ZMID4200

Inductive Position Sensor IC

Description

The ZMID4200 is an inductive position sensor IC, applicable for absolute rotary or linear motion sensing in industrial, medical, and consumer applications. The ZMID4200 uses the physical principles of induction in a wire loop and eddy currents to detect the position of an electrically conducting target that is sliding or rotating above a set of coils, consisting of one transmitter coil and two receiver coils.

The three coils are typically printed as copper traces on a printed circuit board (PCB). They are arranged such that the transmitter coil induces a secondary voltage in the receiver coils that depends on the position of the metallic target above the coils.

A signal representative of the target's position over the coils is obtained by demodulating and processing the secondary voltages from the receiver coils. The target can be any kind of metal, such as aluminum, steel, or a PCB with a printed copper layer.

Three output options are available, selectable by user programming:

- 10-bit Analog output (default)
- 10-bit PWM digital output (programming option)
- 12-bit SENT digital output (programming option)

Physical Characteristics

- Operation temperature: -40 C to +150°C
- Supply voltage: 4.5V to 5.5V
- Small 14-TSSOP package

Application Usage

- Qualified for industrial, medical and consumer applications only – not qualified for usage in automotive applications
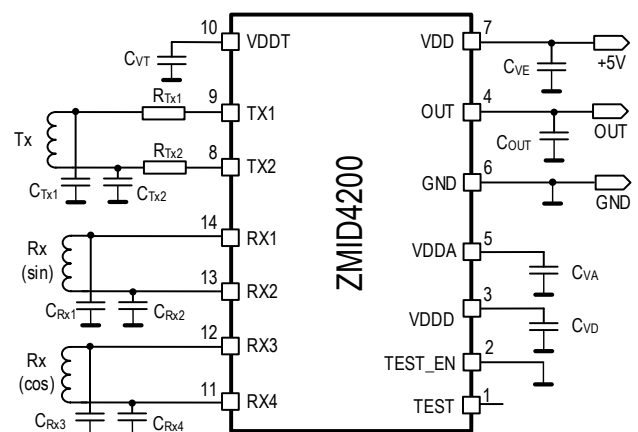
Typical Applications

- Rotary position sensors up to 360°; e.g. rotary actuators, potentiometer replacement
- Small-angle sensors or arc-motion sensors, e.g. industrial pedal or valve sensors, robotics
- Linear motion sensors, e.g. linear-actuators, position sensors, fluid-level sensors, slide potentiometer replacement

Features

- Position sensing based on inductive principle
- Cost effective; no magnet required
- Immune to magnetic stray fields; no shielding required
- Suitable for harsh environments and extreme temperatures
- Only three wires (ground, supply, output)
- Nonvolatile user memory; programming through output pin
- Single IC supports on-axis and off-axis rotation, linear motion, and arc motion sensing
- High resolution, even for small angle ranges
- High accuracy: ≤ 0.2% full scale
- 9-point user linearization
- Rotation sensing up to a full turn of 360º
- Overvoltage and reverse-polarity protection: -14V to +18V maximum, depending on product
- ESD and short-circuit protection
- Power or ground loss detection
- Programmable linearization
- Adaptive gain control supporting a wide range of coil designs and target displacement

Application Circuit Example

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1. Pin Assignments

The ZMID4200 is available in a 14-TSSOP RoHS package.

Figure 1. Pin Assignments for 14-TSSOP Package – Top View

2. Pin Descriptions

Table 1. Pin Descriptions

Number	Name	Type	Description
1	TEST	Input/output	Factory test pin; must be left unconnected.
2	TEST_EN	Input/output	Factory test pin. Connect to the GND pin.
3	VDDD	Supply	Internal regulated digital supply voltage. Connect capacitor CVD = 100nF from the VDDD pin to the GND pin, no other load.
4	OUT	Analog output (default setting)	When configured as analog output, refer to section 8.1, Figure 5, and Figure 6 for external connections.
		PWM digital output	When configured as PWM digital output, refer to section 8.2 and Figure 8 for external connections.
		SENT digital output	When configured as SENT output, refer to section 8.3, and Figure 12 for external connections.
		Digital input/output: programming only	Digital One-Wire Interface (OWI) used during programming.
5	VDDA	Supply	Internal regulated analog supply voltage. Connect CVA = 100nF from the VDD pin to the GND pin; no other load.
6	GND	Ground	Common ground connection.
7	VDD	Supply	External supply voltage. Connect the VDD pin to CVE = 100nF capacitor in parallel with a 1pF to 10pF capacitor connected to the GND pin.
8	TX2	Analog output	Connect the transmitter coil to TX1 and TX2 via the series resistors RTx1 and RTx2. The resonant frequency is adjusted with capacitors C_{Tx1} and C_{Tx2} between TX1and TX2 to GND (see the Application Circuit Example and Figure 4).
9	TX1		C_{Tx1} and C_{Tx2} must have the same capacitance value. They can be calculated with Equation 4.
10	VDDT	Supply	Internal supply voltage for transmitter amplifier. Connect to CVT = 100nF to GND.
11	RX4	Analog input	Connect receiver coil 2 between the RX4 and RX3 pins.
12	RX3		
13	RX2	Analog input	Connect receiver coil 1 between the RX2 and RX1 pins.
14	RX1		

3. Absolute Maximum Ratings

The absolute maximum ratings are stress ratings only. Stresses greater than those listed below can cause permanent damage to the device. Functional operation of the ZMID4200 at the absolute maximum ratings is not implied. Exposure to absolute maximum rating conditions could affect device reliability.

Table 2. Absolute Maximum Ratings

Symbol	Parameter	Conditions	Minimum	Maximum	Units
V_{VDD}	External supply voltage		-18	18	V
V_{OUT_ANA}	Analog output voltage	For negative voltage, external current must be limited to 10mA	-14	14	V
		Without external current limitation	-0.3	14	V
V_{OUT_PWM}	PWM output voltage	For negative voltage, external current must be limited to 10mA	-14	18	V
		Without external current limitation	-0.3	18	V
V_{OUT_SENT}	SENT output voltage	For negative voltage, external current must be limited to 10mA	-14	18	V
		Without external current limitation	-0.3	18	V
V_{OSC_COIL}	Oscillator coil pins: EP, EN		-0.3	5.5	V
V_{RX1}	Receiver coil pin: RX1				
V_{RX2}	Receiver coil pin: RX2		-0.3	3.6	V
V_{RX3}	Receiver coil pin: RX3				
V_{RX4}	Receiver coil pin: RX4				
V_{TEST_ENA}	Test pin: TEST_ENA		-0.3	5.5	V
V_{TEST_D}	Test pin: TEST_D		-0.3	3.6	V
V_{VDDA}	Regulated supply voltage pin: VDDA		-0.3	3.6	V
V_{VDDD}	Regulated supply voltage pin: VDDD		-0.3	3.6	V
V_{VDDT}	Regulated supply voltage pin: VDDT		-0.3	4.2	V

4. Operating Conditions

Conditions: VDD = 5V ±10%, TAMB = -40°C to +150°C.

Table 3. Operating Conditions

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Units
T_{AMB}	Ambient temperature		-40		150	ºC
T_J	Junction temperature		-40		175	ºC
T_{STOR}	Storage temperature		-50		150	ºC
R_{THJA}	Thermal resistance junction to ambient				140	ºC/W
V_{VDD}	Supply voltage		4.5	5	5.5	V
ESD	Electrostatic discharge, HBM 100pF/1.5kΩ	Pins GND, VDD			±4	kV
		Pin OUT			±3	kV
		All other pins			±2	kV

5. Electrical Characteristics

The following electrical specifications are valid for the operating conditions as specified in Table 3 (T_{AMB} = -40°C to +150°C).

Table 4. Electrical Characteristics

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Units
$V_{VDD\_TH\_H}$	VDD switch ON threshold	The device is activated when VDD increases above this threshold			4.4	V
t_{START}	Startup Time	Time between VDD > $V_{VDD\_TH\_H}$ and valid output at OUT		5	9	ms
$V_{VDD\_TH\_L}$	VDD switch OFF threshold	The device is deactivated when VDD decreases below this threshold	4			V
V_{VDD_OVH}	Over-voltage detection high	The device is deactivated after VDD increases above this voltage			7	V
V_{VDD_OVL}	Over-voltage detection low	The device is activated after VDD decreases below this voltage	5.6			V
V_{VDDA}	Regulated analog supply output voltage	Internally regulated, fixed		3.3		V
V_{VDDD}	Regulated digital supply output voltage	Internally regulated, fixed		2.0		V
V_{VDDT}	Regulated coil driver supply output voltage	Internally regulated, user programmable. Nominal voltage at room temperature	2.7	3.3	4.1	V
TC_{VDDT}	Temperature coefficient of VDDT regulator			4000		ppm/K
I_{CC}	Current consumption	Without coils. no load	5		9	mA
		With coils, no load; depending on programmable Tx coil current		12	20	mA
Angle Calculation						
$t_{REFRESH}$	Output update rate	Analog output			10	kHz
RES_{CORDIC}	CORDIC resolution	Internal; over 360° electrical		16		bits
Performance						
INL	Accuracy[a]	See note [a].		0.2		% FS[b]

[a] The achievable accuracy depends on proper coil and target design. Nonlinearity errors in the calculated position might be further improved by 9-point linearization.

