Brief Description

The ZSSC3218 is a sensor signal conditioner (SSC) integrated circuit for high-accuracy amplification and analog-to-digital conversion of a differential or pseudo-differential input signal. Designed for high-resolution sensor module applications, the ZSSC3218 can perform offset, span, and 1st and 2nd order temperature compensation of the measured signal. Developed for correction of resistive bridge or absolute voltage sensors, it can also provide a corrected temperature output measured with an internal sensor.

The measured and corrected sensor values are provided at the digital output pins, which can be configured as I2C™ (≤ 3.4MHz) or SPI (≤ 20MHz). Digital compensation of signal offset, sensitivity, temperature, and non-linearity is accomplished via a 26-bit internal digital signal processor (DSP) running a correction algorithm. Calibration coefficients are stored on-chip in a highly reliable, non-volatile, multiple-time programmable (MTP) memory. Programming the ZSSC3218 is simple via the serial interface. The interface is used for the PC-controlled calibration procedure, which programs the set of calibration coefficients in memory. The ZSSC3218 provides accelerated signal processing, increased resolution, and improved noise immunity in order to support high-speed control, safety, and real-time sensing applications with the highest requirements for energy efficiency.

Features

- Flexible, programmable analog front-end design; up to 18-bit analog-to-digital converter (ADC)
- Fully programmable gain amplifier for optimizing sensor signals: gain range 6.6 to 216 (linear)
- Internal auto-compensated temperature sensor
- Digital compensation of individual sensor offset; 1st and 2nd order digital compensation of sensor gain as well as 1st and 2nd order temperature gain and offset drift
- Programmable interrupt operation
- High-speed sensing: e.g. 16-bit conditioned sensor signal measurement rate >500s⁻¹
- Typical sensor elements can achieve an accuracy of better than ±0.10% FSO** at -40 to 85°C

Benefits

- Integrated 26-bit calibration math digital signal processor (DSP)
- Fully corrected signal at digital output
- Layout customized for die-die bonding with sensor for high-density chip-on-board assembly
- One-pass calibration minimizes calibration costs
- No external trimming, filter, or buffering components required
- Highly integrated CMOS design
- Integrated reprogrammable non-volatile memory
- Excellent for low-voltage and low-power battery applications
- Optimized for operation in calibrated resistive (e.g., pressure) sensor or calibrated absolute voltage (e.g., thermopile) sensor modules

Physical Characteristics

- Supply voltage range: 1.68V to 3.6V
- Current consumption: 1.0mA (operating mode)
- Sleep State current: 20nA (typical)
- Temperature resolution: <0.003K/LSB
- Best-in-class energy-efficiency: with 16-bit resolution: <140pJ/step
  with 18-bit resolution: <50pJ/step
- Operation temperature: −40°C to +85°C
- Small die size
- Delivery options: die for wafer bonding

ZSSC3218 Application Example

* I2C™ is a trademark of NXP.
** FSO = Full Scale Output.
Applications

- Barometric altitude measurement for portable navigation or emergency call systems
- Altitude measurement for car navigation
- Weather forecast
- Fan control
- Industrial, pneumatic, and liquid pressure
- High-resolution temperature measurements
- Object-temperature radiation (via thermopile)

<table>
<thead>
<tr>
<th>Sales Code</th>
<th>Description</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZSSC3218Bl1B</td>
<td>Die—temperature range: –40°C to +85 °C; thickness 304µm</td>
<td>Unsawn wafer</td>
</tr>
<tr>
<td>ZSSC3218Bl2B</td>
<td>Die—temperature range: –40°C to +85 °C; thickness 725µm (w/o backlapping)</td>
<td>Unsawn wafer</td>
</tr>
<tr>
<td>ZSSC3218BI3R ES</td>
<td>PQFN24—temperature range: –40°C to +85 °C; engineering samples</td>
<td>Packaged die</td>
</tr>
</tbody>
</table>
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1 IC Characteristics

1.1. Absolute Maximum Ratings

Note: The absolute maximum ratings are stress ratings only. The ZSSC3218 might not function or be operable above the recommended operating conditions. Stresses exceeding the absolute maximum ratings might also damage the device. In addition, extended exposure to stresses above the recommended operating conditions might affect device reliability. IDT does not recommend designing to the “Absolute Maximum Ratings.”

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>Min</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Reference</td>
<td>$V_{SS}$</td>
<td>0</td>
<td>0</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Analog Supply Voltage</td>
<td>$V_{DD}$</td>
<td>-0.4</td>
<td>3.63</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Voltage at all Analog and Digital IO Pins</td>
<td>$V_{A,IO}, V_{D,IO}$</td>
<td>-0.5</td>
<td>$V_{DD}+0.5$</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Input Current into any Pin except RES, SS 1), 2)</td>
<td>$I_{IN}$</td>
<td>-100</td>
<td>100</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Electrostatic Discharge Tolerance – Human Body Model (HBM1) 3)</td>
<td>$V_{HBM1}$</td>
<td>±4000</td>
<td>-</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>$T_{STOR}$</td>
<td>-50</td>
<td>125</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>

1) Latch-up current limit for RES, ZMDI-test and SS: ±70mA.
2) Latch-up resistance, reference for pin is 0V.
3) HBM1: $C = 100pF$ charged to $V_{HBM1}$ with resistor $R = 1.5k\Omega$ in series based on MIL 883, Method 3015.7. ESD protection referenced to the Human Body Model is tested with devices in ceramic dual in-line packages (CDIP) during product qualification.

1.2. Operating Conditions

The reference for all voltages is Vss.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>$V_{DD}$</td>
<td>1.68</td>
<td>-</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>VDD Rise Time</td>
<td>$t_{VDD}$</td>
<td>-</td>
<td>200</td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>Bridge Current 1)</td>
<td>$I_{VDDB}$</td>
<td>-</td>
<td>1.8</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Operation Temperature Range</td>
<td>$T_{AMB}$</td>
<td>-40</td>
<td>-</td>
<td>85</td>
<td>°C</td>
</tr>
<tr>
<td>External (Parasitic) Capacitance between VDDB and VSS</td>
<td>CL</td>
<td>0.01</td>
<td>-</td>
<td>50</td>
<td>nF</td>
</tr>
</tbody>
</table>

1) Power supply rejection is reduced if a current in the range of $16.5mA > I_{VDDB} > 1.8mA$ is drawn out of VDDB.
A dynamic power-on-reset circuit is implemented in order to achieve minimum current consumption in idle mode. The VDD low level and the subsequent rise time and VDD rising slope must meet the requirements in Table 1.1 to guarantee an overall IC reset; lower VDD low levels allow slower rising of the subsequent on-ramp of VDD. Other combinations might also be possible. For example, the reset trigger can be influenced by increasing the power-down time and lowering the VDD rising slope requirement. Alternatively, the RES pin can be connected and used to control safe resetting of the ZSSC3218. RES is active-low; a VDD-VSS-VDD transition at the RES pin leads to a complete IC reset.

### Table 1.3 Requirements for VDD Power-on Reset

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Down Time (duration of VDD Low Level)</td>
<td>$t_{SPIKE}$</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>µs</td>
</tr>
<tr>
<td>VDD Low Level</td>
<td>$V_{DDL}$</td>
<td>0</td>
<td>-</td>
<td>0.2</td>
<td>V</td>
</tr>
<tr>
<td>VDD Rising Slope</td>
<td>$SR_{VDD}$</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>V/ms</td>
</tr>
</tbody>
</table>

### 1.3. Electrical Parameters

All parameter values are valid only under the specified operating conditions. All voltages are referenced to Vss.

### Table 1.4 Electrical Parameters

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions/Comments</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External Sensor Supply Voltage, ADC Reference Voltage</td>
<td>$V_{DDB}$</td>
<td>Internally generated</td>
<td>1.60</td>
<td>1.68</td>
<td>1.75</td>
<td>V</td>
</tr>
<tr>
<td>Current Consumption</td>
<td>$I_{VDD}$</td>
<td>Active State, average</td>
<td>1050</td>
<td>1500</td>
<td>µA</td>
<td></td>
</tr>
<tr>
<td>Sleep State, idle current, $\leq 85^\circ C$</td>
<td></td>
<td></td>
<td>20</td>
<td>250</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>Power Supply Rejection $20 \cdot \log_{10} (V_{DD}/V_{DDB})$ (see section 1.4)</td>
<td>$PSR_{VDD}$</td>
<td>$V_{DD} = 1.8V$</td>
<td>17</td>
<td>60</td>
<td>88</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{DD} = 2V$</td>
<td>32</td>
<td>65</td>
<td>91</td>
<td>dB</td>
</tr>
<tr>
<td>Analog-to-Digital Converter (ADC, A2D)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td>$r_{ADC}$</td>
<td>12</td>
<td>18</td>
<td></td>
<td></td>
<td>Bit</td>
</tr>
<tr>
<td>ADC Clock Frequency</td>
<td>$f_{ADC}$</td>
<td>Internal ADC clock</td>
<td>0.9</td>
<td>1</td>
<td>1.1</td>
<td>MHz</td>
</tr>
<tr>
<td>Conversion Rate</td>
<td>$f_{S,raw}$</td>
<td>Conversions per second for single 18-bit external sensor A2D conversion (w/o AZ)</td>
<td>1.1</td>
<td>1.1</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conversions per second for single 16-bit temperature sensor A2D conversion (w/o AZ)</td>
<td>2.3</td>
<td>2.3</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Symbol</td>
<td>Conditions/Comments</td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Unit</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td><strong>Amplifier</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain</td>
<td>G_{amp}</td>
<td>64 steps</td>
<td>6.6</td>
<td>216</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain Error</td>
<td>G_{err}</td>
<td>Referenced to nominal gain</td>
<td>-2.5</td>
<td>-</td>
<td>2.5</td>
<td>%</td>
</tr>
<tr>
<td><strong>Sensor Signal Conditioning Performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IC Accuracy Error 1)</td>
<td>Err_{A,IC}</td>
<td>Accuracy error for sensor that is ideally linear (in temperature and measurand)</td>
<td></td>
<td>0.01</td>
<td></td>
<td>%FSO</td>
</tr>
<tr>
<td>Conversion Rate, 18-Bit SSC</td>
<td>f_{SSC}</td>
<td>Conversion per second for fully corrected 18-bit measurement</td>
<td>270</td>
<td>300</td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Voltage Range</td>
<td>V_{INP}, V_{INN}</td>
<td>Input voltage range at INP and INN</td>
<td>0.65</td>
<td>1.05</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>External Sensor Bridge Resistance</td>
<td>R_{BR}</td>
<td>Full power supply disturbance rejection (PSRR) capabilities</td>
<td>1</td>
<td>10</td>
<td>50</td>
<td>kΩ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced PSRR, but full functionality</td>
<td>100</td>
<td>999</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td><strong>Power-Up</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start-up Time</td>
<td>t_{STA1}</td>
<td>V_{DD} ramp up to interface communication (see section 3.1)</td>
<td>1</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td></td>
<td>t_{STA2}</td>
<td>V_{DD} ramp up to analog operation</td>
<td>2.5</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>Wake-up Time</td>
<td>t_{WUP1}</td>
<td>Sleep to Active State interface communication</td>
<td>0.5</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td></td>
<td>t_{WUP2}</td>
<td>Sleep to Active State analog operation</td>
<td>2</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td><strong>Oscillator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Oscillator Frequency</td>
<td>f_{CLK}</td>
<td></td>
<td>3.6</td>
<td>4</td>
<td>4.4</td>
<td>MHz</td>
</tr>
<tr>
<td><strong>Internal Temperature Sensor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Resolution</td>
<td></td>
<td>-40°C to +85°C</td>
<td></td>
<td>0.003</td>
<td></td>
<td>K/LSB</td>
</tr>
<tr>
<td><strong>Interface and Memory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPI Clock Frequency</td>
<td>f_{C,SPI}</td>
<td>Maximum capacitance at MISO line: 40pF at V_{DD}=1.8V</td>
<td>1</td>
<td>20</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>I²C™ Clock Frequency</td>
<td>f_{C,I2C}</td>
<td></td>
<td></td>
<td>3.4</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>Program Time</td>
<td>t_{prog}</td>
<td>MTP programming time per 16-bit register</td>
<td>5</td>
<td>16</td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>Endurance</td>
<td>n_{MTP}</td>
<td>Number of reprogramming cycles</td>
<td>1000</td>
<td>10000</td>
<td></td>
<td>numeric</td>
</tr>
<tr>
<td>Data Retention</td>
<td>t_{RET_MTP}</td>
<td>1000h at 125°C</td>
<td>10</td>
<td></td>
<td></td>
<td>a</td>
</tr>
</tbody>
</table>

1) Percentage referred to maximum full-scale output (FSO); e.g. for 18-bit measurements: Err_{A,IC} [%FSO] = 100 · MAX{ |ADC_{meas} – ADC_{ideal} | } / 2^{18}. 
1.4. Power Supply Rejection Ratio (PSRR) vs. Frequency

![Graph showing PSRR vs. Frequency for different V_DD values: 1.8V, 1.9V, and 3.3V. The PSRR is calculated as PSRR = 20 \cdot \log \left( \frac{V_{DD}}{V_{DD}} \right).]
2 Circuit Description

2.1 Brief Description

The ZSSC3218 provides a highly accurate amplification of bridge sensor signals. The compensation of sensor offset, sensitivity, temperature drift, and non-linearity is accomplished via a 26-bit DSP core running a correction algorithm with calibration coefficients stored in a non-volatile memory. The ZSSC3218 can be configured for a wide range of resistive bridge sensor types and for absolute voltage source sensors. A digital interface (SPI or I²C™) enables communication. The ZSSC3218 supports two operational modes: Normal Mode and Command Mode. Normal Mode is the standard operating mode. Typically in Normal Mode, the ZSSC3218 wakes up from a Sleep State (low power), runs a measurement in Active State, and automatically returns to the Sleep State. (See section 3.4 for details on operational modes.)

