol	Level/Typ	Status
Ref. ISO 11452-3; test circuit 1; measured in TEM-cell ΔB = 2 mT; V_{CC} = 13.5 V, f_B = 100 Hz; T= 25 °C			
EMC field strength	$E_{TEM\text{-}Cell}$	IV / 250 V/m	AM = 80%, f = 1 kHz

Note: Only valid for C-types!



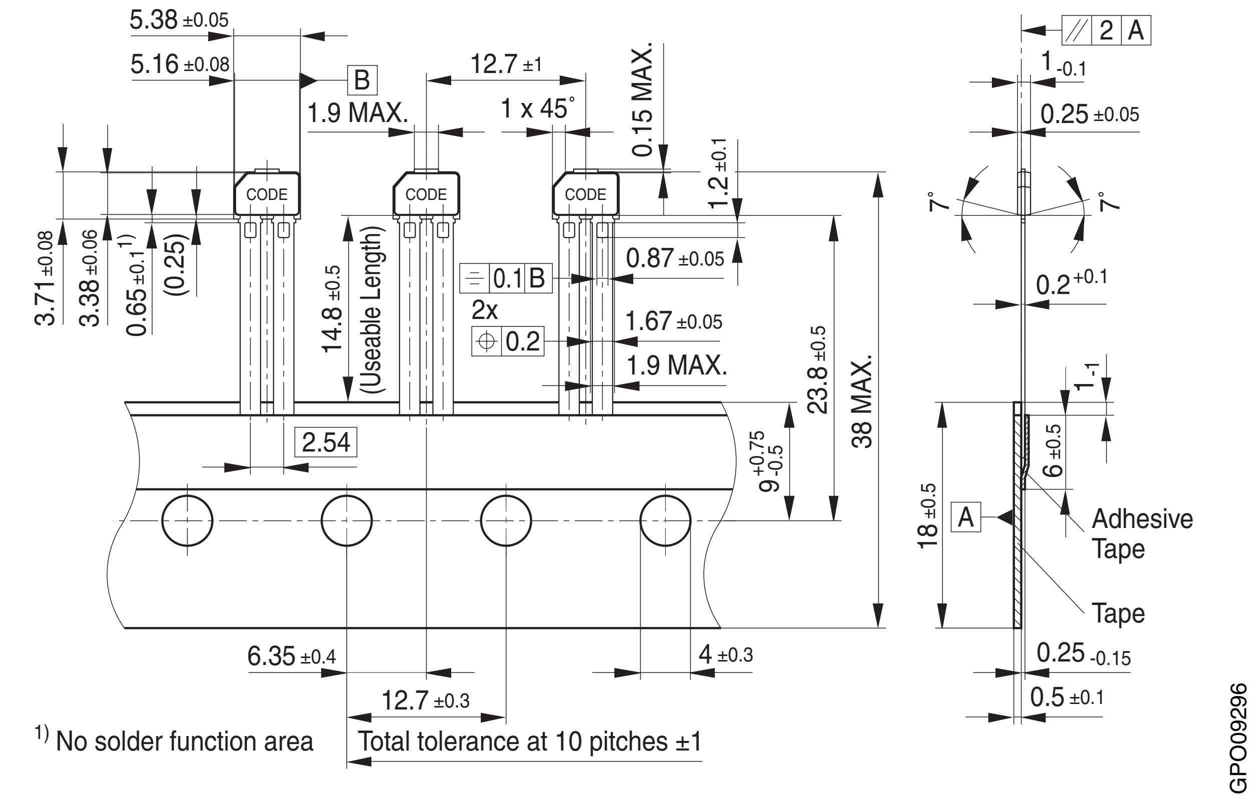
Components:

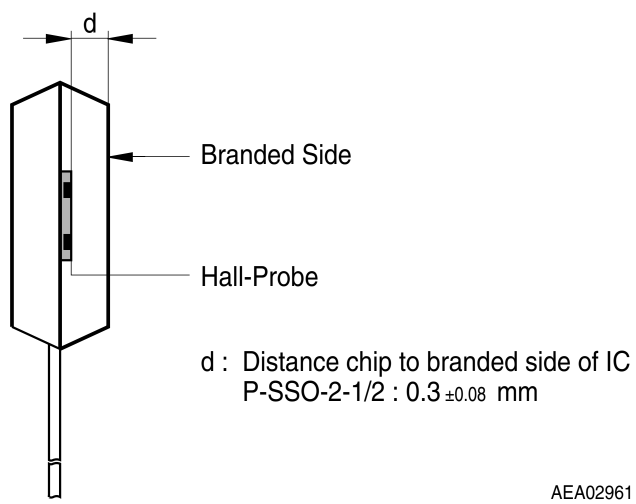
	D1:	1N4007
	D2:	T 5Z27 1J
	C_1:	10 µF/35 V
	C_2:	1 nF/1000 V
	R_M:	75 Ω/5 W

