Scope

In this document the parameters are defined for characterization of the long-term stability of pressure sensor dies and the tests which are used as EPCOS standard for estimation of these parameters.

General information

For the characterization of the long-term stability of the pressure sensor die, only the offset voltage is used, because the stability of a silicon pressure sensor die depends on the offset voltage. The electronic surface effect which affects the surface conductivity only influences the offset voltage and not the sensitivity. While mechanical stress to the passivation layer can affect the sensitivity, it influences the offset voltage to a considerably greater extent.

Tests

For investigating the long-term stability of the pressure sensor die one of the following stress regimes are applied to the dies mounted in Aktiv Sensor's AKR or TO39 housing:

Test Sequence 1

TEST	Test description
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
TL150 1	Temperature load without bias at 150°C for 15 h to cure the samples
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r (Reference) Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V (Reference)
HTBM1	Temperature load at 150 °C for 10 h with a bias of 10 V and scan of V_0 (see HTB test)
HTB	Temperature load at 150 °C for 148 h with a bias of 10 V (see HTB test)
HTBM2	Temperature load at 150 °C for 10 h with a bias of 10 V and scan of V_0 (see HTB test)
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
TL150 2	Temperature load without bias at 150 °C for 15 h
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
TCB	Temperature cycle bias test with 10 temperature cycles –40 °C < T < 135 °C, dT/dt = 1 K/min, V_{DD} = 5 V and scan of V_0 (TCB test)
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
TL150 3	Temperature load without bias at 150 °C for 15 h
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
KL–40	Temperature load at –40 °C without bias for 15 h
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V

Table 1: List of long-term stability tests for pressure sensor dies

Test sequence 2

TEST	Meaning of the tests
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
TL150 1	Temperature load without bias at 150 °C for 15 h to cure the samples
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
TCB	Temperature cycle bias test with 10 temperature cycles –40 °C < T < 135 °C, dT/dt=1 K/min, V_{DD} = 5 V and scan of V_0 (TCB test)
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
TL150 2	Temperature load without bias at 150 °C for 15 h
MR25 Scan 25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
HTBM1	Temperature load at 150 °C for 10 h with a bias of 10 V and scan of V_0 (see HTB test)
HTB	Temperature load at 150 °C for 148 h with a bias of 10 V (see HTB test)
HTBM2	Temperature load at 150 °C for 10 h with a bias of 10 V and scan of V_0 (see HTB test)
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
TL150 3	Temperature load without bias at 150°C for 15h
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V
KL–40	Temperature load at –40 °C without bias for 15 h
MR25 Scan25	MR25 for absolute PSD: Output voltage at T = 25 °C and V_{DD} = 5 V with p = 0.1 p_r Scan25 for relative PSD: Offset voltage at T = 25 °C and V_{DD} = 5 V

Table 2: Alternative list of long-term stability tests for pressure sensor dies

MR25:

For absolute pressure sensor dies the MR25 tests are for data acquisitions before and after thermal and voltage load applications. The output voltage of the pressure sensor die is estimated at p = 0.1 p_r and at a constant temperature of (25 ±0.5) °C. These output voltages are used for estimation of the offset voltage deviation from the reference point. The output voltage values at 0.1 p_r after the TL150 1 load V_{out} (TL150 1, 0.1 p_r) is the reference point for the estimation of the offset voltage deviation. These values are used for $LTSV_0$ estimation.

Scan25:

For gauge pressure sensor dies the Scan25 tests are for data acquisitions before and after thermal and voltage load applications. The offset voltage is scanned for 30 minutes with the data being sampled every 30 s at a constant temperature of 25 °C. For evaluation the mean values of the sampling points of the offset voltage between 20 min and 30 min are used. These offset voltages are used for estimation of the offset voltage deviation from the reference point. The offset voltage values after the TL150 1 load V_0 (TL150 1) is the reference point for the estimation of the offset voltage deviation. These values are used for $LTSV_0$ estimation.

