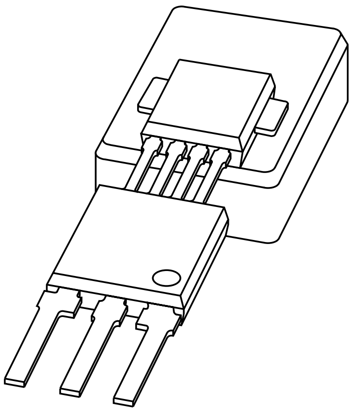
DATA SHEET



KMI22/1
Rotational speed sensor for extended air gap application and direction detection

Objective specification

2000 Sep 04

Philips Semiconductors

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Rotational speed sensor for extended air gap application and direction detection

KMI22/1

FEATURES

- Digital current output signal
- Digital offset compensation
- Extended air gap
- Zero speed capability
- Direction detection
- Digital output protocol
- Three level output signal
- Additional digital input pin
- Wide temperature range
- Insensitive to vibration
- EMC resistant
- Tolerant to positioning.

DESCRIPTION

The KMI22/1 is a sensitive rotational speed sensor for the application with ferrous gear wheels(1). The sensor consists of a magnetoresistive sensor element, a driver IC in BIMOS technology, a digital signal conditioning IC in highly integrated CMOS technology and a ferrite magnet. The digital two wire current output carries a signal proportional to the rotational speed of a gear wheel plus a digital protocol.

CAUTION
Do not press two or more products together against their magnetic forces.

(1) The sensor contains customized integrated circuits. Usage in hydraulic brake systems and in systems with active brake control is forbidden. For all other applications, higher temperature versions of up to 150 °C are available on request.

PINNING

PIN	DESCRIPTION
1	V_{CC}
2	V_{in}
3	V–

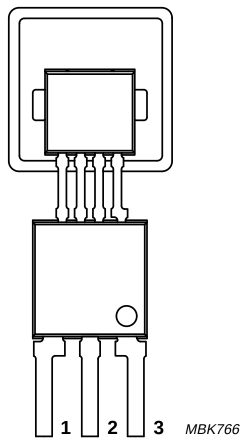


Fig.1 Simplified outline (SOT477B).

QUICK REFERENCE DATA

SYMBOL	PARAMETER	MIN.	TYP.	MAX.	UNIT
V_{CC}	DC supply voltage	0	12	18	V
I_{CCL}	current output signal low	5.6	7.0	8.4	mA
I_{CCPH}	current output signal protocol high	11.2	14	16.8	mA
I_{CCSH}	current output signal speed high	22.4	28	33.6	mA
V_{in}	input voltage pin 2	0	–	100	% V_{CC}
d	sensing distance	0 to 4	0 to 4.5	–	mm
f_r	operating tooth frequency	0	–	2500	Hz
T_{amb}	ambient operating temperature	–40	–	+85	°C

LIMITING VALUES

In accordance to the Absolute Maximum Rating System (IEC 60134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CC}	DC supply voltage between leads 1 + 3	T_{amb} = –40 to +85 °C; R_L = 43 Ω; see Fig.12	0	18	V
V_{in}	input voltage pin 2	T_{amb} = –40 to + 85 °C	V–	V_{CC}	V
T_{stg}	storage temperature range		–65	+150	°C
T_{amb}	ambient operating temperature		–40	+85	°C
T_{sld}	soldering temperature	t < 10 s	–	260	°C
	output short-circuit duration	V_{CC} to GND (see Fig.12)	continuous		
	short-circuit duration	pin 2 to pin 1 and pin 2 to pin 3	continuous		
	wrong polarity	T_{amb} = –40 to +65 °C; R_L = 43 Ω; note 1	continuous		

Note

1. With R_L = 43 Ω the device is continuously protected against wrong polarity of DC supply voltage (V_{CC}) to GND; see Fig.12.