Figure 11 Test Circuit 1

Package Outlines

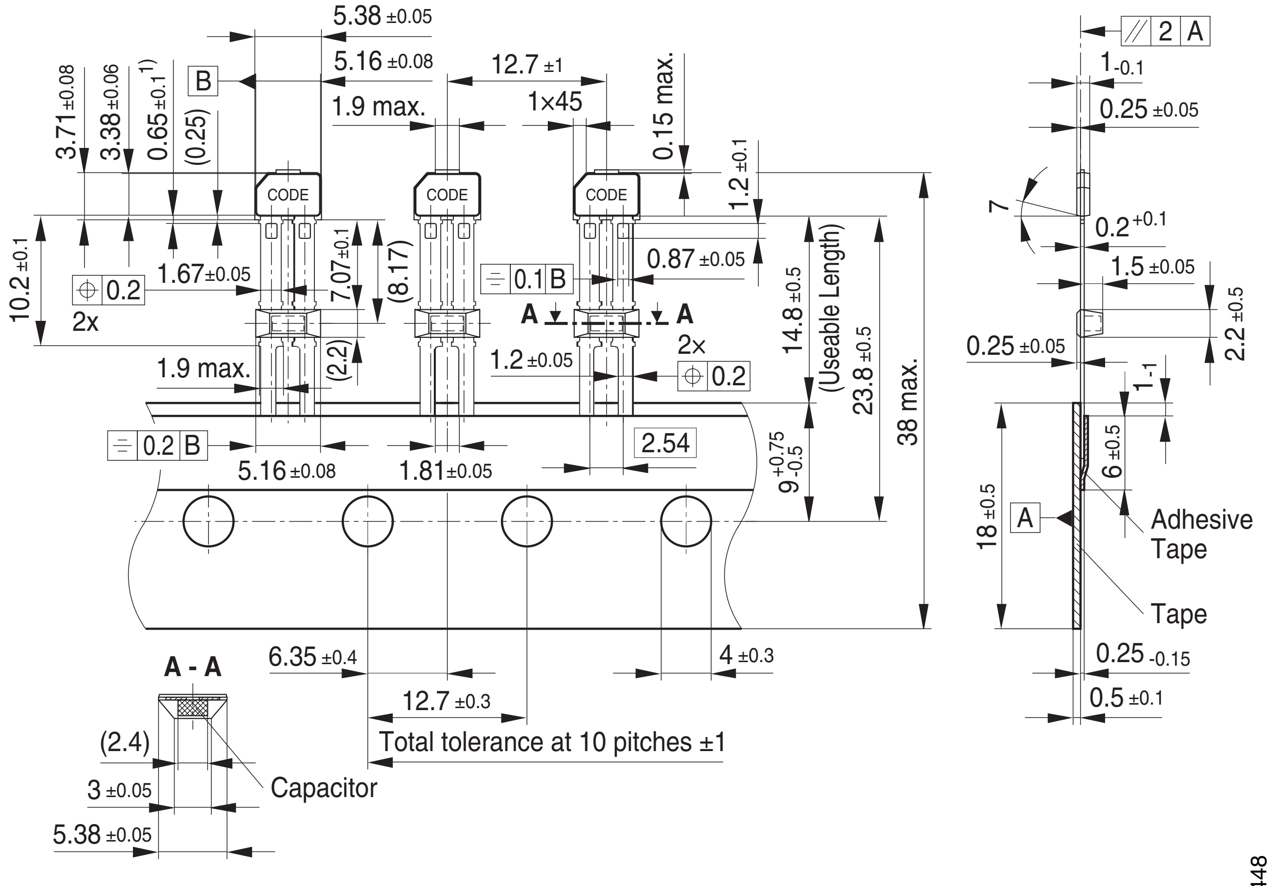
P-SSO-2-1
(Plastic Single Small Outline Package)





Package Outlines

P-SSO-2-2
(Plastic Single Small Outline Package)



1) No solder function area

You can find all of our packages, sorts of packing and others in our Infineon Internet Page "Products": http://www.infineon.com/products.

