

KMA215

Programmable angle sensor with SAE J2716 SENT

Rev. 1 — 24 February 2014 Product data sheet

1. Product profile

1.1 General description

The KMA215 is a magnetic angle sensor module with digital output in accordance with SAE J2716 JAN2010 Single Edge Nibble Transmission (SENT). The MagnetoResistive (MR) sensor bridges, the mixed signal Integrated Circuit (IC) and the required capacitors are integrated into a single package.

This angular measurement module KMA215 is pre-programmed, pre-calibrated and therefore, ready to use. The default configuration for the digital output is SENT2010-03.0us-6dn-npp-nsp-A.3.

The KMA215 allows user-specific adjustments of angular range, zero angle and SENT configuration. The settings are stored in a multi-time programmable non-volatile memory.

1.2 Features and benefits

- High precision sensor for magnetic angular measurement
- Single package sensor module with integrated filters and pulse shaping for improved ElectroMagnetic Compatibility (EMC)
- Automotive qualified in accordance with AEC-Q100 Rev-G
- Programmable user adjustments, angular range, zero angle and SENT configuration
- Fail-safe non-volatile memory with write protection using lock bit
- Independent from magnetic field strength above 35 kA/m
- Ready to use without external components
- Factory calibrated
- High temperature range up to 160 °C
- Overvoltage protection up to 16 V
- Push pull output stage compliant with SAE J2716 JAN2010 SENT with pulse shaping
- Optional high-speed 12-bit SENT message format H.3
- Optional enhanced serial data communication
- Programming via One-Wire Interface (OWI)
- 8 user-programmable SENT messages (8 × 12 bit)
- Magnet-loss and broken bond wire detection

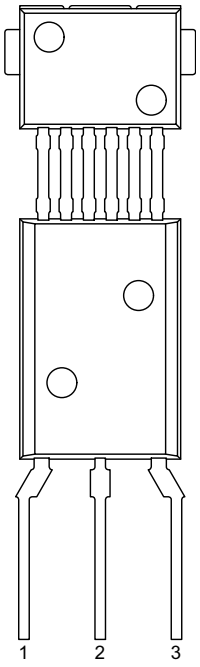
1.2.1 Extract of SENT modes (shorthand notation)

- SENT2010-03.0us-6dn-npp-nsp-A.3 (default configuration)
- SENT2010-03.0us-6dn-npp-esp-A.3
- SENT2010-03.0us-6dn-ppc(297.0)-nsp-A.3
- SENT2010-03.0us-6dn-ppc(297.0)-esp-A.3
- SENT2010-06.0us-6dn-npp-nsp-A.3
- SENT2010-06.0us-6dn-npp-esp-A.3
- SENT2010-06.0us-6dn-ppc(297.0)-nsp-A.3
- SENT2010-06.0us-6dn-ppc(297.0)-esp-A.3
- SENT201x-03.0us-4dn-npp-nsp-H.3
- SENT201x-03.0us-4dn-npp-esp-H.3

Additional SENT modes can be found in Table 8, Table 12 and Table 15.

2. Pinning information

Table 1. Pinning

Pin	Symbol	Description	Simplified outline
1	V_{DD}	supply voltage	
2	GND	ground	
3	OUT/DATA	SENT output or OWI data interface	

3. Ordering information

Table 2. Ordering information

Type number	Package		
	Name	Description	Version
KMA215	-	plastic single-ended multi-chip package; 6 interconnections; 3 in-line leads	SOT1288-2

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4. Functional diagram

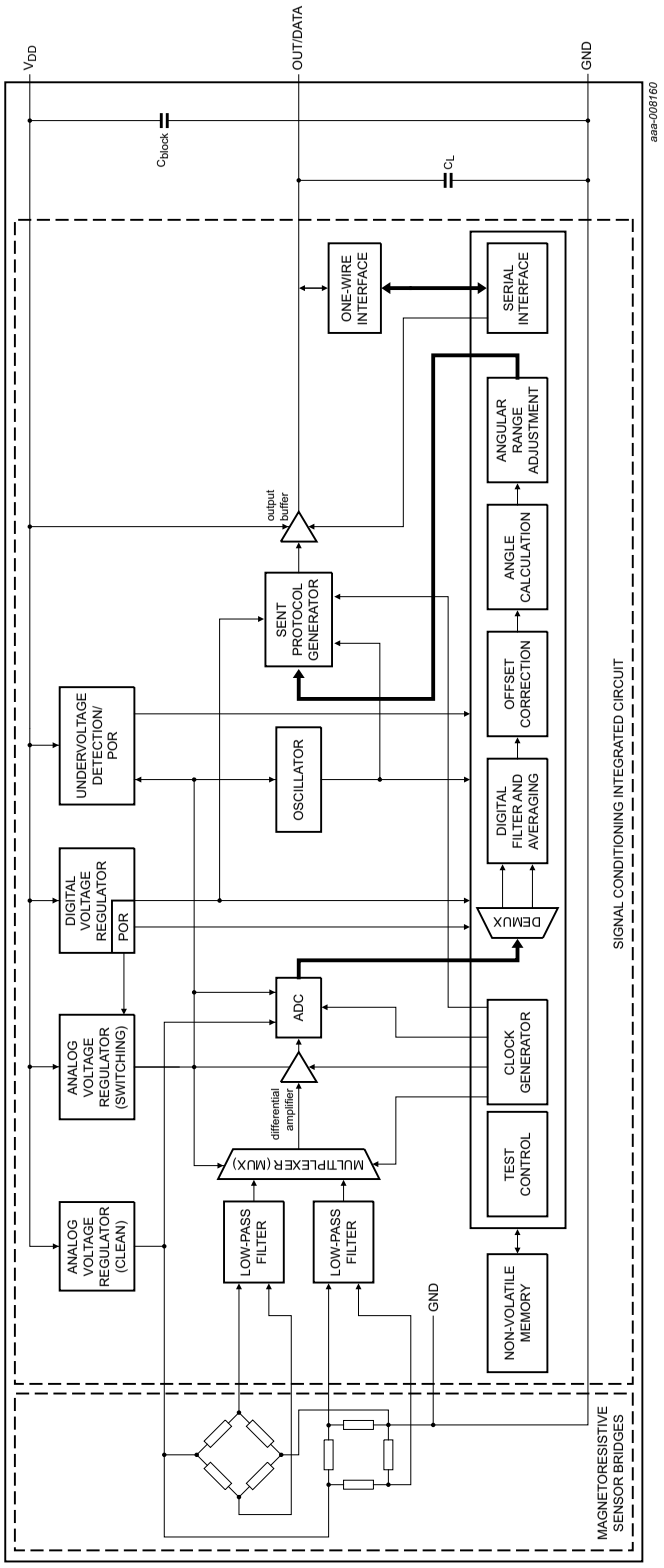


Fig 1. Functional diagram of KMA215

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5. Functional description

The KMA215 amplifies two orthogonal differential signals from MR sensor bridges and converts them into the digital domain. The angle is calculated using the COordinate Rotation DIgital Computer (CORDIC) algorithm and transmitted in a SENT frame compliant to SAE J2716 SENT standard. Zero angle and angular range are programmable. In addition, eight 12-bit Original Equipment Manufacturer (OEM) registers are available for customer purposes, such as sample identification.

The KMA215 comprises a Cyclic Redundancy Check (CRC) and an Error Detection and Correction (EDC) for the non-volatile memory. It also has magnet-loss and broken bond wire detection.

After multiplexing the two MR Wheatstone bridge signals and their successive amplification, the signal is converted into the digital domain by an Analog-to-Digital Converter (ADC). Further processing is done within an on-chip state machine. This state machine controls offset cancelation, calculation of the mechanical angle using the CORDIC algorithm, as well as zero angle and angular range adjustment. The SENT protocol generator converts the angular information into SENT messages that are repeatedly sent via the SENT output.

The configuration parameters are stored in a user-programmable non-volatile memory. The OWI (accessible using pin OUT/DATA) is used for accessing the memory. In order to protect the memory content, a lock bit can be set. After locking the non-volatile memory, its content cannot be changed anymore.

5.1 Angular measurement directions

The differential signals of the MR sensor bridges depend only on the direction of the external magnetic field strength H_{ext}, which is applied parallel to the plane of the sensor. In order to obtain a correct output signal, exceed the minimum saturation field strength.

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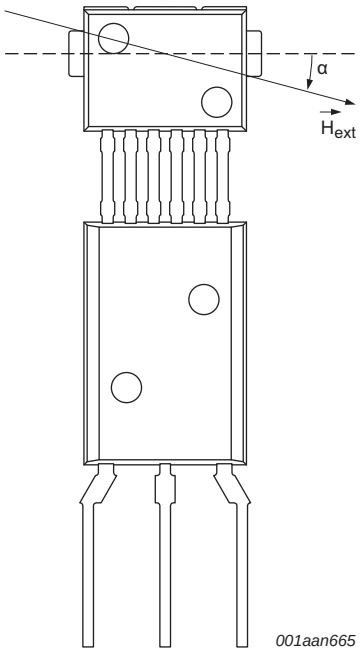


Fig 2. Angular measurement directions

Since the Anisotropic MR (AMR) effect is periodic over 180°, the sensor output is also 180°-periodic. The angle is calculated relative to a freely programmable zero angle. The dashed line indicates the mechanical zero degree position.

6. Digital output

The KMA215 SENT provides a digital output signal on pin OUT/DATA compliant with the SAE J2716 JAN2010 SENT. The measured angle α is converted linearly into a value, which is digital encoded in SENT frames. Either a positive or a negative angular slope characteristic is provided for this purpose.

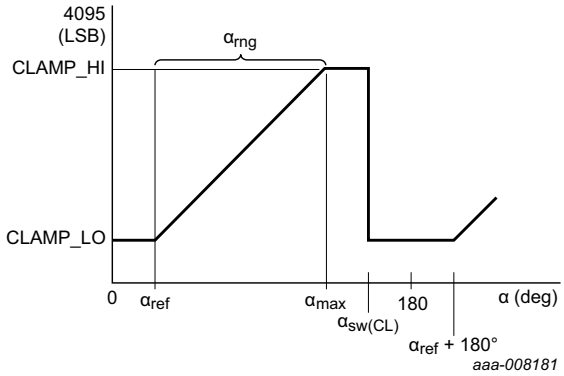
Table 3 describes the digital output behavior for a positive slope. A magnetic field angle above the programmed maximum angle α_{max} but below the clamp switch angle $\alpha_{sw(CL)}$ sets the output to the upper clamping value. If the magnetic field angle is larger than the clamp switch angle, the output value switches from upper to lower clamping value. If there is a negative slope, the clamping levels are changed.

Table 3. Digital output behavior for a positive slope

Magnetic field angle	Data value
$\alpha_{max} < \alpha < \alpha_{sw(CL)}$	CLAMP_HI
$\alpha_{sw(CL)} < \alpha < \alpha_{ref} + 180°$	CLAMP_LO

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$\alpha_{max} = \alpha_{ref} + \alpha_{rng}$

Fig 3. Characteristic of the digital output

6.1 Transmission of sensor messages

The KMA215 repeatedly sends a sequence of pulses based on the encoding scheme of SENT. The transmitted message is a sequence of 4-bit nibbles (SENT frame). The time base of the SENT frame is defined in clock ticks with a configurable duration of T_{clk} = 3.0 µs, 4.5 µs, 6.0 µs, 12.0 µs and 24.0 µs each clock tick. A calibration pulse followed by a STATUS nibble, a constant number of DATA nibbles and a CRC nibble as shown in Figure 4 define one message frame of a SENT transmission. The KMA215 supports the SENT data formats in accordance with the appendix A.1 and A.3 of the SAE J2716 JAN2010 SENT. Additionally a high-speed 12-bit message format H.3 is implemented.

General SENT specification can be found in:

- SAE J2716 FEB2008 SENT
- SAE J2716 JAN2010 SENT

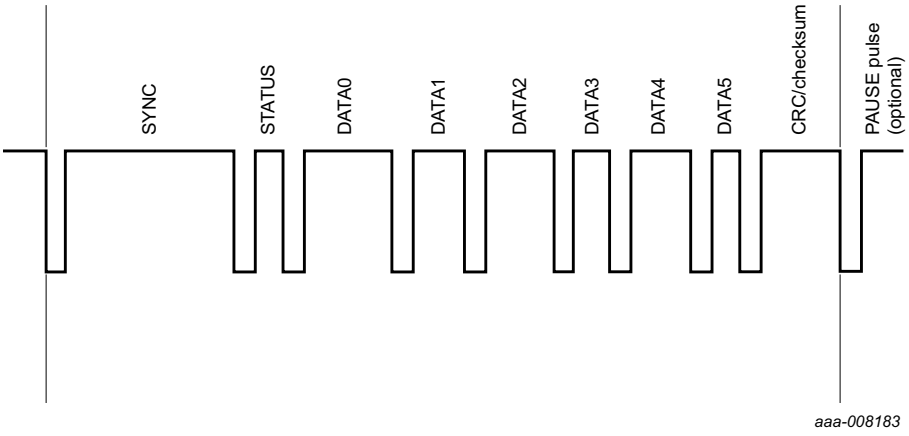


Fig 4. SENT frame

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6.1.1 SYNC nibble

The synchronization and calibration nibble is always 56 clock ticks long. The receiver uses the SYNC nibble to derive the clock tick time from the SENT frame.