CHARACTERISTICS

T_{amb} = 25 °C; V_{CC} = 12 V; d = 2.1 mm; f_t = 2 kHz; test circuit: see Fig.12; R_L = 43 Ω; sensor positioning: see Fig.13; gear wheel: module 2 mm; material 1.0715; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I_L	current output low	T = –40 to +85 °C; see Figs 6 and 8	5.6	7	8.4	mA
I_{PH}	current output protocol high	T = –40 to +85 °C; see Figs 6 and 8;	11.2	14	16.8	mA
I_{SH}	current output speed high	T = –40 to +85 °C; see Figs 6 and 8;	22.4	28	33.6	mA
t_r	output signal rise time	C_L = 100 pF; 10 to 90% value	–	0.5	–	µs
t_f	output signal fall time	C_L = 100 pF; 90 to 10% value	–	0.5	–	µs
f_t	operating tooth frequency	for both rotation directions T = –40 to +85 °C	0	–	2500	Hz
$d_{in\ 0\ Hz}$	sensing distance in initial mode for signals > 0 Hz	see Fig.13	0 to 2.5	0 to 2.9	–	mm
$d_{in\ 1\ Hz}$	sensing distance in initial mode for signals > 1 Hz	see Fig.13	0 to 3.5	0 to 3.9	–	mm
d_{dir}	sensing distance for safe direction detection	see Fig.13	0 to 3	0 to 3.4	–	mm
d_{act}	sensing distance in active mode	see Fig.13	0 to 4	0 to 4.5	–	mm
$\delta_{in\ 0\ Hz}$	duty cycle in initial mode for signals > 0 Hz	T = –40 to +85 °C; see Fig.5	20	50	80	%
$\delta_{in\ 1\ Hz}$	duty cycle in initial mode for signals > 1 Hz	T = –40 to +85 °C; see Fig.5	20	50	80	%
δ_{act}	duty cycle in active mode	T = –40 to +85 °C; see Fig.5	40	50	60	%

FUNCTIONAL DESCRIPTION

The KMI22/1 is sensitive to the motion of ferrous gear wheels. The functional principle is shown in Fig.3. Due to the effect of flux bending the different directions of magnetic field lines in the magnetoresistive sensor element will cause an electrical signal. Because of the chosen sensor orientation and the direction of ferrite magnetization the KMI22/1 is sensitive to movement in the ‘y’ direction in front of the sensor only (see Fig.2).

The KMI22/1 contains a magnetoresistive sensor element and two ICs: a Position Detector IC (PDIC) and a Line Driver IC (LDIC). The sensor signal is fed into the PDIC which converts the signal to the digital domain, applies digital compensation and additional processing. The LDIC contains three current sources (one constant, two switchable), a voltage control unit and a level shifter to provide the signal V_{in} to the PDIC (see Fig.4). The digital output from the device is the combination of the speed pulse and an 8-bit data protocol.

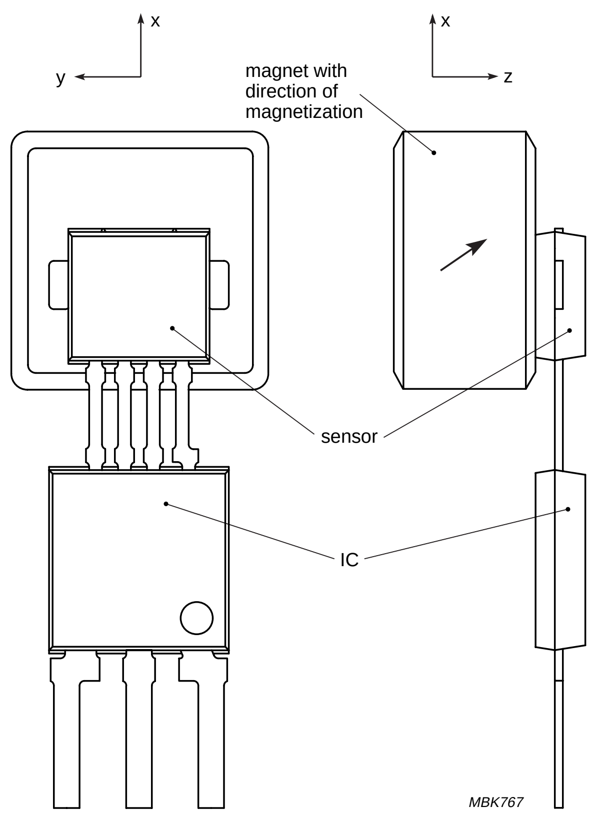


Fig.2 Component detail of the KMI22/1.

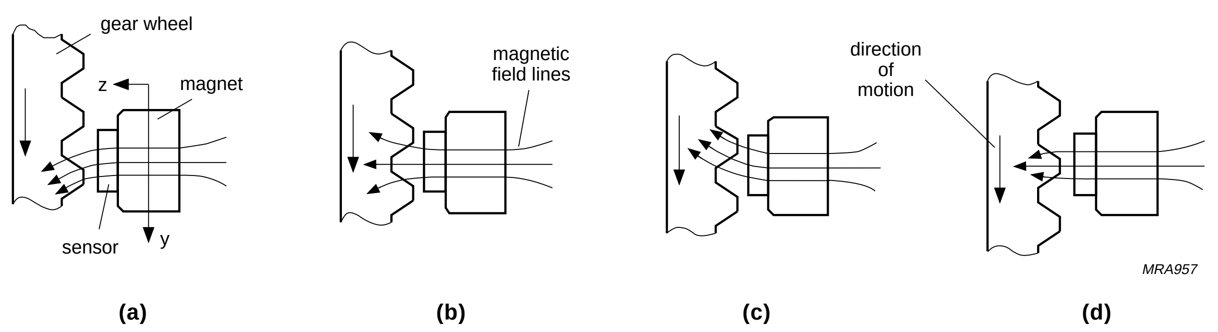


Fig.3 Functional principle.

