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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

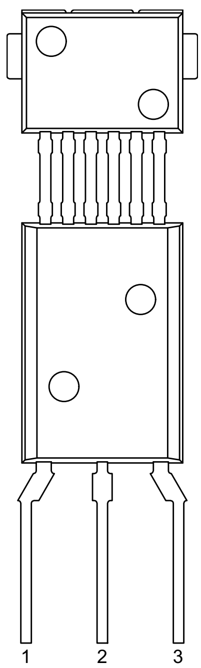
1.2.1 Extract of SENT modes (shorthand notation)

- 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

4. Functional diagram

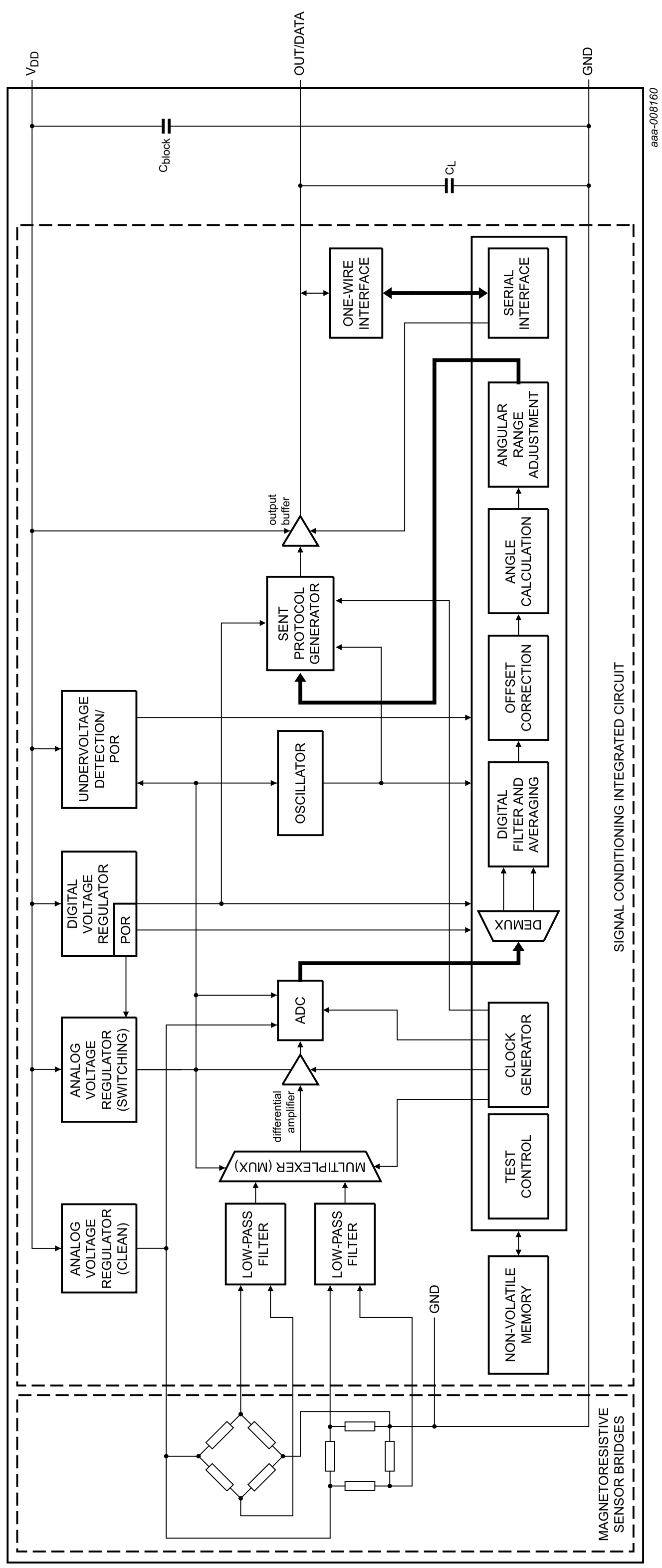


Fig 1. Functional diagram of KMA215

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.

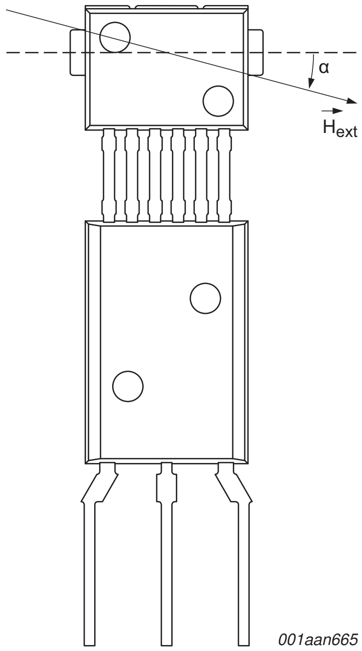


Fig 2. Angular measurement directions

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.