6.1.2 STATUS nibble

The STATUS nibble contains status and slow channel information of the KMA215. Bit #0 reflects the operating mode of the KMA215, normal or diagnostic mode.

Bit #1 depends on the selected data format. If there is single secure sensor format A.3 or high-speed 12-bit message format H.3 selected, bit #1 of the STATUS nibble is a prewarning indication. Prewarning bit is set while the KMA215 is still in normal mode, but one of the following conditions occurred:

- Angular value is above the programmed OOR_HI threshold; see Table 32
- Angular value is below the programmed OOR_LO threshold; see Table 32
- Corrected single bit error of the non-volatile memory (can be disabled via SINGLE_BIT_ERROR_PREWARNING bit in register Dh); see Table 33

If there is dual throttle position sensor format A.1 selected bit #1 behaves the same as bit #0. For detailed diagnostic information read out the ERROR_BYTE of the optional slow channel serial message.

Bit #2 and bit #3 are used for optional slow channel serial data messages, described in Section 6.1.6.

Table 4. STATUS nibble

Bit	Description
3 (MSB)	serial data message bit
2	serial data message bit
1	prewarning[1]
0 (LSB)	bit = 0: normal mode[2]
	bit = 1: diagnostic condition[2][3]

[1] The function of this bit depends on the selected data frame format. If there is A.1 selected this bit behaves like bit #0 of the STATUS nibble. If there is A.3 or H.3 selected this bit is an OR function of OOR_HI, OOR_LO and if enabled also ERROR_CORRECT bit is included in the OR function.

[2] Copy of IN_DIAG_MODE bit of command register.

[3] Enable the serial data communication for detailed diagnostic information

6.1.3 CRC nibble

The CRC nibble contains the 4-bit checksum of the DATA nibbles only. The CRC calculation does not cover the STATUS nibble.

The CRC is calculated using polynominal $x^4 + x^3 + x^2 + 1$ with seed value of 0101. The KMA215 supports both the legacy CRC defined in SENT SAE J2716 FEB2008 and earlier revisions and the recommended CRC defined in SENT SAE J2716 JAN2010. The CRC version can be selected via SENT_LEGACY_CRC bit in the SENT_CONF register; see Table 33. CRC in accordance with SAE J2710 JAN2010 is the default configuration.

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6.1.4 PAUSE pulse

A PAUSE pulse can be optionally attended to the SENT frame to generate messages with a constant frame length of 297.0 clock ticks.

6.1.5 DATA nibbles

In general, the DATA nibbles contain the angular information of the KMA215. The data format depends on the selected sensor type. The KMA215 supports three different DATA nibble formats as defined in the SAE J2716 SENT specification:

- Single secure sensor format A.3
- Dual throttle position sensor format A.1
- High-speed 12-bit message format H.3

A detailed frame format description can be found in the corresponding subsection.

6.1.5.1 Single secure sensor format A.3

The KMA215 transmits the sequence defined in Table 5 repeatedly in accordance with the single secure sensor format defined in SAE J2716 JAN2010 SENT appendix A.3. DATA nibbles D0 to D2 contain the 12-bit angular value. D3 and D4 reflect the value of an 8-bit loop counter. D5 is an inverted copy of the most significant nibble DATA0.

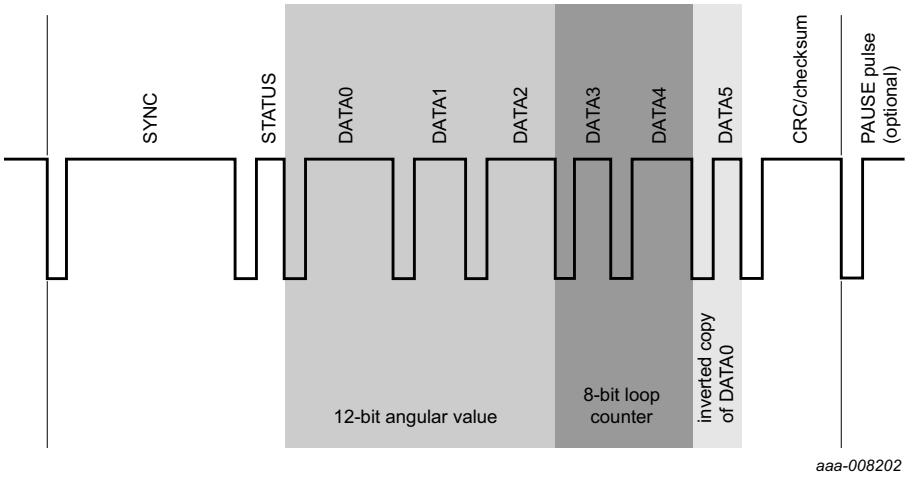


Fig 5. Single secure sensor format A.3

Table 5. Data content of single secure sensor format A.3 frame

SYNC	STATUS	DATA0	DATA1	DATA2	DATA3	DATA4	DATA5	CRC
-	error flag	D0[1]	D1	D2[2]	D3[1]	D4[2]	D5	-
-		12-bit angular value			8-bit loop counter		inverted D0	-

[1] Most Significant Nibble (MSN).

[2] Least Significant Nibble (LSN).

DATA nibbles D0 to D2 contain the angular value information in the single secure sensor format.

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Table 6. DATA nibbles D0 to D2: angular value

D0[1]	D1	D2[2]	12-bit value	Angle
0000	0000	0000	0	0°
:	:	:	:	:
1111	1111	1111	4095	α_{max}

[1] MSN.

[2] LSN.

Table 7. DATA nibbles D3 and D4: 8-bit loop counter

D3[1]	D4[2]	8-bit loop counter
0000	0000	0
:	:	:
1111	1111	255

[1] MSN.

[2] LSN.

The KMA215 supports the single secure sensor format in different configurations which can be programmed in the configuration register. Shorthand notations of available configurations and corresponding SENT mode register values are listed in Table 8.

Table 8. Single secure sensor format configurations

Shorthand notation	SENT mode	SENT release	Clock tick time	DATA nibbles	PAUSE pulse	Serial message	Data format
SENT2010-03.0us-6dn-npp-nsp-A.3 (default)	04h	2010	3.0 µs	6	no	no	A.3
SENT2010-03.0us-6dn-npp-esp-A.3	05h	2010	3.0 µs	6	no	yes	A.3
SENT2010-03.0us-6dn-ppc(297.0)-nsp-A.3	06h	2010	3.0 µs	6	yes	no	A.3
SENT2010-03.0us-6dn-ppc(297.0)-esp-A.3	07h	2010	3.0 µs	6	yes	yes	A.3
SENT2010-04.5us-6dn-npp-nsp-A.3	08h	2010	4.5 µs	6	no	no	A.3
SENT2010-04.5us-6dn-npp-esp-A.3	09h	2010	4.5 µs	6	no	yes	A.3
SENT2010-04.5us-6dn-ppc(297.0)-nsp-A.3	0Ah	2010	4.5 µs	6	yes	no	A.3
SENT2010-04.5us-6dn-ppc(297.0)-esp-A.3	0Bh	2010	4.5 µs	6	yes	yes	A.3
SENT2010-06.0us-6dn-npp-nsp-A.3	0Ch	2010	6.0 µs	6	no	no	A.3
SENT2010-06.0us-6dn-npp-esp-A.3	0Dh	2010	6.0 µs	6	no	yes	A.3
SENT2010-06.0us-6dn-ppc(297.0)-nsp-A.3	0Eh	2010	6.0 µs	6	yes	no	A.3
SENT2010-06.0us-6dn-ppc(297.0)-esp-A.3	0Fh	2010	6.0 µs	6	yes	yes	A.3
SENT2010-12.0us-6dn-npp-nsp-A.3	10h	2010	12.0 µs	6	no	no	A.3
SENT2010-12.0us-6dn-npp-esp-A.3	11h	2010	12.0 µs	6	no	yes	A.3
SENT2010-12.0us-6dn-ppc(297.0)-nsp-A.3	12h	2010	12.0 µs	6	yes	no	A.3
SENT2010-12.0us-6dn-ppc(297.0)-esp-A.3	13h	2010	12.0 µs	6	yes	yes	A.3
SENT2010-24.0us-6dn-npp-nsp-A.3	14h	2010	24.0 µs	6	no	no	A.3
SENT2010-24.0us-6dn-npp-esp-A.3	15h	2010	24.0 µs	6	no	yes	A.3
SENT2010-24.0us-6dn-ppc(297.0)-nsp-A.3	16h	2010	24.0 µs	6	yes	no	A.3
SENT2010-24.0us-6dn-ppc(297.0)-esp-A.3	17h	2010	24.0 µs	6	yes	yes	A.3

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6.1.5.2 Dual throttle position sensor format A.1

The KMA215 transmits the sequence defined in Table 9 repeatedly in accordance with the dual throttle position sensor format defined in SAE J2716 JAN2010 SENT appendix A.1. DATA nibbles D0 to D2 contain the 12-bit angular value. DATA nibbles D3 to D5 contain the opposite slope of the same 12-bit angular value while also the order of these DATA nibbles is reversed.

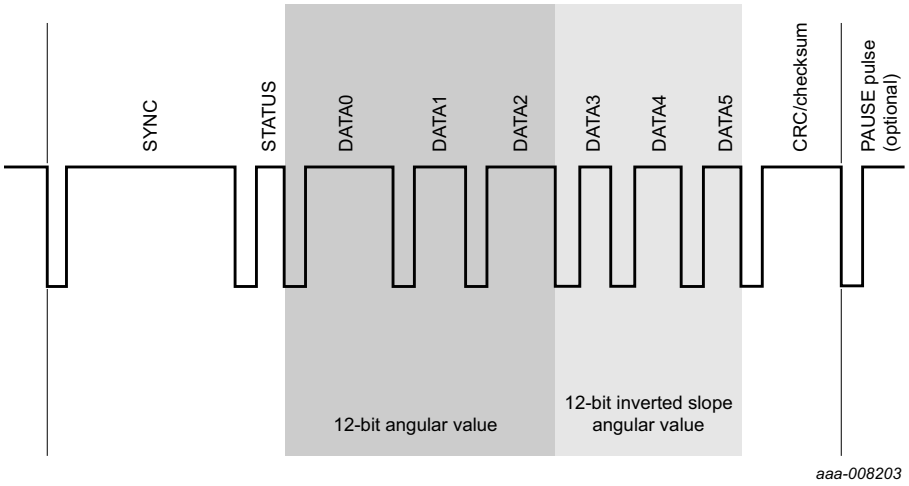


Fig 6. Dual throttle position sensor format A.1

Table 9. Data content of dual throttle position sensor format A.1 frame

SYNC	STATUS	DATA0	DATA1	DATA2	DATA3	DATA4	DATA5	CRC
-	error flag	D0[1]	D1	D2[2]	D5[2]	D4	D3[1]	-
-		12-bit angular value			12-bit inverted slope angular value			-

[1] MSN.

[2] LSN.

DATA nibbles D0 to D2 contain the angular value information in the dual throttle position sensor format.

Table 10. DATA nibbles D0 to D2: angular value

D0[1]	D1	D2[2]	12-bit value	Angle
0000	0000	0001	1	0°
:	:	:	:	:
1111	1111	1110	4094	α_{max}

[1] MSN.

[2] LSN.

For the inverted slope angular value in the DATA nibbles DATA3 to DATA5 the order of the nibbles is also reversed: LSN, MidSN, MSN. When a diagnostic condition occurs, the DATA nibbles D0 to D2 are all set to Fh and DATA nibbles DATA3 to DATA5 are all set to 0h.

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Table 11. DATA nibbles DATA[5:3]: inverted slope angular value

D5[1]	D4	D3[2]	12-bit value	Angle
0000	0000	0001	1	α_{max}
:	:	:	:	:
1111	1111	1110	4094	0°

[1] MSN.

[2] LSN.

For the dual throttle position sensor format A.1 clamping levels must be set to the correct values to comply to the SAE J2716 SENT specification. Otherwise angular values overwrite reserved data range for diagnostic information. The angular range multiplier and clamp switch angle must also be adapted thus the desired angular range is mapped to the remaining data range correctly.

Settings for dual throttle position sensor format A.1 180° full angular range; also see Table 33:

CLAMP_LO: 0001h

CLAMP_HI: 0FFEh

ANG_RNG_MULT: 3FFFh

The KMA215 supports the A.1 dual throttle position sensor format in different configurations which can be programmed in the configuration register. Shorthand notations of available configurations and corresponding SENT mode register values are listed in Table 12.