2.2 Signal Flow and Block Diagram

See Figure 2.1 and Figure 2.2 for the ZSSC3218 block diagram for different input sensors. The sensor bridge supply VDD and the power supply for analog circuitry are provided by a voltage regulator, which is optimized for power supply disturbance rejection (PSRR). See section 1.4 for a graph of PSRR versus frequency. To improve noise suppression, the digital blocks are powered by a separate voltage regulator. A power supervision circuit monitors all supply voltages and generates appropriate reset signals for initializing the digital blocks.

The System Control Unit controls the analog circuitry to perform the three measurement types: external sensor, temperature, and offset measurement. The multiplexer selects the signal input to the amplifier, which can be the external signals from the input pins INP and INN or the internal temperature reference sensor signals. A full measurement request will trigger an automatic sequence of all measurement types and all input signals.

Figure 2.1 ZSSC3218 Functional Block Diagram, Resistive-Bridge Sensor
The amplifier consists of two stages with programmable gain values.

The ZSSC3218 employs a programmable analog-to-digital converter (ADC) optimized for conversion speed and noise suppression. The programmable resolution from 12 to 18 bits provides flexibility for adapting the conversion characteristics. To improve power supply noise suppression, the ADC uses the bridge supply \( V_{DBB} \) as its reference voltage leading to a ratiometric measurement topology if the external sensor is a bridge-type element.

The remaining IC-internal offset and the sensor element offset, i.e., the overall system offset for the amplifier and ADC, can be canceled by means of an offset and auto-zero measurement, respectively.

The DSP accomplishes the auto-zero, span, and 1st and 2nd order temperature compensation of the measured external sensor signal. The correction coefficients are stored in the MTP memory.

The ZSSC3218 supports SPI and I\(^2\)C™ interface communication for controlling the ZSSC3218, configuration, and measurement result output.

### 2.3. Analog Front End

#### 2.3.1. Amplifier

The amplifier has a fully differential architecture and consists of two stages. The amplification of each stage and the external sensor gain polarity are programmable via settings in the Measurement Configuration Register \( SM\_config1 \) and \( SM\_config2 \) (addresses 12\_HEX and 16\_HEX; see section 3.6.2) in the MTP memory (for details, see section 2.4.2).
The first 6 bits of \textit{SM\_config}\textsuperscript{*} are the programmable gain settings \textit{Gain\_stage1} and \textit{Gain\_stage2}. The options for the programmable gain settings are listed in Table 2.1 and Table 2.2.

\textbf{Table 2.1 Amplifier Gain: Stage 1}

<table>
<thead>
<tr>
<th>\textit{SM_config} Bit G2</th>
<th>\textit{SM_config} Bit G1</th>
<th>\textit{SM_config} Bit G0</th>
<th>\textit{Gain}_{amp1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>120</td>
</tr>
</tbody>
</table>

\textbf{Table 2.2 Amplifier Gain: Stage 2}

<table>
<thead>
<tr>
<th>\textit{SM_config} Bit G5</th>
<th>\textit{SM_config} Bit G4</th>
<th>\textit{SM_config} Bit G3</th>
<th>\textit{Gain}_{amp2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1.3</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1.4</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1.7</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

If needed, the polarity of the sensor bridge gain can be reversed by setting the \textit{Gain\_polarity} bit, which is bit 6 in the \textit{SM\_config} register (see section 3.6.2). Changing the gain polarity is achieved by inverting the chopper clock. Table 2.3 gives the settings for the \textit{Gain\_polarity} bit. This feature enables applying a sensor to the ZSSC3218 with swapped input signals at INN and INP; e.g., to avoid crossing wires for the final sensor module's assembly.

\textbf{Table 2.3 Gain Polarity}

<table>
<thead>
<tr>
<th>\textit{Gain_polarity} (\textit{SM_config} Bit 6)</th>
<th>Gain</th>
<th>Setting Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>+1</td>
<td>No polarity change.</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
<td>Gain polarity is inverted.</td>
</tr>
</tbody>
</table>

\textsuperscript{*}The register name \textit{SM\_config} is used for general register content and effect explanations for both \textit{SM\_config1} and \textit{SM\_config2} as the registers' bit assignments are exactly the same for both registers.
2.3.2. Analog-to-Digital Converter

An analog-to-digital converter (ADC) is used to digitize the amplifier signal. To allow optimizing the trade-off between conversion time and resolution, the resolution can be programmed from 12-bit to 18-bit (Adc_bits, SM_config register; section 3.6.2). The ADC processes differential input signals.

Table 2.4 ADC Conversion Times for a Single Analog-to-Digital Conversion

<table>
<thead>
<tr>
<th>Resolution (Bits)</th>
<th>Conversion Time in µs (typical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>140</td>
</tr>
<tr>
<td>13</td>
<td>185</td>
</tr>
<tr>
<td>14</td>
<td>250</td>
</tr>
<tr>
<td>15</td>
<td>335</td>
</tr>
<tr>
<td>16</td>
<td>470</td>
</tr>
<tr>
<td>17</td>
<td>640</td>
</tr>
<tr>
<td>18</td>
<td>890</td>
</tr>
</tbody>
</table>

The ADC can perform an offset shift in order to adapt input signals with offsets to the ADC input range. The shift feature is enabled by setting SM_config register’s bit [15] = 1 (Shift_method = 1). The respective analog offset shift can be set up with bits [14:12], Offset in SM_config. The offset shift causes the ADC to perform an additional amplification of the ADC’s input signal by factor 2. This must be considered for a correct analog sensor setup by means of the pre-amplifier’s gain, the ADC offset shift, and the potential ADC gain.

The overall analog amplification $G_{\text{total}} = G_{\text{amp1}} \cdot G_{\text{amp2}} \cdot G_{\text{ADC}}$ can be determined for the following potential use cases:

- If no offset shift is selected, i.e., $Shift_{\text{method}} = 0$ and $Offset = 000$ in SM_config,
  
  $$G_{\text{total}} = G_{\text{amp1}} \cdot G_{\text{amp2}} \cdot 1$$

- If ADC offset shift is selected, i.e., $Shift_{\text{method}} = 1$ (Offset is arbitrary) in SM_config,
  
  $$G_{\text{total}} = G_{\text{amp1}} \cdot G_{\text{amp2}} \cdot 2$$
Table 2.5  ADC Offset Shift

<table>
<thead>
<tr>
<th>SM_config Bit 15 (Shift_method)</th>
<th>Offset: SM_config Bit 14</th>
<th>Offset: SM_config Bit 13</th>
<th>Offset: SM_config Bit 12</th>
<th>Gain&lt;sub&gt;ADC&lt;/sub&gt;</th>
<th>Compensation of Percentage Offset in Input Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0%</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>6.75%</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>12.50%</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>19.25%</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>25.00%</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>31.75%</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>38.50%</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>43.25%</td>
</tr>
</tbody>
</table>

Note: If no offset shift will be performed and the ADC will not apply the additional gain of factor 2 (leading to Gain<sub>ADC</sub> = 1), then Shift_method = 0 and Offset = 000 in SM_config must be selected. Any other setup with Shift_method = 0 and Offset ≠ 000 leads to erroneous analog setups.

Table 2.6  Typical Conversion Times vs. Noise Performance with Full Sensor Signal Conditioning for AZSM, SM, AZTM, and TM (Bridge-Type Sensor)

<table>
<thead>
<tr>
<th>ADC Resolution: Temperature Sensor</th>
<th>ADC Resolution: External Sensor</th>
<th>Typical Measurement Duration&lt;sup&gt;1)&lt;/sup&gt;, MEASURE, (AA&lt;sub&gt;HEX&lt;/sub&gt;) (ms)</th>
<th>Typical 3-Sigma Noise for SSC-Corrected Output&lt;sup&gt;2)&lt;/sup&gt; (counts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>12</td>
<td>2.2</td>
<td>2.4</td>
</tr>
<tr>
<td>16</td>
<td>13</td>
<td>2.3</td>
<td>2.5</td>
</tr>
<tr>
<td>16</td>
<td>14</td>
<td>2.4</td>
<td>3.0</td>
</tr>
<tr>
<td>16</td>
<td>15</td>
<td>2.6</td>
<td>4.4</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>2.8</td>
<td>5.7</td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>3.2</td>
<td>10.5</td>
</tr>
<tr>
<td>16</td>
<td>18</td>
<td>3.7</td>
<td>18.0</td>
</tr>
</tbody>
</table>

1) Measurement duration is defined as the time from the high/low transition at the EOC pin at the beginning of the measurement until the low/high back-transition of the EOC signal at the end of a single measurement in Sleep Mode.

2) Reference noise values normalized to the respective external sensor’s ADC resolution, obtained with the following setup: 20kΩ sensor bridge, 25°C, Gain=52, Offset=25%, VDD=1.8V.
2.3.3. Selection of Gain and Offset – Sensor System Dimensioning

The optimal gain (and offset) setup for a specific sensor element can be determined by the following steps:

1) Collect sensor element’s characteristic, statistical data (over temperature, ambient sensor parameter, and over production tolerances):
   a. Minimum differential output voltage: \( V_{\text{min}} \)
   b. Maximum differential output voltage: \( V_{\text{max}} \)

   Note: The best possible setup can only be determined if the absolute value of \( V_{\text{max}} \) is bigger than the absolute value of \( V_{\text{min}} \). If this is not the case, the gain polarity should be reversed by means of the \( \text{Gain}_\text{polarity} \) bit in the MTP’s \( \text{SM}_\text{config} \) register.

2) Calculate:
   a. Common mode level, i.e. differential offset of the sensor output: \( V_{\text{CM}} = 0.5 \cdot (V_{\text{atm}} + V_{\text{amm}}) \)
   b. Relative or percentage offset of the sensor output: \( \text{Offset}_{\text{sensor}} [%] = \frac{V_{\text{CM}}}{V_{\text{max}}-V_{\text{min}}} \cdot 100\% \)

3) Determine which of the two following cases is valid.
   a. If \( \text{Offset}_{\text{sensor}} [%] > 43\% \) then select \( \text{Offset} = 111 \) (i.e., 43.25%)
   b. If \( 0\% < \text{Offset}_{\text{sensor}} [%] \leq 43\% \) then select \( \text{Offset} \leq \text{Offset}_{\text{sensor}} [%] \) (Offset setup value; see Table 2.5)

4) The totally required, optimum gain can be determined as:
   \[
   \text{Gain}_{\text{total, opt}} = \frac{1.4 \cdot V_{\text{max}}}{V_{\text{max}} \cdot (1 - \text{Offset}_{\text{sensor}}/100)}
   \]
   then select nearest gain to \( \text{Gain}_{\text{total, opt}} \), where \( \text{Gain}_{\text{total}} \leq \text{Gain}_{\text{total, opt}} \)

5) The gain setup can be separated into the three factors \( \text{Gain}_{\text{amp1}}, \text{Gain}_{\text{amp2}} \) (for the 2-stage amplifier) and \( \text{Gain}_{\text{ADC}} \) (1 for no-shift or 2 for shift operation) according to:
   \[
   \text{Gain}_{\text{total}} = \text{Gain}_{\text{amp1}} \cdot \text{Gain}_{\text{amp2}} \cdot \text{Gain}_{\text{ADC}}
   \]
   a. If no offset shift is performed (\( \text{Shift}_\text{method} = 0 \) and \( \text{Offset} = 000 \)), the amplifier gain is \( \text{Gain}_{\text{total}} \)
   b. If an offset shift is performed (\( \text{Shift}_\text{method} = 1 \)), the amplifier gain is \( 0.5 \cdot \text{Gain}_{\text{total}} \)
2.3.4. Temperature Measurement
The ZSSC3218 provides an internal temperature sensor measurement to allow compensation for temperature effects. See section 1.3 for the temperature sensor resolution. The temperature output signal is a differential voltage that is adapted by the amplifier for the ADC input.