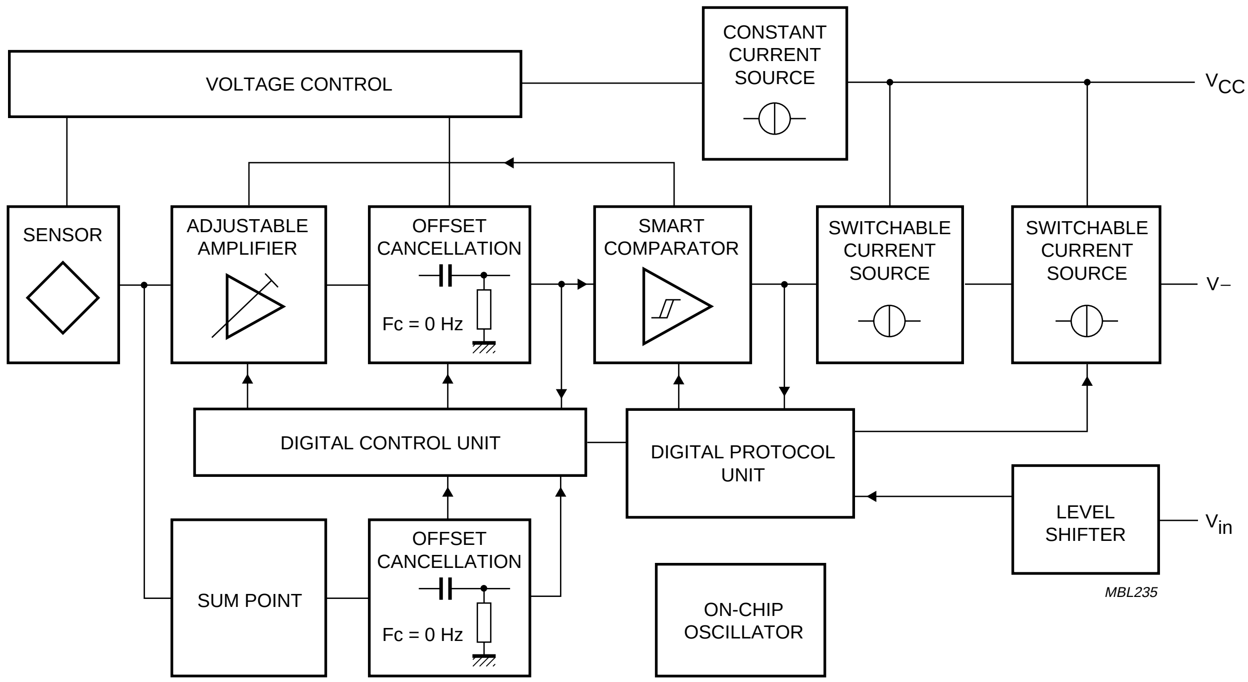


Fig.4 Block diagram.

Figure 5 shows the digital compensation function in algorithmic format. After power on the sensor system is running in INITIAL MODE 0 Hz. The sensor signal is preamplified but not offset compensated. The output signal represents the specified sensing distances (see Chapter “Characteristics”) for every tooth of the wheel, totally speed independent.

When $d_{in\ 0\ Hz} < d < d_{in\ 1\ Hz}$ the system must first detect the sensor signal amplitudes to compensate for the sensor offset INITIAL MODE 1 Hz. An output signal is produced (first compensation run finished) latest after 11 wheel teeth, with a frequency above 1 Hz have been sensed.

After detecting the teeth in initial mode the PDIC changes to the ACTIVE MODE and the sensor signal is permanently offset compensated. The available sensing distance is increased to d_{act}. Quitting ACTIVE MODE is caused by power off or by the teeth frequency falling below 1 Hz. The system is locked into COMPENSATION MODE and continues to detect every wheel tooth down to zero speed.

