Contents

List of Figures

List of Tables

1. Introduction

This document describes the procedures for setting up the IDT ZMID520x internal memory and transmitter (Tx) front-end in order to start measurements with the device in user applications. It describes the settings needed to prepare the device for operation and then gives an internal memory overview.

The steps provided here are needed when configuring a new device in a user application. These procedures can also be applied to any of the ZMID520x application modules provided by IDT; however this is typically not needed because the sensor has been fully configured before the module is shipped.

Recommendation: Read the *ZMID520x Datasheet* before using this document for a better understanding of the ZMID520x:
https://www.idt.com/document/dst/zmid520x-datasheet

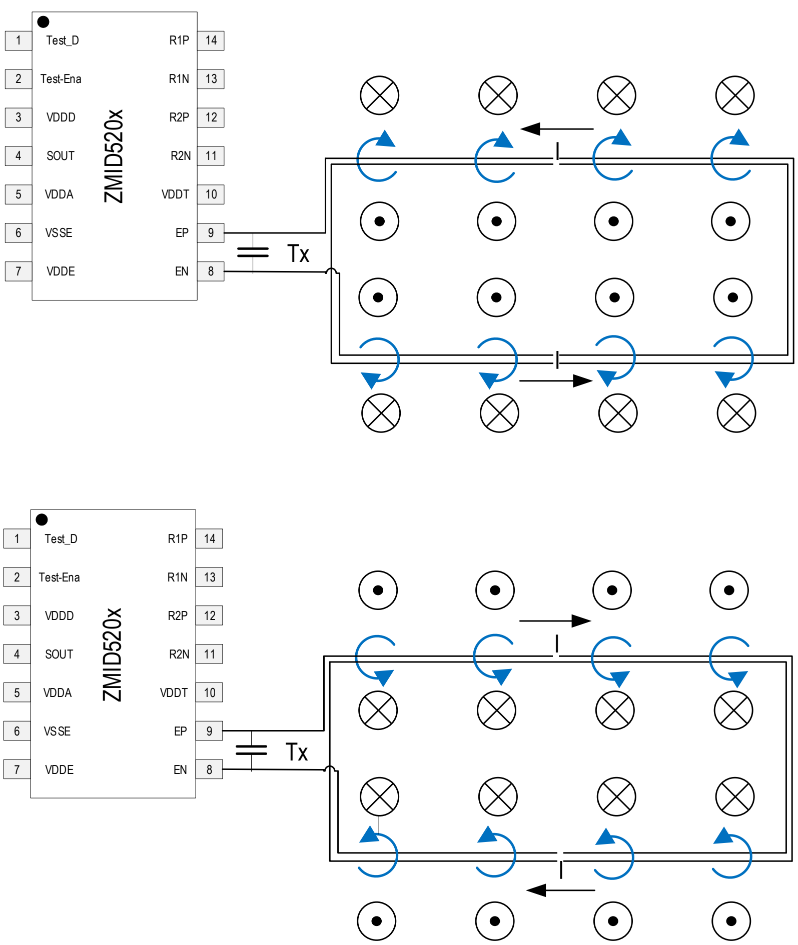
Information on the OWI interface can be found in the *ZMID520x Technical Brief – One Wire Interface (OWI)*.

2. Inductive Sensing Technology Introduction

This section provides some basic principles for inductive position sensing using the ZMID520x family of products, and it covers how the required magnetic fields are generated.

In the application, an LC oscillator generates a magnetic field in the transmit wire loop. The frequency of the oscillation is tuned by the capacitance Ct. The polarity of the magnetic field depends on the direction of the current in the loop.

Figure 1. Tx Loop Magnetic Field



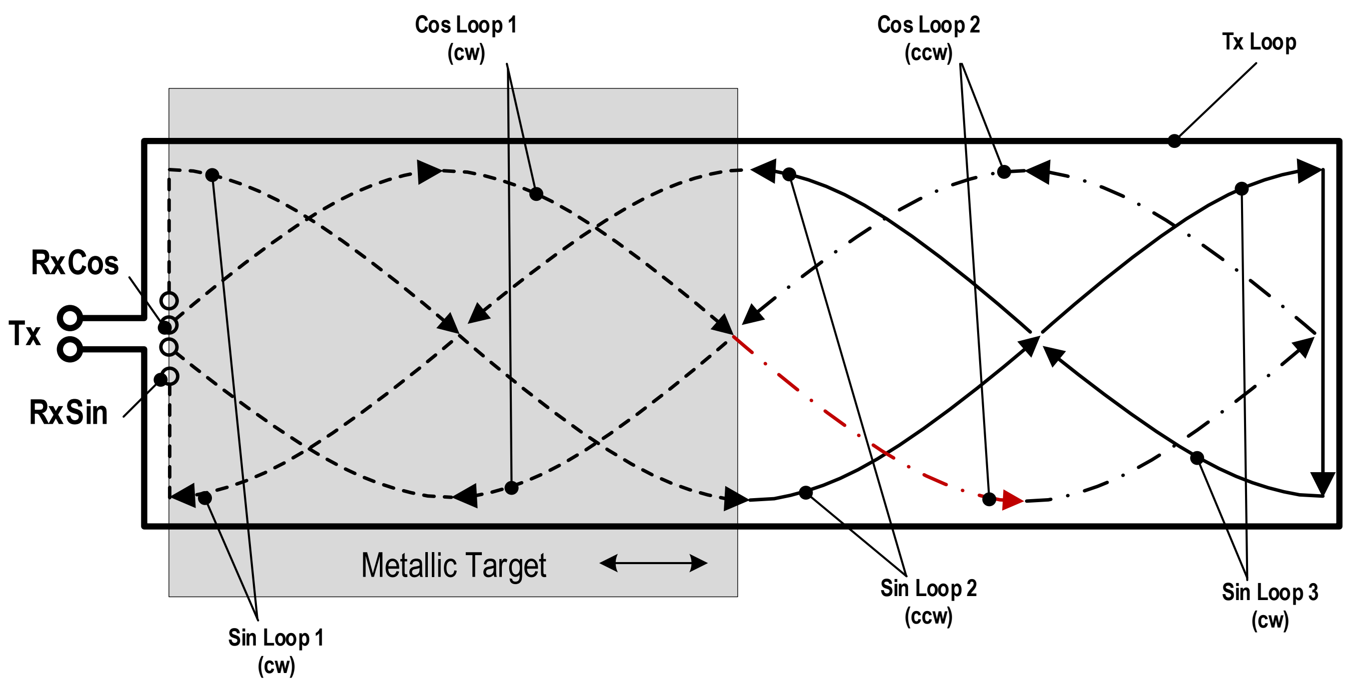
The signal that is generated by the magnetic field of transmitter coil (Tx) is received by two receiver coils.

If a metallic target is placed over the coils, the transmitted energy below the target is dissipated as eddy currents in the target and does not induce a secondary voltage in the receiver coils in that area.

The two receiver coils are designed with a 90° phase shift, and the transmitter coil surrounds them. The target is placed on top of them and moves over a plane parallel to the plane containing all the coils, as shown in Figure 2 below. Depending on the coil's shape, movement can be linear, arc, or rotary. The same physical principle is valid for different coils (and target) shapes.