Table 12. Dual throttle position sensor format configurations

Shorthand notation	SENT mode	SENT release	Clock tick time	DATA nibbles	PAUSE pulse	Serial message	Data format
SENT2010-03.0us-6dn-npp-nsp-A.1	44h	2010	3.0 µs	6	no	no	A.1
SENT2010-03.0us-6dn-npp-esp-A.1	45h	2010	3.0 µs	6	no	yes	A.1
SENT2010-03.0us-6dn-ppc(297.0)-nsp-A.1	46h	2010	3.0 µs	6	yes	no	A.1
SENT2010-03.0us-6dn-ppc(297.0)-esp-A.1	47h	2010	3.0 µs	6	yes	yes	A.1
SENT2010-04.5us-6dn-npp-nsp-A.1	48h	2010	4.5 µs	6	no	no	A.1
SENT2010-04.5us-6dn-npp-esp-A.1	49h	2010	4.5 µs	6	no	yes	A.1
SENT2010-04.5us-6dn-ppc(297.0)-nsp-A.1	4Ah	2010	4.5 µs	6	yes	no	A.1
SENT2010-04.5us-6dn-ppc(297.0)-esp-A.1	4Bh	2010	4.5 µs	6	yes	yes	A.1
SENT2010-06.0us-6dn-npp-nsp-A.1	4Ch	2010	6.0 µs	6	no	no	A.1
SENT2010-06.0us-6dn-npp-esp-A.1	4Dh	2010	6.0 µs	6	no	yes	A.1
SENT2010-06.0us-6dn-ppc(297.0)-nsp-A.1	4Eh	2010	6.0 µs	6	yes	no	A.1
SENT2010-06.0us-6dn-ppc(297.0)-esp-A.1	4Fh	2010	6.0 µs	6	yes	yes	A.1
SENT2010-12.0us-6dn-npp-nsp-A.1	50h	2010	12.0 µs	6	no	no	A.1
SENT2010-12.0us-6dn-npp-esp-A.1	51h	2010	12.0 µs	6	no	yes	A.1
SENT2010-12.0us-6dn-ppc(297.0)-nsp-A.1	52h	2010	12.0 µs	6	yes	no	A.1
SENT2010-12.0us-6dn-ppc(297.0)-esp-A.1	53h	2010	12.0 µs	6	yes	yes	A.1
SENT2010-24.0us-6dn-npp-nsp-A.1	54h	2010	24.0 µs	6	no	no	A.1

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Table 12. Dual throttle position sensor format configurations *...continued*

Shorthand notation	SENT mode	SENT release	Clock tick time	DATA nibbles	PAUSE pulse	Serial message	Data format
SENT2010-24.0us-6dn-npp-esp-A.1	55h	2010	24.0 µs	6	no	yes	A.1
SENT2010-24.0us-6dn-ppc(297.0)-nsp-A.1	56h	2010	24.0 µs	6	yes	no	A.1
SENT2010-24.0us-6dn-ppc(297.0)-esp-A.1	57h	2010	24.0 µs	6	yes	yes	A.1

6.1.5.3 High-speed 12-bit message format H.3

The KMA215 supports a special high-speed 12-bit message format mode that realizes almost a doubling of the update rate compared to the other modes. The increase of the update rate is achieved by transmitting 12-bit angular data with only four DATA nibbles using only 3 bit of the available 4 bit per nibble. The MSB of each nibble is always zero. Additionally, the clock tick length is reduced to 2.7 µs typically with a maximum variation of ±10 %. The SYNC, STATUS and CRC nibble and the serial communication are the same as in the other modes described in Section 6.1.5.1. A PAUSE pulse option is not available for the high-speed 12-bit message format. The high-speed 12-bit message format H.3 complies to the SAE J2716 JAN2010 standard.

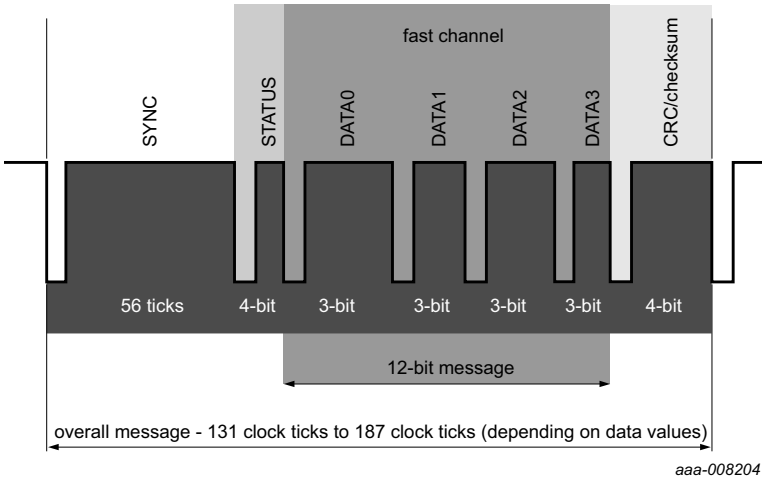


Fig 7. Example encoding scheme for a high-speed 12-bit frame

Table 13. Data content of high-speed 12-bit message format frame

SYNC	STATUS	DATA0	DATA1	DATA2	DATA3	CRC
-	error flag	D0[1]	D1	D2	D3[2]	-
-		12-bit angular value				-

[1] MSN.

[2] LSN.

To limit the total message length below 500 µs respectively 550 µs with serial data communication some data values are reserved as described in Table 14.

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Table 14. DATA nibbles D0 to D3: angular value

The MSB of each nibble is always zero.

D0[1]	D1	D2	D3[2]	12-bit value	Angle
0000	0000	0000	0000	0	initialization; the initialization message is transmitted during the sensor initialization phase until valid value is available
0000	0000	0000	0001	1	0°
:	:	:	:	:	:
0111	0111	0111	0000	4088	α_{max}
0111	0111	0111	0001	4089	reserved
0111	0111	0111	0010	4090	diagnostic condition[3]
0111	0111	0111	0011	4091	reserved
0111	0111	0111	0100	4092	reserved
0111	0111	0111	0101	4093	reserved
0111	0111	0111	0110	4094	reserved
0111	0111	0111	0111	4095	reserved

[1] MSN.

[2] LSN.

[3] For detailed diagnostic information, the serial data communication can be enabled.

For the 12-bit high-speed mode H.3 clamping levels must be set to the correct values to comply to the SAE J2716 SENT specification. Otherwise angular values overwrite reserved data range for diagnostic information. The angular range multiplier and clamp switch angle must also be adapted thus the desired angular range is mapped to the remaining data range correctly.

Settings for high-speed 12-bit fast mode 180° full angular range; also see Table 33:

CLAMP_LO: 0001h

CLAMP_HI: 0FF8h

ANG_RNG_MULT: 3FE0h

The KMA215 supports the high-speed 12-bit message format H.3 in different configurations which can be programmed in the configuration register. Shorthand notations of available configurations are listed in Table 15.

Table 15. High-speed 12-bit message format H.3 configurations

Shorthand notation	SENT mode	SENT release	Clock tick time	DATA nibbles	PAUSE pulse	Serial message	Data format
SENT201x-03.0us-4dn-npp-nsp-H.3	20h	201x	3.0 µs[1]	4	no	no	H.3
SENT201x-03.0us-4dn-npp-esp-H.3	21h	201x	3.0 µs[1]	4	no	yes	H.3

[1] 2.7 µs ± 10 %.

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6.1.6 Enhanced serial data communication

Beside the normal message transmission also a slow serial data communication is realized using bit #2 and bit #3 of the STATUS nibble. The slow channel message stretches over 18 consecutive SENT frames and contains MR sensor bridge temperature, diagnostic/status information and user-programmable messages. These messages comply with the enhanced serial data message format with 8-bit message ID and 12-bit message data described in the SAE J2716 JAN2010 SENT specification.

Table 16 shows the serial message cycle that is constantly repeated when enhanced serial data communication is enabled.

Table 16. Serial message schedule

Message number in serial message cycle	8-bit message ID	Definition	Comment
1	01h	diagnostic status code	
2	23h	ambient temperature	
3	03h	channel 1/2 sensor type	
4	05h	manufacturer code	
5	06h	SENT standard revision	
6	23h	ambient temperature	
7	90h	OEM CODE #1	user-programmable data content
8	91h	OEM CODE #2	
9	92h	OEM CODE #3	
10	93h	OEM CODE #4	
11	94h	OEM CODE #5	
12	95h	OEM CODE #6	
13	96h	OEM CODE #7	
14	97h	OEM CODE #8	

Table 17. Enhanced serial messages

8-bit message ID	12-bit message		
	12-bit code	Definition	Comment
Diagnostic status code			
01h	000h	no error	
	001h	channel 1 out of range HIGH	output value above OOR_THRESHOLD_HI register
	002h	channel 1 out of range LOW	output value below OOR_THRESHOLD_LO register
	003h to 8FFh	not applicable	reserved
	900h to 9FFh	reserved	
	A00h to AFFh	ERROR BYTE (diagnostic bits of command register)	description of the ERROR_BYTE can be found in Table 18

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Table 17. Enhanced serial messages *...continued*

8-bit message ID	12-bit message		
	12-bit code	Definition	Comment
Channel 1/2 sensor type			
03h	051h	acceleration pedal position sensor 1 or acceleration pedal position sensor 2	000b
	052h	acceleration pedal position sensor 1 or secure sensor	001b
	053h	acceleration pedal position sensor 2 (redundant signal) or secure sensor	010b
	054h	throttle position sensor 1 or throttle position sensor 2	011b
	055h	throttle position sensor 1 or secure sensor	100b
	056h	throttle position sensor 2 (redundant signal) or secure sensor	101b
	059h	angle position sensor	110b default value
	05Ah	angle position sensor or secure sensor	111b
Manufacturer code			
05h	04Eh	NXP Semiconductors	fix value
SENT standard revision			
06h	003h	SAE J2716 JAN2010 SENT revision 3	default value
	004h	SAE J2716 xxx201x SENT revision 4	
Supplementary data channel #4,1			
23h	000h to 0FFh	sensor temperature value	000h: −55 °C
			:
			00Fh: −40 °C
			:
			037h: 0 °C
			:
			0D7h: 160 °C
			:
			0FFh: 200 °C
	100h to FFFh	reserved	
OEM CODE #1			
90h	12 bit	OEM CODE #1	
OEM CODE #2			
91h	12 bit	OEM CODE #2	
OEM CODE #3			
92h	12 bit	OEM CODE #3	
OEM CODE #4			
93h	12 bit	OEM CODE #4	
OEM CODE #5			
94h	12 bit	OEM CODE #5	

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Table 17. Enhanced serial messages *...continued*

8-bit message ID	12-bit message		
	12-bit code	Definition	Comment
OEM CODE #6			
95h	12 bit	OEM CODE #6	
OEM CODE #7			
96h	12 bit	OEM CODE #7	
OEM CODE #8			
97h	12 bit	OEM CODE #8	

Table 18. ERROR BYTE - data content

Bit	Symbol	Description
7 (MSB)	-	reserved
6	-	reserved
5	ERR_CORRECT	corrected single-bit error
4	BROKEN_BOND_DET	broken bond wire detected
3	-	reserved
2	-	reserved
1	-	reserved
0 (LSB)	MAGNET_LOSS_DET	magnet-loss detected

7. Diagnostic features

The KMA215 provides several diagnostic features:

7.1 CRC and EDC supervision

The KMA215 includes a supervision of the programmed data. At power-on, a CRC of the non-volatile memory is performed. Furthermore the memory is protected against bit errors. Every 16-bit data word is saved internally as a 22-bit word for this purpose. The protection logic corrects any single-bit error in a data word, while the sensor continues in normal operation mode. Furthermore the logic detects double-bit error per word and switches the output into diagnostic mode.

If there is a CRC error or double-bit error of the non-volatile memory a correct SENT configuration cannot be guaranteed anymore thus the output is set to LOW.

7.2 Magnet-loss detection

If the applied magnetic field strength is not sufficient, the KMA215 can raise a diagnostic condition. In order to enter the diagnostic mode, due to magnet-loss, enable the detection first. The magnet-loss information is then stored in the command register.

7.3 Broken bond wire detection

The broken bond wire detection circuit enables the detection of an interrupted supply or ground line of the MR sensor bridge. If there is a broken bond wire, the corresponding status bit of the command register is set.

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7.4 Out of range detection

The KMA215 can be programmed to raise a diagnostic condition if the angular data value exceeds a programmable data range. If the angular data is above the OOR_THRESHOLD_HI value, the OOR_HI bit of command register is set. If the angular data is below the OOR_THRESHOLD_LO value, the OOR_LO bit of command register is set. These bits are reset if the signal is back in the programmed range.

