Brief Description

The ZSSC5101 is a CMOS integrated circuit for converting sine and cosine signals obtained from magnetoresistive bridge sensors into a ratiometric analog voltage with a user-programmable range of travel and clamping levels.

The ZSSC5101 accepts sensor bridge arrangements for both rotational as well as linear movement. Depending on the type of sensor bridge, a full-scale travel range of up to 360 mechanical degrees can be obtained.

Programming of the device is performed through the output pin, allowing in-line programming of fully assembled 3-wire sensors. Programming parameters are stored in an EEPROM and can be re-programmed multiple times.

The ZSSC5101 is fully automotive-qualified with an ambient temperature range up to 160°C.

Features

- Ratiometric analog output
- Up to 4608 analog steps
- Step size as small as 0.022°
- Programming through output pin via one-wire interface
- Offset calibration of the bridge input signals
- Programmable linear transfer characteristic:
  - Zero position
  - Angular range
  - Upper and lower clamping levels
  - Rising or falling slope
- Loss of magnet indication with programmable threshold level
- Accepts anisotropic, giant, and tunnel magneto-resistive bridge sensors (AMR, GMR and TMR)
- Programmable 32-bit user ID
- CRC, error detection, and error correction on EEPROM data
- Diagnostics: broken-wire detection
- Automotive-qualified to AEC-Q100, grade 0

Benefits

- No external trimming components required
- PC-controlled configuration and single-pass calibration via one-wire interface allows programming of fully assembled sensors
- Can be used with low-cost ferrite magnets
- Allows large air gaps between sensors and magnets
- Optimized for automotive environments with extended temperature range and special protection circuitry with excellent electro-magnetic compatibility
- Power supply monitoring
- Sensor monitoring
- Detection of EEPROM memory failure
- Connection failure management
- High accuracy: ± 0.15° integral nonlinearity (INL) after calibration

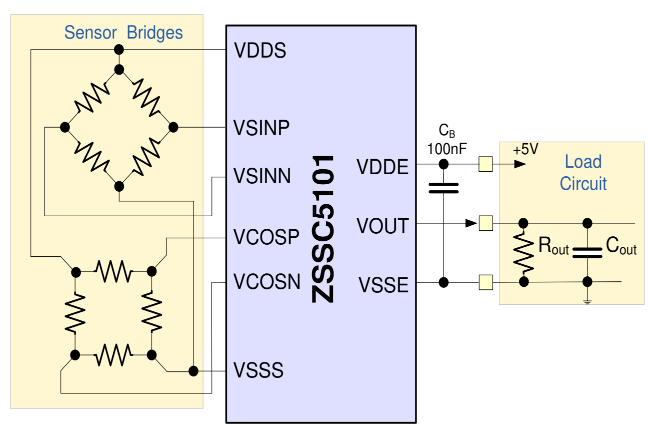
Available Support

- Evaluation Kit
- Application Notes

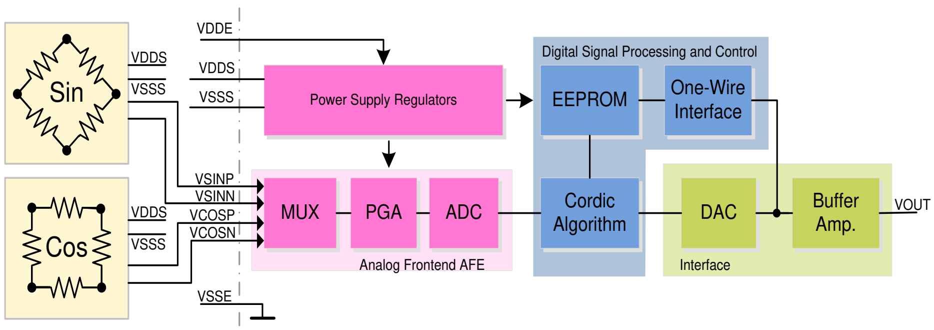
Physical Characteristics

- Wide operation temperature: -40 C to +160 C (die)
- Supply voltage: 4.5V to 5.5V
- SSOP-14 package, bare die, or unsawn wafer

ZSSC5101 Typical Application Circuit



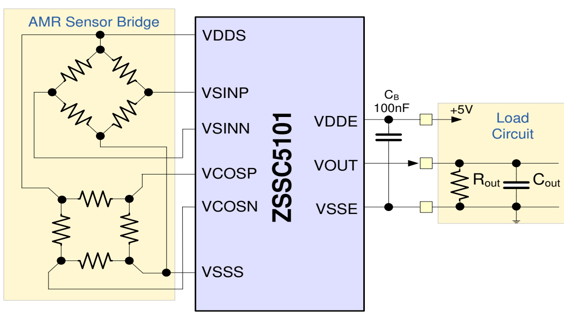
ZSSC5101 Block Diagram



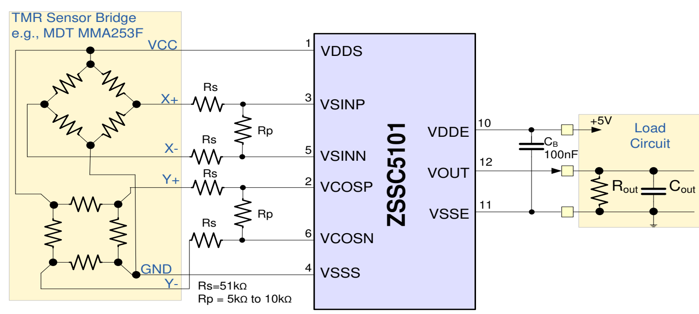
Applications

- Absolute Rotary Position Sensor
- Steering Wheel Position Sensor
- Pedal Position Sensor
- Throttle Position Sensor
- Float-Level Sensor
- Ride Height Position Sensor
- Non-Contacting Potentiometer
- Rotary Dial

Application Circuit for AMR Sensors



Application Circuit for TMR Sensors



Ordering Information

Sales Code	Description	Delivery Package
ZSSC5101BE1B	ZSSC5101 Die – Temperature range: -40°C to +160°C	8” tested wafer, unsawn, thickness = 390 ±15µm
ZSSC5101BE2B	ZSSC5101 Die – Temperature range: -40°C to +160°C	8” tested wafer, unsawn, thickness = 725 ±15µm
ZSSC5101BE3B	ZSSC5101 Die – Temperature range: -40°C to +160°C	8” tested wafer, unsawn, thickness = 250 ±15µm
ZSSC5101BE1C	ZSSC5101 Die – Temperature range: -40°C to +160°C	8” tested wafer, sawn on frame, thickness = 390 ±15µm
ZSSC5101BE4R	ZSSC5101 SSOP-14 – Temperature range: -40°C to +150°C	13” tape and reel
ZSSC5101BE4T	ZSSC5101 SSOP-14 – Temperature range: -40°C to +150°C	Tube
ZSSC5101 KIT	Evaluation Kit: USB Communication Board, ZSSC5101 AMR board, adapters. Software is downloaded (see data sheet).	

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1 IC Characteristics

1.1. Absolute Maximum Ratings

Table 1.1 Absolute Maximum Ratings

Parameter		Symbol	Min	Typ.	Max	Unit
1.1.1.1.	Supply voltage at VDDE pin	V_{DDE}	-0.3		5.7	V
1.1.1.2.	Voltage at VDDS pin	V_{DDS}	-0.3		V_{DDE}+0.3	V
1.1.1.3.	Voltage at VSINP, VSINN, VCOSP, and VCOSN pins		-0.3		V_{DDS}	V
1.1.1.4.	Voltage at VOUT pin	V_{OUT}	-0.3		V_{DDE}+0.3	V
1.1.1.5.	Storage temperature	T_S	-60		160	°C

1.2. Operating Conditions

Table 1.2 Operating Conditions

Note: See important notes at the end of the table.