The position of the target will be indicated through the differential phase and the amplitude of the signals measured on the Rx coils by the ZMID520x

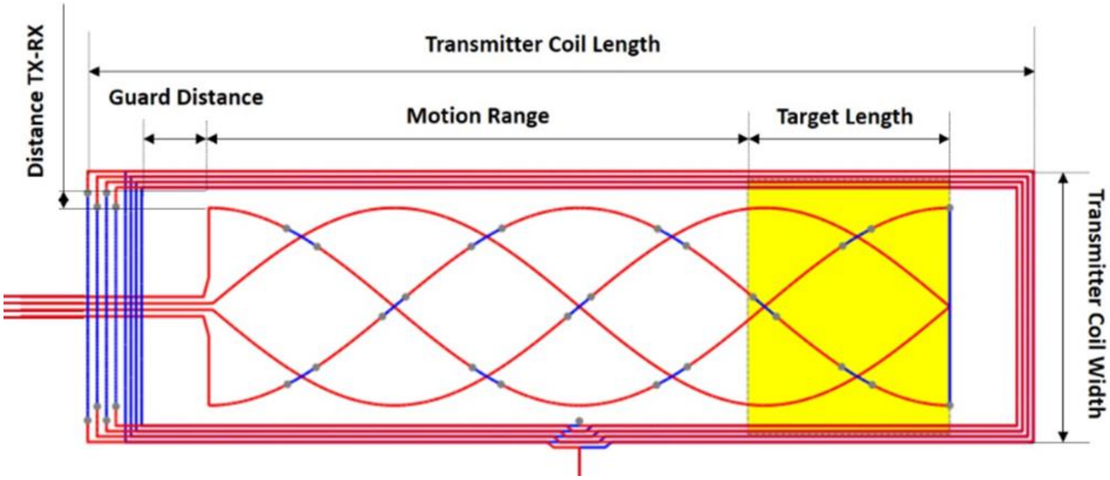
Figure 2. Current Paths and Shapes for Coils – Example for Linear Position Sensing



The key parameters influencing the proper operation of coils with the ZMID520x are the following: the length and width of the Tx and Rx coils, the size of the target, and the airgap between the target and the printed circuit board (PCB) where the coils are integrated. Figure 3 provides an illustration of the length and width of the coils for linear position sensing.

Figure 3. Geometrical Illustration for Coils and Target – Example for Linear Position Sensing

Note: The following display was created by the *ZMID520x Inductive Coil Design Tool Software.*



IDT provides a software tool to support coil design as illustrated in Figure 3:

- *ZMID520x Inductive Coil Design Tool Software*: https://www.idt.com/document/swr/zmid520x-inductive-coil-design-tool-software
- *ZMID520x User Guide – Inductive Coil Design Tool*: https://www.idt.com/document/mas/zmid520x-user-guide-inductive-coil-design-tool

Reference designs for linear, arc and rotary position sensors are shown in the "Layout" section of the applicable *Application Modules User Manual* available on the following application module product pages, which also provide relevant Gerber design files:

ZMID520xMLIN Application Module:

www.idt.com/products/sensor-products/position-sensors/zmid5201mlin-zmid5201-inductive-linear-application-module-analog-output

www.idt.com/products/sensor-products/position-sensors/zmid5202mlin-zmid5202-inductive-linear-application-module-pwm-output

www.idt.com/products/sensor-products/position-sensors/zmid5203mlin-zmid5203-inductive-linear-application-module-sent-output

ZMID520xMARC Application Module:

www.idt.com/products/sensor-products/position-sensors/zmid5201marc-zmid5201-inductive-arc-application-module-analog-output

www.idt.com/products/sensor-products/position-sensors/zmid5202marc-zmid5202-inductive-arc-application-module-pwm-output

www.idt.com/products/sensor-products/position-sensors/zmid5203marc-zmid5203-inductive-arc-application-module-sent-output

ZMID520xMROT Application Module:

www.idt.com/products/sensor-products/position-sensors/zmid5201mrot-zmid5201-inductive-rotary-application-module-analog-output

www.idt.com/products/sensor-products/position-sensors/zmid5202mrot-zmid5202-inductive-rotary-application-module-pwm-output

www.idt.com/products/sensor-products/position-sensors/zmid5203mrot-zmid5203-inductive-rotary-application-module-sent-output

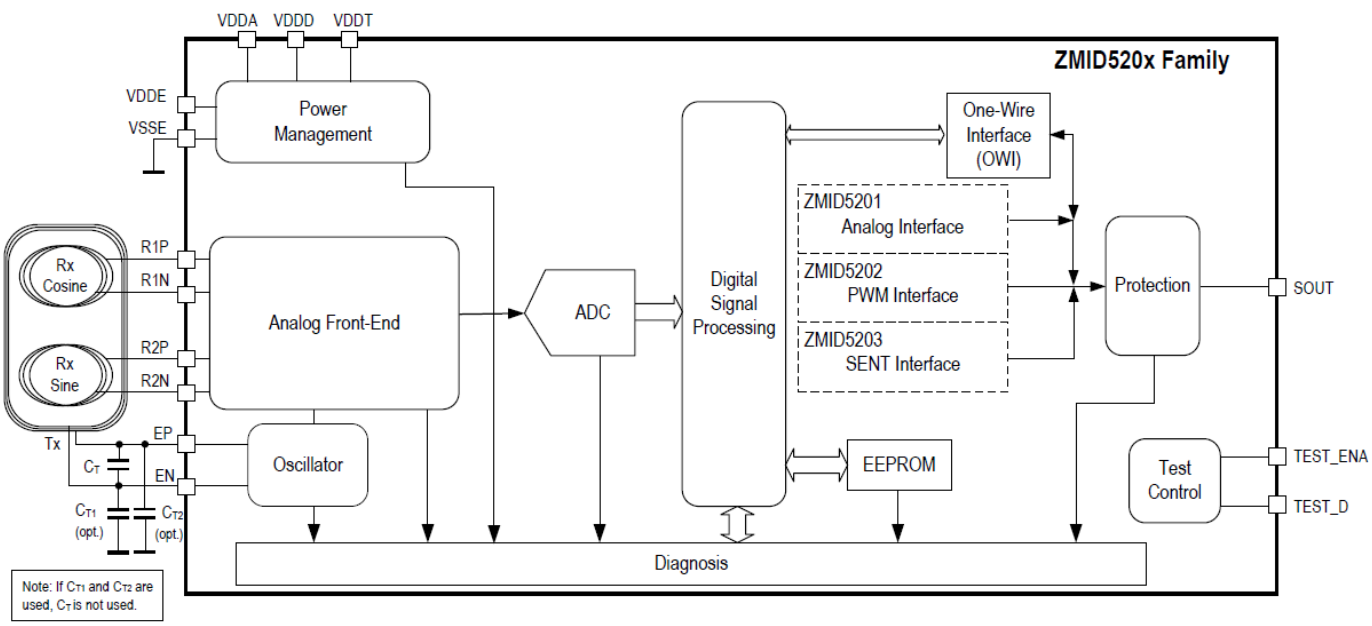
2.1 Device Block Diagram

Refer to the *ZMID520x Datasheet* for the latest block diagram information.

The main building blocks include the following:

- Power management: power-on-reset (POR) circuit and low drop-out (LDO) regulators for internal supplies.
- Oscillator: generation of the transmit 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 for ZMID5201
  - PWM output for ZMID5202
  - SENT output for ZMID5203
- Protection: overvoltage, reverse polarity, short circuit protection.

Figure 4. Main Internal Functional Block Diagram



3. Getting Started

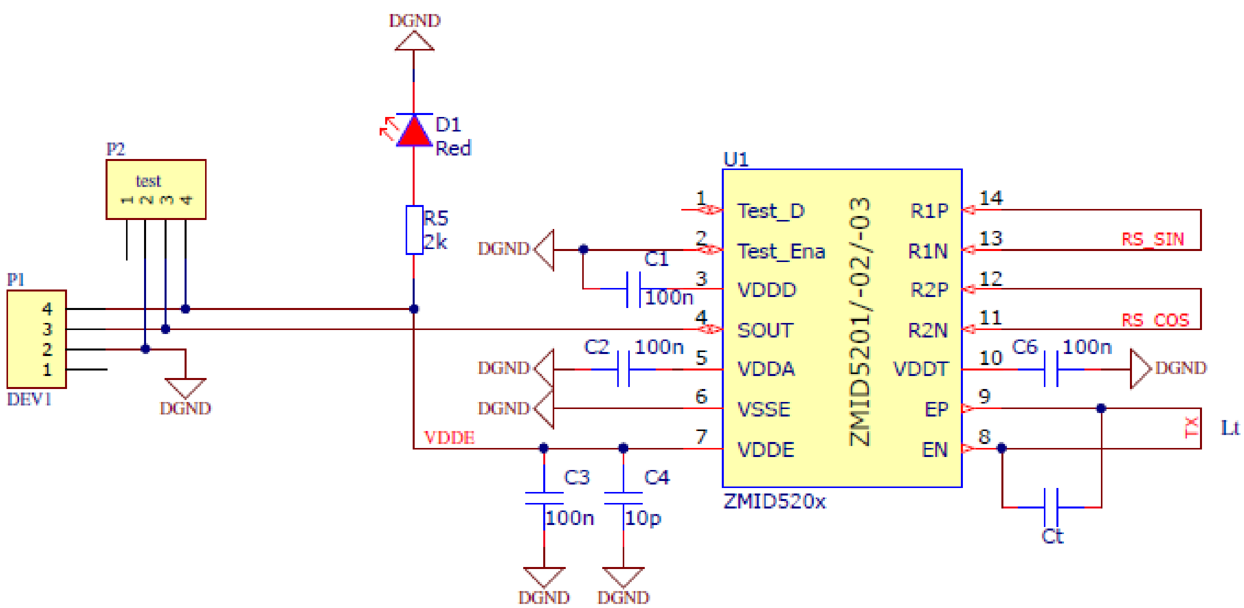
The following procedures require the *ZMID520x EVK Application Software*, which includes the graphical user interface (GUI) provided for the ZMID520x Application Modules.