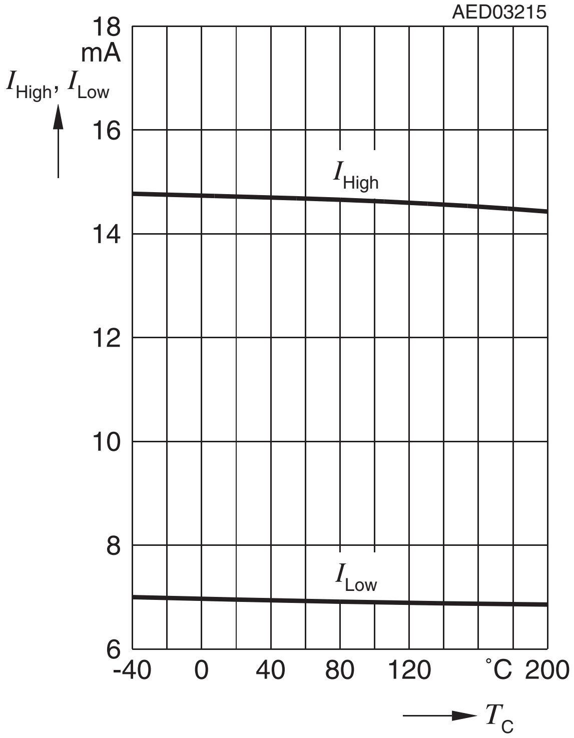
Dimensions in mm

Appendix A

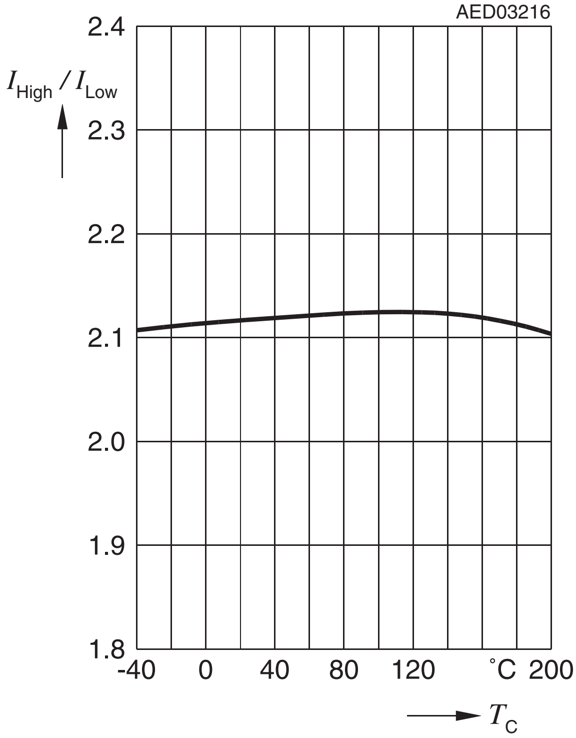
Typical Diagrams (measured performance)