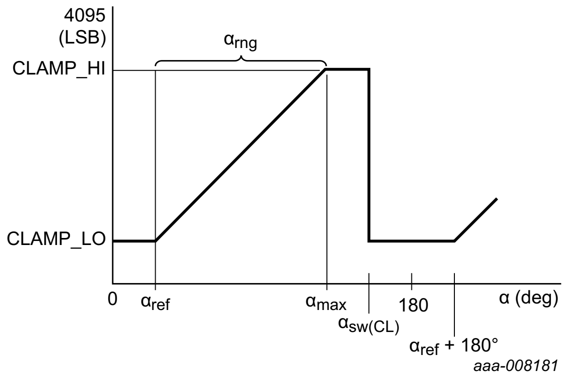
6. Digital output

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



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

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

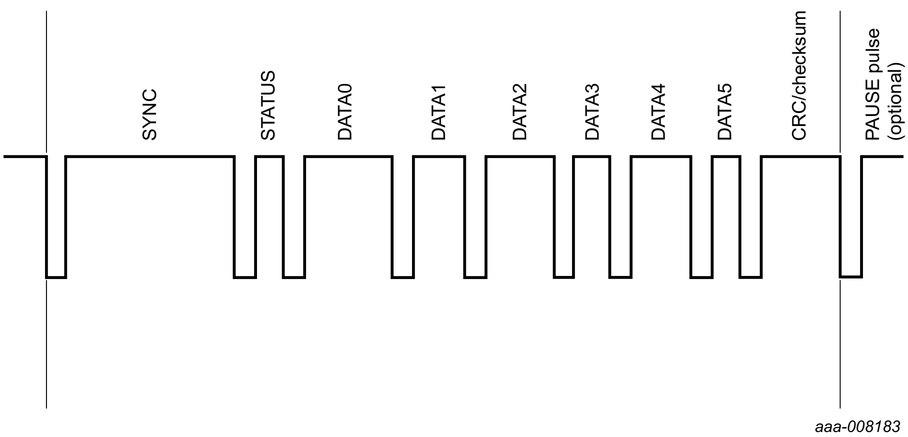


Fig 4. SENT frame

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.

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.

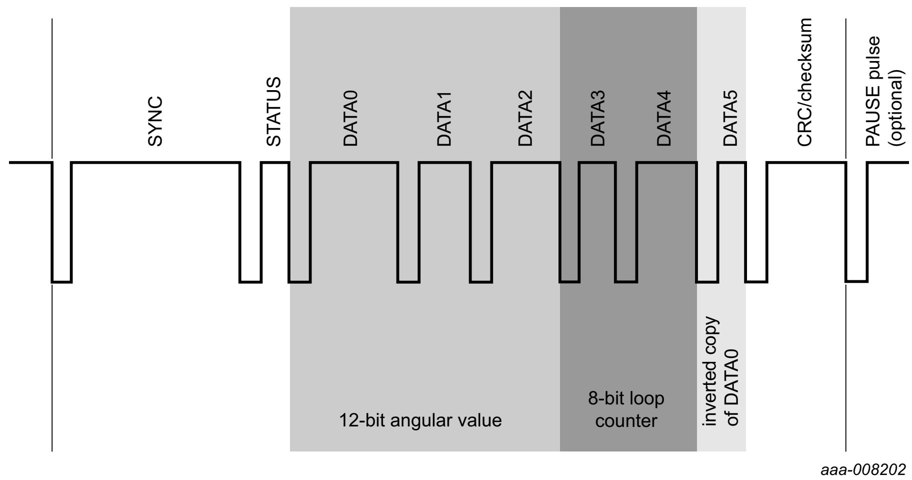


Fig 5. Single secure sensor format A.3

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.

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

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.

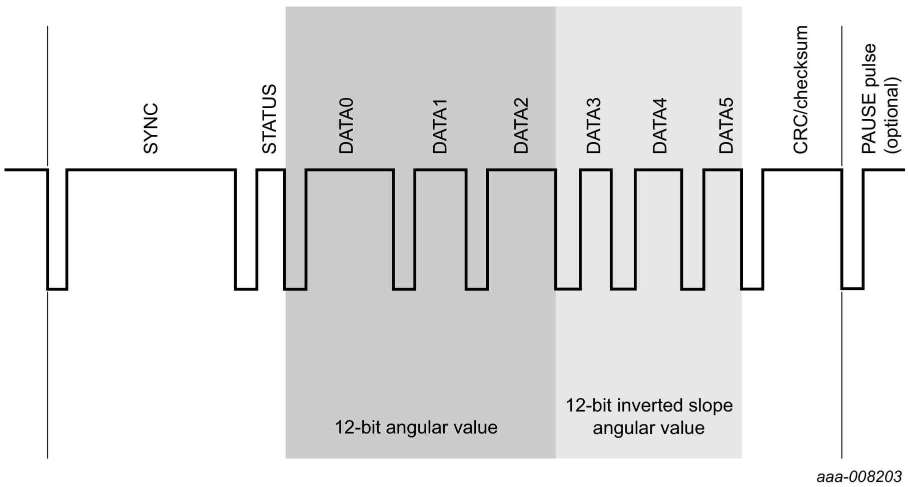


Fig 6. Dual throttle position sensor format A.1

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.