A complete description of the GUI is given in the *ZMID520x Evaluation Kit User Manual,* which is available on the IDT website via the following link, and it includes instructions for downloading and installing the GUI: https://www.idt.com/document/man/zmid520x-evaluation-kit-user-manual-application-modules.

3.1 LC Tank – Tx Front-End Tuning

The transmit circuitry for ZMID520x applications consists of an LC tank that is formed from the inductance of the transmitting coil and a capacitor on the circuit board as shown in Figure 5.

Figure 5. ZMID520x Transmitter LC Tank



The objective of the Tx front-end tuning is to set the oscillation frequency in the range of operation specified in the *ZMID520x Datasheet*; a typical value is approximately 3.5MHz.

The first step is to measure the inductance value of the Tx coil and verify that the value is within the limits specified in the *ZMID520x Datasheet.* Once the inductor value is known, the capacitor value (Ct in Figure 5) can be calculated using Equation 1.

$$f = \frac{1}{2\pi\sqrt{LC}}$$ **Equation 1**

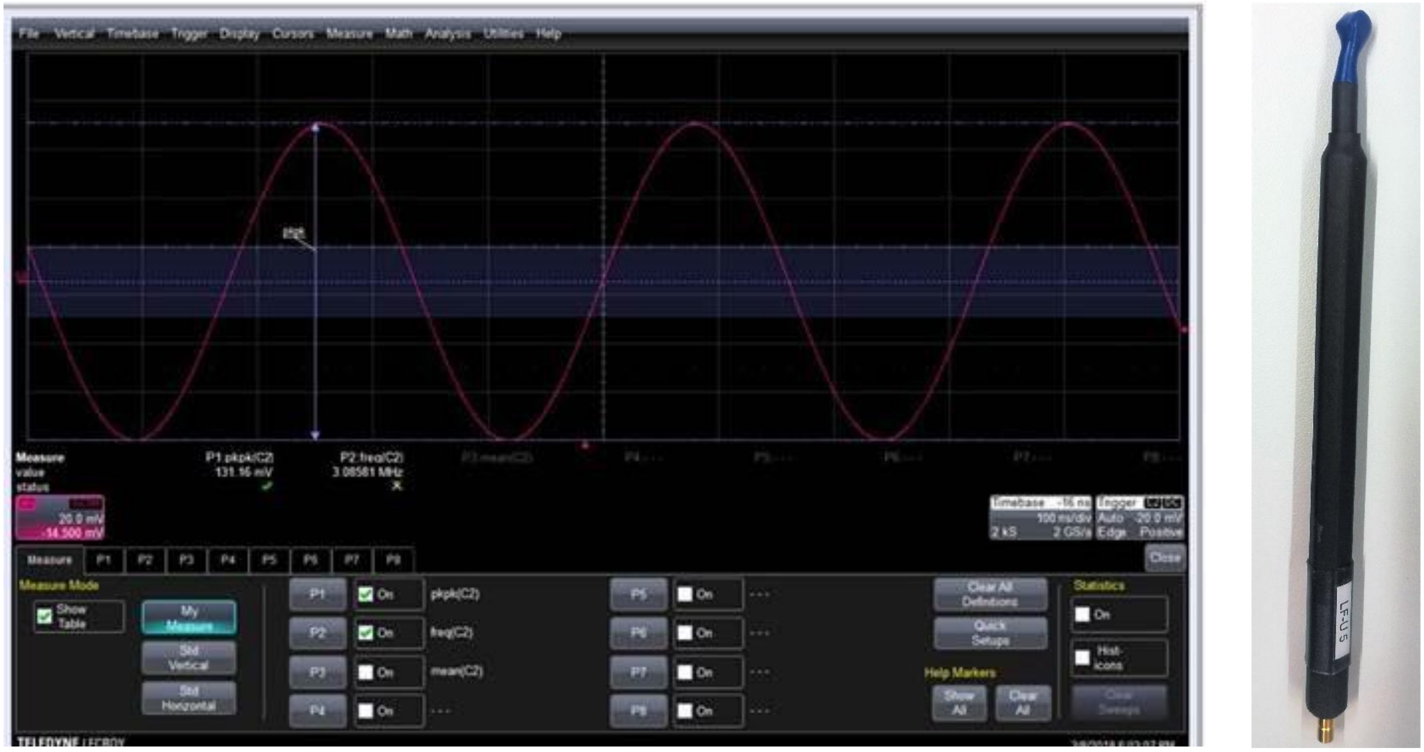
Direct measurement of the frequency will confirm the exact value of the oscillation frequency.

If the measurement of the inductance of the printed circuit board coil (Lt in Figure 5) is not an option, a successive approximation approach can be used; i.e., testing multiple Ct values until the resulting oscillation frequency is as close as possible to 3.5MHz. A capacitor value of 560pF is generally a good starting point.

Recommendation: To ensure a good quality factor and low temperature drift for the LC tank circuit, use ceramic capacitors class C0G (C-zero-G) ceramics also known as NP0 (negative-positive-zero). The capacitor must be placed close to the EP and EN pins on the ZMID520x.

Figure 6 shows the TX pin oscillation detected with a LF-U 5 Near-Field Probe from Langer EMV-Technik.

Figure 6. TX Oscillation and LF-U 5 Probe



3.2 Device Initialization

3.2.1 Output Mode Selection

The ZMID allows selecting one of two output modes: Linear or Modulo 360.

- Linear: The Linear Output Mode is a non-repeating output mode in which the sensor output signal is clamped at the mechanical end points.
- Modulo 360: The Modulo 360 Output (Sawtooth Output) Mode is a repeating output mode in which the sensor output signal is not clamped at the mechanical end points, but it is switched back to its origin.

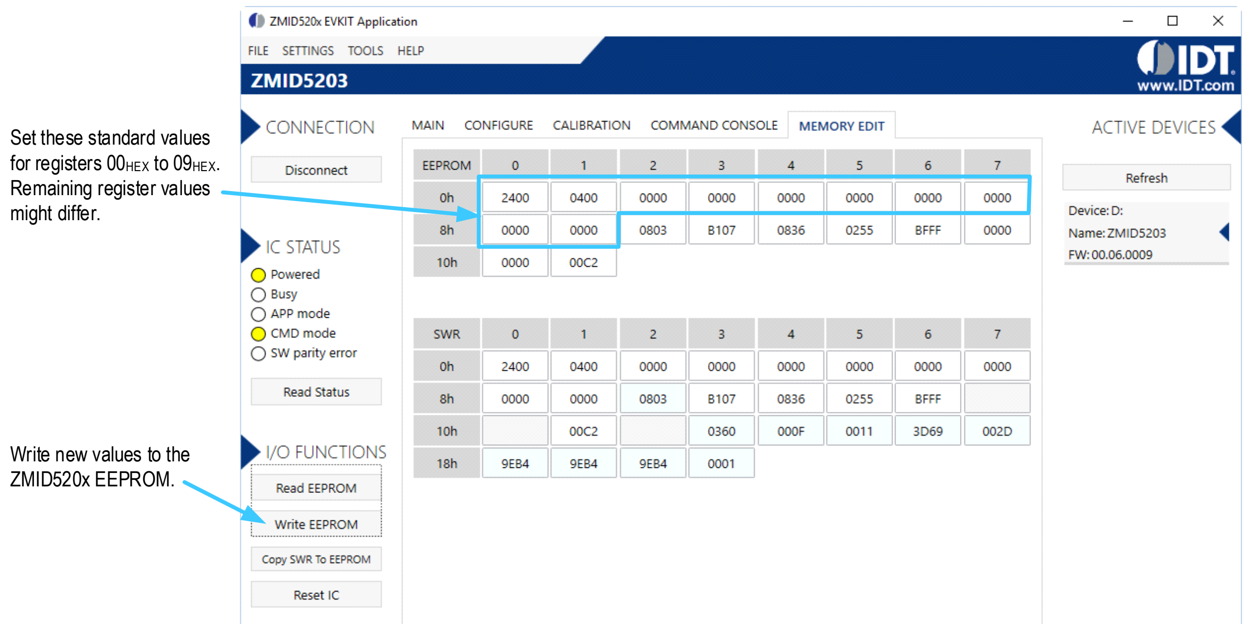
See the *ZMID520x Datasheet* and *ZMID520x EVK User Manual* for further details.