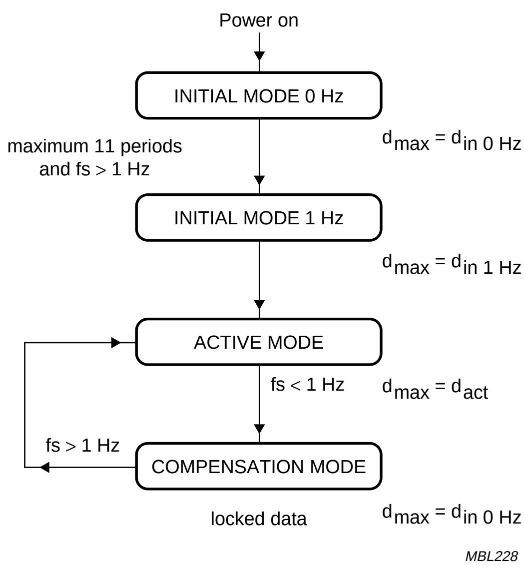


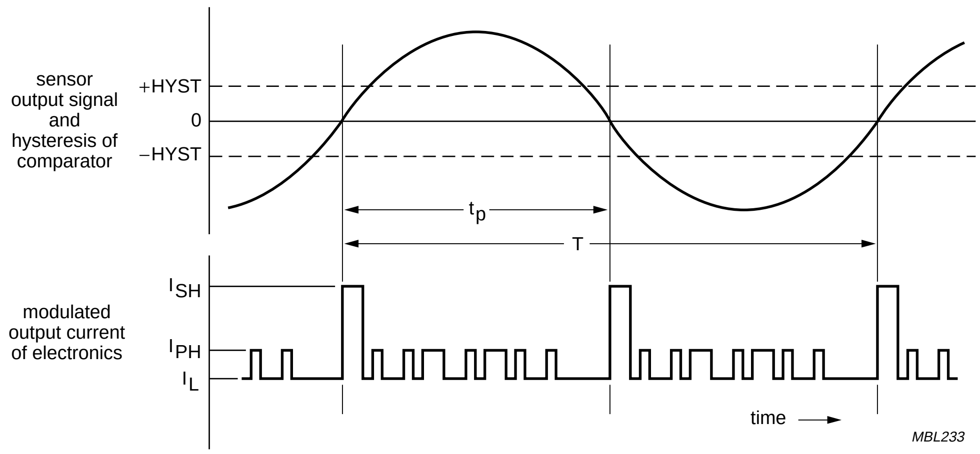
Fig.5 PDIC function algorithm.

Output signal

The output signal is shown in Fig.6. The signal contains a speed signal and an 8-bit protocol following the speed signal. This serial transmission, using the Manchester Code to encode the bits, is realized by modulating the 3-level output current of the sensor system. A short pulse of the highest current level I_{SH} represents the gear wheel structure, whereas the protocol bits are coded by using the protocol current level I_{PH}.

Definition of the protocol data bit value

Figure 7 shows the definition of the protocol data bit value. The protocol data bit has the bit length t_d. It is split into two half signal parts by the current edge in the middle of the data bit. Data bit HIGH is defined by the rising current edge from I_L to I_{PH}. Data bit LOW is defined by the falling current edge. Any data bit without a current edge at its middle is invalid.



$$\delta = \frac{t_p}{T} \times 100\%$$

Fig.6 Output signal.

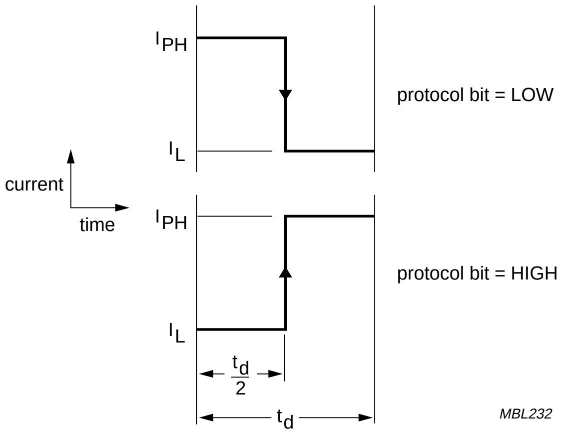


Fig.7 Definition of protocol data bit value.

Timing of the data

The data timing is shown in Figs 8 and 9.

OPERATION AT NORMAL SPEED

The wheel speed pulse is generated whenever a rising or falling edge of the wheel signal is detected. The pulse length is t_s. Following the wheel speed pulse a pre-bit is sent. It is always low and has the length t_p.

After the pre-bit the sensor logic begins to transfer the data protocol bits. The data protocol transferred by the sensor logic consists of 9 data bits (8 data bits and a parity bit; see Table 3). The data bit is length t_d and must contain a current edge its middle.

Following the data protocol bits an end bit with length $0.5 \times t_d$ is transferred. The end bit is always low, switching the current output to I_L until the arrival of the next wheel speed pulse leading edge.