For temperature measurements, the respective settings are defined and programmed in the MTP by IDT.

2.3.5. External Sensor Supply: Bridge Sensors
The ZSSC3218 provides dedicated supply pins VDDB and VSSB for resistive bridge-type sensors (bit \([11]=0\) in \(SM\_config\), MTP registers \(12\_HEX\) or \(16\_HEX\)). The ADC reference voltages for the sensor bridge measurement are derived from these internal voltages such that bridge supply disturbances are suppressed. The current drive ability of \(V\_\text{DOB}\) is limited (see \(I\_\text{VDDB}\) in section 1.2).

2.3.6. External Sensor: Absolute Voltage Source Sensors
The ZSSC3218 can alternatively process signals from an absolute-voltage source sensor, e.g. a thermopile element. The respective input-type selection can be done with \(bit[11]=1\) in \(SM\_config\), MTP registers \(12\_HEX\) or \(16\_HEX\). The respective sensor element must be connected between the pins INP and INN, whereas INN is internally connected to the ZSSC3218’s analog ground (not! being VSSB). VDDB and VSSB should not be connected if an absolute-voltage source sensor is applied. The offset shift should be set to maximum in this case, \(Shift\_method = 1\) and \(Offset = 111\) in \(SM\_config\). The required gain can be determined according to the procedure described in section 2.3.3.
2.4. Digital Section

2.4.1. Digital Signal Processor (DSP) Core
The “DSP Core” block performs the algorithm for correcting the sensor signal. The required coefficients are stored in the MTP memory.

When the measurement results are available, the “end of conversion” signal is set at the EOC pin if no interrupt-threshold has been set up (bits[8:7]=00 in memory register 02_HEX). The internal EOC information is valid only if both the measurement and calculation have been completed. Alternatively, the EOC pin can indicate exceeding or underrunning of a certain threshold or leaving of valid-result range as described in section 3.3.

2.4.2. MTP Memory
The ZSSC3218’s memory is designed with a real MTP structure. The memory is organized in 16-bit registers that can be re-written multiple (at least 1000) times. The user has access to a 57 x 16-bit storage area for values such as calibration coefficients. The required programming voltage is generated internally in the ZSSC3218. A checksum (generation with command 90_HEX) is evaluated for integrity-check purposes of the entire memory.

2.4.3. Clock Generator
The clock generator provides approximately 4MHz, and 1MHz clock signals as the time base for IC-internal signal processing. The frequency is trimmed during production test.

2.4.4. Power Supervision
The power supervision block as a part of the voltage regulator combined with the digital section monitors all power supplies to ensure a defined reset of all digital blocks during power-up or power supply interruptions. “Brown-out” cases at the supply that do not meet the power-on reset (POR) requirements (see Table 1.3), must be resolved with a reset pulse at the RES pin.

2.4.5. Interface
The ZSSC3218 can communicate with the user’s communication master or PC via an SPI or I²C™ interface†. The interface type is selectable with the very first activity at the interface after power-up or reset, with the first activity being

a. If the first command is an I²C™ command and SS pin has been inactive until receiving this command, the ZSSC3218 enters I²C™ mode.

b. If the first interface action is the SS pin being set to active (HIGH-active or LOW-active depending on SS_polarity bit[9] in memory interface register 02_HEX), then the ZSSC3218 enters SPI mode.

During the initiation sequence (after power-up or reset), any potential transition on SS is ignored. Switching to the SPI mode is only possible after the power-up sequence. If SS is not connected, the SS pin internal pull-up keeps the ZSSC3218 in I²C™ mode.

To also provide interface accessibility in Sleep State (all features inactive except for the digital interface logic), the interface circuitry is directly supplied by VDD.

† Functional I²C™ interface properties correspond to the NXP I²C™ bus specification Rev. 0.3 (June 2009).
3 Functional Description

3.1. Power Up
Specifications for this section are given in sections 1.2 and 1.3. On power-up, the ZSSC3218 communication interface is able to receive the first command after a time $t_{STA1}$ from when the VDD supply is within operating specifications. The ZSSC3218 can begin the first measurement after a time of $t_{STA2}$, from when the VDD supply is operational. Alternatively, instead of a power-on-reset, a reset and new power-up-sequence respectively can be triggered by an IC-reset signal (high low) at RES pin.

The wake up time from Sleep State to Active State (see section 3.4) after receiving the activating command is defined as $t_{WUP1}$ and $t_{WUP2}$. In Command Mode, subsequent commands can be sent after $t_{WUP1}$. The first measurement starts after $t_{WUP2}$ if a measurement request was sent.

3.2. Measurements
Available measurement procedures are

- AZSM: auto-zero (external) sensor measurement
- SM: (external) sensor measurement
- AZTM: auto-zero temperature measurement
- TM: temperature measurement

AZSM: The configuration is loaded for measuring the external sensor; i.e., a resistive bridge or an absolute voltage source. The “Multiplexer” block connects the amplifier input to the AGND analog ground reference. An analog-to-digital (A2D) conversion is performed so that the inherent system offset for the respective configuration is converted by the ADC to a digital word with a resolution according to the respective MTP configuration.

SM: The configuration is loaded for measuring the external sensor; i.e., a resistive bridge or an absolute voltage source. The “Multiplexer” block connects the amplifier input to the INP and INN pins. An A2D conversion is performed. The result is a digital word with a resolution according to the MTP configuration.

AZTM: The configuration for temperature measurements is loaded. The “Multiplexer” block connects the amplifier input to AGND. An analog-to-digital conversion is performed so that the inherent system offset for the temperature configuration is converted by the ADC with a resolution according to the respective MTP configuration.

TM: The configuration for temperature measurements is loaded. The “Multiplexer” block connects the amplifier input to the internal temperature sensor. An A2D conversion is performed. The result is a digital word with a resolution according to the MTP configuration.

The typical application’s measurement cycle is a complete SSC measurement (using the commands $AA_{HEX}$ to $AF_{HEX}$; see section 3.4.1) with AZSM, SM, AZTM, and TM followed by a signal correction calculation.
3.3. Interrupt (EOC Pin)

The EOC pin can be programmed to operate either as a pure “measurement busy” and end-of-conversion indicator or as a configurable interrupt indicator. The respective basic operation must be programmed to the INT_setup bits [8:7] in register 02\_HEX (see Table 3.5).

In addition, one or two 24-bit-quantized thresholds can be programmed (TRSH1 and TRSH2 in memory registers 13\_HEX, 14\_HEX, and 15\_HEX).

The respective thresholds are programmed left-aligned in the memory; i.e., they must be programmed with the threshold’s MSB in the memory register’s MSB, etc. The number of LSB threshold bits that are used is equal to the number of bits for the selected ADC resolution (determined by the Adc_bits field in registers 12\_HEX and 16\_HEX); unused LSB bits are ignored.

The interrupt functionality is only available for digital values from the SSC-calculation unit (i.e., after sensor signal conditioning); raw values cannot be monitored by the interrupt feature. Figure 3.1 shows the different setup options and the respective response at the EOC pin. The use of the interrupt functionality is recommended for cyclic operation (command AB\_HEX with the respective power-down setup in the Interface Configuration memory register 02\_HEX). The EOC level continuously represents the respective SSC-measurement results only during cyclic operation. For single or oversample measurement requests without cyclic operation, the EOC output signal is reset to logical zero at the beginning of each new measurement, even though the interrupt thresholds are considered correctly at the end of each measurement (setting EOC to logical one or zero is dependent on the interrupt setup).
**Figure 3.1 Interrupt Functionality**

Case A: threshold1 > threshold2

Case B: threshold1 < threshold2

INT_setup=01: Measurement < threshold1

INT_setup=10: Measurement > threshold1

INT_setup=11
3.4. **Operational Modes**

Figure 3.2 illustrates the ZSSC3218 power-up sequence and subsequent operation depending on the selected interface communication mode (I²C™ or SPI) as determined by interface-related first activities after power-up or reset. If the first command after power-up is a valid I²C™ command, the interface will function as an I²C™ interface until the next power-on-reset. If there is no valid I²C™ command, but an active signal at the SS pin is detected as the first valid activity, then the interface will respond as an SPI slave. With either interface, after the voltage regulators are switched on, the ZSSC3218’s low-voltage section (LV) is active while the related interface configuration information is read from memory. Then the LV section is switched off, the ZSSC3218 goes into Sleep State, and the interface is ready to receive commands. The interface is always powered by V_DD, so it is referred to as the high voltage section (HV).

See Table 3.1 for definitions of the commands.

Figure 3.3 shows the ZSSC3218 operation in Normal Mode (with two operation principles: “Sleep” and “Cyclic”) and Command Mode, including when the LV and HV sections are active as indicated by the color legend. The Normal Mode automatically returns to Sleep State after executing the requested measurements, or periodically wakes up and conducts another measurement according to the setting for the sleep duration configured by CYC_period (bits[14:12] in memory register 02_HEX). In Command Mode, the ZSSC3218 remains active if a dedicated command (Start_NOM) is sent, which is helpful during calibration. Command Mode can only be entered if Start_CM is the first command received after POR.
Figure 3.2 Operational Flow Chart: Power Up

**Color Legend:**
- LV Operation
- HV Operation

**I2C™ Interface**
- Power up LV
- LV Operation
- Save: IC ID / Data / Status
- CommandMode == active || Test==1
- Power Down (switch off LV and wait for command)
- Receive: Command
- Received CMD ID == IC-ID
- Read_bit == 1 (Data Fetch)
- Execute: Data Fetch

**SPI Interface**
- Power up LV
- LV Operation
- Save: Setup / Data / Status
- CommandMode == active || Test==1
- Power Down (switch off LV and wait for command)
- RST(SS)==1
- Receive: Command
- NOP
- Execute: Data Fetch

---

`I2C™™ slave address is loaded, and SS_polarity determines if SS pin is active high or low`
Figure 3.3  Operational Flow Chart: Command Mode and Normal Mode (Sleep and Cyclic)
3.4.1. SPI/I2C™ Commands

The SPI/I2C™ commands supported by the ZSSC3218 are listed in Table 3.1. The command to read an address in the user memory is the same as its address. The command to write to an address in user memory is the address plus 40HEX.

There is a IDT-reserved section of memory that can be read but not over-written by the user.

Table 3.1 SPI/I2C™ Commands

Note: Every return starts with a status byte followed by the data word as described in section 3.5.1.