7.5 Prewarning indication

Bit #1 of the STATUS nibble is a prewarning indication. While the KMA215 is still in normal operation, this bit is set if one of the following conditions occurs:

- The angular data is above the OOR_THRESHOLD_HI value thus the OOR_HI bit is set
- The angular data is below the OOR_THRESHOLD_LO value thus the OOR_LO bit is set
- Optional: A single bit error of the non-volatile memory was corrected and the ERR_CORRECT bit is set. The indication of the single-bit error via prewarning indication in the SENT message can be disabled in the command register

7.6 Low voltage detection and overvoltage protection

If the supply voltage is below the switch-off threshold voltage $V_{th(off)}$ or above the overvoltage threshold $V_{th(ov)}$ voltage, the output is set to LOW. Table 19 describes the system behavior depending on the voltage range of the supply voltage.

Table 19. System behavior

Supply voltage	State	Description
0 V to ≅ 1.8 V	start-up power	high-ohmic output stage; external pull-up resistor defines output voltage
≅ 1.8 V to V_{POR}	power-on reset	The output buffer drives an active LOW. During the reset phase, all circuits are in reset and/or Power-down mode.
V_{POR} to $V_{th(on)}$ or $V_{th(off)}$	initialization	The digital core and the oscillator are active. After reset, the content of the non-volatile memory is copied into the shadow registers. The output buffer drives an active LOW.
$V_{th(on)}$ or $V_{th(off)}$ to minimum V_{DD}	functional operation	All analog circuits are active and the output is set to HIGH for at least 100 µs before SENT transmission starts. Not all parameters are within the specified limits.
Minimum V_{DD} to maximum V_{DD}	normal operation	All analog circuits are active and the measured angle is available at the digital output. All parameters are within the specified limits.
Maximum V_{DD} to $V_{th(ov)}$	functional operation	All analog circuits are active and the measured angle is available at the digital output. Not all parameters are within the specified limits.
$V_{th(ov)}$ to 16 V	overvoltage	The digital core and the oscillator are active but all other circuits are in Power-down mode. The output buffer drives an active LOW.

Table 20 describes the diagnostic behavior and the resulting error flag in the command register depending on the error case. Furthermore the duration and termination condition to enter and leave the diagnostic condition are given, respectively.

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Table 20. Diagnostic behavior

Diagnostic condition	Error bit in command register	STATUS nibble in SENT message	Output behavior	Duration	Termination condition
Low voltage[1]	LOW_VOLTAGE_DET	n/a	output set to LOW	40 μs < t < 120 μs	functional or normal operation
Overvoltage	n/a	n/a	output set to LOW	40 μs < t < 120 μs	functional or normal operation
Single-bit error	ERR_CORRECT	optional: prewarning bit if enabled	diagnostic status code message in Enhanced Serial Protocol (ESP)[2]	n/a	power-on reset[3]
Double-bit error	UNCORR_ERR	n/a	output set to LOW	n/a	power-on reset[3]
Magnet-loss	MAGNET_LOSS_DET	diagnostic bit	diagnostic status code message in ESP[2]	2.5 ms < t < 6 ms	magnet present[3]
Broken bond wire	BROKEN_BOND_DET	diagnostic bit	diagnostic status code message in ESP[2]	0.2 ms < t < 1 ms	power-on reset[3]
Signal out of range HIGH	OOR_HI	prewarning bit	diagnostic status code message in ESP[2]	2.5 ms < t < 6 ms	signal in range
Signal out of range LOW	OOR_LO	prewarning bit	diagnostic status code message in ESP[2]	2.5 ms < t < 6 ms	signal in range

[1] Supply voltage drops below functional operation range longer than 80 μs (typical value) initiate a start-up sequence including diagnostic LOW at the digital output. Supply voltage drops down to 2.3 V (typical value) shorter than 5 μs (typical value) abort the transmission of the current SENT frame. A new SENT frame is started within 400 μs after supply voltage returns to levels higher than the switch-on threshold voltage $V_{th(on)}$. If applicable, the loop counter value of the single secure sensor protocol frame is incremented by 12 to indicate this short voltage drop at the supply. If applicable, the enhanced serial message is also restarted.

[2] Enhanced serial protocol must be enabled to transmit diagnostic message.

[3] Status bit stays set in command register until power-on reset.

7.7 Power-loss behavior

If there is ground or power-loss the output becomes high-ohmic and the external pull-up resistor of the SENT receiver circuit defines the OUT/DATA voltage level.

If there is ground-loss the output goes to supply level without oscillation.

If there is power-loss there is still a connection to the supply voltage via the external pull-up resistor of the SENT receiver circuit. When the voltage between V_{DD} and GND becomes less than $V_{th(off)}$, the output goes to diagnostic LOW. At lower supply voltages, below V_{POR}, the output becomes high-ohmic and is pulled up by the external resistor.

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8. Limiting values

Table 21. Limiting values

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

Symbol	Parameter	Conditions		Min	Max	Unit
V_{DD}	supply voltage			–0.3	+16	V
V_O	output voltage			–0.3	+16	V
$V_{O(ov)}$	overvoltage output voltage	T_{amb} < 140 °C at t < 1 h	[1]	$V_{th(ov)}$	16	V
I_r	reverse current	T_{amb} < 70 °C		-	150	mA
T_{amb}	ambient temperature			–40	+160	°C
$T_{amb(pr)}$	programming ambient temperature			10	70	°C
T_{stg}	storage temperature			–40	+125	°C
Non-volatile memory						
$t_{ret(D)}$	data retention time	T_{amb} = 50 °C		17	-	year
$N_{endu(W_ER)}$	write or erase endurance	$T_{amb(pr)}$ = 70 °C		100	-	cycle

[1] Overvoltage on digital output and supply within the specified operating voltage range.

9. Recommended operating conditions

Table 22. Operating conditions

In a homogenous magnetic field.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DD}	supply voltage		[1]	4.5	5.0	5.25	V
T_{amb}	ambient temperature			–40	-	+160	°C
$T_{amb(pr)}$	programming ambient temperature			10	-	70	°C
$R_{L(pu)}$	pull-up load resistance			10	-	55	kΩ
$C_{L(ext)}$	external load capacitance		[1][2][3]	0	-	3.5	nF
			[2][4]	0	-	6.8	nF
H_{ext}	external magnetic field strength			35	-	-	kA/m

[1] Normal operation mode.

[2] Between ground and digital output.

[3] W/o internal load capacitor C_L; part of capacity is defined as input capacitor inside receiver circuit according to SENT specification; also see application information in Section 16.

[4] Command mode.

10. Thermal characteristics

Table 23. Thermal characteristics

Symbol	Parameter	Conditions	Typ	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient		145	K/W

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11. Characteristics

Table 24. Supply current

Characteristics are valid for the operating conditions, as specified in Section 9.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
I_{DD}	supply current		[1][2]	5	-	12	mA
			[3]	-	-	14	mA
$I_{DD(ripple)}$	ripple supply current	peak-to-peak value		-	1	2	mA
$I_{off(ov)}$	overvoltage switch-off current		[4]	-	-	7	mA
$I_{O(sc)}$	short-circuit output current		[5]	-	-	37	mA

[1] Normal operation excluding overvoltage and undervoltage within the specified operating supply voltage range.

[2] Without load current at the digital output.

[3] Normal operation and diagnostic mode over full voltage range up to limiting supply voltage at steady state.

[4] Diagnostic mode for a supply voltage above the overvoltage threshold voltage up to the limiting supply voltage.

[5] If OUT/DATA is shorted to GND or V_{DD}, respectively.

Table 25. Power-on reset

Characteristics are valid for the operating conditions, as specified in Section 9.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{th(on)}$	switch-on threshold voltage	SENT transmission, if $V_{DD} > V_{th(on)}$	-	4.30	4.45	V
$V_{th(off)}$	switch-off threshold voltage	digital output set to LOW, if $V_{DD} < V_{th(off)}$	3.90	4.10	-	V
V_{hys}	hysteresis voltage	$V_{hys} = V_{th(on)} - V_{th(off)}$	0.1	0.2	-	V
V_{POR}	power-on reset voltage	IC is initialized	-	3.3	3.6	V
$V_{th(ov)}$	overvoltage threshold voltage	digital output set to LOW, if $V_{DD} > V_{th(ov)}$	6.5	7.5	8.0	V
$V_{hys(ov)}$	overvoltage hysteresis voltage		0.1	0.3	-	V

Table 26. Module performance

Characteristics are valid for the operating conditions, as specified in Section 9.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
α_{res}	angle resolution		[1]	-	-	0.044	deg
α_{max}	maximum angle	programmable angular range	[2]	6	-	180	deg
α_{ref}	reference angle	programmable zero angle	[2]	0	-	180	deg
V_{OH}	HIGH-level output voltage	at 0.1 mA DC load current		4.1	-	4.7	V
V_{OL}	LOW-level output voltage	at 0.5 mA DC load current		-	-	0.5	V
$\Delta\phi_{lin}$	linearity error	temperature range −40 °C to +160 °C	[3]	−1	-	+1	deg
		temperature range −40 °C to +140 °C	[3]	−0.9	-	+0.9	deg

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Table 26. Module performance *…continued*

Characteristics are valid for the operating conditions, as specified in Section 9.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$\Delta\phi_{temp}$	temperature drift error	temperature range −40 °C to +160 °C	[1][3][4]	-	-	0.8	deg
		temperature range −40 °C to +140 °C	[1][3][4]	-	-	0.65	deg
$\Delta\phi_{temp\mid RT}$	temperature drift error at room temperature	temperature range −40 °C to +160 °C	[3][4][5]	-	-	0.6	deg
		temperature range −40 °C to +140 °C	[3][4][5]	-	-	0.5	deg
$\Delta\phi_{hys}$	hysteresis error	referred to input	[3]	-	-	0.09	deg
$\Delta\phi_{\mu lin}$	microlinearity error	referred to input	[3]	−0.1	-	+0.1	deg
$\Delta\phi_{ang}$	angular error	temperature range −40 °C to +160 °C	[3][6]	−1.2	-	+1.2	deg
		temperature range −40 °C to +140 °C	[3][6]	−1.05	-	+1.05	deg
m_{ang}	slope of angular error		[3][6]	-	-	0.04	deg/deg
ΔT_{sen}	sensor temperature accuracy	T_{amb} < 0 °C		−20	-	+20	°C
		T_{amb} = 0 °C to 160 °C		−10	-	+10	°C
$T_{sen(res)}$	sensor temperature resolution			-	1	-	°C

[1] α_{max} = 180°.

[2] In steps of resolution < 0.044°.

[3] Definition of errors is given in Section 12.

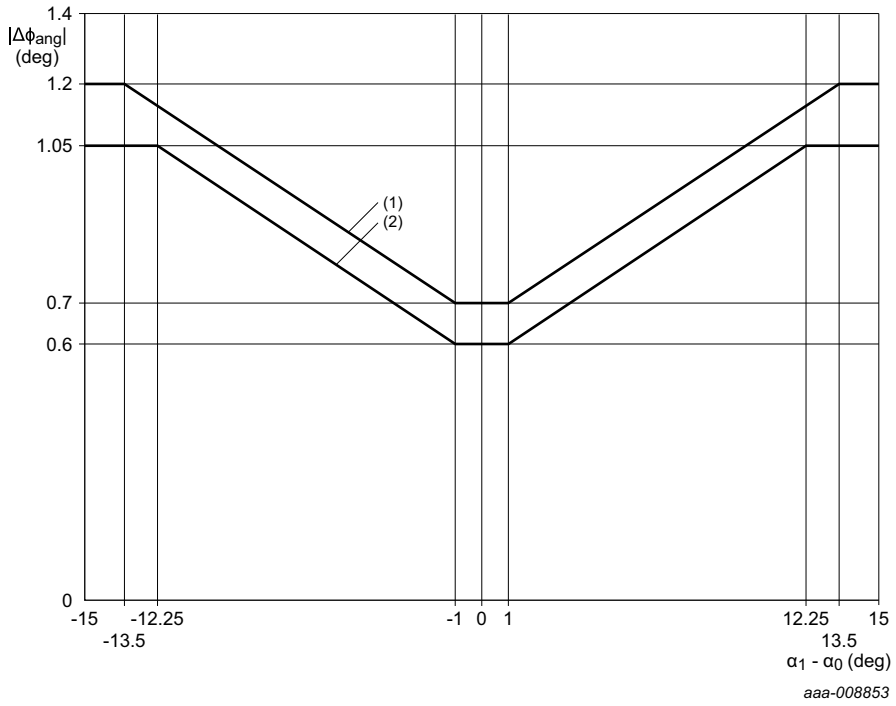
[4] Based on a 3σ standard deviation.

[5] Room temperature is given for an ambient temperature of 25 °C.

[6] Graph of angular error is shown in Figure 8.