[b] Full scale range

Table 5. Coil Specifications

| Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Units
R_{Peq}	Equivalent parallel resistance of the LC resonant circuit	See **Equation** 1	250			Ω
f_{OSC}	Transmitter frequency	LC oscillator	2.2	3.5	5.6	MHz
V_{TX_P}	Transmitter coil amplitude	Peak voltage, pins TX1 vs. TX2			7200	mV$_{pp}$
R_{Tx1}, R_{Tx2}	TX Series resistor	For reduced EMC emission		10		Ohm
C_{Tx1}, C_{Tx2}	LC oscillator capacitor	Split capacitor for LC frequency adjustment		See Equation 4		nF
V_{RX}	Receiver coil amplitude	Input signal range	50		360	mV$_{pp}$
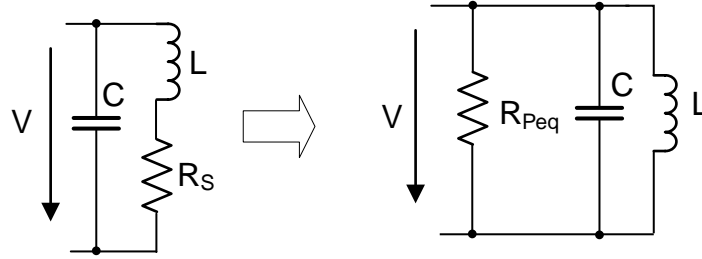
Figure 2. Parallel Resonator Circuit

The equivalent parallel resistance R_{Peq} of the LC oscillator can be calculated using Equation 1. It defines the minimum loss resistance that the oscillator can drive for safe operation.

$$R_{Peq} = \frac{1}{R_S} \times \frac{L}{C}$$

Equation 1

Where

R_{Peq} Equivalent parallel resistance of the LC oscillator.

R_S Serial resistance of the transmitter coil at the transmitter frequency.

L Coil reactance at the resonant frequency.

C Capacitance of the parallel capacitor CT.

The oscillator frequency is determined by the values of coil L and capacitors C_{Tx1} and C_{Tx2} as the following:

Oscillator frequency:

$$f_{TX} = \frac{1}{2\pi\sqrt{\dfrac{L \times C_{Tx1} \times C_{Tx2}}{C_{Tx1} + C_{Tx2}}}}$$

Equation 2

For $C_{Tx1} = C_{Tx2}$:

$$f_{TX} = \frac{1}{2\pi\sqrt{L\dfrac{C_{Tx1}}{2}}}$$

Equation 3

$$CTx1 = CTx2 = \frac{2}{L(2\pi f_{TX})^2}$$

Equation 4

Where:
f_{TX} = Oscillator frequency in MHz
L = Coil impedance in µHenry
C_{Tx1}, C_{Tx2} = Capacitance in µFarad

Table 6. Nonvolatile Memory (EEPROM)

Parameter	Conditions	Minimum	Typical	Maximum	Units
Data retention	T_J= 85°C	10			Years
Endurance; Erase / Write cycles	T_J=25°C	100 000			Cycles
	T_J=125°C	10 000			
Junction temperature	For read cycles	-40		+175	°C
	For write cycles	-40		+125	

6. Circuit Description

6.1 Overview

The ZMID4200 ICs is an inductive position sensor for use in industrial, medical and consumer applications. It operates on the principles of induction in a wire loop and eddy currents. The sensing element is a set of coils that are directly connected to the IC. The coils consist of one transmitter coil and two receiver coils. The transmitter coil and a capacitor form a free running LC oscillator that is directly driven by the IC. It generates a magnetic field within the transmitter coil area that is picked up by the receiver coils.

The voltage generated by the receiver coils depends on the position of the target in the sense that areas shielded by the target generate a weaker secondary voltage compared to areas that are not shaded by the target.

The two receiver coils are arranged so that the secondary voltages are relatively phase shifted by electrical 90°, thereby generating a response curve (receiver coil output voltages versus position) that resembles a sine and cosine waveform over the range of target travel. By having a sine and cosine shaped response, a ratiometric measurement is possible, which greatly improves the robustness of the system because the output signal will remain stable, even if the gap between coils and target is varied.

Figure 3 shows an example of a linear motion sensor with one transmitter coil (Tx loop) and two receiver coils (Sin loop and Cos loop). The arrows in the receiver coils indicate the direction of the induced current relative to each other. The direction of the current either clockwise (cw) or counterclockwise (ccw) determines the polarity of the voltage generated in each loop (RxCos, RxSin).
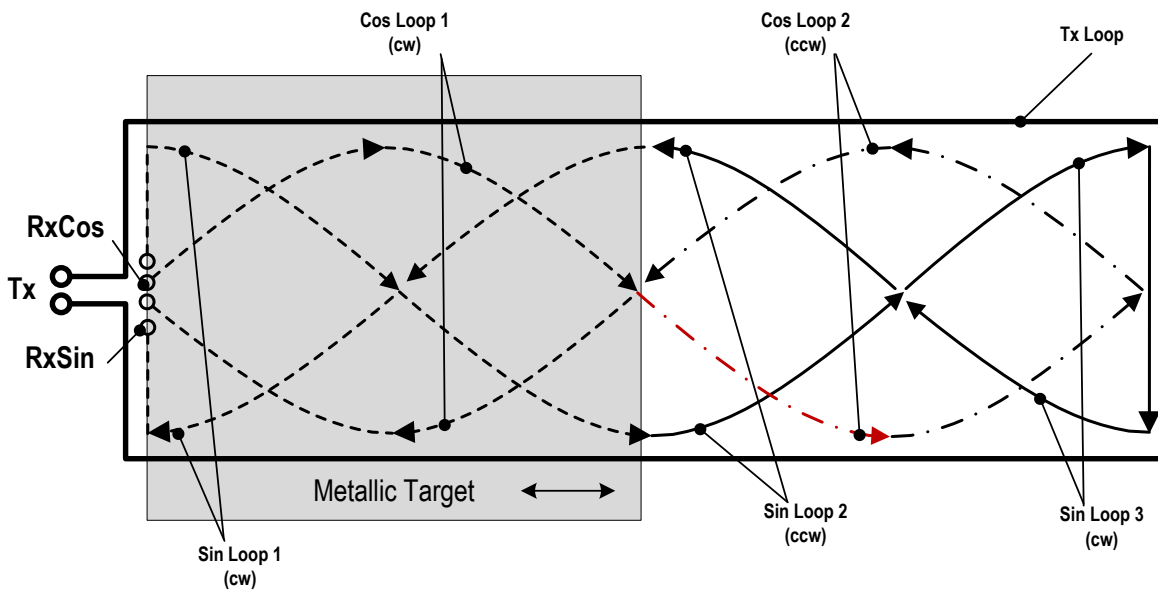

Figure 3. Coil Design for a Linear Motion Sensor

6.2   Block Diagram

Figure 4 shows the block diagram of the ZMID4200
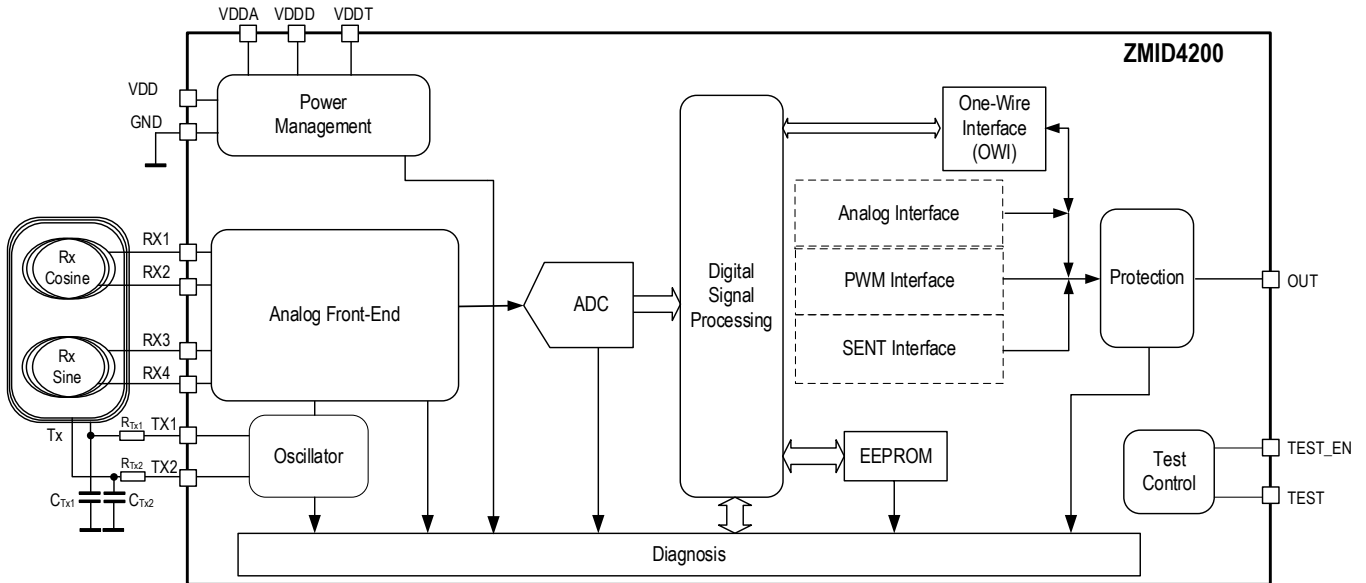

Figure 4. Block Diagram

The main building blocks include the following:

- Power management: power-on-reset (POR) circuit, low drop-out (LDO) regulators for internal supplies.