Parameter		Symbol	Min	Typ.	Max	Unit
1.2.1.1.	Supply voltage for normal operation	V_{DDE}	4.5	5.0	5.7	V
1.2.1.2.	Operating ambient temperature range, bare die [1)]	T_A	-40		160	°C
1.2.1.3.	Extended ambient temperature range, bare die [1), 2)]	T_A	-60		160	°C
1.2.1.4.	Operating ambient temperature range, SSOP-14	T_A	-40		150	°C
1.2.1.5.	Temperature range – EEPROM programming	T_{A-EEP}	10		150	°C
1.2.1.6.	Blocking capacitance between VDDE and VSSE pins	C_B	75	100		nF
1.2.1.7.	Sensor bridge current (sine and cosine)	I_{BRIDGE}			4.0	mA
1.2.1.8.	Capacitive load at outputs	C_{OUT}			20	nF
1.2.1.9.	Output pull-up or pull-down load	R_{LOAD}	5			kΩ
1.2.1.10.	Angular rate (mechanical)				1000	°/s
1.2.1.11.	EEPROM programming time for a single address (condition: $f_{DIGITAL}$ is within specification; see 1.3.1.7)	t_{PROG}	20			ms
1.2.1.12.	Data retention time of memory over lifetime at maximum average temperature 50°C	t_{RET}	17			years
1.2.1.13.	EEPROM endurance		200			cycles
1.2.1.14.	Range of differential input voltage (range of differential sensor output signal)	$V_{IN-RANGE}$			±23	mV/V
1.2.1.15.	Range of offset voltage at input that can be digitally compensated	$V_{OFFSET-COMP}$	-4		+4	mV/V
1.2.1.16.	Range of offset temperature compensation at input that can be digitally compensated	$T_{COEFF-RANGE}$	-4		+4	(µV/V)/K

Parameter		Symbol	Min	Typ.	Max	Unit
1.2.1.17.	Common mode input voltage range	CMR	30%		70%	V_{DDE}
1.2.1.18.	Waiting time after enabling EEPROM charge pump clock	$t_{VPP-RISE}$	1			ms

1) R_{THJA} = 160 K/W assumed.
2) With reduced performance.

1.3. Electrical Parameters

The following electrical specifications are valid for the operating conditions as specified in table 1.2 (T_A = -40°C to 160°C).

1.3.1. ZSSC5101 Characteristics

Table 1.3 Electrical Characteristics

Parameter		Symbol	Min	Typ.	Max	Unit
1.3.1.1.	Leakage current at VSINP, VSINN, VCOSP, and VCOSN pins	$I_{IN-LEAK}$			1	µA
1.3.1.2.	Leakage current at VOUT in high-impedance state	$I_{OUT-LEAK}$	-12		+12	µA
1.3.1.3.	Leakage current difference Vsinp/n, Vcosp/n [1)]	$I_{IN-DIFF-LEAK}$			35	nA
1.3.1.4.	Current consumption	I_{SUPPLY}			7	mA
1.3.1.5.	Peak current consumption at startup [1) 2)]	I_{PEAK}			10	mA
1.3.1.6.	Sensor supply voltage	V_{DDS}	3.8	4	4.2	V
1.3.1.7.	Internal digital master clock frequency (after calibration)	$f_{DIGITAL}$	1.5	1.6	1.8	MHz

1) Maximum characterized on samples, not measured in production.
2) ZSSC5101 can start with such a peak current for ramps of the power supply with a rise-up time > 100 µs.

1.3.2. Input Stage Characteristics

Table 1.4 Input Stage Characteristics

Parameter		Symbol	Conditions	Min	Typ.	Max	Unit
1.3.2.1.	Common mode rejection ratio	CMRR	Input frequency < 100Hz	60			dB
1.3.2.2.	Input preamp offset voltage drift	$TC_{VD\text{-}IN\text{-}OFFSET}$	With chopped amplifier			5	µV/K
1.3.2.3.	Input stage offset	INP_{OFFSET}	Referenced to *ADCaverage* register			±32	LSB_{ADC}
1.3.2.4.	Input differential nonlinearity	DNL_{ADC}	±2 LSB at 12-bit ADC (guaranteed monotony) 1)			±500	ppm
1.3.2.5.	Input integral nonlinearity	INL_{INPUT}	Half input range ±2 LSB at 12-bit ADC			±500	ppm
1.3.2.6.	Output referred noise		Full range input Referenced to ADC steps after average (16-bit *ADCaverageSin* register) 1)			16	LSB eff
1.3.2.7.	Gain low (programmable)			17.8	18	18.2	
1.3.2.8.	Gain high (programmable)			35.6	36	36.4	
1.3.2.9.	Gain matching between high and low gain					0.6	%
1.3.2.10.	Input noise voltage density		At bandwidth < 5kHz			100	nV/sqrt(Hz)

1) Refer to the *ZSSC5101 Application Note – Programming*.

1.3.3. Digital Calculation Characteristics

Table 1.5 Digital Calculation Characteristics

Parameter		Symbol	Condition	Min	Typ.	Max	Unit
1.3.3.1.	Input stage resolution	RES_{INPUT}			12		bit
1.3.3.2.	Resolution at offset measurement	RES_{OFFSET}			14		bit
1.3.3.3.	CORDIC calculation length				16		bit
1.3.3.4.	CORDIC accuracy for angle value			13			bit
1.3.3.5.	CORDIC accuracy for magnitude value			10			bit
1.3.3.6.	Channel switching frequency (i.e., the ADC conversion time)	f_{ADC}			1/16		$f_{DIGITAL}$
			With *average16not8* bit field in *eep_ctrl_manu* register [1)] set to '0'		1/32		$f_{DIGITAL}$
1.3.3.7.	Update rate of VOUT	f_{UPDATE}		2	3.125		kHz
1.3.3.8.	Channel time skew between sampling of sine and cosine channels	t_{SKEW}			1		$1/f_{ADC}$
1.3.3.9.	Digitally programmable output angular range	a_{MAX}	AMR sensors	5		180	° mech
			GMR, TMR	10		360	° mech
1.3.3.10.	Angular resolution		AMR sensors Vout = 5 to 95% VDDE	0.022		0.04	° mech
			GMR, TMR Vout = 5 to 95% VDDE	0.044		0.08	° mech
1.3.3.11.	Zero point adjustment range (digitally programmable)		AMR sensors	0		180	° mech
			GMR, TMR	0		360	° mech

Parameter		Symbol	Condition	Min	Typ.	Max	Unit
1.3.3.12.	Upper output clamping level	$V_{CLAMP-HIGH}$	Max. digital DAC value 4864, fixed resolution (see RES_{CLAMP} below)	40		95	%V_{DDE}
1.3.3.13.	Lower output clamping level	$V_{CLAMP-LOW}$	Min. digital DAC value 256, fixed resolution (see RES_{CLAMP})	5		30.5	%V_{DDE}
1.3.3.14.	Resolution of clamping levels (digitally programmable)	RES_{CLAMP}			1 / 5120 (1/4608 of output range)		V_{DDE}
1.3.3.15.	DAC resolution	RES_{DAC}			1 / 5120 (0.02% of VDDE)		V_{DDE}

1) Refer to the *ZSSC5101 Application Note – Programming*.