$T_c = T_{case, IC}$ = approx. T_j - 5 °C

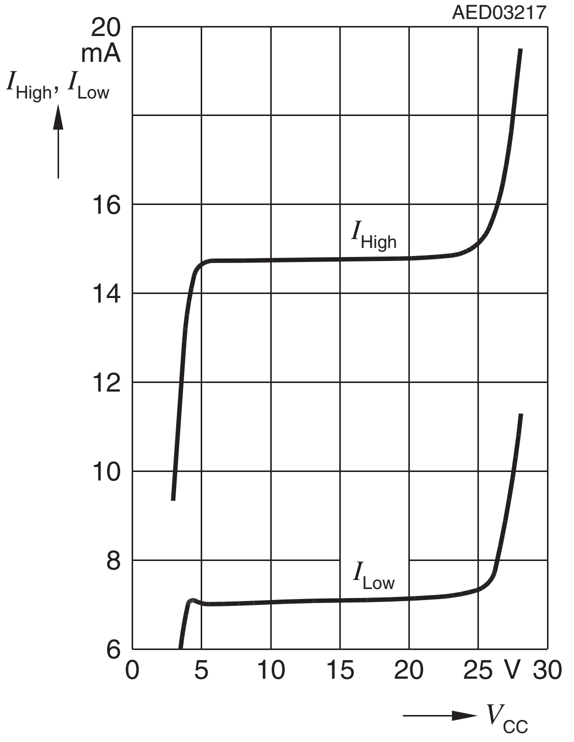
Supply Current



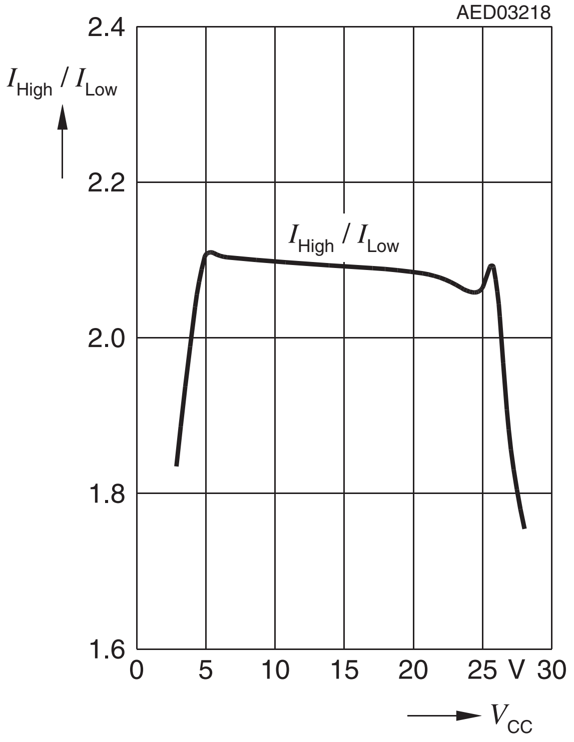
Supply Current Ratio I_{high} / I_{low}



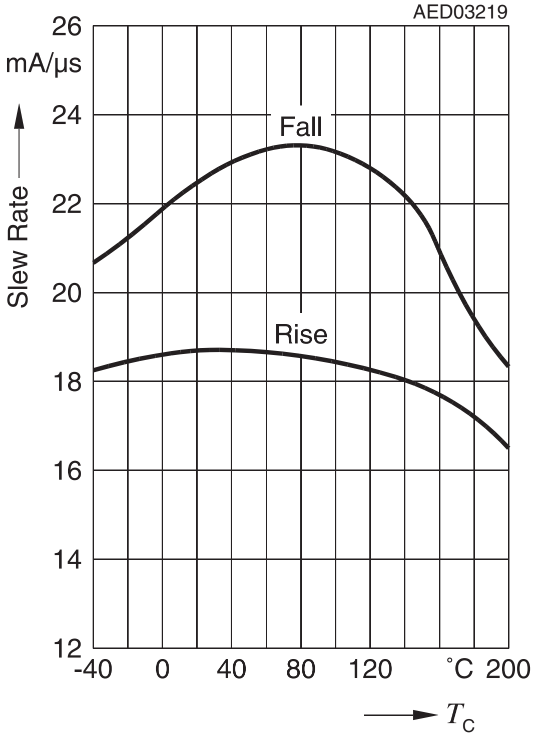
Supply Current = $f(V_{cc})$



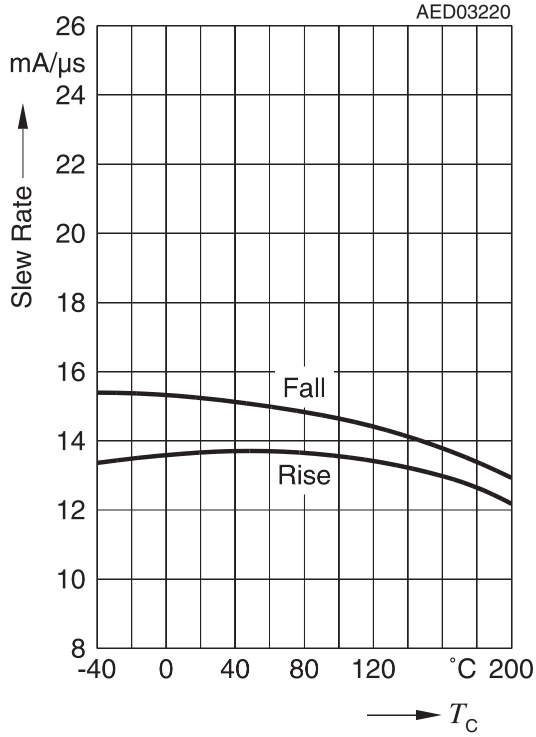
Supply Current Ratio Ihigh/Ilow = $f(V_{cc})$