TL150 x (x=1..3) Temperature load at 150 °C:

Samples are stored at a high temperature load of 150 °C at atmospheric pressure for 15 h without base. No data are acquired during applying the temperature load. This load is a thermal conditioning for annealing the effects due to biasing and temperature load. The result of TL150 after the HTBM1-HTB-HTBM2 tests can be used for root cause detection e.g. mobile load in the oxide.

TCB Temperature cycle bias test

TCB test is performed to accelerate failure mechanisms which are thermally activated by temperature cycling. Continuous measurement under bias conditions determines the mechanical induced instability of sensor output. Without applying a gauge pressure to the pressure sensor die a temperature cycle is applied at {25 °C} hold time 30 min, {25 °C; 135 °C} ramp rate 1 K/min, 10×{135 °C, –40 °C; 135 °C} ramp rate 1 K/min, {135 °C, 25 °C} ramp rate 1 K/min, {25 °C} hold time 30 min, {25 °C, –40 °C; 25 °C} ramp rate 1 K/min, {25 °C} hold time 30 min (see Fig 1 in THV_0 and $TCDV_0$ estimation). From the data of the TCB test the temperature hysteresis of the offset voltage of gauge pressure sensor dies or the output voltage at atmospheric pressure of absolute pressure sensor dies are estimated.

HTBMx (x=1..2) High-temperature bias test with output voltage scanning

The HTBM1 and HTBM2 tests are high-temperature bias tests with a temperature load of 150 °C for 10 h with a bias of 10 V. During the test the output voltage at atmospheric pressure of absolute pressure sensor dies or the offset voltage of gauge pressure sensor dies are sampled every 30 seconds. These tests are part of the 168 h high-temperature bias test which consists of HTBM1-HTB-HTBM2-TL150 tests. This 168 h HTB subsequence is performed to accelerate failure mechanisms which are thermally activated through the use of biased conditions. The data are used for estimation of the stability parameter high-temperature drift of output or offset voltage $HTDV_0$.

HTB High-temperature bias test

The HTB test is a high-temperature bias test with a temperature load of 150 °C for 148 h with a bias of 10 V. The output respective the offset voltage is not scanned to reduce the amount of stored data and to use the measuring station effectively. This test is part of the 168 h high-temperature bias test which consists of HTBM1-HTB-HTBM2-TL150 tests. This 168 h HTB subsequence is performed to accelerate failure mechanisms which are thermally activated through the use of bias conditions.

KL–40 Temperature load at –40 °C

Samples are stored at a low temperature of –40 °C at atmospheric pressure for 15 h without base. No data are acquired during applying the temperature load. This test addresses together with the TL150 3 test the thermo mechanical stability of the die and of the assembling.

Long-term stability parameter estimation

Estimating the parameters $TCDV_0$ and THV_0 from temperature cycle bias test (TCB)