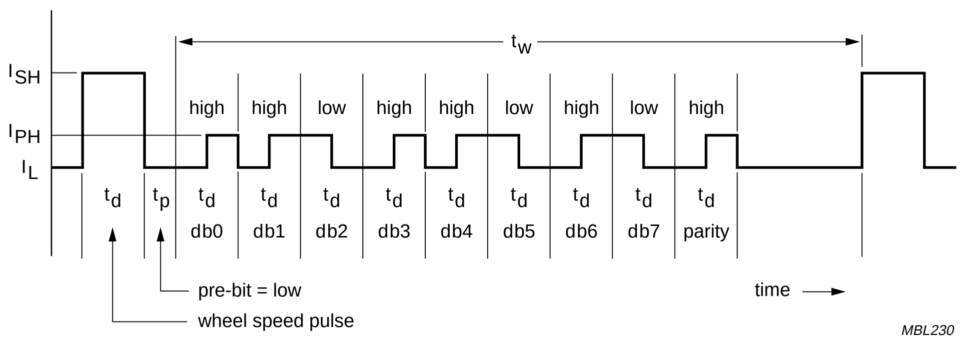


Fig.8 Timing diagram of data protocol at normal wheel speed.

OPERATION AT VERY LOW SPEED

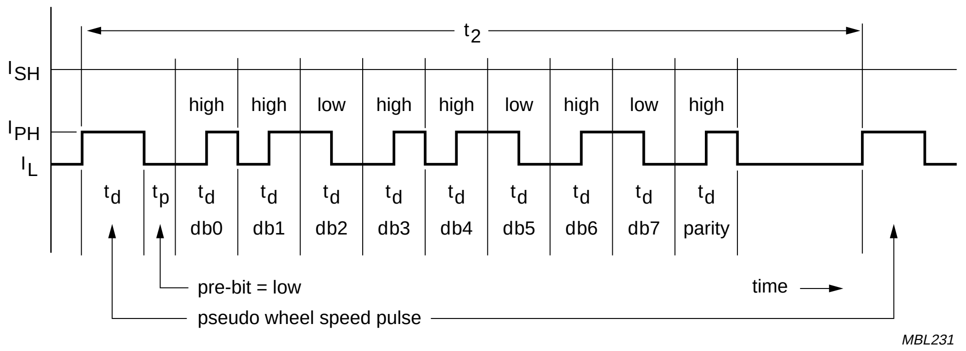


Fig.9 Timing diagram of data protocol at very low speed.

In the event that no wheel speed pulse is detected during time t_2 the protocol transfer is executed as described previously, except that a pseudo wheel speed pulse with protocol level high of I_{PH} instead of I_{SH} is substituted for the wheel speed pulse (see Fig.9).

TIMING AT HIGH SPEED

The pulse width of data bits t_d is fixed, whereas the time interval between wheel speed pulses is not. The higher the speed of the wheel, the shorter the period t_w, therefore not all data bits can be transferred at high wheel speed.

In this situation, calculations are made based on the current wheel speed pulse interval (n) to determine how many will fit into this window. This data is then used to determine the number of data bits that will be transferred during the next wheel speed pulse interval (n + 2), as shown in Table 1.

During time interval n + 2 the sensor current output consists of the wheel speed pulse, pre-bit, data bits (less than 9 bits; see Table 1), and the end bit data.

Referring to Table 1 it can be seen that the minimum number of data bits that will be transferred during period n + 2 is 2. If 3 or less data bits are to be transferred, the end bit length will be reduced to 0.

Table 1 Calculation of the number of protocol bits

MAXIMUM NUMBER OF t_d IN THE CURRENT TIME INTERVAL n (t_w)	PROTOCOL BITS FOR TIME INTERVAL n + 2
<5	2
5	3
6	4
7	5
8	6
9	7
10	8
>10	8

PULSE AND PROTOCOL DEFINITIONS

Table 2 Pulse and protocol timing

T_{amb} = –40 to +85 °C; V_{CC} = 12 V; test circuit: see Fig.12; R_L = 43 Ω; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
t_s	speed signal pulse width	see Figs 8 and 9	40	50	60	µs
t_p	pre-bit pulse width	see Figs 8 and 9	20	25	30	µs
t_d	data pulse width	see Figs 8 and 9	40	50	60	µs
t_2	time between pseudo speed pulses	see Fig.9	120	150	180	ms

Table 3 Definition of data bits

DATA BIT	SYMBOL	DESCRIPTION	REMARK
0	AR	air gap reserve	logic 1 when distance too large; note 1
1	M	mode state	logic 1 when in initial mode, 0 when in active mode
2	V_{in}	digital input state	logic 1 when V_{in} = low; default
3	VDR	validity direction recognition	logic 1 when direction bit is valid; note 2
4	DR	direction recognition	logic 1 when direction is positive (see Fig.10)
5	SD0	sensing distance bit 0	reflects actual sensing distance; LSB; note 3; Fig.10
6	SD1	sensing distance bit 1	reflects actual sensing distance; note 3; Fig.10
7	SD2	sensing distance bit 2	reflects actual sensing distance; MSB; note 3; Fig.10
8	P	parity	‘high’ for even parity: P = XOR (data 0, data 1 to data 7)

Notes

1. Air gap reserve: this bit of the protocol indicates that the processed signal amplitude is smaller than twice the minimum allowed signal amplitude (see Fig.10). If this bit is flagged then the air gap is nearly used up, which means that the sensor system will stop working for a further reduction of the signal amplitude.
2. Correct direction recognition is guaranteed for sensing distance: see Chapter “Characteristics”.
3. Bits SD0 to SD2: These bits are used to quantify the signal amplitude and therefore the air gap can be divided into 8 sections (see Fig.10). For a temperature sweep over the complete specified range the air gap information may change by 2 LSBs due to the temperature coefficient of the sensor signal amplitude.