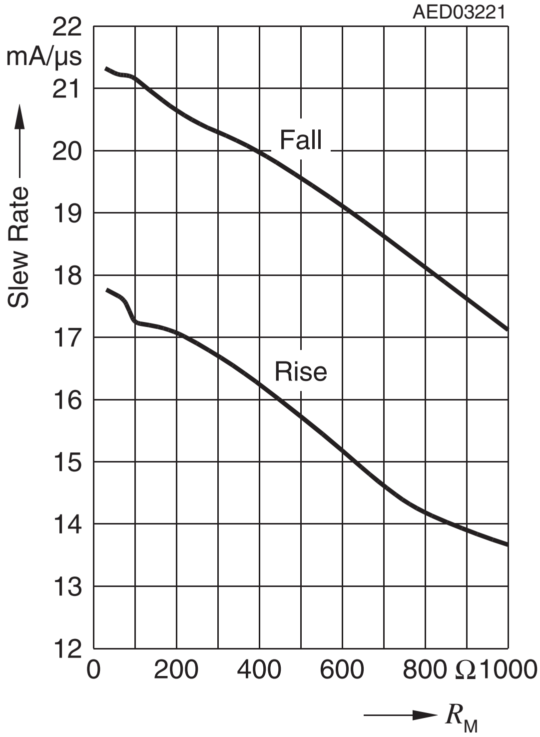
Slew Rate without C, R_M = 75 Ω



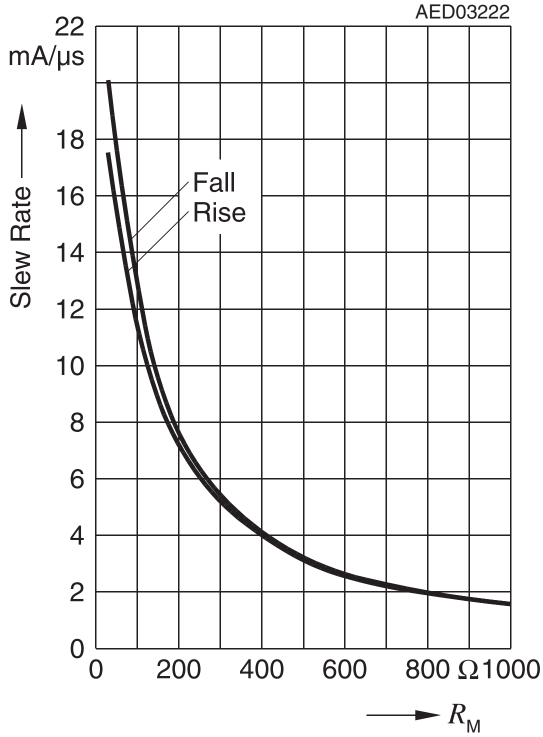
Slew Rate with C = 1.8 nF, R_M = 75 Ω



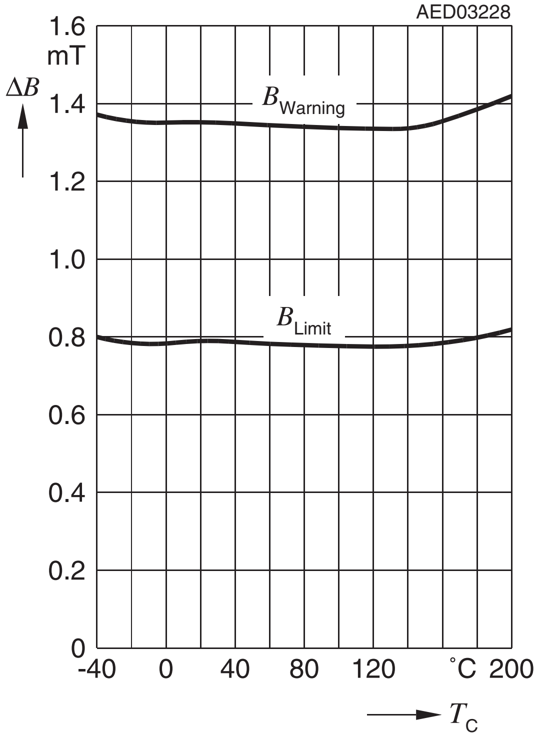
Slew Rate without $C = f(R_M)$



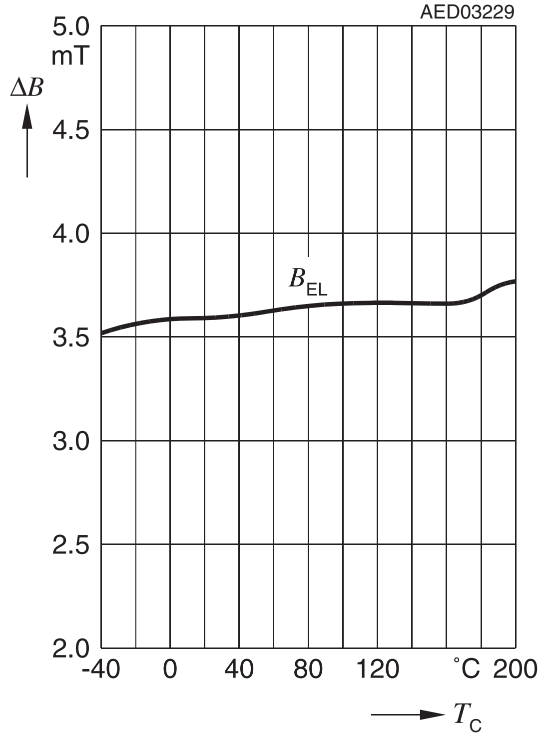
Slew Rate with C = 1.8 nF = $f(R_M)$



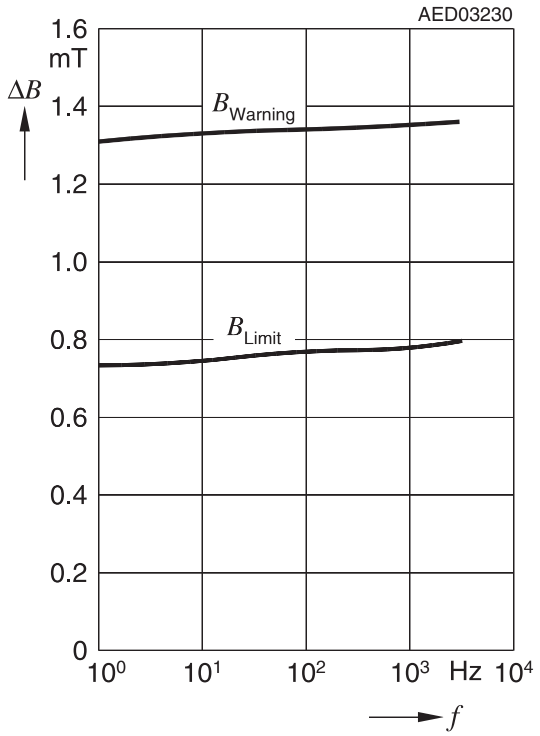
Magnetic Threshold
$\Delta B_{warning}$, ΔB_{limit} at f = 1 kHz



