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1 RBIC1 Dynamic-Link Library (DLL)

The calibration DLL described in this document is designed to expedite the calibration process for the ZSC31050, ZSC31150, ZSSC313x, ZSSC3154, and ZSSC3170 Sensor Signal Conditioner (SSC) products. Unless otherwise noted, the term SSC IC will be used in this document to refer to these five products.

The calibration process compensates the sensor input offset, sensor linearization, and sensor's sensitivity temperature dependency. It uses a polynomial function called *ZMD31050_cal1,* which calculates coefficients for up to 3rd order linearization compensation and up to 2nd order for the temperature compensation. The *RBIC1 DLL* is contained in the Evaluation Software installation folder.

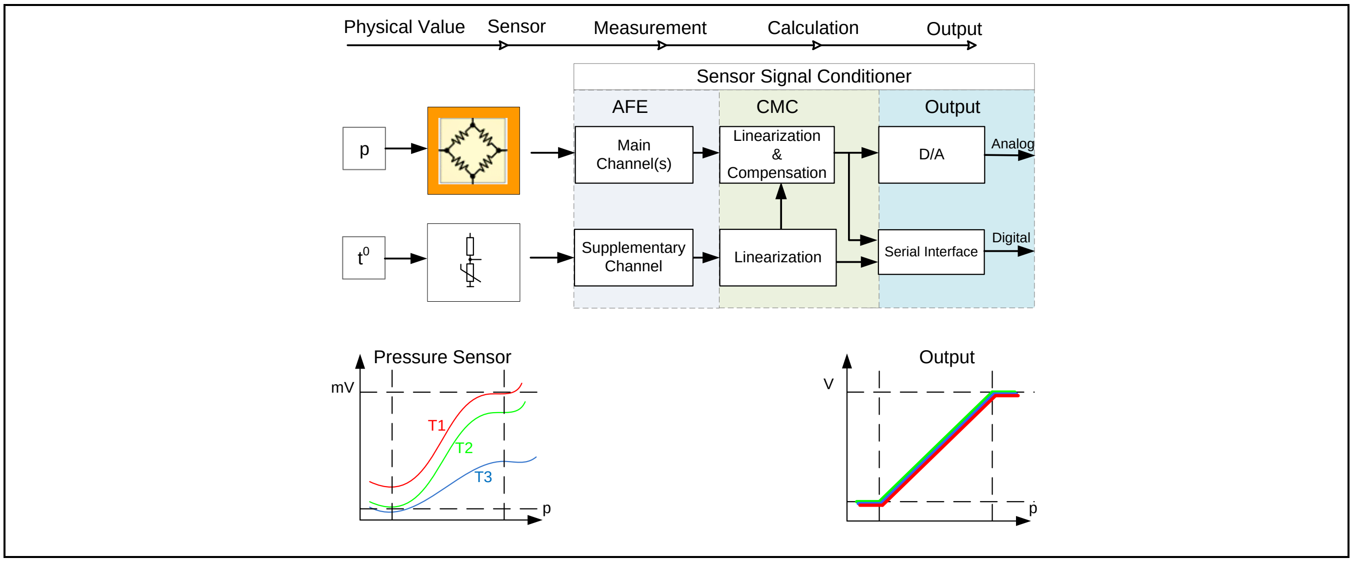
Coefficients resulting from *ZMD31050_cal1* are stored in the SSC EEPROM memory. Table 1.1 provides a list of the resulting coefficients.

***Table 1.1 Coefficients that Result from* ZMD31050_cal1**

Coefficient Name	EEPROM Address	Polynomial Function	Description
C0	00_{HEX}	Offset	Input signal when no sensor excitation is present
C1	01_{HEX}	Gain	Sensor signal gain value
C2	02_{HEX}	Linearization	2nd order non-linearity for three-point calibration
C3	03_{HEX}	Linearization	3nd order non-linearity for four-points calibration
C4	04_{HEX}	Temperature compensation	1st order temperature coefficient sensor offset
C5	05_{HEX}	Temperature compensation	2st order temperature coefficient sensor offset
C6	06_{HEX}	Temperature compensation	1st order temperature coefficient gain dependency
C7	07_{HEX}	Temperature compensation	2st order temperature coefficient gain dependency

Figure 1.1 illustrates a typical signal flow from measuring the physical value to the output of the conditioned result with offset compensation and gain compensation to meet the voltage output targets and signal linearization requirements for the application.