<table>
<thead>
<tr>
<th>Command (Byte)</th>
<th>Return</th>
<th>Description</th>
<th>Normal Mode</th>
<th>Command Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>00HEX to 39HEX</td>
<td>16-bit user data</td>
<td>Read data in the user memory address (00HEX to 39HEX) matching the command (might not be using all addresses).</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3AHEX to 3FHEX</td>
<td>16-bit IDT-reserved memory data</td>
<td>Read data in IDT-reserved memory at address (3AHEX to 3FHEX).</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>40HEX to 79HEX followed by data (0000HEX to FFFFHEX)</td>
<td>—</td>
<td>Write data to user memory at address specified by command minus 40HEX (addresses 00HEX to 39HEX respectively; might not be using all addresses).</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>90HEX</td>
<td>—</td>
<td>Calculate and write memory checksum (CRC).</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>A0HEX to A7HEX followed by XXXXHEX (see Table 3.2)</td>
<td>24-bit formatted raw data</td>
<td>Get_Raw This command can be used to perform a measurement and write the raw ADC data into the output register. The LSB of the command determines how the AFE configuration register is loaded for the Get_Raw measurement (see Table 3.2).</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>A8HEX</td>
<td>—</td>
<td>Start_NOM Exit Command Mode and transition to Normal Mode (Sleep or Cyclic).</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>A9HEX</td>
<td>—</td>
<td>Start_CM Exit Normal Mode and transition to Command Mode (as very first command after power-up).</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>AAHEX</td>
<td>24-bit formatted fully corrected sensor measurement data + 24-bit corrected temperature data</td>
<td>Measure Trigger full measurement cycle (AZSM, SM, AZTM, and TM, as described in section 3.2) and calculation and storage of data in the output buffer using the configuration from MTP.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Command (Byte)</td>
<td>Return</td>
<td>Description</td>
<td>Normal Mode</td>
<td>Command Mode</td>
</tr>
<tr>
<td>---------------</td>
<td>--------</td>
<td>-------------</td>
<td>-------------</td>
<td>--------------</td>
</tr>
<tr>
<td>AB\text{HEX}</td>
<td>24-bit formatted fully corrected sensor measurement data + 24-bit corrected temperature data</td>
<td>Measure Cyclic This command triggers a continuous full measurement cycle (AZSM, SM, AZTM, and TM; see section 3.2) and calculation and storage of data in the output buffer using the configuration from MTP followed by a pause determined by CYC_period (bits[14:12] in memory register 02\text{HEX}).</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AC\text{HEX}</td>
<td>24-bit formatted fully corrected sensor measurement data + 24-bit corrected temperature data</td>
<td>Oversample-2 Measure Mean value generation: 2 full measurements are conducted (as in command AA\text{HEX}), the measurements’ mean value is calculated, and data is stored in the output buffer using the configuration from MTP; no power down or pause between the 2 measurements.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AD\text{HEX}</td>
<td>24-bit formatted fully corrected sensor measurement data + 24-bit corrected temperature data</td>
<td>Oversample-4 Measure Mean value generation: 4 full measurements (as in command AA\text{HEX}) are conducted, the measurements’ mean value is calculated, and data is stored in the output buffer using the configuration from MTP; no power down or pause between the 4 measurements.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AE\text{HEX}</td>
<td>24-bit formatted fully corrected sensor measurement data + 24-bit corrected temperature data</td>
<td>Oversample-8 Measure Mean value generation: 8 full measurements (as in command AA\text{HEX}) are conducted, the measurements’ mean value is calculated, and data is stored in the output buffer using the configuration from MTP; no power down or pause between the 8 measurements.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AF\text{HEX}</td>
<td>24-bit formatted fully corrected sensor measurement data + 24-bit corrected temperature data</td>
<td>Oversample-16 Measure Mean value generation: 16 full measurements (as in command AA\text{HEX}) are conducted, the measurements’ mean value is calculated, and data is stored in the output buffer using the configuration from MTP; no power down or pause between the 16 measurements.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B0\text{HEX}</td>
<td>—</td>
<td>Select SM_config1 register (12\text{HEX} in memory) For any measurement using the memory contents for the analog front-end and sensor setup, the respective setup is loaded from the SM_config1 register; status bit[1]==0 (default).</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Command (Byte)</td>
<td>Return</td>
<td>Description</td>
<td>Normal Mode</td>
<td>Command Mode</td>
</tr>
<tr>
<td>---------------</td>
<td>--------</td>
<td>-------------</td>
<td>-------------</td>
<td>--------------</td>
</tr>
<tr>
<td>B1_HEX</td>
<td>—</td>
<td><strong>Select SM_config2 register</strong> (16_HEX in memory) For any measurement using the memory contents for the analog front-end and sensor setup, the respective setup is loaded from the SM_config2 register, status bit[1]==1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF_HEX</td>
<td>—</td>
<td><strong>STOP_CYC</strong> This command causes a power-down halting the update / cyclic measurement operation and causing a transition to Normal-Sleep operation.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>FX_HEX</td>
<td>Status followed by last 24-bit data</td>
<td><strong>NOP</strong> Only valid for SPI (see sections 3.5.1 and 3.5.2).</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Table 3.2 Get\_Raw Commands**

<table>
<thead>
<tr>
<th>Command (Hex)</th>
<th>Measurement</th>
<th>AFE Configuration Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0_HEX followed by 0000_HEX</td>
<td>SM – Sensor Measurement</td>
<td>SM_config1 register or SM_config2 register.</td>
</tr>
<tr>
<td>A1_HEX followed by ssss_HEX</td>
<td>SM – Sensor Measurement</td>
<td>ssss is the user’s configuration setting for the measurement provided via the interface. The format and purpose of configuration bits must be according to the definitions for SM_config (see Table 3.5).</td>
</tr>
<tr>
<td>A2_HEX followed by 0000_HEX</td>
<td>SM-AZSM – Auto-Zero Corrected Sensor Measurement</td>
<td>SM_config</td>
</tr>
<tr>
<td>A3_HEX followed by ssss_HEX</td>
<td>SM-AZSM – Auto-Zero Corrected Sensor Measurement</td>
<td>ssss is the user’s configuration setting for the measurement provided via the interface. The format and purpose of configuration bits must be according to the definitions for SM_config and valid for temperature measurement in this case (bits [15:12] will be ignored).</td>
</tr>
<tr>
<td>A4_HEX followed by 0000_HEX</td>
<td>TM – Temperature Measurement</td>
<td>IDT-defined register</td>
</tr>
<tr>
<td>A5_HEX followed by ssss_HEX</td>
<td>TM – Temperature Measurement</td>
<td>ssss is the user’s configuration setting for the measurement provided via the interface. The format and purpose of configuration bits must be according to the definitions for SM_config and valid for temperature measurement in this case (bits [15:12] will be ignored).</td>
</tr>
<tr>
<td>A6_HEX followed by 0000_HEX</td>
<td>TM-AZTM – Auto-Zero Corrected Temperature Measurement</td>
<td>IDT-defined register</td>
</tr>
<tr>
<td>A7_HEX followed by ssss_HEX</td>
<td>TM-AZTM – Auto-Zero Corrected Temperature Measurement</td>
<td>ssss is the user’s configuration setting for the measurement provided via the interface. The format and purpose of these configuration bits must be according to the definitions for SM_config and valid for temperature measurement in this case (bits [15:12] will be ignored).</td>
</tr>
</tbody>
</table>

1) Recommended for raw data collection during calibration coefficient determination using the measurement setups pre-programmed in MTP.
2) Recommended for raw data collection during calibration coefficient determination using un-programmed (not in MTP), external measurement setups; e.g., for evaluation purposes.
3.5. Communication Interface

3.5.1. Common Functionality

Commands are handled by the command interpreter in the LV section. Commands that need additional data are not treated differently than other commands because the HV interface is able to buffer the command and all the data that belongs to the command and the command interpreter is activated as soon as a command byte is received.

Every response starts with a status byte followed by the data word. The data word depends on the previous command. It is possible to read the same data more than once if the read request is repeated (I²C™) or a NOP command is sent (SPI). If the next command is not a read request (I²C™) or a NOP (SPI), it invalidates any previous data.

The ZSSC3218 supports the parallel setup of two amplifier-ADC-configurations using SM_config1 and SM_config2. Switching between the two setups can be done with the commands B0_HEX and B1_HEX. Note that the respective activation command must always be sent prior to the measurement request.

The status byte contains the following bits in the sequence shown in Table 3.3:

- **Power indication (bit 6):** 1 if the device is powered (V_DDB on); 0 if not powered. This is needed for the SPI Mode where the master reads all zeroes if the device is not powered or in power-on reset (POR).
- **Busy indication (bit 5):** 1 if the device is busy, which indicates that the data for the last command is not available yet. No new commands are processed if the device is busy. 
  *Note:* The device is always busy if cyclic measurement operation has been set up and started.
- **Currently active ZSSC3218 mode (bits [4:3]):** 00 = Normal Mode; 01 = Command Mode; 1X = IDT reserved.
- **Memory integrity/error flag (bit 2):** 0 if integrity test passed; 1 if test failed. This bit indicates whether the checksum-based integrity check passed or failed. The memory error status bit is calculated only during the power-up sequence, so a newly written CRC will only be used for memory verification and status update after a subsequent ZSSC3218 power-on reset (POR) or reset by means of the RES pin.
- **Config Setup (bit 1):** This bit indicates which SM_config register is being used for the active configuration: SM_config1 (12_HEX) or SM_config2 (16_HEX). The two alternate configuration setups allow for two different configurations of the external sensor channel in order to support up to two application scenarios with the use of only one sensor-ZSSC3218 pair. This bit is 0 if SM_config1 was selected (default). This bit is 1 if SM_config2 was selected.
- **ALU saturation (bit 0):** If the last command was a measurement request, this bit is 0 if any intermediate value and the final SSC result are in a valid range and no SSC-calculation internal saturation occurred in the arithmetic logic unit (ALU). If the last command was a measurement request, this bit is 1 if an SSC-calculation internal saturation occurred. This bit is also 0 for any non-measurement command.

**Table 3.3 General Status Byte**

<table>
<thead>
<tr>
<th>Bit</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning</td>
<td>0</td>
<td>Powered?</td>
<td>Busy?</td>
<td>Mode</td>
<td>Memory error?</td>
<td>Config Setup</td>
<td>ALU Saturation</td>
<td></td>
</tr>
</tbody>
</table>
Table 3.4  Mode Status

<table>
<thead>
<tr>
<th>Status[4:3]</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>Normal Mode (sleep and cyclic operations)</td>
</tr>
<tr>
<td>01</td>
<td>Command Mode</td>
</tr>
<tr>
<td>10</td>
<td>IDT reserved</td>
</tr>
<tr>
<td>11</td>
<td>IDT reserved</td>
</tr>
</tbody>
</table>

Further status information can be provided by the EOC pin. The EOC pin is set high when a measurement and calculation have been completed (if no interrupt threshold is used, i.e. INT_setup==00BIN; see section 3.3).

3.5.2. SPI

The SPI Mode is available if the very first interface activity after ZSSC3218 power-up is an active signal at the SS pin. The polarity and phase of the SPI clock are programmable via the CKP_CKE setting in bits [11:10] in address 02HEX as described in Table 3.5. CKP_CKE is two bits: CPHA (bit 10), which selects which edge of SCLK latches data, and CPOL (bit 11), which indicates whether SCLK is high or low when it is idle. The polarity of the SS signal and pin are programmable via the SS_polarity setting (bit 9). The different combinations of polarity and phase are illustrated in the figures below.

Figure 3.4  SPI Configuration CPHA=0

[Diagram of SPI configuration with CPHA=0]
In SPI mode, each command except NOP is started as shown in Figure 3.6. After the execution of a command (busy = 0), the expected data can be read as illustrated in Figure 3.7 or if no data are returned by the command, the next command can be sent. The status can be read at any time with the NOP command (see Figure 3.8).

**Figure 3.6  SPI Command Request**

<table>
<thead>
<tr>
<th>Command Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSI</td>
</tr>
<tr>
<td>MISO</td>
</tr>
</tbody>
</table>

Note: A command request always consists of 3 bytes. If the command is shorter, then it must be completed with 0s. The data on MISO depend on the preceding command.
3.5.3. **I²C™**

I²C™ Mode will be selected if the very first interface activity after ZSSC3218 power-up is an I²C™ command. In I²C™ Mode, each command is started as shown in Figure 3.8. Only the number of bytes that are needed for the command must be sent. An exception is the HS-mode where 3 bytes must always be sent as in SPI Mode. After the execution of a command (busy = 0), the expected data can be read as illustrated in Figure 3.11 or if no data are returned by the command, the next command can be sent. The status can be read at any time as described in Figure 3.10.
**Figure 3.9  \textit{i}^2\textsc{c}™ Command Request**

**Command Request (\textit{i}^2\textsc{c}™ Write)**

- Master writes to slave
- Slave acknowledges

**Figure 3.10 \textit{i}^2\textsc{c}™ Read Status**

**Read Status (\textit{i}^2\textsc{c}™ Read)**

- Master reads from slave
- Slave acknowledges

**Figure 3.11 \textit{i}^2\textsc{c}™ Read Data**

**Read Data (\textit{i}^2\textsc{c}™ Read)**

(a) Example: after the completion of a Memory Read command

(b) Example: after the completion of a Full Measurement command (AA\text{HEX})
All mandatory \texttt{I\textsuperscript{2}C}™-bus protocol features are implemented. Optional features such as clock stretching, 10-bit slave address, etc., are not supported by the ZSSC3218's interface.

In \texttt{I\textsuperscript{2}C}-High-Speed Mode, a command consists of a fixed length of three bytes.

3.6. \textbf{Multiple Time Programmable (MTP) Memory}

In the ZSSC3218, the memory is organized in 16-bit wide registers and can be programmed multiple times (ca. 1000). There are 57 x 16-bit registers available for customer use. Each register can be re-programmed. Basically, there are two MTP content sectors:

- **Customer Use:** accessible by means of regular write operations: \texttt{40\textsubscript{HEX} to 79\textsubscript{HEX}}. It contains the customer ID, interface setup data, measurement setup information, calibration coefficients, etc.

- **IDT Use:** only accessible for write operations by IDT. The IDT sector contains specific trim information and is programmed during manufacturing test by IDT.