In most linear and arc applications, the Linear Output Mode is recommended. For rotary applications, the Modulo 360 Mode is recommended.

To ensure a smooth and successful procedure, use the GUI and the instructions in the *ZMID520x EVK User Manual* to set the ZMID520x EEPROM registers from 00_{HEX} to 09_{HEX} to the following values. Note: Ensure that the new values are stored in EEPROM using the "Write EEPROM" function.

- If using the Linear Output Mode, set the following register values as shown in Figure 7: register 00_{HEX} = 2400_{HEX}; register 01_{HEX} = 0400_{HEX}; and registers 02_{HEX} through 09_{HEX} = 0000_{HEX}.
- If using the Modulo 360 Output Mode, set register 00_{HEX} = 0000_{HEX}, register 01_{HEX} = 0400_{HEX}, registers 02_{HEX} through 08_{HEX} = 0000_{HEX}, and register 09_{HEX} = 1000_{HEX}.

Figure 7. ZMID520x EEPROM Memory Values – ZMID5203 Example for the Linear Output Mode Settings

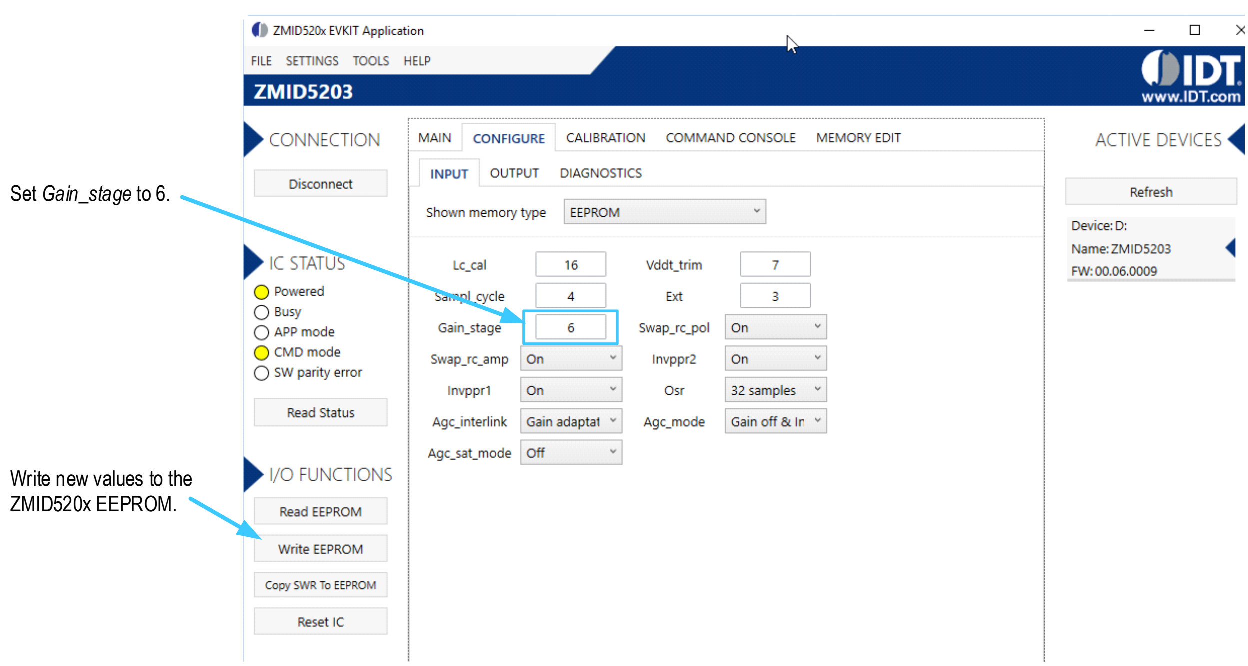


3.3 Offset Check for Rx Coils

The ZMID520x has a selectable input gain, which can be set via the GUI using the *Gain_stage* entry field found on the "INPUT" subtab under the "CONFIGURE" tab as described in section 3.4. Before checking the offset of the Rx coils, set the *Gain_stage* value to a preliminary setting of 6 using the entry field shown in the example for the ZMID5203 given in Figure 8, which is applicable to all ZMID520x ICs.

Save the new value in the ZMID520x EEPROM memory by clicking the "Write EEPROM" button, which updates register $0C_{HEX}$.

Figure 8. ZMID520x EEPROM Gain Stage Setting – Example using the ZMID5203

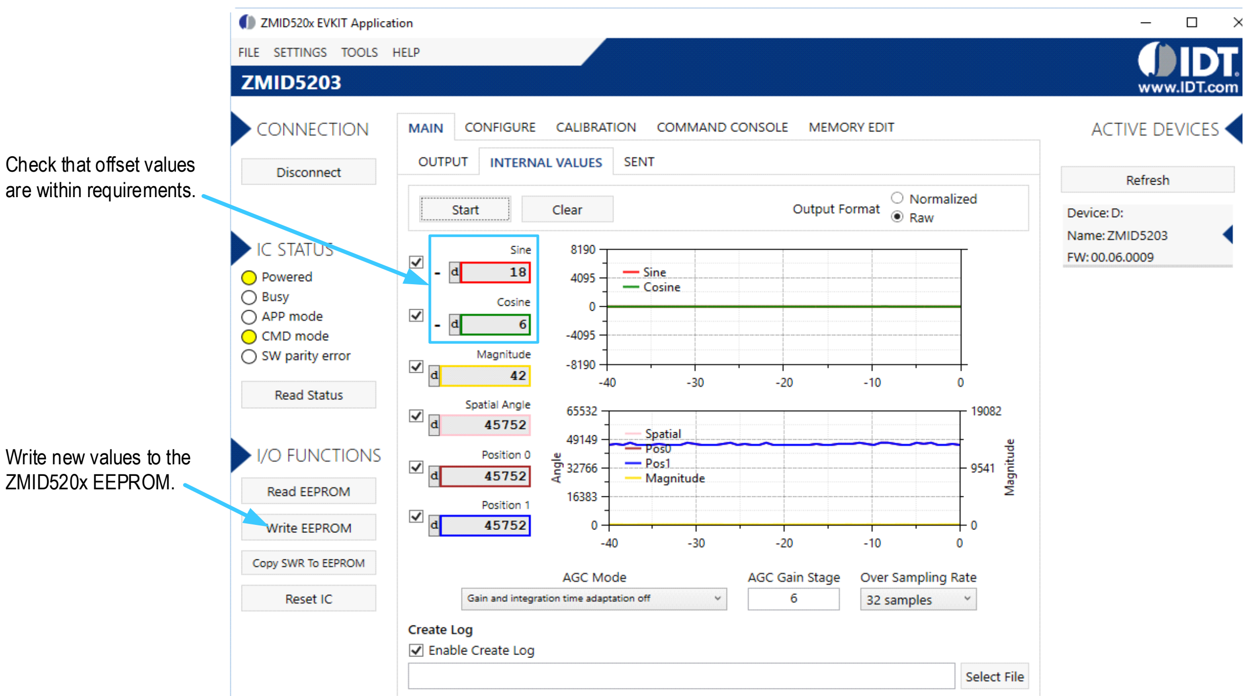


Next, remove the target from the sensor board (distance between the target and the Rx coils must be greater than 20mm). With this condition, use the GUI to read the “Sine” and “Cosine” values on the “INTERNAL VALUES” subtab under the “MAIN” tab as shown in the ZMID5203 example given in Figure 9.