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

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.

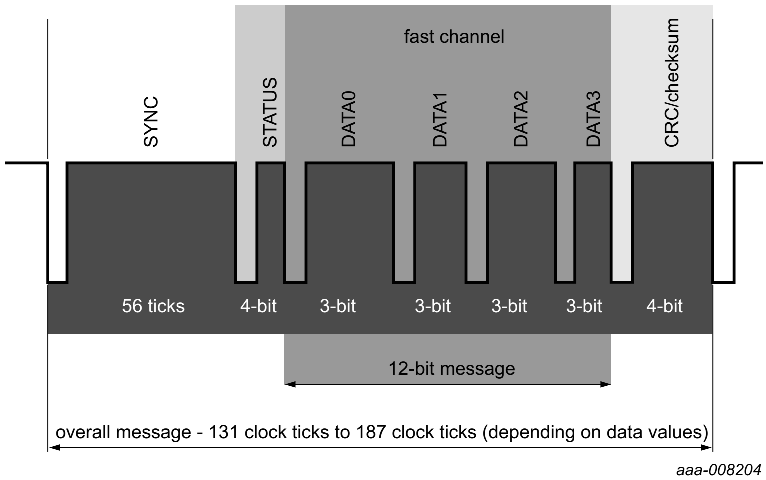


Fig 7. Example encoding scheme for a high-speed 12-bit frame

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.

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 %.

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

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	

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.

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.

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.

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

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

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°.

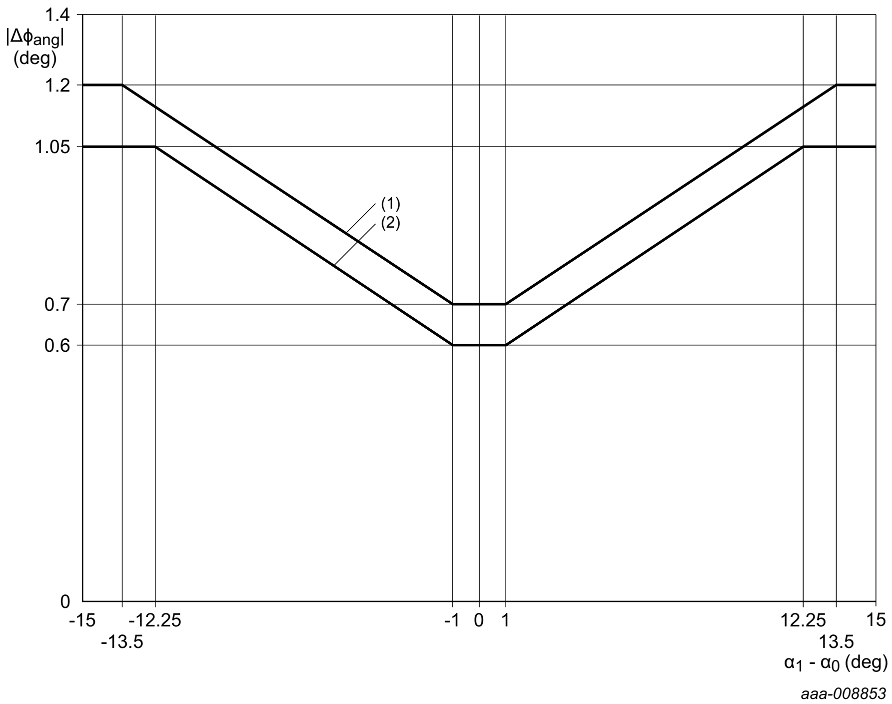
[2] In steps of resolution < 0.044°.

[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.



(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

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).

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.

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.

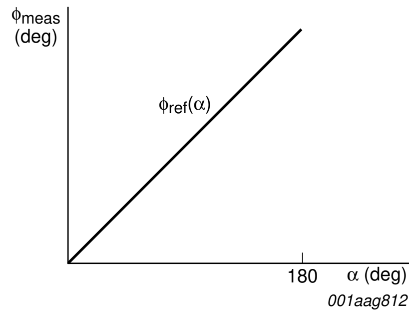


Fig 9. Definition of the reference line

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 $\Delta\phi_{hys}$.

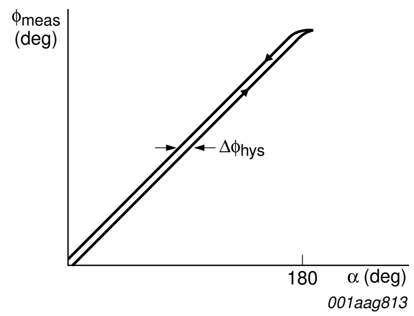


Fig 10. Definition of the hysteresis error

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

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