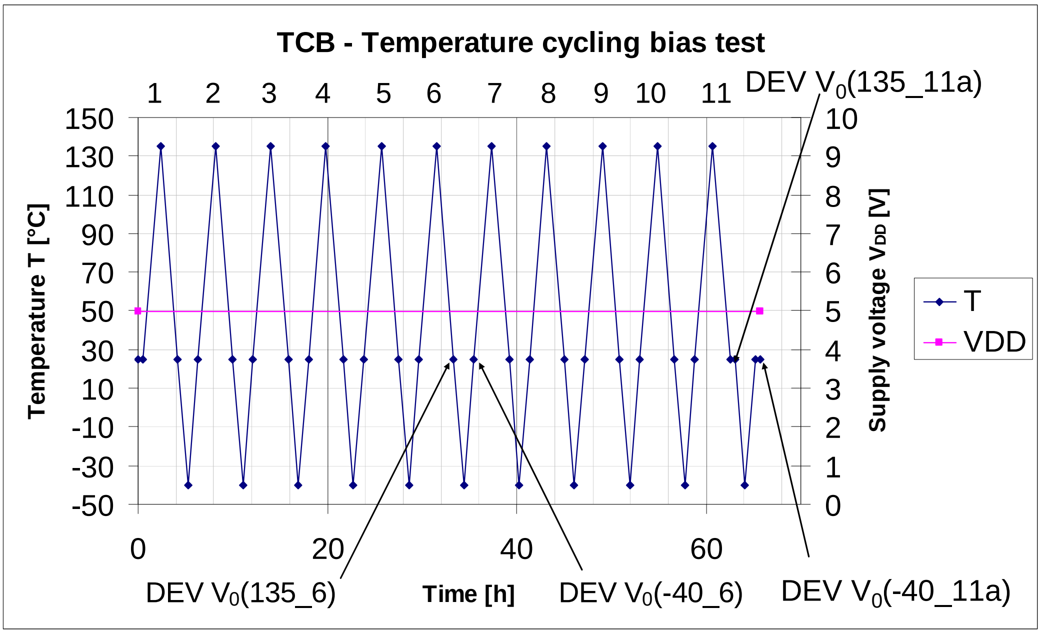

Fig. 1: Applied temperature cycle for estimating the temperature hysteresis and the long-term drift of the offset voltage

Fig 1: Shows the applied temperature cycle for estimating the temperature hysteresis and the long-term drift of the output voltage at atmospheric pressure for absolute pressure sensor dies or offset voltage for gauge pressure sensor dies.
The corresponding output voltages to the sampling points at 25 °C are assigned V_0 (135_#) and V_0 (–40_#).
At the temperature cycle 11 the temperature is hold at 25 °C for 30 min.
The sampling points are assigned with an additional letter a.

Description	Short term	T[°C]	V_{DD}[V]
Measurement points	V_0(T_#x)	25	5
Temperature rate		1/min	

Table 3: Conditions for the TCB test and data collecting

THV_0: Temperature hysteresis of output voltage at atmospheric pressure

The temperature hysteresis of the output voltage at atmospheric pressure is calculated from sampling points V_0 (135_11a) and V_0 (-40_11a) (see Fig1) using the equation:

$$THV_0 = \frac{V_0(135\_11a) - V_0(-40\_11a)}{FSON} [\%FSON]$$

with FSON the rated output span as defined in the specification. In most cases FSON = 120 mV.
The temperature hysteresis strongly depends on assembly conditions (gluing, material of mounting base). It will be tested for design verification on samples mounted on AKR (AKR data sheet from AS).

$TCDV_0$: Temperature cycle drift of offset or output voltage at atmospheric pressure

The long-term stability of the offset voltage of gauge pressure sensor dies respective output voltage at atmospheric pressure of absolute pressure sensor dies is tested by observing the temperature cycle drift. The temperature cycle drift of the output voltage at atmospheric pressure is measured by applying temperature cycles as described in Fig 1. It is estimated from V_0 (135_11) and V_0 (135_1) (see Fig1) using the equation:

$$TCDV_0 = \frac{V_0(135\_11) - V_0(135\_1)}{FSON} \ [\%FSON]$$

with FSON the rated output span as defined in the specification.
To match the specification for gauge pressure sensor dies this condition has to be fulfilled:

$$|TCDV_0| < \text{specified value}$$

For absolute pressure sensor dies the output voltage changed with the output pressure. To eliminate the influence of the atmospheric pressure on measurement results, the mean value (MV) and the standard deviation (σ) of TCDVa of samples, which are measured at the same time, are estimated. To match the specification, these conditions have to be fulfilled:

$$|TCDV_0 - MV| < \text{specified value}$$
$$3\sigma < \text{specified value}$$

The temperature drift of offset voltage depends strongly on assembly conditions (gluing, material of mounting base). It will be tested for design verification on samples mounted on AKR (AKR data sheet from AS).