For properly designed coils, typical offset values are below 100_{DEC} for “Sine” and “Cosine” values as shown in the example in Figure 9.

The coil design should meet the criteria of having a maximum symmetry for the two Rx coils. See section 2 for the links for software and documentation for the *ZMID520x Inductive Coil Design Tool Software* provided by IDT for addressing this requirement.

Figure 9. Coil Offset Reading – Example using the ZMID5203

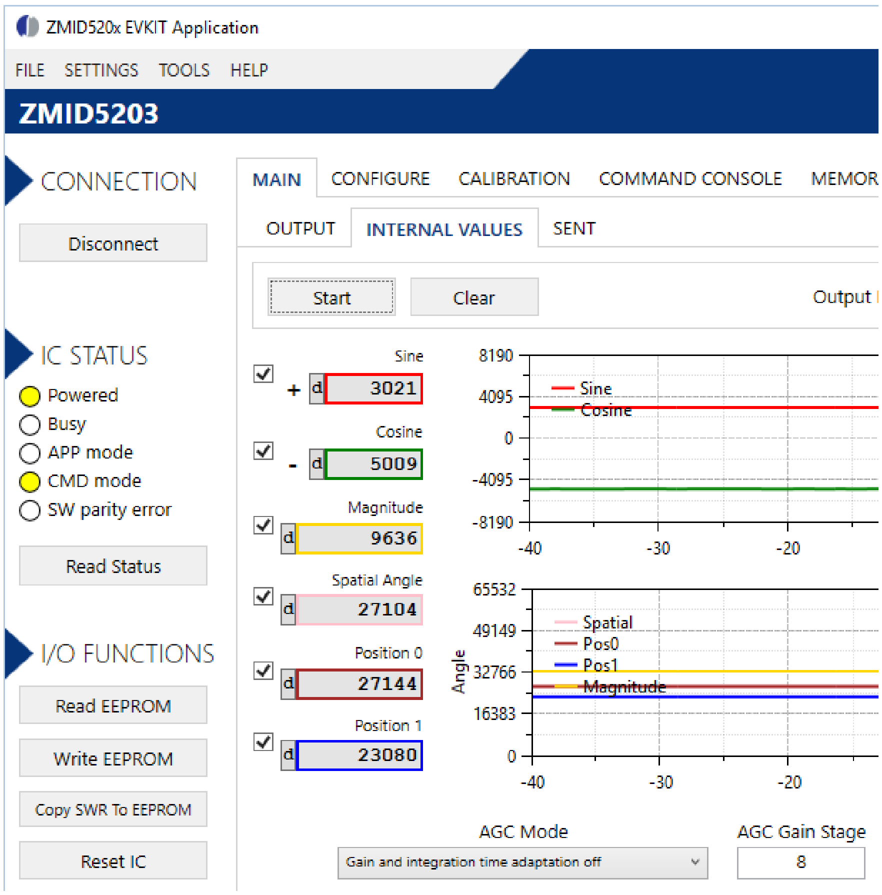


3.4 Gain Stage Setting

Select the value of the *Gain_stage* setting so that the value of the "Magnitude" parameter is in the range of 6000_{DEC} to 10000_{DEC} when the target is positioned at the nominal air gap over the sensor board. The GUI displays the "Magnitude" parameter tab on the "INTERNAL VALUES" subtab under the "MAIN" tab for checking that this requirement has been met. In the ZMID5203 example given in Figure 10, *Gain_stage* has been set to 8_{DEC} resulting in a "Magnitude" value within the required range.

For most applications, the automatic gain control (ACG) functionality can be disabled (see the "AGC Mode" setting in Figure 10).

Figure 10. Magnitude for Gain Selection – Example for the ZMID5203

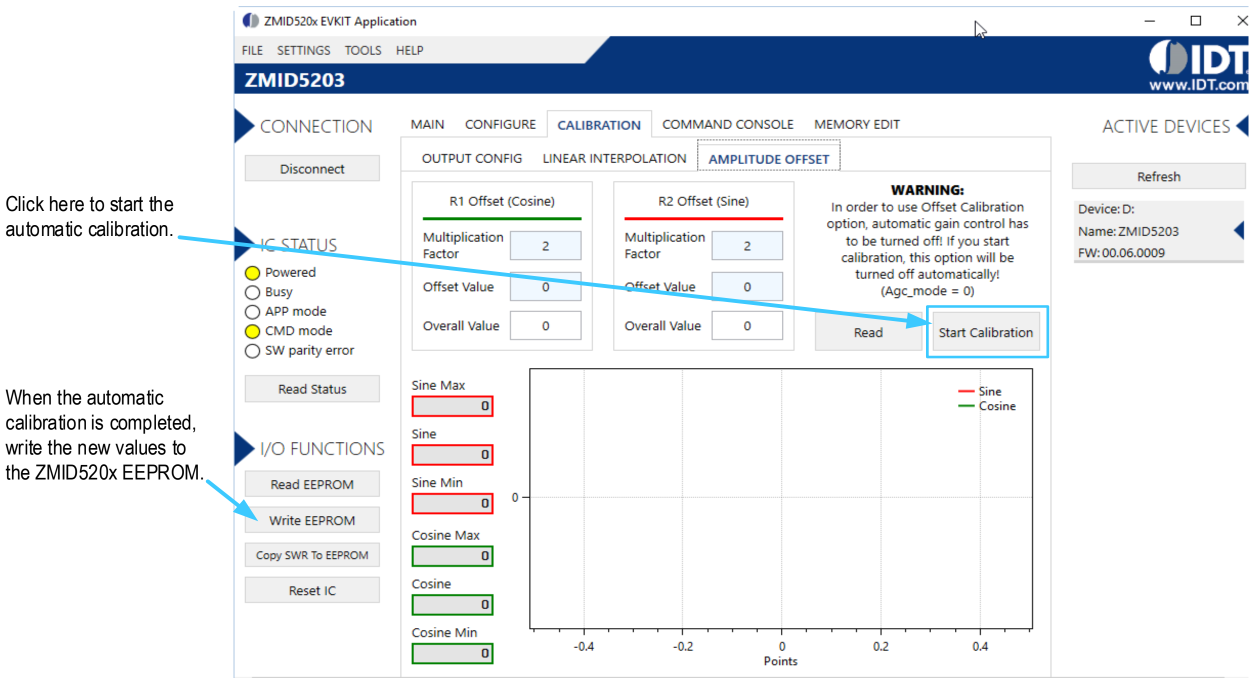


3.5 Input Amplitude Offset Compensation

The GUI offers an automated procedure for performing the input amplitude offset compensation with the target in place. For this procedure the target must be positioned at the operational distance from the receiving coils (air gap).

1. Start the procedure by clicking the “Start Calibration” button located on the “AMPLITUDE OFFSET” subtab under the “CALIBRATION” tab as shown in the ZMID5203 example given in Figure 11, which applies to all ZMID520x ICs. Follow instructions in the resulting dialog windows to complete the calibration.
2. When the calibration is finished, click the “Write to EEPROM” button before moving to the next steps. This procedure modifies the contents of register 08_{HEX}.

Figure 11. ZMID520x Input Amplitude Offset Compensation – Example for the ZMID5203



3.6 Output Calibration

The GUI offers an automated procedure for performing output calibration with the target in place at the operational distance from the receiving coils (air gap).

1. Select the “Out MODE” setting as described in section 3.2.1.
2. Start the procedure by clicking the “Start Calibration” button on the “OUTPUT CONFIG” subtab under the “CALIBRATION” tab as shown in the ZMID5203 example given in Figure 12.
3. Click the “Write to EEPROM” button before moving to the next steps. This procedure modifies the contents of registers 00_{HEX}, 01_{HEX}, and 09_{HEX}.
4. Verify that the calibration was successful by checking the “Position 1” field on the “INTERNAL VALUES” subtab under the “MAIN” tab at the start and end positions of the measurement range via the “INTERNAL VALUES” subtab under the “MAIN” tab as shown in the ZMID5203 example given in Figure 13, which applies to all ZMID520x ICs.