1.3.4. Analog Output Stage Characteristics (Digital to VOUT)

Table 1.6 Analog Output Stage Characteristics

Parameter		Symbol	Condition	Min	Typ.	Max	Unit
1.3.4.1.	Output voltage range	V_{OUT}	At full supply working range 4.5 V < V_{DDE} < 5.7 V	5		95	%V_{DDE}
1.3.4.2.	Error of upper and lower clamping level [1)]			-0.18		0.18	%V_{DDE}
1.3.4.3.	Output offset		Chopped output			±5	LSB_{DAC}
1.3.4.4.	Differential nonlinearity of DAC	DNL_{DAC}	Guaranteed monotony			±2	LSB_{DAC}
1.3.4.5.	Integral nonlinearity of DAC	INL_{DAC}				±3.9	LSB_{DAC}
1.3.4.6.	Output current	I_{OUT}	Analog output in Normal Operating Mode			3	mA
1.3.4.7.	Output current limit [2)]	$I_{OUT-LIMIT}$	Analog output			20	mA

1) Can be digitally compensated during calibration.
2) Overwrite-able for entering the Command Mode. See section 2.3.

1.3.5. Analog Input to Analog Output Characteristics (Full Path)

Table 1.7 Full Analog Path Characteristics

	Parameter	Symbol	Condition	Min	Typ.	Max	Unit
1.3.5.1.	Output voltage temperature drift	$V_{OUT-TEMP-DRIFT}$	For full angular range including complete function			1.6	mV
1.3.5.2.	Overall linearity error	INL_{ALL}	Full mechanical input range [1)] 5% to 95% VDDE output range 8.2 LSB of DAC, orthogonal analog input to analog output			±0.18	% V_{DDE}
1.3.5.3.	Output voltage noise	$V_{NOISE-OUT}$	With external low pass filter f_C = 0.7kHz			1.3	mVeff
1.3.5.4.	Propagation delay time to 90% output level change	$t_{PROP-DELAY}$	45°mech step for AMR, 90°mech step for GMR;TMR			1.8	ms
1.3.5.5.	Power-on time	t_{ON}	Time until first valid data on VOUT after V_{DDE} > V_{PW-ON} (see specification 1.3.7.2)	256			$1/f_{DIGITAL}$
						5	ms

1) Corresponds to 180° mechanical range for AMR sensors or 360° for GMR, TMR sensors.

1.3.6. Digital Interface Characteristics (CMOS compatible)

Table 1.8 gives the digital signal levels during one-wire interface (OWI) communication.

Table 1.8 Digital Interface Characteristics

	Parameter	Symbol	Condition	Min	Typ.	Max	Unit
1.3.6.1.	Input HIGH level	$V_{IN-HIGH}$		75%			V_{DDE}
1.3.6.2.	Input LOW level	V_{IN-LOW}				25%	V_{DDE}
1.3.6.3.	Output HIGH level	$V_{OUT-HIGH}$	$I_{OUT-HIGH}$ = 2mA	90%			V_{DDE}
1.3.6.4.	Output LOW level	$V_{OUT-LOW}$	$I_{OUT-LOW}$ = 2mA			10%	V_{DDE}
1.3.6.5.	Switching level	V_{SWITCH}			50%		V_{DDE}
1.3.6.6.	Hysteresis of Schmitt-triggers on VOUT pin	$V_{OUT-ST-HYST}$	Centered around V_{SWITCH}	10		16	%V_{DDE}

1.3.7. Supervision Circuits

See section 2.4 for details for specifications in Table 1.9 that are related to power-up/power-down characteristics.

Table 1.9 Supervision Circuits

Parameter		Symbol	Condition	Min	Typ.	Max	Unit
1.3.7.1.	Time to enter Command Mode [1)]	t_{CODE}	Start-up sequence	16	20	26	ms
1.3.7.2.	Power watch on-level [2)]	$V_{PW\text{-}ON}$		4.05	4.30	4.45	V
1.3.7.3.	Power watch off-level [3)]	$V_{PW\text{-}OFF}$		3.9	4.2	4.3	V
1.3.7.4.	Hysteresis on/off	V_{HYST}	$V_{HYST} = V_{PW\text{-}ON} - V_{PW\text{-}OFF}$	100		350	mV
1.3.7.5.	Power-on level [4)]	V_{ON}		2.4	2.7	3.3	V
1.3.7.6.	Lower diagnostic range	$V_{DIAG\text{-}LOW}$	Fixed as DAC value 96			4%	V_{DDE} (min)
1.3.7.7.	Upper diagnostic range	$V_{DIAG\text{-}HIGH}$	Fixed as DAC value 5024	96%			V_{DDE} (min)

1) After power-on, device checks for correct signature until t_{CODE} expires.
2) If V_{DDE} is above this level, VOUT is on in Normal Operating Mode.
3) If V_{DDE} is below this level, VOUT is set to the defined Diagnostics Mode.
4) If V_{DDE} is equal to or below this level, VOUT is in reset state or diagnostics LOW state (see Table 2.1).

1.3.8. Power Loss Circuit

Table 1.10 Power Loss Circuit

Parameter		Symbol	Condition	Min	Typ.	Max	Unit
1.3.8.1.	Output impedance at VOUT for power loss	$R_{P\text{-}LOSS}$	VDDE – VSSE < 0.7V Corresponds to diagnostics range for pull-up/pull-down ≥ 5kΩ			200	Ω

2 Circuit Description

2.1. Overview

The ZSSC5101 is a sensor signal conditioner and encoder for magnetoresistive sensor bridges. In a typical set-up for rotational or linear motion, the sensor bridges provide two sinusoidal signals, which are phase-shifted by 90° (Vsin and Vcos). The ZSSC5101 converts these two signals into a linear voltage ramp, proportional to the rotation angle or linear distance by means of a CORDIC (Coordinate Rotation Digital Computer) algorithm.

The output voltage V_{OUT} (see specification 1.3.4.1) is ratiometric to V_{DDE}; the typical supply voltage is 5V ±10%.

Using the ZSSC5101's one-wire interface (OWI), a sensor assembly containing an xMR sensor bridge and the ZSSC5101 can be connected to a host controller by means of just three wires:

- V_{DDE} (4.5 to 5.5V)
- VOUT (sensor output and programming input)
- V_{SSE} (ground)

The VOUT pin is used for sensor output, programming, and diagnostics for the ZSSC5101 through the OWI (see section 2.3). All parameters are stored in a nonvolatile memory (EEPROM) and can be read and re-programmed by the user.

By using the output pin for programming, no additional wires are required to calibrate the sensor. This facilitates in-line programming and re-programming of fully assembled sensor modules.

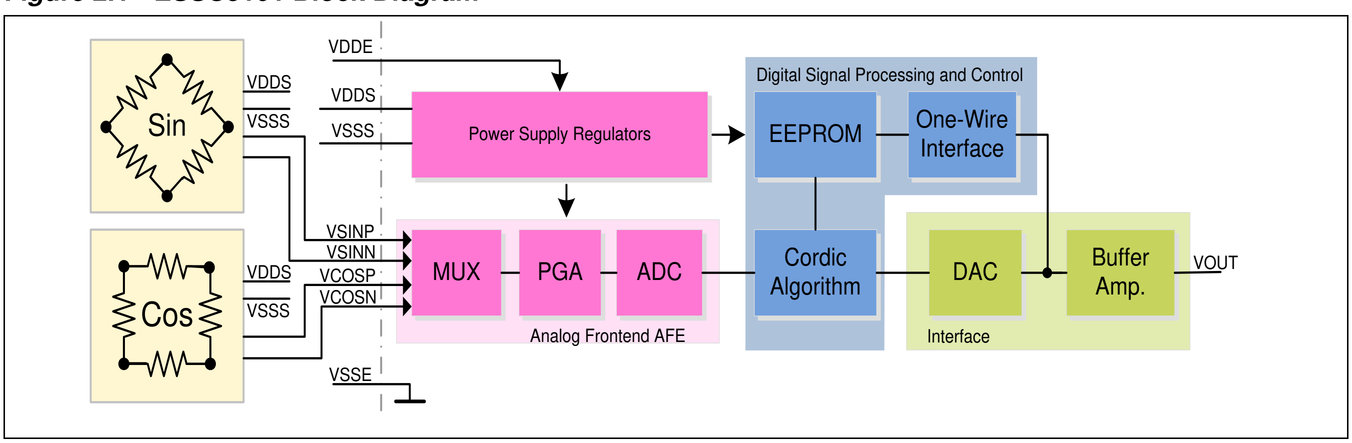
The ZSSC5101 also provides failure mode detection, such as broken supply or broken ground detection. In Normal Operating Mode, the output voltage ranges from ≥5% V_{DDE} to ≤95% V_{DDE}. Both clamping levels are programmable (see specifications 1.3.3.12 and 1.3.3.13).