3.6.1. \textbf{Programming Memory}

Programming memory is possible with any specified supply voltage level at \texttt{VDD}. The MTP programming voltage itself is generated by means of an integrated charge pump, generating an internal memory programming voltage; no additional, external voltage, other than \texttt{VDD} (as specified) is needed. A single 16-bit register write will be completed within 16ms after the respective programming command has been sent. After the memory is programmed, it must be read again to verify the validity of the memory contents.
3.6.2. Memory Contents

Table 3.5 MTP Memory Content Assignments

<table>
<thead>
<tr>
<th>MTP Address</th>
<th>Word / Bit Range</th>
<th>Default Setting</th>
<th>Description</th>
<th>Notes / Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Cust_ID0</td>
<td>Customer ID byte 0 (combines with memory word 01&lt;sub&gt;HEX&lt;/sub&gt; to form customer ID).</td>
</tr>
<tr>
<td>01&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Cust_ID1</td>
<td>Customer ID byte 1 (combines with memory word 00&lt;sub&gt;HEX&lt;/sub&gt; to form customer ID).</td>
</tr>
</tbody>
</table>

**Interface Configuration**

<table>
<thead>
<tr>
<th>MTP Address</th>
<th>Word / Bit Range</th>
<th>Default Setting</th>
<th>Description</th>
<th>Notes / Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>02&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>6:0</td>
<td>00 0000&lt;sub&gt;BIN&lt;/sub&gt;</td>
<td>Slave_Addr</td>
<td>I²C™ slave address; valid range: 00&lt;sub&gt;HEX&lt;/sub&gt; to 7F&lt;sub&gt;HEX&lt;/sub&gt; (default: 00&lt;sub&gt;HEX&lt;/sub&gt;). Note: address codes 04&lt;sub&gt;HEX&lt;/sub&gt; to 07&lt;sub&gt;HEX&lt;/sub&gt; are reserved for entering the I²C™ High Speed Mode.</td>
</tr>
<tr>
<td></td>
<td>8:7</td>
<td>00&lt;sub&gt;BIN&lt;/sub&gt;</td>
<td>INT_setup</td>
<td>Interrupt configuration, EOC pin functionality:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>00 End-of-conversion signal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>01 0-1 transition if threshold1 (TRSH1) is exceeded and 1-0 transition if threshold1 is underrun again</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 0-1 transition if threshold1 is underrun and 1-0 transition if threshold1 is exceeded again</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11 EOC is determined by threshold settings (see section 3.3):</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If (TRSH1 &gt; TRSH2) then EOC/INT (interrupt level) = 0 if (TRSH1 &gt; MEAS ≥ TRSH2) where MEAS is the conditioned measurement result. Otherwise EOC/INT=1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If (TRSH1 ≤ TRSH2) then EOC = 1 if (TRSH1 ≤ MEAS &lt; TRSH2). Otherwise EOC = 0.</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0&lt;sub&gt;BIN&lt;/sub&gt;</td>
<td>SS_polarity</td>
<td>Determines the polarity of the Slave Select pin (SS) for SPI operation:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0 ⊆ Slave Select is active low (SPI and ZSSC3218 are active if SS==0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 ⊆ Slave Select is active high (SPI and ZSSC3218 are active if SS==1)</td>
</tr>
<tr>
<td>MTP Address</td>
<td>Word / Bit Range</td>
<td>Default Setting</td>
<td>Description</td>
<td>Notes / Explanations</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------</td>
<td>-----------------</td>
<td>-------------</td>
<td>----------------------</td>
</tr>
</tbody>
</table>
| 11:10       | 00\text{bin}    | CKP\_CKE        | Clock polarity and clock-edge select—determines polarity and phase of SPI interface clock with the following modes:  
00 \(\Leftrightarrow\) SCLK is low in idle state, data latch with rising edge and data output with falling edge  
01 \(\Leftrightarrow\) SCLK is low in idle state, data latch with falling edge and data output with rising edge  
10 \(\Leftrightarrow\) SCLK is high in idle state, data latch with falling edge and data output with rising edge  
11 \(\Leftrightarrow\) SCLK is high in idle state, data latch with rising edge and data output with falling edge |
| 14:12       | 000\text{bin}   | CYC\_period     | Update period (ZSSC3218 sleep time, except oscillator) in cyclic operation:  
000 \(\Leftrightarrow\) not assigned  
001 \(\Leftrightarrow\) 125ms  
010 \(\Leftrightarrow\) 250ms  
011 \(\Leftrightarrow\) 500ms  
100 \(\Leftrightarrow\) 1000ms  
101 \(\Leftrightarrow\) 2000ms  
110 \(\Leftrightarrow\) 4000ms  
111 \(\Leftrightarrow\) not assigned |
| 15          | 0\text{bin}     | SOT\_curve      | Type/shape of second-order curve correction for the sensor signal.  
0 \(\Leftrightarrow\) parabolic curve  
1 \(\Leftrightarrow\) s-shaped curve |
<table>
<thead>
<tr>
<th>MTP Address</th>
<th>Word / Bit Range</th>
<th>Default Setting</th>
<th>Description</th>
<th>Notes / Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>03&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Offset_S[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide sensor offset correction coefficient Offset_S. (The MSBs of this coefficient including sign are Offset_S[23:16], which is bits [15:8] in 0D&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>04&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Gain_S[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide value of the sensor gain coefficient Gain_S. (The MSBs of this coefficient including sign are Gain_S[23:16], which is bits [7:0] in 0D&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>05&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Tcg[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide coefficient Tcg for the temperature correction of the sensor gain. (The MSBs of this coefficient including sign are Tcg[23:16], which is bits [15:8] in 0D&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>06&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Tco[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide coefficient Tco for temperature correction of the sensor offset. (The MSBs of this coefficient including sign are Tco[23:16], which is bits [7:0] in 0E&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>07&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>SOT_tco[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide 2&lt;sup&gt;nd&lt;/sup&gt; order term SOT_tco applied to Tco. (The MSBs of this term including sign are SOT_tco[23:16], which is bits[15:8] in 0F&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>08&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>SOT_tcb[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide 2&lt;sup&gt;nd&lt;/sup&gt; order term SOT_tcb applied to Tcg. (The MSBs of this term including sign are SOT_tcb[23:16], which is bits[7:0] in 0F&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>09&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>SOT_sens[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide 2&lt;sup&gt;nd&lt;/sup&gt; order term SOT_sens applied to the sensor readout. (The MSBs of this term including sign are SOT_sens[23:16], which is bits[15:8] in 10&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>0A&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Offset_T[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide temperature offset correction coefficient Offset_T. (The MSBs of this coefficient including sign are Offset_T[23:16], which is bits[7:0] in 10&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>0B&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Gain_T[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide absolute value of the temperature gain coefficient Gain_T. (The MSBs of this coefficient including sign are Gain_T[23:16], which is bits[15:8] in 11&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>0C&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>15:0</td>
<td>0000&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>SOT_T[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide 2&lt;sup&gt;nd&lt;/sup&gt;-order term SOT_T applied to the temperature reading. (The MSBs of this coefficient including sign are SOT_T[23:16], which is bit[7:0] in 11&lt;sub&gt;HEX&lt;/sub&gt;)</td>
</tr>
<tr>
<td>MTP Address</td>
<td>Word / Bit Range</td>
<td>Default Setting</td>
<td>Description</td>
<td>Notes / Explanations</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------</td>
<td>-----------------</td>
<td>-------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>0D&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>7:0</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Gain_S[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide sensor gain correction coefficient Gain_S. (The LSBs of this coefficient are Gain_S[15:0] in register 04&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td></td>
<td>15:8</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Offset_S[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide sensor offset correction coefficient Offset_S. (The LSBs are Offset_S[15:0] in register 03&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td>0E&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>7:0</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Tco[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide coefficient Tco for temperature correction for the sensor offset. (The LSBs are Tco[15:0] in register 06&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td></td>
<td>15:8</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Tcg[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide coefficient Tcg for the temperature correction of the sensor gain. (The LSBs are Tcg[15:0] in register 05&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td>0F&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>7:0</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>SOT_tcg[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide 2&lt;sup&gt;nd&lt;/sup&gt; order term SOT_tcg applied to Tcg. (The LSBs are SOT_tcg[15:0] in register 08&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td></td>
<td>15:8</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>SOT_tco[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide 2&lt;sup&gt;nd&lt;/sup&gt; order term SOT_tco applied to Tco. (The LSBs are SOT_tco[15:0] in register 07&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td>10&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>7:0</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Offset_T[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide temperature offset correction coefficient Offset_T. (The LSBs are Offset_T[15:0] in register 0A&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td></td>
<td>15:8</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>SOT_sens[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide 2&lt;sup&gt;nd&lt;/sup&gt; order term SOT_sens applied to the sensor readout. (The LSBs are SOT_sens[15:0] in register 09&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td>11&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>7:0</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>SOT_T[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide 2&lt;sup&gt;nd&lt;/sup&gt; order term SOT_T applied to the temperature reading. (The LSBs are SOT_T[15:0] in register 0B&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td></td>
<td>15:8</td>
<td>00&lt;sub&gt;HEX&lt;/sub&gt;</td>
<td>Gain_T[23:16]</td>
<td>Bits [23:16] including sign for the 24-bit-wide absolute value of the temperature gain coefficient Gain_T. (The LSBs are Gain_T[15:0] in register 0B&lt;sub&gt;HEX&lt;/sub&gt;.)</td>
</tr>
<tr>
<td>MTP Address</td>
<td>Word / Bit Range</td>
<td>Default Setting</td>
<td>Description</td>
<td>Notes / Explanations</td>
</tr>
<tr>
<td>------------</td>
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<td>----------------------</td>
</tr>
<tr>
<td>Measurement Configuration Register 1 (SM_config1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:0</td>
<td>000&lt;sub&gt;BIN&lt;/sub&gt;</td>
<td>Gain_stage1</td>
<td>Gain setting for the 1&lt;sup&gt;st&lt;/sup&gt; PREAMP stage with Gain_phase1 $\Rightarrow Gainamp1$:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>000 $\Rightarrow$ 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>001 $\Rightarrow$ 12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>010 $\Rightarrow$ 20</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>011 $\Rightarrow$ 30</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>100 $\Rightarrow$ 40</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>101 $\Rightarrow$ 60</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>110 $\Rightarrow$ 80</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>111 $\Rightarrow$ 120 (Might affect noise and accuracy specifications depending on sensor setup)</td>
<td></td>
</tr>
<tr>
<td>5:3</td>
<td>000&lt;sub&gt;BIN&lt;/sub&gt;</td>
<td>Gain_stage2</td>
<td>Gain setting for the 2&lt;sup&gt;nd&lt;/sup&gt; PREAMP stage with Gain_phase2 $\Rightarrow Gainamp2$:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>000 $\Rightarrow$ 1.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>001 $\Rightarrow$ 1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>010 $\Rightarrow$ 1.3</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>011 $\Rightarrow$ 1.4</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>100 $\Rightarrow$ 1.5</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>101 $\Rightarrow$ 1.6</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>110 $\Rightarrow$ 1.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>111 $\Rightarrow$ 1.8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0&lt;sub&gt;BIN&lt;/sub&gt;</td>
<td>Gain_polarity</td>
<td>Set up the polarity of the sensor bridge’s gain (inverting of the chopper) with</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 $\Rightarrow$ positive (no polarity change)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 $\Rightarrow$ negative (180° polarity change)</td>
<td></td>
</tr>
<tr>
<td>10:7</td>
<td>0000&lt;sub&gt;BIN&lt;/sub&gt;</td>
<td>Adc_bits</td>
<td>Absolute number of bits for the ADC conversion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ADC_bits:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0000 $\Rightarrow$ 12-bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0001 $\Rightarrow$ 13-bit</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0010 $\Rightarrow$ 14-bit</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>0011 $\Rightarrow$ 15-bit</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0100 $\Rightarrow$ 16-bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0101 $\Rightarrow$ 17-bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0110 $\Rightarrow$ 18-bit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0111 to 1111 $\Rightarrow$ not assigned</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>0&lt;sub&gt;BIN&lt;/sub&gt;</td>
<td>AbsV_enable</td>
<td>Enable bit for thermopile input selection (INN connected to AGND, INP connected to absolute voltage source) with AbsV_enable:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 $\Rightarrow$ absolute voltage input disabled (default)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 $\Rightarrow$ absolute voltage input enabled (e.g. for a thermopile)</td>
<td></td>
</tr>
<tr>
<td>MTP Address</td>
<td>Word / Bit Range</td>
<td>Default Setting</td>
<td>Description</td>
<td>Notes / Explanations</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------</td>
<td>----------------</td>
<td>-------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>14:12</td>
<td>000_{BIN}</td>
<td>Offset</td>
<td>Differential signal’s offset shift in the ADC; compensation of signal offset by x% of input signal: 000 $\Rightarrow$ no offset compensation 001 $\Rightarrow$ 6.75% offset 010 $\Rightarrow$ 12.5% offset 011 $\Rightarrow$ 19.25% offset 100 $\Rightarrow$ 25% offset 101 $\Rightarrow$ 31.75% offset 110 $\Rightarrow$ 38.5% offset 111 $\Rightarrow$ 43.25% offset Note: Bit 15 below must be set to 1 to enable the offset shift.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0_{BIN}</td>
<td>Shift_method</td>
<td>Offset shift method switch: 0 $\Rightarrow$ No offset shift. Offset (bits [14:12] in 12_{HEX}) must be set to 000_{BIN}; Gain_{ADC} = 1 1 $\Rightarrow$ Offset shift ADC; Gain_{ADC} = 2</td>
<td></td>
</tr>
<tr>
<td>13_{HEX}</td>
<td>15:0 0000_{HEX}</td>
<td>TRSH1[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide interrupt threshold1, TRSH1. (The MSB bits for this threshold are TRSH1[23:16], which is bits [7:0] of register 15_{HEX}.)</td>
<td></td>
</tr>
<tr>
<td>14_{HEX}</td>
<td>15:0 0000_{HEX}</td>
<td>TRSH2[15:0]</td>
<td>Bits [15:0] of the 24-bit-wide interrupt threshold2, TRSH2. (The MSB bits for this threshold are TRSH2[23:16], which is bits[15:8] of register 15_{HEX}.)</td>
<td></td>
</tr>
<tr>
<td>15_{HEX}</td>
<td>7:0 00_{HEX}</td>
<td>TRSH1[23:16]</td>
<td>Bits [23:16] of the 24-bit-wide interrupt threshold1, TRSH1. (The LSB bits for this threshold are TRSH1[15:0], which is bits[15:0] of register 13_{HEX}.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15:8 00_{HEX}</td>
<td>TRSH2[23:16]</td>
<td>Bits [23:16] of the 24-bit-wide interrupt threshold2, TRSH2. (The LSB bits for this threshold are TRSH2[15:0], which is bits[15:0] of register 14_{HEX}.)</td>
<td></td>
</tr>
</tbody>
</table>