Figure 12. Output Calibration

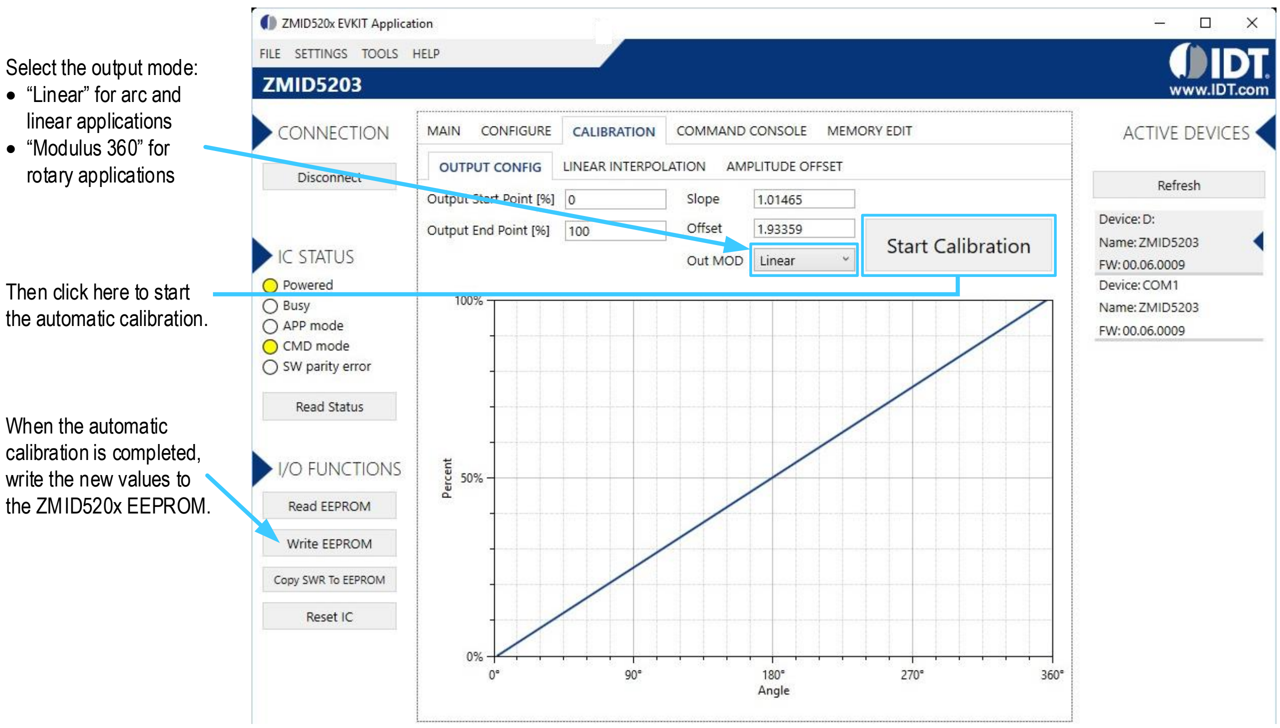
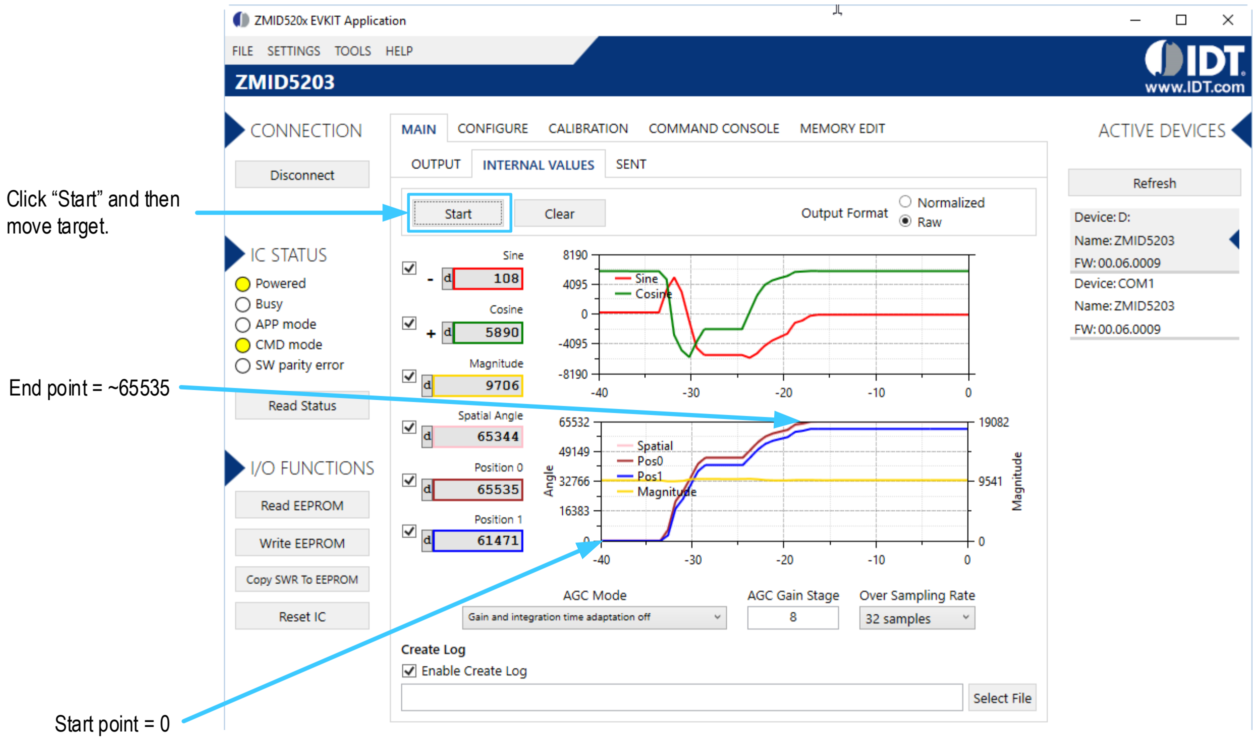


Figure 13. Output Calibration Verification



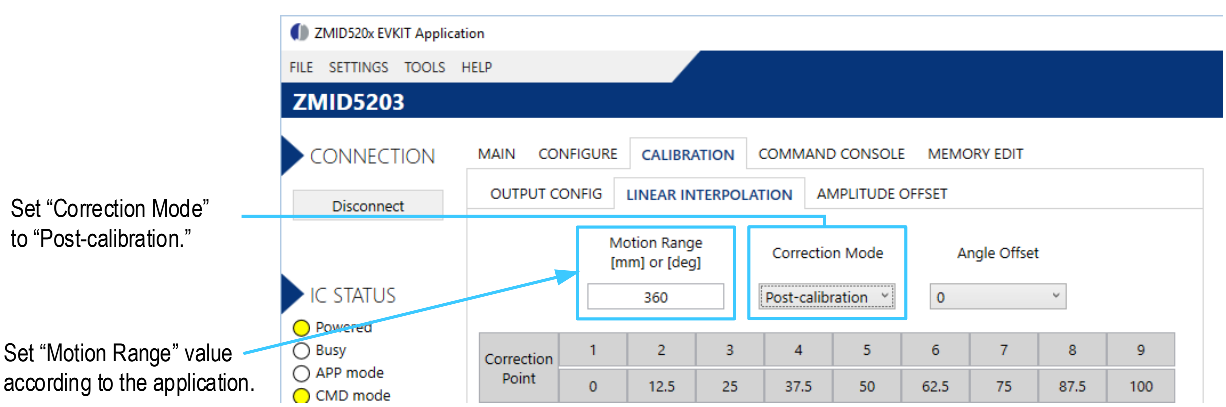
3.7 Output Linearization

This section provides a basic output linearization procedure for the ZMID520x. Using a target positioning system for these procedures is strongly recommended.