- Oscillator: generation of the transmitter coil signal.

- Analog front-end: demodulator and gain control for the receive signals.

- Analog-to-digital converter (ADC): conversion into digital domain.

- Digital signal processing: offset correction; conversion of sine and cosine signals into angle and magnitude; angle range adjustment; and linearization.

- EEPROM: nonvolatile storage of factory and user-programmable settings.

- One-wire interface (OWI): programming of the chip through the output pin.

- Interface options:

  - Analog output

  - PWM output

  - SENT output

- Protection: overvoltage, reverse polarity, short circuit protection.

- Test control: factory testing; connect TEST_D and TEST_ENA pins as indicated in Table 1.

Note: For the LC tank circuit, the capacitor C_T should be placed as close as possible to the ZMID4200 pins TX1and TX2 to minimize the loop area between pins and capacitor(s).

7. Protection and Diagnostics

7.1 I/O Protection

In order to meet high quality requirements for overvoltage and reverse-polarity protection on both the output and power supply pins, the ZMID4200 includes several protection and diagnosis features:

- Detection of broken power line, interrupted output signal, and broken ground connection on the receiving side
- Protection against short circuit of output pin to GND, output pin to VDD, and supply VDD to GND
- Overvoltage protection on supply pin VDD
- Overvoltage protection on output pin
- Reverse-polarity protection on supply pin VDD to GND
- Reverse-polarity protection on output pin to GND
- Reverse-polarity protection on output pin to VDD

7.2 Diagnostics

The ZMID4200 monitors a number of diagnostic features as described in following list:

- Supply voltage too low or too high
- Rx sine coil: open, short, short to ground, or short to Rx cosine coil
- Rx sine coil: amplitude error or offset error
- Rx cosine coil: open, short, short to ground, or short to Rx sine coil
- Rx cosine coil: amplitude error or offset error
- Tx coil: amplitude too low or open
- Tx coil: frequency out of range
- LC oscillator failure
- CORDIC magnitude too high or too low
- Missing target
- Internal EEPROM failure
- ADC signal processing overflow

8. Selection of the Output Interface

The ZMID4200 offers three different types of output interfaces on pin 4 (OUT):

1. Analog interface, see section 8.1 for details
2. PWM interface, see section 8.2 for details
3. SENT interface, see section 8.3. for details

In the default configuration at initial shipment, the output interface is set to Analog output. PWM or SENT interfaces can be configured by the user through programming (see section 9).

8.1 Analog Output (Default Setting)

Typical interface circuits for the ZMID4200 configured with an analog output are shown in Figure 5 and Figure 6.

Note: The pull-up or pull-down resistors are not mandatory for normal operation. However, they are recommended for proper detection of broken ground or broken supply wires at the receiving side.

Note: R$_F$, C$_F$ = optional low pass filter. Values depend on user's application.
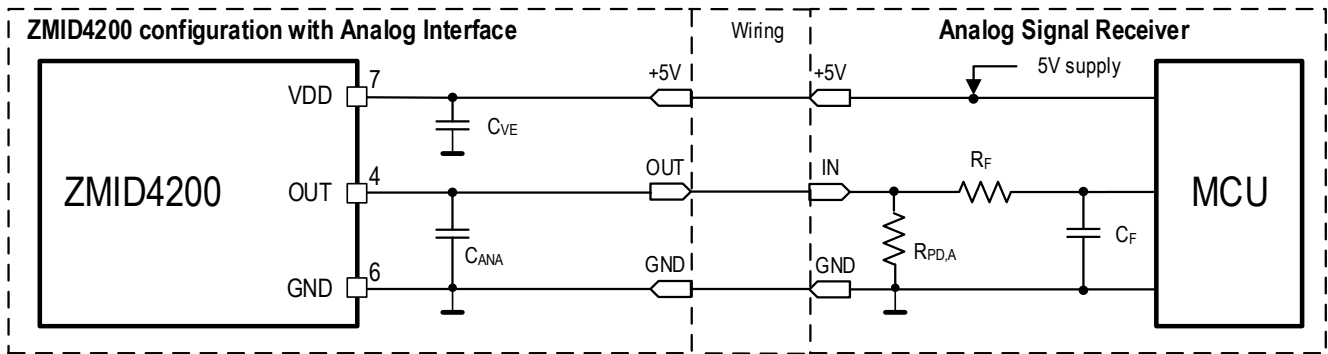

Figure 5. External Components for ZMID4200 Analog Interface with Pull-Down Resistor
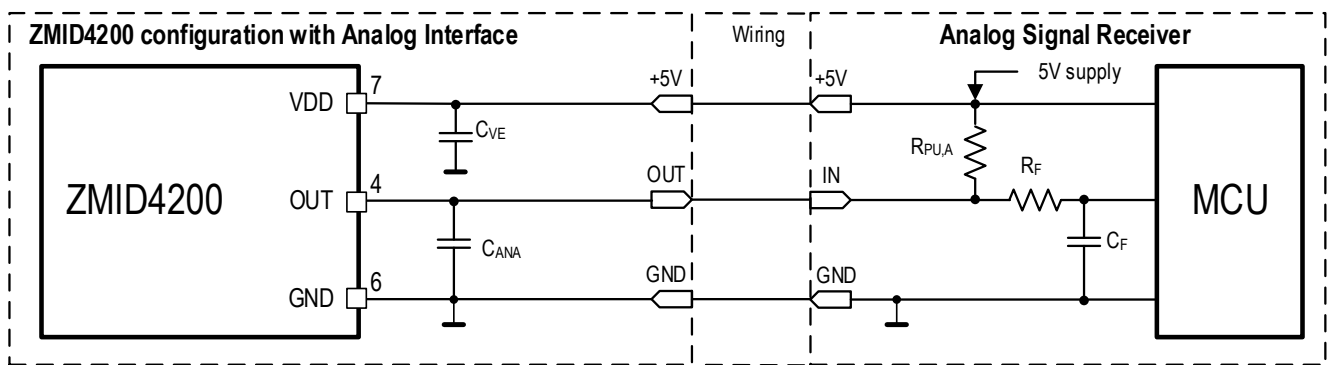

Figure 6. External Components for ZMID4200 Analog Interface with Pull-up Resistor

Table 7. Analog Output Buffer Characteristics

Note: Refer to the VDD pin description in Table 1 for the value of C$_{VE}$.

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Units
Out_err	Analog output error	Offset and nonlinearity error	-6		6	mV
Step_large	Output response, large step	Step = 4.5V, C$_{ANA}$ = 10nF, R$_{PD,A}$ = 5kΩ, 10% to 90%			160	µs
T$_{UPD,ANA}$	Analog output update rate (programmable)	Minimum oversampling rate	50.1	55.7	61.2	µs
		Maximum oversampling rate	401	445.4	490	
C$_{ANA}$	Load capacitor for analog output	Max. 6.8nF for OWI programming	0.47		27	nF
RES$_{ANA}$	Analog output resolution	Resolution of DAC			10	bits
R$_{PU,A}$	Output pull-up resistor		3	4.7	10	kΩ
R$_{PD,A}$	Output pull down resistor		3	4.7	10	kΩ
	Normal operating range	Limits are programmable	5		95	%VDD
Diag_high_ana	Diagnostic high for analog		96			%VDD
Diag_low_ana	Diagnostic low for analog				4	%VDD
V$_{CL\_L}$	Clamping level, low [a]	Programmable in 1% steps	5		68	%VDD
V$_{CL\_H}$	Clamping level, high [a]	Programmable in 1% steps	32		95	%VDD
Current_limit	Output node short current	Short to VDD or GND			50	mA

[a] Low clamping level must be programmed lower than the V$_{CL\_H}$ high clamping level.

For the ZMID4200, the 100% position range is mapped to a voltage range from 250mV to 4750mV. The stepping rate of the clamping parameters is 1% so that the analog voltage stepping rate is 47.5 mV/%. The diagnostic low level is ≤ 200mV and the diagnostic high level is ≥ 4800mV.