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(1) −40 °C to +160 °C

(2) −40 °C to +140 °C

Fig 8. Envelope curve for the magnitude of angular error

Table 27. Dynamics

Characteristics are valid for the operating conditions, as specified in Section 9.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
t_{on}	turn-on time	until first falling edge of SENT frame		-	-	5	ms
f_{upd}	update frequency		[1]	1.2	-	2.2	kHz
t_s	settling time	after an ideal mechanical angle step of 45°, until first falling edge of start of the SENT frame where 90 % of the final value is reached	[2]	-	-	1.8	ms
T_{clk}	clock period	SENT clock tick time 3.0 µs	[3]	2.7	3.0	3.3	µs
		SENT clock tick time 4.5 µs		3.6	4.5	5.4	µs
		SENT clock tick time 6.0 µs		4.8	6.0	7.2	µs
		SENT clock tick time 12.0 µs		9.6	12.0	14.4	µs
		SENT clock tick time 24.0 µs		19.2	24.0	28.8	µs

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Table 27. Dynamics *…continued*

Characteristics are valid for the operating conditions, as specified in Section 9.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
t_{jit}	jitter time	variation of maximum nibble time (6σ) compared to the expected time derived from the calibration pulse				
		T_{clk} = 3.0 µs	-	-	0.1	µs
		T_{clk} = 4.5 µs	-	-	0.15	µs
		T_{clk} = 6.0 µs	-	-	0.2	µs
		T_{clk} = 12.0 µs	-	-	0.4	µs
		T_{clk} = 24.0 µs	-	-	0.8	µs
t_f	fall time	from 3.8 V to 1.1 V output level				
		SLOPE_TIME setting 6.5 µs	4.5	5.5	6.5	µs
		SLOPE_TIME setting 9.75 µs	6.75	8.25	9.75	µs
		SLOPE_TIME setting 13.0 µs	9	11	13	µs
t_r	rise time	from 1.1 V to 3.8 V output level				
		SLOPE_TIME setting 6.5 µs	-	-	18	µs
		SLOPE_TIME setting 9.75 µs	-	-	27	µs
		SLOPE_TIME setting 13.0 µs	-	-	36	µs
t_{stab}	stabilization time	output level below 1.39 V (LOW) or above 3.8 V (HIGH)				
		T_{clk} = 3.0 µs	6	-	-	µs
		T_{clk} = 4.5 µs	9	-	-	µs
		T_{clk} = 6.0 µs	12	-	-	µs
		T_{clk} = 12.0 µs	24	-	-	µs
		T_{clk}= 24.0 µs	48	-	-	µs
$t_{cmd(ent)}$	enter command mode time	after power-on	20	-	30	ms
$t_{rec(ov)}$	overvoltage recovery time	after overvoltage	-	-	4	ms

[1] SENT update rate at T_{clk} = 3.0 µs, 6 DATA nibbles and no PAUSE pulse.

[2] The mechanical angle step is not synchronized with the SENT frame. Thus the worst case settling time is extended with the length of a complete SENT frame.

[3] 12-bit fast mode; T_{clk} = 2.40 µs (minimum), 2.67 µs (typical), 3.0 µs (maximum).

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Table 28. Programming interface (OWI)

Characteristics are valid for the operating conditions, as specified in Section 9.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{IH}	HIGH-level input voltage			80	-	-	$\%V_{DD}$
V_{IL}	LOW-level input voltage			-	-	20	$\%V_{DD}$
V_{OH}	HIGH-level output voltage	I_O = 2 mA		80	-	-	$\%V_{DD}$
V_{OL}	LOW-level output voltage	I_O = 2 mA		-	-	20	$\%V_{DD}$
I_{od}	overdrive current	absolute value for overdriving the output buffer		-	-	25	mA
t_{start}	start time	LOW level before rising edge	[1]	5	-	-	µs
t_{stop}	stop time	HIGH level before falling edge		5	-	-	µs
T_{bit}	bit period	the load capacitance limits the minimum period		10	-	100	µs
ΔT_{bit}	bit period deviation	deviation between received clock and sent clock		$0.8T_{bit}$	$1T_{bit}$	$1.2T_{bit}$	µs
t_{w0}	pulse width 0			$0.175T_{bit}$	$0.25T_{bit}$	$0.375T_{bit}$	µs
t_{w1}	pulse width 1			$0.625T_{bit}$	$0.75T_{bit}$	$0.825T_{bit}$	µs
t_{to}	time-out time	communication reset guaranteed after minimum t_{to}		250	-	-	µs
$t_{tko(slv)}$	slave takeover time	duration of LOW level for slave takeover		1	-	5	µs
$t_{tko(mas)}$	master takeover time	duration of LOW level for master takeover		$0T_{bit}$	-	$0.5T_{bit}$	µs
t_{prog}	programming time	for a single memory address		20	-	-	ms

[1] To enter the command mode, the OUT/DATA pin must be kept HIGH for at least t_{to} before sending the initial command sequence.

Table 29. Internal capacitances

Characteristics are valid for the operating conditions, as specified in Section 9.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
C_{block}	blocking capacitance		[1]	50	100	150	nF
C_L	load capacitance		[1]	1.1	2.2	3.3	nF

[1] Measured at 1 MHz.

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12. Definition of errors

12.1 General

Angular measurement errors by the KMA215 result from linearity errors, temperature drift errors and hysteresis errors. Figure 9 shows the output signal of an ideal sensor, where the measured angle ϕ_{meas} corresponds ideally to the magnetic field angle α. This curve represents the angle reference line $\phi_{ref}(\alpha)$ with a slope of 0.01°/LSB.

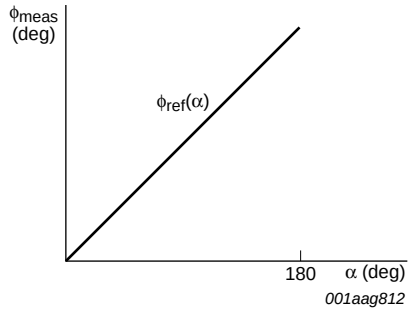


Fig 9. Definition of the reference line

The angular range is set to α_{max} = 180° for a valid definition of errors.

12.2 Hysteresis error

The device output performs a positive (clockwise) rotation and negative (counter clockwise) rotation over an angular range of 180° at a constant temperature. The maximum difference between the angles defines the hysteresis error $\Delta\phi_{hys}$.

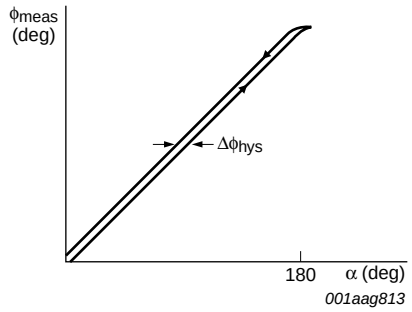


Fig 10. Definition of the hysteresis error

Equation 1 gives the mathematical description for the hysteresis value $\Delta\phi_{hys}$:

$$\Delta\phi_{hys}(\alpha) = \left|\phi_{meas}(\alpha \rightarrow 180^{\circ}) - \phi_{meas}(\alpha \rightarrow 0^{\circ})\right| \quad (1)$$

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12.3 Linearity error

The KMA215 output signal deviation from a best straight line ϕ_{BSL}, with the same slope as the reference line, is defined as linearity error. The magnetic field angle is varied at fixed temperatures for measurement of this linearity error. The output signal deviation from the best straight line at the given temperature is the linearity error $\Delta\phi_{lin}$. It is a function of the magnetic field angle α and the temperature of the device T_{amb}.

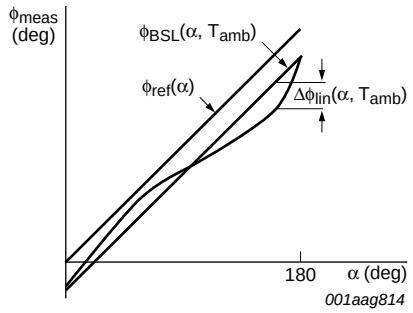


Fig 11. Definition of the linearity error

12.4 Microlinearity error

α is the magnetic field angle. If $\Delta\alpha$ = 1°, the microlinearity error $\Delta\phi_{\mu lin}$ is the device output deviation from 1°.

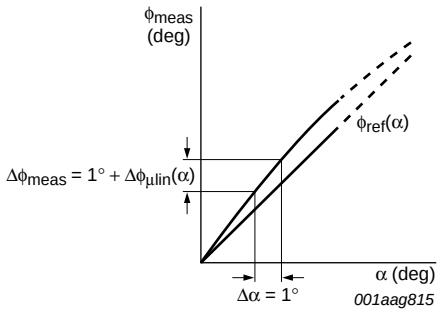


Fig 12. Definition of the microlinearity error

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12.5 Temperature drift error

The temperature drift $\Delta\phi_{temp}$ is defined as the envelope over the deviation of the angle versus the temperature range. It is considered as the pure thermal effect.

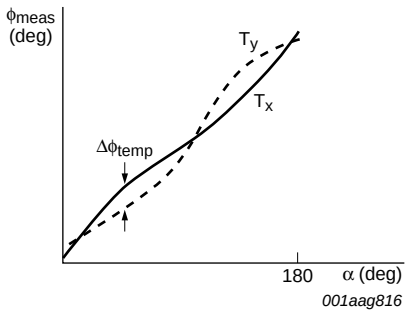


Fig 13. Definition of the temperature drift error

Equation 2 gives the mathematical description for temperature drift value $\Delta\phi_{temp}$:

$$\Delta\phi_{temp}(\alpha) = \left|\phi_{meas}(\alpha, T_x) - \phi_{meas}(\alpha, T_y)\right| \quad (2)$$

with:

T_x: temperature for maximum ϕ_{meas} at angle α

T_y: temperature for minimum ϕ_{meas} at angle α

The deviation from the value at room temperature $\Delta\phi_{temp|RT}$ describes the temperature drift of the angle, compared to the value, which the sensor provides at room temperature:

$$\Delta\phi_{temp|RT}(\alpha, T_{amb}) = \left|\phi_{meas}(\alpha, T_{amb}) - \phi_{meas}(\alpha, T_{RT})\right| \quad (3)$$

with:

T_{RT}: room temperature (25 °C)

12.6 Angular error

The angular error $\Delta\phi_{ang}$ is the difference between mechanical angle and sensor output during a movement from α_0 to α_1. Here α_0 and α_1 are arbitrary angles within the angular range. The customer initially programs the angle measurement at α_0 at room temperature and zero hour upon production. The angle measurement at α_1 is made at any temperature within the ambient temperature range:

$$\Delta\phi_{ang} = (\phi_{meas}(\alpha_1, T_{amb}) - \phi_{meas}(\alpha_0, T_{RT})) - (\alpha_1 - \alpha_0) \quad (4)$$

with:

α_0, α_1: arbitrary mechanical angles within the angular range

$\phi_{meas}(\alpha_0, T_{RT})$: programmed angle at α_0, T_{RT} = 25 °C and zero hour upon production

$\phi_{meas}(\alpha_1, T_{amb})$: the sensor measures angle at α_1 and any temperature within T_{amb}

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This error comprises non-linearity and temperature drift related to the room temperature.

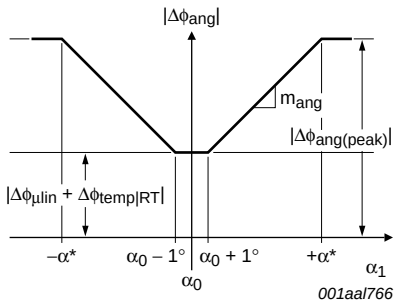


Fig 14. Envelope curve for the magnitude of angular error

Figure 14 shows the envelope curve for the magnitude of angular error $|\Delta\phi_{ang}|$ versus α_1 for all angles α_0 and all temperatures T_{amb} within the ambient temperature range. If α_1 is in the range of ±1° around α_0, $|\Delta\phi_{ang}|$ has its minimum. Here only the microlinearity error $\Delta\phi_{\mu lin}$ and the temperature drift related to the room temperature $|\Delta\phi_{temp|RT}|$ occurs. If α_1 deviates from α_0 by more than 1° in either direction, $|\Delta\phi_{ang}|$ can increase. Slope m_{ang} defines the gradient.

Equation 5 to Equation 8 express the angular error:

for $|\alpha_1 - \alpha_0| \leq 1°$

$$\left|\Delta\phi_{ang}\right| = \left|\Delta\phi_{\mu lin} + \Delta\phi_{temp|RT}\right| \quad (5)$$

for $1° < |\alpha_1 - \alpha_0| < \alpha^*$

$$\left|\Delta\phi_{ang}\right| = \left|\Delta\phi_{\mu lin} + \Delta\phi_{temp|RT}\right| + m_{ang} \times (\left|\alpha_1 - \alpha_0\right| - 1°) \quad (6)$$

for $|\alpha_1 - \alpha_0| \geq \alpha^*$

$$\left|\Delta\phi_{ang}\right| = \sqrt{(\Delta\phi_{lin})^2 + (\Delta\phi_{temp|RT})^2} \quad (7)$$

with:

$$\alpha^* = \frac{\left|\Delta\phi_{ang(peak)}\right| - \left|\Delta\phi_{\mu lin} + \Delta\phi_{temp|RT}\right|}{m_{ang}} + \alpha_0 + 1° \quad (8)$$

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13. Programming

13.1 General description

The KMA215 provides an OWI to enable programming of the device which uses pin OUT/DATA bidirectionally.