**Measurement Configuration Register 2 (SM_config2)**

<table>
<thead>
<tr>
<th>MTP Address</th>
<th>Word / Bit Range</th>
<th>Default Setting</th>
<th>Description</th>
<th>Notes / Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>16_{HEX}</td>
<td>2:0 000_{BIN}</td>
<td>Gain_stage1</td>
<td>Gain setting for the 1st PREAMP stage with Gain_stage1 $\Leftrightarrow$ Gain_{amp1}: 000 $\Rightarrow$ 6 001 $\Rightarrow$ 12 010 $\Rightarrow$ 20 011 $\Rightarrow$ 30 100 $\Rightarrow$ 40 101 $\Rightarrow$ 60 110 $\Rightarrow$ 80 111 $\Rightarrow$ 120 (Might affect noise and accuracy specifications depending on sensor setup)</td>
<td></td>
</tr>
<tr>
<td>MTP Address</td>
<td>Word / Bit Range</td>
<td>Default Setting</td>
<td>Description</td>
<td>Notes / Explanations</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------</td>
<td>-----------------</td>
<td>------------------------------------------------------------------------------</td>
<td>----------------------</td>
</tr>
</tbody>
</table>
| 5:3         | 000<sub>BIN</sub> | Gain<sub>_stage2</sub> | Gain setting for the 2<sup>nd</sup> PREAMP stage with Gain<sub>_stage2</sub> ⇔ Gain<sub>amp2</sub>: | 000 ⇔ 1.1  
001 ⇔ 1.2  
010 ⇔ 1.3  
011 ⇔ 1.4  
100 ⇔ 1.5  
101 ⇔ 1.6  
110 ⇔ 1.7  
111 ⇔ 1.8 |
| 6           | 0<sub>BIN</sub>   | Gain<sub>_polarity</sub> | Set up the polarity of the sensor bridge’s gain (inverting of the chopper) with | 0 ⇔ positive (no polarity change)  
1 ⇔ negative (180° polarity change) |
| 10:7        | 0000<sub>BIN</sub>| Adc<sub>_bits</sub> | Absolute number of bits for the ADC conversion ADC<sub>_bits</sub>: | 0000 ⇔ 12-bit  
0001 ⇔ 13-bit  
0010 ⇔ 14-bit  
0011 ⇔ 15-bit  
0100 ⇔ 16-bit  
0101 ⇔ 17-bit  
0110 ⇔ 18-bit  
0111 to 1111 ⇔ not assigned |
| 11          | 0<sub>BIN</sub>   | AbsV<sub>_enable</sub> | Enable bit for thermopile input selection (INN connected to AGND, INP connected to absolute voltage source) with AbsV<sub>_enable</sub>: | 0 ⇔ absolute voltage input disabled (default)  
1 ⇔ absolute voltage input enabled (e.g. for a thermopile) |
| 14:12       | 000<sub>BIN</sub>| Offset           | Differential signal’s offset shift in the ADC; compensation of signal offset by x% of input signal: | 000 ⇔ no offset compensation  
001 ⇔ 6.75% offset  
010 ⇔ 12.5% offset  
011 ⇔ 19.25% offset  
100 ⇔ 25% offset  
101 ⇔ 31.75% offset  
110 ⇔ 38.5% offset  
111 ⇔ 43.25% offset |
|             |                  |                 | Note: Bit 15 below must be set to 1 to enable the offset shift. | |
### Offset Shift Method

- **0BIN Shift_method**: No offset shift. Offset (bits[14:12] in 16HEX) must be set to 000BIN; GainADC = 1
- **1BIN Shift_method**: Offset Shift ADC, GainADC = 2

### Post-Calibration Offset Correction Coefficients

<table>
<thead>
<tr>
<th>Address</th>
<th>Word / Bit Range</th>
<th>Default Setting</th>
<th>Description</th>
<th>Notes / Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>17HEX</td>
<td>15:0</td>
<td>0000HEX</td>
<td>SENS_Shift[15:0]</td>
<td>Bits [15:0] of the post-calibration sensor offset shift coefficient SENS_Shift. (The MSB bits of SENS_Shift are bits [7:0] of register 19HEX.)</td>
</tr>
<tr>
<td>18HEX</td>
<td>15:0</td>
<td>0000HEX</td>
<td>T_Shift[15:0]</td>
<td>Bits [15:0] of the post-calibration temperature offset shift coefficient T_Shift. (The MSB bits of T_Shift are bits [15:8] of register 19HEX.)</td>
</tr>
<tr>
<td>19HEX</td>
<td>7:0</td>
<td>00HEX</td>
<td>SENS_Shift[23:16]</td>
<td>Bits [23:16] of the post-calibration sensor offset shift coefficient SENS_Shift. (The LSB bits of SENS_Shift are in register 17HEX.)</td>
</tr>
<tr>
<td></td>
<td>15:8</td>
<td>00HEX</td>
<td>T_Shift[23:16]</td>
<td>Bits [23:16] of the post-calibration temperature offset shift coefficient T_Shift. (The LSB bits of T_Shift are in register 18HEX.)</td>
</tr>
</tbody>
</table>

### Free Memory – Arbitrary Use

<table>
<thead>
<tr>
<th>Address</th>
<th>Word / Bit Range</th>
<th>Default Setting</th>
<th>Description</th>
<th>Notes / Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>20HEX</td>
<td>15:0</td>
<td>0000HEX</td>
<td></td>
<td>Not assigned (e.g., can be used for Cust_IDx customer identification number)</td>
</tr>
<tr>
<td>21HEX</td>
<td>15:0</td>
<td>0000HEX</td>
<td></td>
<td>Not assigned (e.g., can be used for Cust_IDx customer identification number)</td>
</tr>
<tr>
<td>…</td>
<td></td>
<td></td>
<td></td>
<td>Not assigned (e.g., can be used for Cust_IDx customer identification number)</td>
</tr>
<tr>
<td>37HEX</td>
<td>15:0</td>
<td>0000HEX</td>
<td></td>
<td>Not assigned (e.g., can be used for Cust_IDx customer identification number)</td>
</tr>
<tr>
<td>38HEX</td>
<td>15:0</td>
<td>0000HEX</td>
<td></td>
<td>Not assigned (e.g., can be used for Cust_IDx customer identification number)</td>
</tr>
<tr>
<td>39HEX</td>
<td>15:0</td>
<td>-</td>
<td>Checksum</td>
<td>Generated (checksum) for the entire memory through a linear feedback shift register (LFSR); signature is checked on power-up to ensure memory content integrity</td>
</tr>
</tbody>
</table>

The memory integrity checksum (referred to as CRC) is generated through a linear feedback shift register with the following polynomial:

\[ g(x) = x^{16} + x^{15} + x^2 + 1 \]

with the initialization value: FFFFHEX.

If the CRC is valid, then the “Memory Error” status bit is set to 0.
3.7. Calibration Sequence

Calibration essentially involves collecting raw signal and temperature data from the sensor-ZSSC3218 system for different known sensor-element values (i.e., for a resistive bridge or an absolute voltage source) and temperatures. This raw data can then be processed by the calibration master (assumed to be the user’s computer), and the calculated calibration coefficients can then be written to on-chip memory.

Here is a brief overview of the three main steps involved in calibrating the ZSSC3218.

1. **Assigning a unique identification to the ZSSC3218.** This identification is written to shadow RAM and programmed in MTP memory. This unique identification can be stored in the two 16-bit registers dedicated to the customer ID. It can be used as an index into a database stored on the calibration PC. This database will contain all the raw values of the connected sensor-element readings and temperature readings for that part, as well as the known sensor-element measurand conditions and temperature to which the sensor-element was exposed.

2. **Data collection.** Data collection involves getting uncorrected (raw) data from the external sensor at different known measurand values and temperatures. Then this data is stored on the calibration master using the unique identification of the device as the index to the database.

3. **Coefficient calculation and storage in MTP memory.** After enough data points have been collected to calculate all the desired coefficients, the coefficients can be calculated by the calibration master. Then the coefficients can be programmed to the MTP memory.

**Result.** The sensor signal and the characteristic temperature effect on output will be linearized according to the setup-dependent maximum output range.

It is essential to perform the calibration with a fixed programming setup during the data collection phase. In order to prevent any accidental misprocessing, it is further recommended to keep the MTP memory setup stable during the entire calibration process as well as in the subsequent operation. A ZSSC3218 calibration only fits the setup used during its calibration. Changes of functional parameters after a successful calibration can decrease the precision and accuracy performance of the ZSSC3218 as well as of the entire application.

The ZSSC3218 supports operation with different sensor setups by means of the SM_config1 and SM_config2 registers. However, only one calibration coefficient set is supported. Therefore, either an alternative ZSSC3218-external signal calibration using the alternate SM_config settings must be performed to ensure that the programmed SSC coefficients are valid for both setups, or a full reprogramming of the SSC coefficients must be performed each time the sensor setup is changed. The selection of the external sensor setup (i.e., the AFE configuration) can be done with the interface commands B0HEX and B1HEX.

3.7.1. **Calibration Step 1 – Assigning Unique Identification**

Assign a unique identification number to the ZSSC3218 by using the memory write command (40\text{HEX} + data and 41\text{HEX} + data; see Table 3.1 and Table 3.5) to write the identification number to Cust_ID0 at memory address 00\text{HEX} and Cust_ID1 at address 01\text{HEX} as described in section 3.6.1. These two 16-bit registers allow for more than 4 billion unique devices.
3.7.2. Calibration Step 2 – Data Collection

The number of unique points (measurand and/or temperature) at which calibration must be performed generally depends on the requirements of the application and the behavior of the sensor in use. The minimum number of points required is equal to the number of correction coefficients to be corrected with a minimum of three different temperatures at three different sensor values. For a full calibration resulting in values for all 7 possible (external) sensor coefficients and 3 possible temperature coefficients, a minimum of 7 pairs of sensor with temperature measurements must be collected.

Within this minimum field of 3 measurand measurements x 3 temperature measurements, data must be collected for the specific value pairs (at known conditions) and then processed to calculate the coefficients. In order to obtain the potentially best and most robust coefficients, it is recommended that measurement pairs (temperature vs. measurand) be collected at the outer corners of the intended operation range or at least at points that are located far from each other. It is also essential to provide highly precise reference values as nominal, expected values. The measurement precision of the external calibration-measurement equipment should be ten times more accurate than the expected ZSSC3218 output accuracy after calibration in order to avoid accuracy losses caused by the nominal reference values (e.g., measurand signal and temperature deviations).

Note: The coefficients $SENS_{\text{shift}}$ and $T_{\text{shift}}$ must not be determined during this calibration step. These coefficients can be pre-determined as zero until after initial calibration.

Note: An appropriate selection of measurement pairs can significantly improve the overall system performance.