Figure 1.1 SSC Block Diagram and Signal Flow for a Pressure Sensor Example



2 Calibration Sequence

A typical calibration flow contains five steps in the following order:

1. Set-up and initialization
2. Data collection
3. Coefficient calculation
4. EEPROM programming
5. Verification

These five steps are very similar for all applicable products; there might be some insignificant differences in the Evaluation Software user interface.

Connect the SSC IC to the user's PC using the selected interface applicable to the product: I^2C™*, OWI, LIN, or SPI. Refer to the product's *Functional Description* document for the available command set.

* I^2C™ is a trademark of NXP.

2.1. Set-up and Initialization

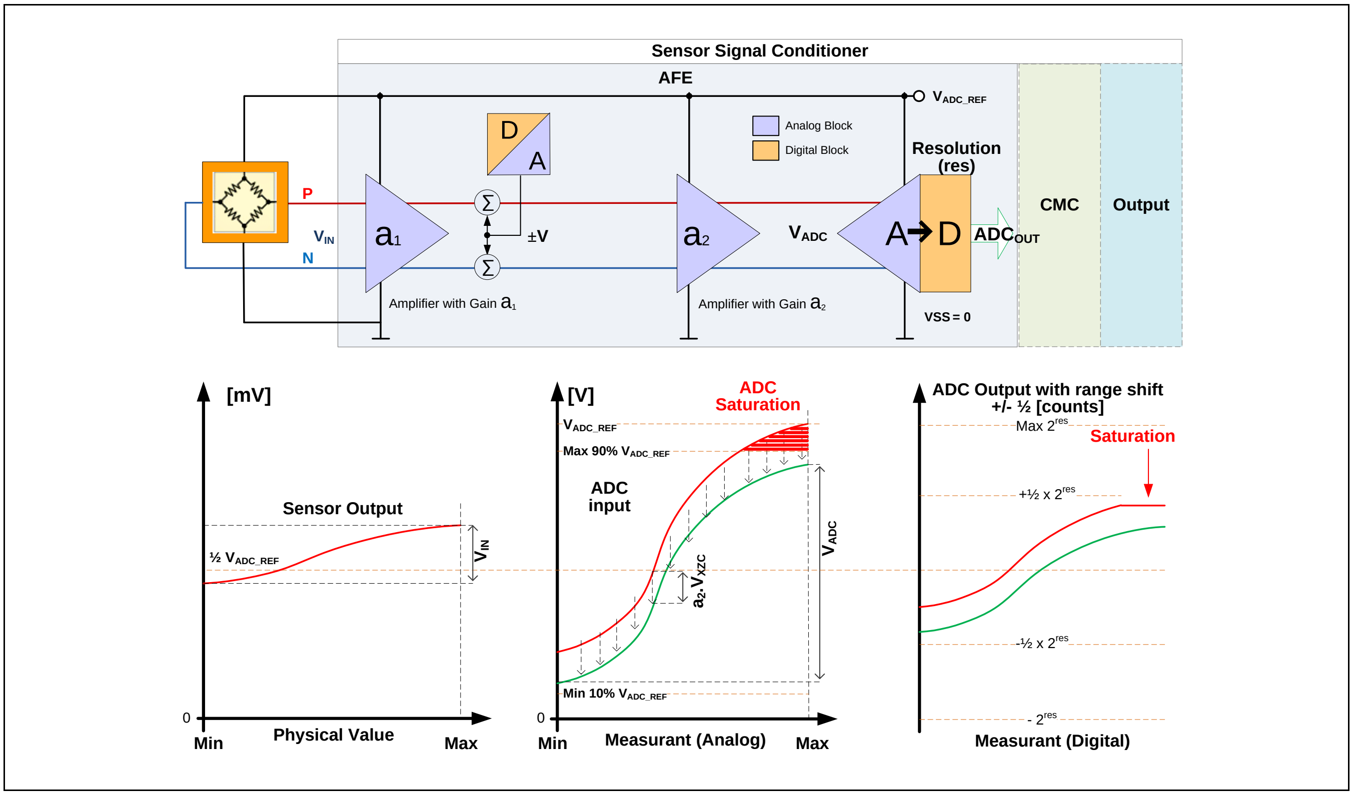
Prior to data collection, the SSC must to be configured so that the analog front-end (AFE), temperature measurement, and additional SSC functions fit the sensor's parameters and application requirements. This includes gain selection, sensor signal range, ADC resolution, temperature sensor in use, output format, and diagnostic functions.