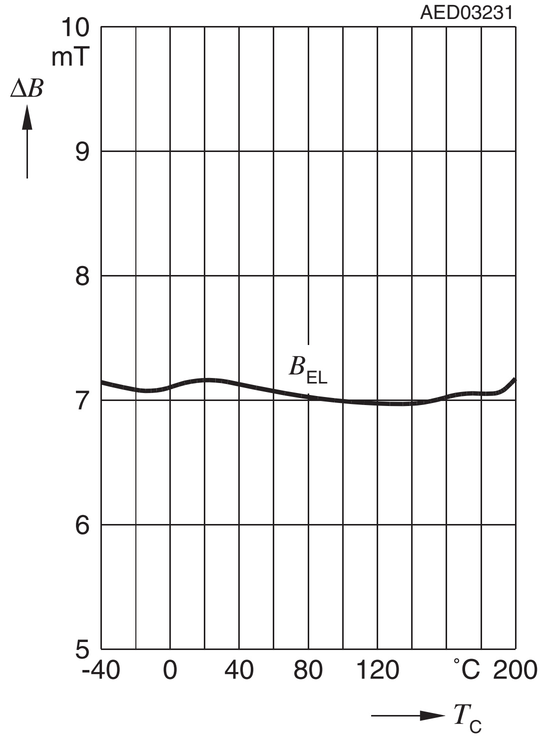
Magnetic Threshold
$\Delta B_{EL\ 01}$



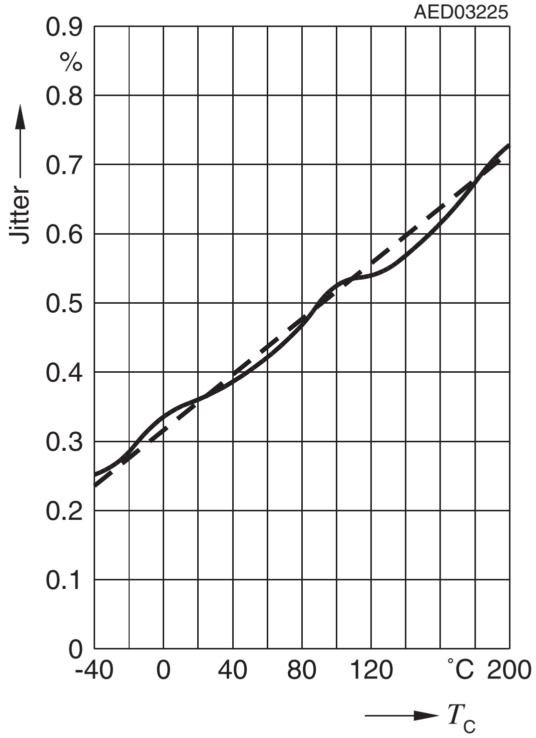
Magnetic Threshold
Magn. Thresholds = $f(f)$