In general the device runs in digital output mode, the normal operation mode. The embedded programming data configures this mode. After a power-on reset once time t_{on} has elapsed, it starts. In this mode, the magnetic field angle is repeatedly transmitted with SENT protocol.

A second mode, the command mode enables programming. In this mode, the customer can adjust all required parameters (for example zero angle, angular range, SENT configurations) to meet the application requirements. The data is stored in the non-volatile memory. After changing the contents of the memory, recalculate and write the checksum (see Section 13.4).

In order to enter the command mode, keep OUT/DATA pin HIGH for at least t_{to} and send a specific command sequence after a power-on reset and during the time slot $t_{cmd(ent)}$. The external source used to send the command sequence must overdrive the output buffer of the KMA215. In doing so, it provides current I_{od}.

During communication, the KMA215 is always the slave and the external programming hardware is always the master. Figure 15 illustrates the structure of the OWI data format.

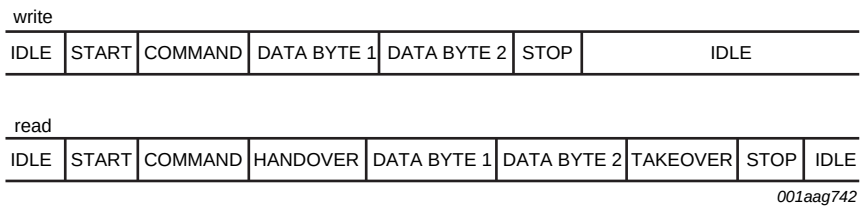


Fig 15. OWI data format

The master provides the start condition, which is a rising edge after a LOW level. Then a command byte which can be either a read or a write command is sent. Depending on the command, the master or the slave has to send the data immediately after the command sequence. If there is a read command, an additional handover or takeover bit is inserted before and after the data bytes. The master must close each communication with a stop condition. If the slave does not receive a rising edge for a time longer than t_{to}, a time-out condition occurs. The bus is reset to the idle state and waits for a start condition and a new command. This behavior can be used to synchronize the device regardless of the previous state.

All communication is based on this structure (see Figure 15), even for entering the command mode. In this case, the write command 94h and the signature are required. The customer can access the non-volatile memory, CTRL1, TESTCTRL0 and SIGNATURE registers (described in Section 13.5). Only a power-on reset leaves the command mode. A more detailed description of the programming is given in the next sections.

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13.2 Timing characteristics

As described in the previous section, a start and stop condition is necessary for communication. The LOW-level duration before the rising edge of the start condition is defined as t_{start}. The HIGH-level duration after the rising edge of the stop condition is defined as t_{stop}. These parameters, together with all other timing characteristics are shown in Table 28.

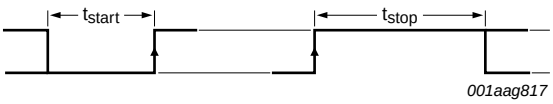


Fig 16. OWI start and stop condition

Figure 17 shows the coding of a single bit with a HIGH level of V_{IH} and a LOW level of V_{IL}. Here the pulse width t_{w1} or t_{w0} represents a logic 1 or a logic 0 of a full bit period T_{bit}, respectively.

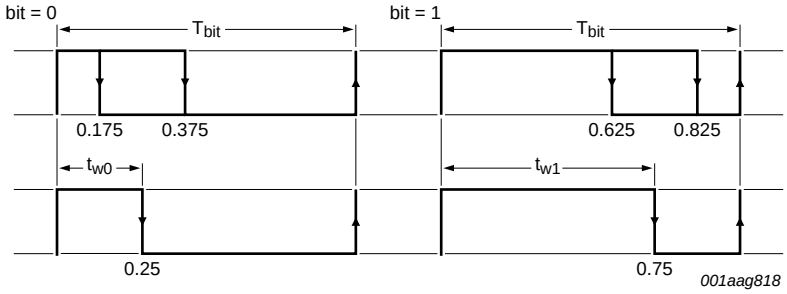


Fig 17. OWI timing

13.3 Sending and receiving data

The master has to control the communication during sending or receiving data. The command byte defines the region, address and type of command the master requests. Read commands need an additional handover or takeover bit. Insert this bit before and after the two data bytes (see Figure 15). However the OWI is a serial data transmission, whereas the Most Significant Byte (MSB) send at first.

Table 30. Format of a command byte

7	6	5	4	3	2	1	0
CMD7	CMD6	CMD5	CMD4	CMD3	CMD2	CMD1	CMD0

Table 31. Command byte bit description

Bit	Symbol	Description
7 to 5	CMD[7:5]	region bits
		000 = 16-bit non-volatile memory
		001 to 011 = reserved
		100 = 16-bit register
		101 to 111 = reserved

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Table 31. Command byte bit description *...continued*

Bit	Symbol	Description
4 to 1	CMD[4:1]	address bits
0	CMD0	read/write
		0 = write
		1 = read

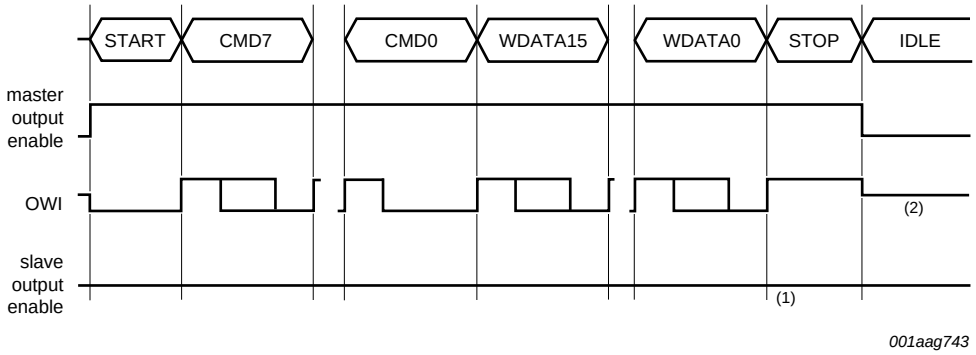
A more detailed description of all customer accessible registers is given in Section 13.5. Both default value and the complete command including the address and write or read request are also listed.

13.3.1 Write access

To write data to the non-volatile memory, perform the following procedure:

1. Start condition: The master drives a rising edge after a LOW level
2. Command: The master sends a write command, that is the last bit is not set (CMD0 = 0)
3. Data: The master sends two data bytes
4. Stop condition: The master drives a rising edge after a LOW level

Figure 18 shows the write access of the digital interface. The signal OWI represents the data on the bus from the master or slave. The signals: master output enable and slave output enable indicate when the master or the slave output is enabled or disabled, respectively.



(1) Missing rising edges generate a time-out condition and the written data is ignored.

(2) If the master does not drive the bus, the bus-pull defines the bus.

Fig 18. OWI write access

Note: As already mentioned in Section 13.1, use the write procedure to enter the command mode. If command mode is not entered, communication is not possible and the sensor operates in normal operation mode. After changing an address, the time t_{prog} must elapse before changing another address. After changing the content of the non-volatile memory, recalculate and write the checksum (see Section 13.4).

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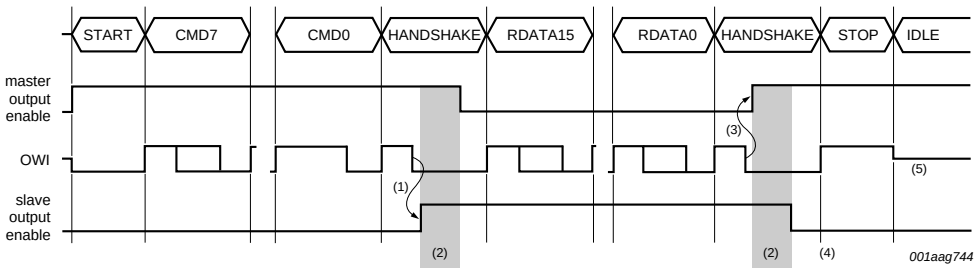
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13.3.2 Read access

To read data from the sensor, perform the following procedure:

1. Start condition: The master drives a rising edge after a LOW level
2. Command: The master sends a read command (CMD0 = 1)
3. Handover: The master sends a handover bit, that is a logic 0 and disables the output after a three-quarter bit period
4. Takeover: The slave drives a LOW level after the falling edge for $t_{tko(slv)}$
5. Data: The slave sends two data bytes
6. Handover: The slave sends a handover bit, that is a logic 0 and disables the output after a three-quarter bit period
7. Takeover: The master drives a LOW level after the falling edge for $t_{tko(mas)}$
8. Stop condition: The master drives a rising edge after a LOW level

Figure 19 shows the read access of the digital interface. The signal OWI represents the data on the bus from the master or slave. The signals: master output enable and slave output enable indicate when the master or the slave output is enabled or disabled, respectively.



(1) Duration of LOW level for slave takeover $t_{tko(slv)}$.

(2) The master output enable and the slave output enable overlap, because both drive a LOW level. However this behavior ensures the independency from having a pull-up or pull-down on the bus. In addition, it improves the EMC robustness, because all levels are actively driven.

(3) Duration of LOW level for master takeover $t_{tko(mas)}$.

(4) If the master does not take over, the pull-up generates the stop condition. Otherwise a time-out is generated if there is a pull-down and the slave waits for a rising edge as start condition.

(5) If the master does not drive the bus, the bus-pull defines the bus.

Fig 19. OWI read access

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13.3.3 Entering the command mode

After a power-on reset, the sensor provides a time slot $t_{cmd(ent)}$ for entering the command mode. Keep OUT/DATA pin HIGH for at least t_{to} and send a specific command sequence (see Figure 20). If command mode is not entered, the sensor starts in the normal operation mode.

During the command mode sequence, the digital SENT output is enabled. The external programming hardware has to overdrive the output with current I_{od}. If command mode is activated, the digital SENT output is disabled and pin OUT/DATA operates as a digital bidirectional programming interface.

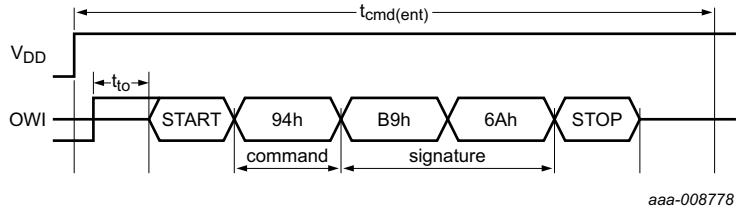


Fig 20. OWI command mode procedure

13.4 Cyclic redundancy check

As already mentioned in Section 7, there is an 8-bit checksum for the non-volatile memory data. To calculate this value, the MSB of the memory data word generates the CRC at first over all corresponding addresses in increasing order.

Read out all addresses from 0h to Eh for calculating the checksum. The Least Significant Byte (LSB) of address Eh contains the previous checksum. Overwrite the value with 0h before starting the checksum calculation.

The generator polynomial for the calculation of the checksum is:

$$G(x) = x^8 + x^2 + x + 1 \quad (9)$$

With a start value of FFh and the data bits are XOR at the x^8 point.

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13.4.1 Software example in C

```
#include <stdio.h.>

int generate_crc(unsigned int data[], int arr_length)
{
     // generator polynomial
     const int gpoly = 0x107;                  // initial value of checksum
     int crc = 0xFF;
     // print data values and calculate CRC
     printf("\nAddress\tValue\n");
     for (int index = 0; index <= arr_length-1; index++) {
          printf("0x%1X\t0x%04X\n", index, data[index]);
          for (int bitnr = 15; bitnr >= 0; bitnr--) {
               crc <<= 1;
               crc |= (int) ((data[index] & (1u<<bitnr))>>bitnr);
               if (crc & 0x100) crc ^= gpoly;
          }
     }
     // print calculated checksum
     printf("\nCalculated Checksum: 0x%02X\n", crc);
     return crc;
}
int main_crc(void)
{
     // data array for checksum calculation
     // 8 LSB are CRC, fill with 0
     unsigned int data[] = {0x0818, 0x0000, 0x0800,
                            0x0FFF, 0x0000, 0x0FFF,
                            0x0000, 0x0000, 0x0000,
                            0x0000, 0x0000, 0x0000,
                            0x0000, 0x0FFF, 0x0000};
     // determine size of data array
     int arr_length = sizeof(data) / sizeof(unsigned int);
     // calculate checksum
     generate_crc(data, arr_length);
     return 1;
}
```

This example refers to the default register values. The checksum of this data sequence is DBh.

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13.5 Registers

13.5.1 Command registers

To enter the command mode, write the signature given in Table 32 into the specific register using the OWI. Do this procedure as described in Section 13.3.3, with a write command, the signature follows it, but after a power-on reset and not later than $t_{cmd(ent)}$.