The goal is to adjust the gain so the sensor signal is as close as possible to the acceptable ADC voltage range for the full operational temperature range. For this, the sensor span, offset, and tolerances must be taken into account.

Next, write the initial configuration into the RAM or the EEPROM of the SSC IC.

Note: Setting initial coefficients values is not required (initially coefficients can be set to 0 or any value).

Figure 2.1 Basic Analog Front-End

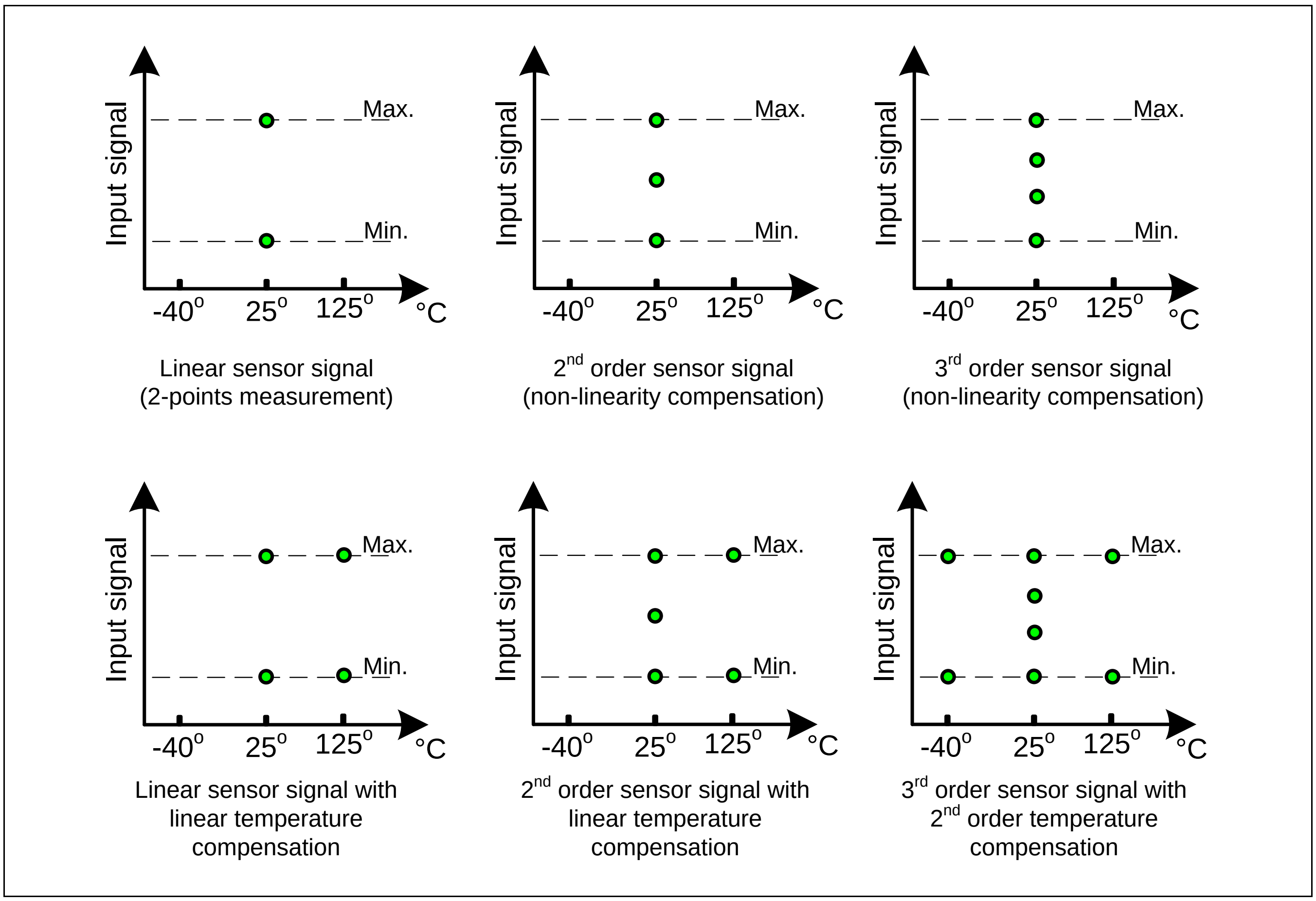


2.2. Data Collection

After the coefficients in EEPROM are initialized, data collection can begin. The minimum number of calibration points required varies between two and as many as eight for the main sensor and two or three for the temperature sensor. This depends on the precision required and the behavior of the sensor in use. In general, taking more calibration points will result in a better calibration.