In the case of failure detection, the output voltage will be outside the normal operating range (<4%V_{DDE} and >96%V_{DDE}).

2.2. Functional Description

Figure 2.1 provides the block diagram for the ZSSC5101. See section 11 for the definitions of the abbreviations.

Figure 2.1 ZSSC5101 Block Diagram



The ZSSC5101 is supplied by a single supply voltage V_{DDE} of 5V ±10%. Internal low-dropout linear voltage regulators (LDOs) generate the required analog and digital supply voltages as well as the supply voltage for the sensor bridge, VDDS.

The ZSSC5101 accepts fully differential signals from both sine and cosine sensor bridges. These signals are connected to the VSINP, VSINN pins and the VCOSP, VCOSN pins, respectively.

Both sine and cosine signals are then multiplexed, sequentially pre-amplified, and sampled by a 12-bit ADC. The xMR COS/SIN-bridge circuitry is alternately sampled at a frequency of ~200kHz to ensure an identical signal conversion in both sine and cosine paths.

Following data conversion, the digital sine and cosine values representing X and Y rectangular coordinates are converted into their respective polar coordinates, phase, and magnitude by means of coordinate transformation using a CORDIC algorithm.

Phase information ranges from 0 to 2π, which is equivalent to one full wave of the input signal. This information is further used to calculate the analog output voltage, depending on the user-programmable settings, such as zero position or angle range. See section 4.3 for further details.

The **magnitude information** is equivalent to the strength of the input signal (Vpeak). This information is further used to determine a “magnet loss” error state. See section 2.6 for further details.

Based on the calculated phase information and the user-programmed zero, slope, and clamping parameters, the corresponding output values are calculated and routed to the DAC input. The DAC output is driven by a buffer amplifier and routed to the output pin VOUT.

2.3. One-Wire Interface and Command Mode (CM)

In Normal Operating Mode (NOM), the VOUT pin is a buffered, analog output, providing an output voltage equivalent to the sensor input signals.

Because the same pin is used for programming via the OWI, a specific sequence is required to put the ZSSC5101 into command / programming mode (CM):

- After power-on, the circuit starts in NOM and provides a valid output signal after t_on.
- In parallel, the ZSSC5101 monitors the VOUT pin for a valid signature command from the programming system to enable the Command Mode (authorization). Therefore, the programming system must be able to overdrive the output buffer with a driver strength greater than $I_{OUT-LIMIT}$ (see 1.3.4.7).
- The ZSSC5101 can only be unlocked by receiving a predefined user-programmable signature. This signature is stored in the EEPROM in a write-only register.
- If CM is active, the output buffer is switched to *high impedance and communication over the one-wire interface is enabled.*
- The time frame to enter CM with a valid signature command is limited to t_{CODE}, but it is always open in Diagnostics Mode (see section 2.6).
- Digital data transmission over the one-wire-interface bus is accomplished using PWM-coded signals. For further information on the OWI protocol, please contact IDT technical support (see contact information on page 28).

2.4. Power-Up/Power-Down Characteristics

Table 2.1 describes the behavior of the ZSSC5101 during ramp-up and ramp-down of the power supply voltage V_{DDE}. See Table 1.7 and Table 1.9 for the timing and voltage specifications. In each condition, the ZSSC5101 is in a defined state, which is a substantial feature for safety-critical applications.

Table 2.1 Output Modes during Power-Up and Power-Down

V_{DDE} Voltage Range [V]	Description	Behavior at VOUT
0.0 to 1.5	The ZSSC5101 is in reset state.	Active driven output to a voltage level between 0 and VDDE/2
1.5 to 2.5	VOUT is driven to LOW state.	Diagnostics LOW level
2.5 to 4.2	If $V_{DDE} > V_{ON}$, the power-on reset is released and all modules are activated.	Diagnostics Mode (see section 2.6)
4.2 to 4.5	If $V_{DDE} > V_{PW\text{-}ON}$, VOUT is turned on after t_{ON} and drives the last calculated angle value from the DAC. If $V_{DDE} < V_{PW\text{-}OFF}$, the ZSSC5101 enters Diagnostics Mode; however, brief voltage drops are ignored.	Analog output with reduced accuracy
4.5 to 5.7	Normal operation range.	Normal Operation Mode Analog output with specified accuracy

2.5. Power Loss / GND Loss

2.5.1. Purpose

In NOM, the output voltage of the ZSSC5101 is within the range of 5%VDDE ≤ VOUT ≤ 95% VDDE.

In the event of a loss of VDDE or VSSE, for example due to a broken supply wire, the output voltage VOUT will be driven into the diagnostics range, which is a voltage level outside of the normal operating range. This makes a power loss easily identifiable by the host controller.

The diagnostic levels are defined as

- Diagnostics LOW level: VOUT <= 4% VDDE; see specification 1.3.7.6
- Diagnostics HIGH level: VOUT >= 96% VDDE; see specification 1.3.7.7

2.5.2. Power Loss Behavior

In order to ensure that the output can be safely driven to the Diagnostics Mode levels, a pull-up or pull-down resistor ≥ 5kΩ must be connected at the receiving side of the VOUT signal.

Table 2.2 Power Loss Behavior

External Resistor	VDDE Loss	VSSE Loss
Pull-Up ≥ 5kΩ	Diagnostics LOW level	Diagnostics HIGH level
Pull-Down ≥ 5kΩ		

2.6. Diagnostics Mode (DM)

In addition to the power loss indication described above, the ZSSC5101 also indicates other error states by switching the output VOUT into Diagnostics Mode. These errors are described in Table 2.3.

Table 2.3 Diagnostics Mode

Error Source	Error Condition	Error De-activation
Loss of input signal	Loss of magnet; magnitude is below a pre-programmed threshold	Magnitude must be above the threshold; power-on reset
EEPROM	CRC error	Power-on reset
EEPROM	EEPROM read failure	Power-on reset
DAC	No valid DAC values	Valid DAC values are available
Supply voltage	Low V_{DDE}; $V_{DDE} < V_{PW\text{-}OFF}$; see specification 1.3.7.3	VDDE > $V_{PW\text{-}ON}$; see specification 1.3.7.2

The state of the Diagnostics Mode is programmable in the EEPROM, it has the following options:

- Diagnostics LOW level
- Diagnostics HIGH level
- High impedance (in this setting, external pull-up or pull-down resistors must be connected to VOUT)

3 EEPROM

The ZSSC5101 contains a non-volatile EEPROM memory for storing manufacturer codes and calibration values as well as user-programmable data. Access to the EEPROM is available over the output pin VOUT by using IDT's one-wire interface (see section 2.3).

3.1. User Programmable Parameters in EEPROM

Table 3.1 shows the user accessible settings of the EEPROM. These settings are used to adjust the analog output VOUT to the mechanical movement range and provide space for a user-selectable identification number.