For additional information on calibration and linearization, refer to the *ZMID520x Evaluation Kit User Manual.* For the ZMID5201, also see the *ZMID5201 Manual for Calibration and Linearization Using the Analog Output* available on the ZMID5201 product web page. www.idt.com/document/man/zmid5201-manual-calibration-and-linearization-using-analog-output

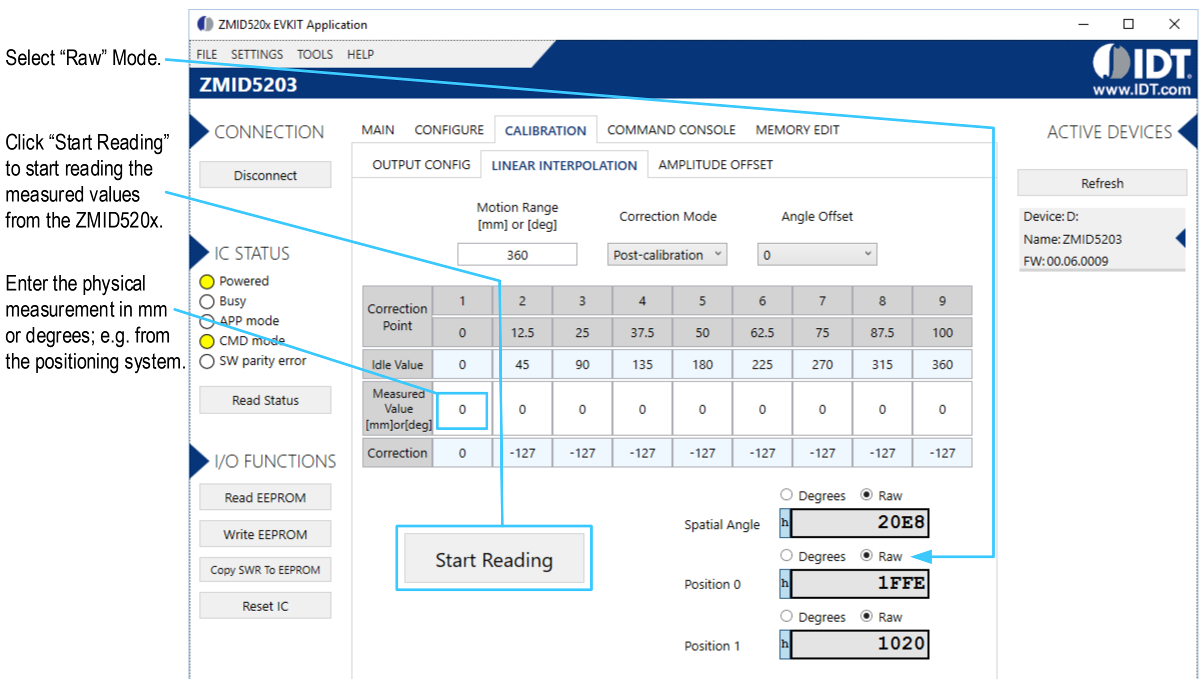
1. Set the "Correction Mode" drop-down menu to "Post-calibration" on the "LINEAR INTERPOLATION" subtab under the "CALIBRATION" tab (see Figure 14). This modifies register 09_{HEX}.
2. Set the value for the "Motion Range" entry field according to the receiver coil shape.

Figure 14. Correction Mode Selection



3. Select the "Raw" mode via the radio buttons above the fields for "Spatial Angle," "Position 0," and "Position 1" as shown in Figure 15.
4. Click the "Start Reading" button to start reading position values via the ZMID520x. The button changes to "Stop," and the adjacent readings should update to show the position readings.
5. Move the actual target position until the value in the "Position 0" field is 0000_{HEX}. Note: The points identified by "Position 0" = 0000_{HEX} and "Position 0" = $FFFF_{HEX}$ are the start and end points identified with the calibration procedure.
6. Then physically measure the actual position or read the measured value from the positioning system (in mm or degrees) and enter the value in the first column in the "Measured Value" row in the matrix on the "LINEAR INTERPOLATION" tab. Figure 15 shows an example of the matrix for a 360 rotary position sensing application for the ZMID5203.

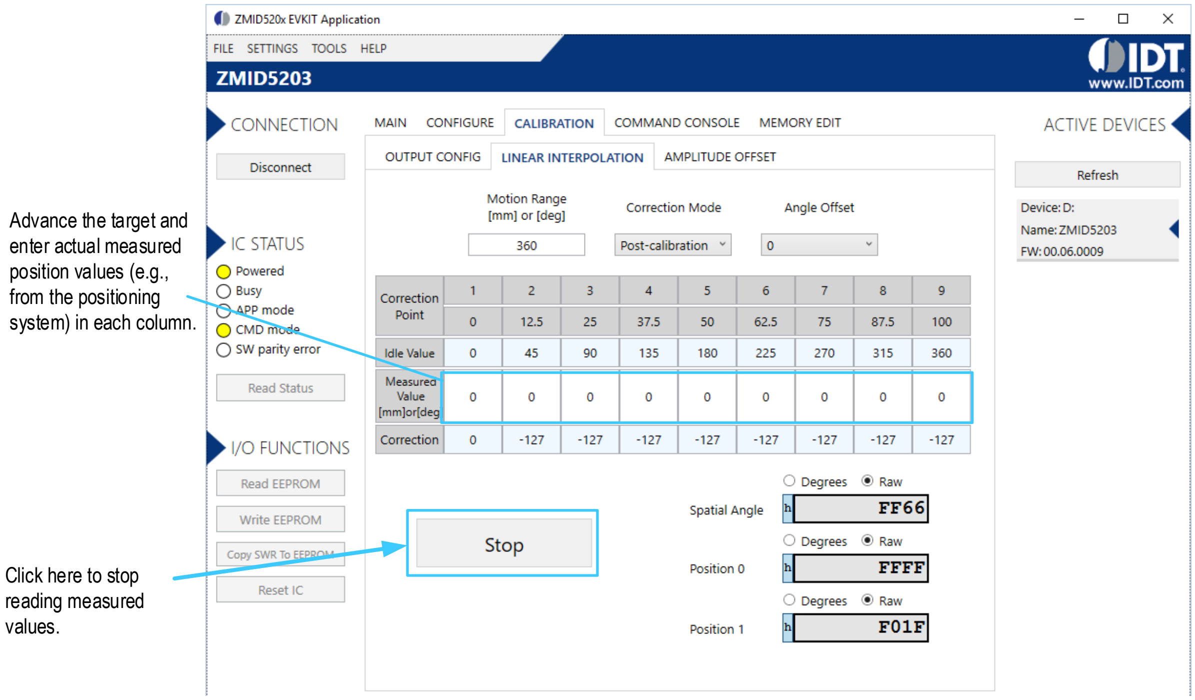
Figure 15. Measured Value Readings for 9 Linearization Points



7. Move the target again (e.g., with the positioning system) until the value in the "Position 0" field is $1FFF_{HEX}$. Then physically measure the new actual position or read the measured value from the positioning system and enter the value in the second column in the "Measured Value" row in the matrix.
8. Repeat the previous step for "Position 0" = (1FFF x n) + n – 1 where n = 2 to 8 to obtain actual measurements for the remaining positions in the matrix so that all 9 linearization points identified in Figure 16 have measured values entered in the "Measured Value" row. The software immediately calculates the correction values, and the resulting values are displayed below the applicable "Measured Values" entry.
9. Click on "Write EEPROM" to save the new values in registers 03_{HEX} to 07_{HEX}.

The linearization procedure is completed. The values in the *Pos1* register will differ from those in *Pos0* register, reflecting the linearization correction performed (see Table 1). The device is ready for operation in the application environment.

Figure 16. Input Fields for the 9 Linearization Points Measured Values



4. Internal Memory

Figure 17 shows the internal memory structure of the ZMID520x products, which is divided into a nonvolatile EEPROM and a volatile shadow RAM (SWR) section. After the ZMID520x start up, the EEPROM content is copied into the SWR. During ZMID520x operation in OWI mode, changes in the SWR will take immediate effect; whereas changes in the EEPROM require a memory WRITE command or a ZMID520x power cycle (power off / power on).