Table 32. Command registers

Command write/read	Register	Bit	Access	Field	Description
82h/83h	CTRL1	15	R	IN_DIAG_MODE	shows if there is a diagnostic condition present; the setting of register field FORCE_DIAG_OFF does not affect this bit
		14	W	FORCE_DIAG_OFF	force diagnostic mode off; default: 0b
		13	-	-	reserved
		12	R	LOW_VOLTAGE_DET	low voltage condition detected
		11 to 9	-	-	reserved
		8	R	ERR_CORRECT	single-bit error of non-volatile memory has been detected and corrected; updated every memory readout; bit remains set until the diagnostic condition disappears and a power-on reset is done
		7	R	UNCORR_ERR	double-bit error of non-volatile memory has been detected; updated every memory readout; bit remains set until the diagnostic condition disappears and a power-on reset is done
		6	R	MAGNET_LOSS_DET	magnet-loss detected; bit remains set until the diagnostic condition disappears and a power-on reset is done; enable magnet-loss detection for raising diagnostic condition
		5	R	BROKEN_BOND_DET	broken bond wire detected; bit remains set until the diagnostic condition disappears and a power-on reset is done
		4	R	CRC_BAD	checksum error detected; updated every start-up
		3	R	OOR_HI	angular value above OOR_THRESHOLD_HI threshold value
		2	R	OOR_LO	angular value below OOR_THRESHOLD_LO threshold value
		1 and 0	-	-	reserved
94h/-	SIGNATURE	15 to 0	W	SIGNATURE	to enter command mode, write signature B96Ah within $t_{cmd(ent)}$; for more details, see Section 13.3.3

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13.5.2 Non-volatile memory registers

The device includes several internal registers which are used for customization and identification.

The initial signature allows read access to all areas but only write access to customer registers. Write accesses to reserved areas are ignored. Since these registers are implemented as non-volatile memory cells, writing to the registers needs a specific time t_{prog} after each write access to complete.

As there is no check for the programming time, make sure that no other accesses to the non-volatile memory are made during the programming cycle. Do not address the non-volatile memory during the time t_{prog}.

Note: To calculate the checksum, read out and consult register addresses 0h to Eh.

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Table 33. Non-volatile memory registers

Address	Command write/read	Register	Bit	Description	MSB/LSB Default[1]
0h	00h/01h	SENT_CONF	15 to 9	SENT_MODE; SENT modes; see Table 8, Table 12 and Table 15	08h/18h (04h)
			8	SLOPE_RATIO; ratio between falling and rising slope of SENT output **0b —** 7/5 **1b —** 1/1	(0b)
			7 and 6	SLOPE_TIME; slope time of SENT output **00b —** 6.5 µs **01b —** 9.75 µs **10b —** 9.75 µs **11b —** 13.0 µs	(00b)
			5	SLOPE_DIR; slope of angular characteristic **0b —** normal **1b —** inverted	(0b)
			4 to 2	SENSOR_TYPE; channel 1/2 sensor type that is sent in the enhanced serial message ID 03h; see Table 17 **000b —** sensor type 051h **001b —** sensor type 052h **010b —** sensor type 053h **011b —** sensor type 054h **100b —** sensor type 055h **101b —** sensor type 056h **110b —** sensor type 059h **111b —** sensor type 05Ah	(110b)
			1	SENT_REV; SENT revision that is sent in the enhanced serial message ID 06h; see Table 17 **0b —** SAE J2716 JAN2010 SENT revision 3 **1b —** SAE J2716 xxx201x SENT revision 4	(0b)
			0	SENT_LEGACY_CRC **0b —** recommended CRC compliant to SAE J2716 JAN2010 SENT revision 3 and future **1b —** legacy CRC compliant to SAE J2716 FEB2008 SENT revision 2 and earlier	(0b)
1h	02h/03h	ZERO_ANGLE	15 to 0	mechanical zero degree position; see Table 34	00h/00h
2h	04h/05h	ANG_RNG_MULT_MSB	15 to 0	most significant bits of the angular range multiplicator; see Table 37	08h/00h[2]

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Table 33. Non-volatile memory registers *...continued*

Address	Command write/read	Register	Bit	Description	MSB/LSB Default[1]
3h	06h/07h	ANG_RNG_MULT_LSB	15 to 13	ANG_RNG_MULT_LSB; least significant bits of the angular range multiplicator	0Fh/FFh (000b)[2]
			12	BROKEN_BONDWIRE; broken bond wire detection **0b —** enabled **1b —** disabled	(0b)
			11 to 0	CLAMP_SW_ANGLE; when the measured angle is bigger than CLAMP_SW_ANGLE the output switches to CLAMP_LO for a positive slope; see Table 39	(FFFh)[2]
4h	08h/09h	CLAMP_LO	15 to 12	undefined[3]	00h/00h
			11 to 0	lower clamping level; see Table 35	(000h)[2]
5h	0Ah/0Bh	CLAMP_HI	15 to 12	undefined[3]	0Fh/FFh
			11 to 0	upper clamping level; see Table 36	(FFFh)[2]
6h	0Ch/0Dh	OEM CODE #7 MSB	15 to 12	user programmable code that is sent in the enhanced serial message ID 96h; see Table 17	00h/00h (0h)
		OEM CODE #1	11 to 0	user programmable code that is sent in the enhanced serial message ID 90h; see Table 17	(000h)
7h	0Eh/0Fh	OEM CODE #7	15 to 12	user programmable code that is sent in the enhanced serial message ID 96h; see Table 17	00h/00h (0h)
		OEM CODE #2	11 to 0	user programmable code that is sent in the enhanced serial message ID 91h; see Table 17	(000h)
8h	10h/11h	OEM CODE #7 LSB	15 to 12	user programmable code that is sent in the enhanced serial message ID 96h; see Table 17	00h/00h (0h)
		OEM CODE #3	11 to 0	user programmable code that is sent in the enhanced serial message ID 92h; see Table 17	(000h)
9h	12h/13h	OEM CODE #8 MSB	15 to 12	user programmable code that is sent in the enhanced serial message ID 97h; see Table 17	00h/00h (0h)
		OEM CODE #4	11 to 0	user programmable code that is sent in the enhanced serial message ID 93h; see Table 17	(000h)
Ah	14h/15h	OEM CODE #8	15 to 12	user programmable code that is sent in the enhanced serial message ID 97h; see Table 17	00h/00h (0h)
		OEM CODE #5	11 to 0	user programmable code that is sent in the enhanced serial message ID 94h; see Table 17	(000h)
Bh	16h/17h	OEM CODE #8 LSB	15 to 12	user programmable code that is sent in the enhanced serial message ID 97h; see Table 17	00h/00h (0h)
		OEM CODE #6	11 to 0	user programmable code that is sent in the enhanced serial message ID 95h; see Table 17	(000h)
Ch	18h/19h	OOR_THRESHOLD_LO	15 to 12	undefined[3]	00h/00h
			11 to 0	out of range threshold LOW value	(000h)

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Table 33. Non-volatile memory registers *...continued*

Address	Command write/read	Register	Bit	Description	MSB/LSB Default[1]
Dh	1Ah/1Bh	OOR_THRESHOLD_HI	15	undefined[3]	0Fh/FFh
			14	SINGLE_BIT_ERROR_PREWARNING **0b —** enabled **1b —** disabled	(0b)
			13 and 12	undefined[3]	-
			11 to 0	OOR_THRESHOLD_HI; out of range threshold HIGH value	(FFFh)
Eh	1Ch/1Dh	CTRL_CUST	15	LOCK; irreversible write protection of non-volatile memory **1b —** enabled	00h/[4] (0b)
			14 to 8	MAGNET_LOSS; magnet-loss detection **00h —** disabled **49h —** enabled	(00h)
			7 to 0	CRC; checksum (see Section 13.4)	(00h)

[1] Values represent the default 16-bit value of the memory address while the values in parenthesis represent the default register value.

[2] Settings for single secure sensor mode A.3: ANG_RNG_MULT: 40h/00h, CLAMP_SW_ANGLE: 0Fh/FFh, CLAMP_LO: 00h/01h, CLAMP_HI: 0Fh/FFh

Settings for dual throttle position sensor format A.1 180° full angular range: ANG_RNG_MULT: 3Fh/FFh, CLAMP_SW_ANGLE: 0Fh/FFh, CLAMP_LO: 00h/01h, CLAMP_HI: 0Fh/FEh. In the dual throttle position sensor format A.1 some of the output codes are reserved for diagnostic purposes that limits the output range to 4094 codes. The range must be limited by setting CLAMP_LO to 1, CLAMP_HI to 4094 and ANG_RNG_MULT = (CLAMP_HI − CLAMP_LO)/4095 set to 3Fh/FFh.

Settings for high-speed 12-bit fast mode H.3 180° full angular range: ANG_RNG_MULT: 3FE0h, CLAMP_SW_ANGLE: 0Fh/FFh, CLAMP_LO: 00h/01h, CLAMP_HI: 0Fh/F8h. In the high-speed 12-bit SENT mode H.3 some of the output codes are reserved for diagnostic purposes that limits the output range to 4088 codes. The range must be limited by setting CLAMP_LO to 1, CLAMP_HI to 4088 and ANG_RNG_MULT = (CLAMP_HI − CLAMP_LO)/4095 set to 3Fh/E0h.

[3] Undefined; write as zero for default.

[4] Variable and individual for each device.

Table 34. ZERO_ANGLE - mechanical zero degree position (address 8h) bit allocation

Data format: unsigned fixed point; resolution: 2^{-16}.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}	2^{-8}	2^{-9}	2^{-10}	2^{-11}	2^{-12}	2^{-13}	2^{-14}	2^{-15}	2^{-16}

Mechanical angular range 0000h = 0° to FFFFh = 180° − 1 LSB.

Examples:

- Mechanical zero angle 0° = 0000h
- Mechanical zero angle 10° = 0E38h
- Mechanical zero angle 45° = 4000h

Table 35. CLAMP_LO - lower clamping level output data (address 4h) bit allocation

Data format: unsigned integer; resolution: 2^{0}.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	U[1]	U[1]	U[1]	U[1]	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

[1] Undefined; write as zero for default; returns any value when read.

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Examples:

- 80° = 1820
- 40° = 910
- 0° = 0

Table 36. CLAMP_HI - upper clamping level output data (address 5h) bit allocation

Data format: unsigned integer; resolution: 2^0.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	U[1]	U[1]	U[1]	U[1]	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

[1] Undefined; write as zero for default; returns any value when read.

Examples:

- 180° = 4095
- 140° = 3185
- 100° = 2275

Table 37. ANG_RNG_MULT_MSB - most significant bits of angular range multiplicator (address 2h) bit allocation

Data format: unsigned fixed point; resolution: 2^{-1}.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}	2^{-8}	2^{-9}	2^{-10}	2^{-11}

Table 38. ANG_RNG_MULT_LSB - least significant bits of angular range multiplicator (address 3h) bit allocation

Data format: unsigned fixed point; resolution: 2^{-14}.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	2^{-12}	2^{-13}	2^{-14}	[1]	CLAMP_SW_ANG											

[1] BROKEN_BONDWIRE

$$ANG_RNG_MULT = \frac{CLAMP_HI - CLAMP_LO}{4095} \times \frac{180°}{ANGULAR_RANGE} \quad (10)$$

Example:

- Reserved data range for dual throttle position sensor format A.1 180° full angular range: $ANG_RNG_MULT = \frac{4094 - 1}{4095} \times \frac{180°}{180°} = \dot{0}9995115995 \rightarrow 3FFFh$
- Reserved data range for SENT 12-bit fast mode 180° full angular range: $ANG_RNG_MULT = \frac{4088 - 1}{4095} \times \frac{180°}{180°} = 0.998046398 \rightarrow 3FE0h$

Table 39. CLAMP_SW_ANGLE - clamp switch angle (address 3h) bit allocation

Data format: unsigned integer; resolution: 2^0.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value	ANG_RNG_MULT_LSB			[1]	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

[1] BROKEN_BONDWIRE

Mechanical angular range 000h = 0° to FFFh = 180° − 1 LSB.

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$$CLAMP_SW_ANGLE = \frac{1}{2} \times \left(1 + \frac{CLAMP_HI - CLAMP_LO}{4095} \times \frac{1}{ANG_RNG_MULT}\right) \quad (11)$$

If the magnetic field angle is larger than the CLAMP_SW_ANGLE, the output switches to CLAMP_LO for a positive slope. Program the value of CLAMP_SW_ANGLE, which can be calculated from other non-volatile memory constants.

14. Electromagnetic compatibility

EMC is verified in an independent and certified test laboratory.

14.1 Emission (CISPR 25)

Tests according to CISPR 25 were fulfilled.

14.1.1 Conducted radio disturbance

Test of the device according to CISPR 25, third edition (2008-03), Chapter 6.2.

Classification level: 5.

14.1.2 Radiated radio disturbance

Test of the device according to CISPR 25, third edition (2008-03), Chapter 6.4.

Classification level: 5 (without addition of 6 dB in FM band).