Figure 2.2 shows the expected placement of calibration points for the different calibration options. The order of the points taken is not important; however, the number of points per temperature must be followed or the calibration might fail. The location and order of the temperature values is also not important – however for best results, the temperatures should be spread evenly throughout the user's specification range. It is important to keep the calibration points as orthogonal as possible to maximize calibration accuracy.

Figure 2.2 Calibration Points



The calibration point configuration can be any setup from 2-points linear calibration to 3rd order non-linearity compensation and 2nd order temperature dependency compensation.

2.3. Coefficient Calculation

2.3.1. Function Call for Main Sensor Channel

ZMD31050_cal1 (Zp1m, Zp2m, Zp4m, Zp3m, Zp1u, Zp2u, Zp1l, Zp2l, A, B, M2, M, Ztmed, Ztupp, Ztlow, adc_res, &C0, &C1, &C2, &C3, &C4, &C6, &C5, &C7);

Figure 2.3 Calibration Points and Target Values for Sensor Measurements

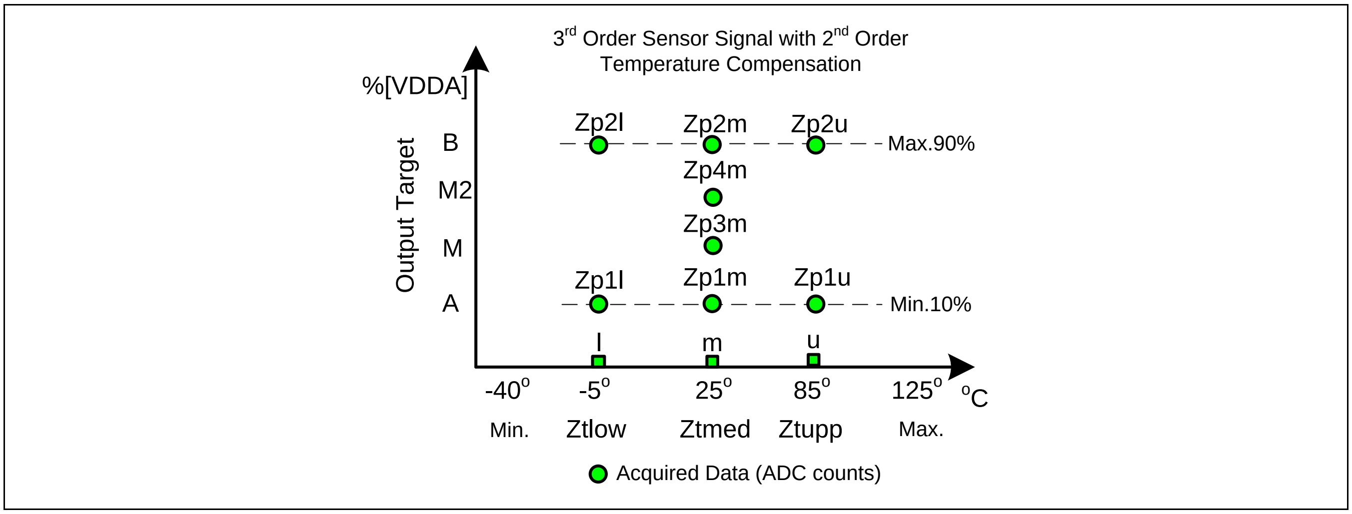


Table 2.1 List of Calibration Parameters

Name	Description	Type	Range	If not used	Condition
ZMD31050_cal1	Function call, main sensor channel	int	4 bytes		Returns 0 if successful
Zp1m	Sensor minimum output	float	$\pm 2^{15}$	Required	Medium temperature
Zp2m	Sensor maximum output	float	$\pm 2^{15}$	Required	
Zp3m	Sensor output (2nd order nonlinearity)	float	$\pm 2^{15}$	0	
Zp4m	Sensor output (3rd order nonlinearity)	float	$\pm 2^{15}$	0	
Zp1u	Sensor minimum output	float	$\pm 2^{15}$	0	Upper temperature
Zp2u	Sensor maximum output	float	$\pm 2^{15}$	0	
Zp1l	Sensor minimum output	float	$\pm 2^{15}$	0	Lower temperature
Zp2l	Sensor maximum output	float	$\pm 2^{15}$	0	
A	Target output value in [%] multiplied by 0.01 for digital output target 0.006875 for analog output target	float	0 to 1	Required	A < M < M2 < B
M		float	0 to 1	0	
M2		float	0 to 1	0	
B		float	0 to 1	Required	