Note that the minimum and maximum output positions can be mapped to the mechanical range of the application by programming the zero angle offset, slope programming (linear vs. sawtooth), and clamping level register

settings (refer to section 0 and Figure 8). For example, for a pedal sensor with ratiometric analog output, having 20° mechanical degrees of movement range and clamping levels of 5% and 95%, the output value 0.25V (5% of VDD) represents 0° mechanical degrees and the output value 4.75V (95% of VDD) represents 20° mechanical degrees. Note that the slope can be programmed to either rising (as shown in Figure 8) or falling with increasing electrical angle.
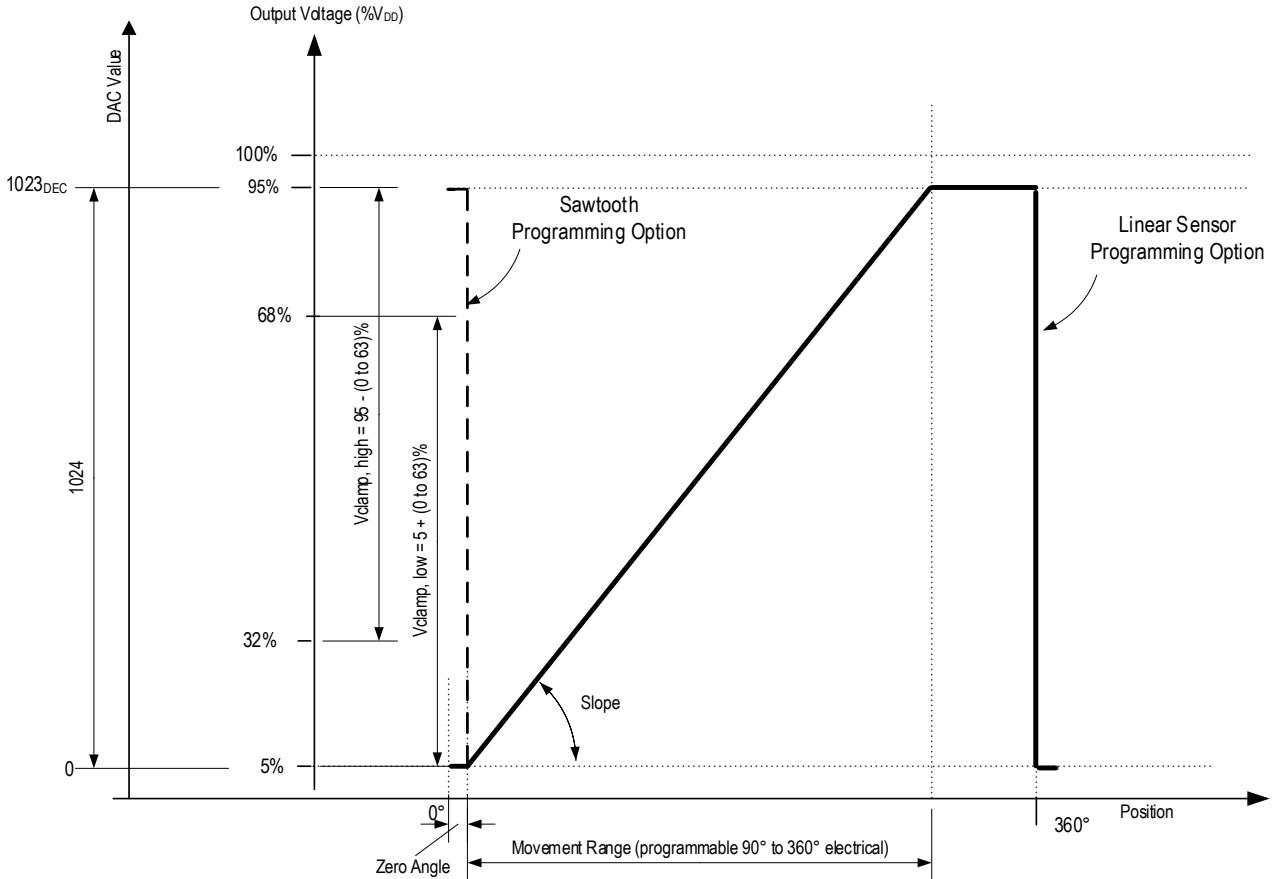
Note: An example of 5% and 95% clamping levels and a rising slope setting is illustrated.

Figure 7. Example of Analog Output Transfer Function and Programming Options

8.2 PWM Output (Programming Option)

The typical interface circuit for the ZMID4200 with PWM output is shown in Figure 8.

Note: R_F, C_F = optional low pass filter. Values depend on user's application.
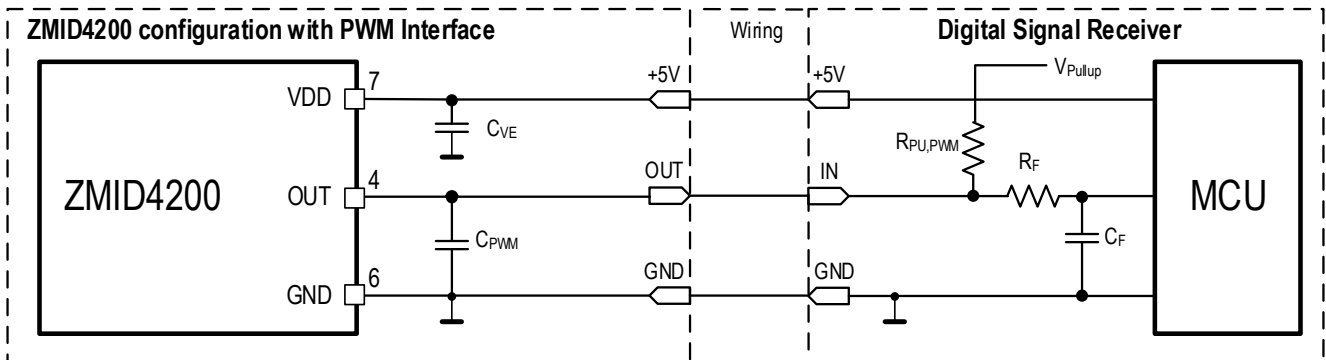

Figure 8. External Components for ZMID4200 PWM Interface with Pull-Up Resistor

Table 8. PWM Output Buffer Characteristics

Note: Refer to VDD pin in Table 1 for the value of C_{VE}.

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Units
f_{PWM}	PWM output frequency	User programmable	Typical – 7%	0.125 0.25 0.50 0.75 1.00 1.25 1.50 2.00	Typical + 7%	kHz
t_{PWM_FALL}	PWM fall time	C_{PWM}=4.7nF, $R_{PU,PWM}$=1kΩ, V_{Pullup}=5V, 2 correction bits	2.45		4.55	µs
RES_{PWM}	PWM resolution				10	bits
V_{Pullup}	PWM output voltage (pull-up)				16	V
$R_{PU,PWM}$	Pullup resistor for PWM	V_{Pullup}=5V	1		10	kΩ
		V_{Pullup}=16V	3		10	
C_{PWM}	Load capacitor for PWM output	Max. 6.8nF for OWI programming	1	4.7	20	nF
	Normal operating range	Limits are programmable	5		95	% duty cycle
Diag_high_PWM	Diagnostic high for PWM		96	97.5		% duty cycle
Diag_low_PWM	Diagnostic low for PWM			2.5	4	% duty cycle
D_{CL_L}	Clamping level , low [a]	Programmable in 1% steps	5		68	% duty cycle
D_{CL_H}	Clamping level, high [a]	Programmable in 1% steps	32		95	% duty cycle

[a] Low clamping level must be programmed lower than the D_{CL_H} high clamping level.

The 100% position range is mapped to a duty cycle of 5% to 95%. A clamping step of 1% is mapped to a duty cycle change of 0.9%. The diagnostic low level is mapped to a 2.5% (typical) duty cycle; the diagnostic high level is mapped to a 97.5% (typical) duty cycle.
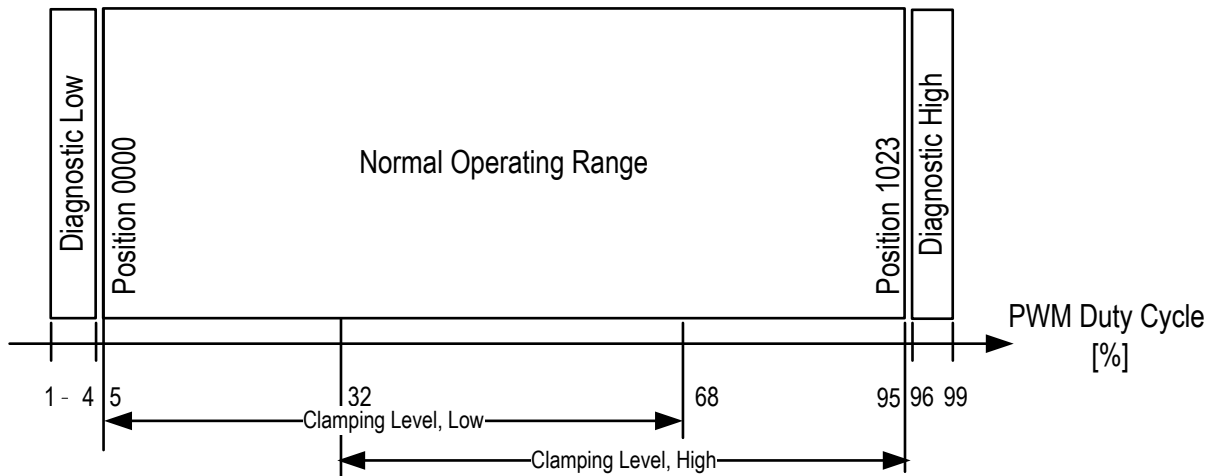

Figure 9. PWM Signal Range

The graph in Figure 10 shows examples of different PWM signals with 5%, 50%, and 95% duty cycle, representing the minimum, 50%, and maximum output values.