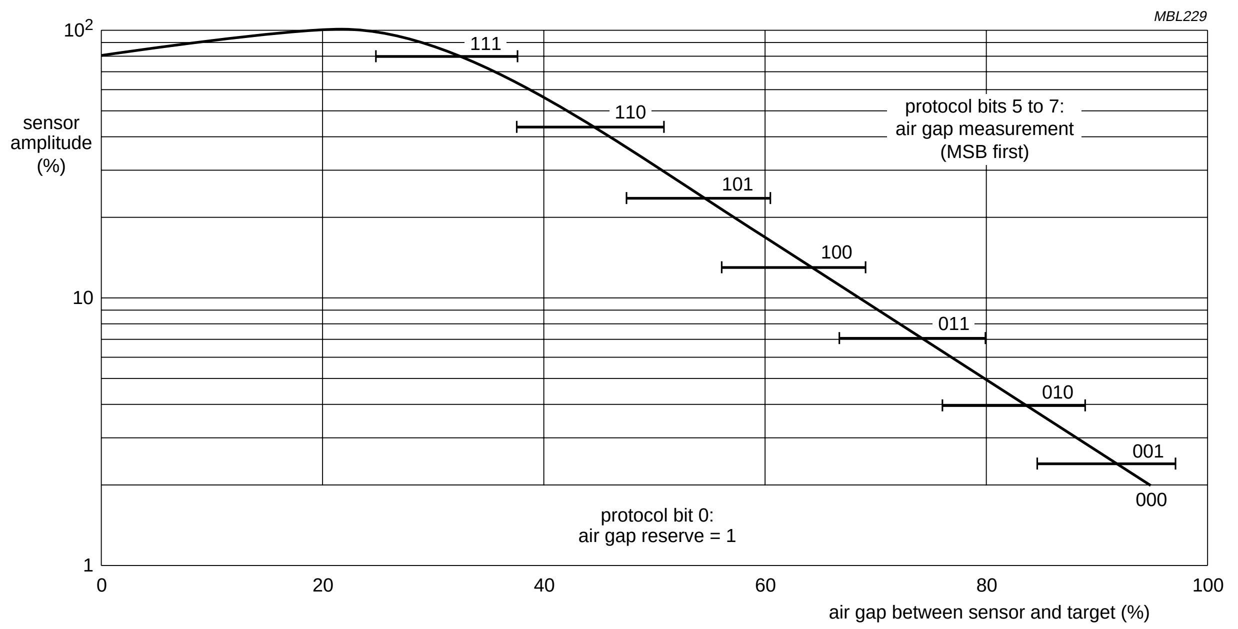


Fig.10 Sensor amplitude versus air gap.

Mounting conditions

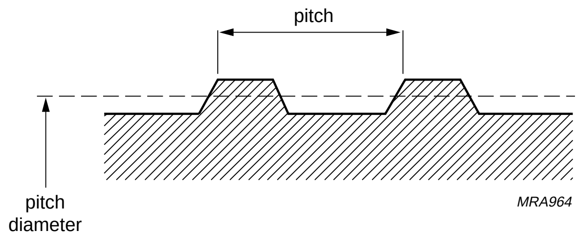
The recommended sensor position in front of a gear wheel is shown in Fig.13. The distance 'd' is measured between the sensor front and the tip of a gear wheel tooth. The KMI22/1 senses ferrous indicators like gear wheels in the y direction only (no rotational symmetry of the sensor); see Fig.2. The symmetrical reference axis of the sensor corresponds to the axis of the ferrite magnet.

Table 4 Gear wheel dimensions

SYMBOL	DESCRIPTION	UNIT
German DIN		
z	number of teeth	
d	diameter	mm
m	module m = d/z	mm
p	pitch $\pi = p \times m$	mm
ASA; note 1		
PD	pitch diameter (d in inches)	inch
DP	diametric pitch DP = z/PD	$inch^{-1}$
CP	circular pitch CP = π/DP	inch

Note

1. For conversion from ASA to DIN: m = 25.4 mm/DP; p = 25.4 mm $\times$ CP.



$$\text{module} = \frac{\text{pitch diameter}}{\text{number of teeth}}$$

$\text{pitch} = \text{module} \times \pi$

Fig.11 Gear wheel dimensions.