Name	Description	Type	Range	If not used	Condition
Ztmed	Temperature sensor	float	$\pm2^{15}$	-33000.0	Medium temperature
Ztupp	Temperature sensor	float	$\pm2^{15}$	-33000.0	Upper temperature
Ztlow	Temperature sensor	float	$\pm2^{15}$	-33000.0	Lower temperature
adc_res	ADC resolution	int	9 to 16	-	Given in bits
C0 to C7	Calculated coefficients	float	4 bytes	0	Results upon success

Data acquisition commands: **D8**$_{\mathbf{HEX}}$ for sensor and **D9**$_{\mathbf{HEX}}$ for calibration temperature.

Command format: [7bit Slave Address] [0] [8-bit command]

Evaluation software command:

I^2C™ interface: IW_78001**D8**

OWI interface: OW_78001**D8**

LIN interface: LW_3c0087F05B4**D8**FFFFFFFF

2.3.2. Function Call for Temperature Channel

TQuad (Ztlow, Ztupp, Ztmed, Tlow, Tupp, Tmed, adc_res, &Ct0, &Ct1, &Ct2);

TLin (Ztmed, Ztupp, Tmed, Tupp, &Ct0, &Ct1);

Table 2.2 **List of Temperature Calculation Function Parameters**

Name	Description	Type	Range	Condition
TQuad	Function call, temperature channel 2nd order	bool		Returns 0 if successful
TLin	Function call, temperature channel linear	bool		Returns 0 if successful
Ztmed	Temperature sensor	float	$\pm2^{15}$	Medium temperature
Ztupp	Temperature sensor	float	$\pm2^{15}$	Upper temperature
Ztlow**	Temperature sensor	float	$\pm2^{15}$	Lower temperature
Tlow	Target value calculated by:	float	0 to 1	$temp_{range} = T_{low} - T_{min}$
Tmed	$temp_{range} * \frac{Target_{max} - Target_{min}[\%VDDA]}{Target_{max} - Target_{min}[°C]} + \frac{Target_{min}[\%VDDA]}{100}$	float	0 to 1	$temp_{range} = T_{med} - T_{min}$
Tupp	Where VDDA stands for analog power supply and ADC reference voltage of the IC.	float	0 to 1	$temp_{range} = T_{upp} - T_{min}$
adc_res	ADC resolution, temperature channel	int	9 to 16	Given in bits
Ct1 to Ct3	Calculated coefficients, temperature channel	float	4 bytes	Result upon success

Data acquisition commands: **DA**$_{HEX}$

Command format: [7bit Slave Address] [0]   [8-bit command]

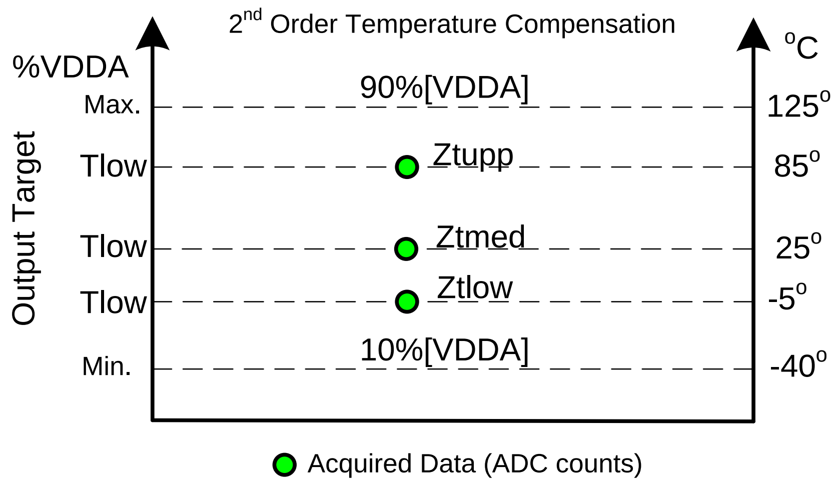
Evaluation Software Command:

I^{2}C™ interface: IW_78001**DA**

OWI interface: OW_78001**DA**

LIN interface: LW_3c0087F05B4**DA**FFFFFFFF

Figure 2.4   Calibration Points and Target Values for Temperature Measurement



The upper and lower limits (Max. and Min.) are usually selected as 10% and 90% of the ADC reference voltage (the analog voltage supply). Note that this varies depending on the SSC IC. In this input range, the ADC has the best performance for linearity.