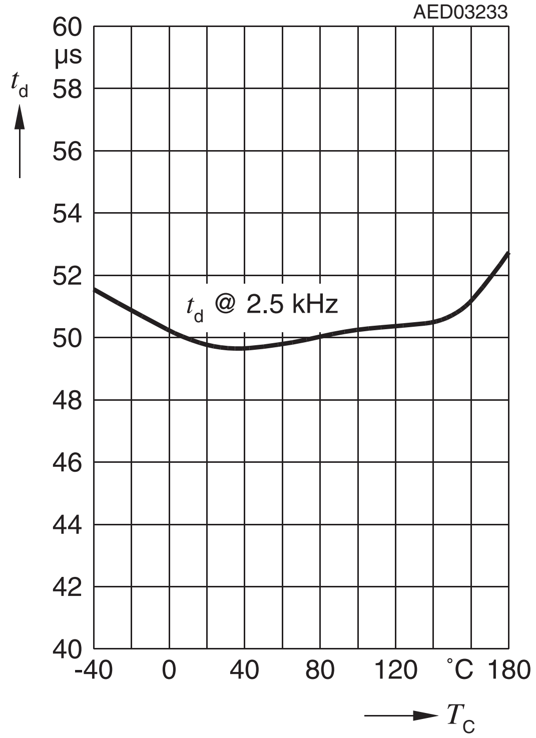
Magnetic Threshold
$\Delta B_{EL\ 04}$



Jitter 1σ at ΔB = 2 mT, 1 kHz



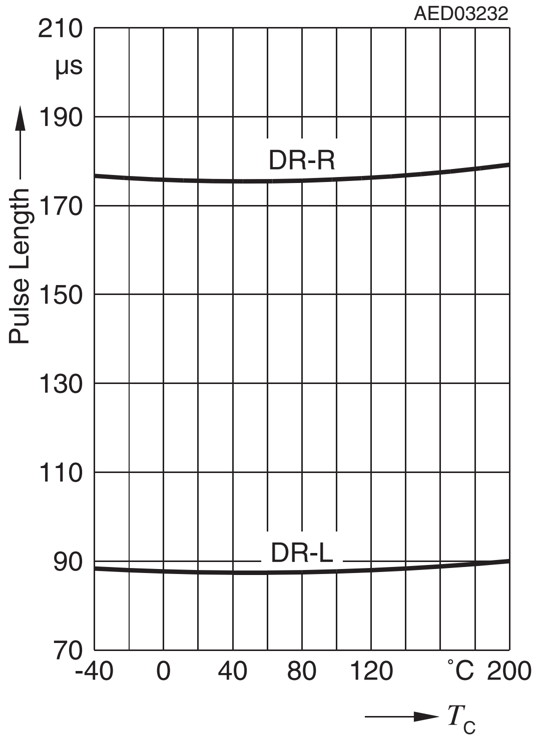
Delaytime t_d incl. $t_{pre-low}$ 1)



1) t_d is the time between the zero crossing of ΔB = 2 mT sinusoidal input signal and the rising edge (50%) of the signal current .

Pulse Length of Direction Signal Left and Right (Temp. Behaviour of Other Pulse Lengths are similar)

Pulse Length t_{DR-L}, t_{DR-R}



Appendix B

Release 1.1

Occurrence of initial calibration delay time $t_{d,input}$

If there is no input signal (standstill), a new initial calibration is triggered each 0.7 s. This calibration has a duration $t_{d,input}$ of max. 300 µs. No input signal change is detected during that initial calibration time.

In normal operation (signal startup) the probability of $t_{d,input}$ to come into effect is:

$t_{d,input}$ / time frame for new calibration 300 µs/700 ms = 0.05%.

After IC resets (e.g. after a significant undervoltage) $t_{d,input}$ will always come into effect.

Magnetic input signal extremely close to a switching threshold of PGA at signal startup

After signal startup normally all PGA switching into the appropriate gain state happens within less than one signal period. This is included in the calculation for $n_{DZ\text{-}Start}$. For the very rare case that the signal amplitude is extremely close to a PGA switching threshold and the full range of the following speed ADC respectively, a slight change of the signal amplitude can cause one further PGA switching. It can be caused by non-perfect magnetic signal (amplitude modulation due to tolerances of pole-wheel, tooth wheel or air gap variation). This additional PGA switching can result in a further delay of the output signal ($n_{DZ\text{-}Start}$) up to three magnetic edges leading to a worst case of $n_{DZ\text{-}Start} = 9$. Due to the low probability of this case it is not defined as max. value in the data sheet.

(For a more detailed explanation please refer to the document "TLE4941/42 - Frequently Asked Questions").

Fast change of direction signal at small fields

The described behaviour can happen when rotation direction is changed in $t < 0.7$ s