$HTDV_0$: High-temperature drift of offset voltage or output voltage at atmospheric pressure

For the calculation of $HTDV_0$, HTBM1-HTB-HTBM2 subsequence out of the long-term stability test sequence 1 or 2 is needed. Fig 2 shows the subsequence HTBM1-HTB-HTBM2-TL150. After the HTBM2 test the samples are annealed at 150 °C (TL150). The result of annealing can be used for root cause detection e.g. mobile load in the oxide. The markings s1 and s2 as well m1-m3 refer to the data collecting procedure. Table 5 shows an overview of the data collecting needed for the calculation of $HTDV_0$. (Remark: the data acquired at m1 and m3 are part of the calculation of $LTSV_0$)

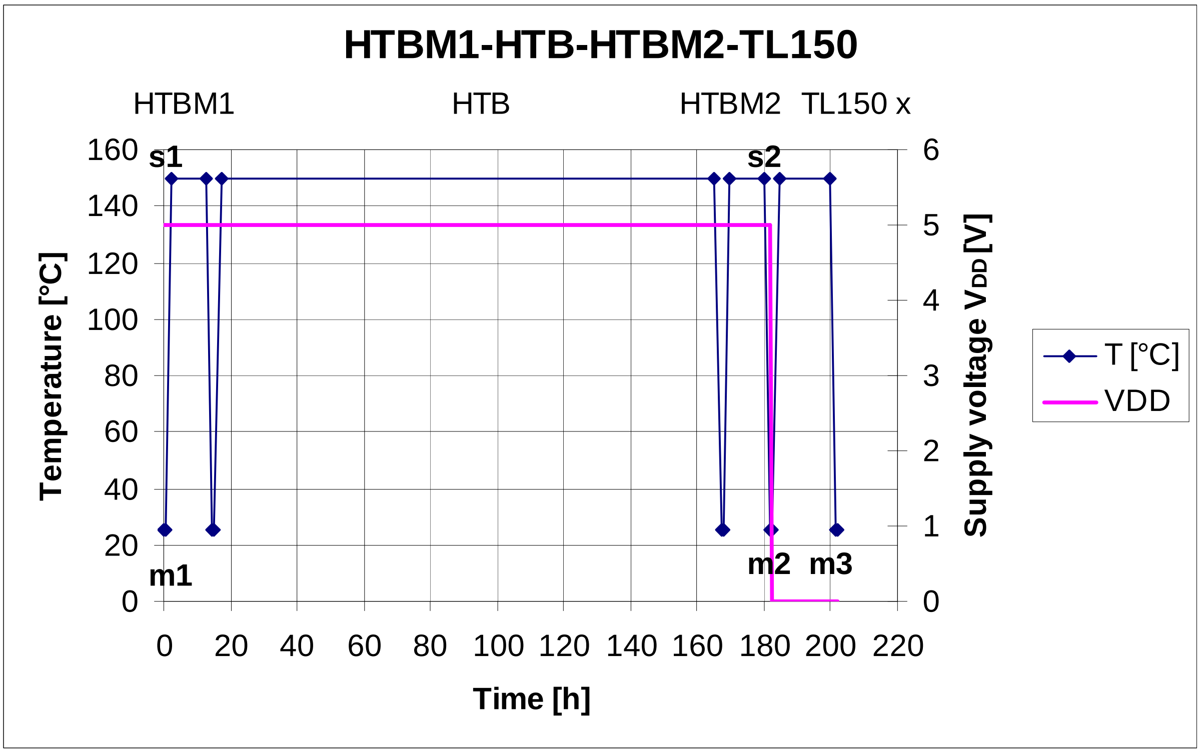

Fig 2: Load regime of the high-temperature bias related tests HTBM1, HTB, HTBM2 and TL150

Description	T[°C]	V_{DD}[V]	Load Time[h]
HTBM1	150	10	10
HTB	150	10	148
HTBM2	150	10	10
TL150 x	150	0	15

Table 4: Load regime of the high-temperature bias related tests HTBM1, HTB, HTBM2 and TL150 x

Measuring point	Data collecting	T[°C]	V_{DD}[V]	Time after load application
m1	MR25	25	5	before HTBM1
s1	Scan during HTBM1	150	10	3h after start of HTBM1
s2	Scan during HTBM2	150	10	12h after start of HTBM2
m2	MR25	25	5	after HTBM2
m3	MR25	25	5	after TL150 x

Table 5: Data acquire regime of the high-temperature bias related tests HTBM1, HTB, HTBM2 and TL150 x.