2.3.3. Returned Error Codes

Note: bit [0] is not used

Table 2.3 Returned Error Codes

Flags	HEX	Bit	Description
0000 0000 0000 0010	0002_{HEX}	bit[1]	No solution found for given input data.
0000 0001 0000 0010	0102_{HEX}	bit[1] and bit[8]	Calculated coefficients are out of range (linear calibration).
0000 0010 0000 0010	0202_{HEX}	bit[1] and bit[9]	Offset: No solution found or coefficients are out of range.
0000 0100 0000 0010	0402_{HEX}	bit[1] and bit[10]	Gain: No solution found or coefficients are out of range.
0000 1000 0000 0010	0802_{HEX}	bit[1] and bit[11]	2nd order: No solution found or coefficients are out of range.
0001 0000 0000 0010	1002_{HEX}	bit[1] and bit[12]	3rd order: No solution found or coefficients are out of range.
0000 0000 0000 0100	0004_{HEX}	bit[2]	Range check error.
0000 0001 0000 0100	0104_{HEX}	bit[2] and bit[8]	Offset compensation error.
0000 0010 0000 0100	0204_{HEX}	bit[2] and bit[9]	Gain calculation error.
0000 0100 0000 0100	0404_{HEX}	bit[2] and bit[10]	C1 and C2 calculation error.
0000 0100 0000 0100	0804_{HEX}	bit[2] and bit[11]	C3 and C4 calculation error.
0000 1000 0000 0100	1004_{HEX}	bit[2] and bit[12]	C5 calculation error.
0010 0000 0000 0100	2004_{HEX}	bit[2] and bit[13]	C6 calculation error.
0100 0000 0000 0100	4004_{HEX}	bit[2] and bit[14]	C7 calculation error.
0000 0000 0000 1000	0008_{HEX}	bit[3]	Temperature behavior linearization calculation error.
0000 0001 0000 1000	0108_{HEX}	bit[3] and bit[8]	Offset temperature coefficient calculation (C4 and C5).
0000 0010 0000 1000	0108_{HEX}	bit[3] and bit[9]	Gain temperature coefficient calculation (C6 and C7).
0000 0000 0001 0000	0010_{HEX}	bit[4]	Coefficients range check error.
0000 0001 0001 0000	0110_{HEX}	bit[4] and bit[8]	Coefficient range check (C0 and C1) error.
0000 0010 0001 0000	0210_{HEX}	bit[4] and bit[9]	Non-linearity coefficient range check (C2 and C3).

2.3.4. Calculation Examples

ADC max.: 90%[VDDA]
ADC min.: 10%[VDDA]
ADC resolution: 14 bit
Data points: 10%, 50%, 70% and 90%
Temperature points: -40°C, -5°C, 25°C, 85°C and 125°C

Linear (two points, no non-linearity and temperature compensation)
ZMD31050_cal1 (data #1, data #2, 0, 0, 0, 0, 0, 0, 0.1, 0.9, 0, 0, -33000, -33000, -33000, 14, &C0, &C1, &C2, &C3, &C4, &C6, &C5, &C7);

2nd order non-linearity compensation (three points at 10%, 50%, and 90%, no temperature compensation)
ZMD31050_cal1 (data #1, data #2, 0, data #3, 0, 0, 0, 0, 0.1, 0.9, 0, 0.5, -33000, -33000, -33000, 14, &C0, &C1, &C2, &C3, &C4, &C6, &C5, &C7);

3rd order non-linearity compensation (four points at 10%, 50%, 70%, and 90%, no temperature compensation)
ZMD31050_cal1 (data #1, data #2, data #4, data #3, 0, 0, 0, 0, 0.1, 0.9, 0.7, 0.5, -33000, -33000, -33000, 14, &C0, &C1, &C2, &C3, &C4, &C6, &C5, &C7);