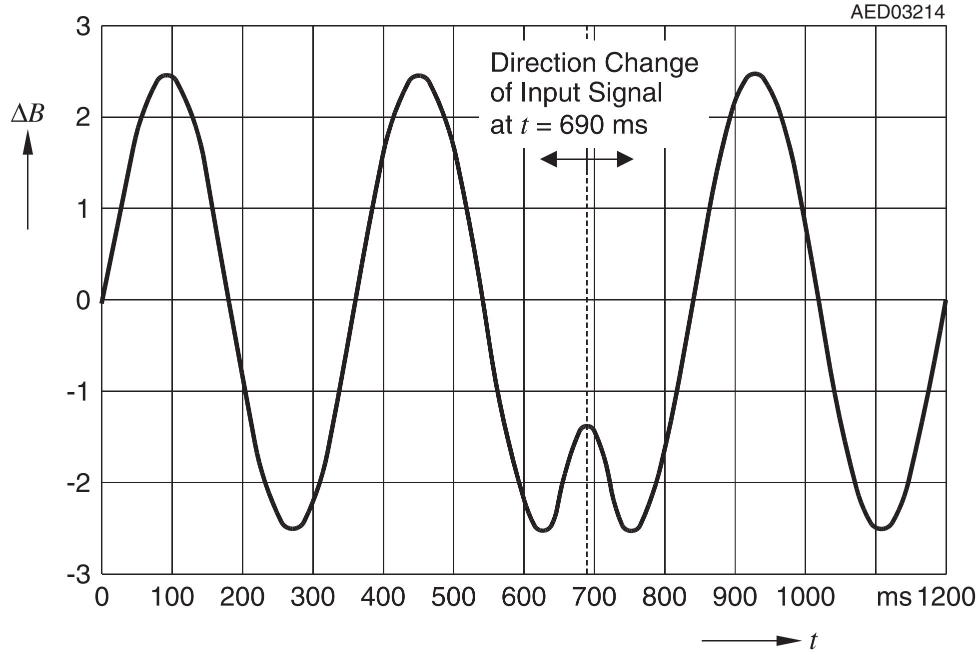


Figure 12

A local extreme (maximum or minimum) of the magnetic input signal can be caused during a reversal of rotation direction. In this case the local extreme can be detected by the IC and used for offset calibration. (E.g. a local maximum marked by an arrow in the above diagram.) Obviously the calculated offset value will be incorrect with respect to the following signal. As worst case a duty cycle up to max. 15% to 85% could occur for a few pulses. After a re-calibration, which typically takes place after 2...3 zero-crossings the offset will be correct again and hence the duty cycle also.

As a result of "bad" duty cycle after fast direction reversal the sampling points for direction detection are at unusual signal phase angles also. At small magnetic input signals ($\Delta B < 1.7 \times \Delta B_{warning}$) this can lead to incorrect direction information. Duration: max. 7 pulses, in very rare cases (additional PGA transition during calibration similar to **Magnetic input signal extremely close to a switching threshold of PGA at signal startup**) max. 9 pulses.

A local extremum close to the zero-crossing theoretically could lead to distances down to 45 µs of two consecutive output pulses at the point of direction reversal as well as a $B_{warning}$ pulse also.

Behaviour close to the magnetic thresholds $B_{warning}$, B_{Limit}, (B_{EL})

Real non-perfect magnetic signals and intrinsic thermal noise cause amplitude variations. Very close to the magnetic thresholds a mix of output pulse widths representing the referring magnetic values occur. For similar reasons pulse widths of 90, 180, 360, 720 µs can be observed occasionally for single pulses at B_{Limit}.

Behaviour close to speed v5 ($f_{EL\text{-}bit}$ = ca. 117 Hz)

Signal imperfections like duty cycle and jitter result in a mix of output pulses with and without assembly bit (EL) information. Input signal duty cycles apart from 50% increase the range where both pulse widths appear.

Dependency of direction detection on input signal pitch

The direction detection is optimised for a target wheel pitch of 5 mm where it will work down to $B_{warning}$. ($B_{warning}$ and direction detection thresholds meet at 5 mm pitch.) For pitches other than 5 mm the magnetic input signal has to be increased to compensate for the inevitable signal attenuation.

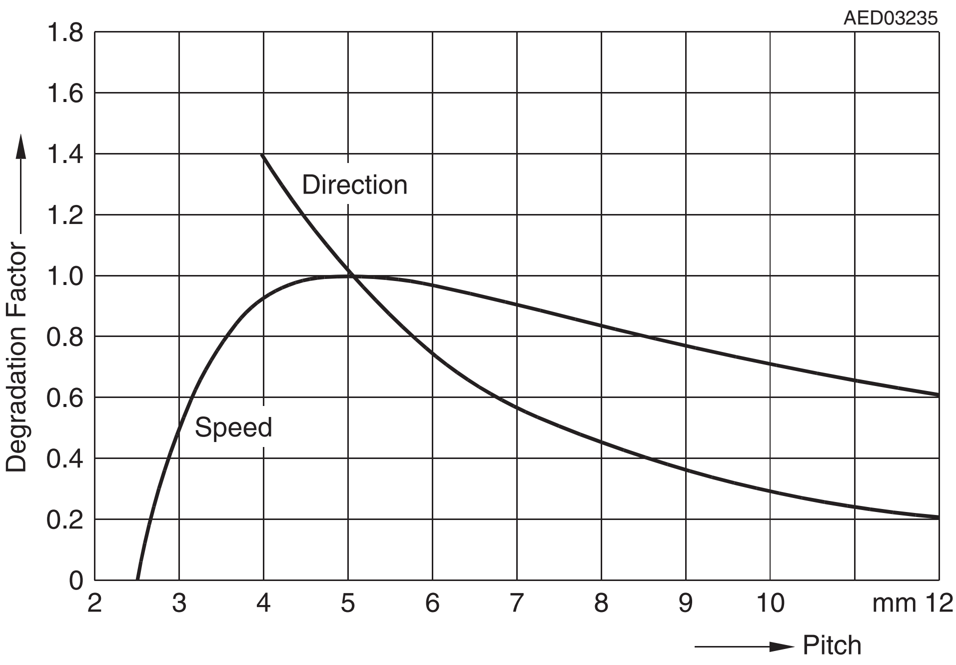


Figure 13 Degradation of Speed and Direction Signal at Sinusoidal input Signals = f(pitch)