Table 3.1 EEPROM — User Area

Function	Description
Zero angle	Mechanical zero position
Magnet loss	Threshold that defines when the magnet loss error diagnostic state is turned on/off
Angular range slope	Multiplication factor for determining the slope of the analog output
Clamp low and high	Upper and lower clamping levels when the mechanical angle is at the minimum, maximum, or outside of the normal operation range
User ID	32-bit user-selectable identification number
Clamp switch angle	Angle position at which the output changes the clamping level state
Slope direction	Rising or falling slope of output voltage vs. rotation; clockwise or counterclockwise operation
PGA gain	Input preamplifier gain: low/high
Diagnostics Mode	VOUT state in Diagnostics Mode: LOW, HIGH, or high impedance

For detailed information about EEPROM programming and register settings, refer to the *ZSSC5101 Application Note – Programming*.

3.2. CRC Algorithm

EEPROM data is verified by implementing an 8-bit cyclic redundancy check (CRC).

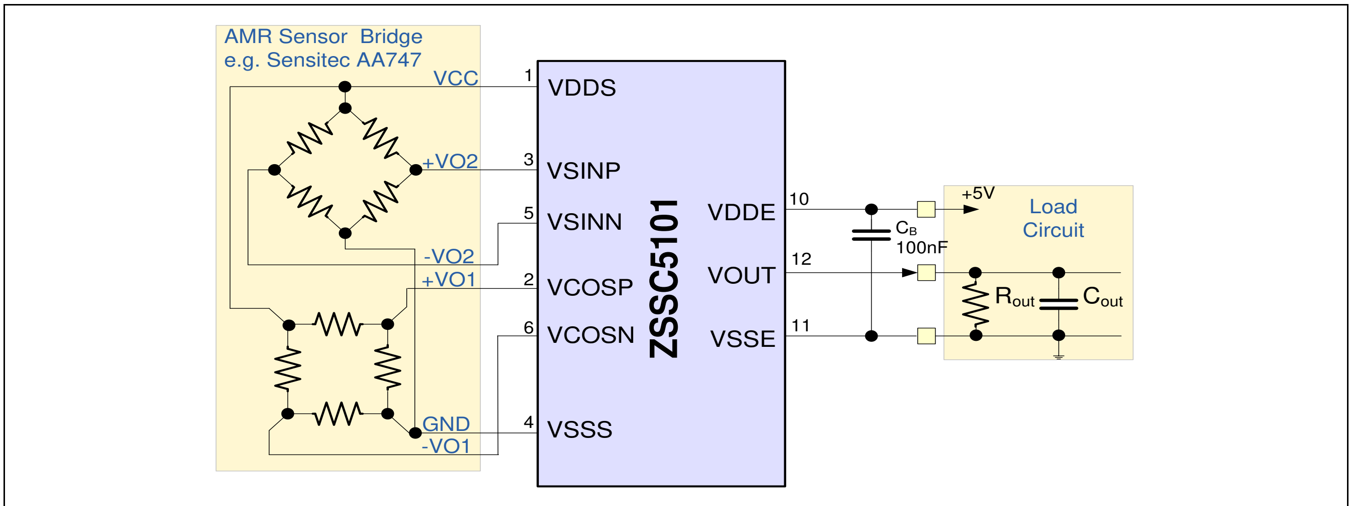
3.3. EDC Algorithm

The EEPROM is protected against bit errors through an error detection and correction (EDC) algorithm. The protection logic corrects any single-bit error in a data word and can detect all double-bit errors. A single-bit error is corrected, and the ZSSC5101 continues in Normal Operating Mode. On detection of a double-bit error, the ZSSC5101 enters the Diagnostics Mode.

4 Application Circuit Examples

4.1. Typical Application Circuit for AMR Double Wheatstone Sensor Bridges

Figure 4.1 ZSSC5101 with AMR Sensor Bridge

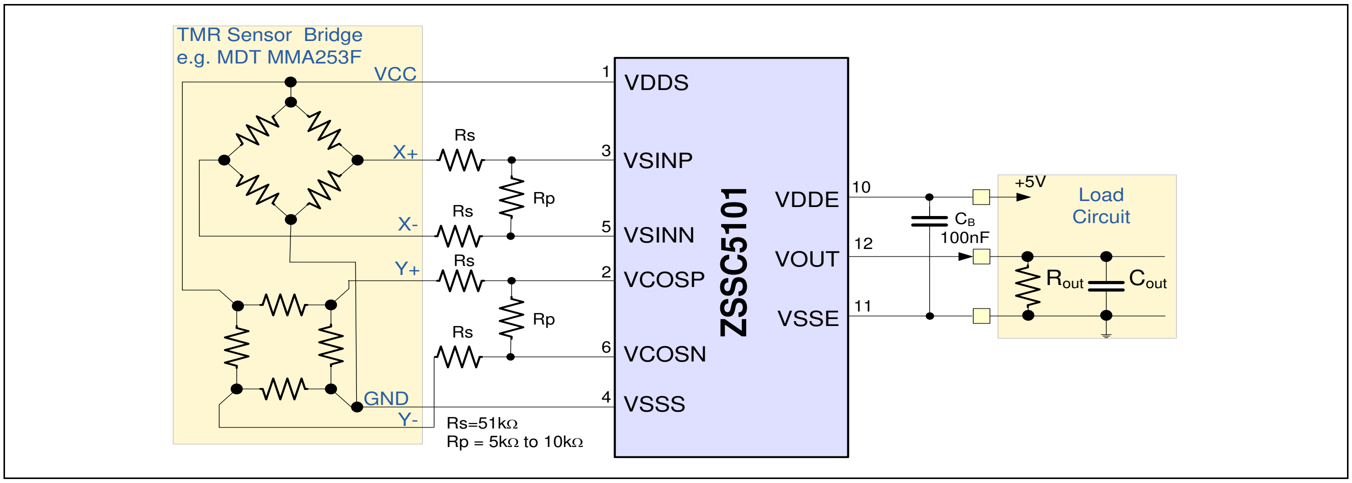


The circuit diagram in Figure 4.1 shows a typical application for the ZSSC5101 with an AMR double Wheatstone sensor bridge. Due to the nature of AMR sensors, the periodicity of these sensor signals is 180 mechanical degrees.

The sensor bridges are mechanically rotated by 45° from each other, providing differential output signals that are 90 electrical degrees apart. The ZSSC5101 converts these sine and cosine signals into a linear output voltage with a programmable full-scale angle range from 0° to 5° up to 0° to 180° with a resolution of 0.022° to 0.04° per step (see specification 1.3.3.10). The ZSSC5101 accepts sensor signals with a sensitivity up to ±23mV/V (see specification 1.2.1.14), which is sufficient for a typical AMR sensor bridge. No external components are required at the sensor inputs.

4.2. Typical Application Circuit for TMR Sensor Bridges

Figure 4.2 ZSSC5101 with TMR Sensor Bridge



The circuit diagram in Figure 4.2 shows a typical application for the ZSSC5101 with two TMR sensor bridges. TMR and GMR sensors have a periodicity of 360 mechanical degrees; therefore this configuration can be used to measure the absolute angle of a full mechanical turn.

The sensor bridges are mechanically rotated by 90° from each other, providing differential output signals that are 90 electrical degrees apart. The ZSSC5101 converts these sine and cosine signals into a linear output voltage with a programmable full-scale angle range from 0° to 10° up to 0° to 360° with a resolution of 0.044° to 0.08° per step (see specification 1.3.3.10). As a TMR sensor bridge has a much higher sensitivity than an AMR Sensor (up to 2 orders of magnitude), a resistive divider consisting of 2x Rs and Rp is added to each sensor input channel (sin, cos) of the ZSSC5101 to match the sensor bridge with the ZSSC5101 inputs.

For best temperature compensation, Rs and Rp should have the same temperature coefficient TC and routed close together on the same printed circuit board (PCB).