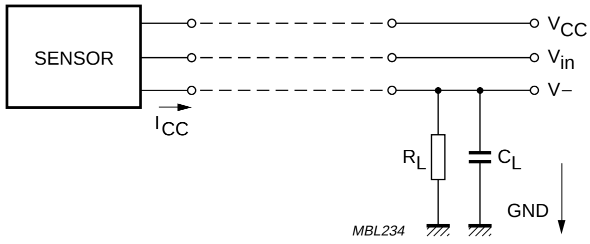
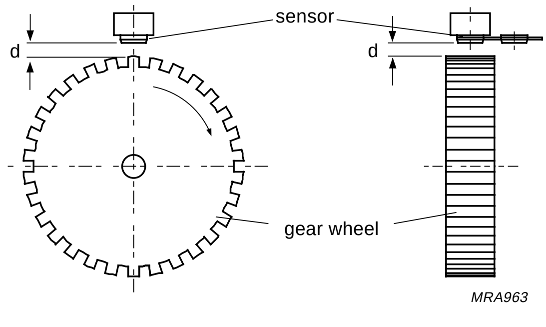
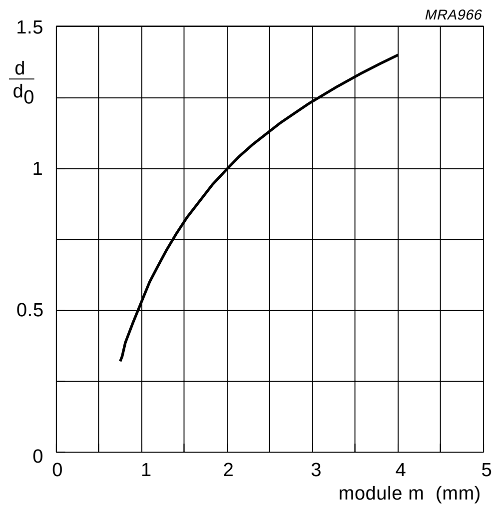


Fig.12 Test and application circuit.



Centre die position: see Chapter “Package outline”.

Fig.13 Sensor positioning.



d_0 = measuring distance for a gear wheel with module m = 2 mm.

Fig.14 Normalized maximum sensing distance as a function of gear wheel module; typical values.

EMC

Figure 15 shows a recommended application circuit for automotive applications. It provides a protection interface to meet Electromagnetic Compatibility (EMC) standards and safeguard against voltage spikes. Table 5 lists the tests which are applicable to this circuit and the achieved class of functional status. Protection against 'load dump' (test pulses 5 according to *"DIN 40839"*) means a very high demand on the protection circuit and requires a suitable suppressor diode with sufficient energy absorption capability.

The board net often contains a central load dump protection that makes such a device in the protection circuit of the sensor module unnecessary.

Tests for electrostatic discharge (ESD) were conducted in line with *"IEC 801-2"* to demonstrate the KMI22/1's handling capabilities. The *"IEC 801-2"* test conditions were: C = 150 pF, R = 150 Ω, V = 4 kV.

Electromagnetic disturbances with fields up to 150 V/m and f = 1 GHz (ref. *"DIN 40839"*) have no influence on performance.

Table 5 EMC test results

EMC REF. DIN 40839	SYMBOL	MIN. (V)	MAX. (V)	REMARKS	CLASS
Test pulse 1	V_{LD}	–100	–	t_d = 2 ms	C
Test pulse 2	V_{LD}	–	100	t_d = 0.2 ms	A
Test pulse 3a	V_{LD}	–150	–	t_d = 0.1 μs	A
Test pulse 3b	V_{LD}	–	100	t_d = 0.1 μs	A
Test pulse 4	V_{LD}	–7	–	t_d = 130 ms	B
Test pulse 5	V_{LD}	–	120	t_d = 400 ms	B

