Active Temperature Compensation & Calibration for MEMS Pressure Sensors with Constant Voltage

1. Description

This guide provides a simplified procedure for active temperature compensation by implementing a microcontroller (MCU) and a minimal four-point calibration scheme. High accuracy applications will require additional calibration points and more complex compensation techniques. The following procedure is just one of several temperature and calibration techniques.

For additional accuracy, it is highly recommended that the system design includes AutoZero during normal system operation. AutoZero is a simple algorithm that recalibrates the system zero pressure point upon start-up. This simple technique will significantly improve system level accuracy.

The MEMS Pressure Sensor is basically a Wheatstone bridge with output signals in the mV range and requires amplification to interface with the microcontroller analog-to-digital converter (ADC) as shown in the system diagram below:

Figure 1: System Diagram. The MEMS pressure sensor is connected to MCU through a basic signal conditioning circuit. Additionally, a temperature sensor T is part of the system.
Basic Sensor Output Equation:

\[ V_{out}(T) = S(T)P + V_{zero}(T) = S_{amb}(1 + TCS(T - T_{amb}))P + V_{zero, amb} + TCZ(T - T_{amb}) \]

Test Equipment Requirements:

- Temperature dwell times will depend on system design and oven capacity/volume.
- Determine appropriate dwell time by ensuring output voltage stabilizes once a stable temperature point is reached.

2. Definition of Terms:

- \( T_{amb} \) = Ambient Temperature (Typically 25°C)
- \( T_{max} \) = High Temperature Point (Typically, 75% to 100% of the Maximum operating temperature of application)
- \( P_0 \) = Ambient Pressure
- \( P_1 \) = First Pressure Calibration Point
- \( P_{fs} \) = Fullscale Pressure of sensor
- \( V_{out} \) = Output Voltage
- \( V_{oamb} \) = Vout at Ambient Temperature and Ambient Pressure
- \( V_{1amb} \) = Vout at Ambient Temperature at \( P_1 \)
- \( V_{omax} \) = Vout at Maximum Temperature and Ambient Pressure
- \( V_{1max} \) = Output Voltage at Maximum Temperature at \( P_1 \)
- \( \Delta T \) = \( T_{max} - T_{amb} \)
- \( \Delta P \) = \( P_1 - P_0 \)
- \( SENS_{amb} \) = Sensitivity at Ambient Temperature
- \( SENS_{max} \) = Sensitivity at Maximum Temperature
- \( TCS \) = Temperature Coefficient of Span
- \( TCZ \) = Temperature Coefficient of Zero Offset
3. Temperature Compensation Procedure:

**Step 1:** At Ambient Temperature and Pressure, record data:
- Ambient temperature, Tamb
- Ambient pressure, Po
- Output Voltage, Vo-amb (this measurement is repeated with AutoZero technique)

**Step 2:** Keep at Ambient Temperature and Raise Pressure to P1, record data:
- P1 of Pressure Source
- Output Voltage, V1-amb

**Step 3:** Raise temperature to maximum and adjust back to Ambient Pressure, record data:
- Output Voltage, Vo-max
- Maximum Temperature, Tmax

**Step 4:** Keep at Maximum Temperature, and raise pressure to P1 and record data:
- Output Voltage, V1-max

(The four-point calibration procedure has been completed.)

**Step 5:** Calculate the zero offset and System Sensitivity at Ambient and Maximum Temperature:
- \( \Delta P = P1 - Po \)
- \( SENS_{amb} = (V1_{amb} - Vo_{amb}) / \Delta P \)
- \( SENS_{max} = (V1_{max} - V0_{max}) / \Delta P \)

For absolute sensors:
- \( V_{zero,amb} = Vo_{amb} - S(T_{amb}) \cdot patm \)
- \( V_{zero,max} = Vo_{max} - S(T_{max}) \cdot patm \)

For differential and gauge sensors:
- \( V_{zero,amb} = Vo_{amb} \)
- \( V_{zero,max} = Vo_{max} \)

**Step 6:** Calculate Temperature Coefficient of Span TCS (= Sensitivity Change over Temperature).
- \( \Delta T = Tmax - Tamb \)
- \( TCS = (SENS_{max} - SENS_{amb}) / \Delta T \cdot SENS_{amb} \)

**Step 7:** Calculate Temperature Coefficient of Zero Offset TCZ (= Offset Voltage, Vo, change over temperature).
- \( TCZ = (V_{zero,max} - V_{zero,amb}) / \Delta T \cdot Pfs \cdot SENS_{amb} \)

**Step 8:** Implement data into Basic Sensor Output Equation into MCU with following:
- \( p = \frac{[V_{out}(T,P) - (V_{zero}(T_{amb}) + TCZ \cdot S(T_{amb}) \cdot Pfs \cdot (T-T_{amb}))]}{S(T_{amb}) \cdot (1+TCS \cdot (T-T_{amb}))} \)

where T is the current operating temperature of the sensor.

**Step 9:** AutoZero technique is recommended during normal system operation.

For additional questions, please consult sales@si-micro.com
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