Note that the minimum and maximum output positions can be mapped to the mechanical range of the application by programming the zero angle offset, slope programming (linear or sawtooth), and clamping level (minimum/maximum duty cycle) register settings (see section 0 and Figure 12). For example, for a pedal sensor with PWM output, having 20° mechanical degrees of movement range and clamping levels of 5% and 95%, the

output value 0 represents 0° mechanical degrees and the output value 1023_{DEC} represents 20° mechanical degrees. Note that the slope can be programmed to either rising (as shown in Figure 12) or falling with increasing electrical angle.
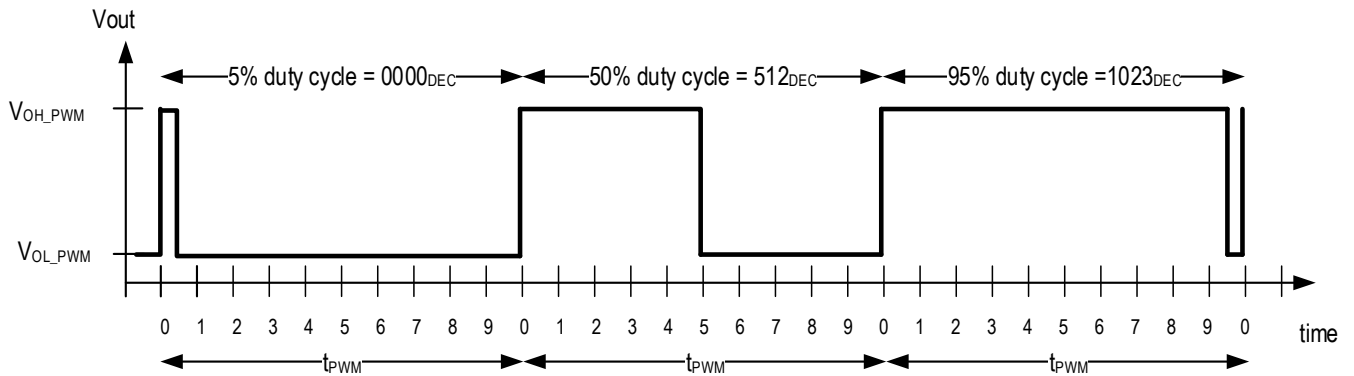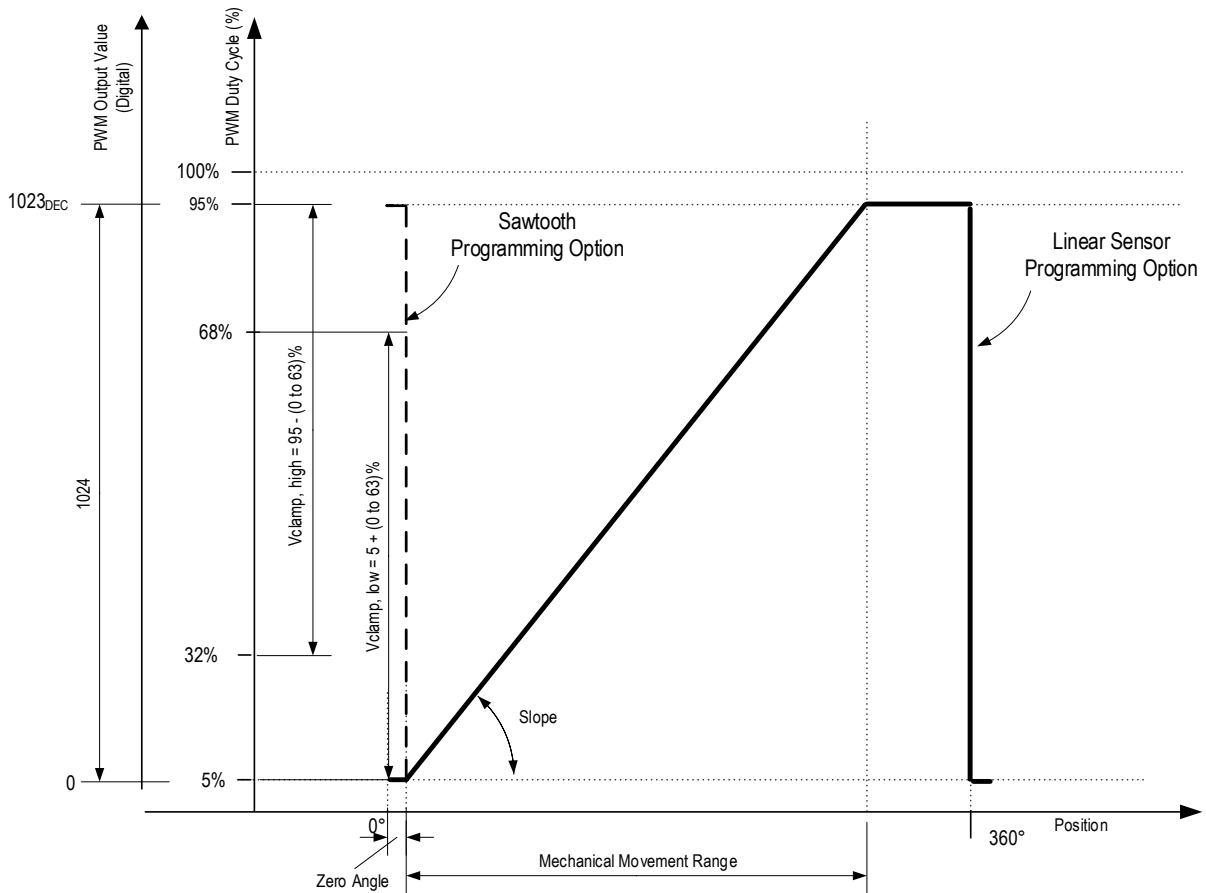

Figure 10. Example of PWM Output Signal

Note: An example of 5% and 95% clamping levels and a rising slope setting is illustrated.

Figure 11. Example of ZMID4200 PWM Output Transfer Function and Programming Options

8.3   SENT Output (Programming Option)

The typical interface circuit for the ZMID4200 with SENT output is shown in Figure 12.

Values for C_1, C_2 and R_0 depend on user's application.
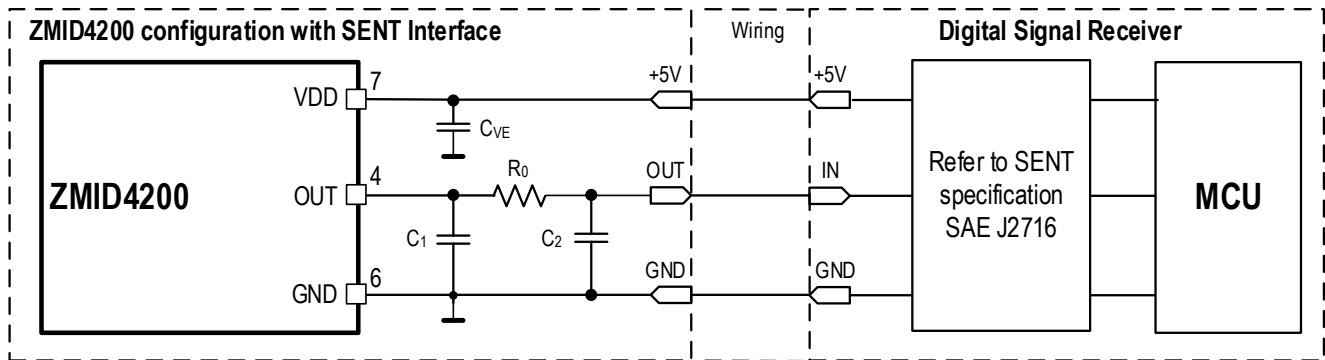

Figure 12. External Components for ZMID4200 SENT Interface

Table 9. SENT Output Buffer Characteristics

Note: Refer to VDD pin in Table 1 for the value of C_{VE}.

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Units
RES_{SENT}	SENT output resolution				12	bits
t_{STABLE_HIGH}	SENT HIGH stabilization time	HIGH level at 3.8V	6			µs
V_{OL}	Output LOW level				0.5	V
V_{OH}	Output HIGH level		4.1			V

8.3.1.   SENT Protocol

The SENT (Single Edge Nibble Transmission) protocol conforms to SAE J2716, Revision 2. In addition, SENT Pause and CRC can be programmed according to SAE J2716, Revision 3.