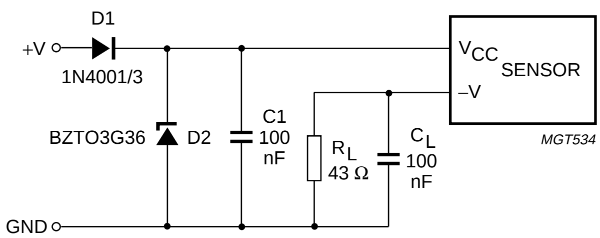
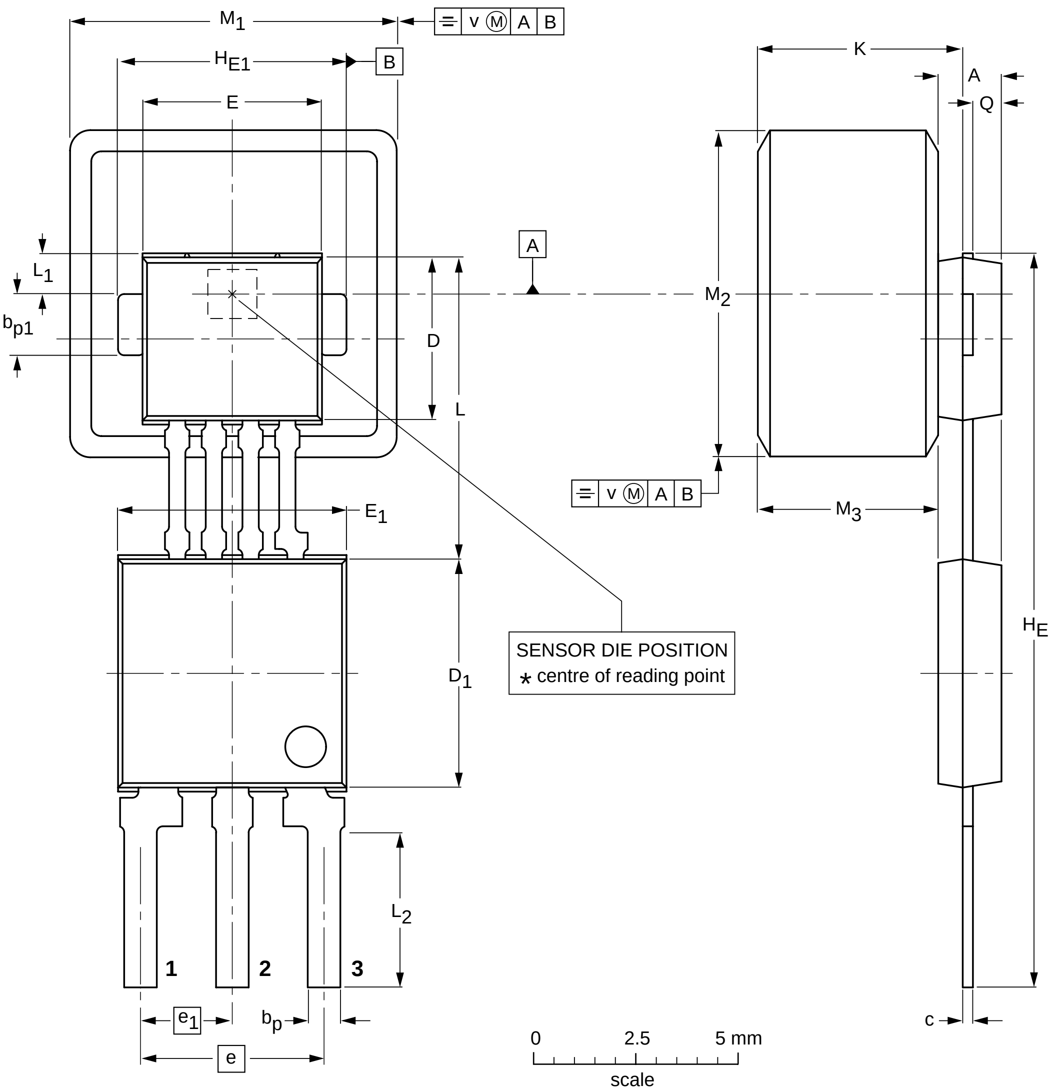


Fig.15 EMC: test and application circuit.

PACKAGE OUTLINE

Plastic single-ended multi-chip package; magnetized ferrite magnet (8 x 8 x 4.5 mm); 4 interconnections; 3 in-line leads **SOT477B**



DIMENSIONS (mm are the original dimensions)

UNIT	A(1)	b_p	b_{p1}	c	D(2)	D_1(2)	E(2)	E_1(2)	e	e_1	H_E	H_{E1}	K max.	L	L_1	L_2	M_1	M_2	M_3(1)	Q	v
mm	1.7	0.8	1.57	0.3	4.1	5.7	4.5	5.7	4.6	2.35	18.2	5.6	5.37	7.55	1.2	3.9	8.15	8.15	4.7	0.75	0.25
	1.4	0.7	1.47	0.24	3.9	5.5	4.3	5.5	4.4	2.15	17.8	5.5		7.25	0.9	3.5	7.85	7.85	4.3	0.65	

Notes

1. Glue thickness not included.
2. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT477B						~~99-09-23~~ 00-08-31

DATA SHEET STATUS

DATA SHEET STATUS	PRODUCT STATUS	DEFINITIONS [(1)]
Objective specification	Development	This data sheet contains the design target or goal specifications for product development. Specification may change in any manner without notice.
Preliminary specification	Qualification	This data sheet contains preliminary data, and supplementary data will be published at a later date. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
Product specification	Production	This data sheet contains final specifications. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.

Note

1. Please consult the most recently issued data sheet before initiating or completing a design.

DEFINITIONS

Short-form specification — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

Limiting values definition — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

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