4.3. Mechanical Set-up for Absolute Angle Measurements

Figure 4.3 shows a typical set-up for an absolute rotation angle measurement. A diametrically magnetized magnet is mounted at the end of a rotating shaft with a specific gap. The rotation axis of the magnet is centered over the xMR sensor (see sensor manufacturer’s data sheet for exact location). Depending on the maximum angle to be measured, the sensor can be either an AMR sensor with a maximum absolute angle of 180° or a TMR/GMR sensor with a maximum absolute angle of 360° (see 4.1 and 4.2 for further details).

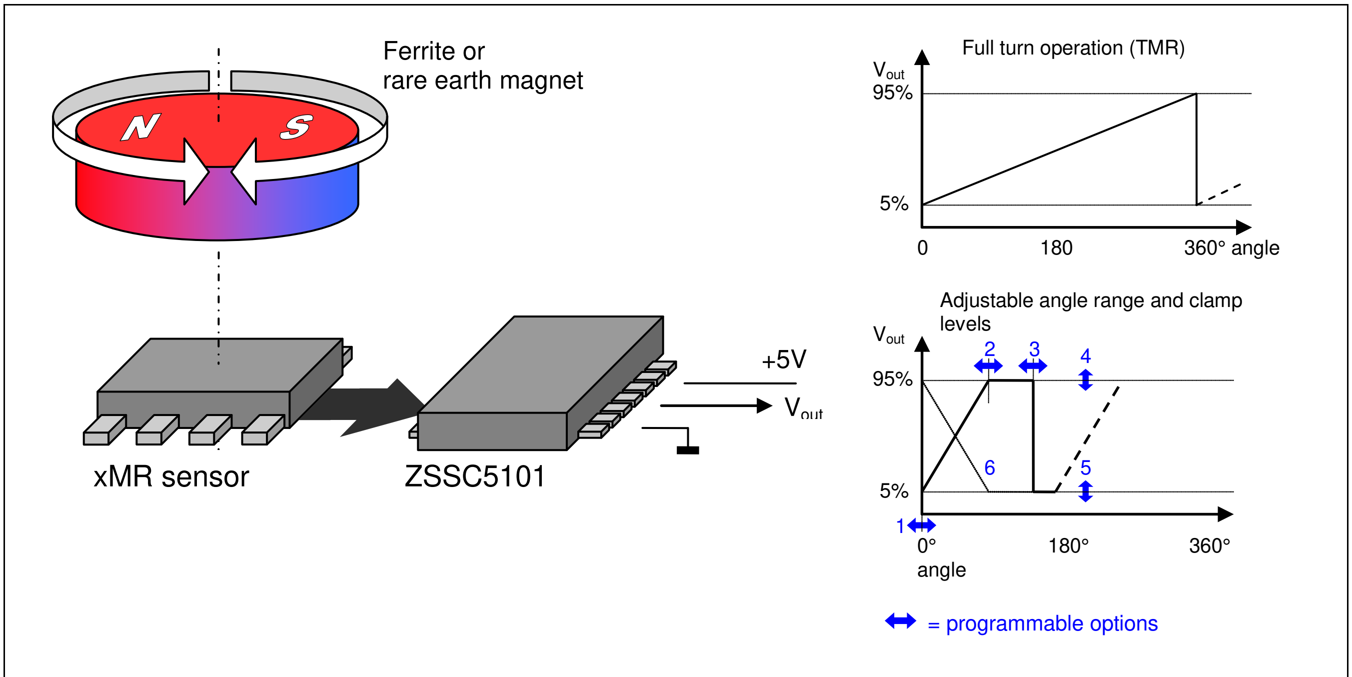
The ZSSC5101 converts the sine and cosine signals generated by the xMR sensor bridge into a linear ramp that is proportional to the rotation angle.

The gap between magnet and sensor is determined by the strength of the magnet and the type of sensor. Stronger magnets allow larger air gaps, and due to their higher sensitivity, TMR sensors allow larger air gaps than AMR sensors. The air gap should be chosen such that the sensor output signal remains undistorted and sinusoidal.

In order to adjust the linear ramp to the mechanical angle range, the ZSSC5101 provides several programmable parameters. These parameters are stored in an on-chip EEPROM and can be re-programmed by the user (see Figure 4.3):

- Zero angle position: aligns the mechanical zero position to the electrical zero position
- Maximum angle position: matches the full stroke of the ramp to the mechanical angular range
- Clamp switch angle: defines the angle position where the output voltage returns from $V_{out,max}$ to $V_{out,min}$
- Maximum output voltage, upper clamping level $V_{out,max}$
- Minimum output voltage, lower clamping level $V_{out,min}$
- Ramp direction: rising or falling ramp

Figure 4.3 Mechanical Set-up for Rotational Measurements and Programming Options



4.4. Mechanical Set-up for Linear Distance Measurements

Figure 4.4 shows a typical set-up for a linear distance measurement. The xMR sensor provides a sinusoidal signal that is proportional to the length of a magnetic pole (AMR) or to the length of a magnetic pole pair (TMR). The graph shown below shows a setup for an AMR sensor (e.g., Sensitec AA700 family; www.sensitec.com, Measurement Specialties KMT series, www.meas-spec.com).

As the magnet is moving on a linear path, one output ramp is generated with each pole; hence an absolute linear distance measurement is possible within the length of one pole:

$$absolute\_position = L_P * \frac{V_{out} - V_{out,\min}}{V_{out,\max} - V_{out,\min}}$$

where: L_P = pole length of the sensor magnet

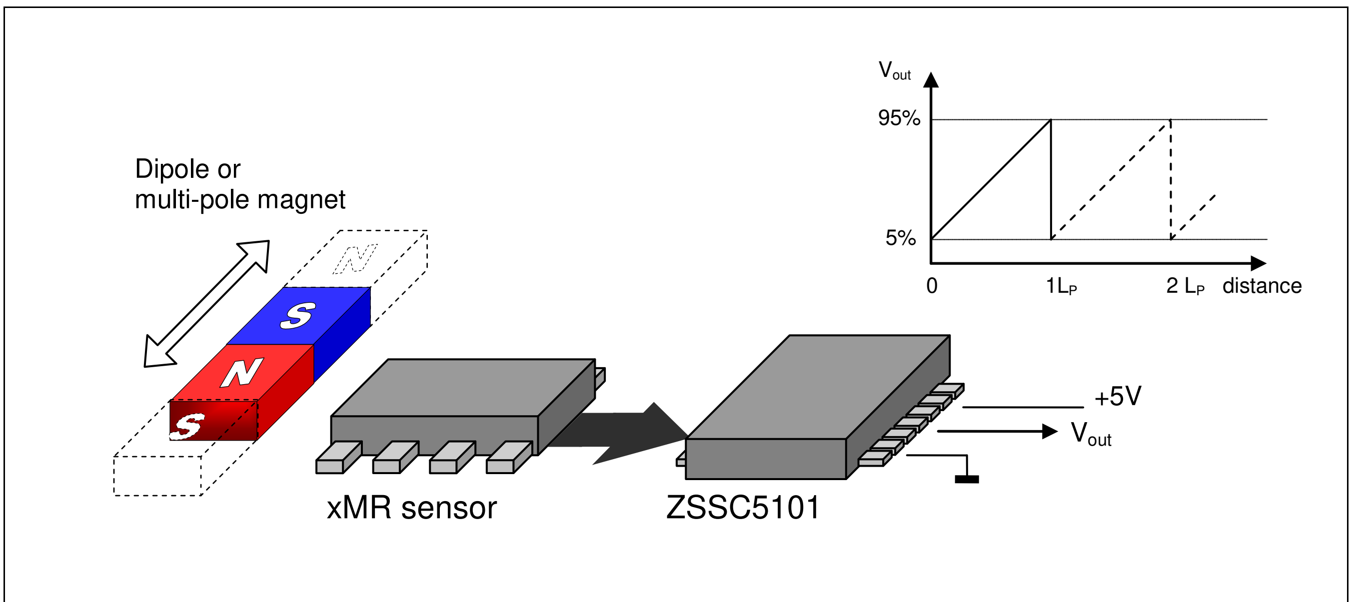
V_{OUT} = output voltage of the ZSSC5101

$V_{OUT,max}$ = maximum output clamping voltage of ZSSC5101 (programmable; e.g. 95% VDD)

$V_{OUT,min}$ = minimum output clamping voltage of ZSSC5101 (programmable; e.g. 5% VDD)

Longer linear distances can be measured by using multi-pole magnetic strips and by counting the number of ramps from a defined home position. Each full ramp ($V_{OUT,min}$ to $V_{OUT,max}$) corresponds to the length of one magnetic pole.