For transmitting a nibble with the 0 value, 12 clock ticks are required: a fixed LOW period of 5 ticks followed by a HIGH period of 7 ticks. One tick equals t_{TICK} = 3.0µs to 3.67µs (see Table 10).
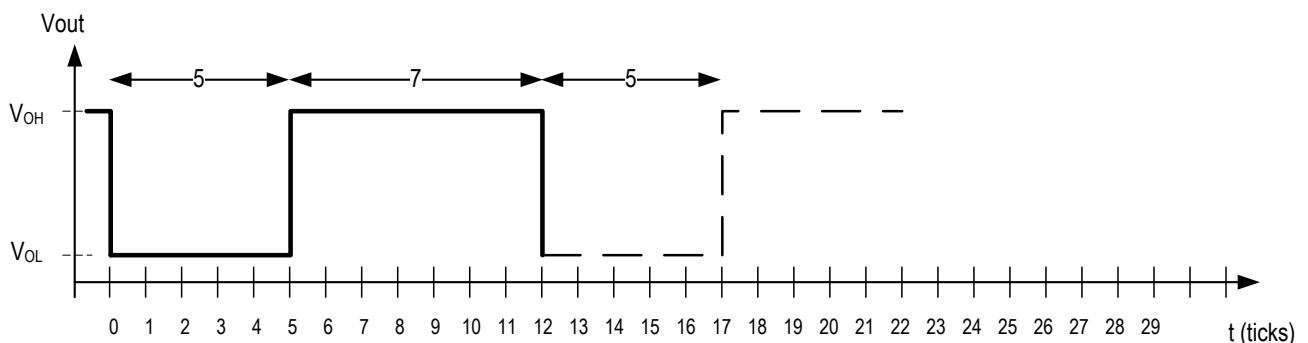

Figure 13. SENT Nibble Output for Value = 0_{DEC}

For transmitting a nibble with the value 15_{DEC} (1111_{BIN}, F_{HEX}), 27 clock ticks are required: a fixed LOW period of 5 ticks followed by a HIGH period of 22 ticks. The total time for one nibble can be calculated as with the following equation:

$t_{NIBBLE} = t_{TICK}*(12 + x)$

Where x = the nibble decimal value = 0 to 15.

Table 10. SENT Tick Length

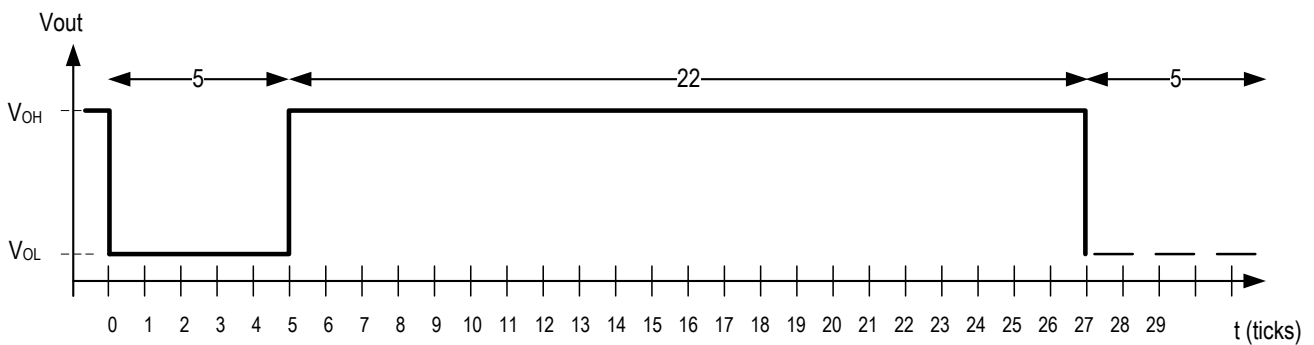| Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Number of Ticks	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

Figure 14. SENT Nibble Output for Value = 15$_{DEC}$

The SENT protocol frame consists of a fixed-length synch pulse (LOW period of 5 ticks followed by a HIGH period of 51 ticks), followed by a status nibble, 6 data nibbles, and a CRC nibble. An optional pause pulse can be programmed to adjust the SENT frame to a fixed length of 270 ticks.
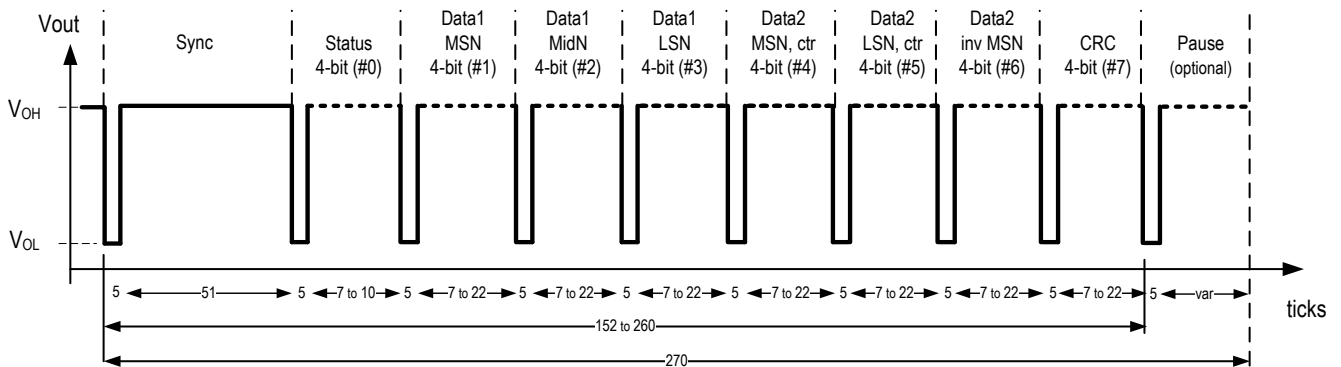

Figure 15. SENT Frame

Note that the status nibble has a maximum length of only 5 + 10 = 15 ticks since bits 2 and 3 are always zero:

Status nibble: 0000_{BIN} = Normal operation

0011_{BIN} = Diagnostic state

The SENT output frame format can be programmed in one of two options:

1. 12-bit position data + 8-bit rolling counter ("ctr" in Figure 15) + inverted copy of Data1 MSN (nibble #1 in Figure 15) + cyclic redundancy check (CRC). In this option, the SENT frame length is between 152 and 260 ticks with a variable frame length and 270 ticks with a fixed frame length.

2. 12-bit position data + "000" data + CRC. In this option, if the pause pulse is disabled, the SENT frame has the shortest possible length: less than 220 ticks.

Note that the minimum and maximum output positions can be mapped to the mechanical range of the application by programming the zero angle offset and slope register settings (see section 9 and Figure 16). For example, for a pedal sensor with SENT output having 20° mechanical degrees of movement range, the output value 0 represents 0° mechanical degrees and the output value 4095_{DEC} represents 20° mechanical degrees. Note that the slope can be programmed to either rising (as shown in Figure 16) or falling with increasing electrical angle.
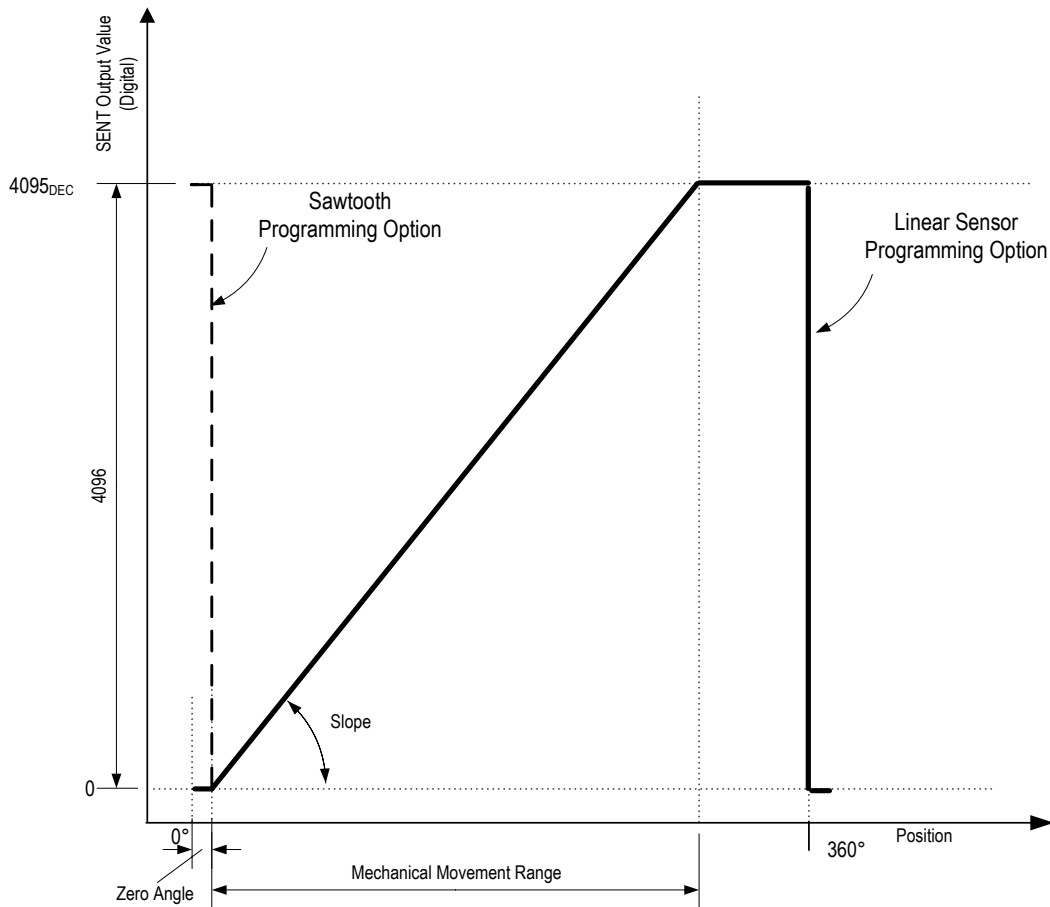
Note: An example using the rising slope setting is illustrated.