The determination of the measurand-related coefficients will use all of the measurement pairs. For the temperature-related correction coefficients, 3 (at three different temperatures) of the measurement pairs will be used.

Note: There is an inherent redundancy in the 7 sensor-related and 3 temperature-related coefficients. Since the temperature is a necessary output (which also needs correction), the temperature-related information is mathematically separated, which supports faster and more efficient DSP calculations during the normal usage of the sensor-ZSSC3218 system. The recommended approach for data collection is to make use of the raw-measurement commands described in Table 3.2.

For external sensor values, either of the following commands can be used depending on the user’s requirements:

- $A2_{\text{HEX}} + 0000_{\text{HEX}}$ single sensor measurement for which the configuration register will be loaded from the $SM_{\text{Config1}}$ register ($12_{\text{HEX}}$ in MTP); preprogramming the measurement setup in the MTP is required.

- $A3_{\text{HEX}} + ssss_{\text{HEX}}$ single sensor measurement for which the $SM_{\text{Config}}$ configuration register (Gain, ADC, Offset, etc.) will be loaded as the user’s configuration $ssss_{\text{HEX}}$, which must be provided externally via the interface as the data part of this command.

For temperature values, either of the following commands can be used depending on the user’s requirements:

- $A6_{\text{HEX}} + 0000_{\text{HEX}}$ single temperature measurement for which the configuration register will be loaded from an internal temperature configuration register (preprogrammed by IDT in the MTP); preprogramming of the respective configuration is done by IDT prior to ZSSC3218 delivery. This is the recommended approach for temperature data collection.
• A7\text{HEX} + ssss\text{HEX} single temperature measurement for which the configuration register (Gain, ADC, Offset, etc.) will be loaded as the user’s configuration ssss\text{HEX}, which must be provided externally via the interface as the data part of this command. The format and purpose of these configuration bits must be according to the definitions for \textit{SM\_config} and valid for temperature measurement in this case (bits [15:12] will be ignored).

3.7.3. Calibration Step 3a) – Coefficient Calculations
The math to perform the coefficient calculation is complicated and will not be discussed in detail. There is a brief overview in the next section. IDT provides software (DLLs) to perform the coefficient calculation (external to the sensor-ZSSC3218 system) based on auto-zero corrected values. After the coefficients are calculated, the final step is to write them to the MTP memory of the ZSSC3218.

3.7.4. Calibration Step 3b) – Post-Calibration Offset Correction
There are two special SSC coefficients, \textit{SENS\_shift} and \textit{T\_shift}. Normally, these coefficients must be predetermined as zero during the initial sensor calibration. The primary purpose of these two coefficients is to cancel additional offset shifts that could occur during or after final sensor assembly; e.g. if a respective sensor is finally placed and soldered on an application board.

If the final sensor assembly induced any kind of offset (on either the temperature or external sensor signal), the respective influence can be directly compensated by means of the \textit{SENS\_shift} and \textit{T\_shift} coefficients without the need to change the original SSC coefficient set. However, this post-calibration offset correction must be done under known ambient conditions (i.e., sensor measurand and/or temperature).

3.7.5. SSC Measurements
After the completion of the calibration procedure, linearized external sensor and temperature readings can be obtained using the commands AA\text{HEX} to AF\text{HEX} as described in Table 3.1.

Typically, only one external sensor is used in a single analog configuration using the setup in the \textit{SM\_config1} MTP register (12\text{HEX}). However, the ZSSC3218 can support a second analog configuration that is set up in the \textit{SM\_config2} MTP register (16\text{HEX}). This might be useful in cases where only one sensor-ZSSC3218 pair must support the measurand ranges for two different external sensors that have different precisions, required amplification, and sensor offset.

If a respective switching between setups is to be performed, the SSC coefficients for the alternate external sensor must be handled with one of the following methods:

• The programmed SSC coefficients are not used for the alternate external sensor. The ZSSC3218 performs only a factor-one transfer, i.e. no effective digital SSC correction – only a transfer of the auto-zero corrected raw ADC readings to the ZSSC3218 output without any scaling, etc.

• The coefficients are re-programmed each time the analog setup is changed.

\textit{SM\_config1} is selected as the analog setup register by default, so no specific activation is needed if only \textit{SM\_config1} is used. If \textit{SM\_config2} will also be used, the activation command B1\text{HEX} must be sent once prior to the measurement request. To switch to using \textit{SM\_config1}, the activation command B0\text{HEX} must be sent prior to use. This respective activation must be refreshed after any power-on-reset or RES pin reset.
3.8. The Calibration Math

3.8.1. Bridge Signal Compensation

The saturation check in the ZSSC3218 detects saturation effects of the internal calculation steps, allowing the final correction output to be determined despite the saturation. It is possible to get potentially useful signal conditioning results that have had an intermediate saturation during the calculations. These cases are detectable by observing the status bit[0] for each measurement result. Details about the saturation limits and the valid ranges for values are provided in the following equations.

The calibration math description assumes a calculation with integer numbers. The description is numerically correct concerning values, dynamic range, and resolution.

SOT_curve selects whether second-order equations compensate for sensor nonlinearity with a parabolic or S-shaped curve. The parabolic compensation is recommended for most sensor types.

For the following equations, the terms are as follows:

- $S$ = Corrected sensor reading output via $\text{I}^{2}\text{C}\text{™}$ or SPI; range [0_{HEX} to FFFFFFF_{HEX}]
- $S_{\text{Raw}}$ = Raw sensor reading from ADC after AZ correction; range [-0x7FFFF, 0x7FFFF]
- $Gain\_S$ = Sensor gain term; range [-0x7FFFF, 0x7FFFF]
- $Offset\_S$ = Sensor offset term; range [-0x7FFFF, 0x7FFFF]
- $Tcg$ = Temperature coefficient gain term; range [-0x7FFFF, 0x7FFFF]
- $Tco$ = Temperature coefficient offset term; range [-0x7FFFF, 0x7FFFF]
- $T_{\text{Raw}}$ = Raw temperature reading after AZ correction; range [-0x7FFFF, 0x7FFFF]
- $SOT\_tcg$ = Second-order term for Tcg non-linearity; range [-0x7FFFF, 0x7FFFF]
- $SOT\_tco$ = Second-order term for Tco non-linearity; range [-0x7FFFF, 0x7FFFF]
- $SOT\_sens$ = Second-order term for sensor non-linearity; range [-0x7FFFF, 0x7FFFF]
- $SENS\_shift$ = post-calibration, post-assembly sensor offset shift; range [-0x7FFFF, 0x7FFFF]
- $\lfloor \ldots \rfloor = \text{absolute value}$
- $\lfloor \ldots \rfloor_{ll}^{ul} = \text{bound/saturation number range from } ll \text{ to } ul, \text{ over/under-flow is reported as saturation in the status byte}$
The correction formula for the differential signal reading is represented as a two-step process depending on the SOT_curve setting.

Equations for the parabolic SOT_curve setting (SOT_curve = 0):

Simplified:

\[ K_1 = 2^{23} + \frac{T_{\text{Raw}}}{2^{23}} \cdot \left( \frac{4 \cdot \text{SOT}_{\text{tcg}}}{2^{23}} \cdot T_{\text{R}} + 4 \cdot T_{\text{cg}} \right) \]  

(1)

\[ K_2 = 4 \cdot \text{Offset}_S + S_{\text{Raw}} + \frac{T_{\text{Raw}}}{2^{23}} \cdot \left( \frac{4 \cdot \text{SOT}_{\text{tco}}}{2^{23}} \cdot T_{\text{R}} + 4 \cdot T_{\text{co}} \right) \]  

(2)

\[ Z_{SP} = \frac{4 \cdot \text{Gain}_S}{2^{23}} \cdot \frac{K_1}{2^{23}} \cdot K_2 + 2^{23} \]  

(delimited to positive number range)

(3)

\[ S = \frac{Z_{SP}}{2^{23}} \cdot \left( \frac{4 \cdot \text{SOT}_{\text{sens}}}{2^{23}} \cdot Z_{SP} + 2^{23} \right) + \text{SENS}_\text{shift} \]  

(delimited to positive number range)

(4)
Complete:

\[ K_1 = \left[ 2^{23} + \left[ \frac{T_{\text{Raw}}}{2^{23}} \cdot \left[ \frac{SOT_{\text{tcg}}}{2^{21}} \cdot T_{\text{Raw}} \right]_{-2^{20}}^{2^{20}-1} + 4T_{\text{tcg}} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \]  

(5)

\[ K_2 = \left[ 4 \cdot \text{Offset}_S + S_{\text{Raw}} + \left[ \frac{T_{\text{Raw}}}{2^{23}} \cdot \left[ \frac{SOT_{\text{tco}}}{2^{21}} \cdot T_{\text{Raw}} \right]_{-2^{20}}^{2^{20}-1} + 4T_{\text{tco}} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \]  

(6)

\[ Z_{SS} = \left[ \frac{\text{Gain}_S}{2^{23}} \cdot \left[ K_1 \cdot K_2 \right]_{-2^{25}}^{2^{25}-1} + 2^{23} \right]_{-2^{25}}^{2^{25}-1} \]  

(7)

\[ B = \left[ \frac{Z_{SS}}{2^{23}} \cdot \left[ \frac{SOT_{\text{sens}}}{2^{21}} \cdot \left[ Z_{\text{BP}} + 2^{21} \right]_{-2^{25}}^{2^{25}-1} + \text{SENS \_shift} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \]  

(8)

Equations for the S-shaped SOT\_curve setting (SOT\_curve = 1):

Simplified:

\[ Z_{SS} = \frac{4 \cdot \text{Gain}_S}{2^{23}} \cdot \frac{K_1}{2^{23}} \cdot K_2 \]  

(9)

\[ S = \frac{Z_{SS}}{2^{23}} \left( \frac{4 \cdot \text{SOT}_{\text{sens}}}{2^{21}} \cdot \left[ Z_{SS} + 2^{21} \right]_{-2^{25}}^{2^{25}-1} + \text{SENS \_shift} \right) \quad \text{(delimited to positive number range)} \]  

(10)

Complete:

\[ Z_{SS} = \left[ \frac{\text{Gain}_S}{2^{23}} \cdot \left[ K_1 \cdot K_2 \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} \]  

(11)

\[ S = \left[ \frac{Z_{SS}}{2^{23}} \cdot \left[ \frac{SOT_{\text{sens}}}{2^{21}} \cdot \left[ Z_{SS} + 2^{21} \right]_{-2^{25}}^{2^{25}-1} \right]_{-2^{25}}^{2^{25}-1} + 2^{23} + \text{SENS \_shift} \right]_{-2^{25}}^{2^{25}-1} \]  

(12)
3.8.2. Temperature Signal Compensation

Temperature is measured internally. Temperature correction contains both linear gain and offset terms as well as a second-order term to correct for any nonlinearities. For temperature, second-order compensation for nonlinearity is always parabolic.

The correction formula is best represented as a two-step process as follows:

**Simplified:**

\[
Z_T = \frac{4 \cdot Gain_T}{2^{23}} \cdot (T_{Raw} + 4 \cdot Offset_T) + 2^{23} \quad \text{(delimited to positive number range)}
\] (13)

\[
T = \frac{Z_T}{2^{23}} \left( \frac{4 \cdot SOT_T}{2^{23}} \cdot Z_T + 2^{23} \right) + T_{Shift} \quad \text{(delimited to positive number range)}
\] (14)

**Complete:**

\[
Z_T = \left[ \left( \frac{Gain_T}{2^{21}} \cdot T_{Raw} + 4 \cdot Offset_T \right) 2^{21} \right]_{0} + 2^{23} \quad \text{(15)}
\]

\[
T = \left[ \frac{Z_T}{2^{21}} \left( \frac{SOT_T}{2^{21}} \cdot Z_T + 2^{21} \right) 2^{21} \right]_{0} + T_{Shift} \quad \text{(16)}
\]

Where

- \( T \) = Corrected temperature sensor reading output via \( I^2C \)™ or SPI; range \([0_{\text{HEX}} \text{ to } FFFFFF_{\text{HEX}}]\)
- \( Gain_T \) = Gain coefficient for temperature; range \([-7FFFFFFH \text{ to } 7FFFFFFH]\)
- \( T_{Raw} \) = Raw temperature reading after AZ correction; range \([-7FFFFFFH \text{ to } 7FFFFFFH]\)
- \( Offset_T \) = Offset coefficient for temperature; range \([-7FFFFFFH \text{ to } 7FFFFFFH]\)
- \( SOT_T \) = Second-order term for temperature source non-linearity; range \([-7FFFFFFH \text{ to } 7FFFFFFH]\)
- \( T_{Shift} \) = Shift for post-calibration/post-assembly offset compensation; range \([-7FFFFFFH \text{ to } 7FFFFFFH]\)
3.8.3. Measurement Output Data Format

The data format and bit assignment of the raw measurement and SSC-corrected outputs of the ZSSC3218 are defined in the following tables. Any ADC measurement and SSC calculation output is formatted as a 24-bit wide data word, regardless of the effective ADC resolution used. The values are either in two’s complement or sign-absolute format.