Figure 4.4 Mechanical Set-up for Linear Distance Measurements and Programming Options



4.5. Input-to-Output Characteristics Calculation Examples

Figure 4.5 shows a detailed view of the possible settings for clamping levels, zero position, ramp slope, and clamp switch angle.

The total output range VOUT from 0 to 100% VDDE is 5120 DAC steps.

In the normal operating range (5 to 95% VDDE), the DAC output can range from 256 to 4864, allowing 4608 steps (12.17bit) for the analog output voltage.

The full-scale angular range is 180° for AMR sensors and 360° for GMR and TMR sensors. Consequently, the full-scale angular step resolution is

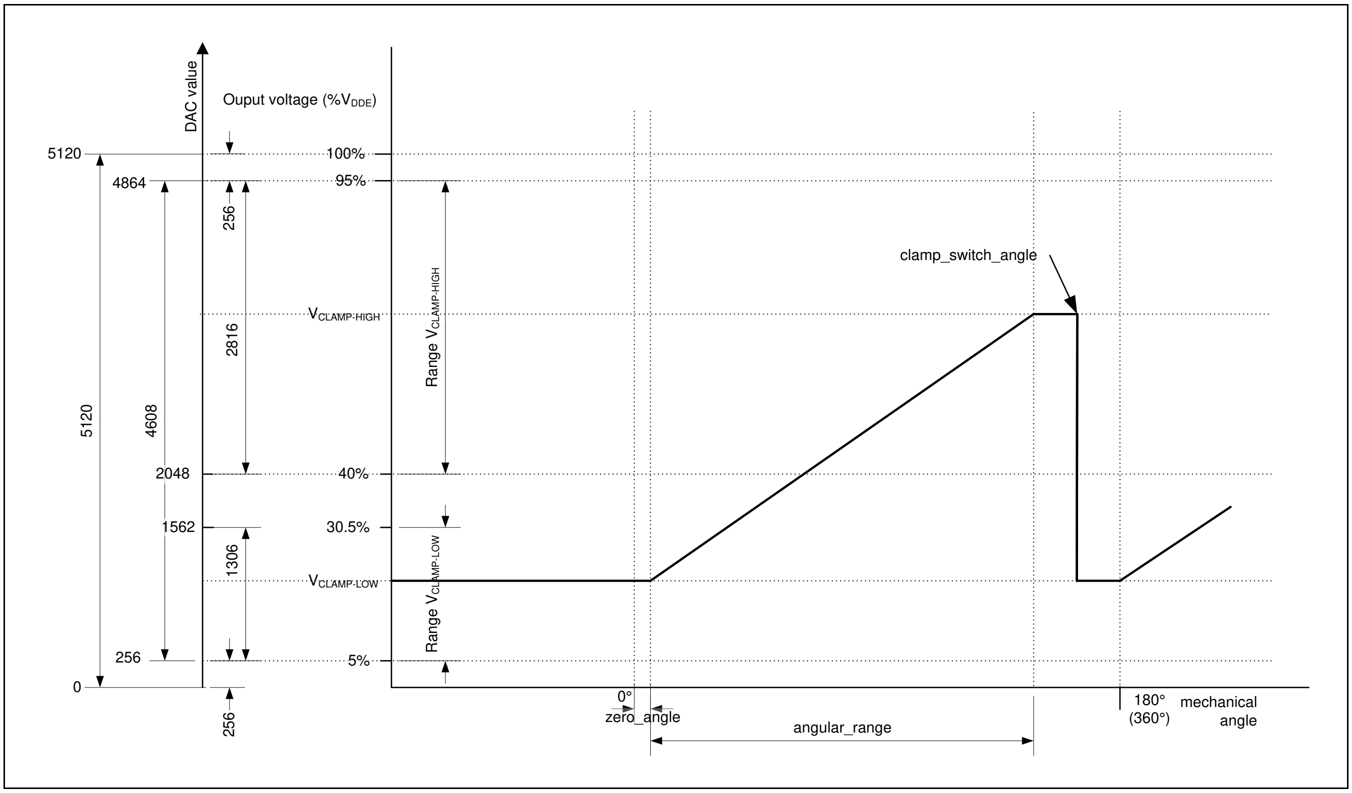
180°/4608 = 0.039 mechanical degrees for AMR sensors and

360°/4608 = 0.078 mechanical degrees for GMR and TMR sensors

Smaller angular ranges result in a finer angular step resolution. The smallest angle step is 0.022° (= 180°/8192). For example, a total stroke of 30° (e.g., in a pedal application) will yield the following results:

30°/0.022° = 1365 steps (using an AMR sensor)

Figure 4.5 Input-to-Output Characteristics with Parameters



5 ESD and Latch-up Protection

5.1. Human Body Model

The ZSSC5101 conforms to standard MIL-STD-883D Method 3015.7, rated at 4000V, 100pF, 1.5kΩ according to the Human Body Model. This protection is ensured at all external pins (VOUT) including the device supply (VDDE, VSSE). ESD protection on all other pins (VDDS, VSSS, VSINP, VSINN, VCOSP, VCOSN) is up to 2000V.

5.2. Machine Model

The ZSSC5101 conforms to standard EIA/JESD22-A115-A, rated at 400V, 200pF, and 0kΩ according to the machine model. This protection is ensured at all external pins (VOUT) including device supply (VDDE, VSSE). ESD protection on all other pins (VDDS, VSSS, VSINP, VSINN, VCOSP, VCOSN) is up to 200V.

5.3. Charged Device Model

The ZSSC5101 conforms to standard AEC Q100 (Rev. F) and EIA/JESD22/C101, rated at 750V for corner pins and 500V for all other pins (class C3B) according to the Charge Device Model. This protection is ensured at all external pins,

5.4. Latch-Up

The ZSSC5101 conforms to EIA/JEDEC Standard No. 78.

6 Pin Configuration and Package Dimensions

The ZSSC5101 is available in a SSOP14 green package or as bare die.