Figure 17. ZMID520x Internal Memory

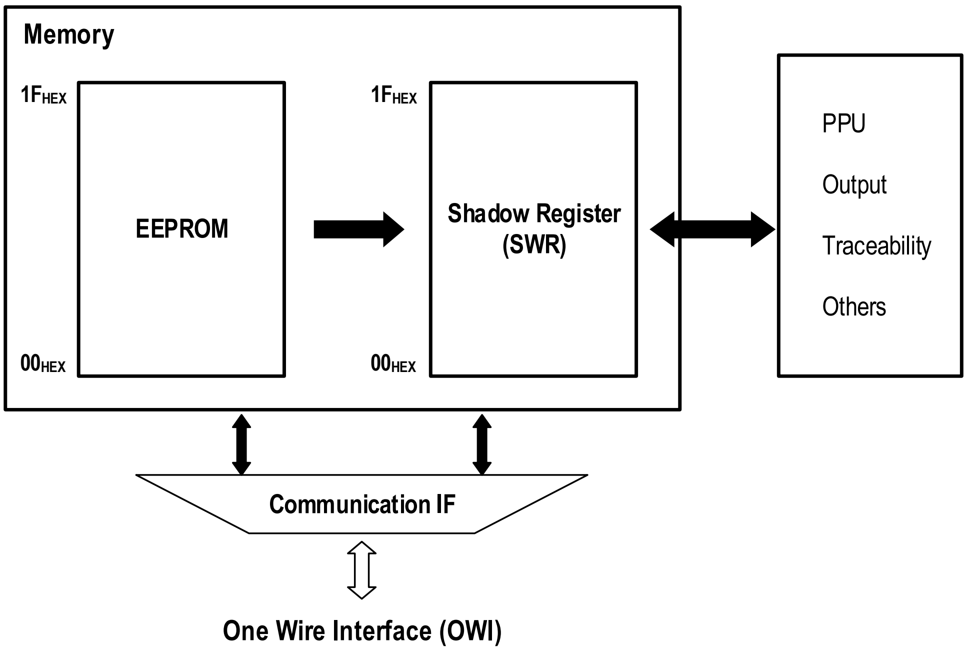


Table 1. EEPROM and Shadow RAM Contents

Address	Type	Location	Function
00_{HEX}	R/W	EEPROM/SWR	This register value is the 14-bit zero-angle offset of output signal, which is used for device calibration and sets the offset value of the output transfer function.
01_{HEX}	R/W	EEPROM/SWR	This register value is the 13-bit slope value of output signal, which is used for device calibration and sets the slope value of the output transfer function.
02_{HEX}	R/W	EEPROM/SWR	This register value is used with the analog and PWM output protocols in order to clamp the upper and lower output levels of the transfer function respectively below 95% and above 5%.
03_{HEX}	R/W	EEPROM/SWR	This register value is used in linearization. The position transfer function can be modified by a correction curve over the whole position range. The correction curve is defined by 9 linearization points. This register contains the correction factor for points n°2 and n°1. Bits [15:8] are the correction factor for the position at 12.5% (45°), and bits [7:0] are the correction factor for the position at 0% (0°).
04_{HEX}	R/W	EEPROM/SWR	This register value is used in linearization (see register 03_{HEX} for description). This register contains the correction factor for points n°4 and n°3. Bits [15:8] are the correction factor for the position at 37.5% (135°), and bits [7:0] are the correction factor for the position at 25% (90°).

Address	Type	Location	Function
05_{HEX}	R/W	EEPROM/SWR	This register value is used in linearization (see register 03_{HEX} for description). This register contains the correction factor for points n°6 and n°5. Bits [15:8] are the correction factor for the position at 62.5% (225°), and bits [7:0] are the correction factor for the position at 50% (180°).
06_{HEX}	R/W	EEPROM/SWR	This register value is used in linearization (see register 03_{HEX} for description). This register contains the correction factor for points n°8 and n°7. Bits [15:8] are the correction factor for the position at 87.5% (315°), and bits [7:0] are the correction factor for the position at 75% (270°).
07_{HEX}	R/W	EEPROM/SWR	This register value is used in linearization (see register 03_{HEX} for description). This register contains the correction factor for point n°9. Bits [15:8] are not used, and bits [7:0] are the correction factor for the position at 100% (360°).
08_{HEX}	R/W	EEPROM/SWR	This register value is the signal offset correction of the demodulated input signals sin and cos (R1and R2). It is used for input amplitude offset correction; the defined register offset values are added/subtracted to/from the amplitude values of the receiver coil values.
09_{HEX}	R/W	EEPROM/SWR	This register contains the control bits for selecting the output mode of the sensor (Linear Output Mode or Modulo 360 Output Mode), the type of linearization (pre or post-calibration), the angle offset for linearity correction (0° or -22.5°), the option to reverse the polarity of the receiver coils, and the option to invert the phase polarity of the receiver coils.
$0A_{HEX}$	R/W	EEPROM/SWR	This register value is used to define the type of communication interface (SENT, analog, or PWM). It is used for configuration of the output SENT CRC, SENT pause; PWM slope current, PWM frequency, and analog diagnostic level.
$0B_{HEX}$	R/W	EEPROM/SWR	This register value is used to control the voltage of the internal VDDT voltage regulator, the current of the Tx excitation coil, the oversampling rate of the ADC, and the PWM output slope time.
$0C_{HEX}$	R/W	EEPROM/SWR	This register value is used to set the gain stage value, the adjustment of the integration cycle in relation to the Tx coil period, and the integration time in terms of the ADC sample periods vs. the oversampling rate.
$0D_{HEX}$	R/W	EEPROM/SWR	This register value is used to set the CORDIC magnitude upper and lower levels, the upper and lower limits for the Tx coil frequency, the gain and integration time adaptation combined settings, and mixed operation modes.
$0E_{HEX}$	R/W	EEPROM/SWR	This register value is used to mask diagnostic register bits to prevent a diagnostic flag setting the output in the diagnostic status.
$0F_{HEX}$	R/W	EEPROM	Internal use only.
10_{HEX}	R/W	EEPROM	Internal use only.
11_{HEX}	R/W	EEPROM/SWR	This register value is used to the trigger actions for the shadow register, diagnostic register, Tx coil alarm, Rx coils alarm, double-error detection for the EEPROM memory, parity error detection on the SWR memory, ADC overflow, AGC offset saturation, Tx coil alarm, and a set of parameters used in test mode only.
13_{HEX}	R	SWR	This register value is used for analog front-end / automatic gain regulation; polarity of R1 and R2 ADC gain; and number of integration cycles for the AGC.
14_{HEX}	R	SWR	This register value is the 13-bit CORDIC raw input signal for *Xsine*.
15_{HEX}	R	SWR	This register value is the 13-bit CORDIC raw input signal for *Ycosine*.
16_{HEX}	R	SWR	This register value is the 15-bit CORDIC output angle (0° to 90°).

Address	Type	Location	Function
17_{HEX}	R	SWR	This register value is the 15-bit CORDIC output magnitude.
18_{HEX}	R	SWR	This register value is the 16-bit output spatial angle (0° to 360°) before output calibration and linear error correction.
19_{HEX}	R	SWR	This register value is Position 0, which is the 16-bit output angle (0° to 360°) after output calibration. If linearization is done before the output calibration, this value = Position 1. If linearization is done after the output calibration, this value is not the same value as Position 1.
$1A_{HEX}$	R	SWR	This register value is Position 1, which is the 16-bit output angle (0° to 360°) after output calibration and linearization. This value is always affected by linearization.
$1B_{HEX}$	R	SWR	Internal use only.

Complete information about registers map is available upon request. Contact: https://www.idt.com/support

5. Programming the ZMID520x EEPROM

The ZMID520x EEPROM can be programmed using the ZMID-COMBOARD USB Communication and Programming Board for ZMID Application Modules in conjunction with the *ZMID520x EVK Application Software.* Instructions for using the software to program the EEPROM are given in the *ZMID520x Evaluation Kit User Manual.* See section 2.1 for details for obtaining the software and the kit manual.

Additional information and documentation for the ZMID-COMBOARD are provided on the following IDT web page: https://www.idt.com/products/sensor-products/position-sensors/zmid-comboard-usb-communication-and-programming-board-zmid-application-modules

6. Glossary

Acronym	Definition
ADC	Analog Digital Converter
AGC	Automatic Gain Control
EEPROM	Electrically Erasable Programmable Read Only Memory
LSB	Least Significant Bit
MSB	Most Significant Bit
OWI	One-Wire Interface
OSR	Over-Sampling Rate
SWR	Shadow Word Register Bank

7. Revision History

Revision Date	Description of Change
April 6, 2018	Initial release

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit www.renesas.com/contact-us/.