14.2 Radiated disturbances (ISO 11452-1 third edition (2005-02), ISO 11452-2, ISO 11452-4 and ISO 11452-5)

The common understanding of the requested function is that an effect is tolerated as described in Table 40 during the disturbance. The reachable values are setup-dependent and differ from the final application.

Table 40. Failure condition for radiated disturbances

Parameter	Comment	Max	Unit
Variation of angular value	value measured relative to the output at test start	±1.8	deg
SENT sequence	allowed sequentially failing frames	2	frame
SENT transmission	allowed failing frames within 100 following frames	3	frame

14.2.1 Absorber lined shielded enclosure

Tests according to ISO 11452-2, second edition (2004-11), were fulfilled.

Test level: 200 V/m; extended up to 4 GHz.

State: A.

14.2.2 Bulk-current injection

Tests according to ISO 11452-4, third edition (2005-04), were fulfilled.

Test level: 200 mA.

State: A.

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14.2.3 Strip line

Tests according to ISO 11452-5, second edition (2002-04), were fulfilled.

Test level: 200 V/m; extended up to 1 GHz.

State: A.

14.2.4 Immunity against mobile phones

Tests according to ISO 11452-2, second edition (2004-11), were fulfilled.

State: A.

Definition of Global System for Mobile Communications (GSM) signal:

- Pulse modulation: per GSM specification (217 Hz; 12.5 % duty cycle)
- Modulation grade: ≥ 60 dB
- Sweep: linear 800 MHz to 3 GHz (duration 10 s at 890 MHz, 940 MHz and 1.8 GHz band)
- Antenna polarization: vertical, horizontal
- Field strength: 200 V/m during on-time [calibration in Continuous Wave (CW)]

In deviation of ISO 11452-2, a GSM signal instead of an AM signal was used.

14.3 Electrical transient transmission by capacitive coupling [ISO 7637-3, second edition (2007-07)]

The common understanding of the requested function is that an effect is tolerated as described in Table 40 during the disturbance.

Tests according to ISO 7637-3 were fulfilled.

Test level: IV (for 12 V electrical system).

Classification level: A for positive and negative pulses assuming a start of a new SENT frame within 400 μs is allowed otherwise B.

14.4 Electrical transient transmission by inductive coupling [ISO 7637-3, second edition (2007-07)]

The common understanding of the requested function is that an effect is tolerated as described in Table 40 during the disturbance.

Tests according to ISO 7637-3 were fulfilled.

Test level: IV (for 12 V electrical system).

Classification level: A for positive and negative pulses assuming a start of a new SENT frame within 400 μs is allowed otherwise B.

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15. ElectroStatic Discharge (ESD)

15.1 Human body model (AEC-Q100-002)

The KMA215 is protected up to 8 kV, according to the human body model at 100 pF and 1.5 kΩ. This protection is ensured at all external pins (OUT/DATA, V_{DD} and GND).

Classification level: H3B.

Furthermore, all interconnects (pins between package head and package body) must not be damaged at 2 kV.

Classification level: H2.

15.2 Human metal model (ANSI/ESD SP5.6-2009)

The KMA215 is protected up to 8 kV, according to the human metal model at 150 pF and 330 Ω inside the ESD gun. This test utilizes waveforms of the IEC 61000-4-2 standard on component level. Apply the contact discharge in an unsupplied state at pins OUT/DATA and V_{DD} referred to GND which is connected directly to the ground plane.

Test setup: A.

Test level: 5.

15.3 Machine model (AEC-Q100-003)

The KMA215 is protected up to 400 V, according to the machine model. This protection is ensured at all external pins (OUT/DATA, V_{DD} and GND).

Classification level: M4.

Furthermore, all interconnects (pins between package head and package body) must not be damaged at 200 V.

Classification level: M3.

All pins have latch-up protection.

15.4 Charged-device model (AEC-Q100-011)

The KMA215 is protected up to 750 V, according to the charged-device model. This protection is ensured at all external pins (OUT/DATA, V_{DD} and GND).

Classification level: C4.

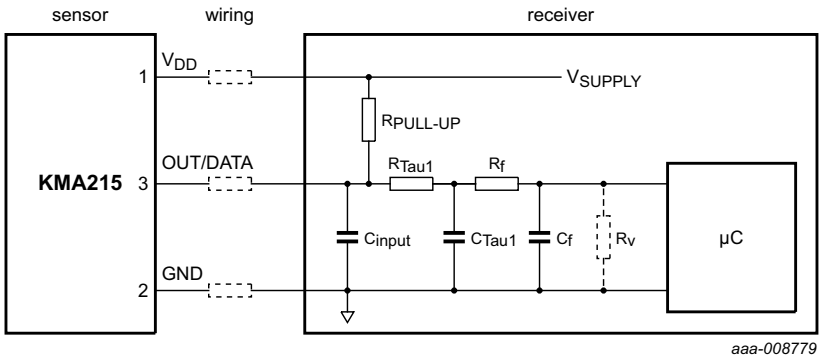
Furthermore, all interconnects (pins between package head and package body) is protected up to at 500 V.

Classification level: C3B.

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16. Application information



KMA215 with receiver load according to figure 6.3-2 (recommended SENT system interface circuit topology J2716) of SAE J2716 JAN2010 SENT without additional external components near KMA215

Fig 21. Application diagram of KMA215

17. Test information

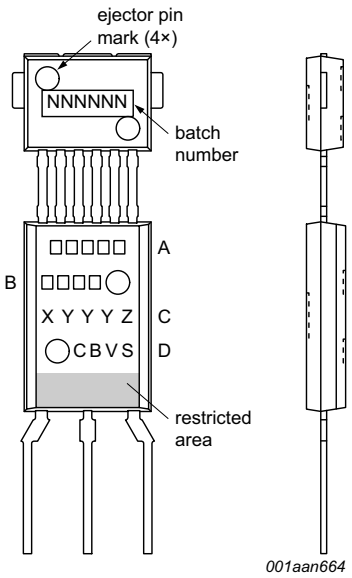
17.1 Quality information

This product has been qualified in accordance with the Automotive Electronics Council (AEC) standard *Q100 Rev-G - Failure mechanism based stress test qualification for integrated circuits*, and is suitable for use in automotive applications.

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18. Marking



Marking paint: laser

Code: see drawing

Type face: DIN 1451 condensed type

Letter height: 0.8 mm

Line spacing: 0.25 mm

Crossing of lines not allowed

A: leading letters of type number (5 characters max.)

B: number and attached letters of type number (6 characters max.)

C: day code/date code

D: additional marking

C: capacitor type (T: TDK; M: Murata)

B: burn-in information (0: without burn-in; 1: with burn-in)

V: IC version (1, 2, 3, ...)

S: development status (X: development; C: validated; blank: released)

Line A and line C to be marked in centered position

Date code: X YYY Z

X: product manufacturing code; m for manufacturing Manila

Day code: X YYY Z

X: ---

Y: day of year

Z: year of production (last figure)

Fig 22. Marking

19. Terminals

Lead frame material: CuZr with 99.9 % Cu and 0.1 % Zr.

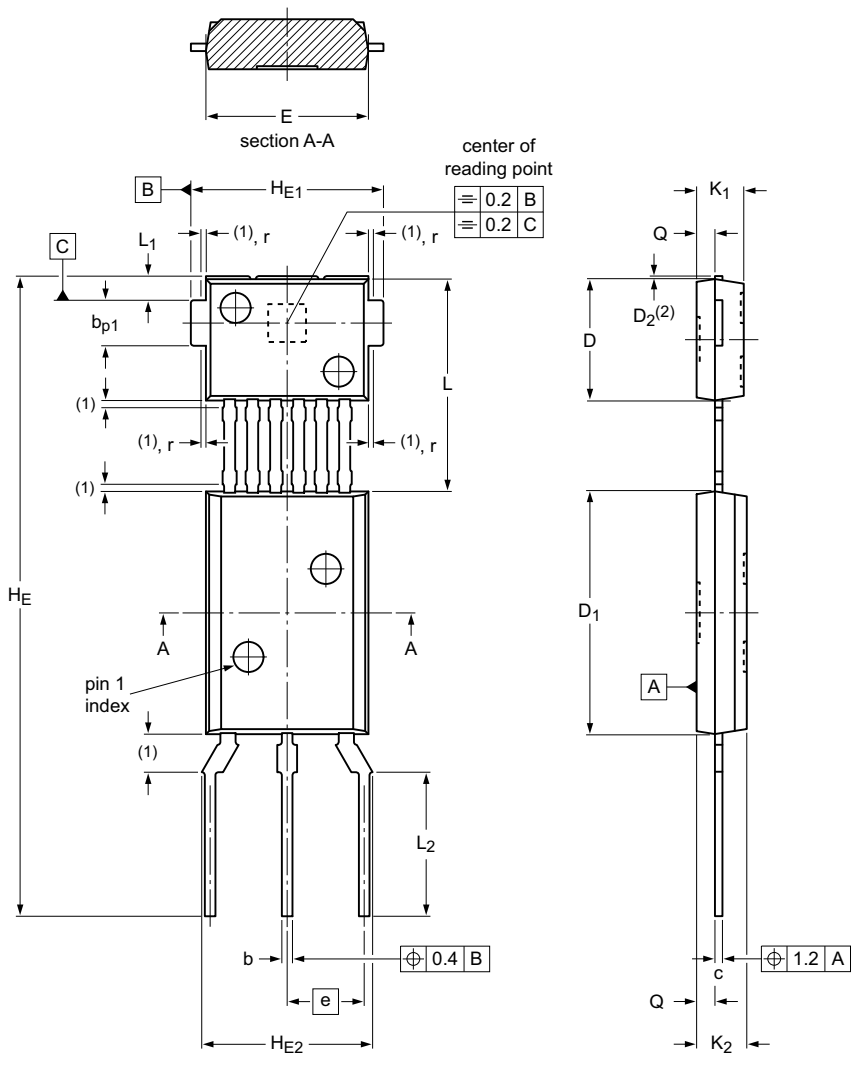
Lead finish: matt tin; thickness 7 μm to 11 μm.

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20. Package outline

Plastic single-ended multi-chip package;
6 interconnections; 3 in-line leads **SOT1288-2**



Dimensions

Unit		b	b_{p1}	c	D	D_1	D_2	E	e	H_E	H_{E1}	H_{E2}	K_1	K_2	L	L_1	L_2	Q	r
mm	max	0.41	1.57	0.30	4.1	8.1	0.15	5.45	2.54	21.4	6.42	5.85	1.65	1.75	7.1	0.85		0.65	0.17
	nom																		
	min	0.34	1.47	0.24	3.9	7.9	0.05	5.25		21.0	6.32		1.45	1.55	6.9	0.75	4.75	0.55	

Note
1. Terminal within this zone are uncontrolled to allow for flow of plastic between and besides the leads/fins.
2. A Cpk of 1.67 cannot be safeguarded by production in-line tests, due to limited accuracy for the measurement of this dimension.

sot1288-2_po

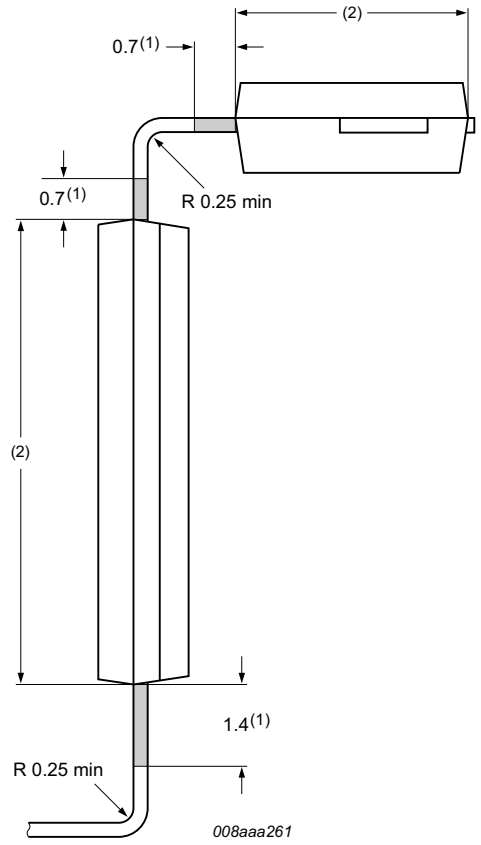
Outline version	References				European projection	Issue date
	IEC	JEDEC	JEITA			
SOT1288-2						~~13-06-24~~ 13-08-05

Fig 23. Package outline SOT1288-2

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21. Handling information



Dimensions in mm

(1) No bending allowed.

(2) Plastic body and interface plastic body - leads: application of bending forces not allowed.

Fig 24. Bending recommendation

22. Solderability information

The solderability qualification is according to AEC-Q100 Rev-G. Recommended soldering process for leaded devices is wave soldering. The maximum soldering temperature is 260 °C for maximum 5 s. Device terminals are compatible with laser and electrical welding. The device is reflow capable.

23. Revision history

Table 41. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
KMA215 v.1	20140224	Product data sheet	-	-

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24. Legal information

24.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

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