Figure 16. Example of ZMID4200 SENT Output Transfer Function and Programming Options

9. Programming Options

The ZMID4200 offers a variety of programming options. The IC is programmed through the output pin 4 (OUT) via a proprietary bi-directional one-wire interface (OWI). For programming, no additional wires or programming voltage is required, so the IC can be fully programmed in the field.

Additional documents related to programming are available for download on the ZMID4200 product page:

- *ZMID4200 Technical Brief OWI Interfac*e: one wire interface protocol description.
- *ZMID4200 Register Map*: detailed memory map.

The main programming functions are described in Table 11.

Table 11. Programming Options Overview

Function	Programming Option	Notes
Output interface	Analog (default), PWM or SENT	Selection of the output interface
Coil input	Reverse coil polarity (increasing or decreasing output relative to target movement)	Invert coils to change the direction of the output values
Input amplifier	Offset of sine and cosine channels	Offset correction before CORDIC angle calculation
Slope of transfer function	Steepness of slope, rising/falling	Adjustment of angle range
Zero position	Zero angle	To match mechanical zero position with electrical zero position
Linearization	9-point linearization	To increase accuracy and compensate for imperfections in coil design
Transmitter coil	Coil driver current and amplitude	To optimize Tx oscillator
Output mode	Linear or sawtooth	Single or multiple ramps
Clamp low, clamp high	Minimum, maximum output voltage	Define normal operating range
	Minimum, maximum PWM duty cycle	Define normal operating range
Diagnostic levels	Output voltage in diagnostic mode	To indicate diagnostic alarm
	PWM duty cycle in diagnostic mode	To indicate diagnostic alarm
PWM fall time	PWM output signal slew rate	To optimize EMC performance
PWM base frequency	PWM frequency	Base frequency of PWM signal
SENT CRC	CRC according to SAE J2716, Rev.2 or Rev.3	Implementation of CRC calculation
SENT Pause	Optional pause setting according to SAE J2716, Revision 2 or Revision 3	Revision 2: No pause pulse Revision 3: Fixed frame length + pause
SENT Frame	Type of data transmitted in SENT frame	A) 12-bit position data + 8-bit rolling counter + inverted copy of first data nibble + CRC (see Figure 17). 12-bit position data + "000" data + CRC
Diagnostics	CORDIC magnitude upper and lower levels	To trigger alarm if CORDIC magnitude is out of range
	Transmitter coil frequency alarm	Detects out of range Tx frequency
	Automatic gain control (AGC)	Detects AGC out of range
	EEPROM double error; shadow register parity error	Internal memory errors
	R1 or R2 coil open or short	Detect defective receiver coils
	Signal processing overflow	Internal processing errors

10. Operation at High Rotation Speeds

The ZMID4200 is primarily designed for low-speed or static operation due to their inherent interface types (analog ramp, PWM, SENT). There is no upper speed limit for using the ZMID4200 in high speed applications; however, due to the maximum data rate at the various outputs, the resolution (on a rotary application: number of steps per revolution) will be reduced with increasing speed.

10.1 Data Rates, Resolution, and Rotational Speed

The maximum output data rates for the various versions are given in Table 12.

Table 12. Maximum Output Data Rate

Type of Output	Maximum Output Rate, Updates per Second	Notes
Analog ramp	10000	Linear analog ramp
PWM	2000	Programmable from 125Hz to 2000Hz
SENT	1235	270 ticks at 3µS

With these maximum output data rates, the resolution versus rotation speed relationship is shown in the graph in Figure 12.

Examples of the number of steps per revolution at 10rpm and 1000rpm electrical speed are given in Table 13.

Table 13. Resolution at Different Rotation Speeds

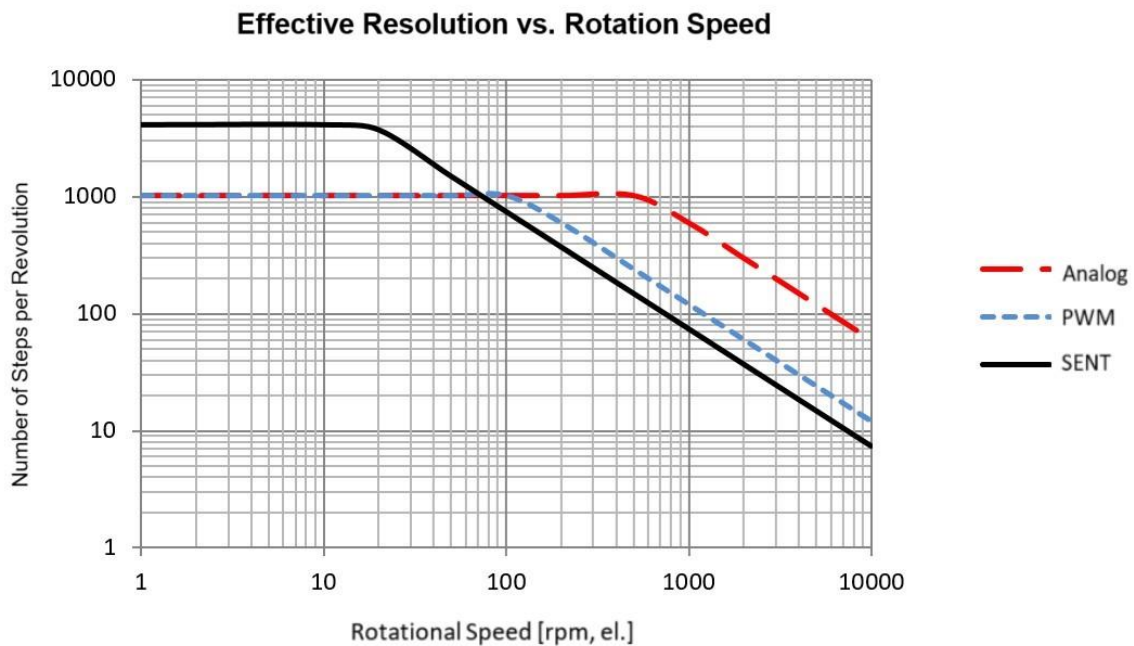| Type of Output	Steps per Revolution at 10 rpm	Steps per Revolution at 1000 rpm, el.
Analog ramp	1024	600
PWM	1024	120
SENT	4096	74

Figure 17. Relationship between Resolution and Rotational Speed

10.2 Electrical vs. Mechanical Speed

Rotation speed is given in electrical rpm [rpm, el], which is the number of electrical periods per minute. To calculate the mechanical rotation speed in multi-period coil designs, divide the electrical rpm by the number of periods per 360°.

For example:

- 1-periodic coil design, 1 × 360° angle range per revolution: mechanical speed = electrical speed
- 2-periodic coil design, 2 × 180° angle range per revolution: mechanical speed = electrical speed / 2

11. Interpolation, Linearity Error Correction

A post-CORDIC linearity correction is available to correct nonlinearities and to further increase the overall accuracy of the system.

The correction factors are applied by linear interpolation between 9 equidistant points over one phase (0 to 360°) with one of two options:

- Option 1: Starting at 0° with intervals of 45°
- Option 2: Same as option1 shifted by 22.5°, starting at 22.5° with intervals of 45°

Table 14. Linearity Correction Points

Point	1	2	3	4	5	6	7	8	9
Option 1	0°	45°	90°	135°	180°	225°	270°	315°	360°
Option 2	22.5°	67.5°	112.5°	157.5°	202.5°	247.5°	292.5°	337.5°	382.5° (22.5°)

Note that in a rotating application, correction point 1 (0°) and point 9 (360°) coincide at the same angle. Therefore, in such cases, it is useful to use the same correction values for both point 1 and point 9.

In general, the correction points are applicable as follows:

Correction point 1 is used for angles 0° ≤ α < 45° and optionally for 22.5° ≤ α < 67.5°(…)

Correction point 9 is used for angles 315° ≤ α < (360° = 0°) and optionally for 337.5° ≤ α < 22.5°.

For each point, an offset can be applied. Angle values between two points are corrected by linear interpolation between the two linearization points.

12. Application Examples

Typical coil and target arrangements are shown in Figure 18 to

Figure 23: linear motion; arc motion; and on-axis (end of shaft) and off-axis (side shaft) rotary. Many other arrangements are also possible. In the figures, blue indicates the target and the dashed lines indicate range of travel. See Table 15 for resolution values.