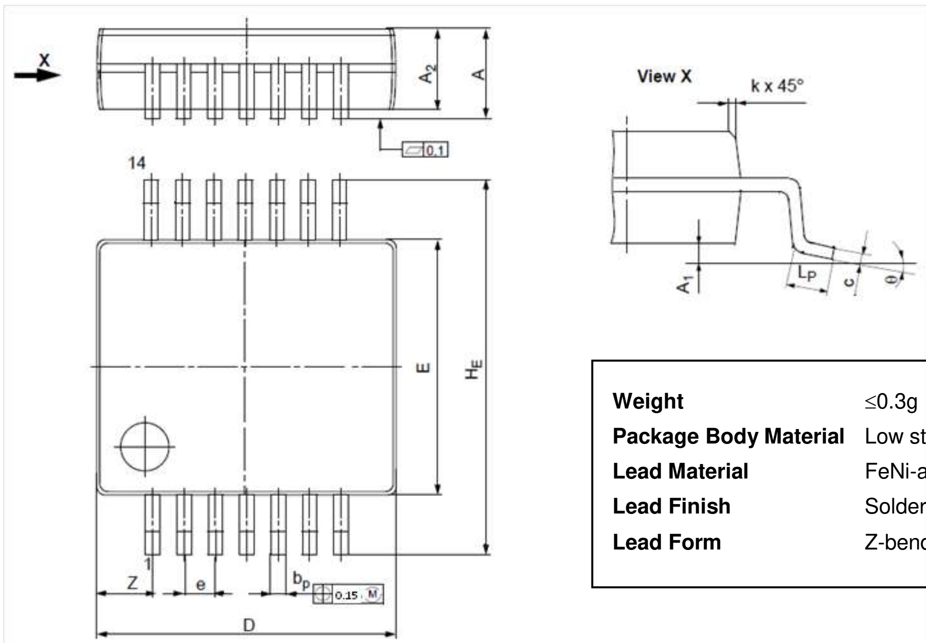
Table 6.1 Pin Configuration

Pin No Die	Pin No SSOP-14	Pin Name	Description	Notes
1	10	VDDE	Positive analog supply voltage	Positive supply voltage, 5V ±10%
2	11	VSSE	Negative analog supply voltage	Negative supply voltage, must connect to GND
3	12	VOUT	Analog output/one-wire interface (OWI)	
4	1	VDDS	Positive sensor supply voltage	
5	2	VCOSP	Positive sensor signal cosine channel input	
6	3	VSINP	Positive sensor signal sine channel input	
7	4	VSSS	Negative sensor supply voltage	
8	5	VSINN	Negative sensor signal sine channel input	
9	6	VCOSN	Negative sensor signal cosine channel input	
	7	N.C.	Unconnected pin	Must be left open
	8	TEST	Factory test pin	Must be left open
	9	N.C.	Unconnected pin	Must be left open
	13	N.C.	Unconnected pin	Must be left open
	14	TEST	Factory test pin	Must be left open

6.1. Package Drawing – SSOP-14

The SSOP-14 package is a delivery option for the ZSSC5101. The package dimensions based on the JEDEC JEP95: MO-150 standard illustrated in Figure 6.1.

Figure 6.1 Package Dimensions – SSOP-14



Weight	≤0.3g
Package Body Material	Low stress epoxy
Lead Material	FeNi-alloy or Cu-alloy
Lead Finish	Solder plating
Lead Form	Z-bends

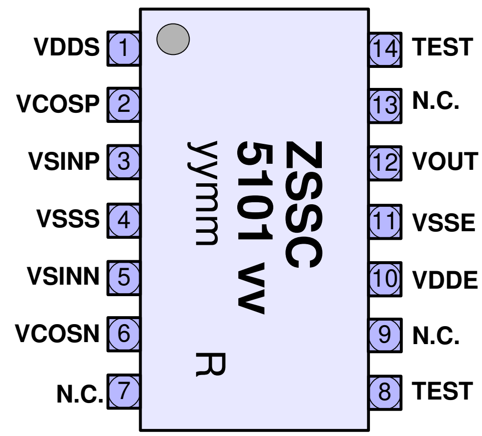
Dimension	Minimum	Maximum
A	1.73	1.99
A_1	0.05	0.21
A_2	1.68	1.78
b_P	0.25	0.38
c	0.09	0.20
D *	6.07	6.33
e	0.65 nominal	
E *	5.20	5.38
H_E	7.65	7.90
k	0.25	
L_P	0.63	
θ	0°	10°
* Without mold-flash		

Figure 6.2 Pin Map and Pad Position of the ZSSC5101 SSOP-14 Package

Package SSOP-14

Package marking codes:

vv	Version code
yymm	Manufacturing date: **yy** = last two digits of year **mm** = two digits for month
R	indicates RoHS compliance



6.2. Die Dimensions and Pad Coordinates

Die dimensions and pad coordinates are available on request in a separate document. See section 10.

7 Layout Requirements

Recommendation: Keep the traces between the xMR sensor and the ZSSC5101 (VDDS, VSSS, VSINP, VSINN, VCOSP, and VCOSN pins) as short as possible. Additional resistors for using TMR sensors (see Figure 4.2) should have the same temperature coefficient TC and be routed close together on the same PCB.

8 Reliability and RoHS Conformity

The ZSSC5101 is qualified according to the AEC-Q100 standard, operating temperature grade 0.

The ZSSC5101 complies with the RoHS directive and does not contain hazardous substances.
The complete RoHS declaration update can be downloaded at www.IDT.com.

9 Ordering Information

Sales Code	Description	Delivery Package
ZSSC5101BE1B	ZSSC5101 Die – Temperature range: -40°C to +160°C	8" tested wafer, unsawn, thickness = 390 ±15µm
ZSSC5101BE2B	ZSSC5101 Die – Temperature range: -40°C to +160°C	8" tested wafer, unsawn, thickness = 725 ±15µm
ZSSC5101BE3B	ZSSC5101 Die – Temperature range: -40°C to +160°C	8" tested wafer, unsawn, thickness = 250 ±15µm
ZSSC5101BE1C	ZSSC5101 Die – Temperature range: -40°C to +160°C	8" tested wafer, sawn on frame, thickness = 390 ±15µm
ZSSC5101BE4R	ZSSC5101 SSOP-14 – Temperature range: -40°C to +150°C	13" tape and reel
ZSSC5101BE4T	ZSSC5101 SSOP-14 – Temperature range: -40°C to +150°C	Tube
ZSSC5101 KIT	ZSSC5101 Evaluation Kit including USB Communication Board, ZSSC5101 AMR board, adapters. Software can be downloaded from www.IDT.com/ZSSC5101 after free customer login, which is described in section 10 (see the *ZSSC5101 Evaluation Kit and GUI Description* for details).	

10 Related Documents

Document
ZSSC5101 Feature Sheet
*ZSSC5101 Evaluation Kit and GUI Description **
*ZSSC5101 Technical Note – Die Dimensions ***
*ZSSC5101 Application Note – Programming ***

Visit the ZSSC5101 product page www.IDT.com/ZSSC5101 or contact your local sales office for the latest version of these documents.

* Note: Documents marked with an asterisk (*) require a free customer login account.

** Note: Documents marked with two asterisks (**) are available only on request.

11 Glossary

Term	Description
AFE	Analog Frontend
AMR	Anisotropic Magnetoresistance
CM	Command Mode
CORDIC	Coordinate Rotation Digital Computer
DAC	Digital-to-Analog Converter
DM	Diagnostic Mode
EDC	Error Detection and Correction
GMR	Giant Magnetoresistance
INL	Integral Nonlinearity
LDO	Low-Dropout Linear Voltage Regulators
MUX	Multiplexer
NOM	Normal Operating Mode
OWI	One-Wire Interface
PCB	Printed Circuit Board
THJA	Junction to Ambient Thermal Resistance
TMR	Tunnel Magnetoresistance

12 Document Revision History

Revision	Date	Description
1.00	August 25, 2014	First release document
1.10	September 10, 2014	Add package drawing
1.20	April 13, 2015	Updates for INL_{DAC}, TMR application schematic, pin names. Addition of package marking codes in Figure 6.2. Removal of references to half-bridge applications. Corrections for step number in section 4.5 and Figure 4.5. Update for contact information. Minor edits for clarity.
1.21	April 17, 2015	Correction for maximum temperature for SSOP-14.
1.22	April 29, 2015	Removal of reference to amplitude calibration on page 1.
	January 22,2016	Changed to IDT branding.

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