3rd order non-linearity and 2nd order temperature compensation (8 points for sensor and 3 points for temperature)
ZMD31050_cal1 (data #1, data #2, data #4, data #3, data #5, data #6, data #7, data #8, 0.1, 0.9, 0.7, 0.5, temp#1, temp#2, temp#3, 14, &C0, &C1, &C2, &C3, &C4, &C6, &C5, &C7);
TQuad (temp#1, temp#2, temp#3, 0.27, 0.71, 0.42, 14, &Ct0, &Ct1, &Ct2);

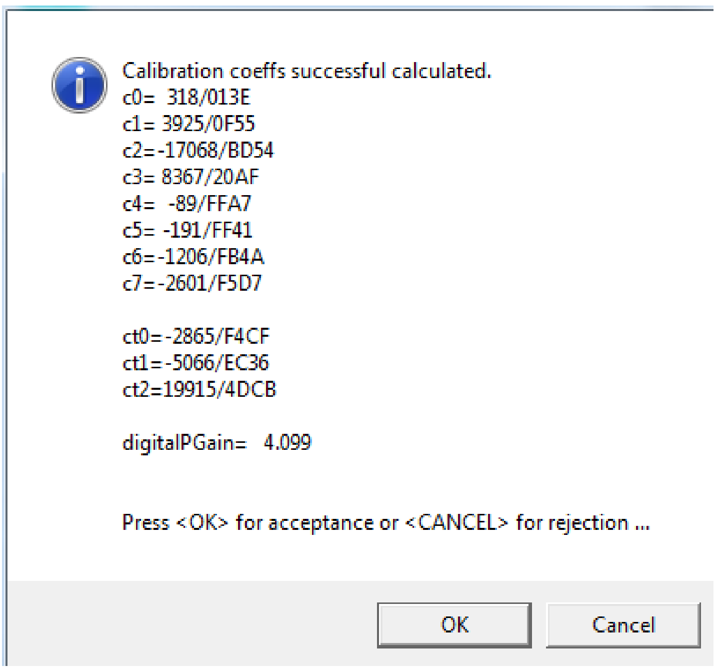
2.4. EEPROM Programming

Programming of the SSC IC can be done via the Evaluation Software provided for each SSC IC. Software can be downloaded from the product pages on www.IDT.com.

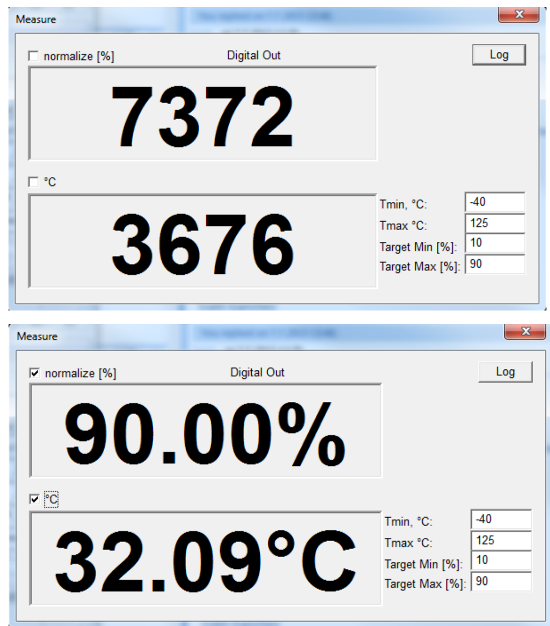
Refer to the *Evaluation Kit Description* for the SSC IC for further details.

2.5. Verification

Figure 2.5 Calculation and Measurement Results



Digital readout:



After successful calibration, the output of the SSC IC should vary between the target limits specified during calibration. For digital data, the readout values match the resolution of the data format used.

For analog output, the output voltage is generated using a resistor-string digital-to-analog converter (DAC) with 5632 steps, of which 5120 steps (256 to 5375) can be addressed. As a result, an adjustable range from 5% to 95% of the supply voltage is guaranteed, including all possible tolerances.

Visit IDT's website www.IDT.com or contact your nearest sales office for the latest version of various support documents.

3 Glossary

Term	Description
ADC	Analog-to-Digital Converter
DAC	Digital to Analog Converter
DLL	Dynamic-Link Library
SSC	Sensor Signal Conditioner

4 Document Revision History

Revision	Date	Description
1.00	July 9, 2015	First release.
	April 26, 2016	Changed to IDT branding.

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