Note: The coils are shown in a simplified form. Detailed guidelines on coil design and programming options are available on request from Renesas application support. Note that within each base configuration, the movement range can be further fine-trimmed by user programming.

Examples:

An angle sensor for 0 to 270° angle range would use a 360° base configuration (360°/1) and could then be trimmed to a maximum angle of 270° by user programming.

An angle sensor for 0 to 110° angle range would use a 120° configuration (360°/3) and could then be trimmed to a maximum angle of 110° by user programming.
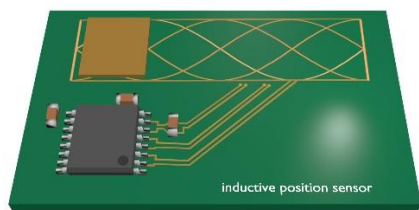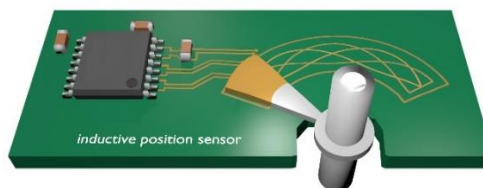
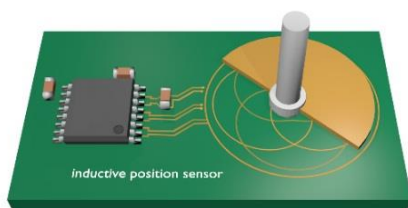**Figure 18. Example Setup: Linear Motion**

Figure 19. Example Setup: Arc Motion

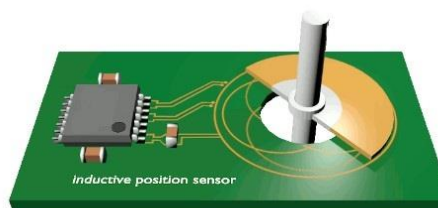**Figure 20. Example Setup: End-of-Shaft Rotation,
1 × 360°**

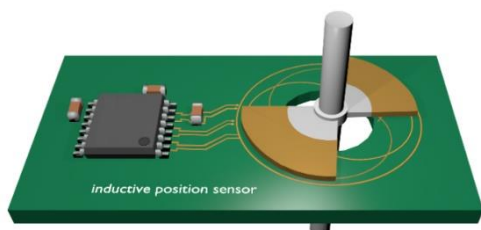**Figure 22. Example Setup: Through-Shaft Rotation,
1 × 360°**

**Figure 21. Example Setup: Through-Shaft Rotation,
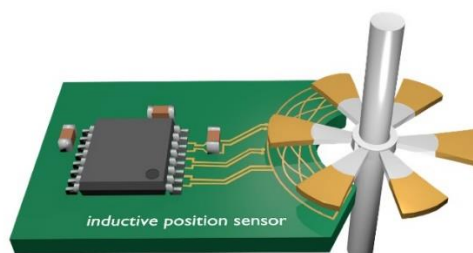2 × 180°**

**Figure 23. Example Setup: Side-Shaft Rotation,
6 × 60°**

One of the key advantages of inductive position sensors is the flexibility to adapt the coil design to the needs of any given application. They can be designed for rotary, arc, or linear motion and in addition, the movement range can be adjusted. This way, the maximum resolution can be achieved, even for applications having only a small range of travel. Table 15 shows examples for calculating the effective resolution (movement range for 1 LSB or step), depending on coil design and output configuration.

Table 15. Examples of Resolution Differences Depending on Configuration

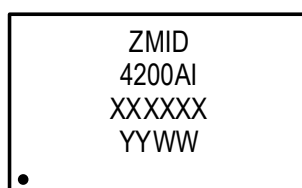| Range of Travel for Example Application	Resolution of Measurement	
	Analog and PWM Output (1024 Steps per Phase)	**SENT Output (4096 Steps per Phase)**
Linear Position Sensing Range of Travel = Coil Length Minus Target Length (See the example in Figure 18)	(Range of Travel)/1024	(Range of Travel)/4096
Arc Position Sensing Range of Travel = Coil Arc Angle Minus Target Angle (Width of Target) (See the example in Figure 19)	(Range of Travel)/1024	(Range of Travel)/4096
Arc Position Sensing Range of Travel = 1 × 130°	130°/1024 = 0.127°	130°/4096 = 0.0317°
1 × 360° (See the examples in Figure 20 and Figure 22)	0.35°/Step	0.088°/Step
2 × 180° (See the example in Figure 21)	0.18°/Step	0.044°/Step
6 × 60° (See the example in Figure 23)	0.059°/Step	0.015°/Step

13. Electromagnetic Compatibility (EMC)

Guidelines for EMC compliant circuit designs are available in the *ZMID4200 EMC Recommendations* document on the ZMID4200 product page.

14. Package Outline Drawings

The package outline drawings are appended at the end of this document and are accessible from the link below. The package information is the most current data available and is subject to change without notice or revision of this document.

https://www.renesas.com/eu/en/document/psc/14-tssop-package-outline-drawing44mm-body-065mm-pitchpgg14t1

15. Marking Diagram
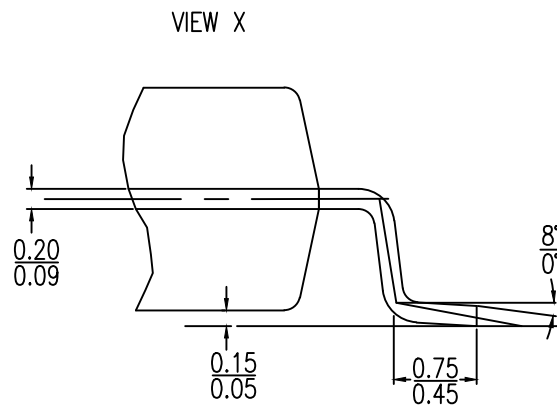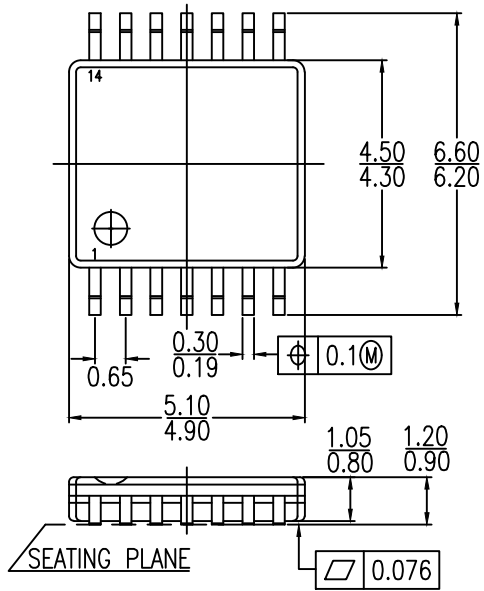
```
ZMID
4200AI
XXXXXX
YYWW
●
```

Line 1: First four characters of part code (ZMID)

Line 2: Next four characters of the part code (4200) followed by

      A = Design revision

      I = Industrial qualification

Line 3: "XXXXXX" = Lot number

Line 4: "YYWW" = Manufacturing date:

      YY = last two digits of manufacturing year

      WW = manufacturing week

16. Ordering Information

Orderable Part Number	Description and Package	MSL Rating	Carrier Type	Temperature
ZMID4200AI1R	14-TSSOP, 4.4 mm × 5.0 mm	1	13" Reel, 4000 parts / reel	-40°C to +150°C
ZMID4200STKIT	ZMID4200 Starter Kit including USB communication board, 3 application modules and connection cables			

17. Revision History

Revision Date	Description of Change
Aug. 19, 2021	Initial release.

VIEW X

$\frac{4.50}{4.30}$ $\frac{6.60}{6.20}$

$\frac{0.30}{0.19}$ ⊕ $\boxed{0.1 Ⓜ}$

0.65

$\frac{5.10}{4.90}$

$\frac{1.05}{0.80}$ $\frac{1.20}{0.90}$

SEATING PLANE

$\boxed{\square \; 0.076}$

$\frac{0.20}{0.09}$

$\frac{0.15}{0.05}$

$\frac{0.75}{0.45}$

$\frac{8°}{0°}$

NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS
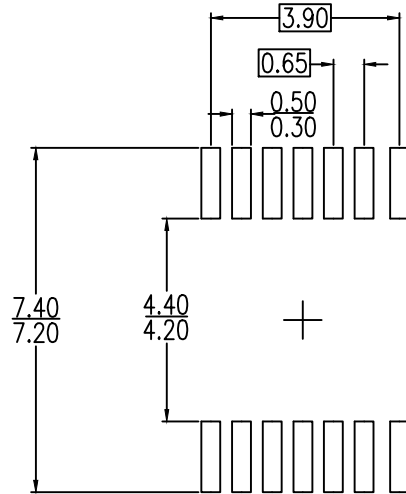
LAND PATTERN DIMENSIONS

NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS

Package Revision History		
Date Created	Rev No.	Description
Mar, 10 2017	Rev 01	Added Land Pattern
Dec, 19 2017	Rev 02	New Format

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