The high-temperature drift of offset voltage $HTDV_0$ is estimated with:

$$HTDV_0 = \frac{V_0(s2) - V_0(s1)}{2 \cdot FSON} [\%FSON]$$

with FSON the norm output span as defined in the specification. To match the specification for gauge pressure sensor dies this condition has to be fulfilled:

$$|HTDV_0| < \text{specified value}$$

For absolute pressure sensor dies the output voltage changed with the output pressure. To eliminate the influence of the atmospheric pressure on measurement results, the mean value (MV) and the standard deviation σ of $HTDV_0$ of samples, which are measured at the same time, are estimated. To meet the specification, these conditions have to be fulfilled:

$$|HTDV_0 - MV| < \text{specified value}$$
$$3\sigma < \text{specified value}$$

$LTSV_0$: Long-term stability of the output voltage

$LTSV_0$ is a measure for stability of the offset voltage. It is estimated as the deviation of the offset voltage, measured after all tests and measured after the TL150 1 load. For gauge pressure sensor dies the V_0 data are acquired with Scan25 at (25 ±0.5) °C. (Remark: the TL150 1 load is a thermal conditioning of the samples. The reference point is the Scan25 test after the TL150 1 load in the test sequences). The parameter long-term stability of the offset voltage $LTSV_0$ is defined by the maximum value of all estimated deviations from V_0(TL150 1):

$$LTSV_0 = MAX\left[\frac{|V_0(\text{after tests}) - V_0(\text{TL150 1})|}{FSON} \underset{Tests \neq Start}{\forall} V_0(\text{after tests})\right]$$

For absolute pressure sensor dies the V_0 data are acquired with MR25 at (25 ±0.5) °C. (Remark: the TL150 1 load is a thermal conditioning of the samples. The reference point is the MR25 test after the TL150 1 load in the test sequences). The parameter long-term stability of the offset voltage $LTSV_0$ is defined by the maximum value of all estimated deviations from V_{out}(TL150, 0.1p_r):

$$LTSV_0 = MAX\left[\frac{|V_{out}(\text{after tests, } 0.1p_r) - V_{out}(\text{TL150 1, } 0.1p_r)|}{FSON} \underset{Tests \neq Start}{\forall} V_{out}(\text{after tests, } 0.1p_r)\right]$$

The start values V_0 (Start, 0.1 p_r) or V_0 (Start) respectively are excluded from the estimation of $LTSV_0$. FSON is the so called norm value of an output span, which is defined in the specification. In most cases, this value is set to 120 mV, which is the standard typical value of the output span at rated pressure. For an arbitrary output span the $LTSV_0$ (V_s) can be calculated with:

$$LTSV_0(V_s)[\%FS] = \frac{V_s}{V_{s,norm}} LTSV_0 \ [\%FSON]$$

V_s is the arbitrary output span, $V_{s,norm}$ is defined in the specification as fixed value for the output span, $LTSV_0$ is related to $V_{s,norm}$ and $LTSV_0(V_s)$ is related to V_s.

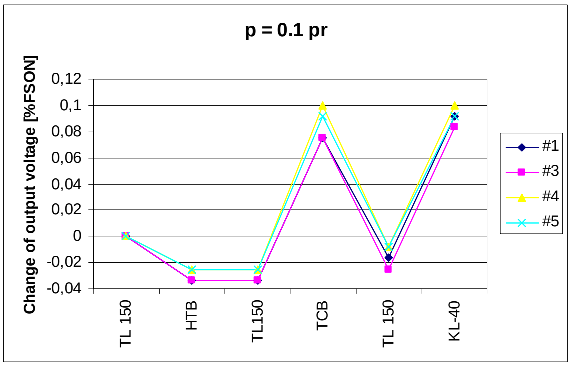

Fig 3: Example for $LTSV_0$ estimation from test results of an absolute pressure sensor die
For die #4 $LTSV_0$ is 0.1% FSON in relation to V_s = 120 mV. For an output span of 60 mV, $LTSV_0$(60 mV) is 0.2% FS.