Table 3.6 Measurement Results of ADC Raw Measurement Request (two’s complement)

<table>
<thead>
<tr>
<th>Bit</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>...</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning, Weighting</td>
<td>-2^0</td>
<td>2^-1</td>
<td>2^-2</td>
<td>2^-3</td>
<td>...</td>
<td>2^-22</td>
<td>2^-23</td>
</tr>
</tbody>
</table>

Table 3.7 Calibration Coefficients (Factors and Summands) in Memory (sign-magnitude)

<table>
<thead>
<tr>
<th>Bit</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>...</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning, weighting</td>
<td>0=positive 1=negative</td>
<td>2^1</td>
<td>2^0</td>
<td>2^-1</td>
<td>...</td>
<td>2^-20</td>
<td>2^-21</td>
</tr>
</tbody>
</table>

Table 3.8 Output Results from SSC-Correction Math or DSP—Sensor and Temperature

<table>
<thead>
<tr>
<th>Bit</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>...</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning, weighting</td>
<td>2^0</td>
<td>2^-1</td>
<td>2^-2</td>
<td>2^-3</td>
<td>...</td>
<td>2^-22</td>
<td>2^-23</td>
</tr>
</tbody>
</table>

Table 3.9 Interrupt Thresholds TRSH1 and TRSH2—Format as for SSC-Correction Math Output

<table>
<thead>
<tr>
<th>Bit</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>...</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning, weighting</td>
<td>2^0</td>
<td>2^-1</td>
<td>2^-2</td>
<td>2^-3</td>
<td>...</td>
<td>2^-22</td>
<td>2^-23</td>
</tr>
</tbody>
</table>
4 Package Information and Pad Assignments

The ZSSC3218 is available in die form or as engineering samples in the PQFN24 package. See Figure 4.1 for additional die dimensions.

In Figure 4.1, the outer dimensions shown are (minimum) estimations for a die after sawing without remaining scribe-line silicon around the core die. Therefore, the effective outer dimensions might differ slightly.

*Figure 4.1 ZSSC3218 Pad Placement*
**Table 4.1 Pad Assignments**

<table>
<thead>
<tr>
<th>Name</th>
<th>Direction</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>IN</td>
<td>Supply</td>
<td>IC positive supply voltage for the IC.</td>
</tr>
<tr>
<td>VSS</td>
<td>IN</td>
<td>Supply</td>
<td>Ground reference voltage signal.</td>
</tr>
<tr>
<td>RES</td>
<td>IN</td>
<td>Digital</td>
<td>IC reset (low active, internal pull-up).</td>
</tr>
<tr>
<td>VDDDB</td>
<td>OUT</td>
<td>Analog</td>
<td>Positive external bridge-sensor supply.</td>
</tr>
<tr>
<td>INN</td>
<td>IN</td>
<td>Analog</td>
<td>Negative sensor signal (or sensor-ground for absolute voltage-sources sensors).</td>
</tr>
<tr>
<td>EOC</td>
<td>OUT</td>
<td>Digital</td>
<td>End of conversion or interrupt output.</td>
</tr>
<tr>
<td>MISO</td>
<td>OUT</td>
<td>Digital</td>
<td>Data output for SPI.</td>
</tr>
<tr>
<td>SS</td>
<td>IN</td>
<td>Digital</td>
<td>Slave select for SPI.</td>
</tr>
<tr>
<td>INP</td>
<td>IN</td>
<td>Analog</td>
<td>Positive sensor signal.</td>
</tr>
<tr>
<td>VSSB</td>
<td>OUT</td>
<td>Analog</td>
<td>Negative external bridge-sensor supply (sensor ground).</td>
</tr>
<tr>
<td>MOSI/SDA</td>
<td>IN/Out</td>
<td>Digital</td>
<td>Data input for SPI; data in/out for I²C™.</td>
</tr>
<tr>
<td>SCLK/SCL</td>
<td>IN</td>
<td>Digital</td>
<td>Clock input for I²C™/SPI.</td>
</tr>
<tr>
<td>ZMDI-test</td>
<td>-</td>
<td>-</td>
<td>Do not connect to these pads.</td>
</tr>
</tbody>
</table>

**Table 4.2 Die Connection and Bond Parameter**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TYP</th>
<th>MAX</th>
<th>Description / Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au Bond, Pull-Force</td>
<td>-</td>
<td>8g</td>
<td>Soft bonding recommended.</td>
</tr>
<tr>
<td>Cu Bond, Pull-Force</td>
<td>not specified</td>
<td></td>
<td>Strongly not recommended.</td>
</tr>
<tr>
<td>Contact Push-Force to Pad</td>
<td>0.05g/µm</td>
<td>0.1g/µm</td>
<td>Applied force during wafer sort and/or bond-wire connection.</td>
</tr>
<tr>
<td>Probing Overdrive</td>
<td>-</td>
<td>55µm</td>
<td>Up to 4 touch downs at 85°C maximum; cantilever probe.</td>
</tr>
</tbody>
</table>

Generally, it is strongly recommended that bond and connection experiments be conducted in order to determine a proper assembly setup (golden wire, time, power, bonding force, etc. by means of wire-pull test, ball-shear test, and others) that does not lead to any IC and/or pad damages. Higher bond pull-forces maybe possible depending directly on the bond tool and temperature.
**Figure 4.2  General PQFN24 Package Dimensions**

**Table 4.3  Physical Package Dimensions**

<table>
<thead>
<tr>
<th>Parameter / Dimension</th>
<th>Min (mm)</th>
<th>Max (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.80</td>
<td>0.90</td>
</tr>
<tr>
<td>A₁</td>
<td>0.00</td>
<td>0.05</td>
</tr>
<tr>
<td>b</td>
<td>0.18</td>
<td>0.30</td>
</tr>
<tr>
<td>e</td>
<td></td>
<td>0.5nom</td>
</tr>
<tr>
<td>H₀</td>
<td>3.90</td>
<td>4.10</td>
</tr>
<tr>
<td>Hₑ</td>
<td>3.90</td>
<td>4.10</td>
</tr>
<tr>
<td>L</td>
<td>0.35</td>
<td>0.45</td>
</tr>
<tr>
<td>Pin No.</td>
<td>Name</td>
<td>Direction</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
<td>ZMDI-test</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>RES</td>
<td>IN</td>
</tr>
<tr>
<td>3</td>
<td>VDDB</td>
<td>OUT</td>
</tr>
<tr>
<td>4</td>
<td>INN</td>
<td>IN</td>
</tr>
<tr>
<td>5</td>
<td>EOC</td>
<td>OUT</td>
</tr>
<tr>
<td>6</td>
<td>MISO</td>
<td>OUT</td>
</tr>
<tr>
<td>7</td>
<td>ZMDI-test</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>n.c.</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>n.c.</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>n.c.</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>n.c.</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>SCLK/SCL</td>
<td>IN</td>
</tr>
<tr>
<td>13</td>
<td>MOSI/SDA</td>
<td>IN/Out</td>
</tr>
<tr>
<td>14</td>
<td>VSSB</td>
<td>OUT</td>
</tr>
<tr>
<td>15</td>
<td>INP</td>
<td>IN</td>
</tr>
<tr>
<td>16</td>
<td>ZMDI-test</td>
<td>-</td>
</tr>
<tr>
<td>17</td>
<td>SS</td>
<td>IN</td>
</tr>
<tr>
<td>18</td>
<td>ZMDI-test</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td>ZMDI-test</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>n.c.</td>
<td>-</td>
</tr>
<tr>
<td>21</td>
<td>n.c.</td>
<td>-</td>
</tr>
<tr>
<td>22</td>
<td>VDD</td>
<td>IN</td>
</tr>
<tr>
<td>23</td>
<td>n.c.</td>
<td>-</td>
</tr>
<tr>
<td>24</td>
<td>VSS</td>
<td>IN</td>
</tr>
<tr>
<td>25</td>
<td>Exposed Pad</td>
<td>-</td>
</tr>
</tbody>
</table>

1) n.c. stands for not connected / no connection required / not bonded.
5 Quality and Reliability

The ZSSC3218 is available as a qualified IC for consumer-market applications. All data specified parameters are guaranteed if not stated otherwise.

6 Ordering Sales Codes

<table>
<thead>
<tr>
<th>Sales Code</th>
<th>Description</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZSSC3218BI1B</td>
<td>Die—temperature range: –40°C to +85 °C, thickness 304µm</td>
<td>Unsawn wafer</td>
</tr>
<tr>
<td>ZSSC3218BI2B</td>
<td>Die—temperature range: –40°C to +85 °C, thickness 725µm (w/o backlapping)</td>
<td>Unsawn wafer</td>
</tr>
<tr>
<td>ZSSC3218BI3R ES</td>
<td>PQFN24—temperature range: –40°C to +85 °C, engineering samples</td>
<td>Packaged die</td>
</tr>
</tbody>
</table>

Contact IDT Sales for additional information.

7 Related Documents

<table>
<thead>
<tr>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZSSC3218 Feature Sheet</td>
</tr>
</tbody>
</table>

Visit the ZSSC3218 product page www.IDT.com/ZSSC3218 or contact your nearest sales office for ordering information or the latest version of these documents.
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2D</td>
<td>Analog-to-Digital</td>
</tr>
<tr>
<td>ACK</td>
<td>Acknowledge (interface’s protocol indicator for successful data/command transfer)</td>
</tr>
<tr>
<td>ADC</td>
<td>Analog-to-Digital Converter or Conversion</td>
</tr>
<tr>
<td>ALU</td>
<td>Arithmetic Logic Unit</td>
</tr>
<tr>
<td>AZ</td>
<td>Auto-Zero (unspecific)</td>
</tr>
<tr>
<td>AZSM</td>
<td>Auto-Zero Measurement for (external) Sensor Path</td>
</tr>
<tr>
<td>AZTM</td>
<td>Auto-Zero Measurement for Temperature Path</td>
</tr>
<tr>
<td>Au</td>
<td>Gold</td>
</tr>
<tr>
<td>CLK</td>
<td>Clock</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>DAC</td>
<td>Digital-to-Analog Conversion or Converter</td>
</tr>
<tr>
<td>DF</td>
<td>Data Fetch (command type)</td>
</tr>
<tr>
<td>DSP</td>
<td>Digital Signal Processor</td>
</tr>
<tr>
<td>EOC</td>
<td>End of Conversion</td>
</tr>
<tr>
<td>FSO</td>
<td>Full Scale Output (value in percent relative to the ADC maximum output code; resolution dependent)</td>
</tr>
<tr>
<td>LSB</td>
<td>Least Significant Bit</td>
</tr>
<tr>
<td>LFSR</td>
<td>Linear Feedback Shift Register</td>
</tr>
<tr>
<td>MR</td>
<td>Measurement Request (command type)</td>
</tr>
<tr>
<td>MSB</td>
<td>Most Significant Bit</td>
</tr>
<tr>
<td>MTP</td>
<td>Multiple-Time Programmable Memory</td>
</tr>
<tr>
<td>NACK</td>
<td>Not Acknowledge (interface’s protocol indicator for unsuccessful data/command transfer)</td>
</tr>
<tr>
<td>POR</td>
<td>Power-on Reset</td>
</tr>
<tr>
<td>PreAmp</td>
<td>Preamplifier</td>
</tr>
<tr>
<td>PSRR</td>
<td>Power Supply Disturbance Rejection Ratio</td>
</tr>
<tr>
<td>SM</td>
<td>Signal Measurement</td>
</tr>
<tr>
<td>SOT</td>
<td>Second-Order Term</td>
</tr>
<tr>
<td>TC</td>
<td>Temperature Coefficient (of a resistor or the equivalent bridge resistance)</td>
</tr>
<tr>
<td>TM</td>
<td>Temperature Measurement</td>
</tr>
</tbody>
</table>
# 9 Document Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>August 21, 2014</td>
<td>First release.</td>
</tr>
<tr>
<td>1.02</td>
<td>October 2, 2014</td>
<td>Update of SSC-noise values in Table 2.6.</td>
</tr>
<tr>
<td>1.03</td>
<td>November 17, 2014</td>
<td>Corrections in Table 3.5 for settings for CYC_period, Gain_stage1, Gain_stage2, Adc_bits and Offset. Correction for Figure 2.3.</td>
</tr>
<tr>
<td></td>
<td>April 20, 2016</td>
<td>Changed to IDT branding.</td>
</tr>
</tbody>
</table>
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